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

Deliverable: D1.2

Observatory of research and demonstration initiatives on future electricity grids and markets

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 864334

H2020 – LC-ES-1-2019

Document	
D1.2	Observatory of research and demonstration initiatives on future electricity grids and markets

Dissemination level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Author(s)	Institution	Contact (*e-mail, phone*)
Clara Gouveia	INESC TEC	clara.s.gouveia@inesctec.pt
Everton Alves	INESC TEC	everton.l.alves@inesctec.pt
José Villar	INESC TEC	jose.villar@inesctec.pt
Ricardo Ferreira	INESC TEC	ricardo.j.ferreira@inesctec.pt
Ricardo Silva	INESC TEC	ricardo.emanuel@inesctec.pt
José Pablo Chaves	Comillas	Jose.chaves@comillas.edu
Tomás Gómez	Comillas	Tomas.gomez@comillas.edu
Leslie Herding	Comillas	leslie.herding@comillas.edu
Nicolás Morell	Comillas	nicolas.morell@comillas.edu
Michel Rivier	Comillas	Michel.rivier@comillas.edu
David Ziegler	Comillas	David.ziegler@comillas.edu
Mathaios Panteli	UNIMAN	mathaios.panteli@manchester.ac.uk
Jan Budke	E.ON	jan.budke@eon.com
Katarzyna Zawadzka	E.DSO	projects@edsoforsmartgrids.eu
Catarina Augusto	E.DSO	catarina.augusto@edsoforsmartgrids.eu

Key word	Observatory of research and demonstration initiatives on future electricity grids and markets
Due Delivery Date	2021/01/31
Date of Delivery	2021/01/29

Document version	Date	Change
1.0	2020/12/16	1st draft
1.1	2021/01/29	Final draft

Reviewers		email	Validation date
EASE	Emin Aliyev	e.aliyev@ease-storage.eu	2021/01/15
EASE	Brittney Elzarei	b.elzarei@ease-storage.eu	2021/01/15
IEN	Rafal Magulski	r.magulski@ien.gda.pl	2021/01/18

Table of Contents

List of Tables

List of Figures

List of Abbreviations

AASS	Ancillary Services
ADMS	Advanced Distribution Management System
ADS	Active Demand & Supply
aFRR	Automatic Frequency Restoration Reserve
AGR	Aggregator
AMI	Advanced Metering Infrastructure
AMR	Automatic Meter Reading
AP	Active Power
B2B	Business-to-business
BRP	Balance Responsible Party
BS	Black-start
BUC	Business Use Case
CAES	Compressed-Air Energy Storage
CHP	Combined Heat and Power
CM	Congestion Management
D-SCADA	Distribution SCADA
DA	Day-Ahead
DER	Distributed Energy Resources
DERMS	Distributed Energy Resources Management Systems
DG	Distributed Generation
DMS	Distribution Management System
DRES	Distributed Renewable Energy Source
DSM	Demand-Side Management
DSO	Distribution System Operator

DSR	Demand Side Response
EV	Electric Vehicle
FCR-D	Frequency Containment Reserve for Disturbances
FCR-N	Frequency Containment Reserve for Normal operation
FFR	Fast Frequency Response
FRT	Fault-Ride Through
FSP	Flexibility Service Provider
GIS	Geographic Information System
HEMS	Home Energy Management Systems
ICT	Information and Communications Technology
ID	Intraday
IED	Intelligent Electronic Device
IO	Isolated/Islanded Operation
ISP	Imbalance Settlemet Period
LFM	Local Flexibility Market
LV	Low Voltage
LT	Long-term
mFRR	manual Frequency Restoration Reserve
MGT	Management
MO	Market Operator
MOL	Merit Order List
MQTT	Message Queuing Telemetry Transport
MT	Medium-term
MV	Medium Voltage
OLTC	On-load Tap Changer
OP	Operational

OPF	Optimal Power Flow
PCC	Point of Common Coupling
PF	Power Flow
PMU	Phasor Measurement Unit
RES	Renewable Energy Sources
REST API	Representational State Transfer Application Programming Interface
RP	Reactive Power
RR	Replacement Reserve
RT	Real Time
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
SE	State Estimation
SESP	Smart Energy Service Provider
SIM	Subscriber Identity Module
SO	System Operator
ST	Short-term
TLC	Traffic Light Concept
TLQ	Traffic Light Quantification
TSO	Transmission System Operator
UMEI	Universal Market Enabling Interface
VRE	Variable RES
WLS	Weighted Least Squares

Executive Summary

Under the European H2020 program, the EUniversal Project has the main objective to foster the universal access of system operators to the available flexibility, mainly provided by Distributed Energy Resources (DER), through the interaction with new Flexibility Markets and innovative services. With the development of solutions and services that allow the massive integration of the Distributed Generation (DG), energy storage, and the active participation of consumers, the project aims to tailor the concept of the Universal Market Enabling Interface (UMEI). The UMEI will look to overcome the limitations that the system operators, especially the Distribution System Operator (DSO), experience in the use of flexibilities, addressing the interlinking of electricity markets with active network management.

The aim of this deliverable is to identify and analyse a set of relevant initiatives and projects that may provide relevant inputs on three main basic topics for future project tasks:

- Flexibility needs, services and products addressed in these initiatives, as a preliminary catalogue of the needs and services definition that should come out from task T2.1. The focus is on the DSO side.
- Markets organisations proposed and tested in these initiatives for TSO and DSO to procure these flexibilities under coordinated mechanisms that will provide input to task T5.1 on market design.
- Technologies involved at the resources levels, but especially at the DSO side in terms of tools needed to integrate the existing flexibility into the planning and operating procedures of the DSO, and to interface with these flexibilities for activation and verification.

A set of 24 initiatives and projects have been selected by task T1.2 partners for this analysis, considering different types of approaches from conceptual proposals to demonstration projects. Table 1 provides the list of projects considered.

The main findings are:

- The list of grid and non-grid DSO needs and services identified in the projects analysed. Table 2 summarises that set of needs and services;
- The main markets organisations used in the different projects for the services addressed, discussed throughout chapter 3;
- The resulting matching between the identified markets organizations, and the DSO needs-services-products (tables Table 44-Table 47, summarised also in Table 3);
- Architectural aspects and tools and technologies used to enable the use of flexibility for the distribution management systems, and DER types and interfaces for DER control and monitoring, discussed throughout chapter 4.

Table 1: List of projects and initiatives analysed

Project name
Architecture of Tools for Load Scenarios (ATLAS)
CoordiNet
De-Flex-Market
EcoGrid 2.0
EMPOWER H2020
Enera
FLECH-iPower
Flex-DLM
FlexHub Eu-SysFlex
FLEXICIENCY
FlexMart
Future Network Modelling Functions
GOPACS-IDCONS
InteGrid
Interflex
INTERRFACE
IREMEL
NODES
Open Networks
Piclo Flex (and Piclo)
PlatOne
Power Potential, National Grid
SENSIBLE
USEF

Table 2: Needs and services identified

Needs	Services		Definitions	Category
Voltage Control	Reactive power management	Steady state control	Service to maintain the voltage profile inside the limits, in steady state (normal operation)	Grid service
		Dynamic control	Service to control the voltage variations under system disturbances	Grid service
	Active power management		Service for voltage control by increasing/decreasing active power	Grid service
Congestion Management (CM)	Operational		Service for CM in operational timeframe, activated to mitigate congestions caused by faults, and to other remedial actions	Grid service
	Short-term planning (D-1 to M-1)		Service for CM in timeframe of D-1 (day before) up to M-1 (month before)	Grid service
	Long-term planning (>M-1 to Y-1 or more)		Service for CM considering several months or years before, and may as well result in network reinforcement deferrals	Grid service
Service Restoration	Black Start for distribution islands		Service for system restoration after blackout situations. In the distribution specific case, at present, large generators that are already designed for blackout services can be used for black start in parts of the distribution network	Grid service
	Isolated/Islanding operation mode		Specific services can be offered for parts of the grid operating in islands/isolated mode (e,g, isolated microgrids). Some needs to attend these services are local balancing and voltage control (and others).	Grid service
Voltage sag mitigation	FRT		Service to provide FRT (fault ride through) capability, supporting the mitigation of voltage sag on the distribution system. FRT as a flexibility service is in early discussions.	Grid service
Planning and predictive management	Flexibility forecasting Generation forecasting Load forecasting		Forecasting services, for distribution loads, generation and flexibility, to have better estimations of generation and demand, and the expected impacts for the DSO, considering also the flexibilities available.	Non-grid services
• Observability of the flexibility. • Procurement and settlement; • SO coordination	Visibility over available flexibility		Service to provide DSO enhanced observability of the system, with better awareness of their assets, their available flexibility and location, improving the system management.	Non-grid services

Table 3: Mapping markets types-services-projects

Market Model	DSO Needs / Grid Services							
	Voltage Control		Congestion Management			Service Restoration		Voltage Sag Mitigation
	RP (reactive power)	AP (active power)	OP (operational)	ST (short-term)	LT (long-term)	BS (black-start)	IO (isolated operation)	FRT (fault ride-through)
M1 - Centralised flex market								
M2 - Local and global flex market	▪ Piclo Flex (and Piclo) ▪ SENSIBLE	▪ CoordiNet ▪ EcoGrid 2.0 ▪ EMPOWER H2020 ▪ FLEXICIENCY ▪ Interflex ▪ IREMEL ▪ SENSIBLE	▪ CoordiNet	▪ CoordiNet ▪ EMPOWER H2020 ▪ Enera ▪ FLECH-iPower ▪ Flex-DLM ▪ GOPACS-IDCONS ▪ Interflex ▪ IREMEL ▪ NODES ▪ Piclo Flex (and Piclo) ▪ SENSIBLE	▪ CoordiNet ▪ De-Flex-Market ▪ EcoGrid 2.0 ▪ FLECH-iPower ▪ FlexMart ▪ Piclo Flex (and Piclo)		▪ CoordiNet ▪ EMPOWER H2020 ▪ Interflex	
M2/3 - Local and global flex market with balancing coordination		▪ USEF	▪ INTERRFACE	▪ INTERRFACE ▪ USEF	▪ INTERRFACE		▪ USEF	
M3 - Local and global flex markets with shared responsibility	▪ CoordiNet ▪ FlexHub EU-SysFlex	▪ CoordiNet						
M4 - Common TSO-DSO flexibility market			▪ INTERRFACE	▪ CoordiNet ▪ INTERRFACE	▪ CoordiNet ▪ INTERRFACE			
M5 - Integrated flexibility market for TSO, DSO and BRP								

1. Introduction

1.1 Context and main objectives

The EUniversal project, funded by the European Union, aims to develop a universal approach on the use of flexibility by Distribution System Operators (DSO) and their interaction with the new flexibility markets, enabled through the development of the concept of the Universal Market Enabling Interface (UMEI) – a unique approach to foster interoperability across Europe.

The UMEI represents an innovative, agnostic, adaptable, modular and evolutionary approach that will be the basis for the development of new innovative services, market solutions and, above all, implementing the real mechanisms for active consumer, prosumer, and energy communities participation in the energy transition.

Deregulation first, then decentralisation and decarbonisation of the power system are some of the main drivers that are shaping the recent and future evolution of the power system. Deregulation changed the traditional paradigm of centralised vertical energy supply with the aim of introducing competition at different levels (wholesale markets and retail markets) to increase efficiency and to let the market adapt to the evolving environment. Decentralisation and decarbonisation are leading to the progressive closure of conventional fossil fuel-based generation, being replaced by renewable generation plants (mainly wind and solar farms). This new generation, non-dispatchable and less predictable, is making the balance of generation and supply harder, with a progressive decrease of the dispatchable generation that had traditionally and is still providing most system services needed to guarantee the system security. This new paradigm implies new system scarcities, and therefore, new needs to guarantee a secure energy supply, as well as the need to improve the integration of all new distributed energy resources (RES) into the system (including low-voltage resources at consumers' level) as potential flexibility suppliers to satisfy the system needs.

The electrical system historically relied upon a set of "implicit services"[1], provided by classical generation plants. Assuming the future scenarios and the upcoming perspectives, the availability of resources that provide these classical types of services will become significantly reduced. The current panorama of electrical systems shows a growing trend towards the incorporation of DER in the networks. Consequently, the introduction of new ancillary services and explicit services (replacing the previous implicit ones) turns out to be an essential requirement to assure the safe management of the electrical system. Addressing such new services strictly follows the evolution and the integration of multiple electricity markets, to stress the new services needed in the forthcoming panorama, whilst promoting the participation of new flexibility resources in the markets, finally leading these markets to an integration at the European level.

The constant evolution of the electricity networks associated to electricity markets' structures, follows the advances in promoting the renewables, and, through this, new participants are entering the electricity markets, such as the Aggregators (AGR), the Flexibility Providers (e.g., residential and commercial energy storage systems, electric vehicles, flexible generators as CHP and biogas, demand response, etc.), the Balance Responsible Parties (BRP), among many others.

Many projects and conceptual initiatives have been proposed to improve DER integration as active flexibility providers in local (oriented to distribution grid) and system-wide (oriented to transmission grid) services to contribute to a more efficient operation of the system.

The aim of this deliverable is to identify and analyse a set of relevant initiatives and projects that may provide relevant inputs on three main basic topics relevant for other EUniversal project tasks:

[1] Implicit services here refers to those services that are not directly traded in markets

- Flexibility needs, services and products addressed in these initiatives.
- Market organisations proposed and tested in these initiatives for TSO and DSO to procure these flexibilities under coordinated mechanisms.
- Technologies involved at the resources' levels, but especially at the DSO side in terms of tools needed to integrate the existing flexibility into the planning and operating procedures of the DSO, and to interface with these flexibilities for activation and verification.

Up to 24 research and demonstration projects were selected as their lessons and proposals could be relevant to the EUniversal Project objectives of defining future scenarios for European electricity grids and markets.

The results obtained in this task were provided as inputs to the following tasks of the project:

- The identification of the DSO needs, services and products, that follows from the review of the initiatives, provides the preliminary catalogue of the needs and services related to the progress and results of task T2.1;
- The identification of market models and their organisations, emphasising the coordination schemes, procurement methods, and market negotiation characteristics will provide inputs to task T5.1;
- The characterisation of distribution network control and management tools and technologies to enable the participation of DER in flexibility markets (focusing on DSO grids) that will provide information to task T3.1.

1.2 Methodology

The methodology used for this Deliverable consisted in the following steps:

1. Selection of an appropriate set of projects and initiatives, proposed and agreed by all task T1.2 partners, related with the topics to be investigated, namely:
    a. Grid operators' needs for a more efficient operation of their grids, with special emphasis on distribution grids, under the current context of decarbonisation and decentralisation of energy resources. For each of the needs the main services proposed to satisfy these needs where also investigated, as well as the products negotiated for each of these services;
    b. Markets organisations mechanisms (including TSO-DSO coordination strategies) to negotiate the products for the identified services. At this stage, a more in-depth description of the products negotiated in the markets was also performed;
    c. Characterisation of distribution network control and management tools and technologies to enable the participation of DER in the flexibility markets;

2. For each project, INESC TEC performed a preliminary analysis focusing on several relevant topics that would later allow to prioritise the analysis (to provide rapid feedback to other projects' tasks) as well as to ask for specific contributions from the task T1.2 partners. These selected topics are collected in Table 4. This preliminary analysis was complemented with more detailed contributions provided by some of the partners on a reduced set of projects;
3. For each of the three main topics investigated (needs and services, markets and technologies) a specific methodology was developed, which is described in each of the corresponding sections, namely section 2 for Needs and services, section 3 for markets organization, and section 4 for technologies. For each topic, templates were designed and/or used to collect the

information in an organised and systematic way. Relevant attributes were initially collected for each of the topics and refined during the subsequent work;

4. For each of the three main topics analysed, after collecting the information from the projects, this information was analysed and processed to present it in a compact, organised, and summarised way to highlight the main findings. Discussion and conclusions accompany each of the three sections mentioned. At this stage specific collaborations of task T1.2 partners were requested attending to their expertise;
5. A final discussion, main findings and conclusions were then elaborated and included at the end of this document.

Table 4: List of topics for the preliminary projects' characterization

Topics	Description
General description	Brief description of project and the approach to flexibility provision
Dates	Starting and ending date of the initiative, to identify how up to date it is and if it is still on-going.
Countries/EPEX/partners	Countries, power exchanges and partners involved in the initiative.
Level/status of deployment	To clarify if it is a conceptual proposal, a pilot demonstrator or a platform in partial or full operation.
Energy/Flexibility	To describe if it considers commercial energy exchanges or only flexibility provision to regulated procurers (TSO and/or DSO).
TSO Flexibility and services	Does it provide flexibility to the TSO? For which types of services? Characterization of the flexibility products.
DSO Flexibility and services	Does it provide flexibility to the DSO? For which types of services? Characterization of the flexibility products.
DSO network operation tools with flexibility	How is the flexibility used in the DSO operating tools? To what extend the use of flexibility is integrated in the DSO operating tools?
DSO network operation and planning tools	How is the flexibility used in the DSO planning tools? To what extend the use of flexibility is integrated in the DSO planning tools?
DSO monitoring and control requirements	High level description of DSO monitoring and control requirements, and DSO interfaces with flexible DER.
Markets integration model (TSO-DSO coordination)	Classification of the coordination model according to a predefined set of models to be reviewed and complemented.
DER characterisation (types, sizes, aggregation)	Characterization of the DER considered in the initiative, for example with respect to the technologies, the minimum size to participate, level of aggregation, etc.
Other possible partners	Suggestion of other possible partners that could contribute to help in the characterisation of this initiative.

Table 5 shows the final projects and initiatives that were selected for analysis by task T1.2 partners, considering different types of approaches from conceptual proposals to demonstration projects, all of them to some extent related with the three main topics investigated in this report. For each project, a small description is provided as well as some basic references.

Table 5: List of projects and initiatives reviewed

Project name & Country Leader	Description	Refs.
Architecture of Tools for Load Scenarios (ATLAS) UK	The aim of the ATLAS project was to develop credible methodologies and associated prototype tools (technical development of improved methods of load estimation, creation of scenarios, and indicative comparison to network capacity, rather than technical or commercial solutions to any loading constraints identified) for the long-term forecasting of demand and generation across the Grid & Primary networks of Electricity North West (UK). ATLAS develops a method to deliver historic estimates and future annual scenarios of asset loading to 2031 and make indicative comparisons of these to thermal capacity. Completion Date: December 2017.	[1], [2]
CoordiNet Spain	The CoordiNet project aims to establish and demonstrate different collaboration schemes of coordination between TSO, DSO, and consumers to contribute to the development of a smart, secure and more resilient energy system. Within this, several standardised products are defined and tested along with the related key parameters for grid services, reservation and activation process for the use of the assets and settlement process. Analysis and definition of flexibility in the grid is made in every voltage level, ranging from the TSO and DSO domain to consumer participation, thus enabling all market participants to provide energy services. Completion Date: June 2022.	[3], [4], [5]
De-Flex-Market Germany	The De-Flex-Market is a model that suggests, in addition to the existing central markets, such as power exchanges (including futures markets, day-ahead and intra-day markets), over the counter and balancing markets, the introduction of a decentralised market for flexibility options which can be used by the distribution network operators to address local capacity constraints while avoiding or deferring network reinforcement, if this is the most efficient option. It is emphasised with the project that the proposal of De-Flex-Market (2.0) is not a market model by classical understanding, but a market-based instrument. Completion Date: early 2015.	[6], [7]
EcoGrid 2.0 Denmark	EcoGrid 2.0 is a Danish project that demonstrates how flexibility from households can be utilized through DR to offer power system services to both the TSO and DSO. Around 800 private households from the island of Bornholm participate in the project, providing flexibility through the management of their heating assets. In parallel, a market platform was demonstrated, for request and trading of small-scale flexibility by BRP, DSO and TSO, based on the Danish "Supplier-centric Model" (Engrosmodellen). Design of this platform was made so that integration with existing markets is possible. Completion Date: June 2019.	[8], [9], [10]
EMPOWER H2020 Norway	EMPOWER aims to develop and verify a local marketplace and innovative business models, including operational methods, encouraging micro-generation and the active participation of prosumers to exploit the flexibility created for the benefit of all connected to the local grid. One of the project's goals is a toolkit allowing more cities and organisations to take up the EMPOWER concept. It will include an evidence database, business model templates, software tools and advice on evaluation methodology. The toolkit will help industry, policy makers, city authorities and employers to understand and successfully implement positive incentive schemes using smart technologies in the context of existing infrastructure, policy and measures. Completion Date: April 2018.	[11], [12]

enera Germany	The main objective of Enera is to develop and demonstrate scalable showcase solutions for the energy transition in the focus fields grid, market and data by launching a local market platform for flexibility sources together with the system operators. The Local market platform for flexibility sources is designed to avoid uneconomic excess wind generation curtailment and grid congestion. Availability is presently restricted to members of a consortium, but depending on the results, it is expected to be implemented in much larger scale in the future. Completion Date: December 2020.	[13], [14], [15], [16]
FLECH-iPower Denmark	FLECH-iPower (flexibility clearing house) proposes a market that runs in parallel with the existing markets, oriented to the distribution grid, to assist the DSO to mitigate the congestions and empower the small-scale DER integration in the flexibility services. Completion Date: 2016.	[17], [18], [19], [20], [21], [22]
Flex-DLM Spain	Flex-DLM proposes a flexibility market led by the DSO focusing on solving distribution grid congestions. It implements a comprehensive framework for a decentralized market for the provision of demand flexibility services at the distribution-level grid: serving the flexibility providers (AGR on behalf of customers) and the flexibility buyers (DSO), addressing the local congestions. Moreover, Flex-DLM follows a decentralized approach, which means that several markets can exist for different areas in the distribution network. Completion Date: Flex-DLM was proposed in a paper in 2018.	[23]
FlexHub Eu-SysFlex Ireland	Project for efficient coordinated use of flexibilities for the integration of a large share of RES. Identification of new types of services to meet the system' needs with more than 50% of RES. It will find the right blend of flexibility and system services to support secure and resilient transmission system operation. Completion Date: October 2021.	[24], [25], [26]
FLEXICIENCY Spain	The objective of FLEXICIENCY was the development of a marketplace based on standardised interactions among electricity stakeholders, and the realization (along with the project partners) of a common EU marketplace, which connects smoothly together four countries, making available to share multiple energy services, as flexibility offers and metering data to exchange. Three service categories were covered: Advanced energy monitoring (with energy consumptions and production information made available to the customers); Local energy control (tools and algorithms for local energy control and modulation); Flexibility (by a group of aggregated customers, distributed systems of loads and generators, including a micro grid). Completion Date: January 2019.	[27], [28], [29], [30], [31]
FlexMart Belgium	FlexMart proposes an empirical model that works as a long-term planning tool for DSO, providing the ability to purchase demand flexibility offered by residential consumers, trying to minimize DSO's overall cost considering the cost of flexibility activation, the cost of line reinforcement, and the cost of energy curtailment. The consumers are rewarded for the flexibility service with a fixed benefit covering the difference between the cost of flexibility-related equipment and the benefit due to a consumption shift in off-peak hours (it highlights the relevance of dynamic network tariff). Completion Date: Model was proposed in a 2016 paper.	[32]
Future Network Modelling Functions UK	Project objective was to produce a report assessing the expected future requirements for system modelling within a distribution network operator in Great Britain. The research project also intended to devise a strategic approach to meet the requirements using both existing and new technologies. The main topics addressed by the project comprised: Requirements identification; Strategic assumptions; Scenario modelling; Summary Analysis; Key risks and dependencies. Completion Date: September 2017.	[33]

GOPACS-IDCONS The Netherlands	GOPACS (Grid Operators Platform for Congestion Solutions) is a project for TSO/DSO market-based redispatch platform and it uses as one of the products the IDCONS (Intra-day congestion spreads), with the objective to develop a mechanism to increase volume of available flexibility, reduce costs, and standardise and harmonize grid operator products and processes to address congestion on lower voltage levels. Completion Date: the platform and product are active.	[14], [34]
InteGrid Portugal	InteGrid's focus is to bridge the gap between citizens and technology/solution providers such as utilities, AGR, manufacturers and all other agents providing energy services, hence expanding DSO's distribution and access services to active market facilitation and system optimisation services while ensuring sustainability, security and quality of supply. One of the project's goals is the development of a Market Hub Platform with the objective of empowering local energy communities by democratizing the access to smart meter data. Another is the development of business models for new data-driven energy services. Completion Date: October 2020.	[35], [36], [37], [38]
Interflex France	Dutch project dealing with congestion management, comparing time-of-use tariffs, dynamic tariffs and a Local Flexibility Market (LFM) approach with long lead times. Completion Date: December 2019.	[39], [40]
INTERRFACE Luxembourg	The INTERRFACE project (TSO-DSO-Consumer INTERFACE aRchitecture to provide innovative grid services for an efficient power system) has for main objective the increased coordination between TSO and DSO. The project focus on the design, development and exploitation of the Interoperable pan-European Grid Services Architecture (IEGSA) functioning as the interface between TSO/DSO and the customers, providing a seamless and coordinated operation of all the stakeholders to use and procure common services. INTERRFACE market structures will exploit state-of-the-art digital tools based on blockchains and big data management. Completion Date: December 2022.	[41], [42], [43]
IREMEL Spain	The main goal of the project IREMEL (Integration of Energy Resources through Local Electricity Markets) is to define and test a Flexibility Market Model capable of addressing prosumers and distribution system operators' needs, enabling the efficient integration of DER (renewables, proactive consumers, storage installations, etc.) and their participation in solving those needs, for example for local congestions. This is to be achieved through their participation in the existing European electricity markets (Daily and Intraday) for the periods where no restriction exists, and in the local flexibility markets that would be created in case of necessity. Completion Date: not informed, the project is ongoing.	[44], [45]
NODES Norway	NODES, as an independent market operator, provides a platform where BRP and network operators can procure local flexibility in the intraday timeframe, aiming to facilitate optimal use of flexibility in the grid, through an open, integrated marketplace to all flexibility providers and grid operators. Furthermore, the offered flexibility, which is not needed locally, will be forwarded to other existing market platforms, i.e. the intraday and balancing market.	[14], [46]

Open Networks UK	The Open Networks Project is a major industry initiative and seeks to enable the uptake of new smart energy technologies by more homes, businesses, and communities in the UK. Allowing customers to take advantage of these new technologies to manage their energy consumption and lower the bills. The project is enhancing data sharing between gas and electricity networks, sharing information on managing network constraints, and improving short term forecasting to optimise existing processes through greater interaction. It aims to change how the networks operate to facilitate the transition to a smart, flexible energy system. The Distribution Network Operators will take a more active role in managing their networks, allowing them to address periods of high and low demand, and power outages efficiently, with new low-carbon solutions. Completion Date: December 2020.	[48], [47]
Piclo Flex (and Piclo) UK	Piclo is a software platform for decentralised energy markets, offering a P2P energy matching service based on smart meter data. Piclo Flex is a service that lets a client upload its flexibility assets to a platform and offer biddings to smart grids and DSO, empowering both sellers and buyers with increased visibility over the grid and the other players. Completion Date: the platform is active.	[14], [49], [50], [51]
PlatOne Germany	PlatOne (Platform for Operation of Distribution Networks) aims at defining new approaches to increase the observability of renewable energy resources and of the less predictable loads while exploiting their flexibility. The purpose of PlatOne is to develop a cost effective two-layer platform for distribution network operation and market operation creating a seamless integration of local prosumer in an open market structure ensuring a joint data management of volatile generation and consumption. A blockchain based platform is the access layer to generators' and customers' flexibilities, and upper layer will implement a new concept of blockchain-based open market platform to link the local system to the TSO domains. Completion Date: August 2023.	[52], [53], [54]
Power Potential, National Grid UK	The objective of Power Potential, by National Grid and UK Power Networks, is the creation of a new regional reactive power market for distributed energy resources (DER) connected to the distribution, and generate additional capacity on the network, providing the services to GB SO: dynamic voltage control from DER (Mvar for high and low voltage conditions); active power support for constraint management and system balancing. This project estimates that it could save energy consumers over £400m by 2050. It could also generate up to an additional 4 GW in the South East region of the UK. Completion Date: not informed, the project is ongoing.	[55], [56]
SENSIBLE Germany	In Project SENSIBLE, the aim is to understand the economic benefits that energy storage can bring to households, communities, and commercial buildings. From the technical objectives: develop and demonstrate locally focused energy market services; define specifications enabling new distributed energy storage products, markets and businesses. An important aspect of the project is understanding how to connect local storage capacity with energy markets in a way that results in sustainable business models for small scale storage deployment, especially in buildings and communities. Completion Date: December 2018.	[57], [58], [59], [60]

USEF The Netherlands	USEF is an organisation, founded by seven key players, active across the smart energy industry, with the goal to accelerate the establishment of an integrated smart energy system with benefits for all stakeholders, from energy companies to domestic household consumers. The organisation presents an assortment of white papers and other documents centred around a common framework where a market for flexibility plays a pivotal role. The framework defines each stakeholder role in the energy market, how they interact and how they can benefit by doing so, detailing specifications and real-life pilots in the market. Completion Date: the organisation is active.	[61], [62], [63]

2. Flexibility Needs and Services

This section focuses on the first main topic to be investigated in this deliverable, namely, what are the main flexibility needs, the services to satisfy these needs, and the products negotiated to provide these services, as they are proposed in the projects analysed. However, since products are much related to the market clearing mechanisms, products are introduced here but addressed in more detail in section 3.

2.1 Methodology

The methodology used for this section consisted of the following steps:

1. Use the selected projects and initiatives agreed with task T1.2 partners;
2. Revision of each project to identify and collect the needs and services addressed. A comprehensive excel template was filled in to collect in detail the information gathered;
3. Classification proposal of the needs and the services;

   At this stage, a graphical summary was provided as feedback to task 2.1, including some additional information on the product attributes typically proposed for the provision of the services identified;

   Grid and non-grid needs and services were also distinguished;
4. Discussion of the results.

2.2 Flexibility for TSO vs. Flexibility for DSO

System operators (TSO and DSO) bear the responsibility of operating their networks securely and reliably. To do so, each system operator must be able to make decisions regarding the networks under their supervision.

Transmission System Operators (TSO) are responsible for the reliable transmission of electricity from large-sized generation plants to regional or local electricity Distribution System Operators (DSO) by means of a high voltage electrical grid [64]. The TSO provides grid access to the electricity market players (i.e. generating companies, energy storage operators, traders, suppliers, distributors and directly connected customers) according to non-discriminatory and transparent rules. TSO are tasked with maintaining, operating, and planning a robust and cost-efficient transmission network. The main responsibility of TSO is to ensure that the grid always remains stable, to safeguard the consumer's security of supply. This entails meeting the demand for transmission while keeping generation/consumption levels balanced, to avoid any fluctuations in frequency, interruptions in supply or grid failure. Maintaining this balance between generation and consumption requires the availability of appropriate levels of generation reserve capacity. This reserve capacity could be partially delivered by flexibility providers operating in the distribution network.

DSO are the operating managers (and sometimes owners) of energy distribution networks, operating at low, medium and, in some cases, high voltage levels [65]. As such, DSO are responsible for the reliable distribution of electricity from primary substations (HV/MV) to the consumers and the transport of excess electricity due to decentralized generation to the TSO within the distribution systems under their supervision. Like the TSO, DSOs have the duty to ensure security of supply and quality of service to all end-users. Traditionally, electrical power systems have been one-directional from power generation to consumers. However, electrical energy is being increasingly generated locally and connected directly to distribution networks, from solar panels to small power plants. This is generally referred to as distributed energy resources (DER) and, in the specific case of renewables, distributed renewable energy sources (DRES). As electricity generated from renewable sources is predominantly variable in nature (wind and solar) the DSO's core mission of providing a secure electricity supply and quality of service is becoming increasingly challenging. In addition to this changing nature of the local energy supply, new forms of energy demand are also increasing, such as electric vehicles (EV). In line with this, the Clean Energy for all Europeans package states in its e-directive [66] that "*Member States should also introduce network development plans for distribution systems in order to support the integration of installations generating electricity from renewable energy sources, facilitate the development of energy storage facilities and the electrification of the transport sector, and provide to system users adequate information regarding the anticipated expansions or upgrades of the network, as currently such procedures do not exist in the majority of Member States.*"

As a result, DSO are facing the challenge of making the best use of new DER and DRES while keeping infrastructure costs down. To tackle this challenge, complementary IT solutions are being introduced, adding communication, sensors and automation, which allow DSO to actively manage the varying generation and demand within the networks under their supervision. DSO are thus becoming increasingly active system managers, with the flexibility in their networks becoming a new variable to be considered not only in the daily operation of the system, but also in the long-term decision-making process (e.g. distribution reinforcing planning).

2.2.1 System needs vs local needs

Given that DSO and TSO have different responsibilities regarding the networks under their supervision, they also have different flexibility needs, even though they sometimes share common issues.

DSOs typically face challenges that are mostly local, in the sense that they include a range of problems that can be solved by means of a local intervention, e.g. relieving branch congestions, avoiding under-voltages and over-voltages, network reconfiguration due to outages, avoiding renewable generation curtailment. Even when dealing with more complex issues, such as network islanding, black start or the supply of emergency power, DSO must find feasible solutions within an enclosed geographical area. This condition makes most of their problems, and therefore flexibility needs, local in nature.

TSOs, in contrast, must deal with their network's flexibility needs (the same as for DSO plus the need for balancing), as they are responsible for monitoring and maintaining the overall system's nominal frequency, thus requiring available reserves for primary, secondary and tertiary control [67]. TSOs also must ensure that there is always enough generation capacity and inertia in the system, which can be a complex problem in systems with a large share of volatile renewable resources (wind and solar power plants). Thus, TSOs' needs for flexibility can be less local if they are widespread throughout the whole system. This will lead to situations where the TSO will become more dependent on the use of flexibility connected at the distribution level. TSO will therefore need to procure and activate such services from DSO grid users.

2.2.2 The growing importance of local flexibility

Shifting from predictable demand and supply patterns to decentralised, more uncertain and bidirectional power flow is having a significant impact in the planning and operation of distribution networks. This requires the evolution of the traditional DSO business model, to meet the growing expectations of customers and enable all types of market participants. DSO, as neutral market facilitators, should be able to supervise and resort to the flexibility available in their networks as a tool to operate their grids in a cost-efficient way. The use of these technologies should not lead to market disturbance. Whenever more efficient, a market-based solution should be chosen.

Under this new paradigm, DER can provide important flexibility services to the DSO, enabling them to operate their networks more efficiently and economically. For instance, the use of flexibility such as energy storage and demand response can help DSOs to shift supply and demand peaks, to prevent congestion (voltage and current issues) and avoid power quality problems. Furthermore, flexibility can serve as an alternative to network reinforcement when it is more cost-efficient than traditional reinforcement of the network.

With the use of flexibility provision from market parties or the DSO's own technical solutions, it may be possible to solve a wide range of technical problems (needs) and, in some cases, to postpone reinforcements of the distribution grid that would otherwise be undeferrable. However, the use of flexibility must be promoted without compromising the network's reliability and security of operation.

It is often accepted that DSO should be in control of the use of the flexibility resources in their grids, supported by locational information and well-defined product specifications. However, coordination mechanisms must be put in place to allow these local flexibility resources to provide wider system services. In this sense, coordination and information exchange between DSO and TSO are key to manage the complete system. This must be done to allow DSO and TSO to select the most efficient flexibilities from the flexibility available, but avoiding double flexibility activations at the same time, or the activation of a distribution flexibility resources by TSO without previous notification to the DSO. However, to maximize the business opportunities of the flexibility providers, it is also important to allow the provision of services that can be stacked [68], so the same assets portfolio can provide services to both TSO and DSO in a coordinate manner. When these flexibility resource can provide services to both TSO and DSO, mechanisms should be in place so that both parties can access them.

2.3 System needs, Services and Products definitions

According to EDSO [69]:

> "*Flexibility is defined as the modification of generation injection and/or consumption patterns, on an individual or aggregated level, often in reaction to an external signal, in order to provide a service within the energy system or maintain stable grid operation. The parameters used to characterise flexibility can include: the amount of power modulation, generation forecasts, the duration, the rate of change, the response time and the location. The delivered service should be reliable and contribute to the security of the system.*"

System needs have been increasing in recent years, because of the changing operation conditions of the power system, both within the transmission grid but also within distribution systems. The growing integration of variable renewable based generation, coupled with recent incentives to induce changes in the behaviour of consumers, increase the uncertainty in load diagrams and power flows, and consequently increases the complexity in the operation of distribution networks. Note that, as already explained in previous sections, flexibility needs are generally not the same for TSO and DSO.

One of the consequences of this new paradigm, is to operate network close to their technical limits, increasing the possibility of occurring congestion and voltage control problems, and ultimately network outages. Traditionally, congestion at the transmission level has been handled by re-dispatching, i.e. adjusting the scheduled generation of centralised power plants. At the distribution level however, congestion has historically been dealt with by means of network reinforcement, which might not be the most cost-effective solution to deal with large DER integration scenarios, characterized as referred before with a higher uncertainty. The use of flexibility can help DSO to shift supply and demand, to prevent voltage and current issues. It can also contribute to the improvement of power quality.

There is usually a permanent discussion on how system needs, services and products are defined and distinguished among them, since very often, this distinction is confusing and context dependent. In this deliverable the way these three concepts are interpreted is provided in Figure 1 and explained below.

- A **system need** is defined here as the requirement of a high-level strategical action or set of actions for the better operation and/or planning of the grid (in terms of security and quality of supply) related to a specific grid aspect. In this sense, as will be shown later, congestion management has, for example, been considered a system need.

- A **service** is defined as a specific strategy to help satisfy one or several system needs, where the service providers have to comply with the service technical requirements, designed according to the needs they are focused on, to be able to participate.

- A **product** is the specific commodity that is negotiated and delivered by the service providers to provide a particular service, which can be described by a set of technical attributes. In the vision proposed here, products are directly related to the negotiation and clearing (sometimes called selection) algorithm of the market. Indeed, in the case of simple clearing algorithms, products tend to be very much standardised and generic, with very little flexibility to adapt to the particularity of the resources offering them. Therefore, the complexity of complying with the technical specificities of the product falls on the side of the service provider that must aggregate its resources somehow to produce the required product. However, in the case of more complex and flexible clearing algorithms, it may be possible for the algorithm to build the required product for the specific grid problem to be solved by aggregating, in some optimal way, different products with different characteristics. In these cases, products can then be more tailored and adapted to the technical constraints of the offering resources since part of the aggregation complexity falls on the side of the market clearing mechanism.

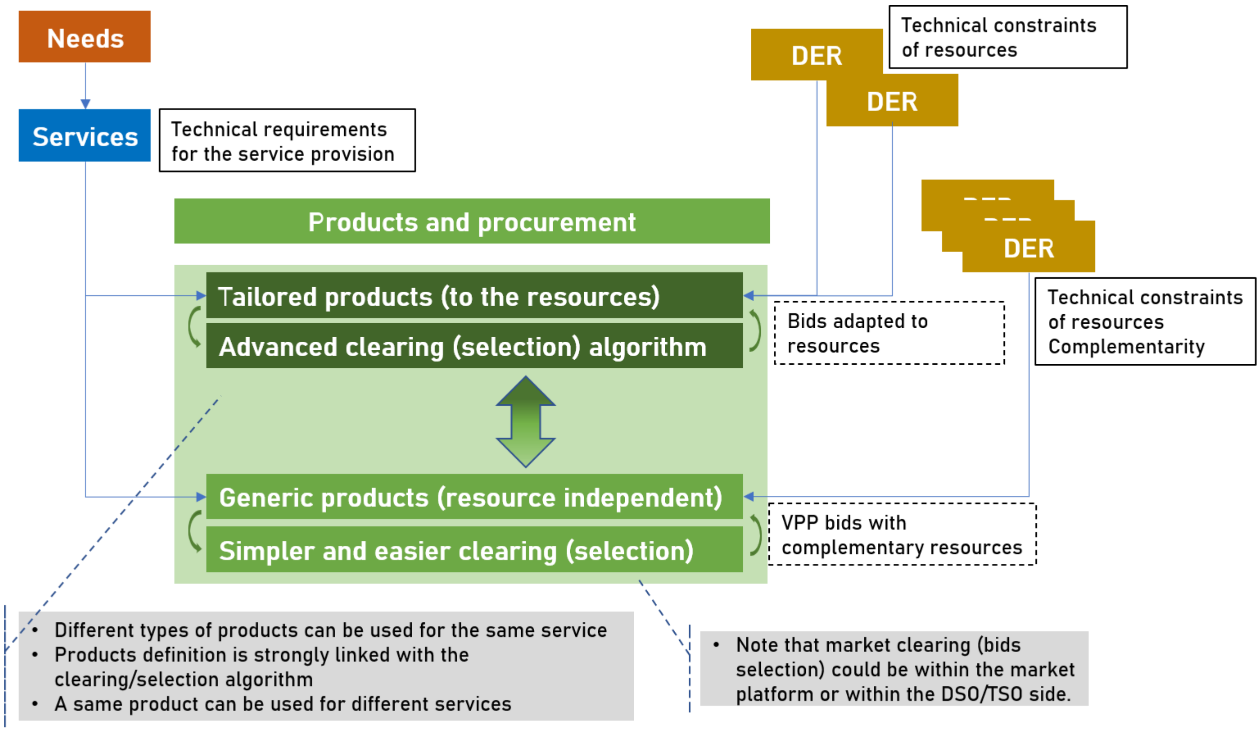


Figure 1: How needs, services, markets and products interrelate

2.4 TSO and DSO needs and services identification

Although the focus of this deliverable is mainly on the DSO side, according to the main objectives of the EUniversal project, in this task the needs and services for both TSO and DSO found in the projects analysed were collected and are presented.

2.4.1 TSO needs and services identification

Table 6 shows the main TSO needs and services identified during the projects literature review. The first column reports needs and services as found in the original documents, the second column includes some additional objectives reported in the documentation consulted, and the last column reports the projects investigated that address this particular need.

Table 6: Summary of TSO flexibility needs and services

TSO needs and services	Additional objectives	Project
Balancing: - Frequency Containment (Primary Regulation): - FCR-N: FCR capacity for normal operation; - FCR-D: FCR capacity for disturbances; - Frequency Restoration (Secondary Regulation) - mFRR; - aFRR; - Reserve Replacement (Tertiary Regulation): - RR (replacement reserve); - DSR (demand side response); - FFR (Fast Frequency Response); - Ramp control; - Smoothed Production; - BRP Portfolio Balancing (non-regulated)	Maintain system stability and reliability; Avoid curtailment of renewable generation; Slow time to reach nadir/zenith - FFR; Contain frequency - FCR; Return frequency to nominal - FRR; RR - Replace faster reserves used	CoordiNet; EcoGrid 2.0; EMPOWER H2020; FlexHub Eu-SysFlex; Enera; FlexHub Eu-SysFlex; InteGrid; Interflex; INTERRFACE; IREMEL; NODES; SENSIBLE; USEF
Congestion Management: - Operational; - Short-term planning; - Long-term planning; - Cross-border redispatch; - Cross-border countertrading	Delay/avoid grid reinforcements	CoordiNet; EcoGrid 2.0; FlexHub Eu-SysFlex; GOPACS-IDCONS; INTERRFACE; USEF
Controlled Islanding	Reduce frequency and duration of outages	CoordiNet; INTERRFACE; USEF
Damping of power system oscillations.	Avoid further loss of generation and cascading outage events	CoordiNet
Fault-Ride Through (FRT)	Avoid loss of generation and possibility of severe disturbances.	CoordiNet
Flexibility Platform for TSO: - Visibility over available flexibility; - Complementary services such as weather, load and generation forecasting; - Real-time data delivery by use of advanced analytics and machine learning; - Coordination mechanism between TSO and DSO and TSO	Visibility over available flexibility; Coordination guaranteed between DSO and TSO (an accepted offer will not trigger a new congestion in another area)	Enera; GOPACS-IDCONS; NODES
Grid Capacity Management: - Generation scheduling; - Load scheduling	Avoid curtailment of renewable generation; Avoid disproportionately high costs if annual peak load is exceeded; Avoid reinforcement deferral; Peak generation and load shift; Optimize asset use and reduce grid losses	NODES; USEF
Inertial Response	Minimise RoCoF (rate of change of frequency)	CoordiNet; FlexHub Eu-SysFlex
National capacity markets	Reduced requirement for peak generation capacity	USEF
Redundancy (n-1) Support: - Black Start; - Supply of emergency power	Reduce frequency and duration of outages	CoordiNet; INTERRFACE; USEF
Voltage control	Minimization of power losses; Keep a steady state security	CoordiNet; FlexHub Eu-SysFlex; INTERRFACE USEF

2.4.2 DSO needs and services identification

Table 7 shows the main DSO needs and services identified during the project literature review. The first column reports needs and services as found in the original documents, the second column includes some additional objectives reported in the documentation consulted, and the last column reports the projects investigated that address this particular need.

As can be seen, some of the DSO needs mostly addressed are balancing, congestion management, and voltage control. For that reason, we decided to maintain congestion management and voltage control as separate needs. Local grid balancing was only discussed or mentioned as a service to address the need of Service Restoration, specifically for operating the grid in isolated/islanding mode. It should not be considered as a need in this context, but rather as a service or as part of a service. For that reason, we decided to define the need of Service Restoration, encompassing two services to address it: (1) Black Start for distribution islands and (2) Isolated/Islanding operation mode. Some of the listed needs and services were included in this division, while others were discarded given the lack of relevant information provided in the initiatives reviewed. Exception was made for FRT, generation, load and flexibility forecasting and for the service of visibility over available flexibility. We considered FRT as a service addressing the need of voltage sag mitigation. Generation, load and flexibility forecasting were considered as services for addressing the need for planning and predictive management. Finally, the service of visibility over available flexibility provided by flexibility platforms was considered as addressing a non-grid service as will be explained in the following chapters.

Reorganising the information of Table 7, complemented with some additional details, the following sections present graphical summaries of the main needs identified (brown boxes), the services used to satisfy these needs (blue boxes), provide a brief explanation of these needs and services (white boxes), and highlight the projects that address these needs and services (grey boxes, where bold letter indicates more detailed descriptions or emphasis on the services described). The proposed organisation of needs and services is partly a result of all the information collected during the project revision process, but also includes the personal vision of INESC TEC, task responsible and main working team.

Table 7: Summary of DSO flexibility needs and services

DSO needs and services	Additional objectives	Project
Congestion management: - Short-term planning; - Long-term planning; - Operational (balancing); - Peak shaving; - Time shifting; - Flexibility: peak shaving + time shifting; - Cross-border redispatch; - Cross-border countertrading	Mitigate network overloadings and outages; Delay/avoid grid reinforcements	CoordiNet; De-Flex-Market; EcoGrid 2.0; EMPOWER H2020; Enera; FLECH-iPower; Flex-DLM; FlexMart; GOPACS-IDCONS; Interflex; INTERRFACE; IREMEL; NODES; Piclo Flex (and Piclo); SENSIBLE; USEF
Controlled islanding	Reduce frequency and duration of outages	CoordiNet; USEF
Damping of power system oscillations	-	CoordiNet
Fault-Ride Through (FRT)	-	CoordiNet
Flexibility forecasting	-	SENSIBLE
Flexibility platform for DSO: - Visibility over available flexibility; - Complementary services such as weather, load and generation forecasting; - Real-time data delivery by use of advanced analytics and machine learning; - Coordination mechanism between DSO and DSO and TSO	Reinforcement deferral: Support planned maintenance and unplanned interruptions; Reduce peak dispatchable capacity; Coordination guaranteed between DSO and DSO and TSO (an accepted offer will not trigger a new congestion in another area)	Enera; FLEXICIENCY; GOPACS-IDCONS; NODES; Piclo Flex (and Piclo)
Generation forecasting	-	CoordiNet; InteGrid; SENSIBLE
Grid Capacity Management: - Generation scheduling; - Load scheduling	Avoid curtailment of renewable generation; Avoid disproportionately high costs if annual peak load is exceeded; Avoid grid reinforcement; Peak generation and load shift; Optimize asset use and reduce grid losses; Planned maintenance	NODES; USEF
Inertial Response	-	CoordiNet
Load forecasting	-	CoordiNet; EMPOWER H2020; InteGrid; SENSIBLE
Local Grid Balancing: - Frequency Restoration (same as Secondary Control): - mFRR (manual frequency restoration reserve); - DSR (demand side response); - Flexibility of generators	Mitigate network overloadings; Avoid curtailment of renewable generation; Address imbalances that may arise from flexibility activations	EcoGrid 2.0; EMPOWER H2020; Enera; Flex-DLM; Interflex; NODES; Piclo Flex (and Piclo)
Redundancy (n-1) Support: - Black Start; - Supply of emergency power	Reduce frequency and duration of outages	CoordiNet; INTERRFACE; USEF
Voltage control: - Active power management; - Reactive power management	Avoid grid reinforcement; Avoid curtailment of renewable generation; Minimization of power losses; Keep a steady state security	CoordiNet; EcoGrid 2.0; EMPOWER H2020; FlexHub Eu-SysFlex; FLEXICIENCY; Interflex; IREMEL; Piclo Flex (and Piclo); SENSIBLE; USEF

2.4.2.1 DSO grid needs and services

Figure 2 focuses on the voltage control needs and services. As can be seen this need is considered by many of the projects analysed, and the main services proposed are based on reactive and active power flexibilities. In the case of reactive power, some approaches distinguish between voltage control under normal operation (steady state control) and voltage control under system disturbances (dynamic control).

Figure 3 focus on congestion management needs and services, a need that was even more frequently addressed than voltage control.

By analysing the services addressed to resolve the congestions management needs, it was decided to group them into three categories.

The first service considered has been called operational and refers to congestion problems that occur in real time, possibly due to equipment faults or forecast errors. It is a rather corrective service, and therefore reacts to recent measurements. As such, it may need capacity reservation negotiation before the even triggering the problem to guarantee flexibility availability in real time, or other regulated mechanism.

Short-term planning refers usually to day-ahead to month ahead planning and is based on taking the actions needed to solve the short term expected congestions that result from the grid analysis based on expected load and generation forecasts. Very often, intraday planning does not differ significantly from day ahead planning, shares most tools and strategies, and should therefore be also included in the same short-term planning service. Note also that services for flexibility activation based on Optimal Power Flow (OPF) tend to solve simultaneously grid voltages and congestion problems and could, therefore, satisfy both needs.

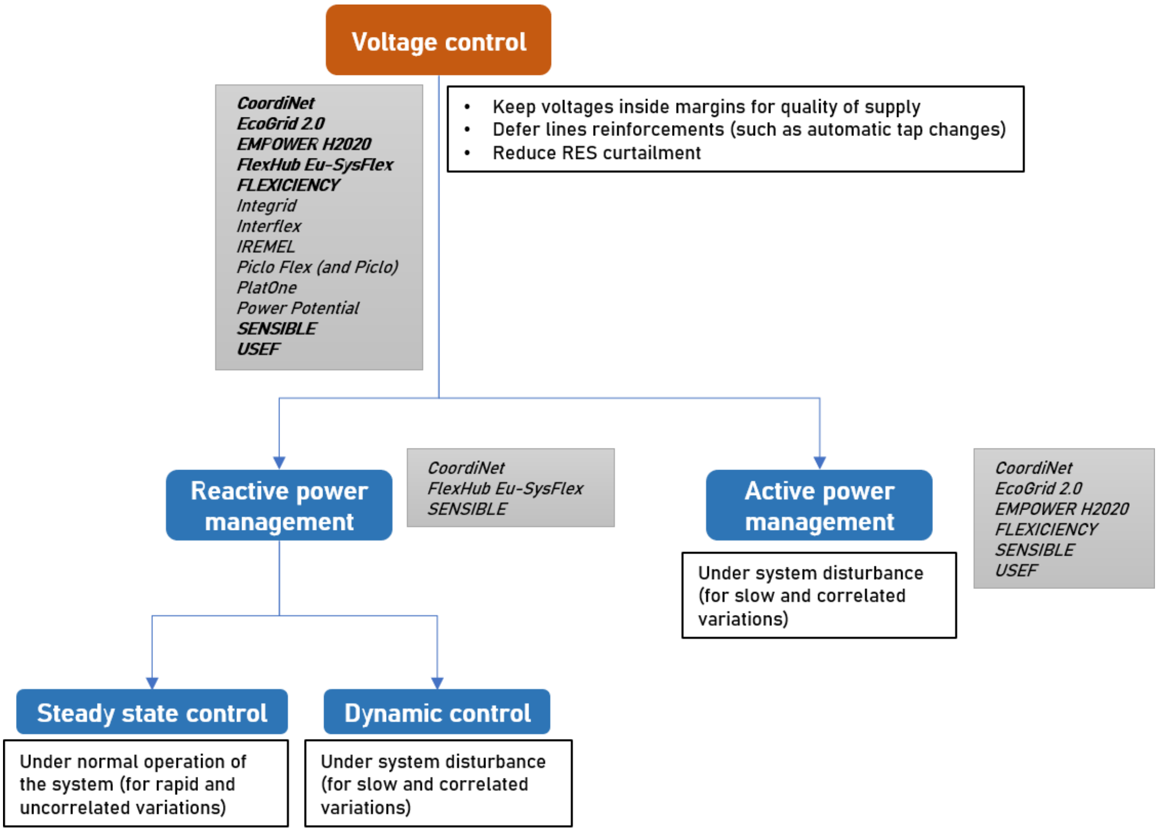


Figure 2: DSO voltage control need and services

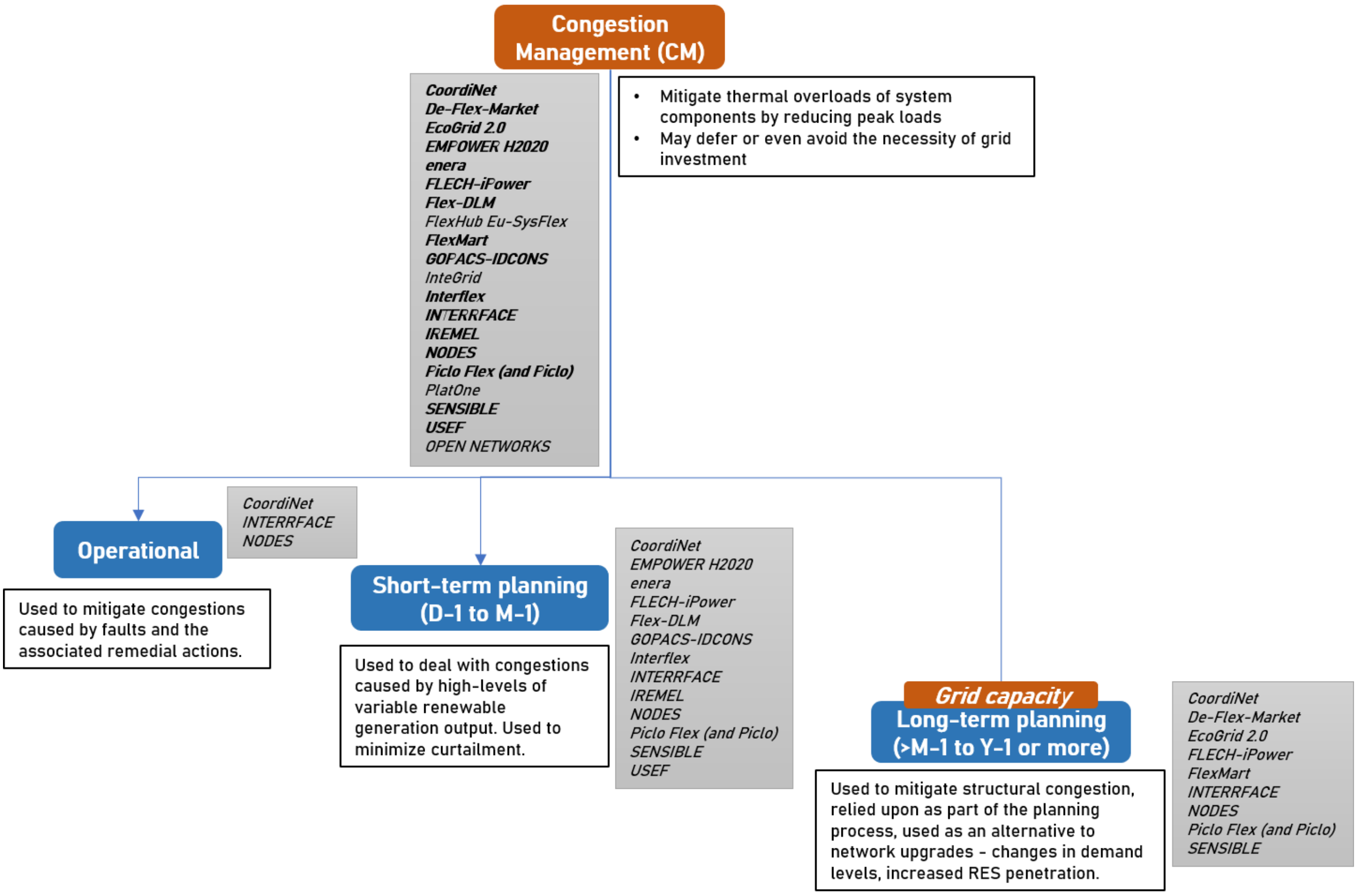


Figure 3: DSO congestion management need and services

Finally, the third category is related to long-term planning. In this case, grid reinforcements should be compared to flexibility usage to assess the benefit and potential risks of the different alternative solutions, since long term actions imply also larger uncertainties. In this case, it is also common that grid planning has a larger scope than congestion constraints solving. Indeed, depending on the methodology used to solve the congestions, it may happen (as already mentioned) that a same service is used simultaneously for several needs. This occurs if, for example, the flexibility is selected by an Optimal Power Flow that typically considers simultaneously voltage and congestion grid constraints. This is especially relevant in long term planning, where grid reinforcements are usually decided considering all existing grid constraints, so for example, the reservation of long-term capacity could be a service for both voltage control and congestion management. However, this was not much explicit in the projects analysed, maybe because voltage control is usually less addressed than congestion management and tend to focus more on short term voltage control strategies.

Note also this initial proposal may be refined and improved in subsequent project tasks, such as task T2.1 that counts with the explicit participation of the DSO members of the project.

Figure 4 shows the graphical summaries for the service restoration need, and for the voltage sag mitigation need. These are much less addressed needs in the projects analysed, as can be seen in the figure.

In the case of service restoration, two different services were identified, the black start service, parallel to the black start TSO service, but applied to distribution islands to restore the service when disconnected from the grid, and the operation itself of the distribution island also when disconnected from the grid. In this last case, frequency regulation mechanisms may be needed at distribution level to be able to operate the grid.

Finally, voltage sag mitigation is almost not addressed, and only one project refers to it. This is possibly since it is very often considered a mandatory behaviour specified as a requirement in grid codes. However, it could be possible in some scenarios to transform this into a market-based service.

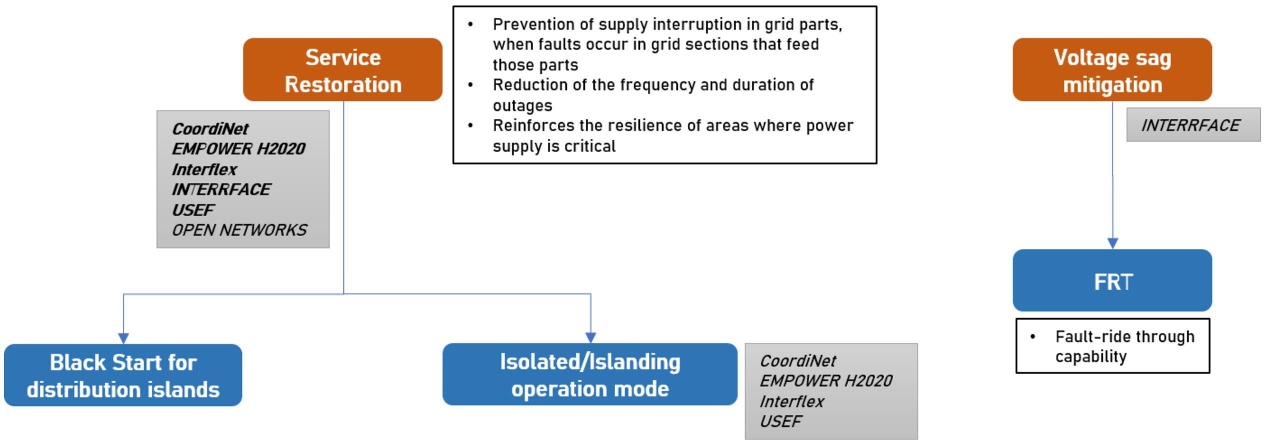


Figure 4: DSO service restoration and voltage sag mitigation need and services

2.4.3 DSO non-grid needs and services

Although not being the focus of the EUniversal project, and in particular of this task, it was decided to also collect the main non-grid services and needs identified. By non-grid services it is meant, in general, services to provide platform and data to contribute to the better operation of the grid, but not including the provision of physical flexibility, such as active or reactive power, grid reconfiguration, etc.

Figure 5 shows non-grid needs and services related to planning and predictive maintenance, basically centred on the forecast of relevant magnitudes such as generation, load and available flexibility.

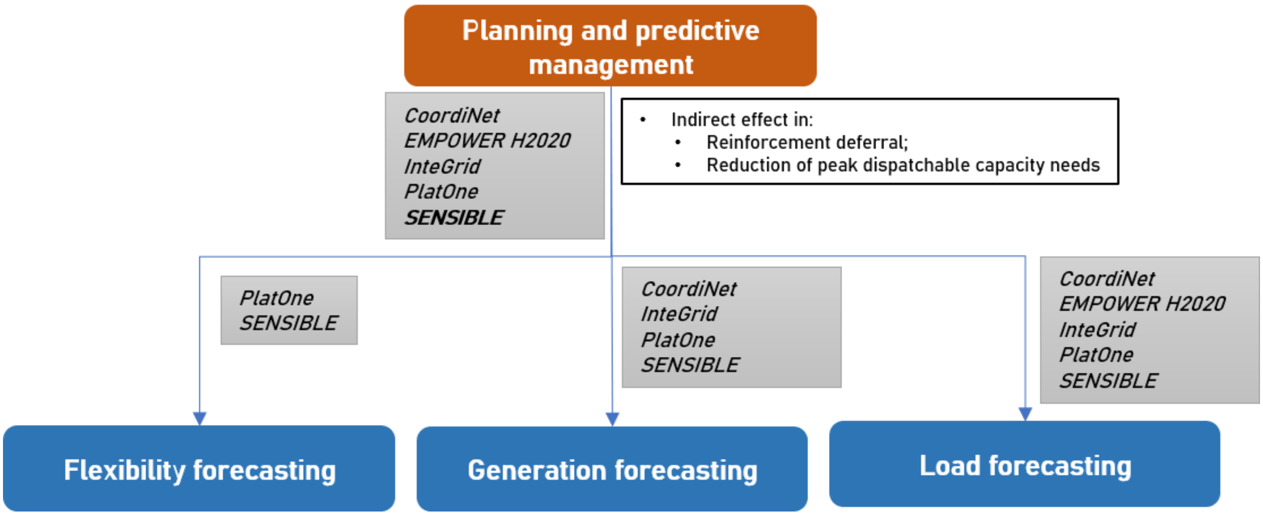


Figure 5: DSO planning and predictive management need and services

Similarly, Figure 6 focus on the needs for observability of the flexibility available, for flexibility procurement and settlement, and for coordinating TSO and DSO use of the available flexibilities. Therefore, this need refers mainly to the flexibility platforms.

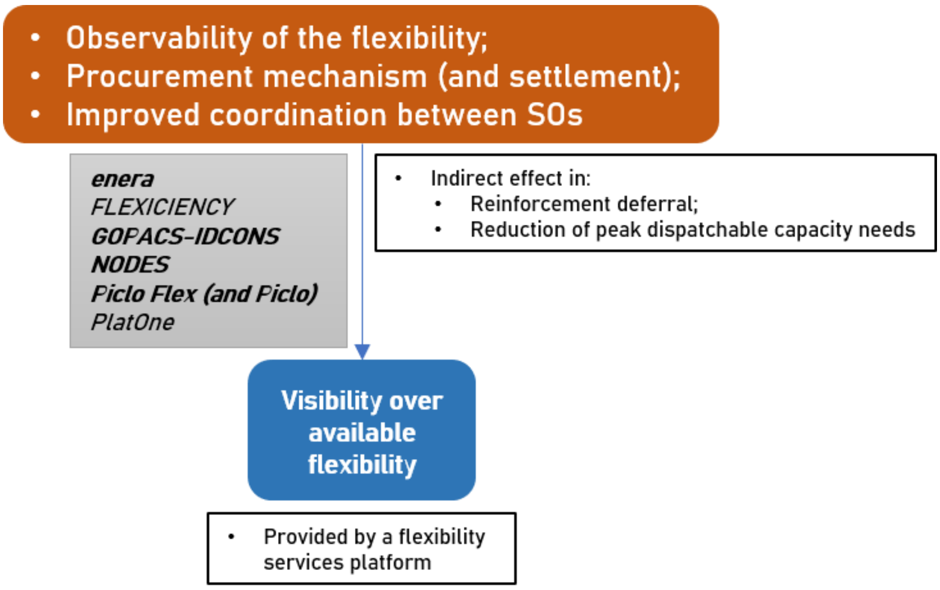


Figure 6: DSO planning and predictive management need and services

2.4.4 Summary of the DSO needs and services

Table 8 summarizes the grid and non-grid services identified and described so far.

Table 8: Characterization of the DSO needs and services identified

Needs	Services		Definitions	Category
Voltage Control	Reactive power management	Steady state control	Service to maintain the voltage profile inside the limits, in steady state (normal operation).	Grid service
		Dynamic control	Service to control the voltage variations under system disturbances.	Grid service
	Active power management		Service for voltage control by increasing/decreasing active power.	Grid service
Congestion Management (CM)	Operational		Service for CM in operational timeframe, activated to mitigate congestions caused by faults, and to other remedial actions.	Grid service
	Short-term planning (D-1 to M-1)		Service for CM in timeframe of D-1 (day before) up to M-1 (month before).	Grid service
	Long-term planning (>M-1 to Y-1 or more)		Service for CM considering several months or years before, and may as well result in network reinforcement deferrals.	Grid service
Service Restoration	Black Start for distribution islands		Service for system restoration after blackout situations. In the distribution specific case, at present, large generators that are already designed for blackout services can be used for black start in parts of the distribution network.	Grid service
	Isolated/Islanding operation mode		Specific services can be offered for parts of the grid operating in islands/isolated mode (e,g, isolated microgrids). Some needs to attend these services are local balancing and voltage control (and others).	Grid service
Voltage sag mitigation	FRT		Service to provide FRT (fault ride through) capability, supporting the mitigation of voltage sag on the distribution system. FRT as a flexibility service is in early discussions.	Grid service
Planning and predictive management	Flexibility forecasting		Forecasting services, for distribution loads, generation and flexibility, to have better estimations of generation and demand, and the expected impacts for the DSO, considering also the flexibilities available.	Non-grid services
	Generation forecasting			
	Load forecasting			
- Observability of the flexibility. - Procurement mechanism (and settlement); - Improved coordination between SO	Visibility over available flexibility		Service to provide DSO enhanced observability of the system, with better awareness of their assets, their available flexibility and location, improving the system management.	Non-grid services

2.4.5 Discussion

Figure 7 summarises the main needs and services identified, organised by timeframes, where the blue colour represents services based on active or reactive power flexibility, being darker for those services more addressed in the projects and initiatives reviewed, and with other alternative ways of resolving the needs marked in green.

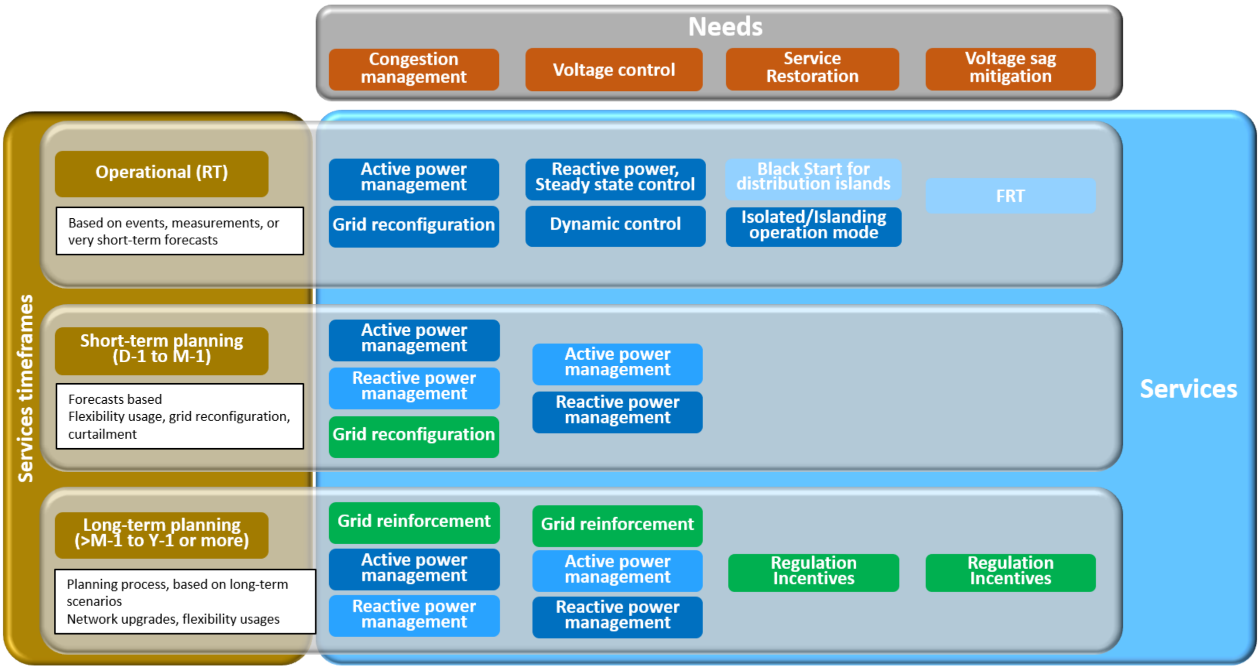


Figure 7: DSO needs and services summary

A survey was also conducted by EDSO among some of its DSO partners to complement and discuss the results obtained so far from the revision of the projects and initiatives. The template of this survey can be found in Annex I – Template of the survey conducted by EDSO among DSOs. These are the main conclusions from this survey.

Even though the identified needs and services are generally known and accepted by DSOs, it should be considered that the availability of services is different for each DSO. National regulations restrict the offering of certain services, while in other cases these services cannot be financed, or the technology has not yet been fully researched and assessed.

Regarding the list of needs identified, voltage control is the major need of DSO. Both needs for reactive power management and active power management are already addressed by most DSOs. Still, active power control plays a subordinated role for voltage control compared to reactive power management of distributed generation.

Even though congestion management is considered as a relevant need, operational management, short-term and long-term planning, are still a costly solution to implement in the next 5 years for some DSOs.

Service restoration needs raise some concern at the LV level about the value of implementing these services. The services Black Start for distribution islands or/and Isolated/Islanding operation mode are considered to be irrelevant for some DSOs. In addition, in many countries' regulatory framework limits DSOs' activities in that area. However, when moving to operation scenarios with 100% RES integration and when tackling resilience as a relevant operation and planning criteria, this perspective is expected to change.

The FRT, answering to voltage sag mitigation needs, is classified as suitable for most DSOs. In cases of DSOs where it has not been implemented yet, implementation is planned over the next 5 years. This is a control function already available in most of medium-scale smart inverters (with powers above 100kVA). However, more detailed studies are required to understand the relevance of such control function in strong interconnected distribution networks.

For planning and predictive management, the three forecasting services (flexibility forecasting, generation forecasting, load forecasting) presented in Table 8 are relevant services for DSO. However, flexibility forecasting stands out as a service yet not available for all DSO at full potential. In some cases, this service is still in development to be a standardised process. Also, the flexibility market in some countries is at a very early stage (not expected to be legislated in the next 5 years).

Visibility over available flexibility has the same answer as the flexibility forecasting service. Some DSO see it as a service that may be developed in the future once flexibility platforms are launched.

Summing up, the differences noted in the opinions of DSO result mainly from three factors: the lack of necessary knowledge/technology development, the lack of legislation in the DSO's country regarding the services mentioned, or unprofitability of offering services for the necessary investments. It should be also considered that not all services are needed by all DSOs in all circumstances.

2.4.6 Conclusions

DSOs typically face challenges that are mostly local, in the sense that they include a range of problems that can be solved by means of a local intervention. It is hence becoming increasingly important to develop the tools that will help identify, unlock and better understand the flexibility potentials of distributed energy resources to support DSO dealing with emerging needs, such as congestion management and voltage control (Figure 7). Such an understanding would enable the systematic integration of these services to network planning standards and market mechanisms.

This has been recognised as a pressing need from system operators around the world, resulting in pilot and trial projects. In the UK for example, the Power Potential project [56] in South East UK by UK Power Networks and National Grid ESO is investigating, as a world-first trial, the potential of voltage control services to the transmission network from DER technologies. Another UK example includes the Distributed ReStart project [70], a world-first initiative exploring how DER, such as solar, wind and hydro, can be used to support the power restoration to transmission networks in the unlikely event of a blackout. In Europe, ENTSO-E and E.DSO recently published a report [71] outlining the benefits and potentials of an integrated approach to active system management, with the focus on congestion management and balancing services to ensure the efficient interaction with market parties. Indeed, this report proposes some market-based TSO-DSO coordination mechanisms that are discussed in section 3.2.8 devoted to the identification of the market mechanisms for the provision of DSO services.

This has resulted in the emergence of new players in the provision of flexibility services, namely the AGR [72] which offer a unique opportunity to exploit the flexibility potential of aggregating smaller, DER customers dispersed in distribution networks. This, however, dictates the design of a flexibility market that will be largely determined by the operational, planning and market rules set out in EU network codes. Hence, to allow aggregated flexibility to participate in spot and intra-day markets, as well as exploring their contribution to operational, short-term and longer-term grid planning (as outlined in Figure 7), several issues would need to be addressed, including, for example, amendment of market rules and clearly defining and metering the balancing responsibility on a connection.

An additional critical service that is emerging as a direct impact of the increasing frequency and impacts of extreme events, such as severe weather or large-scale disturbances, is the consideration and provision of resilience as an explicit criterion for DER and distribution network planning. However, existing network planning standards do not effectively capture and enable this transition to a more resilience-oriented distribution network planning, as they are driven by the traditional reliability standards which are based and quantified using average or expected metrics, which undermine the resilience to high-impact low-probability events. For example, aggregated DER can provide reserve services of varying duration to support TSO dealing with disturbances. Key energy stakeholders and policy and regulatory decision-making bodies have recognised the growing need of amending the network planning and regulatory standards to account for resilience services as a planning criterion, including for example the recent report by the UK National Infrastructure Commission [73]. This will become increasingly important as the uncertainty and dependence on intermittent renewable sources, as well as the complexity and TSO-DSO interactions are growing in the future.

Hence, it is apparent that new market mechanisms need to be developed to allow and enable the active participation of existing and emerging flexibility providers in the market of the future integrated power systems, both at the transmission and distribution levels. This matter is addressed in the following chapter, where different flexibility market integration models are discussed.

3. Flexibility market integration models

3.1 Methodology

The methodology used for this section consisted of the following steps:

1. Use the selected projects and initiatives agreed with task T1.2 partners;
2. Definition of an initial set of market models to classify the markets proposals found in the projects and initiatives reviewed;
3. Agree the market models classification with task T1.2 partners;
4. Perform the revision of each market model found in the project selected by:
    a. Filling-in the market description template prepared in T5.1 for better coordination with WP5 (Annex II – Templates for markets characterization: Excel template for markets description);

Filling-in a graphical summary template of the markets' organisation of each selected project for a more concise and fruitful feedback to other project tasks. This graphical summary was used to provide rapid feedback to other project tasks and for T1.2 partners' discussion (Annex II – Templates for markets characterization:

b. Power point template for markets description);

5. Map markets with services and products;
6. Discussion of the results.

Figure 8 shows graphically the followed methodology, with, on the right side, the main concepts considered for the graphical summary template of the markets' organization.

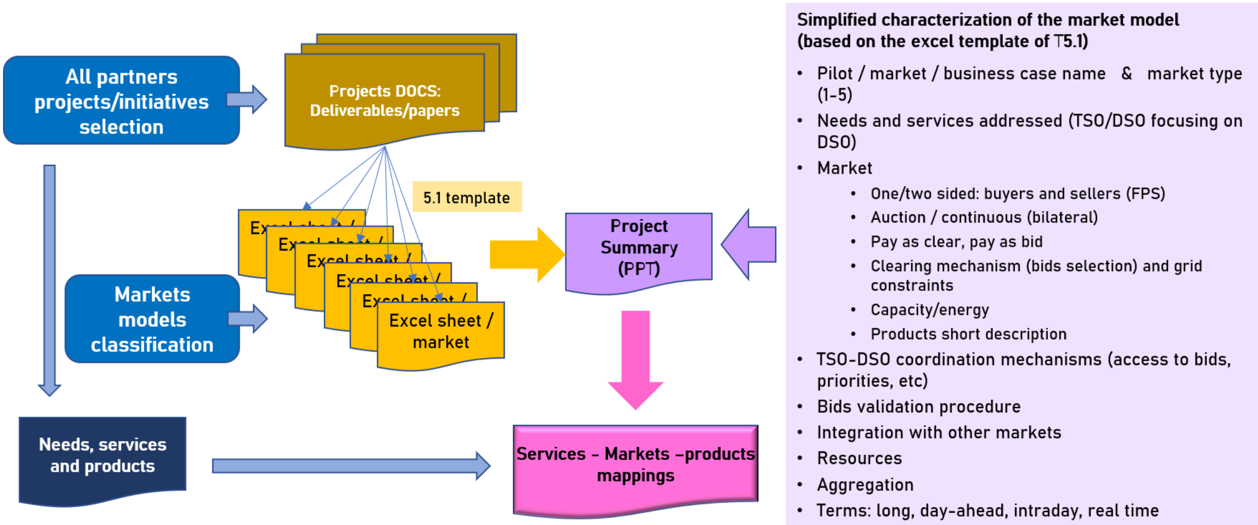


Figure 8: Methodology for markets models analysis

3.2 Main market models for DER integration and SO coordination

According to [71], "*a market is defined as a Merit Order List (MOL) combining specific products for a specific timeframe. The separated markets mean separate MOLs, a combined market means a combined MOL (a subset MOL is regarded as a combined MOL).*"

Therefore, combined markets refer to a common set of flexibility bids where selection is performed with a unified procedure that has the capability of seeing all flexibility bids to satisfy all the combined needs according to some kind of optimality criteria.

Based on the SmartNet project classification of the coordination mechanisms between TSO and DSO [74], six main market models have been initially proposed to classify the markets proposals found in the reviewed projects. Models M1, M2, M3, M4 and M5 are adapted from those proposed in the SmartNet project, and a new model in between M2 and M3, model M2/3 was also added.

Note that proposed market models focus on the functional aspects rather than on administrative or entities/roles' organisational aspects. See section 3.2.3 for some additional clarifications based on the M2 example.

3.2.1 Comments on the classification proposed for the markets' organisation

The classification of market organisations focuses on the functional aspects rather than administrative or entities/roles organisational aspects. This means that the main objective is to make clear what are the functions that can or must be performed in each case, without specifying the entity responsible for performing each task. Using M2 example (see section 3.2.3), Figure 9 tries to clarify these points. Namely:

- The proposed markets organisations focus on the functional tasks needed for the DSO-TSO coordination, rather than organisational aspects. Therefore, there are no assumptions about which entity acts as market operator (MO). However, the technical part of the bids' selection process is part of the responsibilities of the transmission or distribution system operator (SO) and should be directly or indirectly (subcontracting the service) performed by them;
- Validating local bids for the TSO usage is also a technical task that should be the responsibility of the DSO;
- Market operators could be an independent entity, or the DSO/TSO could act as market operators/facilitators of their respective markets;
- Flexibility activation could be performed by publication of the market clearing results at the corresponding market platform, or after receiving as activation signal from SO/MO. In such cases, the flexibility service provider (FSP) is responsible for activation. Activation could also be performed directly by SO. The activation mode may depend on the type of need addressed and product type and is not addressed in the diagrams of the market types.

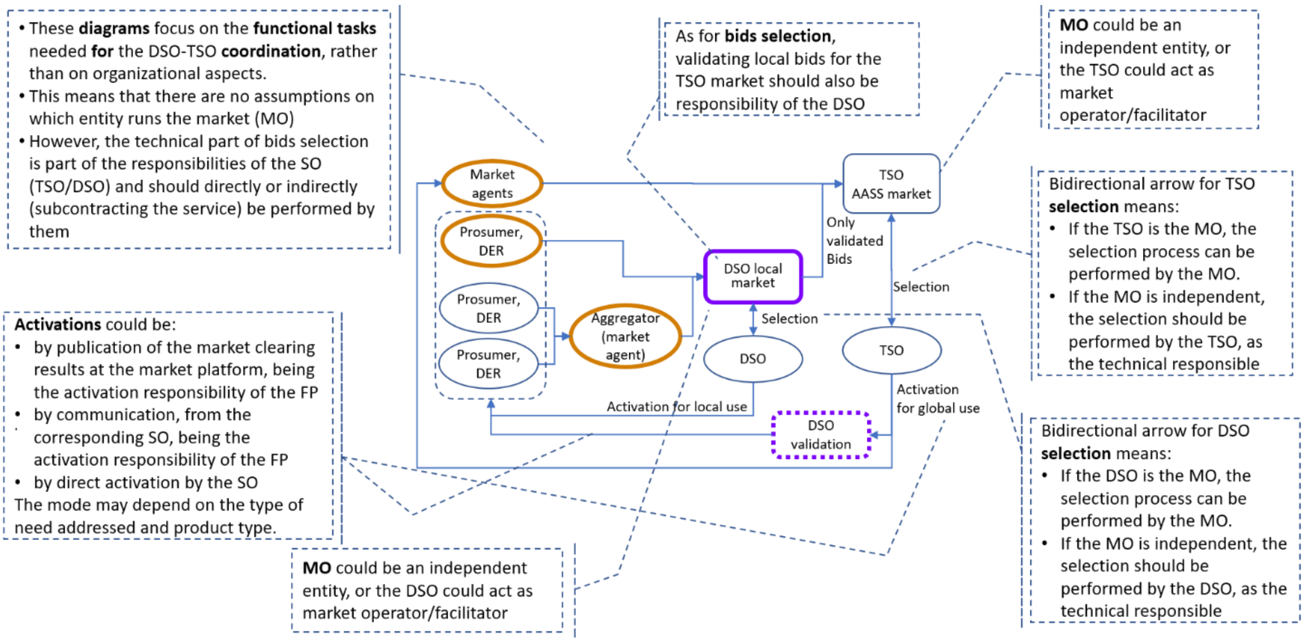


Figure 9: Clarifications on the proposed market organizations

However, during the revision performed, administrative and other relevant aspects (not considered in these diagrams) were reported in the corresponding Excel template, as well as in the summary figures elaborated for each project when considered relevant enough, see Annex II – Templates for markets characterization.

3.2.2 Market organization M1: centralised flexibility market

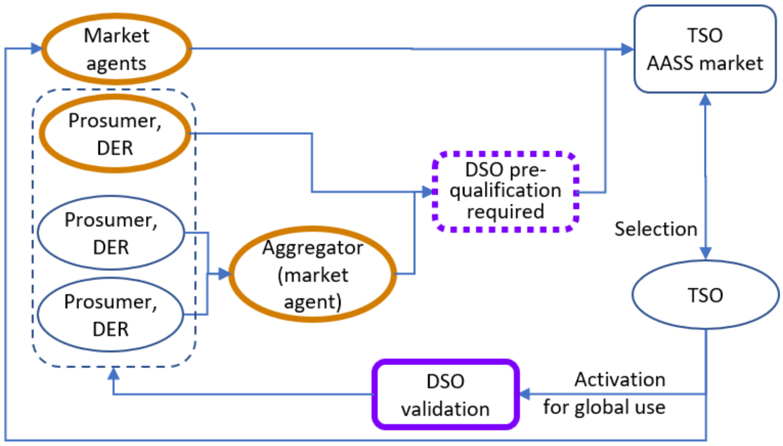


Figure 10: Centralised flexibility market

The main characteristics of this market organisation are:

- It is the approach closer to the current situation, where DSOs generally do not procure flexibility;
- The flexibility is procured by the TSO in a unique centralised market, where aggregated DER are also allowed to participate under certain conditions;
- A pre-qualification process of the DER can take place to guarantee that their activation does not put in trouble the DSO grid;
- If the TSO-DSO coordination is more advanced, a DSO validation could also take place, close to real time, before the activation of the bids finally selected by the TSO.

3.2.3 Market organization M2 and M2-MO: local and global flexibility markets

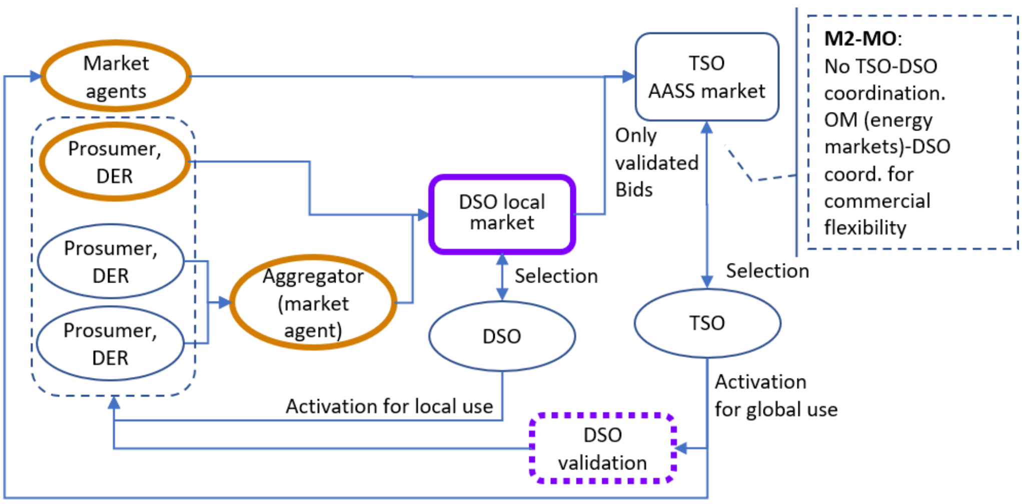


Figure 11: Local and global flexibility markets

The main characteristics of this market organisation are:

- The flexibility offered by the DER is managed in a local DSO flexibility market;

- The DSO uses these local resources for its own flexibility needs;
- The remaining flexibility bids, not needed by the DSO, become somehow available for the TSO;
- The DSO can also validate that the bids finally selected by the TSO do not compromise its grid safe operation before the activation of the resources offered.

There is also an alternative market organisation (that has been called M2-MO) where the coordination does not take place between the TSO and DSO for the provision of regulated flexibility (for system services), but between the Iberian MIBEL (joint Spanish and Portuguese Iberian electricity market) market operator or MO (as a potential provider of local flexibility markets platforms) and the DSO to allow the participation of DER in energy markets, namely day ahead and intraday markets, for the provision of commercial flexibility for BRP. It was included here due the conceptual similarities between M2 and M2-MO, from the DSO side responsibilities.

3.2.4 Market organization M3: local and global flexibility markets with shared responsibility

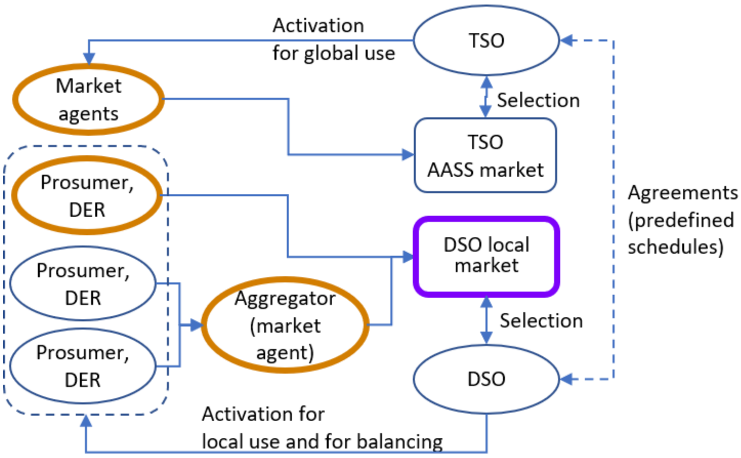


Figure 12: Local and global flexibility markets with shared responsibility

The main characteristics of this market organisation are:

- Being similar to the previous market organisation (M2), in this case the TSO set agreements with the DSO for a profile to fulfil the TSO needs at the TSO-DSO interface, so it does not have direct access to the DER bids. These agreements could be for balancing purposes, but also for other TSO services;
- The DSO is then responsible for providing the agreed profile using its local market resources;
- Detailed DER location remains implicit for the TSO that only needs to know the DSO grid at which the DER is connected.

3.2.5 Market organization M2/3: local and global flexibility markets with balancing coordination

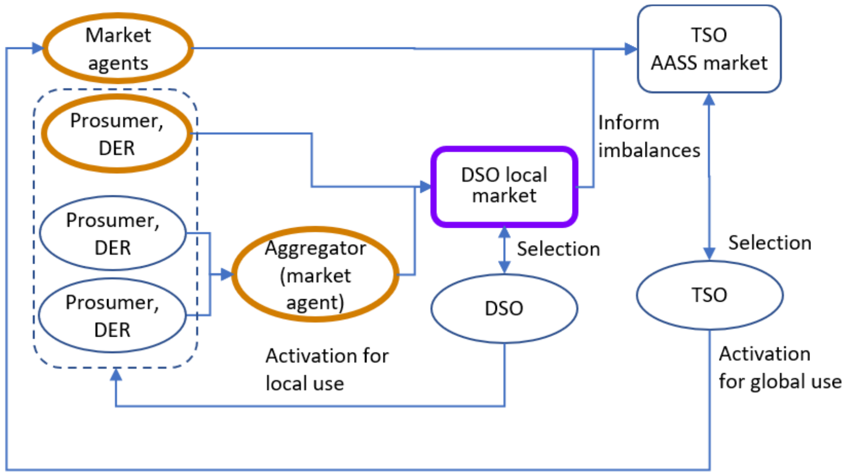


Figure 13: Local and global flexibility markets with balancing coordination

Under this market's organisation, as in M2, the local DSO flexibility market and the global TSO flexibility market coexist. In addition, the DSO informs about the amount of flexibility locally activated so that the TSO can take the corresponding actions to balance the system.

The main characteristics of this market organization are:

- Flexibility offered by DER is managed in a local DSO flexibility market;
- The DSO uses these local resources for its own flexibility needs;
- When DSO flexibilities activation can cause imbalances, the DSO communicates these imbalances to the TSO;
- The flexibility not used by the DSO could or not be made available to the TSO market. However, in the initiatives analysed, the only TSO-DSO coordination identified for those classified as M2/3 was the notification, from the DSO to the TSO, of the local flexibility activated.

3.2.6 Market organization M4: common TSO and DSO flexibility market

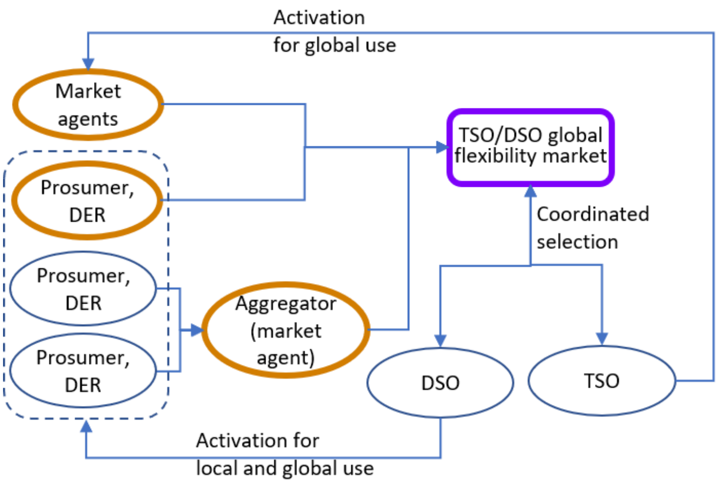


Figure 14: Common TSO-DSO flexibility market

The main characteristics of this market organisation are:

- Flexibility is selected in a unique market to satisfy both TSO and DSO needs;
- Selection of flexibility bids by DSO and TSO is carried out in a coordinated process and considers the constraints of all the grids involved;
- The level of TSO/DSO coordination can vary depending on the regional grid topology;
- If resources are used for grid constraints the TSO needs the resources' location information.

3.2.7 Market organization M5: integrated market for TSO, DSO and BRP flexibility

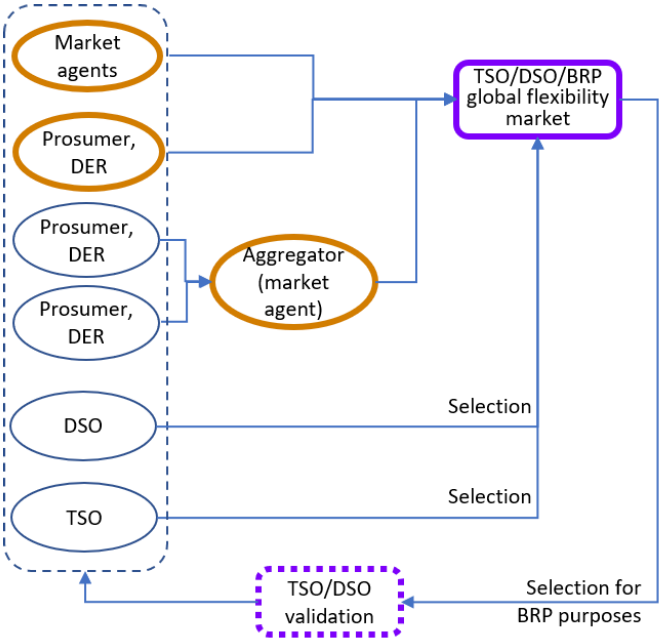


Figure 15: Integrated flexibility market for TSO, DSO and BRP

The main characteristics of this market organisation are:

- Grid operators and BRP all compete together for the available flexibilities in the market;
- Flexibility services are bought by those that are willing to pay more for them;
- Bids cannot be excluded due to grid constraints, so it is the responsibility of the grid operators to make the appropriate bids to guarantee the secure operation of their grids, being all under competition;
- If resources are used for grid constraints the operators must know resources location to assess their impact on their grids;
- For a more secure operation, TSO/DSO could still have the possibility to validate assignments for third parties (e.g. BRPs) before allowing activation.

3.2.8 Correspondences with other markets classifications

Most market classifications are based on SmartNet project proposals [74], and in general correspondences can be established between other market classifications and the markets organisations proposed in this deliverable (also inspired on the SmartNet project).

For example, CoordiNet project proposes the classification that is on the right side of Figure 16. This classification was also considered and analysed, concluding that, in fact, it can be established a correspondence between the Coordinate models and the models proposed in task T1.2. This correspondence is also shown in the left side of Figure 16. Again, it was decided that, in case of noticeable differences among the classification proposed in this task and the market proposals of the project reviewed, these would be specifically outlined for each case.

Note that the last mechanism of Figure 16 is not properly a TSO-DSO coordination mechanism for the provision of local or global flexibility, but rather a mechanism for both TSO and DSO to operate their own grids by limiting the physical delivery resulting from commercial energy exchanges. However, it has some similarities with the mechanism M2-MO where the DSO can send limitations to the wholesale MO to limit the commercial energy exchanges of distributed resources to avoid grid constraints violation.

		NEED Which SO-need(s) will be addressed?	**BUYER** Which stakeholder(s) buy(s) the flexibility to answer the considered need(s)?	**# MARKETS** How many markets are considered?	**RESOURCES** Does the TSO have access to DER?
M2	Local Market Model	Local need	DSO	1	NA
M1	Central Market Model	Central need	TSO	1	Yes or No
M4	Common Market Model	Local and central need	DSO and TSO	1	Yes
M2	Multi-level Market Model			> 1	Yes
M3	Fragmented Market Model				No
M5	Integrated Market Model		DSO, TSO and commercial parties	1	Yes
No relevant for flexibility provision	Distributed Market Model	Local need Local and central need	Peers	≥ 1	NA

Figure 16: Coordination schemes considered within CoordiNet project (D1.3) and correspondences with T1.2 proposed models

Another relevant reference is [71] where ENTSO-E and associations representing DSO (CEDEC, EDSO for smart grids, EURELECTRIC and GEODE), propose several coordination schemes focusing on congestion management and balancing.

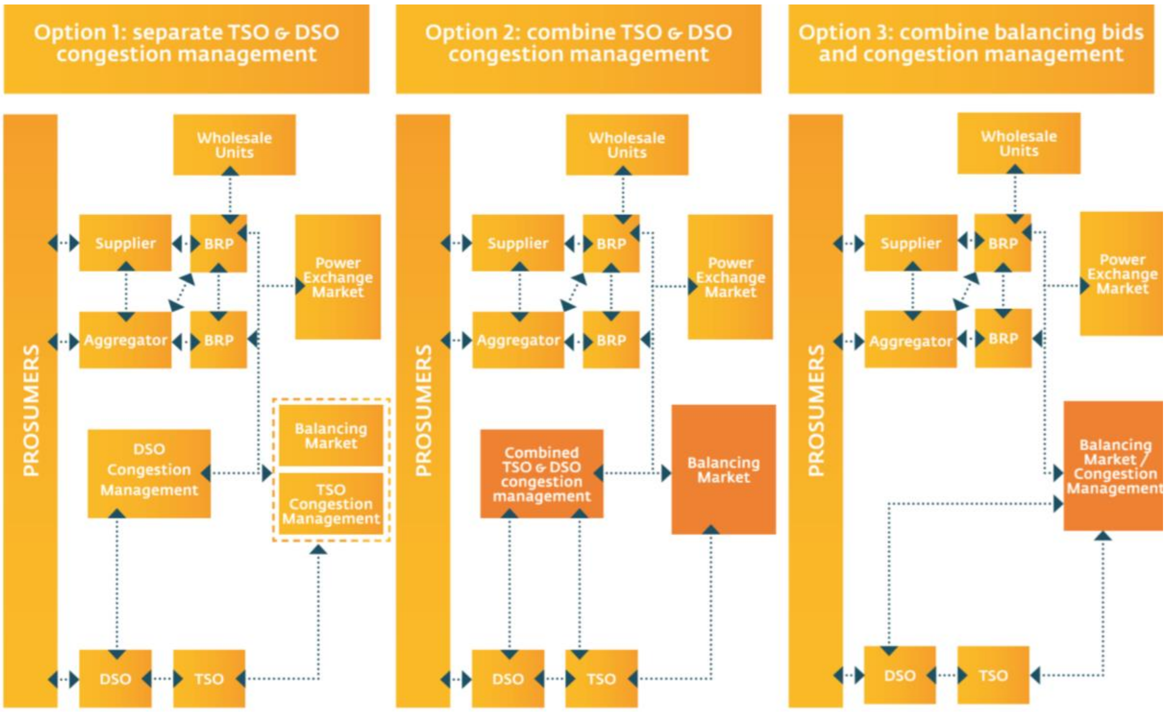


Figure 17: Coordination schemes for congestions management and balancing proposed by ENTSO-E and associations representing DSO [71]

The proposed options in Figure 17 can be explained as follows. The correspondences with the market organisations proposed above are also established.

- Option 1, separated TSO and DSO congestion management: DSO congestion management is done through a local market for flexibility, and separate from the TSO congestion management and balancing markets. In turn, the TSO may have separate markets for congestion and balance or have a single market for both. Separate markets are more flexible and simpler to implement and allow for better differentiation of congestion costs (paid by network operators) and balancing costs (paid by those responsible for deviations) but lead to a TSO-DSO coordination that may be insufficient or less efficient (for example by double activation of same resources in different markets). Moreover, the separation of congestion management and balancing markets may lead to less liquidity if FSP do not necessarily have to decide between both services and are not incentivised to submit prices to maximise their return on one market or the other. It is noteworthy saying that, on the other hand, considering a centralised or decentralised marketplace for congestion management alone is argued to not have a distinctive impact on liquidity [75].

This option corresponds to M2 market organisation for congestion management, with two separated but somehow coordinated DSO and TSO markets, and for M1 market organisation for system balancing.

- Option 2, combined TSO and DSO congestion management, with separated balancing: congestion management of DSO and TSO are carried out in a single market that brings together the needs of DSO and TSO (which could overlap). This system may lead to more efficient TSO-DSO coordination, less fragmentation and greater market liquidity when compared to separate balancing and congestion management, and therefore lower costs. But it is necessary to harmonise products, organise a market management shared by both operators, and the market could have less liquidity than option 3 if the balancing market's flexibilities can have location information.

This option corresponds to M4 market organisation for congestion management, with two separated but somehow coordinated DSO and TSO markets, and for M1 market organisation for system balancing.

- Option 3, combined balancing and congestion management for all system operators together: bids for TSO and DSO congestion management and for system balancing are combined in a single market, for example, by integrating congestion resolution in the future European coordination platform reserves to balance the system. A single market would allow for better TSO-DSO coordination in activating flexibilities, greater liquidity when compared to separate balancing and congestion management, and lower costs. Nevertheless, it would need the proper harmonisation of offers, it would introduce a certain opacity by mixing the costs due to congestion and the balancing, and above all, a greater complexity in relation to the operation of the market (with several regulated entities involved) and the optimisation algorithms for the selection of the flexibilities to activate (this being an important and complex challenge).

  This option corresponds to M4 market organisation for all flexibilities (DSO and TSO congestion management and balancing).

3.2.9 Characterisation of the markets identified in the analysed projects

This section presents, for each market organisation identified, a summary table of the main market characteristics.

Table 9 shows the table template used. It is based on the graphical template described in the Annex II – Templates for markets characterization:

Power point template for markets description. Note that, although this present section shows a reduced description of the markets identified in the projects, detailed information of each one can be found in the Excel files that go with this deliverable, following the Excel template described in the Annex II – Templates for markets characterization: Excel template for markets description.

The following subsections present the markets' characterisation for each of the projects analysed, regarding the business use-cases (BUC) explored within them.

Table 9: Table template to characterise the project markets

Project name - BUC name	
Market Model	Market organisation (according to section 3.2)
Needs / Services Addressed on the BUCs	For each business use case (BUC) of each project, the main needs and services addressed by each BUC are described.
Market Structure	Attributes describing the market, such as one or two-sided market, trading mechanism, price computation, clearing mechanism, energy/capacity products, short product description.
TSO-DSO coordination mechanisms	Description of the TSO-DSO coordination mechanisms described in the corresponding BUC.
Bids validation procedure	Procedures to validate bids, in case they are described.
Integration with other markets	Describe interaction with other new or existing markets in case they are explicitly described.
Resources	Resources considered in the market as potential provider of flexibility.
Aggregation	Indicates if aggregation of resources is or not allowed and under which conditions.
Terms	Considered market term (long term, day ahead, intraday, close to real-time, real time).

3.2.10 CoordiNet

CoordiNet explores definitions of requirements to achieve the formulation of a platform at the European level, addressing coordination schemes, and exploring, for this, several BUCs in demonstrators in three countries: Greece, Sweden and Spain. The project studies six models of coordination between the system operators and the participants in the electricity markets, local and central, and how to coordinate, in these markets, the use of the flexibilities from the distribution network resources. The BUCs approach various coordination market models, including purely local markets (without DSO-TSO coordination).

Table 10: Market organisation of the BUC ES-2 of the CoordiNet project

Project CoordiNet – BUC ES-2 (not tested in the ES demo)	
Market Model	M1 (CoordiNet - Central Market): centralised flexibility market
Needs / Services Addressed on the BUCs	• Balancing for TSO
Market Structure	• Characterisation: one-sided market • Trading Type: not specified • Price computation: not specified • Clearing mechanism: not specified • Type: energy • Products short description: the products are defined as standard products, having characteristics in common with the system services across Europe (shared all SO)
TSO-DSO coordination mechanisms	In this scheme, only the TSO operates the market, that uses DER flexibilities to solve the central needs. DSO can set limits on the energy bids
Bid validation procedure	CoordiNet platform receives balancing energy bids; sends activation signals
Integration with other markets	CoordiNet interface allows DSO to call markets for different needs, based on structural information already existent
Resources	Small renewable assets, large generators, AGR, consumers, storage
Aggregation	Aggregation allowed
Terms	Day ahead, Intraday, Near Real-time markets

Table 11: Market organisation of the BUCs ES-1b, ES-4 & SE-2 of the CoordiNet project

Project CoordiNet – BUCs ES-1b, ES-4 & SE-2 (SE-2 not tested in the SE demo)	
Market Model	M2 (CoordiNet - Local Market): local and global (global to be considered in upcoming phases of the project) flexibility markets
Needs / Services Addressed on the BUCs	• Islanding operation mode for DSO (balancing and voltage control) • Congestion management for DSO (short-term) • Congestion management for DSO (long-term)
Market Structure	• Characterisation: one-sided market • Trading Type: not specified • Price computation: not specified • Clearing mechanism: not specified • Type: capacity and energy • Products short description: very specific situation, as the products under analysis are inertia, FCR and/or reactive power
TSO-DSO coordination mechanisms	At first no coordination is considered – it shall be discussed in the project advancement. (Obs.: CoordiNet Platform is responsible for communicating with the TSO of the potential islands. It communicates the islanding/reconnection operations)
Bids validation procedure	TSO does not have access to DER bids
Integration with other markets	No integration is considered
Resources	Storage (1250kW), PV (in MV and LV) and other small renewable assets, large generators, AGR, consumers
Aggregation	Aggregation allowed
Terms	Long-term, Day ahead, Intraday, Near Real-time markets

Table 12: Market organisation of the BUC SE-1b of the CoordiNet project

Project CoordiNet – BUC SE-1b	
Market Model	M2 (CoordiNet - Distributed Market): local and global (global to be considered in upcoming phases of the project) flexibility markets
Needs / Services Addressed on the BUCs	• Congestion management for DSO (operational)
Market Structure	• Characterisation: one-sided market (FSP are the buyers and sellers - *"peers"*) • Trading Type: not specified • Price computation: not specified • Clearing mechanism: platform receives bid or offers; market is cleared in a distributed manner • Type: capacity • Products short description: the products are defined as standard products, having characteristics in common with the system services across Europe (shared all SO)
TSO-DSO coordination mechanisms	In the distributed market, local needs, or local + central needs are solved using peer-to-peer scheme involving the DER, through rules established by the SO aiming for a global objective
Bids validation procedure	Not specified
Integration with other markets	No integration is considered
Resources	Market is open for all flexibility providers that meet pre-qualification criteria
Aggregation	Aggregation allowed
Terms	Long-term, Day ahead, Intraday, Near Real-time markets

Table 13: Market organisation of the BUCs GR-1a, GR-2a, SE-1a & SE-3 of the CoordiNet project

Project CoordiNet – BUCs GR-1a, GR-2a, SE-1a & SE-3	
Market Model	M2 (CoordiNet - Multi-level Market): local and global flexibility markets
Needs / Services Addressed on the BUCs	• Voltage control for TSO and DSO (active power management) • Voltage control for TSO and DSO (reactive power management) • Congestion management for TSO and DSO (short-term) • Congestion management for TSO and DSO (long-term) • Congestion management for TSO and DSO (operational) • Balancing services for TSO
Market Structure	• Characterisation: one-sided market • Trading Type: not specified • Price computation: not specified • Clearing mechanism: not specified • Type: capacity and energy • Products short description: the products are defined as standard products, having characteristics in common to the system services across Europe (shared all SO)
TSO-DSO coordination mechanisms	Central and local needs are solved in this market model, and DSO/TSO cooperation & info. exchange is needed (being each SO responsible for their own market). TSO could access DER, as bids not selected for the local market can participate in the central market
Bids validation procedure	DER bid in local DSO market first; DSO validates the bids after reception. Remaining bids are available to TSO. TSO has access to DER only after DSO needs are covered For Voltage Control: platform receives Q bids; runs Voltage Control Market; communicates SO; sends activations, and proceeds to settlement For Congestion Management: after Pre-qualification, the platform receives the needs; receives P bids; runs a CM; communicates SO; sends activations and proceeds to settlement CM and voltage (Q bids) markets are separate and run sequentially in this order
Integration with other markets	Integration with the existing markets: balancing
Resources	DG, large generators, AGR, consumers, backup generators and other flexibility providers
Aggregation	Aggregation allowed; (at connection point for reactive power management service)
Terms	Long-term, Day ahead, Intraday, Near Real-time markets

Table 14: Market organisation of the BUCs GR-1b & GR-2b of the CoordiNet project

Project CoordiNet – BUCs GR-1b & GR-2b	
Market Model	M3 (CoordiNet - Fragmented Market): local and global flexibility markets with shared responsibility
Needs / Services Addressed on the BUCs	• Congestion management for DSO (short-term) • Congestion management for DSO (long-term) • Voltage control for DSO (active power management) • Voltage control for DSO (reactive power management)
Market Structure	• Characterization: one-sided market • Trading Type: not specified • Price computation: not specified • Clearing mechanism: not specified • Type: capacity and energy • Products short description: the products are defined as standard products, having characteristics in common to the system services across Europe (shared all SO)
TSO-DSO coordination mechanisms	DSO in coordination with TSO decides distribution system reconfiguration and the power exchange (active and reactive power) between them
Bids validation procedure	DER bid in local DSO market first; DSO validates the bids after reception For Voltage Control: platform receives Q bids; runs Voltage Control Market; communicates SO; sends activations, and proceeds to settlement For Congestion Management: after Pre-qualification, the platform receives the needs; receives P bids; runs a CM; communicates SO; sends activations and proceeds to settlement CM and voltage (Q bids) markets are separate and run sequentially in this order
Integration with other markets	No integration is considered
Resources	DG, large generators, AGR, consumers, backup generators and other flexibility providers
Aggregation	Aggregation allowed; (at connection point for reactive power management service)
Terms	Day ahead, Intraday, Near Real-time markets

Table 15: Market organization of the BUCs ES-1a & ES-3 of the CoordiNet project

Project CoordiNet – BUC ES-1a & ES-3	
Market Model	M4 (CoordiNet - Common Market): common TSO and DSO flexibility market
Needs / Services Addressed on the BUCs	• Congestion management for DSO (short-term) • Congestion management for DSO (long-term) • Voltage control for DSO (active power management) • Voltage control for DSO (reactive power management)
Market Structure	• Characterization: one-sided market • Trading Type: not specified • Price computation: not specified • Clearing mechanism: Separate clearing of active and reactive power bids • Type: energy, capacity products shall be explored in a 2nd phase of demo (in a short-term/day-ahead timeframe) • Products short description: the products are defined as standard products, having characteristics in common to the system services across Europe (shared all SO)
TSO-DSO coordination mechanisms	For the common market, needs for the DSO and for the TSO are considered in a single way, thus both SO have access to DER, and therefore in this market the system could be optimized in a whole way
Bids validation procedure	For Voltage Control: platform receives Q bids; runs Voltage Control Market; communicates SO; sends activations, and proceeds to settlement For Congestion Management: after Pre-qualification, the platform receives the needs; receives P bids; runs a CM; communicates SO; sends activations and proceeds to settlement CM and voltage (Q bids) markets are separate and run sequentially in this order
Integration with other markets	Integration with the existing markets: balancing
Resources	Small renewable assets, large generators, AGR, consumers, storage
Aggregation	Aggregation allowed; (at connection point for reactive power management service)
Terms	Day ahead, Intraday, Near Real-time markets

3.2.11 De-Flex-Market

In the De-Flex-Market project, end consumers, being typically represented by their FSP or energy provider, agree on following a schedule of restriction requirements for a contracting timeframe no shorter than a year.

Figure 18 shows a comprehensive description of the product defined in the initiative.

The following information is communicated to each metering point, which includes controllable appliances within the respective aggregated distribution area:

DSO	Aggregated Distribution Grid Area	15min-Operational Periods (with 31 days per month, there are 2976 consecutive quarter hours)	Level of Restriction Requirement
I	1	64-72; 150-152; etc.	64-66 (0); 67-69 (0,8); 70-72 (0,1); etc.
I	2	66-78; 160-168; etc.	66-68 (0,7); 69-72 (1.5); etc.
II	1	64-72; 150-152; etc.	64-66 (0); 67-69 (0,8); 70-72 (0,1); etc.

*A requirement level of 0 means that the network user (i.e. the end consumer) would have to comply with the maximum defined threshold, for example 4kW maximum load (which is a value set between 15 and 35% percent of the overall available capacity). A requirement level of 0.7 would set the allowed maximum load to 4kW + 0.7 * 4kW = 6.8kW. If the controllable appliance is a PV system or a storage unit a maximum injection per metering point can also be defined by providing negative restriction requirement levels. Based on a 4kW threshold, a level of (-0.8) would set the maximum injection to the network in the correspondent 15-min operational period to 0.8 * 4 kw = 3.2kW.*

Furthermore it is proposed that the DSO is not allowed to define more than 12 fully restricted (i.e. restriction requirement level of 0) quarter hours per day as operational periods for a certain aggregated distribution area. For other restriction requirement levels communicated "the number of allowed 15min-operational periods results from the remaining difference between 12 and the added values consisting of the restriction requirement level of the respective quarter hours summed with the maximum value of 1."

Figure 18: Thorough description of the product defined in De-Flex-Market. Adapted from [7].

Table 16: Market organisation of the De-Flex-Market project

Project De-Flex-Market	
Market Model	M2: local and global flexibility markets
Needs / Services Addressed on the BUCs	• Congestion management for DSO (long-term planning, Y-1)
Market Structure	• Characterisation: one-sided market End consumers, typically represented by their FSP or energy provider, agree on following a schedule of restriction requirements for a contracting timeframe no shorter than a year. Given that premise, the proposed market is one-sided, with the DSO setting the schedule and the level of restriction requirements during the contracting timeframe • Trading Type: periodic closed gate auction (yearly auction) Since contracting timeframes are proposed to have a duration not shorter than a year, it seems plausible that a periodic closed gate auction takes place every year at the very least • Price computation: pay-as-bid; although listing as possibilities both direct incentive payment and network tariff reductions, the authors advise on putting in place a system based on direct incentive payment structures, allowing for broader participation (AGR and other service providers); Since a yearly contracting timeframe is defined, the DSO must submit their bids a year ahead with a suitable interval from the beginning of the next year (some months probably) • Clearing mechanism: unclear • Type: energy service provision (kWh) • Products short description: the product consists in the compliance with a DSO-defined scheduling of restriction requirement levels for 15-minute blocks, supported per aggregated distribution grid area (Figure 18). The restriction requirements levels consist of a command-and-control option or a pre-defined switch option, reserved for a third-party (flexibility service provide or the energy supplier) that limits the possibility to use the electric grid compared to the allowed and technically possible capacity at the point of interconnection with the local distribution grid. The operational period schedule is defined per aggregated distribution grid area which can be viewed as a congestion zone defined by the DSO (more information is provided in the contents to the right). The proposal states that it is imperative to develop a uniform standard for service products offered in areas as large as possible (at least on a country basis). This mechanism requires a fix deadline for all DSO to announce and transmit the required information to each aggregated distribution grid areas, for example on the 16th day of each previous month at 00:00 or on a specific day during the previous week (in case of shorter contracting timeframes). With the implementation and roll-out of intelligent metering systems, a more short-term communication solution can be designed
TSO-DSO coordination mechanisms	No TSO-DSO coordination mechanism is considered
Bids validation procedure	In accordance with Figure 18
Integration with other markets	Proposed as a parallel market with no clear integration with other markets being defined
Resources	Not thoroughly described. Considers residential consumers available for consumption constraints, PV generators available for curtailment and storage systems available for limiting their injection at their interconnection with the distribution grid
Aggregation	Aggregation seems to be considered as the only viable option for providing flexibility
Terms	Yearly

3.2.12 EcoGrid 2.0

In EcoGrid 2.0, DSOs initiate an auction by sending a list of service requests (mutually exclusive) to the market operator, from one to twelve months ahead of time. The market operator forwards this information to the AGR, without revealing the DSO's willingness to pay for each service, which in turn send their offers.

Figure 19 shows the sequence diagram for communication in EcoGrid 2.0, highlighting the parallel operation of the new local market (Ecogrid 2.0 new congestion market) and the existing markets (such as Elspot, the NordPool day ahead market, Elbas, the NordPool intraday markets, and the NordPool regulating power market).

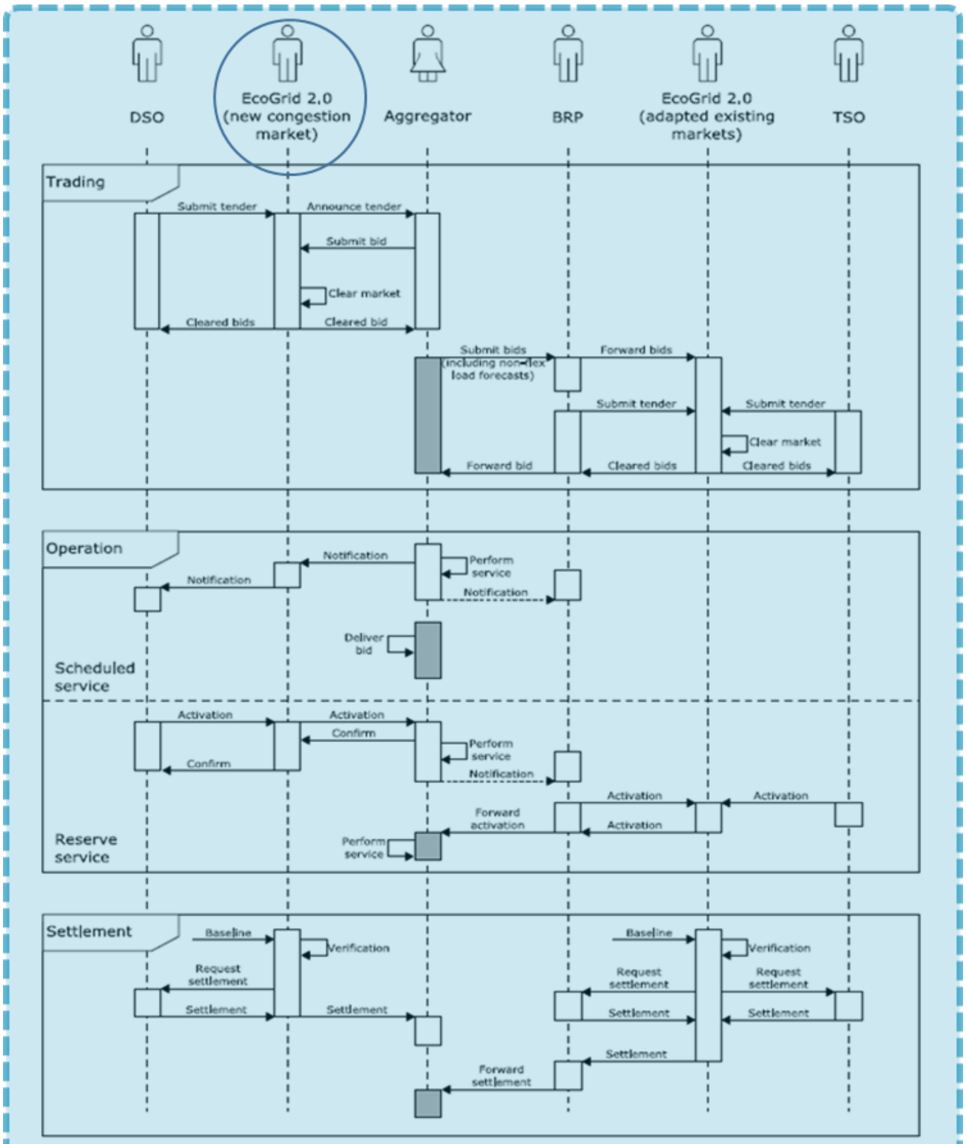


Figure 19 - Message sequence diagram for communication in EcoGrid 2.0; inspired by similar iPower diagrams. Grey blocks indicate aggregator actions in the TSO market.

Figure 19: Sequence diagram for communication in EcoGrid 2.0 Adapted from [76].

Table 17: Market organisation of the EcoGrid 2.0 project

Project EcoGrid 2.0	
Market Model	M2: local and global flexibility markets
Needs / Services Addressed on the BUCs	• Congestion management for DSO and TSO (long-term M-1 to Y-1) • Voltage control for DSO (active power management) • Balancing for TSO (mFRR, FCR) • Regulating power services for BRP
Market Structure	• Characterisation: two-sided market (AGR submit flexibility bids and SO/BRP submit tenders) • Trading Type: periodic closed gate auction (yearly auction) • Price computation: pay-as-clear • Clearing mechanism: the market is cleared by choosing the most economically beneficial service request, and standardised contracts are created between the DSO and the AGR. A service can be delivered by multiple AGR • Type: energy service provision (kWh) • Products short description: products of active power traded in timeslots of fixed length, defined by the market, mainly divided into scheduled and conditional services. A set of 5 standardised products are envisioned for the EcoGrid 2.0 flexibility market: load reduction, load increase, power limitation (addressing congestion management for DSO), voltage control (addressing voltage control for DSO) and balance (addressing mFRR for TSO and regulating power service for BRP), although, for DSO, only capacity limitation and baseline flexibility services are considered throughout the project's lifetime. In both cases, the services can be scheduled (activated regularly at a specified time period) or conditional (may be activated during that time period if deemed necessary)
TSO-DSO coordination mechanisms	No TSO-DSO coordination mechanism is considered. Flexibility activation by the DSO is not expected to generate TSO imbalances. Congestions due to TSO flexibility activation are to be accounted by DSO acquiring additional flexibility if necessary
Bids validation procedure	Bids are composed mainly of the following parameters: service provided, price offered, bid volume (as a multiple of granularity) and divisibility; DSO tenders encompass: service to be acquired; point of delivery; maximum price for service (not broadcast to AGR); tender tolerance; duration of delivery; duration of contract; penalties/consequences for non-delivery; verification requirements (including performance required); availability payment (reservation services); activation payment; time of delivery
Integration with other markets	The EcoGrid 2.0 Market Structure is built in part as a parallel trading platform to the existing markets (Elspot, Elbas, the regulating power market etc.) since existing markets do not allow DER units like those used in the EcoGrid 2.0 project to participate e.g. due to minimum bid sizes, as well as the validation and verification of DER. Nonetheless the project's ambition was that existing markets eventually would integrate the changes it proposes, reducing barriers for DER participation
Resources	The EcoGrid 2.0 consists of about 1,000 heat pumps and electric radiators (electrical heating and hot water boiling) on the Danish island of Bornholm. Flexibility is provided by adjusting consumption in these thermostatically controlled loads, located mainly at private households. The project considers the possibility of using other types of DER, namely small-scale generation although it was not available at the demonstration site
Aggregation	AGR play a central role in the market model, participating as a service provider on behalf of the households it represents. One or more AGR can represent a same household, since the same household can provide different types of DER
Terms	Yearly

3.2.13 EMPOWER H2020

In EMPOWER H2020, local markets for flexibility exist alongside the wholesale market. These local markets have a specific type of AGR which is called the Smart Energy Service Provider (SESP); the SESP makes bids to the market on behalf of the prosumers/consumers and the producers. It also has the responsibility for demand-response programs on behalf of the DSO and can resort to the end-users' flexibility to achieve commercial ends in the balancing market.

Figure 20 shows the EMPOWER H2020 market base concept, detailing the local market and the SESP relationships to other market and energy system operation roles.

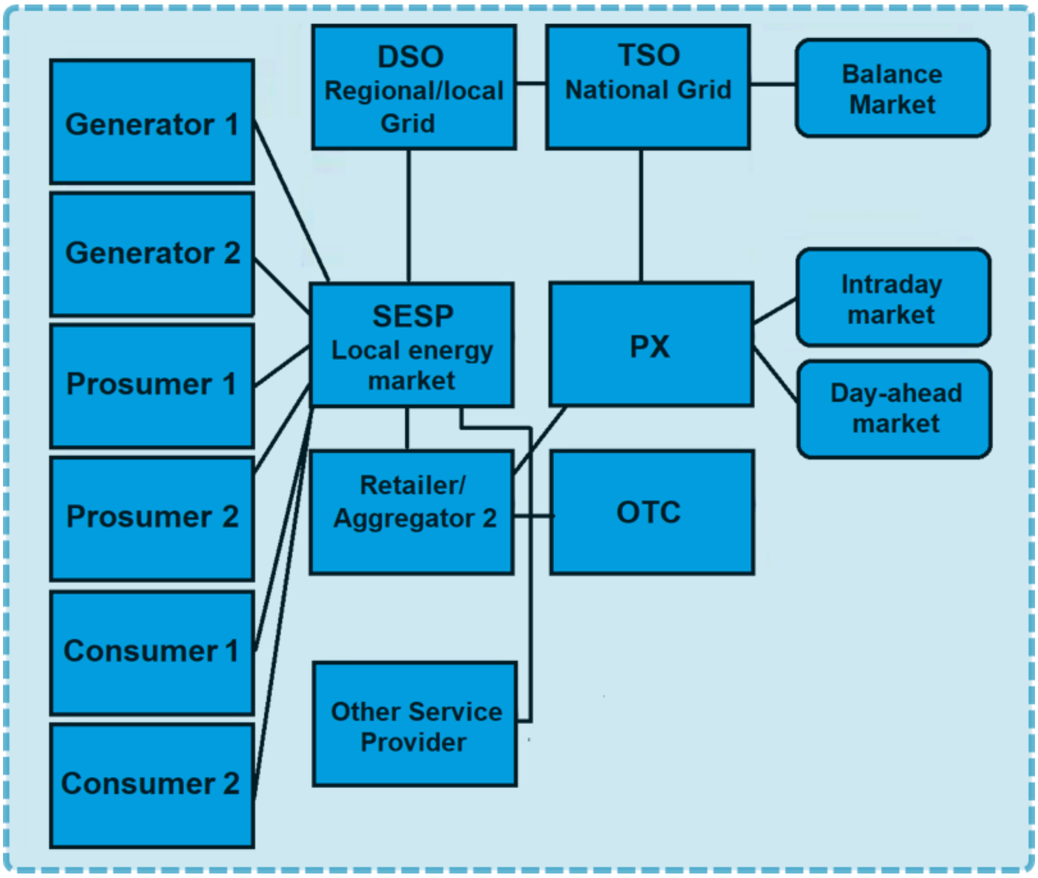


Figure 20: EMPOWER H2020 Market Base Concept. Adapted from [77].

Table 18: Market organisation of the EMPOWER H2020 project

Project EMPOWER H2020	
Market Model	M2: Local Market
Needs / Services Addressed on the BUCs	• Congestion management for DSO (short-term) • Islanding operation mode for DSO • Support distribution grid planning • Voltage control for DSO (active power) • Balancing for TSO (short-term)
Market Structure	• Characterisation: one-sided market • Trading Type: periodic closed gate auction (day-ahead and intraday auctions) • Price computation: pay-as-bid or *price scan auction*, pay-as-bid or price scan auction, depending on the size of the local market and number of participants • Clearing mechanism: clearing can be based on full or partial matches between price and volume of flexibility traded (kW or kWh); in more liquid markets, price scan auctions can take place, in which the SESP calls out a buying price and a selling price. In return, traders offer a volume of flexibility for that price. If the aggregated match between demand and supply is poor a new price will be called. When a good match is established the auction terminates • Type: energy (kWh) and capacity (kW) • Products short description: no standardised products
TSO-DSO coordination mechanisms	Unspecified
Bids validation procedure	The procedure for validating bids has not been described
Integration with other markets	Empower H2020 envisages the coexistence of several local markets, each corresponding to one or more MV networks (and their LV feeders). Local markets coexist with the whole-sale market
Resources	Distributed energy resources (DER) within the MV and LV grids
Aggregation	The local markets have a specific type of AGR which is called the Smart Energy Service Provider (SESP). The SESP is responsible for aggregating the bids from prosumers/consumers within the distribution grid (LV and MV), as well as the regular producers (e.g. small wind or solar parks)
Terms	Day-ahead, intraday

3.2.14 Enera

Project Enera is a regional market platform, where local flexibilities are coordinated for solving congestion management problems for the DSO. Through an integrated model approach for the flexibility market, DSO order books centralise the flexibility offers which can be used by the operators to relieve congestion in the networks.

Table 19: Market organization of the Enera project

Project enera	
Market Model	M5: integrated flexibility markets for TSO, DSO and BRP
Needs / Services Addressed on the BUCs	• Congestion management for DSO (short-term)
Market Structure	• Characterisation: one-sided market • Trading Type: continuous trading • Price computation: pay-as-bid • Clearing mechanism: locational order books centralize flexibility offers that can be used by TSO and DSO to alleviate congestions. Enera matches flexibility offers with demand, (also dealing with the settlement and providing feedback and analytics). Transactions on EPEX SPOT are cleared and settled by ECC (European Commodity Clearing) • Type: energy • Products short description: standardised products - definitions are determined by EPEX SPOT in cooperation with the network operators procuring the flexibility
TSO-DSO coordination mechanisms	Bottom-up coordination - in Enera 1.0 (currently in place) there is a bilateral communication, also considered as coordination, but it is not integrated into the market platform of EPEX. TSO can get access to the DER through buying flexibility in the locational order books; flexibilities that are connected to other networks than the operators own network can be contracted (this must be approved by the connecting operator). This process is established as follows: • Step 1: Top-down communication to all affected local market areas (network areas), from TSO to DSO with asset connected (and any intermediary DSO) • Step 2: Reverse bottom-up communication, informing about the free grid capacities
Bids validation procedure	Procedure is related with EPEX Spot, not described by Enera. The pre-qualification is done by the connecting SO
Integration with other markets	Integration with wholesale intraday market
Resources	All flexibility resources. So far implemented: load, VRE, storage of the HV and MV network level
Aggregation	Allows AGR, suppliers, traders, provided they have a BRP license or can trade on behalf of their BRP
Terms	Intraday timeframe (EPEX Spot local flexibility market platform)

3.2.15 EU-Sysflex

In this project, seven different market integration models were proposed, in four different demonstrators (Finland, Germany, Italy and Portugal). This project focuses on the provision of services to the TSO with distributed flexibility resources. Since TSO-DSO coordination for the provision of these services very often implies partially using these resources for local DSO problems, EU-SysFlex market organisations are also worth revisiting here. Seven different markets are presented in this subsection.

Table 20: Market organization of the PT-FlexHub Q-market of the EU-Sysflex project

Project EU-SysFlex – BUC PT-FlexHub Q-market	
Market Model	M3 (PT-FlexHub Q-market): local and global flexibility markets with shared responsibility
Needs / Services Addressed on the BUCs	• Voltage control (reactive power dynamic control); includes local reactive power (RP) market for TSO and DSO reactive power provision; this service could also be used for congestion management, even though it was not specified as such

Market Structure	• Characterization: one-sided market
	  - TSO: buyer of RP at the TSO-DSO interface
	  - DSO: buyer of RP to balance its own grid
	• Trading Type: periodic closed gate auction (intraday, with 7 hours delivery horizon, and 15 min delivery time)
	• Price computation: pay-as-bid
	• Clearing mechanism: DSO performs joint technical clearing (OPF) to maximize FSP welfare while respecting DSO grid constraints and TSO reactive power needs
	• Type: reactive energy (kvar)
	• Products short description: reactive power blocks with 7 hours delivery horizon, and 15 min delivery time

TSO-DSO coordination mechanisms	DSO performs joint technical clearing (OPF) to maximize FSP welfare while respecting DSO grid constraints and TSO reactive power needs
Bids validation procedure	Bids are cleared in a local market considering DSO grid constraints. No additional validation is addressed
Integration with other markets	Not specifically addresses
Resources	HV distribution grid resources (Wind farms 10-25MW, capacitor banks 4MVA)
Aggregation	Aggregation per bus allowed
Terms	Intraday

Table 21: Market organization of the PT-FlexHub TLQ of the EU-Sysflex project

Project EU-SysFlex – PT-BUC FlexHub TLQ	
Market Model	M1 (PT-FlexHub TLQ): centralized flexibility market
Needs / Services Addressed on the BUCs	• Balancing for TSO (mFRR, short-term); includes Traffic Light Quantification (TLQ) to validate a set of active power bids for the TSO before activation.; this service could also be used for congestion management, even though it was not specified as such; geographical info could allow congestion management (depends on the TSO)
Market Structure	• Characterization: one-sided market - TSO buyer of active power in a redesigned mFRR market • Trading Type: periodic closed gate auction (intraday, with 7 hours delivery horizon, and 15 min delivery time) • Price computation: pay-as-bid • Clearing mechanism: out of the scope of this project • Type: active energy (kWh) • Products short description: active power capacity with 7 hours delivery horizon, and 15 min delivery time, max energy limits, max ramp
TSO-DSO coordination mechanisms	After TSO bid selection, DSO validates bids before activation
Bids validation procedure	TSO access DER bids in its mFRR market and selects those that better fit its needs; after TSO bid selection, DSO validates bids before activation
Integration with other markets	The proposal intends to integrate the DSO bids validation procedure into an extended version of the restoration reserve market of the TSO
Resources	HV-MV distribution grid resources (PV 12MW, Battery 480kW/360kWh)
Aggregation	Aggregation allowed, but resource locational info per bids needed for DSO validation
Terms	Intraday

Table 22: Market organization of the BUCs FI-AP1, FI-AP2 of the EU-Sysflex project

Project EU-SysFlex - BUCs FI-AP1, FI-AP2	
Market Model	M1 (FI-AP1, FI-AP2): centralized flexibility market
Needs / Services Addressed on the BUCs	• Balancing for TSO (mFRR, FCR-N)
Market Structure	• Characterization: one-sided market - TSO buys active power (AP) in existing FCR-N and mFRR markets • Trading Type: periodic closed gate auction (day-ahead market) • Price computation: pay-as-bid • Clearing mechanism: merit order list • Type: active power (MW) • Products short description - FCRn: bid size (0.1-5MW) 5MW - mFRR: cap energy price 5000 €/MWh and activation in 15 min after request
TSO-DSO coordination mechanisms	No explicit DSO validation. Since DSO, retailer and AGR seem to be the same, AGR may be able to limit bids
Bids validation procedure	TSO has access to DER bids sent by the AGR to the reserve markets and selects those that better fit its needs
Integration with other markets	Not specifically addressed
Resources	LV distribution grid resources (400V) operated by the retailer (a retailer battery and a PV connected at 110kV -TSO/DSO-400kV/110kV)
Aggregation	The retailer is the AGR (following regulation) that bids in the hourly market for FCR-N (hourly day-ahead capacity market) It also bids in the mFRR/RR market (not clear if a previous pay-as bid capacity market also exists)
Terms	Day-ahead

Table 23: Market organization of BUC FI-RP of the EU-Sysflex project

Project EU-SysFlex – BUC FI-RP	
Market Model	M3 (FI-RP): local and global flexibility markets with shared responsibility
Needs / Services Addressed on the BUCs	• Voltage control (reactive power dynamic control)
Market Structure	• Characterization: one-sided market - DSO: buyer of RP capacity in new local markets • Trading Type: periodic closed gate auction (monthly reactive power capacity market with hourly detail) • Price computation: pay-as-bid • Clearing mechanism: merit order list • Type: active power (MW) • Products short description: capacity
TSO-DSO coordination mechanisms	See 'aggregation' below
Bids validation procedure	No info on DSO algorithms to select bids
Integration with other markets	Not specifically addressed
Resources	LV distribution grid resources (400V) operated by the retailer (a retailer battery and a PV connected at 110kV -TSO/DSO-400kV/110kV)
Aggregation	An AGR bids in a new DSO market to keep the TSO/DSO reactive power balance under limits to avoid penalties
Terms	Monthly auction

Table 24: Market organization of the BUC DE-AP + DE-RP of the EU-Sysflex project

Project EU-SysFlex – BUCs DE-AP + DE+RP	
Market Model	M3 (DE-AP + DE-RP): local and global flexibility markets with shared responsibility
Needs / Services Addressed on the BUCs	• Congestion management for TSO • Voltage control for TSO

Market Structure	• Characterization: one-sided market
	  - DSO first buyer (based on sensitivities/price) for its own grid
	  - Remaining flexibility is provided to TSO, that selects aggregated schedule
	• Trading Type: periodic closed gate auction (day ahead + intraday markets for active power, with delivery times of 15 minutes)
	• Price computation: pay-as-bid
	• Clearing mechanism: based on sensitivities/price (PQ-maps, active and reactive power are offered and cleared together)
	• Type: active power (MW) and reactive power (Mvar)
	• Products short description: active and reactive power capacity with 7 hours delivery horizon, and 15 min delivery time, max energy limits, max ramp

TSO-DSO coordination mechanisms	DSO is the first buyer (based on sensitivities/price) for its own grid; remaining flexibility is provided to TSO, that selects the aggregated schedule. The DSO sets the final resource schedules
Bids validation procedure	The bids selection algorithm combines the use of both active power and reactive power based on prices and effectiveness. Includes TLQ to validate a set of active power bids for the TSO before activation
Integration with other markets	Not specifically addressed
Resources	DER
Aggregation	Only for the final flexibility offered to the TSO
Terms	Day-ahead, intraday

Table 25: Market organization of the BUC IT-AP of EU-Sysflex project

Project EU-SysFlex – BUC IT-AP	
Market Model	M2 (IT-AP): local flexibility markets
Needs / Services Addressed on the BUCs	• Balancing for TSO (mFRR/RR) • Congestion managing for DSO and TSO
Market Structure	• Characterization: one-sided market - RT market managed by an independent MO or by the DSO - DSO buyer of active power for local congestions. Counter balancing solved with locally bought active power - Remaining bids aggregated and submitted to RT TSO active power market/s (mFRR, RR and congestions) • Trading Type: periodic closed gate auction (real time market each 15 min) • Price computation: pay-as-bid • Clearing mechanism: optimal power flow • Type: active power (MW) • Products short description: no standardised products
TSO-DSO coordination mechanisms	The bids are aggregated (curve AP/price) with an OPF that maximizes active power at the TSO-DSO link for TSO congestions. DSO assets can be used to solve imbalances
Bids validation procedure	OPF that maximizes active power at the TSO-DSO link for TSO congestions
Integration with other markets	DSO uses flexibility first in local market, and remaining bids are sent to TSO active power markets
Resources	DER, DSO assets (OLTC, Statcoms, Batteries) only used for DSO grid operation
Aggregation	Allowed, but seems to be performed by the MO (see above). No explicit AGR considered
Terms	Day-ahead, intraday, 15-minutes

Table 26: Market organization of the BUC IT-RP of the EU-Sysflex project

Project EU-SysFlex – BUC IT-RP	
Market Model	M3 (IT-RP): local and global flexibility markets with shared responsibility
Needs / Services Addressed on the BUCs	• Congestion management for TSO • Voltage control for DSO
Market Structure	• Characterization: one-sided market - TSO: buys reactive power at the TSO-DSO interface for voltage control and CM from an aggregated curved built by the DSO - DSO: buyer of RP to balance its own grid • Trading Type: periodic closed gate auction; hourly intraday plus 15 min RT markets; intraday market with 6 hours delivery horizon to buy reactive power profile, with RT market for final adjustments; delivery time 1 hour Intraday, 15 min RT • Price computation: pay-as-bid • Clearing mechanism: DSO performs joint technical clearing (OPF) to maximize FSP welfare while respecting DSO grid constraints and TSO reactive power needs • Type: reactive power (Mvar) • Products short description: no standardised products
TSO-DSO coordination mechanisms	DSO performs joint technical clearing (OPF) to guarantee requested RP at TSO-DSO link
Bids validation procedure	OPF to guarantee the requested reactive power at the TSO-DSO link
Integration with other markets	Not specifically addressed
Resources	DER, DSO assets (Statcoms and batteries) are only used for DSO grid operation
Aggregation	Allowed
Terms	Day-ahead, intraday, 15-minutes

3.2.16 FLECH-iPower

FLECH stands for FLExibility Clearing House and is a platform for trading ancillary services between aggregated small scale DER (up to 5MW) and DSO. The initiative focuses on a series of well-defined products, richly parametrized and provides a detailed description of the processes and interactions taking place within the market platform.

Table 27: Market organization of the Flech-iPower project

Project FLECH-iPower	
Market Model	M2: local and global flexibility markets
Needs / Services Addressed on the BUCs	• Congestion management for DSO (short-term planning D-1) • Congestion management for DSO (long-term planning >M-1 to Y-1 or more)
Market Structure	• Characterization: two-sided market • Trading Type: periodic closed gate auction • Price computation: - For Reservation market: First-price Sealed Bid, where the AGR submits "sealed" bids to FLECH, and the best priced bid wins the reservation contract and gets paid the respective reservation fee - For Activation market: Auctions - smallest price is accepted first • Clearing mechanism: simple merit order sorting of resources which only considers the price per kWh for the period considered • Type: capacity • Products short description: <u>standardised products:</u> mainly divided into products for load management and for voltage management, characterized by the following parameter fields: service name, contract validity, estimated number of activations during period, size of service in power and in energy, maximum duration of service per activation, maximum allowed activation time, geography (specified by unique consumer numbers), on and off trigger date time values, quality criteria in supply, pricing paid by the DSO to the AGR, estimated price per activation, risk issues that may trigger failure in supply and respective penalties
TSO-DSO coordination mechanisms	DSO activation market clears an hour prior to the TSO markets, day-ahead of operation. It is unclear if the same FSP can participate in the TSO ancillary market and how their bids would be validated by the TSO; nonetheless, a list of priorities to the DER/AGR is compiled, in case of conflicts in serving flexibility for the following needs/services: 1.Emergency actions (TSO); 2.Alert actions (TSO/DSO); 3.Local voltage control (DSO); 4.Peak-shaving (DSO); 5.Voltage support (TSO); 6.Mvar bands (DSO); 7.Frequency control (TSO); 8.Other ancillary services (TSO); 9.Imbalance issues (BRP); 10.Power quality (DSO)
Bids validation procedure	The contracting will be made following two possibilities: 1 - after DSO posts of desired flexibility services at FLECH, AGR will submit flexibility service offers to FLECH, and DSO will get the area merit order list, assessing the feasibility of offers based on OPF. DSO will pick the desirable offers making standard contracts. 2 - AGR submit the flexibility bids to FLECH, then DSO proceeds to flexibility services portfolio optimization, whereby, the preferred bids are taken. DSO will stipulate the types of flexibility services and sign standard contracts with AGR in FLECH
Integration with other markets	Parallel to the NordPool market (designed to run in parallel with other existing day-ahead, intra-day and intra-hour markets, specialized in the distribution grid)
Resources	The project focus on the aggregation of small scale DER (up to 5 MW) and their incapability of alone participating in the wholesale electricity market that, for the NordPool case, has a minimum acceptance volume of 10 MW
Aggregation	Aggregation of low voltage DER flexibility by an AGR is considered
Terms	Reservation market: Long-term horizon: from 2 years down to 6 months prior to initiating activation Activation market: day ahead

3.2.17 FLEXICIENCY

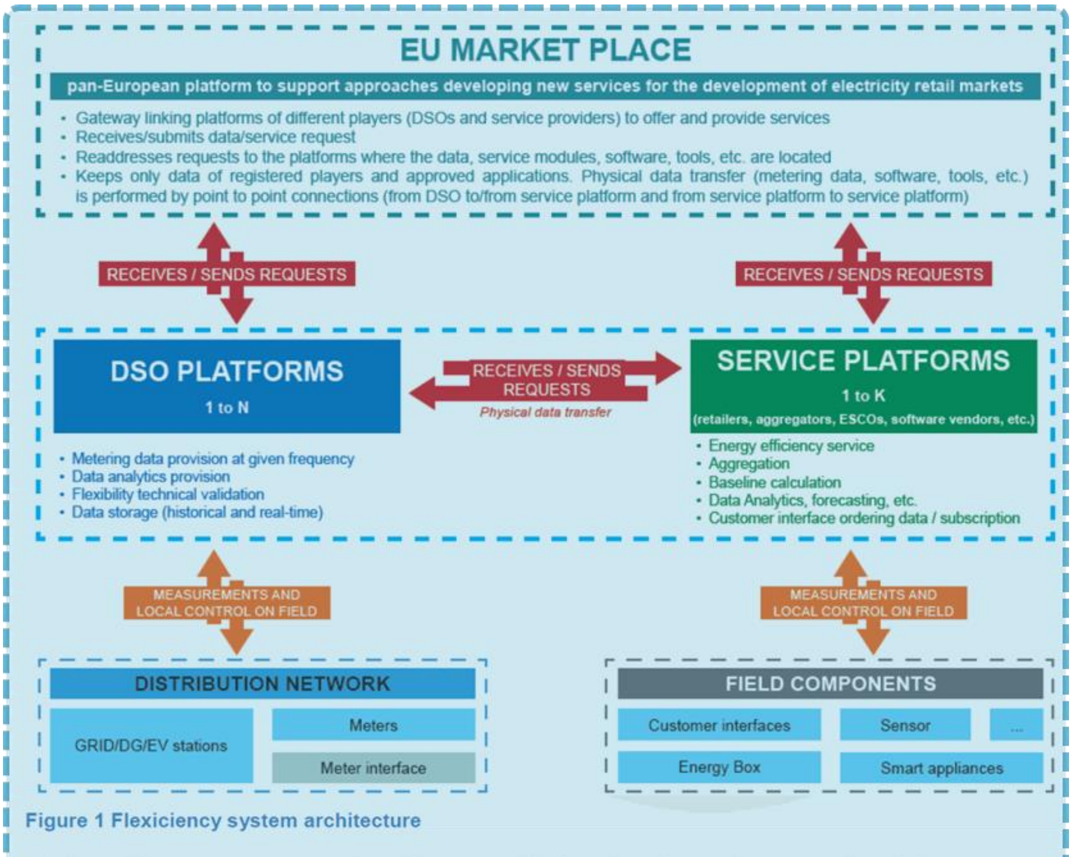
This already concluded project's big focus was on elaborating a platform for metering data transaction through business-to-business (B2B) interactions, mainly between DSO (acting as providers) and Data Requesters such as an Energy Service Operator ESO.

Although having spawned 5 demonstrators in different countries, the Spanish demo was the only one to specifically define as a use case the "Provision of flexibility services to the DSO from a service provider who owns a microgrid."

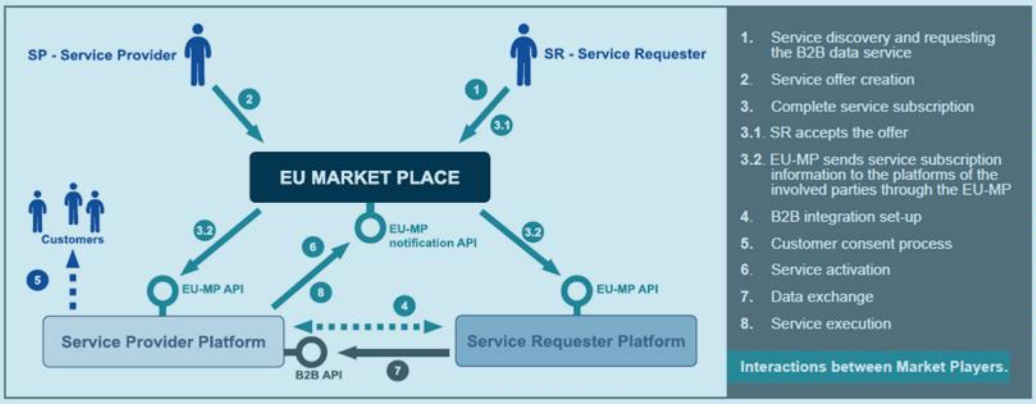
Table 28: Market organization of the FLEXICIENCY project

Project FLEXICIENCY	
Market Model	M2: local and global flexibility markets
Needs / Services Addressed on the BUCs	• Voltage control for DSO (active power management) • Observability over the available flexibility
Market Structure	• Characterization: one-sided market • Trading Type: continuous auction • Price computation: pay-as-bid • Clearing mechanism: Although not specified, it is implied that technical and economical clearing are the responsibility of the DSO procuring the flexibility services • Type: Although not clear, both reservation and activation may be possible given the mechanism provided • Products short description: Standardised and unstandardised products for which the following parameters can be provided a. Period for which service is available b. Location c. Category (regulated and unregulated, individual or aggregated, data or energy support service provision) d. Furthermore, based on the category and subcategory, additional fields can be filled i. Quantity (energy consumption, energy generation, power) ii. Time step (1', 10', 15', 30', 1h, 1d) iii. Aggregation level (none, country, city, street, portfolio) iv. Method: sum or mean v. Other (for standardised products, Terms & Conditions and Pricing Information are pre-defined)
TSO-DSO coordination mechanisms	No TSO-DSO coordination mechanism is considered
Bids validation procedure	Not clear when bid validation is performed
Integration with other markets	No integration with other existing markets is considered
Resources	Different smart devices in a microgrid capable of offering flexibility: demand side response from residential consumers, wind and photovoltaic generation, storage and electric vehicle charging stations
Aggregation	Aggregation is explicit for data support services; for energy support, although not explicit, if located at the same bus aggregation could be possible.
Terms	Not described

Figure 21 shows the FLEXICIENCY system architecture (top) highlighting the separation of responsibilities between DSO Platforms and Service Platforms, and the interactions between market players and the newly proposed EU Market Place (bottom).



(adapted from: FLEXICIENCY Deliverable 2.1 – Definition of services and use cases description v1.0)



(adapted from: FLEXICIENCY Deliverable 11.6 – Final Report)

Figure 21 Top: FLEXICIENCY system architecture; Bottom: Interactions among market players and the newly proposed EU Market Place. Adapted from [30] and [31].

3.2.18 FLEX-DLM

The distinctive feature of FLEX-DLM is the development of a technical clearing optimisation algorithm for the procurement, on the DSO's side, of flexibility services. This technical clearing optimisation algorithm aims at minimising the DSO's total cost of acquiring the distributed flexibility.

Table 29: Market organization of the Flex-DLM project

Project FLEX-DLM	
Market Model	M2: local and global flexibility markets
Needs / Services Addressed on the BUCs	• Congestion management for DSO (short-term, D-1) • Balancing for TSO (possibility)
Market Structure	• Characterization: one-sided market; AGR submit offers to the market platform that can be procured by DSO when in need • Trading Type: continuous auction • Price computation: pay-as-bid, with the article claiming that flexibility prices should be defined within an allowed price range set by DSO • Clearing mechanism: a technical clearing optimization algorithm is proposed for the DSO procuring the flexibility services, aimed at minimizing the DSO total cost of acquiring distributed flexibility. It considers the acquisition of up and down regulation flexibility and takes the rebound effect into account. In accordance with Spanish electricity markets criteria, trading periods of one hour are considered. The optimization horizon is set as the 24 hours of the day-ahead; the conditions under which the rebound effect takes place are agreed upon between the flexibility supplier and the DSO, namely by defining the rebound hour (specific hour, any hour within a time interval of the day or unrestricted) and the rebound power (full activated flexibility or just a percentage of it) • Type: energy service provision (kWh) • Products short description: products consist of increasing or decreasing capacity volumes submitted in the form of up-regulation and down-regulation bids; maximum and minimum acceptance volumes are defined by the DSO as well as a price cap
TSO-DSO coordination mechanisms	No TSO-DSO coordination mechanism is considered
Bids validation procedure	Not clear when bid validation is performed. Their submission is performed after the day-ahead market clearing to address local congestions identified by DSO
Integration with other markets	Flex-DLM is a distribution-level flexibility market that is expected to be running after the day-ahead market clearing
Resources	Demand side response from residential and industrial consumers
Aggregation	Aggregation is considered, namely regarding residential consumers
Terms	Day-ahead

Figure 22 shows the baseline methodology specification for industrial and for residential consumers providing flexibility to the DSO.

Baseline methodology

For industrial consumers:

The up regulation power is computed as the difference between the load at time t of service activation and the minimum load level of a customer. The down regulation power is calculated as the difference between the maximum load level and the load at hour t of service activation.

$$P_{ind,t}^{UREG} = \mathrm{Load}_{ind,t} - \mathrm{MinLoad}_{ind}$$

$$P_{ind,t}^{DREG} = \mathrm{MaxLoad}_{ind} - \mathrm{Load}_{ind,t}$$

For residential customers:

A share percentage for each individual costumer is defined, based on the number of appliances contributing for the flexibility. Per each appliance a flexible share percentage of the flexible load that can be either reduced or increased is also defined. The up regulation power per costumer and per time step is calculated as the sum for all applications of multiplying the flexible share percentage of each application by its load at time step t:

$$P_{res,t}^{UREG} = \sum_{res\_app=1}^{N_{res\_app}} \mathrm{Load}_{res\_app,t}\ \mathrm{Flex}_{\mathrm{Share}\,res\_app,t}^{UREG}$$

The down regulation power per costumer and per time step is calculated as the sum for all applications of multiplying the flexible share percentage of each application by the difference of the its installed capacity minus the load at time step t:

$$P_{res,t}^{DREG} = \sum_{res\_app=1}^{N_{res\_app}} (\mathrm{InstCap}_{res_{app}} - \mathrm{Load}_{res_{app},t})\ \mathrm{Flex\_Share}_{res_{appl},t}^{DREG}$$

Figure 22: Baseline methodology specification for providing flexibility. From [23].

3.2.19 FlexMart

In FlexMart, the DSO resorts to flexibility as a tool for investment deferral. Optimisation techniques are used to assess, on one hand, the existing flexibility needs at a certain location and, on the other hand, the available flexibility that can be activated in that location to satisfy the needs. This analysis allows the DSO to decide whether to investment in network reinforcement: if the availability flexibility enables eliminating the flexibility needs, then no grid reinforcements will be required. Conversely, if the availability of the flexibility is not enough to suppress the flexibility needs, then it will be necessary to make new investments in grid reinforcing.

Table 30: Market organization of the FlexMart project

Project FlexMart	
Market Model	M2: local and global flexibility markets
Needs / Services Addressed on the BUCs	• Congestion management for DSO (long-term)
Market Structure	• Characterization: one-sided market; per location, the DSO assesses what is the available flexibility and by solving an optimization problem decides on contracting the flexibility of the consumers or investing in grid reinforcement • Trading Type: continuous auction; flexibility offers can be submitted to the FlexMart and are evaluated by the DSO when scheduling their needs for the next 3-year period per pre-defined location (it is postulated to assume as single location a small number of feeders since this model is proposed on a single paper which used as a case study 2 feeders as a toy example) • Price computation: modified pay-as-bid; the authors propose a regulated approach that offers the consumer a fixed benefit, eliminating the risk associated with price volatility; this benefit allows consumers to recover their investment in flexibility-associated equipment, i.e. advanced metering devices and control unites, incremented by a predefined return on investment (ROI) rate = 10%; the actual compensation for the consumer is calculated as the fixed benefit minus the savings due to price differences • Clearing mechanism: an empirical planning model using mixed integer linear programming (MILP) with the objective of minimizing DSO total costs considering the acquisition of flexibility, reinforcement investments and RE curtailment. Demand response is shiftable, so a restriction for rebound power within a predefined time frame is considered. The rebound power will correspond to all the activated flexibility within the optimization horizon • Type: capacity market (kW) • Products short description: scheduled up and down-regulation of aggregated household consumption, with a 1hour step. Demand flexibility is modelled as a percentage of total demand at each time interval (roughly varying from 2% to 20%, averaging 10%)
TSO-DSO coordination mechanisms	No TSO-DSO coordination mechanism is considered
Bids validation procedure	Planning model using mixed integer linear programming (MILP)
Integration with other markets	No integration with other markets
Resources	Households are aggregated under the aggregation units (AU) and offer demand flexibility (up- and down-regulation). The optimization problem also considers roof PV installations and the possibility to curtail them
Aggregation	Aggregation through AU which are non-profit intermediaries (for the purposes of the work presented in the paper)
Terms	Long-term capacity market with a lead-time of 3-years (sufficient to consider the possibility of grid reinforcements and not long enough to put into question the available load demand forecasts)

3.2.20 GOPACS-IDCONS

GOPACS focuses on reducing congestion problems using the flexibilities available to the market, through a new market concept. The local market platform makes use of bids with a locational tag, so that the solution of local flexibility problems is procured, with spatially near offers, and considering the spread of the difference between bid and ask prices, making use for this of GOPACS-IDCONS products. GOPACS architecture is depicted Figure 23 that represented the use of congestion spread by the SO to manage congestions once there are offers with locational information on the market platform.

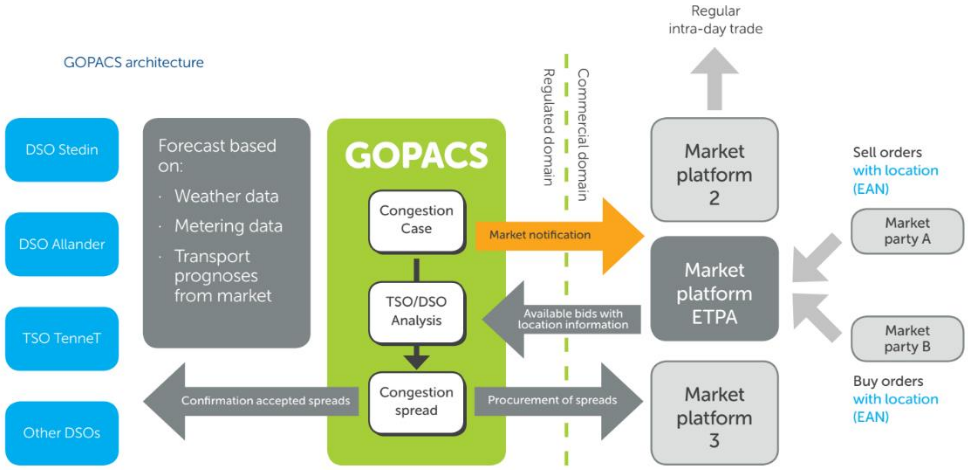


Figure 23: GOPACS architecture, with the regular intraday market, and the congestion management through GOPACS-IDCONS (congestion spread). From [78].

Concerning the congestion spread situation, grid operators can activate intraday bids in specific locations, for managing congestion problems. Figure 24 shows how the orders are chosen in different locations, at different prices, and how GOPACS platform through IDCONS scheme matches these orders, linked to a congestion spread.

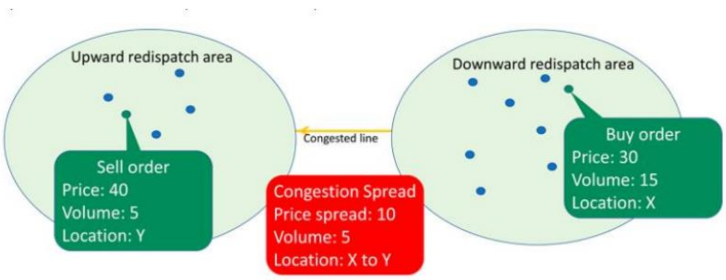


Figure 24: congestion spread case for GOPACS-IDCONS. From [79].

Table 31: Market organization of the GOPACS-IDCONS project

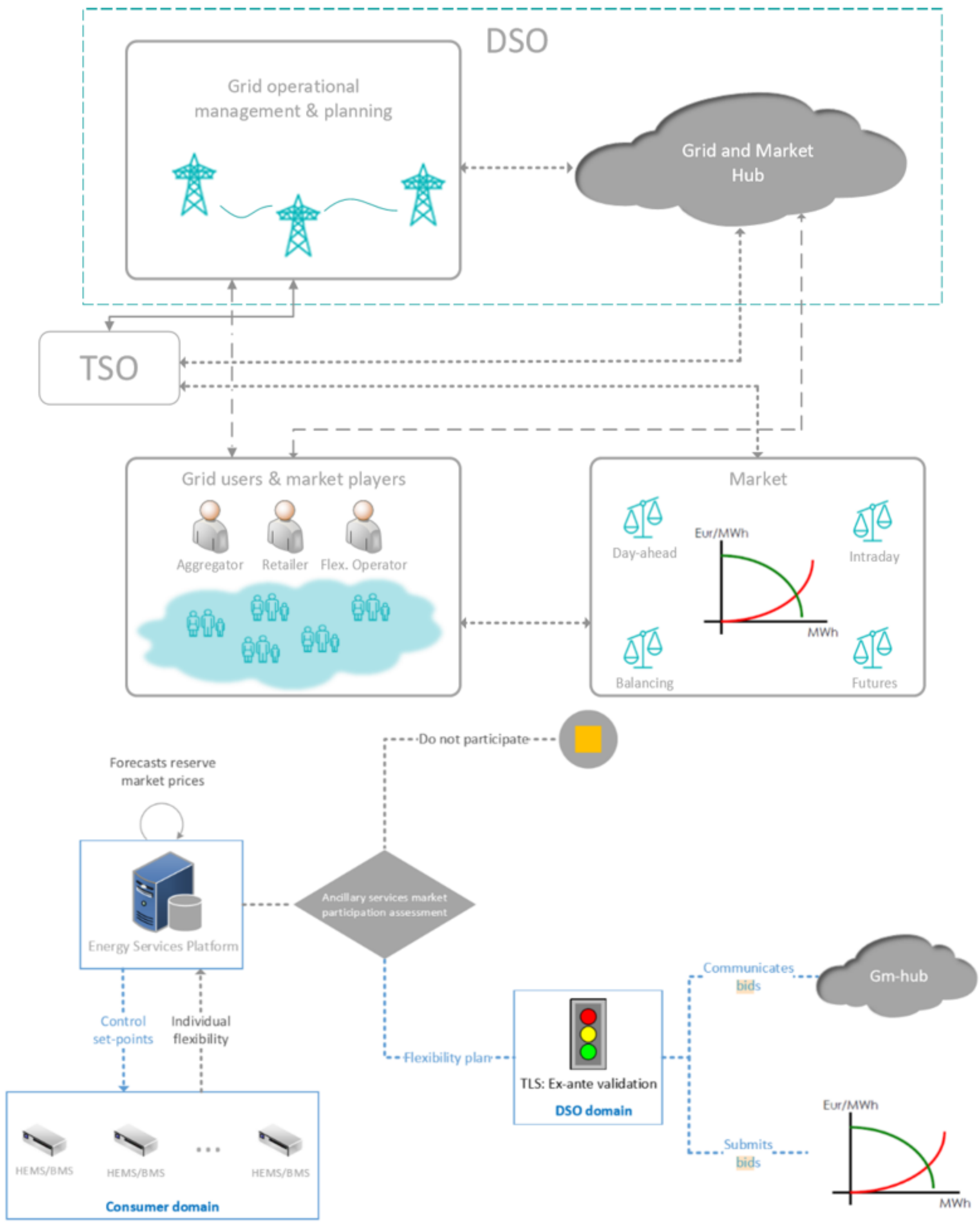
Project GOPACS-IDCONS	
Market Model	M2: local and global flexibility markets
Needs / Services Addressed on the BUCs	• Congestion management for DSO (short-term)
Market Structure	• Characterization: two-sided market • Trading Type: continuous market • Price computation: pay-as-bid • Clearing mechanism: Grid operators analyse suitable orders and create IDCONS through GOPACS, combining the buy and sell order with a location component if they are not already matched by the trading platform. Grid operators pay the spread between the buy and the sell order. Clearing of IDCONS is carried out through the market platform, informing the market parties involved and the grid operators of this fact • Type: energy (kWh) • Products short description: standardised products
TSO-DSO coordination mechanisms	Regulated function implemented via an algorithm in the platform, to avoid offers from one area to trigger congestion in other SO area. A smart algorithm is in development: it will allow DSO and TSO to create and activate spreads taking in account grid conditions
Bids validation procedure	This procedure is not realized on GOPACS platform, not been described. As a requirement, to participate in IDCONS, parties must be connected to a trading platform that supports IDCONS
Integration with other markets	Integration with existing regulated market models is under development
Resources	All types, GOPACS interacts via market platforms with whoever can offer flexibility (in the case of the ETPA platform: medium to small sized commercial customers to effectively become BRP)
Aggregation	Residential customers can be involved in the provision of flexibility indirectly via the BRP/AGR
Terms	Intraday, through ETPA (Energy Trading Platform)

3.2.21 InteGrid

Under the InteGrid market integration model, local flexibility markets for the DSO exist in parallel with the global ancillary market for the TSO.

At the local level, the DSO resorts to distributed flexibilities (active power) connected to the MV and LV networks as providers of non-frequency ancillary services for different goals such as investment deferral, solving real-time technical constraints or minimize energy losses.

At the global level, the TSO is contracting flexibility products on the balancing market (manual Frequency Restoration Reserve (mFRR) and Replacement Reserve (RR)). In this case, the flexibility operators submit their bids to the DSO for technical validation (through the grid-market hub, as shown in Figure 25). If the DSO validates the bids, then the bids are communicated to the TSO via the market gm-hub. Subsequently TSO selects the bids to activate in order to reach the volume of balancing energy needed.



https://integrid-h2020.eu/uploads/public_deliverables/D1.2 Read Use Cases and Requirements.pdf

Figure 25: Schematic representation of the market integration model proposed in InteGrid

Table 32: Market organization of the InteGrid project

Project InteGrid	
Market Model	M2: local and global flexibility markets
Needs / Services Addressed on the BUCs	• Support distribution grid planning (long term) • Balancing for TSO (mFRR, RR)
Market Structure	• Characterization: one-sided market • Trading Type: periodic closed gate auction (day-ahead and intraday auctions) • Price computation: pay-as-bid • Clearing mechanism: merit order sorting of flexibility resources which reflects the amount of energy (kWh) and price (€/kWh) for the period considered • Type: energy (kWh) • Products short description: no standardised products
TSO-DSO coordination mechanisms	DSO uses local flexibility first; the remaining bids are validated before being sent to the TSO
Bids validation procedure	The flexibility operators submit their bids to the DSO for technical validation (through the grid-market hub); if the DSO validates the bids, then the bids are communicated to the TSO via the market gm-hub. The selection process is based on a merit order curve which reflects the amount of energy (kWh) and price (€/kWh) for the period considered
Integration with other markets	Local markets for the DSO coexist with the ancillary services market for the TSO
Resources	Flexibility operators can shed loads at the MV level (global market), as well as send control set-points to the home energy management systems at the LV level (local market). In the latter case, the Energy Services Platform (owned by the Flexibility Operator), gathers information about all of their customers' available flexibility
Aggregation	The offers from prequalified assets are submitted per node
Terms	Day-ahead, intraday

3.2.22 Interflex

The design of the InterFlex flexibility market is based on the Universal Smart Energy Framework (USEF), differing in two main ways. Firstly, the initiative proposes a market between AGR and DSO only, while USEF describes a mechanism between AGR, DSO, BRP and TSO. The latter two roles are not in scope for Interflex. Furthermore, InterFlex introduces a new concept called sanctions to distinguish between different flexibilities. Also, since it is unclear when and at what costs the DSO can switch to orange regime, where in USEF, the DSO can control DER directly, bypassing AGR, this regime is not used in the project.

Table 33: Market organization of the Interflex project

Project Interflex	
Market Model	M2: local and global flexibility markets
Needs / Services Addressed on the BUCs	• Congestion management for DSO (short-term D-1 and Intraday) • Voltage control for DSO (active power management) • Islanding operation mode for DSO (balancing)
Market Structure	• Characterization: one-sided • Trading Type: continuous auction • Price computation: pay-as-bid • Clearing mechanism: Within the Interflex flexibility market it is decided to align the trading of flexibility with the trading on the wholesale markets. This results in two time-schedules for flex trading. The first is day-ahead trading, where flex trading is done before the day-ahead gate closure time. The second is intra-day trading, where the trading is done before the intra-day gate closure time. To have enough time for all parties to process the flexibility trading this will be done well before the gate closure time of the markets • Type: activation • Products short description: for Congestion Management - a flexibility request by the DSO contains the requested flex power (up or down) for a given congestion point and the corresponding time slot. (15-min blocks). The request is also accompanied by the maximum price the DSO is willing to pay for such request as well as the sanction price for non-compliance, differing in these two aspects from the USEF specification on which Interflex is based on
TSO-DSO coordination mechanisms	No TSO-DSO coordination mechanism is considered
Bids validation procedure	Following two different approaches of negotiation, there are two types of bid selection/validation: <u>Request-based</u> flexibility negotiation DSO-AGR: Negotiation is triggered by the DSO, through flexibility requests in the platform, which directs these requests to AGR. AGR evaluate the requests and submit offers to the platform, which returns it to DSO. At this time, the DSO, based on its internal business logic, selects one of the received flexibility offers and posts a flexibility activation request to the flexibility platform. The platform does not limit the DSO to selecting one offer; it is also feasible to post several flexibility activation requests to obtain an even larger flexibility <u>Offer-based</u> flexibility negotiation DSO-AGR: in this alternative, AGR autonomously post flexibility offers to the platform, updating continuously their bid. Afterwards DSO posts requests to the platform, which returns the available offers to the DSO. DSO select offers based on its internal business logic. After the decision, DSO sends flexibility activation request to the platform. which forwards them to the respective AGR proceeding with the fulfilment of DSO needs with activation of selected flexibilities
Integration with other markets	No integration is considered with other markets. Nonetheless it is considered that flexibility offered by AGR can be traded with other interested parties (e.g. TSO, BRP) and/or markets such as wholesale markets
Resources	From France and The Netherlands demonstrators, the resources have the characteristics: NL - Stationary storage assets, controllable PV panels and controlled public charging stations for EV; FR - A variety of flexibilities and activation channels were tested, including residential appliances (e.g. thermal household storage devices), dual-fuel hybrid heating systems (gas/electric), industrial process control, stationary batteries and one EV with V2G capacities
Aggregation	Aggregation is allowed: FSP
Terms	Day ahead; intraday

3.2.23 INTERRFACE

INTERRFACE is a very recent (kick-of date was January 2019) and very ambitious initiative aiming at the definition of innovative grid services, that is still ongoing. For that reason, the concepts presented are still very theoretical and lack a proof-of-concept through proper demonstrations.

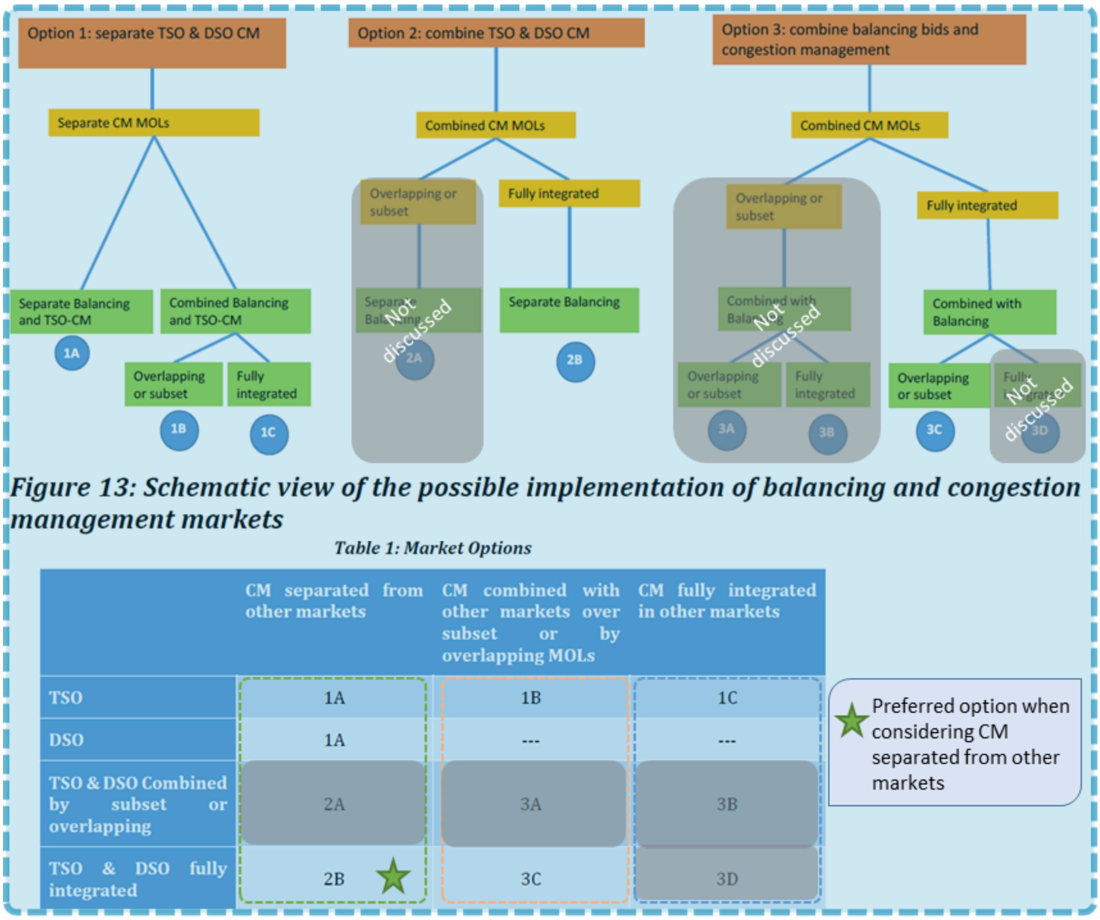
Table 34: Market organization of the INTERRFACE project

Project INTERRFACE – BUC-1	
Market Model	M2/3: local and global flexibility markets with balancing coordination
Needs / Services Addressed on the BUCs	• Congestion management for TSO and DSO (operational) • Congestion management for TSO and DSO (short-term) • Congestion management for TSO and DSO (long-term) • Balancing for TSO (aFRR and mFRR)
Market Structure	• Characterization: one-sided market • Trading Type: continuous auction • Price computation: pay-as-bid • Clearing mechanism: the market is managed in order to select the resources according to a dedicated Merit Order List (MOL) • Type: energy and capacity • Products short description: Products for long-term market: CRP – Conditional Reprofiling bids of FSP (reserve capacity); capacity reservation is done once a year; activation should be made a day ahead of the real-time operation; Products for Day-Ahead (DA) markets: SRP – Scheduled Reprofiling bids of FSP ("obligation of the flexibility to modify the demand or generation at a given time"); attributes: min and maximum bid size, temporal measurement resolution, up/down regulation, activation time, duration, location, rebound condition (payback time and percentage), partial or "all or none" bids, ramping up period, min full activation period, mode of activation (manual, automatic); Products for Operational market: CRP – Conditional Reprofiling bids of FSP – capacity reservation day-ahead
TSO-DSO coordination mechanisms	Three options were explored in the use cases of M2/3 market model of INTERRFACE: all options considered separate congestion management for DSO and TSO (separate MOL). One option considered separate TSO balancing and congestion management, while the combination of the two is considered fully integrated in another option. A third option considered a "middle-course solution" as there is an overlapping MOL of TSO CM and balancing (extended by local information, allowing DSO MOL and TSO CM MOL to be interchangeable)
Bids validation procedure	Not specified
Integration with other markets	Not specified
Resources	CHP plant (coupled with thermal storage), distributed battery (on LV grid 100+100 kWh), EV, scheduling of pumping stations, DR in buildings, medium-size battery, distributed EV stations and homes with smart electric heating installation
Aggregation	Aggregation of resources is considered
Terms	Day ahead; intraday

Table 35: Market organization of the INTERRFACE project

Project INTERRFACE – BUC-2	
Market Model	M4: common TSO and DSO flexibility market
Needs / Services Addressed on the BUCs	• Congestion management for TSO and DSO (operational) • Congestion management for TSO and DSO (short-term) • Congestion management for TSO and DSO (long-term) • Balancing for TSO (aFRR and mFRR)
Market Structure	• Characterization: one-sided market • Trading Type: continuous auction • Price computation: pay-as-bid • Clearing mechanism: the market is managed to select the resources according to a dedicated Merit-Order-List • Type: energy and capacity • Products short description: Products for long-term market: CRP – Conditional Reprofiling bids of FSP (reserve capacity); capacity reservation is done once a year; activation should be made a day ahead of the real-time operation; Products for DA markets: SRP – Scheduled Reprofiling bids of FSP ("obligation of the flexibility to modify the demand or generation at a given time"); attributes: min and maximum bid size, temporal measurement resolution, up/down regulation, activation time, duration, location, rebound condition (payback time and percentage), partial or "all or none" bids, ramping up period, min full activation period, mode of activation (manual, automatic); Products for Operational market: CRP – Conditional Reprofiling bids of FSP – capacity reservation day-ahead
TSO-DSO coordination mechanisms	Two options were explored in the use cases of M4 market model of INTERRFACE (the two considering only one combined CM MOLs): separate balancing or combined with balancing market
Bids validation procedure	Not specified
Integration with other markets	Not specified
Resources	CHP plant (coupled with thermal storage), distributed battery (on LV grid 100+100 kWh), EV, scheduling of pumping stations, DR in buildings, medium-size battery, distributed EV stations and homes with smart electric heating installation
Aggregation	Aggregation of resources is considered
Terms	Day ahead; intraday

Figure 26 shows the possible balancing and congestion management market implementations that are discussed in the early stages of the INTERRFACE project (top), as well as the grouping of the several market implementations listed above based on the combination of Congestion Management (CM) with other markets (bottom). This is an adaptation of the proposed coordination schemes at [71] and depicted in Figure 17.



	CM separated from other markets	CM combined with other markets over subset or by overlapping MOLs	CM fully integrated in other markets
TSO	1A	1B	1C
DSO	1A	---	---
TSO & DSO Combined by subset or overlapping	2A	3A	3B
TSO & DSO fully integrated	2B	3C	3D

Figure 26: Top - possible balancing and congestion management market; Bottom - grouping of the several market implementations. Adapted from [42] and [43].

3.2.24 IREMEL

IREMEL has the particularity that it does not deal with TSO-DSO coordination. Indeed, it proposes MO-DSO coordination mechanisms to allow DER to bid in the MIBEL energy markets with DSO validation, as well as a local flexibility market platform to cover DSO's needs.

Table 36: Market organization of the IREMEL project

Project IREMEL	
Market Model	M2: local and global flexibility markets
Needs / Services Addressed on the BUCs	• Congestion management for DSO (short term) • Support distribution grid planning (long term) • Balancing for TSO (long term)
Market Structure	• Characterization: two-sided market Two market models were considered, global and local. Each of these two was further divided into another two; Thus, four different types of market models were considered (1) Global market without distribution grid constraints, in which local flexibilities (DER) can submit their bids to the global markets directly or through an AGR; local flexibility markets are disabled (2) Global market with potential grid constraints, in which some local flexibilities must be restricted to a specific area or distribution network zone (Zone of Flexibility), so as to ensure safe operation; DER can participate without aggregation or aggregated in the same grid location (where the grid constraints apply); these grid limitations are communicated to the MO by the DSO (3) Local market for network congestion management (localized constraint), in which MO+DSO define local flexibility products; resources can be aggregated only if they have an impact in the same grid constraints; DER can still participate in global markets but may be subject to limitations (4) Local market with a persistent grid constraint: for frequent grid constraints, the DSO may decide to use pre-agreed flexibilities (instead of those from the flexibility local market), through DSO-FSP contracts • Trading Type: periodic closed gate auction (day-ahead and intraday auctions) • Price computation: pay as clear (intraday auctions); pay-as-bid; (continuous intraday market) • Clearing mechanism: clearing can be based on full or partial matches between price and volume of flexibility traded (kW or kWh) • Type: energy (kWh) and power (kW) • Products short description: no standardised products
TSO-DSO coordination mechanisms	No TSO-DSO coordination. OM (energy markets)-DSO coordination for commercial flexibility
Bids validation procedure	In market type 1 (see 'market structure' above), bids can be submitted to the global markets directly or through an AGR; In market types 2, 3 and 4, bids have to be validated by the DSO so as to ensure that the use of flexibility doesn't lead to technical violations
Integration with other markets	Each of the four types of markets described in 'market structure' exist in parallel with the global European market
Resources	distributed energy resources within the MV grid
Aggregation	In market model 1 (see 'market structure' above) the DER are not subject to geographical restrictions; In the other market models, some DER can only participate within their Zone of Flexibility. As such, DER can be aggregated in all cases, but aggregation may be subject to restrictions in market models 2, 3 and 4
Terms	Day-ahead, intraday, in the local market, the activation horizon may depend on the procurement process (bid), not necessarily day-ahead or intraday

3.2.25 NODES

Nodes is not a market organization itself but an independent flexibility local market platform that can be partially configured to be installed in different environments, enabling the producers and consumers of energy and the SO to trade the decentralised flexibility and energy. It integrates various markets, being fully automated and allows real-time trading of available flexibility in the market with transparent prices.

In the Figure 27 it is possible to see how the platform interfaces the different parts and participants of the market, through the Application Programming Interfaces.

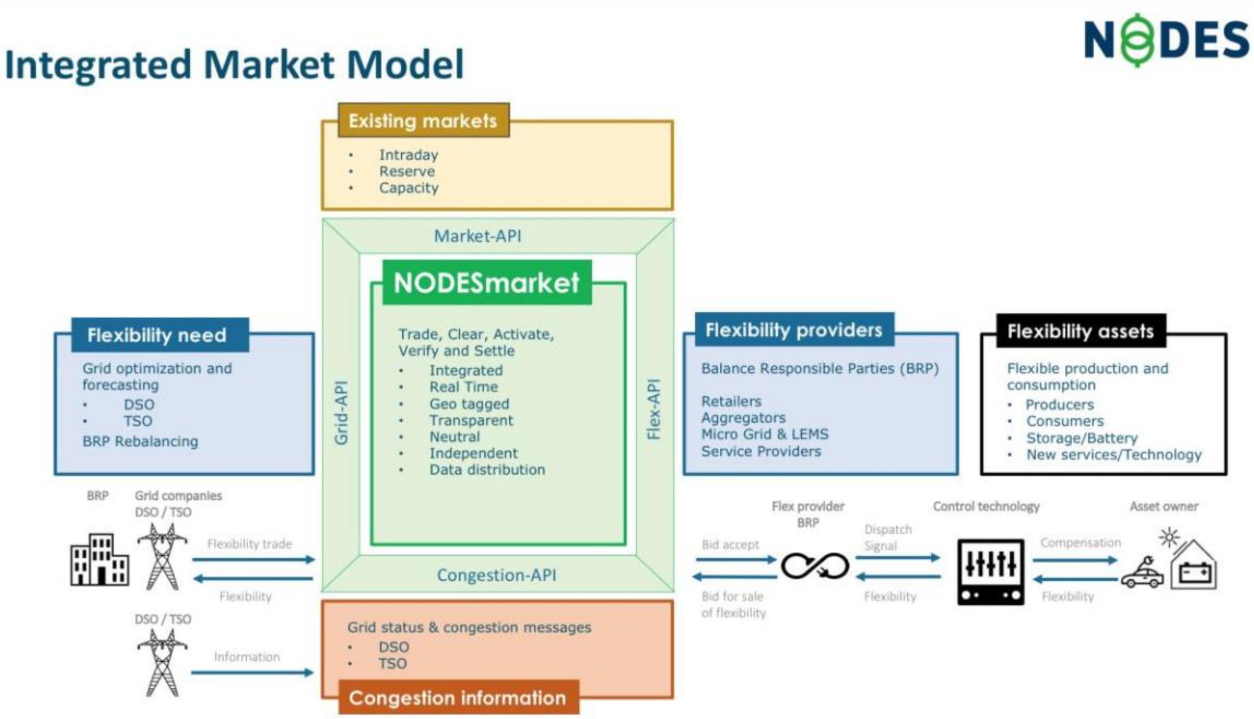


Figure 27: NODES marketplace model, integrated through the several APIs to market participants and functionalities. From [46].

Table 37: Market organization of the Nodes project

Project NODES	
Market Model	M2: local and global flexibility markets
Needs / Services Addressed on the BUCs	• Congestion management for DSO (short-term)
Market Structure	• Characterization: two-sided market • Trading Type: continuous market • Price computation: pay-as-bid • Clearing mechanism: besides building up the platform, NODES also matches flexibility offers with demand (and deals with the settlement, provides feedback and analytics): market participants enter a price for each unit, the market clears at the point where supply matches aggregate demand and winning bidders are paid their bid price for each unit. NODES apply pre-filtering based on buyers' preferences prior to matching on price • Type: energy • Products short description: no standardised products. NODES specify parameters, not products
TSO-DSO coordination mechanisms	TSO-DSO coordination is possible, subject to customer's request
Bids validation procedure	There is a collaboration between NODES and the connecting SO for pre-qualification: upon successful asset approval by the SO, flexibility providers will be able to enter orders in the flexibility market. FSP will group their assets into asset portfolios that reflect locational requirements and submit buy or sell orders based on these portfolios. The DSO will create the grid locations in the NODES platform which enable them to create spatial boundaries for flex offers that are valuable for grid constraint relief
Integration with other markets	Currently, the interfaces between NODES and the existing markets are not in place yet
Resources	NODES is designed to operate a marketplace for any flexibility supplier irrespective of size. Several flexible loads can be activated including smart homes with solar panels and batteries, electric vehicles and commercial and residential demand response customers
Aggregation	AGR/BRP allowed
Terms	Intraday timeframe

3.2.26 Piclo (Piclo Flex)

Piclo Flex, from Piclo, is an independent marketplace with the objective of flexibility trading to provide it market visibility. The online platform gives support to procurement of flexibility for 4 DNOs of the UK, comprising several locations on LV network, to solve network local congestion issues, thus it addresses mainly the DSO on the platform.

Table 38: Market organization of the PICLO FLEX project

Project Piclo (Piclo Flex)	
Market Model	M2: local and global flexibility markets
Needs / Services Addressed on the BUCs	• Congestion management for DSO (short-term) • Congestion management for DSO (long-term) • Observability over available flexibility
Market Structure	• Characterization: one-sided market • Trading Type: auction based • Price computation: pay-as-bid • Clearing mechanism: The methodology follows the match of consumer's preference and generate a price for the customer to choose. The data is based on information from Good Energy, which provides the cost of power generation every 30 minutes, including information on customer preference. The smart contract, billing and customer service are all provided by Good Energy, being Piclo an online service which power suppliers and end-users can achieve transaction through the data assistance • Type: energy and capacity • Products short description: Standardised products are used. DSO can see qualifying assets in the constraint management zones - the resulting map of competitions enables them to source flexibility with highly specific locational, technical and temporal requirements
TSO-DSO coordination mechanisms	No TSO-DSO coordination mechanism is considered (Piclo Flex is a solely DSO platform)
Bids validation procedure	It is informed that there is a pre-qualification procedure, done by the connecting SO
Integration with other markets	No integration with other markets
Resources	Flexibility available on the platform: a very small portion is composed by residential batteries; significantly more are larger batteries; generators Providers also include demand-side response (DSR) AGR, local authorities, industrial facilities and electric vehicle charging operators Piclo does not capture the type of generators, in the trial data, but many are likely to be traditional generators powered by gas or diesel, supplemented by CHP systems, waste-to-power systems and wind farms
Aggregation	Aggregation is allowed
Terms	Piclo offer long-term (i.e. weeks or months ahead) availability contracts

3.2.27 SENSIBLE

In the SENSIBLE project, the market integration model includes a local market for the DSO and a global ancillary market for the TSO. The flexibility for the DSO can be provided by DER both at the LV level (through a retailer that accessed the Home Energy Management Systems (HEMS) of the end-users) and at the MV level. The TSO operates the ancillary service market to acquire reserve capacity for real-time and near future balancing.

Table 39: Market organization of the SENSIBLE project

Project SENSIBLE	
Market Model	M2: local and global flexibility markets
Needs / Services Addressed on the BUCs	• Congestion management for DSO (short term) • Support distribution grid planning (long term) • Voltage control (reactive power) • Balancing for TSO (aFRR and mFRR)
Market Structure	• Characterization: (1) local market for DSO: two-sided market The retailer optimizes its market participation (active and reactive power) by managing the clients' available flexibility. The retailer then shares the profit with the customer and minimizes the Energy Tariff. In a day ahead base, that flexibility will be scheduled in the HEMS, which will manage the client's available flexibility. Deviation between the retailer client's portfolio consumption forecast and the real consumption must be balanced in the intraday market (2) the reserve/ancillary market: one-sided market The TSO operates the ancillary service market to acquire reserve capacity for real-time and near future balancing. The TSO has different mechanisms and interfaces to procure the reserve capacity, which may vary from email procedures to specific trading applications. After the bidding process, awarded balancing capacity and the request to execute that capacity may be communicated to the parties either electronically or for example by phone • Trading Type: periodic closed gate auction (day-ahead and intraday auctions) • Price computation: (1) pay-as-clear; (2) pay-as-bid • Clearing mechanism: (1) the DSO can activate the bids by paying the market price (2) unclear • Type: energy (kWh) and power (kW) • Products short description: no standardised products
TSO-DSO coordination mechanisms	Non-described joint balance settlement
Bids validation procedure	(1) The DSO performs technical validation of the bids (OPF) as to guarantee that no technical violations take place; (2) individual selection of the bids by the TSO, in accordance with its own technical criteria
Integration with other markets	Both the local and ancillary service markets were designed to run in parallel with other existing day-ahead, intra-day and intra-hour markets
Resources	(1) energy storage devices at the LV level under the HEMS, such as water heaters, electrical batteries, PV generators or other flexible loads; and renewable power plants at the MV level that (2) also have capacitor banks, STATCOM and Plug and Play Storage Systems
Aggregation	The retailer acts as an AGR, by combining several decentralized production and demand units in one portfolio
Terms	Day-ahead, intraday

3.2.28 USEF

In the Universal Smart Energy Framework (USEF) project, AGR establish contracts with the prosumers describing the terms and conditions under which it will be possible to exploit the flexibility within the prosumer-defined control space of the active demand & supply asset (ADS). Each AGR then optimizes the value of the flexibility in its portfolio by selling it to the market participants who have the most urgent need for it and hence are willing to procure it at the highest price [61]. To that end, the AGR establishes a flexibility service contract with the BRP responsible for that prosumer's imbalance. The contract specifies the terms and conditions for trading flexibility, including the settlement of imbalance resulting from flexibility transactions (this interaction is shown in Figure 28 where the USEF market framework is illustrated, including the bilateral trading and trading via a market platform and the FUSION market structure and responsibilities).

Table 40: Market organization of the USEF project

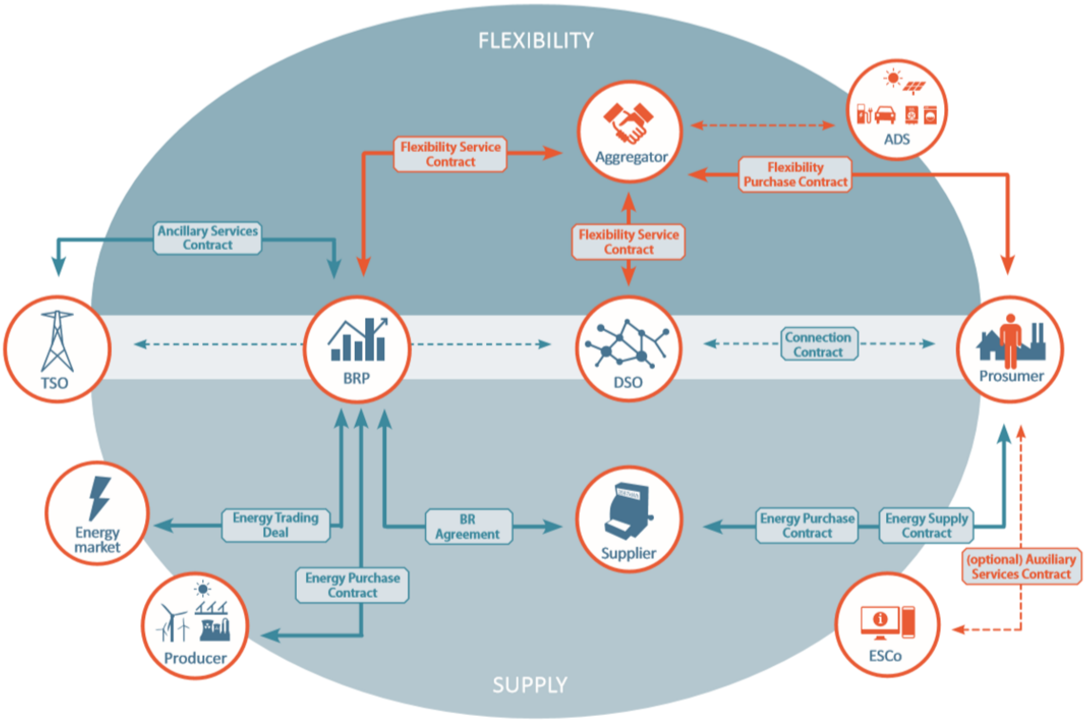
Project USEF – general Market Model proposed	
Market Model	M2/M3: local and global flexibility markets with balancing coordination
Needs / Services Addressed on the BUCs	• Congestion management (short-term) • Controlled islanding • Support grid planning (grid capacity management) • Voltage control (active power management)
Market Structure	• Characterization: one-sided market; DSO and BRP communicate flexibility needs in terms of energy reduction. AGR/BRP can set flexibility offers in terms of volume and price • Trading Type: periodic closed-gate auction • Price computation: pay-as-bid, but long-term flexibility contracts can also be established between AGR and DSO • Clearing mechanism: technical and economical clearing are the responsibility of the DSO procuring flexibility services. Settlement is calculated over a one-month period. Reservation is possible through bilateral contracts with AGR. In the day-ahead grid planning process, DSO will indicate whether the contracted amount of flexibility is needed or not. The DSO determines where congestion may take place and declares Congestion Points. AGR can offer in local market UFLEX to the DSO for a given congestion point. UFLEX corresponds to the energy load reduction offer with a given price for the periods indicated by the DSO in a FlexRequest • Type: energy and capacity • Products short description: products for which the following parameters can be provided - Period for which Flexibility is offered to solve a given FlexRequest - Location - Expiration date - Reference to bilateral contract for reservation if applicable - Baseline characterization - Price - Minimal activation factor in case enabling partial use of flexibility offer - Type of activation (if ISP – imbalance settlement period – represents available capacity or a request for reduction/increase of active power) - Power - Start - Duration
TSO-DSO coordination mechanisms	No TSO-DSO coordination mechanism is considered
Bids validation procedure	Technical and economical clearing are the responsibility of the DSO procuring flexibility services. Settlement is calculated over a one-month period
Integration with other markets	The USEF flexibility market is supposed to exist in parallel with the already existing global market
Resources	DER within the distribution network (through AGR)
Aggregation	Allows for individual or aggregated resources
Terms	Long-term, monthly

Table 41: Market organization of implementation FUSION trial of the USEF project

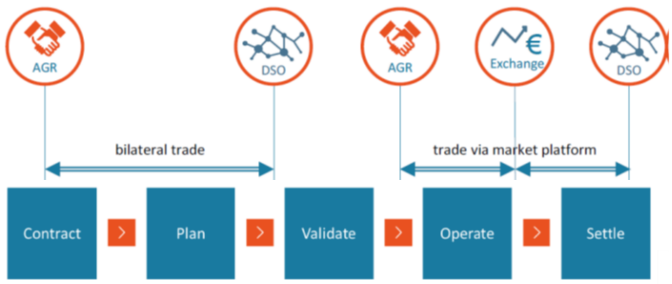
Project USEF - implementation FUSION trial	
Market Model	M2/M3: local and global flexibility markets with balancing coordination
Needs / Services Addressed on the BUCs	• Congestion management (short-term and restoration) • Support grid planning (grid capacity management)
Market Structure	• Characterization: one-sided market; DSO and BRP communicate flexibility needs in terms of energy reduction. AGR/BRP can set flexibility offers in terms of volume and price; framework extended to include pre-fault and post-fault constraint management and restoration support products • Trading Type: periodic closed-gate auction • Price computation: pay-as-bid, but long-term flexibility contracts can also be established between AGR and DSO • Clearing mechanism: technical and economical clearing are the responsibility of the DSO procuring flexibility services. Settlement is calculated over a one-month period. Reservation is possible through bilateral contracts with AGR. In the day-ahead grid planning process, DSO will indicate whether the contracted amount of flexibility is needed or not • Adds a Constraint service provider that interacts with the DSO • Common reference operator manages the publication of both the DSO flexibility requirements and congested point • Type: energy and capacity • Products short description: products for which the following parameters can be provided - Period for which Flexibility is offered to solve a given FlexRequest - Location - Expiration date - Reference to bilateral contract for reservation if applicable - Baseline characterization - Price - Minimal activation factor in case enabling partial use of flexibility offer - Type of activation (if ISP represents available capacity or a request for reduction/increase of active power) - Power - Start - Duration
TSO-DSO coordination mechanisms	No TSO-DSO coordination mechanism is considered
Bids validation procedure	Technical and economical clearing are the responsibility of the DSO procuring flexibility services. Settlement is calculated over a one-month period
Integration with other markets	The USEF flexibility market is supposed to exist in parallel with the already existing global market
Resources	DER within the distribution network (through AGR)
Aggregation	Allows for individual or aggregated resources
Terms	Long-term, monthly

Table 42: Market organization of the implementation Interflex-Enexis of the USEF project

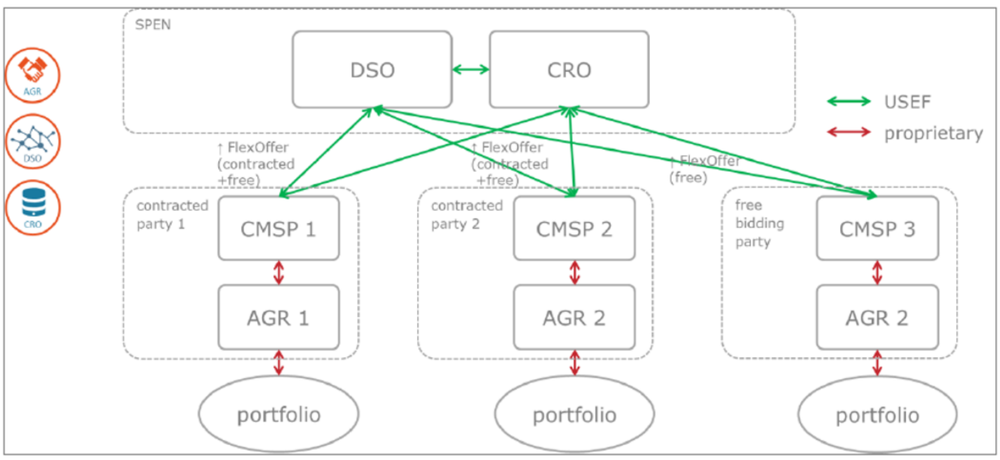
Project USEF- implementation Interflex-Enexis pilot	
Market Model	M2/M3: local and global flexibility markets with balancing coordination
Needs / Services Addressed on the BUCs	• Congestion management (short-term) • Voltage control (active power management)
Market Structure	• Characterization: one-sided market; DSO and BRP communicate flexibility needs in terms of energy reduction. AGR/BRP can set flexibility offers in terms of volume and price; Demonstrator focused on the provision of aggregated flexibility offers based on two types of flexibility: storage and EV • Flexibility AGR platform interface to the DSO via USEF • Trading Type: periodic closed-gat auction • Price computation: pay-as-bid, but long-term flexibility contracts can also be established between AGR and DSO • Clearing mechanism: technical and economical clearing are the responsibility of the DSO procuring flexibility services. Settlement is calculated over a one-month period. Reservation is possible through bilateral contracts with AGR. In the day-ahead grid planning process, DSO will indicate whether the contracted amount of flexibility is needed or not • Adds a Constraint service provider that interacts with the DSO • Common reference operator manages the publication of both the DSO flexibility requirements and congested point • Type: energy and capacity • Products short description: products for which the following parameters can be provided - Period for which Flexibility is offered to solve a given FlexRequest - Location - Expiration date - Reference to bilateral contract for reservation if applicable - Baseline characterization - Price - Minimal activation factor in case enabling partial use of flexibility offer - Type of activation (if ISP represents available capacity or a request for reduction/increase of active power) - Power - Start - Duration
TSO-DSO coordination mechanisms	No TSO-DSO coordination mechanism is considered
Bids validation procedure	Technical and economical clearing are the responsibility of the DSO procuring the flexibility services. Settlement is calculated over a one-month period
Integration with other markets	The USEF flexibility market is supposed to exist in parallel with the already existing global market
Resources	DER within the distribution network (through AGR)
Aggregation	Allows for individual or aggregated resources
Terms	Long-term, monthly



(from: USEF The Framework explained– USEF interaction model)



(Bilateral trading and trading via a market platform from: UFTP: USEF Flexibility Trading Protocol)



(FUSION Market Structure and responsibilities From: https://www.spenergynetworks.co.uk/pages/fusion.aspx)

Figure 28 - USEF Market model, including the flexibility trading protocol and the FUSION market structure. Adapted from [80].

3.2.29 Projects not included

Five projects were not included in the analysis regarding the market models identified due to the reasons presented in Table 43.

Table 43: Projects discarded in the market identification process

Projects not included	Reason
Architecture of Tools for Load Scenarios (ATLAS)	The project was primarily oriented for the development of load forecasting tools for the DSO, not for defining market models.
Future Network Modelling Functions	The project was not directed at defining specific market models or frameworks, but to develop new models for network planning. Few documentation is also available online.
Open Networks	The project does not, to our knowledge extent, clearly define a single or group of market models for DSO. Instead, it provides general guidelines for DSO and their role as a neutral facilitator of markets.
PlatOne	Issues on finding information - the information available at the time of the analysis was not sufficient (published deliverables, publications, etc.).
Power Potential	The project is oriented to transmission system services.

3.3 Results

3.3.1 Mappings between markets, needs and services

Table 44 maps the services identified in the projects analysed (section 2.4.2) to the market organisations used to negotiate them, described in the previous section.

Green colour in the project names indicates that for this particular project and market organization capacity products traded, while red colour refers to energy products.

Although this table considers all the grid services, market models and projects analysed, it was only filled with those needs/services that were effectively described on the BUCs of the projects considered. This explains why some services like FRT are empty in the table.

This table provides insight on what are the most common market organizations depending on the services being provided.

Table 44: Markets–Services mapping

Market Model	DSO Needs / Grid Services							
	Voltage Control		**Congestion Management**			**Service Restoration**		**Voltage Sag Mitigation**
	RP	AP	OP	ST	LT	BS	IO	FRT
M1 - Centralized flex market								
M2 - Local and global flex market	▪ Piclo ▪ SENSIBLE	▪ CoordiNet ▪ EcoGrid 2.0 ▪ EMPOWER H2020 ▪ FLEXICIENCY ▪ Interflex ▪ IREMEL ▪ SENSIBLE	▪ CoordiNet	▪ CoordiNet ▪ EMPOWER H2020 ▪ Enera ▪ FLECH-iPower ▪ Flex-DLM ▪ GOPACS-IDCONS ▪ Interflex ▪ IREMEL ▪ NODES ▪ Piclo ▪ SENSIBLE	▪ CoordiNet ▪ De-Flex-Market ▪ EcoGrid 2.0 ▪ FLECH-iPower ▪ FlexMart ▪ Piclo		▪ CoordiNet ▪ EMPOWER H2020 ▪ Interflex	
M2/3 - Local and global flex market with balancing coordination		▪ USEF	▪ INTERRFACE	▪ INTERRFACE ▪ USEF	▪ INTERRFACE		▪ USEF	
M3 - Local and global flex markets with shared responsibility	▪ CoordiNet ▪ FlexHub EU SysFlex	▪ CoordiNet						
M4 - Common TSO-DSO flexibility market			▪ INTERRFACE	▪ CoordiNet ▪ INTERRFACE	▪ CoordiNet ▪ INTERRFACE			
M5 - Integrated flexibility market for TSO, DSO and BRP								

LEGEND

VOLTAGE CONTROL

- *RP: Reactive Power Management*
- *AP – Active power management*

CONGESTION MANAGEMENT

- *OP: Operational*
- *ST: Short-term planning (D-1 to M-1)*
- *LT: Long-term planning (>M-1 to Y-1 or more)*

SERVICE RESTORATION

- *BS: Black Start for distribution islands*
- *IO – Isolated/Islanding operation mode*

VOLTAGE SAG MITIGATION

- *FRT: Fault-ride Through*

▪ Capacity
▪ Energy

3.3.2 Mappings markets-services-products

The following tables (Table 45, Table 46 and Table 47) extend the analysis performed at Table 44 to include product design options. For each of the main services identified, the information regarding product design from all projects that addressed that specific use case were analysed with the intent to identify patterns and divergences. Each service was also matched with the market models specified in the respective projects.

Table 45: Markets–Services-Products mapping for Need: Congestion Management

Needs	Congestion Management		
Services	OP *(operational)*	ST *(short-term)*	LT *(long-term)*
Product's general attributes	Not thoroughly described on any of the 2 projects reviewed. Product bids consist of capacity reserve, presented in a day-ahead market and their activation is conditional to real-time deviations.	Day-ahead and/or intraday products are discussed on all 13 projects reviewed. No clear distinction between day-ahead and intraday products has been registered on projects that consider both timeframes. The majority of the projects propose standardised products, either bided by DSO or offered by the AGR (complying to a set of requirements), some of them providing greater definition liberty through various parameters (9/13) and others by simply proposing up- and down-regulation active power or energy blocks for fixed time lengths over a pre-defined horizon, in one case complemented with locational info (4/13). A list of the parameters included in the definition of the more versatile standardised products, accompanied by their relative frequency in the reviewed 9 initiatives is provided: - location (geographical, grid node, POD (point of delivery), grid area defined by DSO or other unspecified): 6/9 - activation period (usually parametrized by start time and end time): 6/9 - divisibility (if partial or "all or none" bids; the observed tendency is to accept partial bids): 4/9 - mode of activation (manual or automatic/self-dispatch): 4/9 - product symmetry (usually not required): 4/9 - bid size in power and/or energy (either as a set point or as a band interval of up- or down-regulation): 3/9 - granularity (ranging from 0.01MW to 0.1MW): 3/9 - ramping up period / full activation time: 3/9 - estimated price per activation: 3/9 - temporal delivery and measurement resolution (usually 15 minutes): 2/9 - minimum acceptable bid size (usually defined as 0.1MW or 1MW): 2/9 - quality criteria in supply (such as deviation in max. duration, deviation in volume of service, acceptable no. of unsuccessful activations, deviation from On/Off-Trigger for load reposition/curtailment): 1/9 - maximum acceptable bid size: 1/9 - risk issues that may trigger failure in supply and respective penalties: 1/9 - rebound condition (payback time and percentage): 1/9 Note: Some projects such as FLECH-iPower, define several standardised products for resolving specific issues such as predictable peak loads (divided into a scheduled product and another activated by trigger), specifying a capacity limit per feeder or imposing a power cap on an AGR portfolio.	Lead-times vary from M-1 to 3 years in the 7 reviewed initiatives with each product definition being naturally very heterogeneous. The initiative presenting the greatest lead-time of 3 years, FlexMart, defines a simple product: scheduled up- and down-regulation of aggregated household consumption with a 1h step. Demand flexibility is modelled as a percentage of total demand at each time interval (2% - 20%). Product description gets richer with a diminished lead-time. Also, all products defined for lead times of Y-1 and less are standardised sharing several of the same parameters presented for short-term congestion management. A list of the parameters included in the definition of the more versatile standardised products bided by DSO, accompanied by their relative frequency in the reviewed 6 initiatives is provided: - location (geographical, grid node, POD (point of delivery), grid area defined by DSO or other unspecified): 4/6 - granularity (ranging from 0.01MW to 0.1MW): 4/6 - quality criteria in supply (such as deviation in max. duration, deviation in volume of service, acceptable no. of unsuccessful activations, deviation from On/Off- Trigger for load reposition/curtailment): 3/6 - divisibility (if partial or "all or none" bids; the observed tendency is to accept partial bids): 3/6 - estimated/maximum price per activation: 3/6 - duration of delivery: 3/6 - bid size in power and/or energy (either as a set point for scheduled services or as a band interval of up- or down-regulation for conditional services): 2/6 - full activation time (considered as contract specific and dependent on the mode of activation): 2/6 - risk issues that may trigger failure in supply and respective penalties: 2/6 - mode of activation (manual or automatic/self-dispatch): 2/6 - product symmetry (not required or contract specific): 2/6 - period of capacity reservation (start and duration): 2/6 - (maximum) price paid for availability: 2/6 - time of activation and release trigger: 2/6 - duration of contract: 2/6 - minimum lead time (considered as contract specific, ranging from months to years): 1/6 - temporal delivery and measurement resolution (usually 15 minutes): 1/6 - expected daily reserve activation period (start and duration): 1/6 - estimated number of activations during period: 1/6 - maximum duration of service per activation: 1/6 - maximum allowed activation time: 1/6 - rebound power and duration: 1/6 - full release time: 1/6
Rebound behaviour	Rebound characteristics accompany the respective assets (payback time and percentage) and are considered during the grid prequalification of the collected bids (INTERRFACE).	Not considered in the majority of the projects reviewed, some notes can be found at FLEX-DLM and INTERRFACE. Rebound characteristics can accompany the assets during a registration procedure or can be agreed between FSP and DSO when an agreement between both parties is established (e.g. through bilateral contracts). Main characteristics include a rebound hour or period, and the rebound power percentage, which can be 100% or a smaller percentage of it.	Considered in 3/7 projects, although only 2 clearly define how the rebound behavior problem should be tackled. In one of the initiatives, EcoGrid 2.0, the rebound power is explicitly included in the bid, and can be asymmetric in both power and duration. As for the other initiative, FlexMart, the rebound power is introduced as a restriction in an optimization problem oriented at minimizing DSO total costs with flexibility activation. In this case, the rebound power corresponds to all the activated flexibility within the optimization horizon.
Aggregated product support	Aggregation mechanisms are considered	Aggregation mechanisms are always considered, particularly to overcome minimum capacity barriers on entering flexibility markets. Many of the projects highlight the role of the AGR as the intermediary between DSO and FSP, albeit differing on the degree of its responsibilities. The IREMEL project warns for the possibility that aggregation may be subject to regional restrictions.	Aggregation mechanisms are always considered, usually involving an AGR or a similar player. Aggregation is viewed as the opportunity for DER to be able to deliver different services.
Reservation and/or activation	Reservation	Activation	Reservation

Market models included	M2 M2/3 M4	M2 M2-MO M2/3 M3 M4 M5	M2 M2/3 M4
Pilots/Projects included	CoordiNet INTERRFACE	CoordiNet EMPOWER H2020 Enera FLECH-iPower Flex-DLM GOPACS-IDCONS Interflex INTERRFACE IREMEL NODES Piclo SENSIBLE USEF	CoordiNet De-Flex-Market EcoGrid 2.0 FLECH-iPower FlexMart INTERRFACE Piclo

Table 46: Markets–Services-Products mapping for Need: Voltage Control

Needs	**Voltage Control**	
Services	RP *(reactive power)*	AP *(active power)*
Product's general attributes	Specifications are limited by the number of projects that consider this use case (3) and in the information contained in those initiatives. Eu-Sysflex proposed the definition of reactive power blocks with a delivery horizon of 7 hours and a 15 minute delivery time. SENSIBLE also proposes the definition of reactive power blocks of 1 hour, directly communicated to costumers through a HEMS. CoordiNet proposes a division of reactive power provision for voltage control into two different services, one for normal operation of the system (Steady State Reactive Power - SSRP), which is considered to be slower and correlated and another for system disturbances (Dynamic Reactive Power DRP) which is defined as rapid and uncorrelated. For SSRP the product consists of setpoints of reactive power injection or absorption to maintain a requested voltage. The only parameters specified for a potential product definition are the full activation time <0.1s and the minimum quantity offered of 0.1MVar. The DRP service can only be offered by technologies capable of fulfilling a Q injection/absorption request within specified timescales (non-synchronous generators, static compensators, static VAR compensators, among others, provided they are controlled to support voltage recovery). For a possible product definition, the only consideration provided is that full activation time could range from <0.1s to a few minutes.	4 of the 7 reviewed initiatives explicitly propose standardised products, with 1 of the initiatives not presenting a product description and the remaining 2 suggesting the supply of the service through active power blocks of 1 hour traded either day-ahead or intra-daily. For the initiatives that make a more detailed product definition, the following parameters can be identified: - location (geographical, grid node, POD (point of delivery), grid area defined by DSO or other unspecified): 4/4 - availability period (for reserve products): 4/4 - service start, end and/or duration times (for activation products): 3/4 - bid size in power or energy consumption / absorption: 3/4 - time of full activation (in CoordiNet proposed to be 12,5 minutes) and full release: 2/4 - availability payment (reservation services): 2/4 - activation payment: 2/4 - divisibility (if partial or "all or none" bids; the observed tendency is to accept partial bids): 1/4 - minimum duration of delivery period (in CoordiNet proposed to be 5 minutes): 1/4 - minimal activation factor in case enabling partial use of flexibility offer: 1/4 - mode of activation (in CoordiNet proposed to be "automatic"): 1/4 - verification requirements (including performance required): 1/4 - minimum bid size (in CoordiNet proposed to be 0.1 MW): 1/4 - product symmetry (in CoordiNet "not required"): 1/4 - time step (ranging from 1 minute to 1 hour): 1/4 - penalties/consequences for non-delivery: 1/4 - time of activation and release trigger: 1/4 - maximum duration of delivery period: 1/4 - maximum price for service: 1/4
Rebound behaviour	Not applicable.	Not considered.
Aggregated product support	Aggregation mechanisms are always considered.	Aggregation mechanisms are always considered. The FLEXICIENCY initiative proposes that the bids could be accompanied by information about aggregation level (none, country, city, street, portfolio) and about the aggregation method (sum or mean).
Reservation and/or activation	Activation	Both are possible.
Market models included	M2 M3	M2 M3

Pilots/Projects included	CoordiNet EU-Sysflex Piclo SENSIBLE	CoordiNet EcoGrid 2.0 EMPOWER H2020 FLEXICIENCY Interflex IREMEL SENSIBLE USEF

Table 47: Markets–Services-Products mapping for Need: Service Restoration

Needs	**Service Restoration**
Services	IO *(isolated/islanded operation)*
Product's general attributes	Specifications are limited by the number of projects that consider this use case (3) and in the information contained in those initiatives. In Interflex, a demo was performed where a storage system was operated by an AGR for self-consumption and islanding purposes. The AGR provided the DSO with energy blocks based on power withdraw or injection, fixed for 10 minutes and defined by and algorithm within the islanding system. Orders were made at an hourly time step to a maximum number of cycles defined per day. There was no commitment from the AGR relative to the availability of resource, with the DSO remunerating the service only when it was used. CoordiNet only emphasized the need to define specific products of balancing and voltage control to address this business use case, without providing a product definition. EMPOWER H2020 presented a simple product definition consisting of active power blocks defined by a minimum quantity of 0.1MW. USEF's standardised product definition seems to also apply to this business use case, listing the following parameters: - location (geographical, grid node, POD (point of delivery), grid area defined by DSO or other unspecified) - availability period (for reserve products) - service start, end and/or duration times (for activation products) - bid size in power or energy consumption / absorption - availability payment (reservation services) - activation payment - minimal activation factor in case enabling partial use of flexibility offer
Rebound behaviour	Not considered.
Aggregated product support	Aggregation mechanisms are always considered.
Reservation and/or activation	Both are possible
Market models included	M2 M3
Pilots/Projects included	CoordiNet EMPOWER H2020 Interflex USEF

3.3.3 Discussion

This chapter has made a review on the proposed market integration models for procuring flexibility services in different R&D projects. One of the key aspects reviewed was on the market organizations due to TSO-DSO coordination which in general follow the 5 main schemes proposed in the SmartNet project and summarized in: M1 (centralized flexibility market), M2 (local and global flexibility markets), M3 (local and global flexibility markets with shared responsibility), M4 (common TSO-DSO flexibility market) and M5 (integrated flexibility market for TSO, DSO and BRP).

We identified market model M2 as the most frequent model addressed, considered or proposed by the initiatives. This is in mainly explained by the fact that most initiatives were directed at exploring services for the DSO, rarely specifying any interaction/coordination mechanism between DSO and TSO. More commercial initiatives such as Piclo, Enera or GOPACS, clearly more focused on practical flexibility exchange platforms rather than on the conceptual framework of the market models, do not provide clear explanations on which coordination model they operate, and very often, coordination seems to be left outside the exchange platform, being responsibility of the SO but not specifically provided by the platforms. For these projects the classification of the market model could only be inferred. With that being said, and excluding more conceptual projects such as FLECH-iPower or SENSIBLE, we found that richer discussions on the market models could be found on those projects that also addressed other market models apart from the M2 case, namely CoordiNet, FlexHub EU-SysFlex, USEF, and even INTERRFACE despite being such a recent initiative.

From the projects analysed, CoordiNet and INTERRFACE specifically tackle, as a main objective, TSO-DSO coordination challenges. In these projects, the demonstrators explore the different coordination schemes. They are, however, under development and there are not yet available final and conclusive results.

INTERRFACE focused the coordination challenges' discussion on two of the main services offered on flexibility markets, CM and balancing, considering a triad of options: separating TSO and DSO congestion management MOL, combining both of them or combining CM with the balancing MOL for TSOs (creating a single flexibility market for DSO and TSO). The first two options can be framed under a M2/3 market model while the combination of both CM and balancing is better described by M4. Furthermore, the combination of different MOL is also discussed, with the possibility for fully integrating both lists or only overlapping them to a certain extent (leaving some bids exclusive for one or the other system operator). In truth, the authors build upon the proposed coordination schemes by ENTSO-E and EDSO at [71] depicted in Figure 17, but try to understand which option should be preferred and also which level of integration is the most adequate. Although providing a more descriptive analysis of the several options, and not arguing at this early stage of the project which could be considered more or less suited, the authors seem to prefer options where both CM MOL are fully integrated, at least when CM and balancing are separated (see Figure 26) by stating that "*Since DSO/TSO coordination is highly necessary irrespective of the chosen market model, it seems that all the efforts in constructing the coordination pay off better when the effort is made once to construct the fully-integrated CM market (market option 2B) compared to the situation that coordination between market platforms to avoid interaction is done before buying each bid separately (market option 1A). Besides, market option 2B facilitates participation of FSP in flexibility provision and has higher liquidity because of providing a single entry gate for CM*" [42].

Regarding Coordinet, being it a project that follows the course of the Smartnet project, it is made very clear that, in order to have a successful definition of the characteristics of the market model to be designed, there are a set of fundamental questions that must be addressed from the beginning, outlining through this how the coordination scheme should be. As explored in the [82], it is essential to design the coordination scheme by answering questions such as: which SO needs are being addressed, which stakeholders will buy the flexibility, how many markets are being considered, or if the TSO can or not have access to the DER flexibility. These important, and preliminary, questions form a basis that helped to define the several characteristics used in Chapter 03, for the establishment of the five market models (M1 to M5), and consequently allowing the classification of which market models were explored in the analysed R&D initiatives through this deliverable.

In some pilots there is some kind of integration of the LFM with the wholesale markets. For example, in GOPACS (ETPA[2]) the LFM is integrated with the intraday (ID) market, and in this case the commercial participation of the BRPs is also allowed in addition to TSO and DSO [15]. ID trading is combined with AASS and for the same offer it can be bought either by a BRP or by a SO (TSO or DSO). Other example of a different coordination with wholesale markets is IREMEL (for the MIBEL market), where the participation of DER in the wholesale energy markets (day ahead and intraday) for the provision of commercial flexibility for BRP is allowed. DSO prequalify and establish limits to the activation of these flexibility offers according to the potential violation of their grid constraints, and when needed, make use first of this local flexibility to solve their grid constraints.

With respect to the resources participating in the markets, one of the general objectives is to enable the participation of small units and demand-side resources connected at distribution networks. To make this possible, the role of AGR is key in most of the projects. However, locational constraints are frequently imposed to aggregation to guarantee that the impact on the grid of aggregated resources can properly be assessed. For example, aggregation is often limited for resources located within the same pre-defined geographical areas, delimited by DSO.

Regarding the market structure, most of the projects implement/consider a one-sided market in which the DSO or TSO are the only buyers of the flexibility needs. Nevertheless, projects like USEF highlight the possibility for BRP to interact and acquire flexibility on those markets, serving as an intermediary between markets and FSP. Many of the market platforms are either based on a continuous trading with pay-as-bid market clearing or on a periodic closed-gate auction with pay-as-clear market clearing.

With respect to the services traded, the projects mainly focus on congestion management and voltage control, including both capacity and energy products. Few projects test system restoration services, specifically islanding operation. The timeframe of procurement varies from the long-term to the short-term.

An attempt to correlate the different services and specific market models did not reveal any specific connection which in itself is an important conclusion. We can argue that, at least for the identified services, namely CM, voltage control and service restoration services, the choice of the market model does not seem to limit the possibility to transact those services. We could hypothesize that some services could be better suited to be transacted on specific market models but, at least for the three types of services addressed, that does not seem to be the case. Product definition also appears to be more dependent on other factors such as the market's timescale rather than the market coordination model. Naturally, if a product is designed to be procured by both TSO and DSO rather than by one of them in particular, that must have an impact on its structure (e.g. for TSO, the definition of a minimum capacity for the resource(s) providing a service appears to be more critical than for DSO).

By scrutinizing the information provided on how each service was to be converted into a product, tradable on a flexibility market, we were able to summarize the most common characteristics listed on each project reviewed. An important note must be made on the nomenclature used on most of these projects and the one adopted in this review. Many of the information acquired for product definition came from the structure of the bids that was defined on those projects. Those bids could be either submitted by the flexibility requester or by the supplier, depending on the architecture considered. In our case, we define a product as an adaptation of a service to a concrete market structure, addressing as much as possible the information that is relevant for either party. This means that the information summarized on Table 45-Table 47 came in some cases from bids that are

[2] https://etpa.nl/en/

submitted by FSP and in other cases by bids designed by DSO or BRP when requesting flexibility. A product is therefore viewed as an overlapping of those two different types of bids.

We also identified that CM is most frequently traded as a capacity product rather than an energy product. Reserve times vary between short-term (few hours to day-ahead) and long-term (weeks to months or even years). For longer reservation times, either implicit or explicitly, the need for a comparison between capacity reservation and grid reinforcement is usually highlighted. On the other hand, the complexity of the products' structure does not seem to be related with reservation time. We found highly parametrizable products for short-term and for long-term market structures, but also very simple, up- and down-regulation bids with as little information as quantity and timeframe of activation. Looking at NODES initiative, it draws attention to the possibility of defining non-standardised market products, based on parameters (some mandatory, others customizable), presenting itself as an alternative to many of the other projects, which generally establish standardised products. In fact, initiatives that were oriented at providing guidelines for market structure definition usually presented more standardised products (such as FLECH-iPower for example) with a high degree of parametrization but not, to our knowledge extent, dependent on the type of technology providing flexibility. We identified, with little surprise, that the most frequently addressed parameters on products' definition were related with temporal, geographical and technical constraints (such as ramp times or minimum bid sizes) as well as bid sizes and estimated/maximum prices per activation. On the other hand, only on some of the projects clearly identified how rebound behaviour should be addressed.

Voltage control is also addressed in many initiatives, either through active or reactive power services. Active power services usually share many of the parameters listed for CM products, also being considered for different time scales. Reactive power products are only considered for activation and no mention to reservation products was found. The products designed for this service are usually less complex, focused on essential parameters such as a delivery horizon divided into fixed step blocks of, e.g. 15 minutes, for which a reactive power setpoint is provided. Other temporal constraints may also be conveyed, specifically the full activation time.

As for Service Restoration, the projects often did not provide a thoroughly description of the possible product structure. The only relevant information found was directed at one of the services addressing this need, Isolated/Islanded Operation (IO) but, since this service can be seen as an extension or superposition of other services, which include CM and voltage control along with frequency control, product definition is assumed to follow the same tendencies presented for those other services.

The analysed projects show that there are many different design elements for flexibility markets and different pilots and projects has followed different approaches. Moreover, the work conducted showed that, in order to determine the key aspects that better adapts to the DSO flexibility, an in-depth analysis is needed, considering aspects like the network and resources characteristics, the market models integration with the TSO, and others.

4. Distribution network management and control systems for enabling new services

This section presents the analysis related to the technological attributes of the initiatives and projects reviewed in this deliverable, focusing in particular on the requirements of the distribution management systems to enable DSO flexibility services. The analysis covers the identification and characterization of the tools to integrate the use of the existing flexibility into the DSO operation process, the proposed network management approaches and control systems, and the characteristics of the flexible DER and the interfaces for their control and monitoring.

4.1 Methodology

The methodology used for this section consisted of the following steps:

1. Use the selected projects and initiatives agreed with task T1.2 partners. Select those with relevant information for the current section.
2. General analysis of the solutions proposed in terms of network management and control architecture.
3. Identification of those tools that can be considered as enablers for the efficient flexibility usage in DSO advanced distribution management systems, namely (see sections below):
    a. State estimation for the distribution network;
    b. Power flow for the distribution network;
    c. Optimal power flow for the distribution network;
    d. Load forecast, for short, medium and long-term;
    e. Generation forecast, for short, medium and long-term;
    f. Aggregation tools;
    g. Bids structure and submission functionalities;
    h. Platform for visibility of flexibility offers;
    i. Traffic Light Concept (TLC) functionalities.
4. Analysis of the tools and their integration into market and technical platforms for the provision of the corresponding services.
5. Analysis of DSO monitoring and control technologies for enabling services, interfaces with DER, and potential flexible DER for providing the services.
6. Discussion of the results.

4.2 Projects considered

From the initial list of projects and initiatives analysed in this deliverable, those corresponding to platforms already in operation, mainly the commercial ones, had less technical information available in relation to the control architecture and interfaces with DER. Therefore, in addition to the projects of Table 43 of section 3.2.29, also discarded due to the reasons already exposed in that section, the projects collected in Table 48 were also discarded for the monitoring and control systems analysis due to this verified lack of relevant information.

Table 48: Projects discarded for the monitoring and control systems analysis

Projects not included	Observation
Architecture of Tools for Load Scenarios (ATLAS)	The project was primarily oriented for the development of load forecasting tools for the DSO, not for defining market models.
Enera	Few technical documentation on System Use Cases available for consultation.
Future Network Modelling Functions	The project was not directed at defining specific market models or frameworks, but to develop new models for network planning. Few documentation is also available online.
GOPACS-IDCONS	Few technical documentation on System Use Cases available for consultation.
NODES	Few technical documentation on System Use Cases available for consultation.
Open Networks	The project does not, to our knowledge extent, clearly define a single or group of market models for DSO. Instead it provides general guidelines for DSO and their role as a neutral facilitator of markets.
Piclo (Piclo Flex)	Few technical documentation on System Use Cases available for consultation.
PlatOne	Issues on finding information - the information available at the time of the analysis was not sufficient (published deliverables, publications, etc.).
Power Potential	The project is oriented to transmission system services.

4.3 Advanced Distribution Management Systems (ADMS) for flexibility services pre-qualification, validation and verification

The main identified functionalities that DSO (or other involved parties, depending on the tool purpose) should implement to integrate the use of flexibility into the grid operation are:

a. State estimation for the distribution network;
b. Power flow for the distribution network;
c. Optimal power flow for the distribution network;
d. Load forecast, for short, medium and long-term;
e. Generation forecast, for short, medium and long-term;
f. Aggregation tools;
g. Bids structure and submission functionalities;
h. Platform for visibility of flexibility offers;
i. Traffic Light Concept (TLC) functionalities.

Forecasting tools (both for generation and for consumption), optimal power flows and network state estimators can be highlighted as essential tools for the integration and use of flexibility, through market platforms, into the DSO operation procedures. In fact, the integration of flexibility in network operation, both DSO owned or market enabled, requires the adoption of predictive management strategies, which, based on the load and generation forecast, can identify potential network restrictions and anticipate the most adequate actions to avoid the technical restrictions.

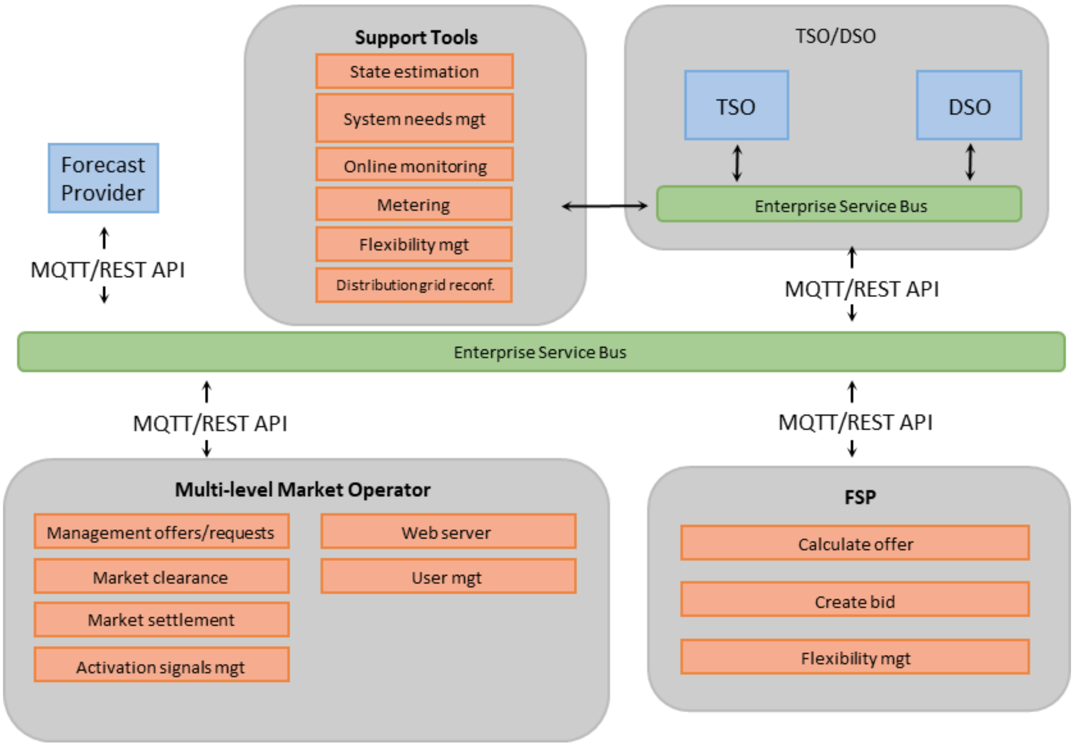


Figure 29: Organization and articulation of the system architecture (edited from CoordiNet [83])

Figure 29 (from the CoordiNet Project, [83]) is an example on how the system architecture could be organized, considering the integration of a market platform (in this case for the Multi-level Market Model), all the necessary functionalities and tools (associated to their respective providers), granting the co-existence of the system operation and planning framework with a market framework.

Figure 30 (from GOPACS Project [84]) is an example on how the flexibility platform is integrated in the distribution network overall operation, highlighting the links and data exchange among the various elements represented.

As can be seen from Figure 29 and Figure 30, the flexibility market platforms, already analysed in section 3 of this document, are part of a system where many functionalities related to the DSO operation are necessary. In order to effectively integrate flexibility in network operation, both predictive and real-time and control tools are required. For enabling preventive mode, combining power flow and load and generation forecasting, allows to identify possible technical restrictions. For defining optimal control, traditional OPF needs to be updated to incorporate multi-temporal restrictions associated to DER resources (e.g. BES SOC, load control restrictions), while considering load and generation forecasting. In real-time, improved monitoring is required at the different voltage levels, in order to further detect technical problems and assess the correct activation of flexible resources. Adapted state estimation tools have been proposed for dealing with limited real-time information, both at LV and MV networks, using pseudo-measurements and historical data.

As already mentioned in the methodology, the analysis of the technical tools for the integration of flexibility into the DSO operation has been organized in two main parts:

1) DSO network operation tools with flexibility, and

2) DSO network planning tools with flexibility – this with the indication, when possible, of the trade-off between using flexibility and grid reinforcement.

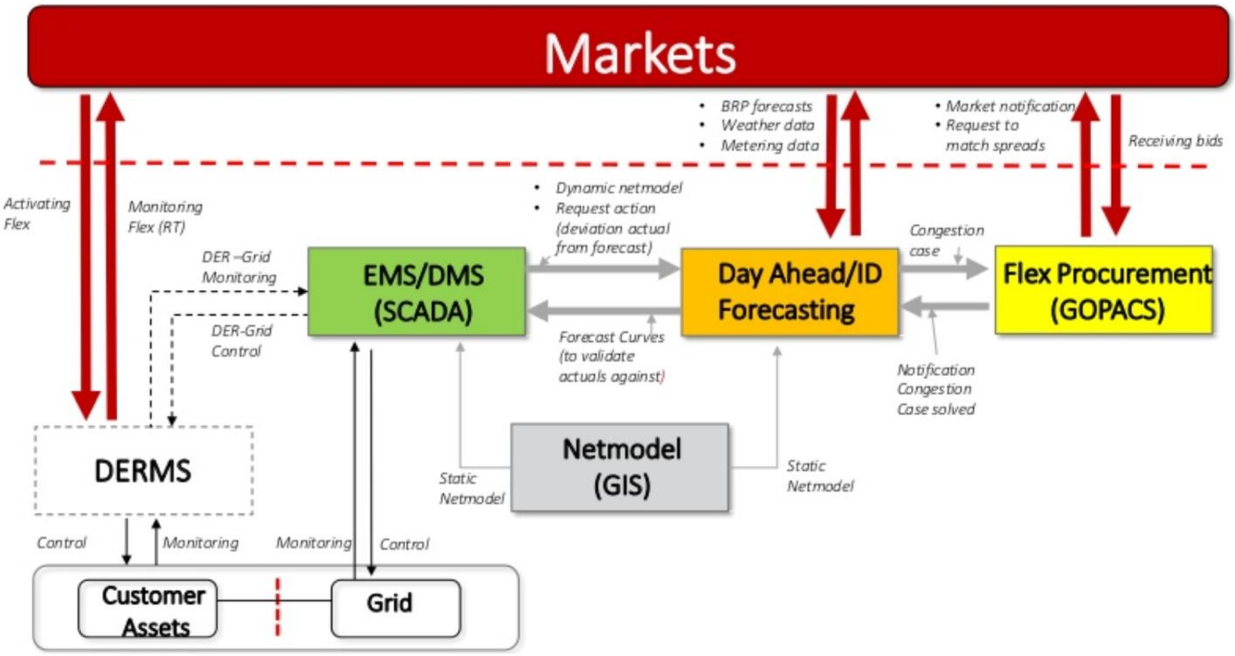


Figure 30: Interactions of the network architecture including a market platform (edited from [84])

4.3.1 DSO network operation tools with flexibility

The **DSO network operation** refers to the continuous operation of the distribution network. This set of tasks, under the responsibility of the DSO, consists in the control, management, and supervision of the network for, assuring operation within technical voltage and current limits. This operation must be performed in a safe manner guaranteeing the quality of the supply and aiming to reduce losses and costs. In addition, the DSO is also responsible for managing and solving problems related to assets and to failures and faults that occur in the network.

To solve these issues, DSO must decide the best approaches in terms of costs, quality, etc., from their available alternatives, that is, for the short-term, using their own grid assets (such as OLTC or capacitor banks) and network reconfiguration. However, it could also benefit from the integration of DER flexibility, though an adequate technical and market framework.

As remarked in [85], system flexibility services are services delivered by market parties and procured by DSO to maximise the security of supply and the quality of service in the most efficient way. Although the focus is very often voltage control and congestion management services, other services already identified in this deliverable in section 2.3 should also be considered. Some of the benefits of using flexibility for the grid operation are ([85]):

- Optimised used of the distribution network capacity, minimizing future investments and technical losses
- Improve power quality (e.g operate within adequate voltage limits, reduce voltage sags)
- Improve reliability and resilience, avoiding outages or minimizing outage duration, considering self-healing strategies (e.g. network islanding, network reconfiguration)
- Increased distributed generation hosting capacity.

Considering this, and the increasing presence of DER into the system, DSO must consider DER in the system operation processes, either to cope with problems due to the volatility and unpredictability of DER, or to take advantage from the benefits of the flexibility that DER can provide.

4.3.2 DSO network planning tools with flexibility

The objective of **DSO network planning** is to ensure the safe operation of the network in the medium and long terms, avoiding problems related to grid capacity, typically network congestions and voltage violations.

Network planning needs to consider the potential increase in distributed generation, consumption (active loads), energy storage, and prosumers. As seen in section 4.3.1 for the grid operation, network planning process has also to consider both, the problems that DER integration can generate to the grid operation, and at the same time could benefit from the flexibility DER can provide to the system, when efficiently integrated, to contribute to a safe grid operation with the required quality of supply.

The long-term operation planning becomes a trade-off that must balance the costs and benefits of grid reinforcements with the cost and benefits of the flexibility usage, subject to the predictability and reliability of the forecasted flexibility. These aspects can strongly depend on the areas considered (for example local or regional), that may determine the high or lower presence of DER and the physical characteristics of the network, among other relevant aspects.

4.3.3 Results of the analysis

Table 49 summarises the tools and functionalities identified in the projects reviewed. Those tools required for a correct integration and activation of the flexibility for the provision of system services have been highlighted in blue, while those tools more devoted to the interaction with the flexibility markets and with the flexibility products have been highlighted in green.

The tools and functionalities have been analysed according to the temporal domain of the services provided by the type of flexibility they are linked to (operation or planning), the entities responsible or capable of making it available and the equipment that is considered necessary for providing the data used by the tools and functionalities (such as RTUs, PMUs, etc.).

For each tool/functionality included, a list of the projects associated is provided at the right part of the table. Given the high number of projects reviewed and their very distinct nature, the description of these tools and functionalities varies in quality and abundance. Some projects address the importance and description of these tools/functionalities more than others, leading us to classify the available information as follows:

- Information about the tools/functionality is provided objectively in the project documentation
- Information about the tools/functionality is not objectively or explicitly provided in the project documentation but can be inferred
- Information about the tool/functionality is not provided nor it can be inferred.

It was decided to include in the last column only those projects whose information falls in the first two bullets, differencing the projects with objective information about a functionality/tool by highlighting them in **bold**. This distinction allows the reader to pinpoint where, in the literature reviewed, further information can be found about the subject at hand.

The following paragraphs organise, and briefly describe and discuss the main tools/functionalities identified and collected in Table 49.

- **Tools for identifying the need for flexibility and its selection**

State estimation (SE) and **Power Flow** (PF) or **Optimal Power Flow** (OPF) calculations are the main tools identified in the projects reviewed as being essential for identifying the flexibility needs of DSO. SE helps the DSO in identifying possible voltage violations at the grid's buses and PF help in identifying possible congestions in the branches power flows. When performed in advance, PF and OPF are naturally dependent on **demand** and **generation forecasts**. These forecasts are basic tools for the distribution grid observability, which combined with PF or OPF, allow to identify, in advance, voltage and congestion problems and help in the solving decision process: either recur to network reinforcements (for network planning) or DSO assets or grid reconfiguration, or recur to third parties' flexibility.

From the retrieved information it could be concluded that SE, PF and OPF are generally considered as being performed by the DSO. To this, DSO must have Supervisory Control and Data Acquisition (SCADA), Automatic Meter Reading (AMR) and Phasor Measurement Units' (PMUs) measurements as well as geographical data from the Geographic Information System (GIS). The advantage of a centralized control framework for integrating these tools and for data storage is the possibility to enlarge the scope of network observability, allowing for optimization algorithms such as the ones used in OPF for example, to consider different network areas that are the responsibility of the same DSO. On the other hand, there is a trend to consider central data hub platforms, that concentrate all metering and flexibility related data to enable mobilization of services [86]). This platform could be further extended to TSO, envisaging better DSO-TSO coordination mechanisms. Benefits can include efficiency increase in the data management process (quality, transparency, economies of scale), less barriers for new agents and data users (retailers and energy services providers), easier data sharing with third parties, and interoperability issues among data platforms.

If this first set of tools presented can help DSO in identifying an eventual need for flexibility, the remaining tools/functionalities highlighted are viewed has complementary to flexibility usage once the decision to use flexibility has already been identified. In other words, they are not necessary or fundamental for flexibility usage but can help the different agents, DSO and AGR or FSP, to transact flexibility as a service. These include tools for promoting aggregation, for defining flexibility as market products, for providing visibility over available flexibility offers from FSP, or even to assess the grid status with the **traffic light concept** (**TLC,** see below)**,** to define privileged frameworks for DSO to fulfil their flexibility needs.

- **Tools for facilitating and/or enhancing flexibility as a service**

When considering small-scale DER flexibility provision, a key aspect in all projects, initiatives and papers reviewed, is that, to achieve technical and foremost economic viability, aggregation of those resources must be considered. Most projects introduce the role of the AGR as the entity responsible for communicating and even controlling those DER in many cases, on behalf of its clients i.e., the players that will effectively provide the flexibility transacted on the market.

Some projects such as SENSIBLE develop on top of this concept and propose that the market platforms should consider **specific tools designed for AGR,** such as an optimization tool with the objective to minimise the operation cost of their flexibility portfolio (composed of batteries, thermal storage and/or curtailable renewables). Furthermore, the same project also considers an interface for DER that are not represented by AGR. Specifically, the project highlights a distributed agent-based solution developed for battery storage systems connected in a communicating network which aims at several objectives such as: "1) savings in electric infrastructures, 2) improve the integration of renewable energy sources to the electric grid, 3) increase economic user's benefits, 4) optimize the usage of batteries and 5) solve the problems of DSO caused by distributed in-feed" [87].

Although already addressed throughout all section 3 as a fundamental piece in market designing, **flexibility bids** can also be understood as tools with specific formats and features that help DSO to fulfil their needs in an effective way. While section 3 presented the structure proposed for the bids, here the focus is their adequacy to the service provided and resources providing it. By adequacy we mean that the bid structure must be suited to the service(s) it addresses, allowing for flexibility requests to convey all necessary information (such as power/energy quantities and period for flexibility provision) and possible restrictions (such as ramping times or acceptance limits for divergencies from scheduled provisions). For that reason, many projects and initiatives dedicate large sections of their documentation to define the structure of those bids. Through our analysis we identified some projects that defined simple generic bid structures while others defined structures that are very specific with a high degree of parametrization.

For example, the De-Flex-Market concept [7] proposes a framework for specifying restriction requirements at interconnection points with the local distribution grid, characterized by high geographical, temporal and restriction level granularity. A FSP or an AGR can accept these bids by managing their portfolio at the specified point in time, limiting the power exchanges at the connection point according to the restriction requirement.

The other initiatives listed at Table 49 (exception made to Interflex) propose more standardised products that can be highly parametrizable through several geographical, temporal, pricing and service-specific settings. Although embedded in a static architecture, the bids for requiring these products have what the projects consider as an adequate level of plasticity for DSO to convey their flexibility needs. In contrast to this, the Interflex project proposes a rather simple structure for what the authors call a "flexibility request". Aimed at congestion management or for islanding operation mode, the bids proposed are simple up- or down-regulation power blocks for fixed period time slots. The simplicity of the bids, in this case, is related to how a flexibility request is performed. In one of the demos of the project, Strijp-S (Eindhoven) living-lab, a grid management system was equipped with a decision-making algorithm that by forecasting periods of congestion in the grid would automatically calculate the necessary up- or down-regulation needed to manage it and subsequently formulate and submit a bid to the market [88]. In this case a simple bid structure was adopted so that requests could be automatically formulated by an algorithm. The adequacy of a bid seems therefore to depend on several factors, namely the service for which it is designed, which has a direct impact on the number and granularity of settings, as well as on its integration with other tools like optimization algorithms.

The adoption of the **TLC** contemplates a well-known and privileged framework for DSO to acquire their flexibility needs. Green light indicates that markets are needed only for commercial flexibility negotiation (for the BRP to solve their commercial imbalances). Flexibility markets are expected to function under the yellow light or phase, when the grid operation requires flexibility support. Finally, emergency regulated mechanisms (not market-based) for flexibility activation are left for the red phase. It is therefore a recurring framework in many of the initiatives reviewed and can be classified as a tool for assessing the grid status and needs, and for unlocking privileged access to flexibility by DSO.

Finally, the consideration of a **platform for visibility of flexibility offers** on many projects and initiatives highlights the utility it can have for DSO when procuring flexibility. Such utility ranges from broadening the visibility of DSO over available flexibility providers, their characteristics, geographical context and willingness, to providing additional tools such as some of the ones listed above. It is frequently highlighted how these platforms can more easily open the market to small FSP, frequently through the mediation of an AGR.

From the analysis carried out in this section, some points regarding the technical and functional needs that enable the establishing of flexibility markets (considering the presence of different participants such as DSO, DER, AGR, etc.) can be highlighted:

- The AGR (or platform with aggregation support) needs computational tools that consider the resources to be used in the aggregated way, considering the points of operation and location of the resources, and the optimization of resource usage schedules. Communication must be bidirectional between the AGR and the DER involved.
- There is a need for generation and demand forecasts, and this may be a service or functionality provided by the AGR, conducted by the DSO itself, or by other participants who have the capabilities and the access to the data needed (historical, weather, etc.). In case the DSO is not the provider of the forecasts, this service becomes part of the flexibility market (as a non-grid service).
- Typical functionalities of the distribution management system (DMS) should be used so that, along with the running of the market, the operation and planning of the distribution network can be carried out in harmony. For this, the DSO has the responsibility of employing (at least) state estimators, load-flow calculation, network topology models, and OPF, in the case of dispatches under its responsibility. This is firmly aligned with what is today widely considered as the functional requirements for boosting distribution networks with intelligent characteristics (namely advanced communication and computing requirements).

Table 49: Tools and functionalities to unlock or enhance flexibility's usage potential by DSO, explored in the projects reviewed

Tool/functionality		Network operation tools with flexibility	Network planning tools with flexibility	Description	Performed by	Uses data from	**Identified**/implicit on the following pilots/projects
State Estimation		•		Estimates voltage magnitude in the different nodes of MV and LV network, based on real-time information, historical data and load allocation for pseudo-measurement generation.	DSO (DMS or MV/LV controllers)	SCADA, RTUs, GIS, AMR/AMI, Smart meters, PMUs	**CoordiNet**, FlexHub EU-Sysflex, INTERRFACE, **InteGrid**
Power Flow		•	•	Numerical analysis of the flow of electric power in an interconnected system operating in steady-state conditions, based on network topology and system equations.	DSO, Platforms	SCADA, GIS	CoordiNet, **Ecogrid 2.0,** Flex-DLM, INTERRFACE
Optimal Power Flow		•		Tool for optimal network operation (economic and technical), defining control strategy for network assets and flexibility mobilization. A multi-temporal approach is proposed to address predictive management strategies)	DSO	SCADA, RTUs, GIS, AMR/AMI, Smart meters, PMUs, Generation and Demand bids, Regulation (tariffs)	**FLECH iPower,** **Flex-DLM** **SENSIBLE** **InteGrid**
Load Forecast	Short-term (e.g.: 1 or more hours – 5 or 15min steps)	•		Forecasts of the demand for power or energy on the short-term timescale.	DSO, Forecast Providers, Prosumers, Platforms, AGR	DSO historical data and measurements, weather information, load owner forecast submission	**CoordiNet**, FlexHub EU-Sysflex, FLEXICIENCY, **Interflex**, **INTERRFACE** **SENSIBLE**
	Medium-term (e.g.: few days – 15min to 1h steps)		•	Forecasts of the demand for power or energy on the medium-term timescale.			**CoordiNet**, **Ecogrid 2.0**, FlexHub EU-Sysflex, FLEXICIENCY, **Interflex**, **INTERRFACE,** **SENSIBLE**
	Long-term (e.g. weeks, months to year – 1 h steps)		•	Forecasts of the demand for power or energy on the long-term timescale.			**CoordiNet**, Ecogrid 2.0, FLECH-iPower, FlexHub EU-Sysflex, FLEXICIENCY, Interflex, **INTERRFACE**

Generation Forecast	Short-term (e.g.: 1 or more hours – 5 or 15min steps)	•		Forecast the power or energy of variable resources' generation in the short-term time scale.	DSO, Forecast Providers, Prosumers, Platforms, AGR	DSO historical data and measurements, weather information, generator owner forecast submission	**CoordiNet**, FlexHub EU-Sysflex, FLEXICIENCY, **INTERRFACE,** SENSIBLE
	Medium-term (e.g.: few days – 15min to 1h steps)		•	Forecast the power or energy of variable resources' generation in the medium-term timescale			**CoordiNet**, FlexHub EU-Sysflex, FLEXICIENCY, **INTERRFACE**, **SENSIBLE**
	Long-term (e.g. weeks, months to year – 1 h steps)		•	Forecast the power or energy of variable resources' generation in the long-term timescale			**CoordiNet**, FlexHub EU-Sysflex, FLECH-iPower, FLEXICIENCY, **INTERRFACE**
Aggregation tools (Interface)		•	•	Tools to interface the link access of AGR to the market platform. E.g.: API	Platforms	AGR	EMPOWER H2020 (SESP Aggregator) **SENSIBLE**
Adequacy of parametrization settings available for bids submission		•	•	Platform/DSO mechanisms related to managing the Order Book of DER, AGR and FSP submitted offers.	Platforms, DSO (DMS)	All market participants: • Loads, • Generators, • AGR, • Operators etc.	**CoordiNet,** **De-Flex-Market**, **Flex-DLM,** **FLEXICIENCY**, INTERRFACE, **Interflex**, **Piclo (Piclo Flex),** **USEF**
Traffic Light Concept		•		Implementation of operation mechanisms linked to the TLC.	DSO, Platforms	DSO network data, SCADA, RTUs, GIS, AMR/AMI, Smart meters, PMUs	**De-Flex-Market**, **Flex-DLM,** **InteGrid,** USEF
Platform for visibility of flexibility offers (e.g. graphical)		•	•	Platform for visualizing and identifying published flexibility needs, with location zones delimitation	Platforms	DSO network data, SCADA, RTUs, GIS, AMR/AMI, Smart meters, PMUs	**FLEXICIENCY** FlexMart, **Piclo (Piclo Flex)** **InteGrid**

4.4 DSO monitoring and control technologies for flexibility and DER interface

The wide range of technologies that are available and employed as DER implicates a diversity of monitoring possibilities to be managed by the network operators that supervise the distribution grid. In the same way, several control methods exist (such as, direct control by the DSO or indirect control through AGR), as well as different types of flexibility activation (such as manual or automatic).

The SCADA system is naturally present in all the architectures used by the DSO and is sometimes being referred in this case as D-SCADA (Distribution SCADA). This supervisory system is employed for the operation of the distribution network, and DER systems must have interfaces of control and monitoring consistent with the SCADA requirements. For instance, to be integrated in the SCADA system, the DER controller must be able to communicate with the remote terminal units (RTUs), responsible for establishing an interface between the grid elements and the DSO. Through these remote interfaces, voltages and direction of power flows are monitored, and the control of the DER is possible (for example the sending of setpoints). DER communication interface must be compatible with the DSO standards, like the more commonly used IEC 60870 and IEC 61850. It is to be noted that IEC 61850 is widely employed in transmission systems, and now is solidly advancing to the distribution.

In conjunction with the SCADA, distribution management system (DMS) is also present in distribution systems, aggregating the applications, tools, and functionalities, responsible for monitoring and controlling the distribution network (e.g. OPF, service restoration, volt/var optimization and control, etc.). Although these traditional DMS/SCADA systems support the integration of DER in the distribution system, the increasing penetration of distributed resources encourages DSO to adopt Advanced Distribution Management Systems (ADMS) which are an evolution of the DMS. ADMS have more advanced functionalities integrated, as for example smarter outage management, self-healing strategies, and intelligent/sophisticated management systems oriented to control and supervise a massive number of DER.

Figure 31, from [89], is an example of grid architecture considering the communications links and the interactions between the system and market participants, in a scenario with integration of DER. As can be seen, communication interfaces must be in place between the DSO and the AGR, and between the AGR, the DER controllers and the consumers/prosumers, that participate in the market.

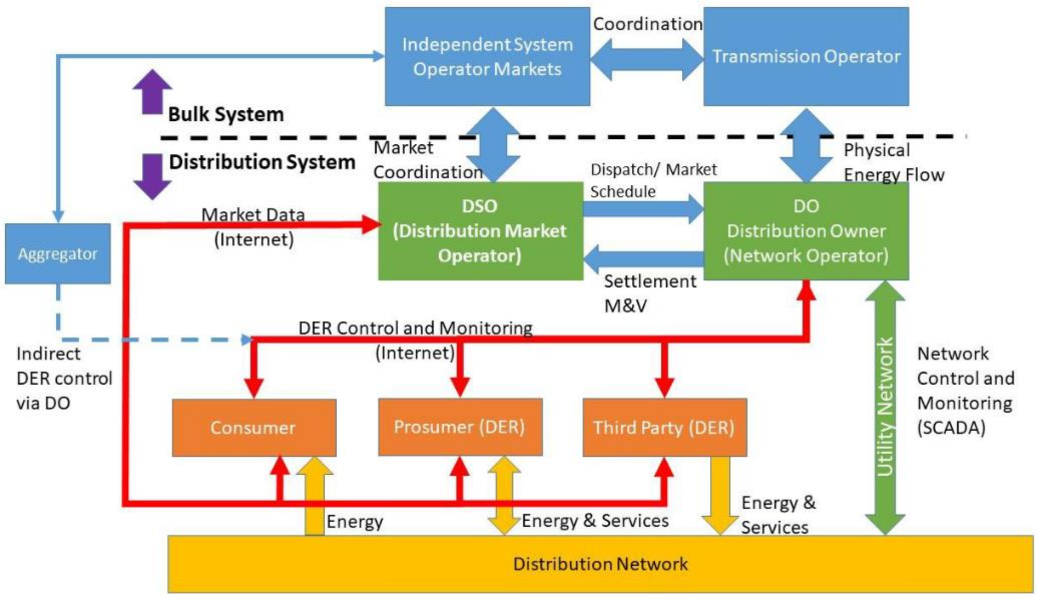


Figure 31: Representation of grid architecture, showing the communication links and interactions among the participants [89].

The DSO ADMS uses real-time information, collected from the network sensors and DER controllers (namely voltage and power flow measurements, load and generation, and physical status of grid equipment), but can also use commercial information from participants in the network (for example forecasts). This allows DSO to perform the calculations regarding the state estimation and the load-flow.

Regarding the control of the DER and management of their activation, the projects analysed consider this being a responsibility of the AGR once the market clearing procedure is done and the results published on the platform. Another possibility, although not verified by the projects investigated, consider the DER activation directly, through sending setpoints by the DSO. For example, the sending of setpoints by the DSO to the DER, for voltage control, requires an interface between the DER (or the intermediary, like the AGR) to the ADMS. Once there are reactive power bids available for the DSO need (with respective per-hour reactive power and reactive energy prices), in the period that the DSO requires the activation of those bids for voltage control, the ADMS will communicate activation commands to the DER. The same happens in the case of active power control, considering the available active power bids for the DSO.

4.4.1 Results of the analysis

It was not possible to match, for each service, which were the control and monitoring requirements proposed in each initiative since: 1) this information is not always available, being very often retrieved or even inferred from different deliverables and resources linked to the projects and 2) when it is available, it is tightly linked to the demonstrators and their specificities rather than being provided per individual services of the demonstrators or as general guidelines that could be extrapolated to other future implementations. The summary of the DSO monitoring and control requirements identified across the reviewed projects can be found in Annex III – , not being included in the documents' main body given its length.

4.4.1.1 Results discussion

- **Regarding monitoring requirements**

The sources of information of the projects analysed presented very scattered details regarding the technical aspects of the monitoring and control schemes and architectures. Even so, some common and relevant aspects were identified.

The use of smart meters is becoming an important requirement. Smart meters are always, explicitly or implicitly addressed in the projects reviewed, for their capability to provide consumption data close to real-time with a high sampling rate, as well as voltage magnitude (e.g. InteGrid and SENSIBLE). The granularity of data adopted is usually compatible with regulatory requirements, ranging from 5 and 15 minutes.

Although not frequently specified among the initiatives reviewed, the CoordiNet project recommends the use of IEC 61850 as a Communication Protocol since it rather new in distribution networks, but it is expected to increase its presence given that these networks are likely to follow an evolution similar to the transmission system one, where the communication standards and data models of the IEC 61850 standard are widely employed.

Regarding monitoring of other types of DER, such as storage units and PV panels, the requisites are similar to the ones presented for smart grids. At the Spanish demo of FLEXICIENCY, measurements of active and reactive power were obtained from on-site devices that included photovoltaic and wind converters and inverters and grid analysers, while SoC measurements came from battery management controllers. These measurements were updated every 15 minutes. At the Strijp-S living-lab demo of Interflex, measurement equipment was installed in every MV feeder, MV/LV transformer and outgoing LV feeder. Measurements included 15-minute average root mean squared values of current, voltage, active and reactive power, bidirectional energy throughput and total harmonic distortion which were transmitted automatically to a central database. Additionally, synchronized measurement devices with a sampling rate of over 100kHz were added to the system, measuring phase currents and voltages. At INTERRFACE, the authors comment on the granularity of metering data, stating that it must depend on the specific needs of the market products designed, but metering infrastructures should be able to provide close to real-time and/or daily and monthly metering data per delivery point should be set in place.

In conclusion, the high penetration of DER, especially variable RES (VRES), required improved monitoring of distribution network. In addition to smart meters, that are key for LV network observability, improving MV network through a combination of both monitoring equipment and state estimation algorithms is also important. This, on the other hand, entails the need of communication and data exchange links with more critical requirements, which requires an important evolution in the distribution network compared to what is traditionally used. In some initiatives, as for example in the Enera project, the consumers that are willing to register for participating in the showcase, receive a new meter compliant with the actual monitoring requirements [90].

Some projects point to the necessity for storing consumption data centrally. EcoGrid 2.0 proposed a DataHub accessible to DSO and AGR, stored in an aggregated format to reduce data-privacy issues. Likely, the level of aggregation is per grid node, although this is only assumed. EMPOWER H2020 envisages a "national metering data-hub" for storing consumer metrics, though it seems that it would only be accessible by the DSO. INTERRFACE goes a little further and proposes the development of a blockchain-supported flexibility register with a metering data module that stores close to real-time metering and resource availability data. The application of blockchain technology in this context guarantees data privacy for consumers sharing their metrics. These findings seem to point in two trends: one is the implementation of mechanisms for the accessibility of consumers' data by DSO (and perhaps by other agents such as AGR) and the other is that such access is made complying with data privacy directives.

Envisaging an increased willingness of consumers, prosumers and Distributed Generation (DG) at the LV level to participate in the flexibility markets, the growing number of nodes with active participation in the functioning of the system will cause a significant increment of data and information produced. This issue is growing in importance, and preliminary treatment of a large amount of data will become a necessity. The DSO already addresses this by employing the solution of data concentrators at the substation level, as for example mentioned in the Spanish BUC of the CoordiNet project, [91] and [92].

In general, DSO seems to maintain the responsibility for collecting data on its own network and controls the distribution of this data from consumers to retailers (for example, for billing functions) and to other third-party entities. The DSO must also ensure the controllability and observability of its network, so that it can guarantee a safe, reliable, quality and economical operation of the grid it operates. Thus, the network switching and breaker devices, existing reactive power support elements (such as capacitor banks and compensators), together with the voltage and current meters of the nodes, transformers and lines, must have communication links with the DSO's control and management system, and the entire communications infrastructure must be adequate, and in harmony with the specificities related to the flexibility market participants.

With the presence of the platforms and the markets mechanisms, the DSO must exchange data and information with these platforms. The forecast data (generation, demand, and even weather) are used for the planning and operation tools of the DSO and serve as inputs to determine the flexibility needs. In this way, the platforms must either incorporate the forecast provision or intermediate with the forecast data providers (of the network where they are located), to support the communications and data exchanges, and to assume the commercial responsibility for providing the data to the DSO. These transactions also characterize a kind of service/product that could possibly be negotiated through the flexibility market platform.

- **Regarding control requirements**

To allow grid management oriented towards a decentralized control of DER, the dependence on smart meters and distributed control is even larger. The operationalization of using DER for flexibility can be achieved through direct control from the DSO or indirectly through the AGR.

Many of the projects reviewed decided to follow or to propose a controlling framework derived from the TLC. In general terms, flexibility is required during the yellow phase of this framework, when the DSO can procure it in the market, and DER control is the responsibility of the Consumers, AGR or FSP. Under the red phase, DSO will have direct access to the available flexibility, overtaking any market interaction, and the control can be given directly to DSO. Given the different nature of DER, not all types that can participate in the yellow phase (i.e., offering flexibility services in the market) will be able to provide a direct control in the red phase. Nonetheless, and taking the example of EcoGrid 2.0, it is possible to endow appliances such as heat pumps and electric radiators with devices that allow for their external control. In Interflex, where the TLC concept was adapted and DER also included PV, smart storage units, electric vehicles and demand-responsive controllable loads, an operational activation channel was implemented through control boxes and smart meters.

Direct control by a third-party is frequently considered more advantageous, and even more convenient for participating consumers, since they do not need to manually activate the use of flexibility, relegating to a third party the access to their flexibility capacity (under some contractual agreements to define the terms of this access) [93]. When the control is performed by the AGR or FSP (which is the considered control scheme in most of the projects and initiatives reviewed), DSO send their flexibility needs to the AGR and supervise the flexibility activation resulting from the operation of the DER. These DER had to pass the DSO prequalification tests that evaluate if the assets comply with the monitoring and control requirements defined per type of DER earlier [94]. On their side, AGR must know the characteristics and types of the DER registered in their comprised area, considering those who have an interest in participating in the local flexibility market. The AGR also need an operational control and a commercial management system, co-existing, so that all the steps necessary to take advantage of these available flexibilities can be enabled. It is possible that Distributed Energy Resources Management Systems (DERMS), are implemented in the architecture, and controllable loads are activated according to the signals that the AGR sends (following DSO flexibility selections). Again, it is reinforced that smart-meters and data concentrators must have near real-time communication features so that this control can be possible. Smart Advanced Metering Infrastructure (AMI) can also be used to send signals to residential loads, given that this AMI structure enables a bidirectional communication network at the level of smart meters and include the features of reading, monitoring and control of several local participants such as consumers, prosumers, feeders or data concentrators. The commands and setpoints that the AGR must forward to the resources are, usually, initially sent to the RTUs, and then, forwarded to the DER controller.

Closely tied to control is the communication system which is frequently presented as bidirectional and operating in real-time, between the DSO SCADA and every controllable device. Regarding the interactions between DSO and AGR it is frequently proposed the establishment of a B2B communication protocol.

Figure 32, from the Interflex project [95], shows an example of a typical architecture (focusing on the voltage control service) to integrate local DER and their controllers, linked to the remote terminal connected to the DSO management system.

Among many advances that the distribution network undergoes to become a smarter grid[3], it is clear that progress and improvements in communications and monitoring technologies are fundamental to enable the integration of DER, fostering their contribution with flexibility to the management and operation of the grid. These requirements are strictly aligned with the evolution of distribution network, such as improvements in Information and Communications Technologies (ICTs), considerable amount of data handling, ensuring proper links between producers and consumers, further supporting the market interactions. In one hand, data must be exchanged appropriately, in quantity and quality, and advances in the measurement infrastructure, with the deployment of smart meters, make this possible. On the other hand, issues such as data privacy, transparency in the use of data, and cyber security must also be considered.

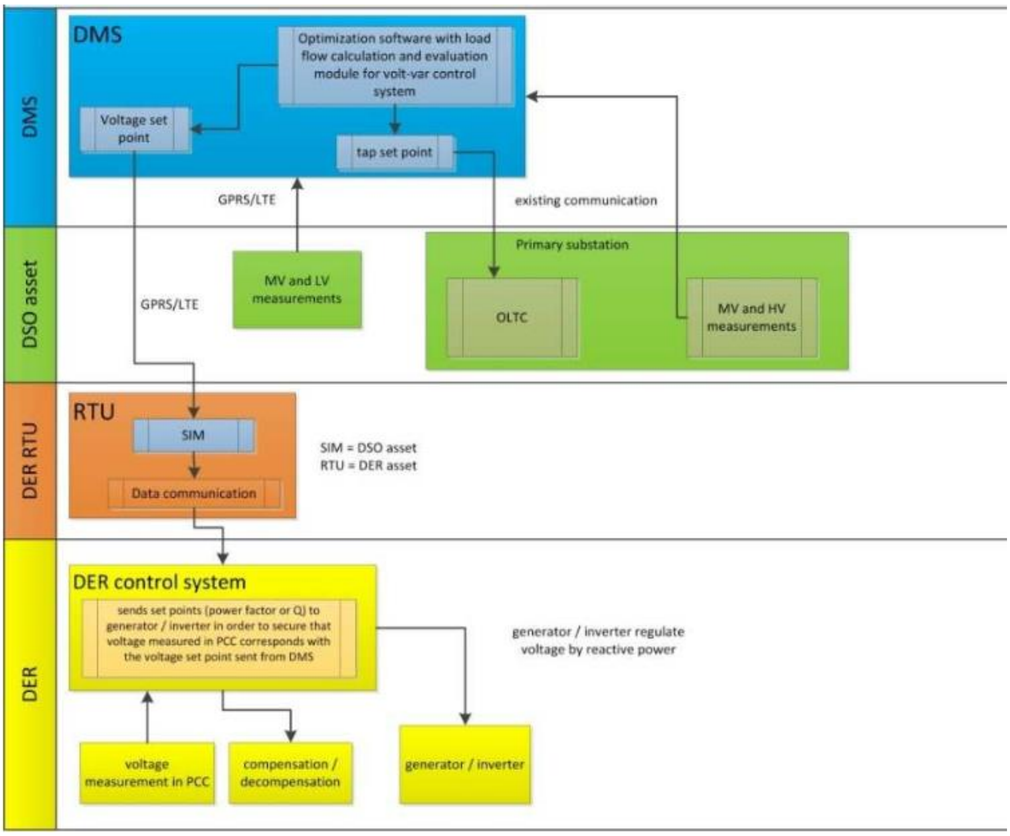


Figure 32: Block scheme of volt-var control concept, from the Interflex initiative [95].

From [97], the following are the main technical aspects to account for the integration of the DER into the distribution network system and market:

- Regarding the hardware requirements:
    - Smart meters and smart network devices;
    - ICT infrastructure;
    - Battery storage devices at the distribution level. Deployment of other DER;

[3] Considering, for example, the definitions from the reference [96], that smart grids are distribution grids with associated intelligence, capable of supporting bi-directional power flows, with advanced communications structure.

- Upgrading network assets to handle erratic and large reverse flows of power;
- (For the grid) active network devices, as automatic On-load Tap Changers (OLTCs), static synchronous compensators, and var compensators, etc.

➢ Regarding the software requirements:

- Smart meter data acquisition software;
- SCADA software.

➢ Regarding the communication protocols:

- Common interoperable standards, at both physical and ICT layers, to increase coordination among AGR, operators, consumers and prosumers.

From a perspective of costs of implementation and timescale of use, [98] presents some characteristics of the use of DER as solutions for the distribution system operation and planning, that can be summarized as follows:

➢ Resources aggregation:

- Timescale (typ.): seconds to days;
- Cost of the solution: variable, in general it could present better cost-benefit comparing to other solutions;
- Type of market: capacity and energy;
- Markets and timeframe: DA and Intraday (ID) markets (long-term (LT), medium-term (MT) and short-term (ST));

➢ Demand response:

- Timescale (typ.): seconds to minutes;
- Cost of the solution: medium, could be higher than aggregating resources;
- Type of market: capacity and energy;
- Markets and timeframe: DA and ID markets (MT and ST);

➢ Electrical vehicles:

- Timescale (typ.): minutes to hours;
- Cost of the solution: medium, could be considered as a solution with costs like Demand Response;
- Type of market: capacity and energy;
- Markets and timeframe: ID markets (MT and ST);

➢ Variable Energy Resources optimization of use:

- Timescale (typ.): minutes to days;
- Cost of the solution: variable, in general it could present better cost-benefit comparing to other solutions;
- Type of market: capacity and energy;
- Markets and timeframe: DA and ID markets (LT, MT and ST);

- Energy Storage (Flywheels, Batteries, Compressed-Air Energy Storage (CAES), pumped hydro):
  - Timescale (typ.): minutes (flywheels, batteries) up to 1 day (CAES, pumped hydro);
  - Cost of the solution: high, in general it could present better cost-benefit comparing to other solutions;
  - Type of market: capacity and energy;
  - Markets and timeframe: ID markets (MT and ST).

Characterization of DER capable of providing flexibility services

From the surveyed projects and initiatives, a matching between services addressed and the DER providing the flexibility required for providing those services was compiled in Annex IV – . No unequivocal relationship can be established since the link between which DER are providing which service is not clearly stated in the documents analysed. It is therefore advisable to take caution when analysing the listed observations in Annex IV – : the table simply matches the identified services addressed in the projects/initiatives and the identified DER responsible for providing flexibility that were either active in the demos, theoretically proposed or simply mentioned.

However, some general conclusions can still be drawn:

- For services related to voltage control, resources with faster response time, of about 1 minute or less, and with direct control possibility, would be more adequate. This is the case for example of the aggregate Electric Vehicles (EVs), residential loads and storage systems [99];
- For services related to congestion management, in addition to aggregate EVs and batteries, the use of Combined Heat and Power (CHP) is also possible, with response time of 15 minutes or less [99];
- For the long-term congestion management markets, the response time and consequent duration of the service ranges from minutes to hours, with the use of aggregated loads and generation [99];
- In general, it is preferable that the network loads and generators participating in the market are controllable (in addition to be monitorable) through smart meters, related software applications, etc. Measurement resolution should be at most of 15-minute intervals (for critical points, when possible, closer to real time 5-minute intervals should be considered). There is a need for bidirectional communications between consumer units to their concentrator, and from the concentrator to the DSO management system [83].

In what concerns the use of DER as flexibility provider for the distribution network under market mechanisms, the following table (adapted to this deliverable from [100]) summarizes what was possible to conclude from the projects reviewed, in line with what can be found in the literature.

Service	DER that can provide the service	Information exchanged
Congestion Management	RES, CHP, distributed storage, DSM	• Real time load and network voltage or fault conditions • Real time generation output & load flexibility: information from DG to the DSO • Reduced setpoint/ reduction signal, sent from the DSO to DG • DG outage programs and availabilities information from DG to the DSO
Voltage Control	PV, Wind, CHP, distributed storage, DSM, aggregated EVs	• Reactive needs, in quantity and location for the delivery • Real time load and network voltage or fault conditions • Real time generation output from DG to the DSO • V, Q, Power Factor setpoints, from the DSO to DG
Islanding Operation	DG, storage, DSM	• Real time active and reactive power flows information exchange from DER to the DSO • V, P, Q setpoints sent from the DSO to DER

Table 50: Mapping of services and DER that can provide those servces. Adapted from [100].

5. Conclusions

This Deliverable has made an in-depth revision of relevant projects, initiatives and papers presenting the common objective of fostering the access of system operators and more specifically of DSO to flexibility, mainly provided by DER.

Some of the initiatives propose new flexibility market concepts, others build upon existing market organizations. Several initiatives identify what in their opinion are the principal needs and services addressed in those markets. Some initiatives are rich in information, providing details about the market organization they consider, clearly defining which services are suited for which DSO needs and how those services should be transacted in the market in the form of products. Other are singular papers where aspects such as an algorithm for an optimal flexibility market clearing are presented, from which we could nonetheless obtain some information regarding the market context in which it could be applied. This work has made a strong effort to analyse the existing information and harmonise it under the main three concepts analysed, needs and services, markets, and technologies, as tools to integrate DER flexibility into DSO grid operation processes.

First, we identified, throughout the projects reviewed, a lack of consistency when defining DSO needs, flexibility services to address those needs and products to bridge those needs and the flexibility markets. We tried to clearly separate what are those three concepts and came to the first result of identifying the main needs and services addressed in each initiative. Furthermore, we decided to classify the services into grid and non-grid services given the type of need they addressed: for direct grid planning/operation of the grid or for decision support, respectively.

Next, we proposed a classification for different market models applied it to the reviewed initiatives. We systematized the analysis of the market models presented in the initiatives, defining what we believed to be the fundamental aspects that characterized those models. From this analysis we compiled a mapping between market models, services and products where for each service considered, we indicate in which market models it was addressed and summarized the main characteristics of the products designed for those services. An important conclusion from this section is the widespread use of the AGR concept, an entity capable of bridging FSP, consumers and producers and the flexibility market, aggregating available flexibility and potentiating its value.

In the final chapter we addressed the technological solutions proposed for integrating flexibility in grid operation. First, we identified which tools were used by DSO in the identification of problems in grid planning or operation, such as voltage violations or power flow congestions. By identifying these problems, the DSO could opt to solve them by recurring to grid reinforcement on the long-term (planning horizon), load and/or renewables curtailment on the short-term (operation horizon) or use available DER flexibility. We observed that, although all the projects reviewed naturally pinpointed the usage of available DER flexibility as the preferable option for either long-term and short-term problem management, very few would address the trade-off between the competing options. Nonetheless, the few projects that to our knowledge addressed this analysis present a significant economic benefit in using flexibility, besides arguing other inherent benefits such as the smaller environmental impact or a better public perception. Posteriorly we presented a résumé of monitoring and control technologies for flexibility and DER interface. Regarding the monitoring requirements presented in the reviewed projects, we observed that an emphasis is given to the importance of grid observability. Smart metering must become widespread in the distribution grid for consumers, prosumers and AGR. Regarding the control requirements, we found that generally the responsibility for flexibility activation does not reside with the DSO but with the AGR or directly with the FSP. The TLC framework is adopted in several projects and initiatives, safeguarding the interests of DSO primarily. Finally, a matching between services and DER capable of providing was made, attending to the technical capabilities of the DER and the requirements of the services.

6. External Documents

[1] ATLAS - Architecture of tools for load scenarios, “Project Registration”, Electricity North West Limited (ENWL) / Network Innovation Allowance (NIA), UK, 2015.

[2] ENWL, “ENWL008 - Architecture of Tools for Load Scenarios (ATLAS)”, 2018. [Online]. Available: https://www.enwl.co.uk/go-net-zero/innovation/smaller-projects/network-innovation-allowance/enwl008---architecture-of-tools-for-load-scenarios-atlas/.

[3] CoordiNet Project, “The project in brief”, 2019. Accessed: Oct. 09, 2020. [Online]. Available: https://CoordiNet-project.eu/projects/project.

[4] CoordiNet, “CoordiNet – Large scale demonstrations for TSO-DSO Cooperation”, 2019, [Online]. Available: https://pt.slideshare.net/sustenergy/CoordiNet-large-scale-demonstrations-for-tsodso-cooperatio.

[5] CoordiNet, “CoordiNet deliverables”, 2019. [Online]. Available: https://CoordiNet-project.eu/publications/deliverables.

[6] P. Faria, “Distributed Energy Resources Management 2018”, MDPI, 2020.

[7] bne, “Decentralized Flexibility Market2.0 A market based solution for organizing access to flexibility on the local distribution network”, 2016.

[8] EcoGrid 2.0, “Main Results and Findings”, Denmark, 2019.

[9] C. Heinrich, C. Zirasa, A. Syrri, H. Bindner, “EcoGrid 2.0: A Large-Scale Field Trial of a Local Flexibility Market”, Denmark, 2020.

[10] E. LARSEN, A. JÓNASDÓTTIR, K. ROSENØRN, “BASELINES FOR EVALUATING DEMAND RESPONSEIN THE ECOGRID 2.0 PROJECT”, Denmark, 2019.

[11] B. A. Bremdal, P. Olivella & J. Rajasekharan, “EMPOWER A network market approach for local energy trade”, Norway, 2017.

[12] EMPOWER, “deliverables – EMPOWER”. [Online]. Available: http://empowerh2020.eu/tag/deliverables/.

[13] enera project, “EWE and EPEX SPOT to create local market platform to relieve grid congestions”, 2018.

[14] T. Schittekatte & L. Meeus, “Flexibility markets: Q&A with project pioneers”, Florence School of Regulation, Italy, 2019.

[15] USEF, “White Paper: Flexibility Platforms”, 2018.

[16] MarketScreener Press release, “Epex Spot : Enera on the way from a showcase to a real market”. 2019. [Online]. Available: https://www.marketscreener.com/news/latest/Epex-Spot-Enera-on-the-way-from-a-showcase-to-a-real-market--28829210/

[17] C. Zhang, Y. Ding, N. C. Nordentoft et al., “FLECH: A Danish market solution for DSO congestion management through DER flexibility services”, J. Mod. Power Syst. Clean Energy 2, 126–133, 2014.

[18] S. Minnit, N. Haque , P. Nguyen & G. Pemen, “Local Markets for Flexibility Trading: Key Stages

and Enablers", ENERGIES, the Netherlands, 2018.

[19] L. Hansen, O. Sundström, S. Harbo, R. Villefrance, "FLECH – Technical requirement specification", Denmark, 2013.

[20] S. Harbo, P. Meibom, L. Hansen, "FLECH - CLEARING HOUSE FOR CONGESTION MANAGEMENT", 2014.

[21] S. Harbo et al., "FLECH - Market Specification Analysis (cross WP4 and WP5 Activity)", 2013.

[22] Y. Ding, L. Hansen, P. Cajar, P. Brath, H. Bindner, C. Zhang, N. Nordentoft, "Development of a dso-market on flexibility services", Denmark, 2013.

[23] A. Esmat, J. Usaola & M. Moreno, "Distribution-Level Flexibility Market for Congestion Management", Energies, 2018.

[24] EU-SysFlex, "D2.2 - Scenarios and Network Sensitivities", 2018.

[25] J. Villar et al. "Flexibility Hub–Multi service framework for coordination of decentralised flexibilities", Portugal, 2019.

[26] EU-SysFlex, "D6.6 - Demonstrators for Flexibility Provision from Decentralized Resources, Common View", 2019.

[27] EWE, "Solution designed with DSOs Avacon Netz, EWE NETZ and the German TSO TenneT", 2018. [Online]. Available: https://www.ewe.com/en/media/press-releases/2018/02/enera-project-ewe-and-epex-spot-to-create-local-market-platform-to-relieve-grid-congestions-ewe-ag.

[28] FLEXICIENCY, "energy services demonstrations of demand response, FLEXibility and energy effICIENCY based on metering data", 2015. [Online]. Available: https://cordis.europa.eu/project/id/646482.

[29] FLEXICIENCY, "Deliverable D4.4 EU Market Place: REX and lesson learned", 2019.

[30] FLEXICIENCY, "Deliverable D2.1 Definition of services and use cases description", 2016.

[31] FLEXICIENCY, "Deliverable D11.6 Final Report", 2019.

[32] K. Spiliotis, A. Ramos, & R. Belmans, "Demand flexibility versus physical network expansions in distribution grids", Applied Energy, 2016.

[33] ENWL, "Future Network Modelling Functions - Project Closedown - Electricity North West. Limited (ENWL) / Network Innovation Allowance (NIA) - Network Innovation Allowance Closedown Report", UK, 2017.

[34] GOPACS, "IDCONS Product Specifications, Version 1.0", 2019.

[35] InteGrid, "Demonstration of Intelligent grid technologies for renewables Integration and Interactive consumer participation enabling Interoperable market solutions and Interconnected WP 1 – Use Cases and System Architecture - Document D1.2 - Use Cases and Requirements", 2017.

[36] R. Bessa et al., "Grid and Market Hub: Empowering Local Energy Communities in IntegGrid", CIRED Workshop, Ljubljana, 2018.

[37] A. Alonso, R. Couto, H. Pacheco, R. Bessa, C. Gouveia, L. Seca, J. Moreira, P. Nunes, P. Matos,

A. Oliveira, "Towards new data management platforms for a DSO as market enabler – UPGRID Portugal demo", CIRED - Open Access Proceedings Journal, vol. 2017, 2926-293, 2017.

[38] P. Matos, "O Caminho da Inovação '18 –Fábricas de Água no Futuro"Visão do tratamento das águas residuais no futuro"", EDP Distribuição, Lisboa, 2018.

[39] R. Fonteijn et al., "Flexibility for congestion management: A demonstration of a multi-mechanism approach" The Netherlands, 2018.

[40] InterFLEX, "THE PROJECT'S FIVE INNOVATION STREAMS - LOCAL FLEXIBILITY MARKETS", 2019. [Online]. Available: https://interflex-h2020.com/results-and-achievements/local-flexibility-markets/.

[41] INTERRFACE, "INTERRFACE (TSO-DSO-Consumer INTERFACE aRchitecture to provide innovative grid services for an efficient power system) The Project", 2019. [Online]. Available: http://www.interrface.eu/The-project.

[42] INTERRFACE, "Deliverable D3.2 Definition of new/changing requirements for Market Designs", 2019.

[43] INTERRFACE, "Deliverable D3.1 Definition of new/changing requirements for services", 2019.

[44] smartEn - Smart Energy Europe, "SmartEn Position Paper Design Principles for (Local) Markets for Electricity System Services", 2019.

[45] OMIE, Proyecto IREMEL: "Modelo de Funcionamento de los Mercados Locales de Electricidad V2.0", 2019.

[46] NODES, "A fully integrated market place for flexibility, White paper", 2018.

[47] USEF, "Universal Smart Energy Framework - USEF: White Paper on Flexibility Platforms", 2018.

[48] ENA, "Open Networks – developing a smart grid". [Online]. Available: https://www.energynetworks.org/creating-tomorrows-networks/open-networks.

[49] Piclo, "Flexibility & Visibility: Investment and opportunity in a flexibility marketplace", 2019.

[50] Piclo, "Local grid charging whitepaper", 2018. [Online]. Available: https://piclo.energy/about.

[51] Open Utility, "A glimpse into the future of Britain's energy economy", 2016. [Online]. Available: https://piclo.energy/publications/piclo-trial-report.pdf.

[52] Platone, "Platone - PLATform for Operation of distribution NEtworks - D1.1 - General functional requirements and specifications of joint activities in the demonstrators", 2020.

[53] PLATform for Operation of distribution NEtworks, "Project description", 2019. [Online]. Available: https://cordis.europa.eu/project/id/864300.

[54] PlatOne, "D8,1 Communication and Dissemination Plan (First Draft)", 2019. [Online]. Available: https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5cada41bc&appId=PPGMS.

[55] C. Collins, A. Boast, K. Phillips, B. Stojkovksa et al., "The Power Potential Project: trialling the procurement of reactive power services from distribution-connected assets", UK, 2018.

[56] UKPN, "Power Potential", 2017. [Online]. Available: https://innovation.ukpowernetworks.co.uk/projects/power-potential/.

[57] SENSIBLE, "Deliverable D1.1 Energy storage domain roles & classification", 2015.

[58] SENSIBLE, "Deliverable D5.4 Energy market interaction of business models", 2017. [Online]. Available: https://www.projectsensible.eu/documents/D5.4-energy-market-interaction-of-business-models.pdf.

[59] SENSIBLE, "Deliverable D1.3 Use Cases and Requirements", 2015. [Online]. Available: https://www.projectsensible.eu/documents/use-cases-and-requirements.pdf.

[60] SENSIBLE, "Project Website'. [Online]. Available: https://www.projectsensible.eu/.

[61] USEF, "Universal Smart Energy Framework - USEF: THE FRAMEWORK EXPLAINED", 2015.

[62] USEF, "White Paper on Flexibility Platforms", 2018. [Online]. Available: https://www.usef.energy/app/uploads/2018/11/USEF-White-Paper-Flexibility-Platforms-version-1.0_Nov2018.pdf.

[63] USEF, "DSO Workstream - Market-based congestion management models", 2018. [Online]. Available: https://www.usef.energy/news-events/publications/.

[64] Renewables Grid Initiative, "Factsheet Transmission System Operators", December 2015

[65] EDSO European Distribution System Operators for SmartGrids, "Why Smart Grids?" available at https://www.edsoforsmartgrids.eu/home/why-smart-grids/

[66] Directive (EU) 2019/944 of the European Parliament and of the Council, "on common rules for the internal market in electricity", 2019.

[67] ENTSO-E, "Synchronous Area Framework Agreement for Regional Group Continental Europe – Annex 1: Policy on Load-Frequency Control and Reserves", April 2019, available at https://www.entsoe.eu/publications/system-operations-reports/#entso-e-initial-dynamic-model-of-continental-europe

[68] USEF, "White Paper on Flexibility Value Stacking", 2018. [Online]. Available: https://www.usef.energy/app/uploads/2018/10/USEF-White-Paper-Value-Stacking-Version1.0_Oct18.pdf.

[69] EDSO European DSO Committee on Flexibility Markets: Electricity Focus, "Flexibility in The Energy Transition – A Toolbox for Electricity DSOs"

[70] National Grid ESO, "Distributed ReStart - What is the Distributed ReStart project?", 2019. [Online]. Available: https://www.nationalgrideso.com/future-energy/projects/distributed-restart.

[71] E. Cedec, ENTSOe, E. Geode, "TSO-DSO Report-An Integrated Approach to Active System Management", 2019, available at https://docstore.entsoe.eu/Documents/Publications/Position%20papers%20and%20reports/TSO-DSO_ASM_2019_190416.pdf.

[72] Eurelectric, "Flexibility and Aggregation: Requirements for their interaction in the market", January 2014.

[73] National Infrastructures Commission, “Anticipate, React, Recover: Resilient infrastructure systems”, May 2020, available at: https://nic.org.uk/app/uploads/Anticipate-React-Recover-28-May-2020.pdf.

[74] SmartNet, TSO-DSO “Coordination for Acquiring Ancillary Services from Distribution Grids”, May 2019, available at http://smartnet-project.eu/wp-content/uploads/2019/05/SmartNet-Booktlet.pdf.

[75] Eu-Sysflex, “Deliverable D3.2 Conceptual market organisations for the provision of innovative system services: role models, associated market designs and regulatory frameworks”, 2018.

[76] EcoGrid 2.0 Market Specification, September 30th 2016.

[77] EMPOWER H2020, Local **E**lectricity Retail **M**arkets for **P**rosumer smart grid p**OWER** services, Project Deliverable 6.1 – “Market Design”, September 2015.

[78] K. Anaya & M. Politt, “PROJECT MERLIN Milestone 1 - A review of international experience in the use of smart electricity platforms for the procurement of flexibility services (Part 1)”, 2020.

[79] L. Hirth & S. Glismann, “Working Paper Congestion Management: From Physics to Regulatory Instruments”, 2018.

[80] SP Energy Networks, “About the FUSION Project – Investment & Innovation”, available online at https://www.spenergynetworks.co.uk/pages/fusion.aspx.

[81] InteGrid, “Demonstration of Intelligent grid technologies for renewables Integration and Interactive consumer participation enabling Interoperable market solutions and Interconnected stakeholders WP 7 – CBA, Regulatory Analysis and Business Models - Document D7.5 - Business Models to Support the Developed Concepts”, 2020.

[82] CoordiNet, “Deliverable D1.3 Definition of scenarios and products for the demonstration campaigns V1.2”, 2019. [Online]. Available: https://private.coordinet-project.eu//files/documentos/5d72415ced279Coordinet_Deliverable_1.3.pdf.

[83] CoordiNet, “Deliverable D5.1 Demonstrator Analysis & Planning V1.0”, 2019. [Online]. Available: https://private.coordinet-project.eu//files/documentos/5e4c2778aea24D5_1%20coordinet.pdf.

[84] STEDIN, “Automatisering in het Elektriciteitsnet: we Regelen het Samen”, 2019. [Online]. Available: https://www.slideshare.net/dutchpower/3-peter-hermans-stedin.

[85] EDSO, “Flexibility: The role of DSOsin tomorrow’s electricity market”, 2014. [Online]. Available: https://www.edsoforsmartgrids.eu/wp-content/uploads/public/EDSO-views-on-Flexibility-FINAL-May-5th-2014.pdf.

[86] THEMA, “DATA EXCHANGE IN ELECTRIC POWER SYSTEMS: European State of Play and Perspectives", 2017. [Online]. Available: https://eepublicdownloads.entsoe.eu/clean-documents/news/THEMA_Report_2017-03_web.pdf.

[87] SENSIBLE, “Deliverable D3.5 Building and Network Storage Aggregator Managers (methods)”, 2016. [Online]. Available: https://www.projectsensible.eu/documents/building-and-network-storage-aggregator-managers-methods.pdf.

[88] R. Fonteijn et al., “The Strijp-S living-lab: testing innovative solutions for fault protection, self-healing, congestion management, and voltage control”, Eindhoven University of Technology, Eindhoven, the Netherlands, 2018.

[89] D. Erickson, "MARKET ARCHITECTURES FOR MANAGING DISTRIBUTED ENERGY RESOURCES - Analysis of three different approaches to a market design for grid services

provided by Distributed Energy Resources", E3R Consulting, Italy, 2018. [Online]. Available: https://cleanpowerexchange.org/wp-content/uploads/2018/02/Market-Architectures-for-Managing-Distributed-Energy-Resources-v3.pdf.

[90] SINTEG, "enera – Digitalisation of energy supply", Germany, 2020. [Online]. Available: https://www.sinteg.de/en/showcases/enera.

[91] CoordiNet, "Deliverable D1.5 Business Use Case: Business Use Casedefinition V2.2", 2019. [Online]. Available: https://private.coordinet-project.eu//files/documentos/5d724207ca982Coordinet_Deliverable_1.5.pdf.

[92] CoordiNet, "Deliverable D3.1 Report of functionalities and services of the Spanish demo V1.0", Spain, 2020. [Online]. Available: https://private.coordinet-project.eu//files/documentos/5e4c274e8190dD3.1%20Coordinet.pdf.

[93] C. Eid, "Managing electric flexibility from Distributed Energy Resources: A review of incentives for market design", Renewable and Sustainable Energy Reviews, Elsevier, vol. 64, 2016.

[94] InteGrid, "Demonstration of Intelligent grid technologies for renewables Integration and Interactive consumer participation enabling Interoperable market solutions and Interconnected stakeholders WP 4 – Self-sustainability Facilitation - Document D4.1 - Detailed specification and guidelines for field testing in SL", 2018.

[95] InterFLEX, "Deliverable D6.1 - Design of solution V1.0", 2017. [Online]. Available: https://interflex-h2020.com/wp-content/uploads/2018/06/D6.1-Design-of-solutions.pdf.

[96] S. Kazmi et al., "Smart Distribution Networks: A Review of Modern Distribution Concepts from a Planning Perspective", Energies 2017.

[97] IRENA, "FUTURE ROLE OF DISTRIBUTION SYSTEM OPERATORS - INNOVATION LANDSCAPE BRIEF", Abu Dhabi, 2019. [Online]. Available: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Feb/IRENA_Landscape_Future_DSOs_2019.PDF.

[98] World Bank Group, "Integrating Variable Renewable energy into Power System operations", 2015. [Online]. Available: https://openknowledge.worldbank.org/bitstream/handle/10986/21359/937850REVISED000Box391409B0LW380OKR.pdf.

[99] IRENA, "MARKET INTEGRATION OF DISTRIBUTED ENERGY RESOURCES INNOVATION LANDSCAPE BRIEF", Abu Dhabi, 2019. [Online]. Available: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Feb/IRENA_Market_integration_distributed_system_2019.pdf.

[100] Eurelectric, "Active Distribution System Management - A key tool for the smooth integration of distributed generation - full discussion paper", February, 2013.

[101] EWE Group, "Monitoring change - Integrated Report 2017 - Condensed version", Germany, 2017. [Online]. Available: https://www.ewe.com/~/media/ewe_com/pdfs%20im%20inhalt/bericht_ewe_com/180423_ewe_igb17_e_kurzversion_s.pdf.

Annex I – Template of the survey conducted by EDSO among DSOs

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

Questionnaire on DSO needs and services

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 864334

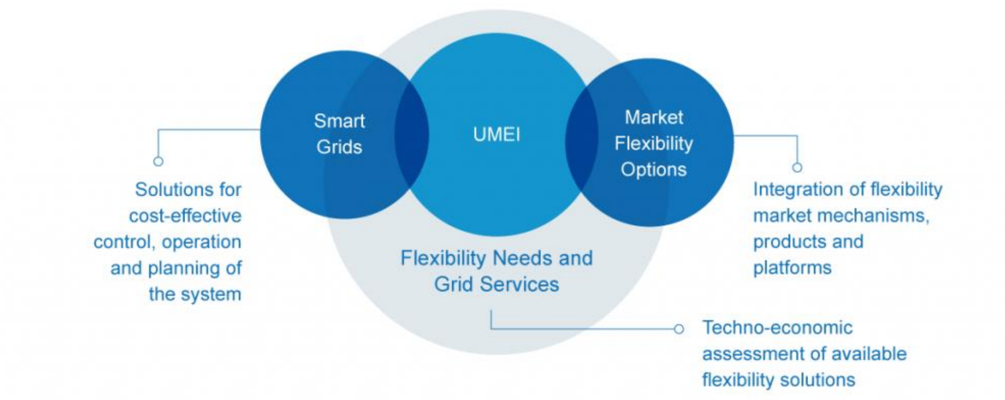
1 About EUniversal

The EUniversal project is a response to the call LC-SC3-ES-1-2019, entitled “Flexibility and retail market options for the distribution grid” of the Horizon 2020 programme. It is coordinated by EDP Distribuição and has 18 partners from seven countries - Portugal, Spain, Germany, Poland, Belgium, Norway and the United Kingdom - who will work together until August 2023 to demonstrate a replicable solution for the interaction of the Distribution Network Operator with the new flexibility markets - Universal Market Enabling Interface (UMEI).

Started in February 2020, it has an expected duration of 42 months and foresees the development of solutions that allow the integration of flexibility in the operation and planning of the distribution network, through market mechanisms and innovative services.

The objective of the project is to allow the massive integration of renewable production through services that allow the participation of flexible resources such as storage systems and electric vehicles - V2G, consumers and energy communities.

The solutions developed within the scope of the project will be demonstrated in three heterogeneous pilots (Portugal, Germany and Poland), with different distribution networks and different regulatory frameworks.



2 About the questionnaire

The purpose of this questionnaire is to assess whether a comprehensive set of DSO needs and services has been identified, to gather information on any missing elements, to obtain information whether individual services are actually already implemented or have been tested in the context of pilot projects in the distribution system operated by your company.

Please note that the data collected here is treated anonymously and will be used for research purposes only. At the end of the questionnaire, you will have the option to leave your email for contact in case we require additional clarification. No additional personal data will be recorded for this survey.

If you have any queries, please send an email to Katarzyna Zawadzka at Katarzyna.zawadzka@edsoforsmartgrids.eu.

3 DSO needs and services

In the table below you can find DSO's needs and corresponding services identified during revision of multiple H2020 projects. Short description and category of each service has been provided.

<table>
<tr><th>Needs</th><th colspan="2">Services</th><th>Definitions</th><th>Category</th></tr>
<tr><td rowspan="3">Voltage Control</td><td rowspan="2">Reactive power management</td><td>Steady state control</td><td>Service to maintain the voltage profile inside the limits, in steady state (normal operation).</td><td>Grid service</td></tr>
<tr><td>Dynamic control</td><td>Service to control the voltage variations under system disturbances.</td><td>Grid service</td></tr>
<tr><td colspan="2">Active power management</td><td>Service for voltage control by increasing/decreasing active power.</td><td>Grid service</td></tr>
<tr><td rowspan="3">Congestion Management</td><td colspan="2">Operational</td><td>Service for CM in operational timeframe, activated to mitigate congestions caused by faults, and to other remedial actions.</td><td>Grid service</td></tr>
<tr><td colspan="2">Short-term planning (D-1 to M-1)</td><td>Service for CM in timeframe of D-1 (day before) up to M-1 (month before).</td><td>Grid service</td></tr>
<tr><td colspan="2">Long-term planning (>M-1 to Y-1 or more)</td><td>Service for CM considering several months or years before, and may as well result in network reinforcement deferrals.</td><td>Grid service</td></tr>
<tr><td rowspan="2">Service Restoration</td><td colspan="2">Black Start for distribution islands</td><td>Service for system restoration after blackout situations. In the distribution specific case, at present, large generators that are already designed for blackout services can be used for black start in parts of the distribution network.</td><td>Grid service</td></tr>
<tr><td colspan="2">Isolated/Islanding operation mode</td><td>Specific services can be offered for parts of the grid operating in islands/isolated mode (e,g, isolated microgrids). Some needs to attend this services are local balancing and voltage control (and others).</td><td>Grid service</td></tr>
<tr><td>Voltage sag mitigation</td><td colspan="2">FRT</td><td>Service to provide FRT (fault ride through) capability, supporting the mitigation of voltage sag on the distribution system. FRT as a flexibility service is in early discussions.</td><td>Grid service</td></tr>
<tr><td rowspan="3">Planning and predictive management</td><td colspan="2">Flexibility forecasting</td><td rowspan="3">Forecasting services, for distribution loads, generation and flexibility, to have better estimations of generation and demand, and the expected impacts for the DSO, considering also the flexibilities available.</td><td rowspan="3">Non-grid services</td></tr>
<tr><td colspan="2">Generation forecasting</td></tr>
<tr><td colspan="2">Load forecasting</td></tr>
</table>

Observability of the flexibility; Procurement mechanism (and settlement); Improved coordination between SOs	Visibility over available flexibility	Service to provide DSOs enhanced observability of the system, with better awareness of their assets, their available flexibility and location, improving the system management.	Non-grid services

3.1 DSO's needs

1) Do you think any other needs should be added to the current list?

If so, what are they? Can you propose any services connected to that need?

Comment

2) Please provide any comments regarding listed needs.

Is that need not relevant? Does that need require additional explanation? Etc.

Need	**Comment**
Voltage Control	
Congestion Management	
Service Restoration	
Voltage sag mitigation	
Planning and predictive management	
Observability of the flexibility; Procurement mechanism (and settlement); Improved coordination between SOs	

3.2 DSO's services

1) Do you think any other service should be added to the current list?

If so, what are they? To which need should they be connected?

Comment

2) Please answer questions in the table and provide any comments regarding listed services.

Need		Relevant? [Y/N]	**Already implemented in any of your grids, or to be implemented in near future (max. 5 years)?** [Y/N]	**If not implemented – WHY?** (Non-realistic? Non-profitable? Too many requirements? Similar services in place?)	**Any other comments**
Reactive power management	Steady state control				
	Dynamic control				
Active power management					
Operational					
Short-term planning (D-1 to M-1)					
Long-term planning (>M-1 to Y-1 or more)					
Black Start for distribution islands					
Isolated/Islanding operation mode					
FRT					
Flexibility forecasting					
Generation forecasting					
Load forecasting					
Visibility over available flexibility					

In case you would like to leave your contact details, please provide data below:

Name:

E-mail address:

Annex II – Templates for markets characterization

Two types of templates have been used in this revision to collect and present the relevant information on markets organization: an excel template prepared during task T5.1 work and used in task T1.2, and a graphical summary template specifically prepared for this task. While the excel template allows to collect (in case they are available) many detailed aspects of the market model considered, being useful as a reference for present and future work, the graphical summaries allow to present a fast, clear and concise vision of each project and the market models it proposes or uses, being a very direct and easy way to provide feedback for other tasks or projects.

Excel template for markets description

Following what was already mentioned, it was agreed that the Excel template worked in task T5.1 would be used during the execution of this task 1.2, as its matches very well much of the work needed in task T1.2 (namely regarding the characterization of market structures under study and possibly demonstrated by the European initiatives analysed). This template aims to describe the main characteristics needed of the market models identified during the projects' revision, in a common and structured format, to help further analysis and to serve as a future reference able to replace, to a large extent, the original projects documentation.

Table 51 was used to characterize the Market Model Design, while Table 52 was used to characterize the Market Operation.

Table 51: Template sheet for the characterization of a market models design

MARKET MODEL DESIGN		
Categories / Parameters		**Detailed Description**
1. Grid services covered		*Define the type of grid services to be covered for the SO:* • *Balancing;* • *Congestion management;* • *Voltage regulation;* • *Controlled islanding;* • *Other non-grid services.*
2. Supply and demand characterization (one-sided vs. two-sided market)		*- either the market is centred around one side (e.g. the buyer, in this case the DSO, or the seller) that sets the volume/price and then the counterparty submit bids in response to the request* *- or flex bids are received from the 2 sides and are then cleared by the market*
3. Periodic closed gate auction or Continuous auction		
4. Pricing & optimisation process	4.1 Price computation methods	*pay-as-bid, pay as clear, auctions (ascending price, descending price)*
	4.2 Cross-periodical optimization and Intertemporal constraints?	*Covering several periods at once (e.g. every quarter hour of one day) to consider interdependencies of periods (e.g. due to rebound effects in congestion period)*
5. Technical parameters at market level	5.1 Price cap	
	5.2 Price floor	
	5.3 Clip size / minimum acceptance volume …	
6. Product characteristics	6.1 Product attributes	Market product definition and technical attributes Locational information included (e.g. congestion zone)? Standardised products? Based on certain products? E.g. ID / mFRR
	6.2 Rebound behaviour	*Mechanisms to describe rebound behaviour of resources*
	6.3 Aggregated product support	*Capability and mechanisms defined to support orders coming from aggregated resources (VPP)*
	6.4 Reservation and/or Activation	
7. Timing	7.1 Bidding period	*Time period when participant can submit market orders*
	7.2 Bid allocation	*Specific rules followed to allocate and match orders (e.g. at market clearing time if clearing)*
	7.3 Pricing (contract creation)	*When price is computed*
	7.4 Frequency / Time horizon for reserve	*Frequency of auctions (if any) and time horizon considered for delivery*
	7.5 Frequency / Time horizon for activation	*Frequency of auctions (if any) and time horizon considered for delivery*

	7.6 Gate closure time for reserve	
	7.7 Gate closure time for activation	
	7.8 Settlement	*Frequency and time period considered for settlement*
8. Integration and relationship with existing energy & ancillary markets	8.1 Day-ahead, intraday markets and ancillary services	*sequencing, order exchanges*
9. Geographical scope / bidding areas		*Zonal (national, regional, custom) or nodal*
10. Integration of DSO/TSO grid data on flexibility platform		*Comprehensive grid model to assess impact of bid selections (e.g. sensitivity factors, grid constraints and switching options) on the grid and take different switching options into account vs. partial grid model (e.g. only for one topology) vs. bid limitations vs. no integration of grid data since DSO/TSO pick the bids*
11. Consideration of switching measures in the clearing process		*In case of auctions and integration of grid data*
12. Grid capacity estimation and allocation		*Computation methods, estimation/assessment in the market or by DSO/TSO, Implicit VS Explicit allocation of grid capacity for flexibility bids*
13. TSO/DSO coordination principles		*Mechanisms, priority and rules setup to ensure T/D coordination, if any*
14. Resources characteristics (e.g. sizes, aggregation, storage treatment)		*Overview of technologies registered on the market and covered by the market products*
15. Metering requirement		*Requirements for metering data (submission time / granularity)*
16. Baseline methodology		*Mathematical methods selected to compute resource baselines*
17. Settlement methodology		*Rules applied, penalties for non-compliance, management of congestion rent*

Table 52: Template sheet for the characterization of a market operation

MARKET OPERATION		
Local Market functions	**Operation responsibility** (DSO, TSO, Joint, Independent Market Operator, Flexibility Seller or Flexibility Buyer)	**Comment**
Resource registration		*Management of the process to register sites & assets owned by the sellers and connected to the grid to provide flexibilities. Can include a formal prequalification phase.*
Grid assessment		*Based on load/gen forecasting to assess the impact of a flexible resource on the grid. Can be carried out for different topologies.*
Bids & Offers exchanges		*Support the exchange and the functional and technical validation of orders between market participants*
Market process scheduling		*Schedule and orchestrate (trigger & monitor) the auctions and the different market process*
Optimization: selection of optimal combination of flexibility bids and switching measures		*Run the optimisation process to select the optimal set of orders and switching measures based on comprehensive grid data.*
Optimization (alternative): selection of optimal combination of flexibility bids (w/o switching measures)		*Run the optimisation process to select the optimal set of orders based on partial grid data (e.g. only one topology).*
Pricing		*Compute contract prices based on the selected approach (pay as clear or pay as bid)*
T/D coordination		*Coordinate flexibilities procurement between DSO and TSO and mitigate conflict situation*
Contract management		*Manage contracts and notify market participants*
Metering (data import, cleaning)		*Import and clean the metering data captured at resource level*
Baselining		*Compute the baseline for the time interval of the contract / dispatch*
Settlement		*Compute the price to be paid by the buyer to the seller for each contract and according to the baseline and energy delivery*
Payment		*Manage the payment process: invoice creation from the settlement and money transfer*
Management financial guarantees		

Power point template for markets description

To provide a concise and graphical intermediate feedback to other project task on the markets organizations in the projects analysed, the template in Figure 33 was used. The information it contains focus on the market organization type, and on a subset of the topics of the previous section tables that was considered most relevant.

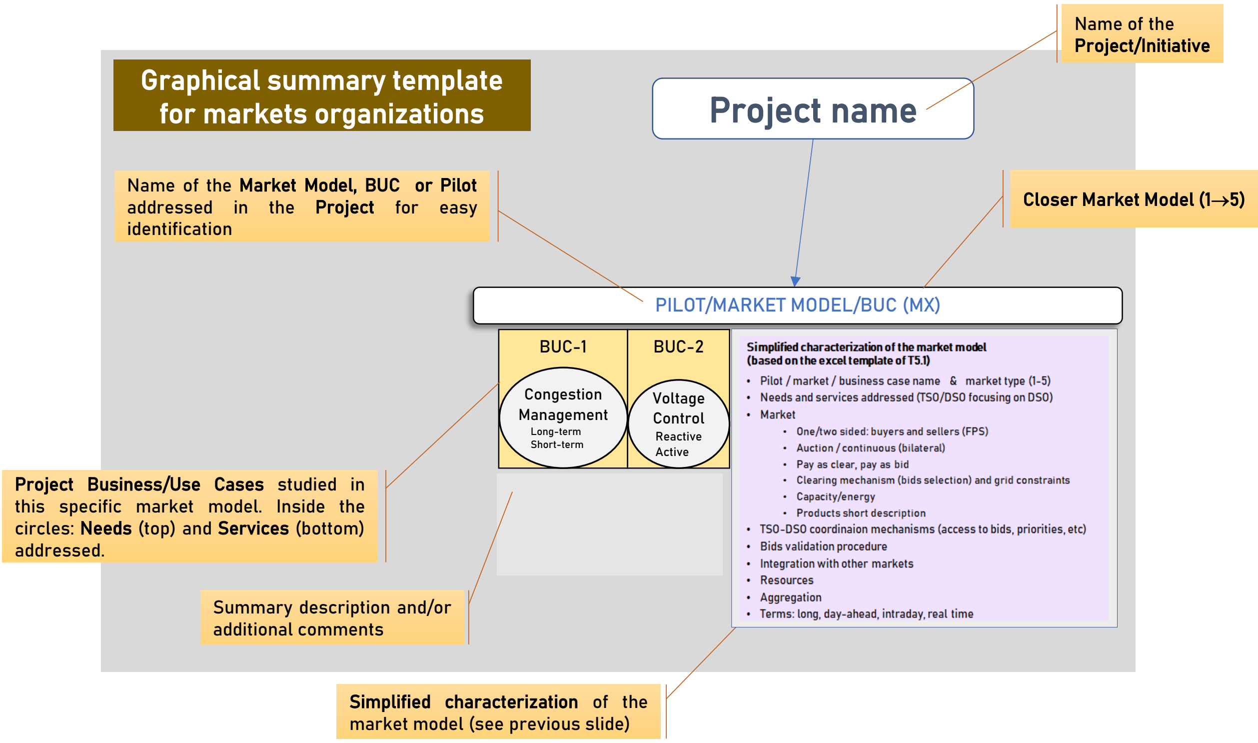


Figure 33: Graphical summary template for markets organizations

Annex III – Monitoring and Control requirements identified in each reviewed project

<table>
<tr><th>Project name</th><th colspan="2">Services identified</th><th>DSO monitoring and control requirements</th></tr>
<tr><td rowspan="8">CoordiNet</td><td rowspan="3">Congestion Management</td><td>Operational</td><td rowspan="8">CONTEXT:
Foster the participation of consumers and renewable energy resources, regardless their sizes and voltage levels of connection points, to be more active, in the management and operations of the system, implementing new products and services, and using existing operational DSO and TSO systems. The TSO-DSO coordination results in needs of real-time data gathering;
Three demonstrators covering 4 market models (M1 to M4).
MONITORING:
Requires data from substations, RES stations and weather forecasters;
Information, such as HV/MV substations, transmission lines and generation units obtained from the TSO EMS;
Requires the location and capacity of customers premises that are willing to participate in DR programs;
PVs: monitored using AMR system. Measurements received twice a week (rate will be increased to a daily basis);
CoordiNet Platform integrates electronic meters of the Wind Farms. Measurements are used to generate 3-Day Ahead forecasts;
Buildings (demand response): building management system (BMS). Uses IGSS SCADA (industrial SCADA able to communicate with building automation devices);
Monitoring Services tool: collect the necessary data for evaluation and KPI calculation;
Uses Real Time Monitoring modules of the WiseGRID Cockpit tool (Greek demo): relevant GIS information and AMR data (with quarterly frequency) of the RES generation located at defined parts of the grid;
Communication Protocols integrated: (e.g. IEC 61850). Import information from different systems (PMUs, PDCs or SCADAs);
(Spanish demo) monitoring and control system through Energy Boxes (EB): in the FSP, the EB directly connected to devices or to local SCADAs, monitor operating state of the providers and send this data to the AGR.
CONTROL:
(Spanish demo) to control the loads, EBs receive operation set points from the AGR and apply it to the flexibility providers;
Meters that actually register the consumption data hourly must pass to 15 minutes in the future, and minimal functionalities required by the meters are being defined, introducing a new concept of “near-real time data”.</td></tr>
<tr><td>ST</td></tr>
<tr><td>LT</td></tr>
<tr><td rowspan="2">Voltage Control</td><td>APM</td></tr>
<tr><td>RPM</td></tr>
<tr><td>Service Restoration</td><td>Islanding Operation</td></tr>
</table>

De-Flex-Market	Congestion Management	LT	CONTEXT: • Very specific service provided by FSP and costumers where DSO's communicate restriction requirement levels per metering point, for extended periods of time with a fixed quarter-hour step. MONITORING: • Controllable appliances such as storage devices or heat pumps are required to have a separate metering point, being a virtual metering point sufficient. CONTROL: • Adoption of TLC; • Requires but does not specify a standardised communication protocol between the FSP and the DSO for transmitting information on which metering points are participating in any pooling unit; • In case of emergency (= red phase) the DSO must have direct access to the controllable appliances; • Outside the red phase, the consumers or respective service providers (FSP or energy suppliers) are responsible for guaranteeing compliance with restriction requirements during operational periods.
EcoGrid 2.0	Congestion Management	LT	CONTEXT: • Proposes standardised products based on limiting power consumption/generation of aggregated loads/generators' portfolios; • The mechanism for providing flexibility is undistinguished between different services (same product structure for congestion management and for voltage control). MONITORING: • Requires high penetration of smart meters (emphasizing the importance of replacing all older-generation meters); • Smart meters sampling rate: 5 minutes; • Consumption data is stored centrally in a DataHub and must be accessible (in aggregated format, reducing data-privacy issues) to DSO and AGR, "the former to calculate which services they need to acquire, and the latter to model flexibility, control their DER effectively, and calculate the amount of flexibility they can offer to DSO. CONTROL: • Requires controllable DER (devices that allow the external control of heat pumps and electric radiators must be installed and maintained); • Daily maintenance of the digital infrastructure (keeping the households 'online') ***Note**: regarding this last bullet of the CONTROL requirements, on average, around 20% of the controllable units did not respond properly to control signals during the demonstration period carried out. This resulted in and overall service delivery MAPE (mean absolute percentage error) of 31% compared to 18% when excluding those houses (baseline energy service);*
	Voltage Control	APM	
EMPOWER H2020	Congestion Management	ST	CONTEXT: • The local markets have a specific type of AGR which is called the Smart Energy Service Provider (SESP); the SESP needs to receive metering data from the prosumers/consumers, and information from the DSO. MONITORING:

	Voltage Control	APM	• Customers with contract with SESP must share their metering data so it can be monitored. In the future, data will also be available through a national metering data hub. • The metering data must be updated to the DSO at least once a day. CONTROL: • The SESP receives metering data from Local Controllers through an Optical reader / EMI sensor, reading signals directly from the Smart meter; • Bidirectional communication in real time must be ensured between the SESP and field devices (EV Chargers, Storage, Generation).; as such, SCADA must be connected in real time with every device controller and SESP.

Enera	Congestion Management	ST	CONTEXT:
			• The focuses of Enera are:
			  o Grid management: using data to improve grid operations and create a “smart grid operator”;
			  o Market: improving the intraday markets to enable procurement of flexibility services from DER to manage the distribution networks;
			  o Data: building secure information and communication systems to gather and analyse data.
			
			MONITORING:
			• Installation of smart meters in all households and companies in the Enera model region;
			• Information from smart meters up-to-minute. Smart consumption applications: automatization for home lighting, adjusts for consumption in line with wind and solar generation, shift of consumption of washing machines, tumble dryers, hot water boilers to night periods or low demand periods;
			• Flexibility providers must avoid double activations (as it is possible to bid in different markets). Activation must be assured to happen whenever needed;
			
			CONTROL:
			• N/A
			
			***Notes**:*
			• *Regarding this last bullet of the CONTROL requirements, no detailed information was found to support it;*
			• *Additional source of information: [101].*

FLECH-iPower	Congestion Management	ST LT	CONTEXT: • Several products for Congestion Management, ranging from power caps to capacity reservation to demand-response; • Little information is provided over the targeted DER. MONITORING: • No relevant information to our knowledge’s extent. CONTROL: • The AGR is the mobilizing stakeholder when DSO emits a control signal. No further relevant information to our knowledge’s extent.

<table>
<tr><td>Flex-DLM</td><td>Congestion Management</td><td>ST</td><td>CONTEXT:
• Single article presenting an optimization algorithm aimed at minimizing DSO’s total costs of acquiring flexibility;
• Products consist up- and down-regulation setpoints.

MONITORING:
• No relevant information to our knowledge’s extent.

CONTROL:
• The AGR is the mobilizing stakeholder when DSO emits a control signal. No further relevant information to our knowledge’s extent;
• Nonetheless, the paper assumes the application of TLC, so a direct control mechanism between DSO and the DER must be established (for a possible red phase scenario).</td></tr>
<tr><td rowspan="5">FlexHub Eu-SysFlex</td><td rowspan="3">Congestion Management</td><td>Operational</td><td rowspan="5">CONTEXT:
• Several products for Congestion Management and Voltage Control, ranging from LV-HV distribution grid resources to (PV, OLTC, Statcoms, batteries) to 10-25 MW Wind farms.

MONITORING:
• Monitoring systems must be able to provide near enough real-time knowledge of the distribution network, regarding the status of its smart grid devices, to encourage the provision of ancillary services for both the TSO and the DSO; as such, measurements must be updated every 15 minutes; this will require the improvement of network observability and forecasting systems.

CONTROL:
• Depending on the type of market, the available flexibility resources can submit bids through an AGR or, in some cases, negotiate directly with the DSO (or the TSO). Activation can be requested either by the DSO or the TSO, but the former must always validate all bids to ensure that the grid is operated safely and within its technical limits;
• To achieve adequate levels of coordination, the exchanges of data between the DSO and the TSO must be defined; also, power modulation at HV/MV substation must be agreed and scheduled, to account for the TSO’s flexibility needs.</td></tr>
<tr><td>ST</td></tr>
<tr><td>LT</td></tr>
<tr><td rowspan="2">Voltage Control</td><td>APM</td></tr>
<tr><td>RPM</td></tr>
<tr><td>FLEXICIENCY</td><td>Voltage Control</td><td>APM</td><td>CONTEXT:
• Products configuration is performed by the FSP and includes geographical, temporal (period of availability and step) and capacity information, among others. Bids are selected by DSO in what is expected to be an optimized decision.

MONITORING:
• Fundamental role of advanced monitoring (smart meters, grid sensors) entailing detailed energy consumptions’ patterns and production information;
• On-site devices monitored include inverters, power analyzers, Battery Management Controllers (BMC), among others;
• Smart metering infrastructures with high frequency and possibly close to real-time;
• At the Spanish demo, measurements were updated every 15 minutes (P, Q, SoC from EB). Grid analyzers measured active and reactive power and energy demand of charging points. Data was also measured and provided by the photovoltaic and wind converters and inverters.</td></tr>
</table>

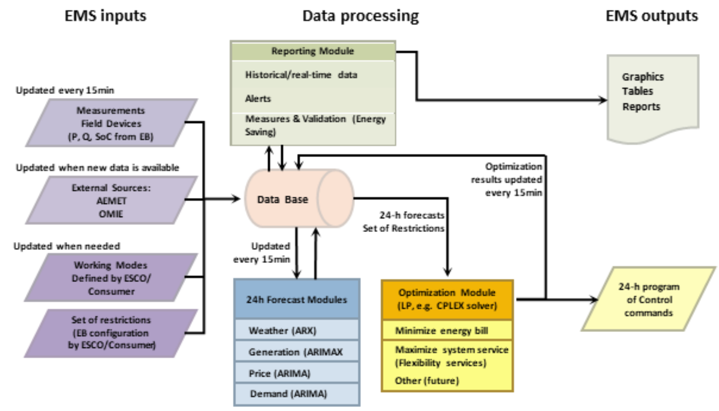
<table>
<tr>
<td></td>
<td>Observability over the available flexbility</td>
<td></td>
<td>


Figure: Algorithm data flow in the Spanish demo.
Adapted from: Andolšek, A., Nemček, M., Gómez López, A., Zocchi, A., Bruna Romero, J., & Oliván Monge, M. Á. (2018). Flexibility and optimization services validation in a microgrid. in CIRED Workshop, 2018, no. 0444, pp. 7–8
CONTROL:

Activation is requested by the DSO, with the AGR informing the required partners to activate their flexibility and send a confirmation message to the DSO, following the proposed B2B communication protocol.

</td>
</tr>
<tr>
<td>FlexMart</td>
<td>Congestion Management</td>
<td>LT</td>
<td>
CONTEXT:

Article proposing an optimization algorithm with the objective of minimizing DSO' total costs of acquiring flexibility, reinforcement investments and curtailment of RE;
Aggregation Units (AU) participate in a one-sided market with offers of flexibility (up- and down-regulation).

MONITORING:

Consumers who are interested in providing demand response services must invest on "advanced metering devices and control unites";
No further relevant information to our knowledge's extent.

CONTROL:

AUs are the proposed way to bridge DSO and consumers. Therefore, and because no explicit control mechanism is defined, it is assumed that the schedule of up- and down-regulation is communicated from the DSO to the AUs and from those to the end consumers.

</td>
</tr>
<tr>
<td>GOPACS-IDCONS</td>
<td>Congestion Management</td>
<td>ST</td>
<td>
CONTEXT:

The focus is the redispatch, to solve the DSO congestion problems: suppliers submit the Intraday congestion spread (IDCONS) bids via GOPACS, and the combination of a buy and a sell order is cleared.

CONTROL:

Requirements not found.

MONITORING:

Requirements not found.

</td>
</tr>
</table>

InteGrid	Congestion Management	ST LT	CONTEXT: • The DSO resorts to distributed flexibilities (active power) connected to the MV and LV networks as providers of non-frequency ancillary services for different goals such as investment deferral, solving real-time technical constraints or minimize energy losses. MONITORING: • The DSO deploys smart meters and other intelligent energy devices in the LV grid for improving monitoring, with real-time communication; • For purposes of LV network technical constraints assessment and management, the DSO should then be able to use (by regulation) the data collected by the smart meters; • A full knowledge of the LV grid's topology and electrical characteristics is required; • A regulatory framework for providing flexibility services must exist where LV prosumers are able to provide flexibility services, exploring the intelligent functions of the HEMS, via their electricity Retailer or Flexibility Operator; • Existence of a defined data model and communication protocols between all the involved actors and roles; MONITORING: • The multi-period availability of flexibility from the LV prosumers must be compatible with the control envisaged for the LV network (period, discretization, format); • All automatic control actions over DSO assets must only be performed under supervision by the DSO and need to be previously validated by the operation centers.

Interflex	Congestion Management	ST	CONTEXT:
			• Special relevance is given to 2 of the demonstrators set-up in this project;
			• At the Eindhoven demonstrator, Strip-S living lab, flexibility was offered in the form of up- and down-regulation products from AGR representing diverse types of DER such as stationary storage, PV and public charging stations for EVs;
			• The French demonstrator focused on behavioral flexibility from residential and industrial appliances, where participation although rewarded, was not obligatory.
			
			MONITORING:
			• From the set-up at the Strijp-S (Eindhoven) living-lab:
			  ○ Measurement equipment was installed in every MV feeder, MV/LV transformer and outgoing LV feeder;
			  ○ Measurements included 15-minute averaged rms values of current, voltage, active and reactive power, bidirectional energy throughput and total harmonic distortion which were transmitted automatically to a central database;
			  ○ The outgoing feeders of the MV/MV substation and four MV/LV substations were furthermore equipped with automation and remote switchgear;
			  ○ In addition, synchronized measurement devices with a sampling rate of over 100kHz were added to the system, measuring phase currents and voltages.

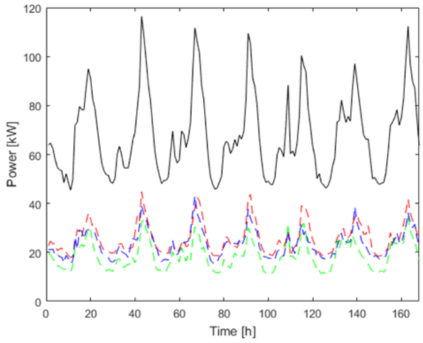
<table>
<tr>
<td></td>
<td>Service Restoration</td>
<td>Islanding Operation</td>
<td>

Figure: Example of measurement profile on LV feeder. Active power (kW)over time for the first week of January 2018. Phase 1 (red), phase 2 (green), phase 3 (blue), and sum of all phases (black).
Adapted from: Fonteijn, Rik & Roos, Martijn & Nguyen, Phuong & Morren, J. & Slootweg, J.G. (2018). The Strijp-S living-lab: testing innovative solutions for fault protection, self-healing, congestion management, and voltage control. 1-6. 10.1109/UPEC.2018.8542117.
CONTROL:

From the set-up at Strijp-S (Eindhoven) living-lab:

DER control was performed by the corresponding local AGR under the yellow region of the TLC followed according to USEF;
The red region being defined as a power outage phase led to the definition of an orange region where the DSO can bypass AGR to control DER directly to avoid grid overloading;
Implementation of an operational activation channel through control boxes or smart meters;

From the set-up at Nice Smart Valley (FR Demo):

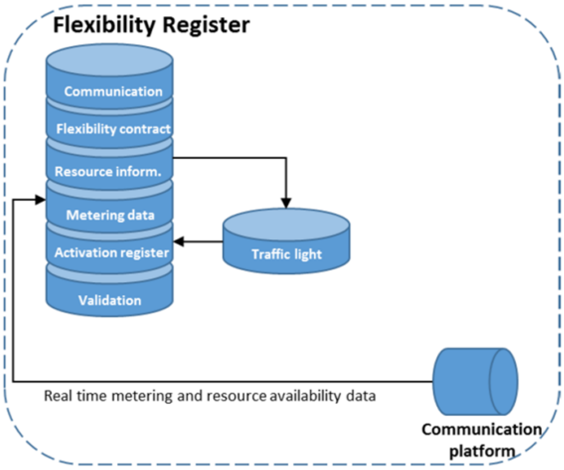
In this demo, behavioral flexibility has been tested;
When the DSO (Enedis) needed to activate flexibility offers, the AGR would send an email and a text message to the customers asking for flexibility during the required time slot. The customers remained the master of the activation and could decide without penalties to reply or not to the activation request;
Other kinds of flexibilities, also tested with residential and professional customers, involved global offers including automatic remote control and value stacking.

</td>
</tr>
<tr>
<td>INTERRFACE</td>
<td>Congestion Management</td>
<td>Operational</td>
<td> CONTEXT:

Embryonic project suggesting products for operational and long-term markets based on conditional reprofiling bids of FSP (reserve capacity) and scheduled reprofiling bids for short-term markets;
Assumed that flexibility is mainly provided by DER such as batteries, residential consumers flexible loads and distributed generation.

MONITORING:

Requirements for metering data include granularity of 15 minutes;
In development is a blockchain-supported flexibility register (based on EWF's Energy Web Flex solution) for the integration of residential-scale distributed energy resources whose main function is to calculate the quantity of capacity reserve ensured or/and energy 'not consumed' or ‘generated’ in each period following specific product requirements. Specifically, the metering data module stores (or links) the information
</td>
</tr>
</table>

		ST LT	collected from metering points (including local devices for close to real-time metering and resource availability data; • Authors contest that metering granularity must depend on the specific needs of the market products designed but the module should contain close to real time or/and daily non-validated metering data and monthly (validated) metering data per delivery point.  **Figure**: Flexibility register concept proposal. Adapted from: *INTERRFACE D3.2 Definition of new/changing requirements for Market Designs (2020).* CONTROL: • The project will likely follow the traffic light concept.
NODES	Congestion Management	Operational ST LT	CONTEXT: • NODES is a marketplace platform, with grid companies setting parameters for the needs and services management (for congestion management and voltage control). Metering requirements are discussed for each project. MONITORING: • N/A. CONTROL: • Flexibility providers have the responsibility to avoid double activations since they can bid on different markets, so it is assumed that it is those actors that have the responsibility to guarantee the product offered whenever it needs to be activated.
Piclo Flex (and Piclo)	Congestion Management	ST LT	CONTEXT: • Online platform launched to enable businesses to transact of local generators of renewable energy, through signing contracts with an electricity retailer supplying the Piclo service. Piclo gives visibility of matched energy data and full visibility of the business energy supply chain. MONITORING: • Use of meter data, generator pricing and consumer preference information to match electricity demand and supply every half hour; • Retailer must send meter data to Piclo, which performs the energy matching. CONTROL:

	Observability over available flexibility		• Assets that pass the testing and procurement processes can be activated by the corresponding SO: activation via SMS, email or other electronic signal in the Piclo Flex competition areas.
SENSIBLE	Congestion Management	ST	CONTEXT: • Residential DER such as PV, flexible loads and small-scale storage are controlled through the Home Energy Management System (HEMS). The flexibility they provide is bided in the market through a Retailer. • In parallel, medium scale power producers at the MV level, such as wind farms, can also send their flexibility bids to the market. MONITORING: • Energy monitoring algorithms operating locally; in particular, the Retailer monitors the deviation "system adjusting factor", which measures the difference between the flexibility need and the available flexibility; • Automatically enabled tools dedicated to monitoring and management of LV network during islanded mode; • Control of Equipment (Residential and Community), and Control algorithms. CONTROL: • A supervisory control tool will be responsible for monitoring the LV network and support the local control layer by promoting the coordination between all participating resources.
		LT	
	Voltage Control	RPM	
USEF	Congestion Management	ST	CONTEXT: • The USEF Market Coordination Mechanism (MCM) sets out the phases and interaction requirements for flexibility transaction. AGR provide only explicit flexibility services to the TSO, DSO or BRP, where flexibility is directly exposed to the market, traded and purchased as a specific product. MONITORING: • Fundamental role of advanced monitoring (smart meters, grid sensors) and forecasting tools, and local energy control (DER controllers); • AGR forecast of the amount of energy to be consumed or produced at a given congestion point (D-Prognosis); • AGR forecasts of planned activations of flexibility (day-ahead and intraday) to be shared with DSO in congested distribution network areas (D-Plan). CONTROL: • Flexibility is controlled by the AGR. In case of flexibility activation, information is exchanged for verification of the delivered amount of flexibility. The Meter Data Company (MDC) collects smart meter data from the prosumer and sends the smart meter data to the DSO; • The DSO uses this data for verification of the actual delivery. In principle, the DSO, AGR and the TSO will evaluate performance based on metering data at the connection level. In practice, however, especially at industrial and commercial sites, the AGR will most likely install a sub-meter for the active demand and supply assets to measure their actual performance. This enables both the AGR and the DSO to better predict and quantify the performance of the demand response service and the provided flexibility; • In Orange regime, "DSO makes autonomous decisions to decrease loads or generation in the grid by limiting connections when the market-based coordination mechanism cannot eliminate network congestions."
	Voltage Control	APM	
	Service Restoration	Islanding Operation	

Annex IV – Survey of DER capable of providing flexibility services

Project name	Services identified		DER characterization
CoordiNet	Congestion Management	Operational	Spanish DER: • PV; Batteries; Mini wind generators [1kW]; Buildings; Biogas generator; CHP; small hydro; Greek DER: • Monitored: Wind Farm Connected to TS; Wind Farm Connected to DS; Photovoltaic Stations Connected to DS; Small Diesel Gensets (will be added after the successful tests); Buildings; Batteries. Controllable: Small Diesel Gensets; Batteries [0.005MW]; Households. (In Mesogia): buildings participating, mainly with controllable ventilation load (AC units). The control will be manual (email or sms) and in some cases automatic.
		ST	
		LT	
	Voltage Control	APM	
		RPM	
	Service Restoration	Islanding Operation	
De-Flex-Market	Congestion Management	LT	• Small scale DER (up to 172 kVA) connected to low voltage distribution network; • Examples provided include: ○ electric vehicles; ○ electric heating appliances; ○ PV systems; ○ storage units; • Aggregation is not only possible but required. ***Notes***: • *Aggregation (called "pooling") is admitted for controllable devices located in the same aggregated distribution grid area ("based on grid topological considerations, an area (connected or not) or segment of the distribution grid chosen by the responsible DSO (or cooperating DSO) for applying a consistent and uniform restriction requirement");* • *An example of pooling is provided with 5 assets between 5 and 20kW, summing 57,5 kW).*
EcoGrid 2.0	Congestion Management	LT	• Demo consisted of 800 households owning a flexible electric heating unit (equipped with a smart meter and the necessary communication and control equipment), half being resistive heaters and the other half heat pumps; • AGR play a central role in the market model, participating as a service provider on behalf of the households it represents. One or more AGR can represent a same household, since the same household can provide different types of DER; • Considers as possible demand response assets: ○ electric vehicles; ○ heat pumps; ○ distributed storage; ○ distributed generation. ***Note***: *"resistive heaters are controlled by adjusting room temperature set-points, whereas a throttle signal can be sent to heat pumps, which ceases their operation"*
	Voltage Control	APM	
EMPOWER H2020	Congestion Management	ST	All types of DER at the distribution level (MV and LV): ○ electric vehicles; ○ distributed storage; ○ distributed generation (including medium-size wind farms at the MV level).
	Voltage Control	APM	
Enera	Congestion Management	ST	• All flexibility resources. So far implemented: load, VRE, storage of the HV and MV network level.
FLECH-iPower	Congestion Management	ST	• Small scale DER (up to 5MW) that individually are unable to access the wholesale electricity market Nordpool (min. = 10MW); • Aggregation is considered. AGR assume the standard functions of assembling and mobilizing DER, offering services to the FLECH market.
		LT	

<table>
<tr><td>Flex-DLM</td><td>Congestion Management</td><td>ST</td><td>

- Curtailable and shiftable loads for industrial and residential customers (few hundred kW);
- Curtailable loads in industrial sector:
  - industrial productions of zinc, copper and aluminum;
- Shiftable loads in industrial sector:
  - cement mills;
  - paper recycling;
  - thermal industrial loads that depend on cooling and heating;
- Curtailable and shiftable loads in residential sector:
  - cooling and heating appliances (e.g. for short periods, AC can be curtailable but for longer periods they become shiftable; the same can be applied to refrigerators and freezers);
- Shiftable loads in residential sector:
  - washing appliances;
- Aggregation is considered, with the role of the AGR being clearly defined.

***Note**: "Curtailable loads can offer demand flexibility without the need for rebound conditions, as they are non-shiftable. Shiftable loads can be moved at any time during the day, but their rebound conditions must be met, as they are uncurtailable"*
</td></tr>
<tr><td rowspan="5">FlexHub Eu-SysFlex</td><td rowspan="3">Congestion Management</td><td>Operational</td><td rowspan="5">

BUC PT-FlexHub Q-market:
- HV distribution grid resources (Wind farms 10-25MW, capacitor banks 4MVA).

BUC-PT FlexHub TLQ:
- HV-MV distribution grid resources (PV 12MW, Battery 480kW/360kWh).

BUCs FI-AP1, FI-AP2:
- LV distribution grid resources (400V) operated by the retailer (a retailer Battery and a PV connected at to 110kV -TSO/DSO-400kV/110kV).

BUC FI-RP:
- LV distribution grid resources (400V) operated by the retailer (a retailer Battery and a PV connected at to 110kV -TSO/DSO-400kV/110kV).

BUC DE-AP + DE+RP:
- All types of DER.

BUC IT-AP:
- DER, DSO assets (OLTC, Statcoms, Batteries) only used for DSO grid operation.

BUC IT-RP:
- DER, DSO assets (Statcoms and batteries) only used for DSO grid operation.
</td></tr>
<tr><td>ST</td></tr>
<tr><td>LT</td></tr>
<tr><td rowspan="2">Voltage Control</td><td>APM</td></tr>
<tr><td>RPM</td></tr>
<tr><td>FLEXICIENCY</td><td>Voltage Control</td><td>APM</td><td>

- The microgrid in the Spanish demo included:
  - PV canopies;
  - wind turbines;
  - a battery energy storage system;
  - a bidirectional electric vehicle charger;
  - peak consumption in the order of tens of kW.
- Aggregation is explicit for data support services; for energy support, although not explicit, if located at the same bus, aggregation could be possible.
</td></tr>
</table>

	Observability over the available flexbility		***Notes***: • *Some conclusions made following the analysis of the results from the demos:* ○ *"The installation of solar photovoltaic generators and the pair storage + PV generation in the analyzed buildings (the initial ones and the other added to the study), even reaching the maximum allowed power of solar modules, only produce light improvements in the grid in terms of losses reduction, devices loading and voltage. To reach more remarkable results, a wider spread of distributed resources must be made";* ○ *"To support the DSO in the operation of the distribution grid, the spread of solar photovoltaic facilities has to reach important levels. In the analyzed grid, about 50 % of penetration has to be reached to observe results reducing the loading of transformer and lines, improve voltage levels and reduce losses";* ○ *"Although the spread of distributed generation can support the operation of the grid, an excessive penetration of renewables could jeopardize it. In the analyzed grid, an installation of 60% respect the total power generates more problems than benefits. To avoid this problem and enable a higher introduction of renewable generation sources manageable inverters should be used providing flexibility to the system; It is proposed the use of a methodology similar to the developed in UC-7 where every prosumer would offer the DSO its possibilities of reducing its energy production to adapt it to operation state of the grid; The cost of this flexibility provided by the customer should be compensated at the price of the electric energy in the selected period";* ○ *"The discharge at full power of the storage systems of the buildings provide light improvements to the grid operation in terms of system losses, loading or voltage along the grid; To reach more remarkable results, a wider spread of distributed resources has to be made".*
FlexMart	Congestion Management	LT	• Average Belgian roof PV of 4kWp and average household consumption available for providing demand flexibility (up- and down-regulation).
GOPACS-IDCONS	Congestion Management	ST	• Demand side response (DSR), power generation and storage control; • All other types; ***Note:*** *GOPACS interacts via market platforms with whoever can offer flexibility (in the case of the ETPA platform: medium to small sized commercial customers to effectively become BRP).*
InteGrid	Congestion Management	ST LT	• Flexibility operators send control set-points to the home energy management systems (HEMS) at the LV level (local market). The Energy Services Platform, owned by the Flexibility Operator, gathers the information about all of their customers' available flexibility: ○ Domestic PV, storage (batteries) or other smart appliances; ○ Heat pumps; ○ Small scale generation at the LV level. • Flexibility operators can also shed loads at the MV level (global market): ○ Industrial loads; ○ Medium scale generation; ○ Other technologies capable of delivering flexibility.
Interflex	Congestion Management	ST	• Considered DER in the several demos include: ○ PV; ○ smart storage units; ○ EVs; ○ Demand Response (DR) involving active customers, performing modulation of controllable loads, while considering users' needs and expectations (e.g. comfort); • Characteristics from the Strijp-S (Eindhoven) living-lab: ○ former industrial district consisting of small-medium enterprises and apartment buildings; ○ flexibility is provided by several controllable distributed energy resources: ▪ 268kWp photovoltaic installation; ▪ 25kVA/315kWh battery energy storage system;

	Service Restoration	Islanding Operation	▪ 26 electric vehicle charge points of 22kW each; ○ these flexibility sources are clustered around 2 ML/LV substations; ○ inflexible loads are provided on those two substations by 3 apartment buildings (~350 apartments) and a parking garage. • Characteristics from the Nice Smart Valley (FR Demo): ○ a variety of flexibilities and activation channels were tested, including: ▪ residential appliances; ▪ dual-fuel assets (gas/electric); ▪ industrial process control; ▪ stationary batteries; ▪ one EV with V2G capacities • Aggregation is considered. Regarding the Strijp-S (Eindhoven) living-lab, a differentiation is made between commercial AGR (responsible for trading flexibility on a market level) and local AGR (responsible for ensuring that flexibility is locally available), both of which were active in multiple number at the demonstrator site.
INTERRFACE	Congestion Management	Operational	• Although not explicitly stated, the DER may include batteries, residential consumers flexible loads and distributed generation; • Aggregation is considered.
		ST	
		LT	
NODES	Congestion Management	Operational	• NODES is designed to operate a marketplace for any flexibility supplier irrespective of size; • Several flexible loads can be activated including smart homes with solar panels and batteries, electric vehicles and commercial and residential demand response customers.
		ST	
		LT	
Piclo Flex (and Piclo)	Congestion Management	ST	• Demand side response (DSR), power generation and storage control (Connection ≤ 11kV); • Generators are likely to be traditional generators powered by gas or diesel, supplemented by combined heat and power (CHP) systems, waste-to-power systems and wind farms; • Small-scale assets - with a capacity of less than 10kW; • Larger assets between 10-25MW; • The resources can be aggregated together into a single controllable unit of flexibility called a Flexible Unit (FU).
		LT	
	Observability over available flexibility		
SENSIBLE	Congestion Management	ST	• PV and flexible loads at the LV level; • Independent power producers at MV level; • Energy storage deployed at all levels on the electricity system; • Residential DER are controlled via Home Energy Management Systems (HEMS).
		LT	
	Voltage Control	RPM	

USEF	Congestion Management	ST	Flexibility from industrial, commercial and small and medium enterprise sectors: ○ Air conditioning; ○ Pool heaters; ○ Fan heaters; ○ Chillers; ○ Ground source heat pumps; ○ Irrigation pumps; ○ EV chargers; ○ Air handling units; ○ Electric heating; ○ Ultra-cold freezers. Flexibility from the farming sector: ○ Refrigerated crop storage; ○ Mechanical ventilation (standby generation to maintain ventilation which could be used to provide flexibility). Flexibility from the domestic sector: ○ Solar PV; ○ Battery storage systems; ○ Ground source heat pumps; ○ Electric vehicle charge points; ○ Time-of-use demand response (10% of peak demand).