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DELIVERABLE D4.3

Integration of Local Flexibility Market into the existing Electricity Trading Frameworks

Work Package:	**WP4 – Local Flexibility Business & Market Models**
Task:	**T4.3 – Investigation of LFM market models for TSO/DSO/Aggregator/Retailer collaboration**
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Executive Summary

The **PARITY project** aims to enable the set-up and operation of local flexibility markets at the distribution network level. Based on a smart contract enabled and blockchain based market platform, internet of things enabled flexibility management tools as well as innovative smart grid management tools, a local market framework will be defined and established. This creates value for a range of stakeholders including prosumers, DSOs and energy retailers. The business opportunities arising in this field will be identified and the resulting business models will be formulated and validated.

This report focusses on the development of the **local market design**, but also on the **integration** of the local market of PARITY **with the conventional electricity markets**. Furthermore, **gaps are identified** in terms of market structure, but also in terms of conventional cutting-edge technologies that enable the implementation of such a local market. Finally, it is the goal of this report to derive a **list of recommendations** to be considered for the further work in the PARITY project. These recommendations arise both from the defined market structure of PARITY and from the gaps identified.

The methodologic approach for this deliverable follows two parallel streams. The first one deals with market structure and the second with market-enabling technologies.

Market Structure

Firstly, **existing European market models** have been reviewed, disentangling the main concepts and creating a common understanding of it. Here, a three-step approach has been applied:

1) The **roles** of market participants and stakeholders have been defined in detail based on the role models from USEF and ENTSO-E. For each role, the **services** offered or requested have been identified.
2) The **markets** have been examined, where these players may participate, and also the **products** traded have been highlighted.
3) The most important mechanisms for utilising demand side flexibility as developed by USEF and ENTSO-E have been introduced.

In contrast to these well-established market models, the **PARITY market design** has been developed. Based on conventional discussions in scientific literature, five market design parameters have been introduced and a PARITY approach for each parameter has been proposed. These parameters are:

- Market participants
- Instruments for providing flexibility
- Market operator(s)
- Definition of the local scope of the market
- Coordination between flexibility requesting parties

This scheme then has been applied for defining the PARITY market design.

In PARITY, two novel markets are introduced: The Local Electricity Market (LEM) and the Local Flexibility Market (LFM). The **LEM** is facilitating P2P trading among prosumers and the platform is operated by the Local Electricity Market Operator (LEMO), a private competitive entity.

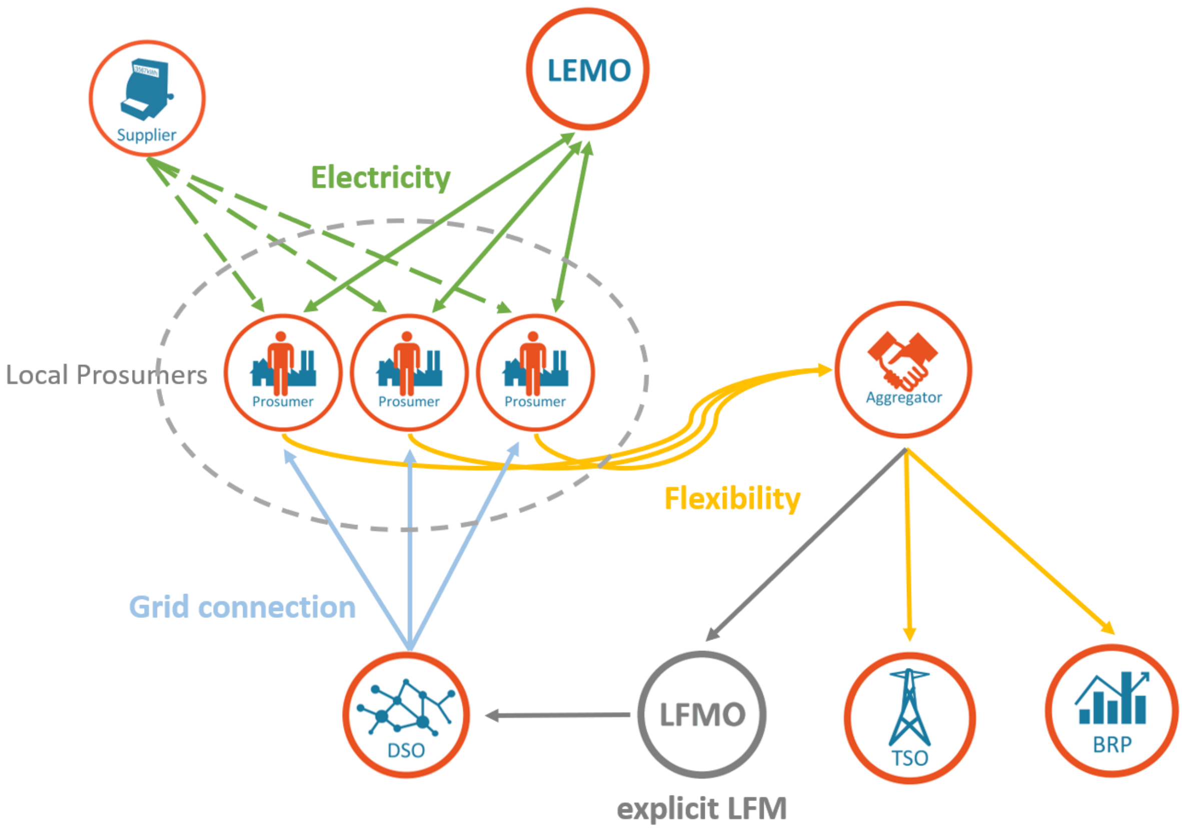
The **LFM** has the purpose to activate flexibility for the DSO's needs. As a first option, it can be implemented as an **explicit** market with a dedicated market platform, that is operated by the Local Flexibility Market Operator (LFMO), a regulated entity. On this platform aggregators can offer flexibility services to the DSO only.

As a second option, the **LFM** can also be **implicitly** integrated in the LEM. This means, that there is no market platform for the LFM and hence no LFMO. However, for activating this implicit LFM, the DSO imposes locationally varying grid prices to the prosumers. Those can react to this price signals by adapting their load and generation profile and their trades on the LEM accordingly and as a result avoid grid constraint violations.

An in-depth discussion about the **local scope** of the PARITY market framework has been performed with market participants, especially DSOs. In the explicit LFM, local tags are assigned to each flexibility bid in order to enable the DSO to solve grid constraint violations precisely when procuring flexibility. For the implicit LFM, this is tackled by the locationally varying grid prices.

The PARITY market framework is **governed by a Traffic Light Concept (TLC)**. In the GREEN phase the LEM is active as well as participation of the prosumers in ancillary services (AS) and wholesale (WS) markets through aggregators. In the YELLOW phase, the LFM is activated. In case of an explicit LFM, the dedicated market platform is opened and all other market activities (LEM, AS/WS participation) are paused. In an implicit LFM, those market activities continue, but the DSO imposes the locationally varying grid prices. Finally, in RED and BLACK state, the DSO takes over control and all market activities are stopped.

The following role model shows the PARITY market structure, developed in this deliverable.



Based on the assessment of conventional electricity market models and the definition of the PARITY market design, a **structural gap analysis** has been delivered, comparing the conventional electricity market models with the proposed PARITY market model and highlighting potential conflicts of interest between stakeholders. For identifying the structural gap, a SWOT analysis has been performed, examining the Strenghts and Weaknesses of the conventional model and the Opportunities and Threats of the PARITY market model. This has been achieved with the help of actual market participants within the project consortium. The main **conflicts of interest have been reported** between i) the DSO and the Retailer (e.g. prices, energy storage use), ii) the DSO and the Aggregator (e.g. rules, data exchange, grid stability) and iii) the Aggregator and Retailer (e.g. energy forecasting errors).

Technologies

For the stream on technologic issues, firstly a **literature review** on current cutting-edge solutions for implementing an LFM and P2P trading has been carried out. Then, an in-depth review of **previous research and pilot projects** has been performed. Two main categories of projects have been analysed:

- Prototype and highly innovative energy transactive frameworks, being deployed in a small or medium geographical scale with main focus on P2P energy transactions.
- Energy transactive frameworks which are in a near-commercial stage, referring mostly to local flexibility markets - being implemented in a large scale in several EU countries.

Following table shows the projects that have been analysed.

Project	Market(s) implemented		
	LFM	LEM	Participation in AS/WS market
Nodes	√		√
EPEX Spot Local Flexibility Market Platform	√		√
GOPACS	√		√
Piclo Flex	√		√
INTERFLEX	√	√	√
DRIvE	√	√	
CATALYST	√	√	√
eDREAM	√	√	
SmartNet	√		√
Brooklyn Microgrid		√	√
INVADE	√		

Based on these projects, a **technological gap** analysis has been delivered. For this analysis, a set of technological indicators has been introduced, which have been derived from the basic technological objectives and the main aspects that PARITY aims to address, as defined in the proposal of the project. They include:

- EV flexibility and smart charging
- Smart contract enabled transactions
- Human centric demand flexibility profiling and control
- Power-to-heat technologies for virtual thermal energy storage
- Smart grid monitoring and management

Then the related previous projects have been analysed according to these indicators. Serious technological gaps have been derived for almost all the specified indicators. For each identified gap, the final and probably most important outcome of the technological gap analysis is to provide trend-setting recommendations and give further technological directions that PARITY project could follow in order to make an attempt and explore the feasibility of covering the identified gaps.

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List of Acronyms and Abbreviations

Term	Description	Term	Description
AASS	Administration and Ancillary Services Section	HV	High Voltage
ADMM	alternating direction method of multipliers	HVAC	Heating, Cooling, Ventilation and Air Conditioning
ANM	Active Network Management	ICT	Information and Communication Technology
API	Application Programming Interface	ID	IntraDay
AS	Ancillary Service	IIoT	Industrial Internet of Things
BESS	Battery Energy Storage System	IIS	Infrastructure Information System
BRP	Balance Responsible Party	IoT	Internet of Things
CA	Control Area	IT	Information Technology
CEC	Citizen Energy Community	kW	Kilowatt
CHP	Combined Heat and Power (plant)	LEM	Local Energy/Electricity Market
CRO	Common Reference Operator	LFC	Load Frequency Control
CRP	Conditional Re-Profiling	LFM	Local Flexibility Market
CRP-2	Bi-directional Conditional Re-Profiling	LIDAR	LIght Detection And Ranging
CS	Coordination Scheme	LP	linear programming
DA	Day Ahead	LV	Low Voltage
DC	Data Centers / Direct Current	MCM	Market-Based Coordination Mechanism
DER	Distributed Energy Resource	MILP	mixed integer linear programming
DG	Distributed Generation	MO	Market Operator
DHW	Domestic Hot Water	MPC	Model Predictive Control
DLMP	Distribution Locational Marginal Price	MV	Medium Voltage
DNO	Distribution Network Operator	MW	Megawatt
DR	Demand Response	NLP	Nonlinear Programming
DSM	Demand Side Management	NPV	Net Present Value
DSO	Distribution System Operator	NRA	National Regulatory Authority
DSR	Demand Side Response	OTC	Over the Counter
EAN	European Article Number	P2P	Peer-to-Peer
EC	European Commission	PBC	Price-Based Control
EES	Electric Energy Storage	PEV	Plug-in Electric Vehicle
EEX	European Energy Exchange	PIT	Potential Islanding Time
EMS	Energy Management System	PV	Photovoltaics
ESCo	Energy Service Company	SGAM	Smart Grid Architecture Model
ETPA	Energy Trading Platform Amsterdam	SLA	Service Level Agreement
EV	Electric Vehicle	SRP	Scheduled Re-Profiling
GDPR	General Data Protection Regulation	SWOT	Strenghts Weaknesses Opportunities Threats
HMI	Human-Machine-Interface	T	Task

TE	Transactive Energy
TLC	Traffic Light Approach
ToU	Time-of-Use
TSO	Transmission System Operator
UC	Use Case
UI	User Interface
UPS	Uninterruptible Power Supply
V2G	Vehicle-to-Grid
V2H	Vehicle-to-Home
VPP	Virtual Power Plant
WP	Work Package

1. Introduction

The PARITY project aims to enable the set-up and operation of local flexibility markets at the distribution network level. The tools that will be developed in the project include:

- A smart contract enabled, blockchain based market platform which will facilitate both **peer-to-peer (P2P)** energy transactions as well as the **sell/purchase of flexibility to smart grid actors**.
- **Internet of things (IoT)** enabled **flexibility management tools** for Distributed Energy Resources (DER).
- **Smart grid monitoring and management tools** to enable the Distribution System Operator (DSO) to optimally manage the low voltage distribution network.

Facilitated by these tools, a well-functioning **local market framework** will be defined and established, creating value for a range of stakeholders including prosumers, DSOs and energy retailers. The business opportunities arising in this field will be identified and the resulting **business models** will be formulated and validated.

PARITY will demonstrate all its results in four **demonstration sites** with varying characteristics in terms of climatic zones, proliferation of RES and demand device types, regulatory frameworks and market codes as well as culture and environmental consciousness. The sites are located in Granada, Spain; Athens, Greece; Southern Sweden, and Massagno, Switzerland.

1.1 Scope and Objectives of the Deliverable

The main purpose of this report is to **disentangle the proposed market concept of PARITY** and to elaborate on the market design. Clarifying the market design is a crucial precondition for the further work in the project. Therefore, at all stages of this task, it was aimed at considering the intentions and perspectives of all consortium partners. As a result, a common understanding of the PARITY market framework was created.

This report focusses not only on the development of the local market design, but also on the **integration** of the local market of PARITY **with the conventional electricity markets**. Furthermore, **gaps are identified** in terms of market structure, but also in terms of current cutting-edge technologies that enable the implementation of such a local market.

Finally, it is the goal of this report to derive a **list of recommendations** to be considered for the further work in the PARITY project. These recommendations arise both from the defined market structure of PARITY and from the gaps identified.

1.2 Structure of the Deliverable

The deliverable starts with an overview of the methodology followed in this task (Chapter 2). Then, all the information and data collected for the subsequent analyses are presented:

- Chapter 3 provides a review of conventional European electricity market models and creates a common typology and a common understanding of the roles, interactions and mechanisms established in these models.
- In chapter 4 an overview of current cutting-edge technologies, relevant for the implementation of the PARITY market framework, is given.
- Chapter 5 presents detailed information of previous research and pilot projects, that deal with the implementation of LFMs or P2P electricity trading.

Based on this foundation, following analyses are carried out:

- After discussing the most important aspects and controversies of local flexibility/electricity markets, chapter 6 establishes the PARITY local market design.
- Chapter 7.1 shows the results of a gap analysis investigating aspects of market structure. Here, the perspectives of actual market participants such as DSOs, retailers and aggregators have been

considered, tackling gaps and potential conflicts of interest arising in the PARITY market structure.

- In chapter 7.2 a technological gap analysis is performed, identifying the gaps between cutting-edge tools that are developed in other projects and those that are envisioned in PARITY.

The key results of these in-depth analyses are finally concluded (chapter 8) and a list of recommendations for the further work in PARITY is derived (chapter 9).

1.3 Relation to Other Tasks and Deliverables

For this report, input was received from T4.1, which is about the identification of barriers for the proliferation of LFMs. Here, mainly barriers on market regulation and technology have been retrieved. By defining the market structure, T4.3 plays a central role in the early stage of the PARITY project. Therefore, this report delivers input for the remaining tasks of WP4. T4.2 builds on the market structure developed in T4.3 for defining smart contracts between market actors, whereas T4.4 uses it for formulating business models for them. Finally, T4.3 feeds into T5.2, where the PARITY market model is finalised and the technical implementation of the market platform starts (Figure 1).

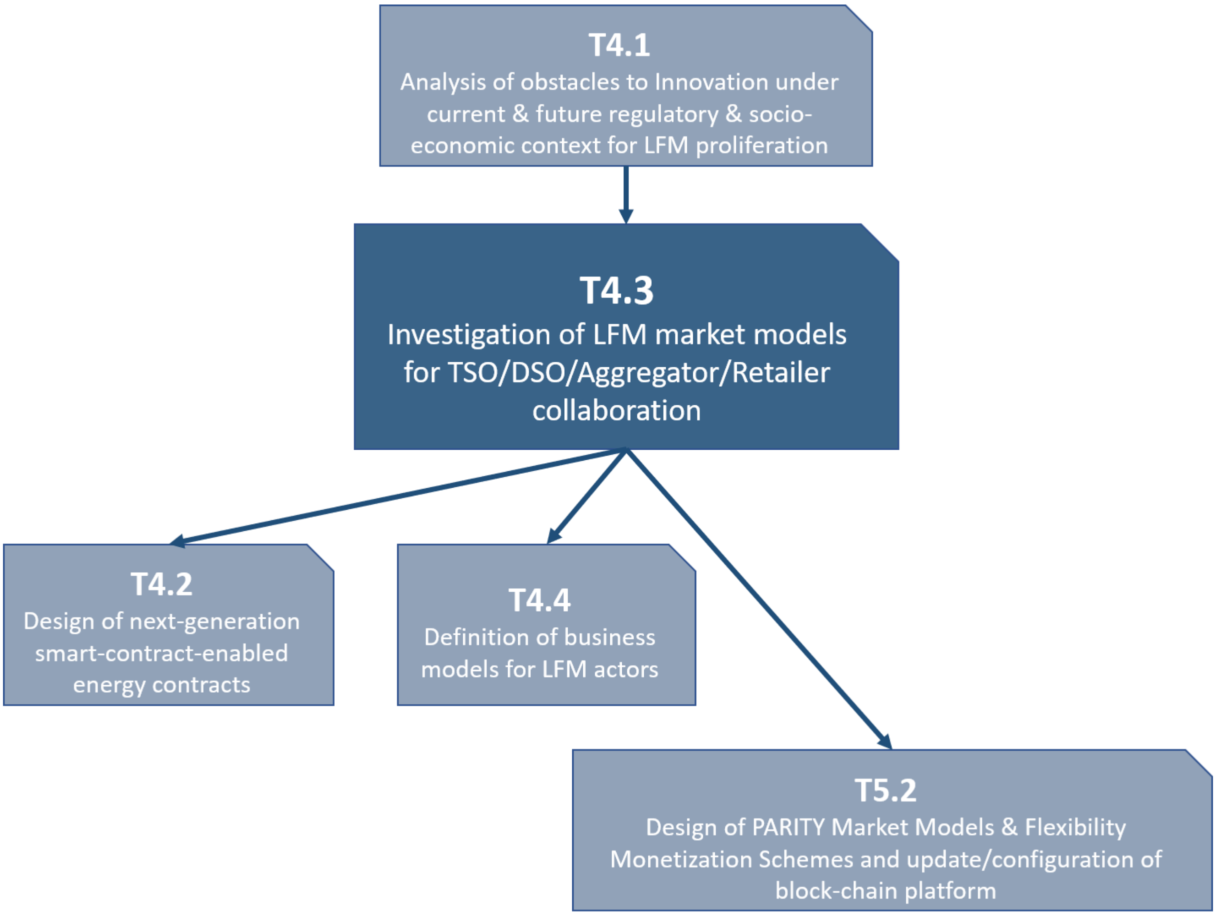

Figure 1. PERT diagram for T4.3

2. Methodology

The methodologic approach for this deliverable follows two parallel streams. The first one discusses market structures and the second one addresses market-enabling technologies.

2.1 Market Structure

Firstly, the aim is to **review existing European market models**, disentangle the concepts and create a common understanding of it. Here, following three-step approach is applied:

1) The **roles** of market participants and stakeholders are defined in detail based on the role models from USEF and ENTSO-E. For each role, the **services** offered or requested are identified.
2) The **markets** are examined, where these players may participate, and also the **products** traded are highlighted
3) The most important mechanisms for utilising demand side flexibility as developed by USEF and ENTSO-E are introduced.

In contrast to these well-established market models, the **PARITY market design** is developed. Based on current discussions in scientific literature, five market design parameters are introduced and the PARITY approach for each parameter is proposed. These parameters are:

- Market participants
- Instruments for providing flexibility
- Market operator(s)
- Definition of the local scope of the market
- Coordination between flexibility requesting parties

Then, a structural **gap** analysis is delivered, comparing the conventional electricity market models with the proposed PARITY market model and highlighting potential conflicts of interest between stakeholders. To identify the structural gap, a SWOT analysis is performed, examining the Strenghts and Weaknesses of the conventional model and the Opportunities and Threats of the PARITY market model. This was achieved with the help of actual market participants within the project consortium.

2.2 Technologies

For the stream on technologic issues, firstly a **literature review** on current cutting-edge solutions for implementing a LFM and P2P trading is carried out. Then, an in-depth review of **previous research and pilot projects** is performed. Two main categories of projects are analysed:

- Prototype and highly innovative energy transactive frameworks, being deployed in a small or medium geographical scale with main focus on P2P energy transactions.
- Energy transactive frameworks which are in a near-commercial stage, referring mostly to local flexibility markets - being implemented in a large scale in several EU countries.

Based on these projects, a **technological gap** analysis is delivered. For this analysis, a set of technological indicators is introduced, which have been derived from the basic technological objectives and the main aspects that PARITY aims to address, as defined in the proposal of the project. They include:

- EV flexibility and smart charging
- Smart contract enabled transactions
- Human centric demand flexibility profiling and control
- Power-to-heat technologies for virtual thermal energy storage
- Smart grid monitoring and management

Then the related previous projects are analysed according to these indicators. By highlighting the gap between the solutions deployed in previous projects and the solutions envisioned in PARITY, the innovation potential of PARITY is specified.

3. Conventional Electricity Market Models

The aim of this chapter is to review the conventional European electricity market models and, as a result, create a common understanding of the roles, interactions and mechanisms established in these models. This chapter serves as a foundation for developing a novel local market model within the framework of PARITY. For this purpose, an extensive literature review has been carried out, examining market concepts addressed in scientific works as well as guidelines from stakeholder organisations. A specific focus has been laid on widely used models of USEF, and ENTSO-E. USEF is a non-profit partnership of different companies from the smart energy industry. It offers a comprehensive framework based on their Flexibility Chain, specifically defined to foster the utilisation of demand side flexibility (USEF 2015). ENTSO-E, European Network of Transmission System Operators for Electricity, has developed its Harmonised Electricity Market Role Model, providing an analytical and exhaustive description of roles in the European electricity system (ENTSO-E 2019). Evaluating these widely used models, a sound integration of the PARITY concept into the conventional market structure can be achieved.

This chapter is organised as follows: At first, essential definitions are discussed and clarified (section 3.1). Then, the roles of market participants and stakeholders are defined in detail as well as the respective services they offer or request (section 3.2). Based on that, the markets are examined, where these players may participate, and also the products traded are highlighted (section 3.3). Finally, the most prominent mechanisms for utilising demand side flexibility as developed by USEF and ENTSO-E are introduced (section 3.4).

3.1 Definitions: Flexibility, Products and Services

Electrical **energy** can be referred to as a commodity that can be traded and used by end-consumers for operating electric devices. In contrast, **flexibility** is defined as the possibility of adjusting patterns of generation and consumption in reaction to a signal (price or activation signal) to contribute to different services (EURELECTRIC 2014). From a technical perspective, flexibility can be seen as a power modification and is described by following 5 attributes (Villar et al. 2018):

1. Direction (up or down)
2. Rate of change (power capacity)
3. Starting time and trigger
4. Duration
5. Location

Flexibility can be provided either as a **product**, for example when an aggregator sells flexibility to another market participant (perspective of flexibility source), or as a **service**, when the market participants buys flexibility from an aggregator and utilises it (perspective of flexibility requesting party). Even though there is a fine line between flexibility products and services, the main difference between them stems from the fact that the same product can turn into different services depending on the participant and how it wants to utilise them once the flexibility has been bought. In this sense, flexibility products can be traded on explicit markets, whereas services can be created from flexibility in general, no matter if it was activated explicitly or implicitly (Jin et al. 2020, Belhomme et al. 2009).

The definition of flexibility **services** therefore **depends on the specific needs of the parties** requesting them (such as TSO, DSO and BRPs), whereas the definition of flexibility **products depends on the market** where they can be traded.

When delivered as a **product**, there are three possibilities, as shown in Table 1. The product definition depends on the market where the flexibility is traded. In this work, a rough differentiation between **unconditional products** and **conditional products** is applied for describing the flexibility markets in chapter 3.3.

Table 1. Classification of flexibility products (Source: Jin et al. 2020, Belhomme et al. 2009)

Flexibility product	Conditionality	Typical example
Scheduled reprofiling (SRP)	Unconditional (obligation)	The aggregator has the duty to provide a specified power adjustment at a defined time for a defined duration
Conditional reprofiling (CRP)	Conditional (real option)	The aggregator must have the capacity to provide a specified power adjustment during a defined duration. The delivery is called upon by the buyer of the flexibility
Bi-directional conditional reprofiling (CRP-2)	Conditional (real option)	The aggregator must have the capacity to provide a specified power adjustment during a defined duration in a bi-directional range [−y, x] MW. The delivery is called upon by the buyer of the flexibility

Instead, the type of flexibility **service** depends on the flexibility requesting party (FRP) utilising the flexibility. The flexibility services are described for each market participant in chapter 3.2.

3.2 Roles and Services

In this section the roles of participants and stakeholders in the European electricity market framework are analysed. Each sub-section starts with a definition of the specific role and its main characteristics. Then, related terms are highlighted and a clear distinction between these terms is provided. In this way, the use of ambiguous terms is avoided and a clear discussion of further concepts can be facilitated. Finally, the services offered or requested by each role are analysed.

Note, that terms printed in **bold** are discussed in a dedicated section, whereas terms printed in *italics* are briefly defined as related terms.

3.2.1 Prosumer

The word prosumer is derived from the words *producer* and *consumer*. A prosumer can be regarded as “an *end-user* that no longer only consumes energy, but also produces energy”. There is no distinction between residential, SME or industrial entities. They are all referred to as prosumers (USEF 2015).

In the sense of ENTSO-E (2019) a prosumer is a party connected to the grid combining the roles of a *consumer* and a *producer*. For practical reasons, when referring to prosumers in general, this may also include pure *consumers* without production units or vice versa small-scale *producers* without significant consumption.

Prosumers are the parties who operate **Distributed Energy Resources (DERs)**. In case *end-users* and *building/facility owners* are not the same entity, conflicts of interest may arise (e.g. in terms of comfort or energy efficiency).

Related terms:

- *Consumer:* A party that consumes electricity connected to the grid (ENTSO-E 2019).
- *Producer:* A party that produces electricity connected to the grid (ENTSO-E 2019).
- *Building/facility owner:* Person or entity possessing title to a building/facility.
- *End-user:* Person or entity occupying a building/facility and consuming the final energy.
- *Facility manager:* Dedicated to ensure functionality, comfort, safety and efficiency of a building/facility. This may be an external professional or internal staff of the organisation occupying the building/facility.
- *Customer:* “A person or an organisation that buys a product or service” (Camebridge 2020). This is not necessarily the same as a *consumer*, but depends on the product or service.

Flexibility services:

On the one hand, a prosumer (or more specifically its **DERs**) is a source of flexibility. This demand side flexibility or D*istributed Generation* can be bundled by an **aggregator**, creating flexibility services to be sold to a **flexibility requesting party (FRP)** (cf. section 3.2.4).

On the other hand, prosumers can receive a range of flexibility services (Figure 2). These services are provided by an **Energy Service Company (ESCo)** and enable energy optimization for the prosumer behind the meter. The most relevant services are Time-of-Use (ToU) optimization (load shifting from high-price intervals to low-price intervals), kWmax control (reduction of maximum load/peak shaving) and self-balancing (e.g. maximising self-consumption of a generation unit). Another service could be controlled islanding during grid outages increasing the availability of power supply for the prosumer in such a situation.

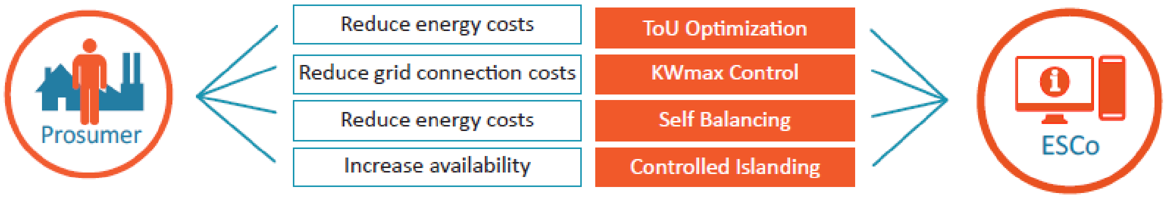

Figure 2. Flexibility services requested by prosumers (Source: USEF 2015, adapted)

3.2.2 Distributed Energy Resource (DER)

DERs typically include controllable loads, *distributed generation* and energy storage (Jin et al. 2020). Therefore, DER means the technical unit that is able to provide flexibility of any kind as a decentralised source. DERs can be operated by individual prosumers or as standalone facilities, such as community battery storage or community photovoltaic (PV) plants.

Related terms:

- *Active Demand & Supply (ADS):* "Represents all types of systems that either demand energy or supply energy and which can be actively controlled" (USEF 2015).
- *Distributed Generation:* Distributed generation is an electric power source connected directly to the distribution network (in front of the meter) or on the *customer's* site (behind the meter (Ackermann, Andersson and Söder 2001).
- *Device:* commonly understood in this context as a technical unit consuming or producing electrical energy. The term does not imply any flexibility potential or any ability to be actively controlled.

Flexibility services:

As DERs represent technical units, the services offered or requested by DERs are the same as for **prosumers**.

3.2.3 Energy Service Company (ESCo)

An ESCo offers energy related services to **prosumers** (Klaassen and Van der Laan 2019) or generally to parties connected to the grid (ENTSO-E 2019). However, it is crucial to note that, unlike the role of an **aggregator**, the ESCo is not active (nor exposed) to wholesale or balancing markets (Klaassen and Van der Laan 2019). ENTSO-E (2019) notes, that ESCos are not directly active in the energy value chain or the physical infrastructure itself.

In the literature, the term ESCo is defined very broad, but often closely related to providers of energy efficiency services such as Energy Performance Contracting or Energy Supply Contracting, where the ESCo accepts some degree of risk for energy efficiency improvements (JRC 2016). Thererfore, service providers offering specifically flexibility services behind the meter can be also referred to as *Flexibility Service Companies (FLESCo)* (Leutgöb et al. 2019). However, in this report we use the broad definition of an ESCo from ENTSO-E and USEF. According to that, ESCos may offer both energy services as well as flexibility services. Here, the difference between both needs to be highlighted. Energy services are in general those which (potentially) affect the amount of energy consumed or produced by the prosumer. Flexibility services specifically focus on deliberate (time limited) changes to the 'normal' energy profile (Klaassen and Van der Laan 2019).

Flexibility services:

As an ESCo is a service provider, it provides to the **prosumer** the flexibility services listed above in Figure 2. Note, that these flexibility services enable a **prosumer** to respond to price signals either from the energy **supplier** or the **DSO**, as shown in Figure 3.

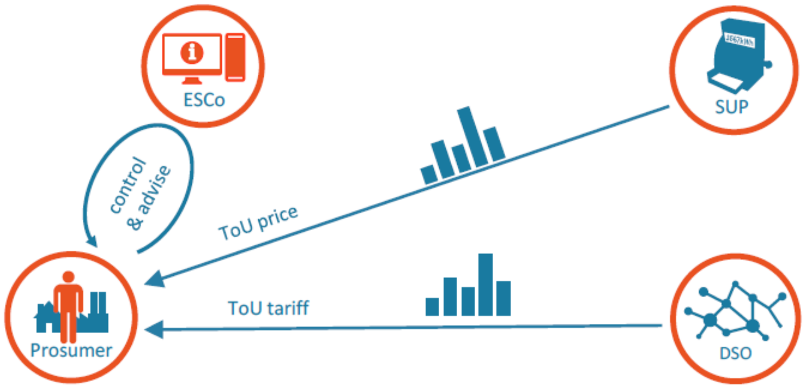

Figure 3. Flexibility services provided by an ESCo as a response to price signals (Source: Van der Veen et al. 2018)

Energy services:

The energy services provided by ESCos are manifold including financing services (e.g. Energy Performance Contracting), energy efficiency monitoring or advisory services and many more. In the context of local communities, the ESCo role can also facilitate peer-to-peer (P2P) energy trade among **prosumers** in the sense of running a shadow administration, which is separated from the administration of a **supplier/BRP** and therefore has no official role in the organisation of the electricity system (Klaassen and Van der Laan 2019)[1].

3.2.4 Aggregator

The role of the aggregator is to accumulate flexibility from **prosumers** and their **DERs** and sell it to *Flexibility Requesting Parties (FRPs)*. The aggregator's goal is to maximise the value of that flexibility by providing it to the party that has the most urgent need and therefore offers the highest price. The aggregator is also responsible for the invoicing process associated with the delivery of flexibility. The aggregator and its **prosumers** agree on commercial terms and conditions for the procurement and control of flexibility (USEF 2015).
Depending on the aggregator model applied, the aggregator needs to act as a **Balance Responsible Party (BRP)**. More specifically, this depends on the contractual arrangements in the aggregator model and how these affect the balance responsibility of the different actors. For a detailed discussion on that, refer to the 'USEF Workstream on aggregator implementation models' (De Heer and Van der Laan 2017). However, for an aggregator providing flexibility services to a **TSO**, this has to be routed via a **BRP** (or a *BSP* which is assigned to one or more **BRPs**), according to USEF (2015).

[1] cf. chapter 3.3.4

In addition to this core element, an aggregator may also assume the role as a facilitator for P2P trading among **prosumers**, as outlined in the EU Renewable Energy Directive (2018)[2]. For further details on P2P trading refer to section 3.3.4.

An aggregator may be an independent market participant, but this role may also be assumed by another stakeholder on the free market, such as a traditional **supplier**.

Related terms:

- *Flexibility Service Provider (FSP):* Market participant offering services using flexible resources. The *FSP* is a generic role that delivers a flexibility service to the specific *Flexibility Requesting Party*. Therefore, an FSP can represent a **BRP** or *BSP*. An aggregator providing flexibility services to an *FRP* can therefore be referred to as an *FSP* (USEF 2015).
- *Flexibility Requesting Party:* A party interested in using flexibility for a specific service. USEF (Klaassen and Van der Laan 2019) defines the **TSO, DSO** and **BRP** as *FRPs*.

Flexibility services:

As shown in Figure 4, an aggregator is an intermediary between the **prosumer** (with their **DERs** as sources of flexibility) and the *Flexibility Requesting Parties (FRPs)*. This means, it acquires flexibility from **prosumers** in order to deliver flexibility services to the FRPs.

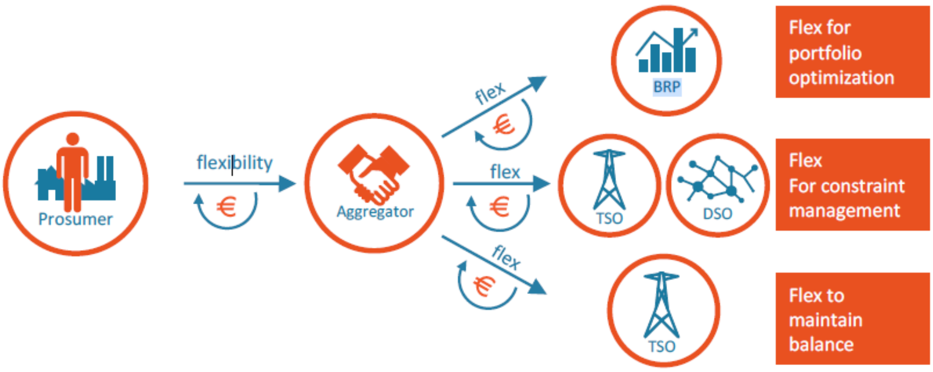

Figure 4. Aggregator as an intermediary between prosumers and Flexibility Requesting Parties (Source: Van der Veen et al. 2018)

3.2.5 Supplier

"The role of the supplier is to source, supply, and invoice energy to its *customers*. The supplier and its *customers* agree on commercial terms for the supply and procurement of energy" (USEF 2015). It is a specialisation of the *trader* role as it exchanges electricity with **prosumers** on the **retail market** (Klaassen and Van der Laan 2019).

A key principle of the European liberalised energy market is the free choice of supplier, manifested in Article 4 of the EU Directive on common rules for the internal market for electricity (2019)[3]. This means, that all *consumers* and **prosumers** have the right to select their preferred electricity supplier. Also, the structure of offered tariffs and other conditions of delivery are not regulated and can be agreed between the contractual parties.

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[2] Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources

[3] Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity

The supplier has to be part of a *balance group* with a **BRP**, the latter being responsible for balancing supply and demand of the energy sourced and sold by the supplier. Therefore, the **BRP** (contracted by the supplier) is responsible also for the imbalances arising from deviations between the supplier's prognosis and the actual load profiles of the **prosumers**.

Related terms:

- *Trader:* A party that is selling or buying electricity (ENTSO-E 2019) with a view to profit (e-Control 2013). USEF (Klaassen and Van der Laan 2019) refers to traders as buyers or sellers on the **wholesale market**.
- *Retailer:* A *trader* selling electricity at the **retail market**, therefore may be used as a synonym for **supplier**.
- *Utility*: An ambiguous term referring to a company that engages in the generation, transmission, and distribution of electricity (Snavely King Majoros, s.a). In the US, it often refers to a grid operator (Direct Energy, s.a.)
- *Producer:* A party connected to the grid that produces electricity (ENTSO-E 2019). Other than the **supplier**, the producer role is not a participant on the retail market, as it is not trading and invoicing electricity.

Flexibility services:

In terms of flexibility services, a supplier may assume the role of an **aggregator** or an **ESCo** and provide the respective services.

As the balance responsibility of the supplier is transferred to a **BRP**, the flexibility needs for balancing the balance group apply to the **BRP**.

Energy supply services:

Energy supply with electricity sourced from centralised power plants is the traditional core business of suppliers. In the concept of a P2P-supplier, a traditional centralised **supplier** can facilitate P2P trading among **prosumers** via a dedicated platform. By providing this P2P supply service, the roles of the **supplier** and the **BRP** remain with the traditional **supplier** running the platform (Klaassen and Van der Laan 2019).

3.2.6 Balance Responsible Party (BRP)

A BRP is responsible for actively balancing supply and demand for its portfolio of *producers*, **suppliers**, wholesale *traders*, **aggregators**, and **prosumers**, with the means granted by those actors. In principle, every party connected to the grid is responsible for their individual balance position and hence must ensure that the exact amount of energy consumed/produced is sourced/supplied in the electricity system (USEF 2015).

In order to guarantee this, each party connected to the grid has to be a member of a *balance group (BG)*. The *BG* tries to minimise its internal imbalances. For the remaining imbalances either flexibility can be purchased on the wholesale market or otherwise imbalance costs are incurred by the *Imbalance Settlement Responsible* (cf. also section 3.2.8). For distributing costs resulting from imbalances within the *BG*, there are individual agreements between *BG* members.

The prosumer's balance responsibility is generally transferred to the **supplier**, which is contracting a BRP. Therefore, the BRP holds the imbalance risk for each **prosumer** in its portfolio (USEF 2015).

Related terms:

- *Balance group (BG):* A group of parties connected to the grid with a balance responsibility. They reflect commercial flows in the energy systems and enable correct allocation of imbalance costs. The party representing the group's balance responsibility as a whole is the BRP (e-Control 2013; ENTSO-E 2019).
- *Balance group representative:* An equivalent term for BRP (e-Control 2013).

- *Balancing Service Provider (BSP)*: A party being able to provide balancing services to the connecting TSO (or LFC/CA operator) (ENTSO-E 2019, Glowacki 2020b). Each bid from a BSP is assigned to one or more BRPs. USEF (Klaassen and Van der Laan 2019) therefore considers a BSP as a specific type of BRP. Note that the BSP role is not distinguished in all EU member states.
- *Imbalance Settlement Responsible*: "A party that is responsible for settlement of the difference between the contracted quantities and the realized quantities of energy products for the BRPs" (ENTSO-E 2019).
- *Flexibility Requesting Party:* A party interested in using flexibility for a specific service. USEF (Klaassen and Van der Laan 2019) defines the **TSO, DSO** and **BRP** as *FRPs*.

Flexibility services:

Figure 5 shows the flexibility services for BRPs. They are mostly related to portfolio optimisation at the supply side and aim at reducing sourcing costs. Portfolio optimisation can include optimized procurement of electricity on the wholesale market (day-ahead or intraday optimisation), generation optimisation (optimising the behaviour of central power plants), self-balancing (reduction of imbalances within a balance group) and passive balancing (BRP receives remuneration from the TSO for deviating from its schedule). The latter is only applicable in some markets (refer to USEF 2015 for more details).

Figure 5. Flexibility services requested by BRPs (Source: USEF 2015)

3.2.7 Distribution System Operator (DSO)

In the EU Directive on common rules for the internal market for electricity[4], a DSO is defined as "a natural or legal person who is responsible for operating, ensuring the maintenance of and, if necessary, developing the distribution system in a given area and, where applicable, its interconnections with other systems, and for ensuring the long-term ability of the system to meet reasonable demands for the distribution of electricity".

From the viewpoint of the Council of European Energy Regulators (CEER), DSOs must act as neutral market facilitators and in the public interest when it comes to new services in the field of demand side flexibility. It is important to minimise the risk of DSOs making use of their natural monopoly position. Therefore, DSOs should not be allowed to be active in areas that can be opened to competition among market participants. DSOs should be involved mainly by procuring flexibility resources in order to perform congestion management and voltage control. From CEER's perspective, DSOs generally should make use of local flexibility resources at distribution system level, but this may require intermediaries such as aggregators (CEER 2019).

In terms of demand-side flexibility, USEF defines the DSO activities as follows (Klaassen and Van der Laan 2019):

[4] Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity

1) check whether demand-side flexibility activation within its network can be safely executed without grid congestion and
2) purchase flexibility from the aggregators to execute its system operations tasks

Related terms:

- *Meter data company:* The Meter Data Company is responsible for collecting and validating meter data. It plays a role in the flexibility settlement process and the wholesale settlement process. In many countries, this role is assumed by the DSO (Klaassen and Van der Laan 2019).
- *Flexibility Requesting Party:* A party interested in using flexibility for a specific service. USEF (Klaassen and Van der Laan 2019) distinguishes the **TSO, DSO** and **BRP** as *FRPs*.

Flexibility services:

Figure 6 shows the flexibility services requested by the DSO. For a detailed discussion on all services, please refer to USEF (2015). Following two services are mostly discussed in relation to demand side flexibility:

- **Voltage Control:** Voltage problems occur i.e. due to high penetration of fluctuating PV generation units. If PV production is high due to sunny weather conditions, voltage limits in specific points of the distribution grid may be exceeded.
- **Congestion Management (CM):** Congestions arise from high loads (in terms of power) that need to be transported by the grid. Distribution grids are mostly not designed for highly fluctuating loads caused by **DERs** (EVs, heat pumps, PV etc.).

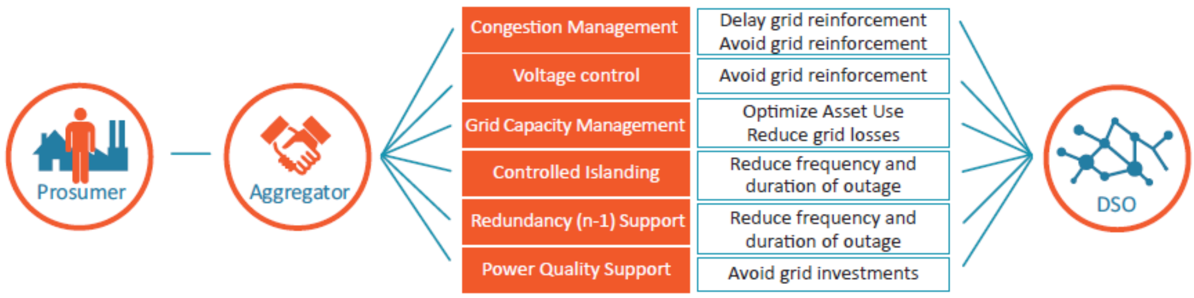

Figure 6. Flexibility services requested by DSOs (Source: USEF 2015)

3.2.8 Transmission System Operator (TSO)

The role of the TSO is to transport electricity from centralised *producers* to distributed industrial prosumers and **DSOs** using its high-voltage grid. The TSO is responsible for the long-term ability of the high-voltage grid to meet electricity transmission demands. Also, the TSO is keeping the system in balance by deploying regulating capacity, reserve capacity, and incidental emergency capacity. The TSO can purchase flexibility indirectly via the **BRP**/*BSP* from **aggregators** active within its area (USEF 2015).

Related terms:

- *Flexibility Requesting Party:* A party interested in using flexibility for a specific service. USEF (Klaassen and Van der Laan 2019) defines the **TSO, DSO** and **BRP** as *FRPs*.

- *Control Area (CA) operator, Load Frequency Control (LFC) operator:* The party responsible for maintaining load frequency within a defined range. The latest version of the Harmonised Electricity Market Role Model (ENTSO-E 2019) describes this role as a Load Frequency

Control (LFC) operator, whereas previous versions mention this role as Control Area (CA) operator (ENTSO-E 2018). Typically, this role is performed by a **TSO** (ENTSO-E 2019).

- *Imbalance Settlement Responsible*: A party that is responsible for settlement of the difference between the contracted quantities and the realized quantities of energy products for the BRPs (ENTSO-E 2019). This role can also be defined as a *Clearing and Settlement Agent (CSA)* or *balance group coordinator* which is an entity with an official license for organizing, clearing and settling the process of electricity balancing[5] (e-Control 2013).

Flexibility services:

As shown in Figure 7, the following flexibility services are requested by the TSO (or the LFC/CA operator) (Van der Veen et al. 2018 and USEF 2015):

- **Primary Control** (Frequency Containment Reserve FCR): FCR aims to contain any system frequency deviation to within a pre-defined range after an incident. Typically, activation time in (milli)seconds is required.
- **Secondary Control** (Automatic Frequency Restoration Reserve aFRR): aFRR aims to restore system frequency and is defined as a reserve which can be activated by an automatic control device.
- **Tertiary Control** (Manual Frequency Restoration Reserve mFRR): Although the objectives of mFRR and aFRR are the same, the requirements for the two services are different. mFRR generally has a longer duration and larger ramp rate, with fewer measurement and prediction updates required.
- **Replacement Reserve** RR: RR replaces the activated reserves to restore the available reserves in the system or for economic optimization. In general, RR has longer duration and slower ramp rate compared to mFRR.
- **Congestion Management** (section 3.3.2.1.4)
- **Voltage control** (section 3.3.2.1.2)
- **System restoration/Black start capability** (section 3.3.2.1.3)
- **Capacity mechanisms** (section 3.3.3.1, 3.3.3.2)
- **Strategic reserve** (section 3.3.3.3)

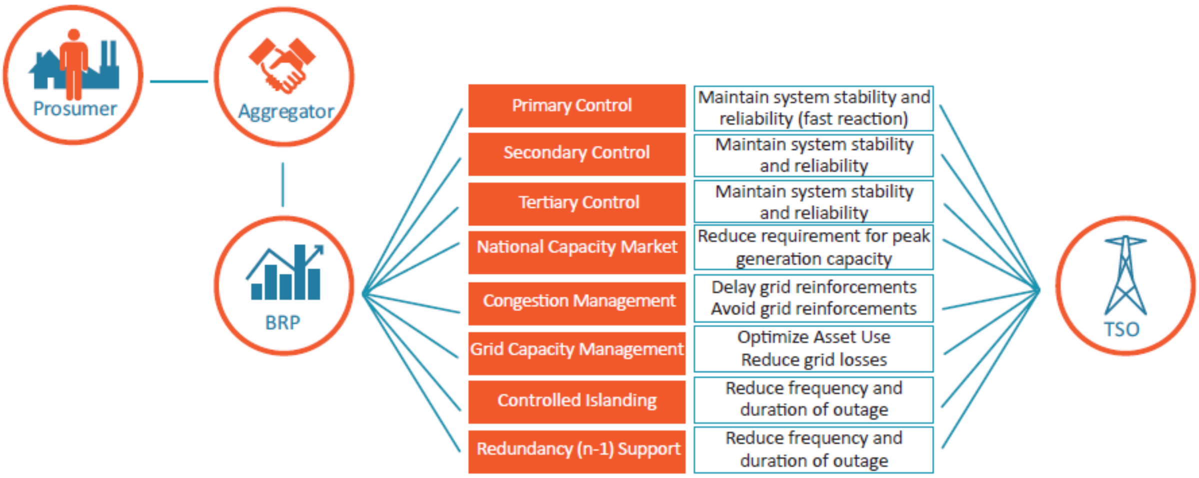

Figure 7. Flexibility services requested by a TSO (Source: USEF 2015)

[5] For a definition of electricity balancing see section 3.3.2.1.1

3.2.9 Market operator (MO)

A MO is defined as "a party that provides a service whereby the offers to sell electricity are matched with bids to buy electricity" (ENTSO-E 2019).

MOs are required for operating market platforms of organised markets, such as the balancing market or the European Energy Exchange (Spot and Forward Market). Trading outside of organised markets (Over the Counter – OTC) does not require a MO.

3.2.10 National Regulatory Authority (NRA)

The NRA of each member state plays an important role for the development of electricity markets. It is responsible for the definition and further development of the market rules that define the tariffs for the grid. The latter is especially relevant, as grid tariffs may represent enablers or barriers for the activation of demand side flexibility, depending on their design. Moreover, grid tariffs have the potential to establish implicit markets for flexibility via dynamic price signals.

3.3 Markets and Products

In this section, existing as well as potential markets where flexibility could be traded are analysed. The flexibility services introduced above are mapped to each market. If applicable, also the types of flexibility products traded on these markets are specified.

3.3.1 Wholesale

Wholesale electricity markets are markets where electricity is traded before being delivered to *consumers*. Increasingly, they are being opened also for the participation of *consumers* and **prosumers**. In practice this means, that on the wholesale market *producers*, larger **prosumers** (e.g. energy intensive industry), **suppliers**, **aggregators** and other *traders* can trade electricity.

This can happen either on the European Energy Exchange (EEX) or over the counter (OTC). The EEX is a standardised and organised market and is divided into

- the forward or futures market (where participants can settle a price to be paid later in time, e.g. six months)
- and the spot market (Day-ahead and Intraday).

OTC trading may be performed via an intermediary/broker, or through direct bilateral trading without an intermediary (CRE 2019).

Flexibility is traded on the wholesale market among **BRPs**. As described in section 3.2.6, all market participants have to be members of a *BG*, represented by a **BRP**. This means, the balance responsibility of each market participant mentioned above is transferred to a **BRP** role. Therefore, the market participants can offer or procure flexibility according to their needs on the wholesale market via their **BRPs**.

Prices on the wholesale market take into account flexibility needs from the perspective of power generation (e.g. due to fluctuating renewable energy sources). However, the wholesale market does not consider the status of the grid, but trades may affect physical grid operation (e.g. by causing congestions).

Flexibility products:

On the wholesale market actual dispatched loads are traded. According to the product definition in section 3.1, this corresponds to **unconditional (SRP)** products (energy-only market). Flexibility can be traded in terms of positive energy (supply of energy/reduction of consumption) or negative energy (consumption of energy/reduction of supply).

Flexibility services:

The flexibility services traded on the wholesale market are related to the **BRP's** needs and therefore mainly include portfolio optimization.

3.3.2 Ancillary Services and Congestion Management Services

This section describes markets for the procurement of services that are necessary in order to properly and securely operate transmission or distribution grids.

Ancillary services (AS) have been initially defined in article 2(17) of the Directive on common rules for the internal market for electricity (2009)[6] as services "necessary for the operation of a transmission or distribution system". In line with this broad definition, dena (Agricola et al. 2014) summarises following four main categories of AS:

- Frequency control
- Voltage control
- System restoration (after grid fault)
- System control (e.g. congestion management)

However, with the recast of the aforementioned directive, the EU Directive on common rules for the internal market in electricity (2019)[7], **excludes congestion management (CM) from the definition of AS**, highlighting that "ancillary service means a service necessary for the operation of a transmission or distribution system, including balancing and non-frequency ancillary services, but not including congestion management". According to this definition frequency AS include frequency control services, whereas non-frequency AS include voltage control and black-start capability (system restoration) among others. Since this is a rather recent change in the definition, services for CM are also often mentioned as part of AS (Glowacki 2020a).

USEF (Van der Veen et al. 2018) distinguishes between balancing services (frequency control) and constraint management services (voltage control, congestion management etc.) but mentions that the term ancillary services can be used for referring to both. Another term often used for summarising all these services necessary for grid operation is 'system services' (e.g. Elia 2020).

In the following sections different markets are described, where AS or CM services are traded. At first markets for procuring these services on TSO level are described, followed by those on DSO level.

3.3.2.1 TSO Level

Markets for AS and CM at **TSO** level are currently mostly operated by the **TSO** itself (or the *LFC/CA operator*). Developing such markets with a third-party independent **market operator (MO)** has been recently tested in some trials (Schittekatte and Meeus 2020).

3.3.2.1.1 Balancing Market

According to an EU Commission Regulation[8] 'electricity balancing' means "all actions and processes, through which **TSO**s ensure, the maintenance of system frequency within a predefined stability range." Therefore, the **balancing market** is the final platform, through which the **TSO**s settle any deviations between demand and supply remaining after the closure of intraday wholesale markets and after the determination of the final schedules (Glowacki 2020c).

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[6] Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity

[7] Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity

[8] Commission Regulation (EU) 2017/2195 of 23 November 2017 establishing a guideline on electricity balancing

In other words, on the balancing market so-called “control energy” is procured by the **TSO** or the responsible *LFC* or *CA* operator. Consequently, control energy describes the total need for flexibility products and comprises the net imbalance among all balance groups (e-Control 2013).

There may be different approaches on how to distribute the costs arising from the different flexibility services such as FCR, aFRR and mFRR (see below). In Austria, for instance, the costs for tertiary control (mFRR) are billed to the **BRP**s according to their individual imbalance, as imbalance costs. In order to minimise their imbalance costs, **BRP**s may procure flexibility by trading on the wholesale market. Costs for primary control (FCR), in contrast, are charged to large *producers* and for secondary control (aFRR) an intermediate approach is applied (e-Control 2013).

A party offering flexibility on the balancing market can be referred to as a **BSP**. Each bid from a BSP is assigned to one or more **BRP**s (Glowacki 2020b).

Related terms:

- *Control Energy Market:* the balancing market is sometimes also called Control Energy Market, as the flexibility procured there is also called control energy.
- Trading of *imbalances*/*balancing energy*: Note that BRPs trading flexibility for minimising their imbalance costs (this is sometimes called trading of balancing energy) comprises transactions on the wholesale market, not at the balancing market in this sense.

Flexibility services:

On the balancing market, following flexibility services are procured (Van der Veen et al. 2018 and USEF 2015):

- **Primary Control (Frequency Containment Reserve FCR):** FCR aims to contain any system frequency deviation to within a pre-defined range after an incident. Typically, activation time in (milli)seconds is required. Remuneration between the TSO (or LFC/CA operator) and the BSP is based on availability, and optionally on the activated energy.
- **Secondary Control (Automatic Frequency Restoration Reserve aFRR):** aFRR aims to restore system frequency and is defined as a reserve which can be activated by an automatic control device. Remuneration is mostly by means of a combination of availability and energy.
- **Tertiary Control (Manual Frequency Restoration Reserve mFRR):** Although the objectives of mFRR and aFRR are the same, the requirements for the two services are different. mFRR generally has a longer duration and larger ramp rate, with fewer measurement and prediction updates required. Only energy remuneration or a combination of energy and availability remuneration are common.
- **Replacement Reserve RR:** RR replaces the activated reserves to restore the available reserves in the system or for economic optimization. In general, RR has longer duration and slower ramp rate compared to mFRR. Remuneration can be energy-based or a combination of energy and availability remuneration.

Flexibility products:

From an analytical perspective, two different balancing market mechanisms apply (Glowacki 2020c):

- *Balancing capacity market:* The BSP agrees to keep available a specific capacity and to submit corresponding flexibility bids to the TSO (or LFC/CA operator).
- *Balancing energy market:* The TSO (or LFC/CA operator) activates these contracts concluded in the balancing capacity market, if required.

Therefore, as described above for each service, the flexibility products traded on the balancing market are **unconditional** (SRP **-** energy based) or **conditional** (CRP/CRP-2 – energy and availability based).

3.3.2.1.2 Voltage Control

The **flexibility service** of voltage control in the transmission grid is mainly realised by controlling larger power plants by means of reactive power supply. The reactive power demand of a grid section must be supplied by local points of feed-in. To find a balance between demand for reactive power and reactive power generation, TSOs dispose of the following measures (non-exhaustive list) on the transmission grid level in addition to the utilisation of active, conventional power plants (Agricola et al. 2014):

- Installation of additional reactive power compensators (inductors, capacitor banks, static VAR compensators, STATCOM)
- Voltage-related redispatch (use of power plants not used due to market-related circumstances with the technically lowest possible active power feed-in)
- Transformer tapping
- Changes to the grid topology (e.g., line shutdowns)
- Load shedding as an emergency measure

As voltage control here has to be provided at TSO level it is not a domain for participation of DERs. Therefore, USEF does not include voltage control as a flexibility service for TSOs (Van der Veen et al. 2018, USEF 2015).

3.3.2.1.3 System Restoration/Black Start Capability

In the event of larger-scale failures, the TSOs are responsible for controlling the system restoration (Agricola et al. 2014). Black start is the procedure to recover from a shutdown of the transmission system which has caused extensive loss of supplies. Black start capability as a **flexibility service** is procured by the TSO from *producers* that can start main blocks of generation from an on-site auxiliary generator, without reliance on external electricity supply. Black-start capability is typically procured during the construction phase of a power plant or when a plant is being refurbished. It is a long-term procurement as it is a technical requirement that only specific electricity production technologies can provide (National Grid 2012).

Power plant types that are suitable for a black start are, for example, hydroelectric power plants or gas power plants. Large scale electricity storage facilities are also potential providers of black start capability (Next Kraftwerke 2020).

3.3.2.1.4 Congestion Management

Congestion management (CM) means avoiding the overload of system components by reducing peak loads. CM is a highly-regulated mechanism, that is currently only applied on TSO level in the most European member states. For CM there are control-based mechanisms (e.g. direct access of TSO to prosumers loads for load curtailment) but also market-oriented approaches where aggregators may participate (Van der Veen et al. 2018).

The most common approach for solving critical congestions in the TSO domain is ‘redispatching’. This means a measure for changing the physical flows in the electricity system in order to relieve a physical congestion, as defined in the Regulation (EU) 2019/943 on the internal market for electricity (2019)[9].

Redispatch is a **flexibility service** that is mainly applied in regions with a high proportion of fluctuating renewable energy sources. For redispatching, a TSO requests from specific *producers* (or *consumers*) to start or increase the production (or decrease the load), while other specific *producers* (or *consumers*) are requested to stop or reduce the production (or to increase the load). Therefore, the redispatch does not change the amount of electricity fed into/taken from the grid, but its locality (Next Kraftwerke 2020).

[9] Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity

3.3.2.2 DSO Level

On DSO level AS/CM services are required for local voltage control and local congestion management. Currently, there are no market-based mechanisms in place for solving these local constraint violations.

Constraints on DSO level are currently solved both in a preventive and a corrective manner. On the one hand, distribution systems have been oversized in order to sustain situations of high loads (preventive). On the other hand, when a constraint violation is detected, tap changers are used for adapting the tap configuration at the transformer stations (corrective). According to Jin, Wu and Jia (2020) this can be referred to as grid side flexibilities.

Market-based approaches for solving local constraint violations are currently under discussion in the scientific community (for a detailed discussion on these approaches see chapter 6.1.2). However, it needs to be highlighted that these are highly innovative concepts, currently not applied in large scale in the EU.

Flexibility services:

The flexibility services that could be procured in a market-based manner at DSO level are voltage control and congestion management, as described in chapter 3.2.7.

3.3.3 Adequacy Services

The aim of adequacy services is to increase security of supply in the long term by arranging contracts for the provision of sufficient generation capacity (Van der Veen et al. 2018). In the EU member states there are different adequacy mechanisms with different services procured through more or less market-based procedures (Figure 8).

For adequacy services, **flexibility products** are **conditional** (CRP/CRP-2 – energy and availability based).

The **flexibility services** are described in the following sub-sections.

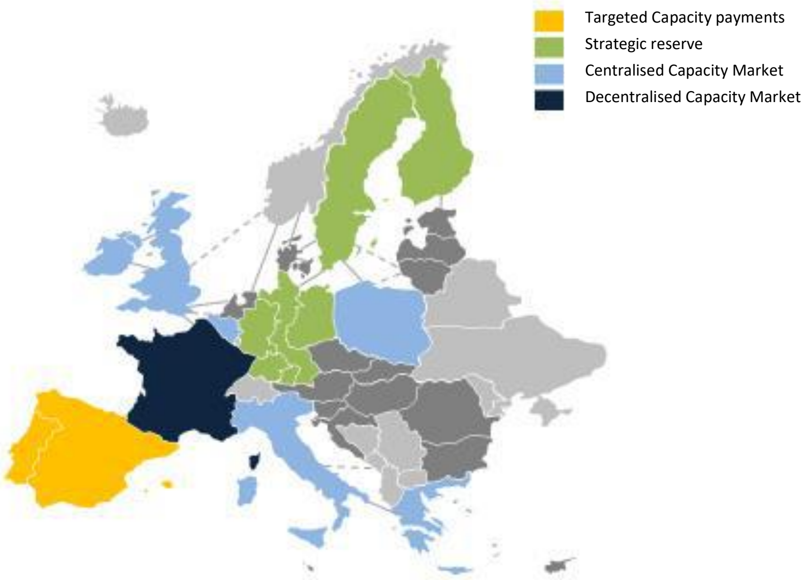


Figure 8. Adequacy services in EU member states (Source: Pugl-Pichler et al. 2020)

3.3.3.1 Capacity Markets

In capacity markets, generation capacity is secured against long-term demand. Here, the generation capacity is procured market-based, ensuring that assets are built/operated providing this service at lowest cost (Van der Veen et al. 2018).

Capacity markets can be designed either in a centralised or a decentralised way. In centralised capacity markets (e.g. UK) the capacity is procured by the **TSO**. The **TSO** estimates the required capacity and contracts all generation assets according to the market clearing at the capacity market. In decentralised capacity markets (e.g. France), the **BRP/supplier** has the capacity obligation and is therefore responsible for procuring the capacity at the capacity market (Van der Veen et al. 2018).

3.3.3.2 Capacity Payments

In (targeted) capacity payment schemes, the capacity providers receive direct payments from the **TSO**. The difference between capacity markets and payments is that payments strive for liquidity on the supply side and have less focus on clearing supply capacity towards expected demand, as the markets do (Van der Veen et al. 2018).

3.3.3.3 Strategic Reserve

The strategic reserve is also procured by the **TSO**. The difference between strategic reserves and capacity markets or payments is that strategic reserves are dedicated for activation by the **TSO**. The reserved resources are generally kept out of the electricity market until the **TSO** provides the signal. In contrast, when applying capacity markets/payments, assets are in operation and can make also bids on the wholesale market.

3.3.4 Retail

Electricity is supplied to *consumers* and **prosumers** through the retail market. As mentioned above (section 3.2.5), **prosumers** can choose their **supplier** freely, creating a competitive retail market with **prosumers** and **suppliers** participating. In addition to that, the **DSO** is obliged to guarantee grid connection and in return is remunerated by a regulated grid fee determined by the **NRA**.

The electricity price a **prosumer** has to pay consists of three components:

- supply price (incurred by the supplier),
- network charges (incurred by the DSO; includes fee for using the transmission and distribution grid)
- and taxes and surcharges

Other than the markets described so far, the retail electricity market can be referred to as an implicit flexibility market. This applies, when c*onsumers* and **prosumers** are subject to dynamic pricing offers. In this way, flexibility can be traded implicitly through the retail market, if *consumers* try to minimise costs through optimally adapting their load profile according to the price. This can be referred to as implicit DR.

The dynamic element of the electricity price may apply to the supply price, the network charges or both.

According to Art. 2(15) of the EU Directive on common rules for the internal market in electricity (2019)[10], a dynamic supply contract means a “contract between a **supplier** and a *consumer* that reflects the price variation in the spot markets, including in the day-ahead and intraday markets”. Due to regulatory steps related to Art. 11 of the aforementioned Directive (“Entitlement to a dynamic electricity price contract”), it is expected that the market for dynamic supply tariffs will grow significantly in the coming years.

[10] Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity

More broadly, Cooke (2011) differentiates between following supply pricing arrangements featuring a dynamic element:

- **Time-of-use (ToU) pricing** refers to a flexible pricing structure incorporating different unit prices for usage during different time periods within a day. ToU rates reflect the average cost of generating and delivering power during those time periods.
- **Real-time-pricing (RTP)** refers to pricing based on real-time movements in electricity prices based on trade in spot markets, balancing markets or other exchanges. It links hourly or half-hourly prices to corresponding changes in real-time or day-ahead power costs. In this case, customers need to be informed about expected RTP prices on a day-ahead or hour-ahead basis to elicit load response.
- **Critical peak pricing (CPP)** is a hybrid combining traditional time of use rates and real time pricing design. The basic rate structure is time of use. However, provision is made for replacing the normal peak price with a much higher pre-determined critical peak pricing event price under specified conditions.

Generally, dynamic pricing is more frequently applied in the supply of energy than in network charges (Glowacki 2020d). However, novel grid tariff schemes with a variable element in terms of time, location or peak load may have an impact on creating flexibility for the distribution grid and the **DSO**.

A market mechanism increasingly gaining attention for its potential to integrate in the retail electricity market is **peer-to-peer (P2P)** trade. This can be achieved either directly between **prosumers** or indirectly via an intermediate broker (Chen et al. 2018). According to article 2(18) of the EU Renewable Energy Directive (2018)[11] peer-to-peer trading (of renewable energy) means the sale of renewable energy between market participants by means of a contract with pre-determined conditions governing the automated execution and settlement of the transaction, either directly between market participants or indirectly through a certified third-party market participant, such as an aggregator.

For facilitating the administrative exchange of energy between prosumers in a Citizen Energy Community, USEF (Klaassen and Van der Laan 2019) points out that the community (or the operator of the P2P trading platform) needs to assume the role of a **supplier** and also has to take on its balance responsibility in the role of a **BRP** (which can also be transferred to an existing **BRP**).

However, there are also traditional centralised **suppliers** offering P2P services, meaning that the **supplier** facilitates and handles this energy exchange via a platform. In this way the **supplier** and **BRP** roles remain with the traditional **supplier** (Klaassen and Van der Laan 2019).

Direct P2P trade without an intermediary supplier role generally also seems to be allowed by European energy law, as the EU Directive on common rules for the internal market for electricity (2019)[12] is formulated rather broadly but without any regulatory frame specifically for direct P2P trade. Therefore, there are many practical barriers for its implementation (Van Soest 2019).

Finally, P2P trade may also be facilitated by an **ESCo** role running a shadow administration, which is separate from the administration of a **supplier/BRP** and therefore has no official role in the organisation of the electricity system. This means that this P2P trading platform has the aim to stimulate the physical (real-time) use of local generation within the community itself. The shadow administration can be combined with the introduction of a (crypto) currency based on the blockchain technology (Klaassen and Van der Laan 2019). However, Rocha, Villar and Bessa (2019) argue that such an unofficial P2P trading scheme is not economically feasible under the current regulation as the benefits for the peers are jeopardised by feed-in tariffs.

[11] Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources

[12] Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity

Flexibility services:

The flexibility services obtained from the retail market include **BRP**-related services as outlined in section 3.2.6 (in case of dynamic supply pricing), or **DSO**-related services as mentioned in section 3.2.7 (in case of novel grid tariffs).

3.4 Demand Side Flexibility Coordination Mechanisms

3.4.1 Market Design Options for Demand Side Response Integration

From the perspective of market designs solutions to integrate Demand Side Response (DSR) into the energy system, ENTSO-E (2015) proposes different arrangements, which are described in this chapter (Figure 9). These market models can be classified initially by whether the DSR is integrated or dissociated from the supply contract. If there is a separation, then it can be further organised in whether there is an agreement between the DSR aggregator and the supplier.

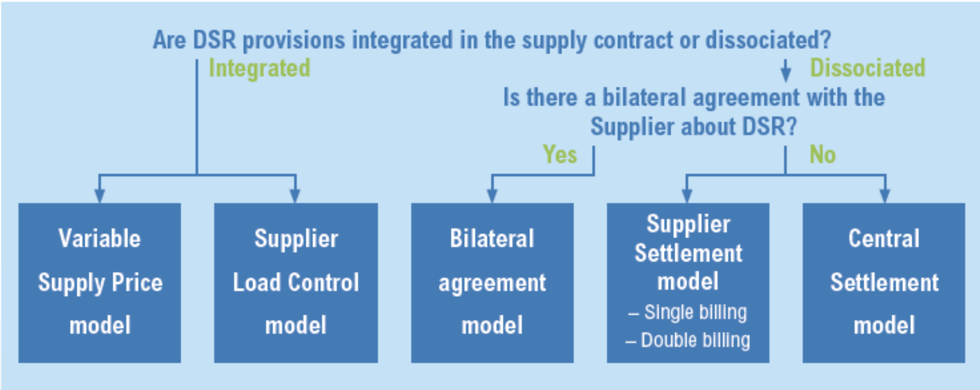


Figure 9. Energy market perspectives with DSR integration (Source: ENTSO-E 2015)

In the **DSR-Supplier integration model**, the energy supply contract between suppliers and consumers would include flexibility clauses. This market design allows the supplier to expand its range of services, while consumers may profit from reduced prices when compared to traditional contracts. Two solutions can be applied to this arrangement, one taking into account a price signal to the consumer and another using load orders directly from the supplier.

- **Variable Supply Price Model***:* The central aspect of this model is the **price variability paid by the consumer.** A contract between the supplier and consumer is set to estipulate the variation on the energy supply price. The energy **supplier will send to the consumer signals of price changes, and then the consumer may choose to reduce its energy consumption**. The consumer's response to the changes of energy price is used by the supplier to anticipate consumer behaviour, which can be used by the BRP source to balance the demand: This market model represents the majority of DSR markets implemented in Europe.

- **Supplier Load Control Model***:* In this case, flexibility clauses in the supplier contract allow the supplier to control the load under particular circumstances. **The consumer should reduce its load to a stipulated range as requested by the supplier.** This arrangement can be used by the BRP source to participate in balancing markets, for self-compensation or even to profit in high prices situations. This market design usually aims medium consumers, such as industries.

In the context of market models, the **integrated approach is the simplest way to implement DSR**, since there are fewer stakeholders involved in the process. Nevertheless, **it restricts the action of other players independent from the supplier**, such as aggregators. This can reduce market flexibility and decrease DSR potential and attractiveness in some markets.

On the other side, there are market designs **where DSR is dissociated from the supplier**. In such cases, independent aggregators may participate different relations to supplier and consumers. As a result of the absence of a two-way contract, some significant concerns may arise, such as:

1. The fair compensation between independent aggregator and BRP_{source} [13] for transferring energy.
2. The so-called "BRP_{source} imbalance risk". With the DSR activation, the BRP_{source} might deviate from its forecasted schedule, which creates imbalance risks. Therefore, there must be some compensation to the BRP_{source} for the imbalances caused by the aggregator.
3. Detailed information about DSR events and occurrences should be provided to the BRP and suppliers due to balancing and forecasting causes.
4. There is a need for confidentiality between the parties, as suppliers can benefit from free information provided by aggregator about DSR activation of consumers. Therefore, to ensure competition in DSR markets there must be a balance between the confidentiality and the necessary information to the supplier.

In this framework, there may be a bilateral agreement between aggregator and supplier/BRP_{source} about the application of DSR, as detailed below:

- **Bilateral Agreement Model:** In this market model, the **independent aggregator and the BRP_{source} or the supplier have a bilateral agreement** to settle critical aspects from the separation of DSR from energy supply (Figure 10). The two-way contract covers the energy transfer between the BRP_{source} and the independent aggregator when activating DSR. A settled price will then be paid by the aggregator to the BRP_{source} for the energy sold in balancing or wholesale markets. This arrangement configures a **shift of the balancing responsibility from the BRP_{source} to the aggregator**. In this configuration, all parts must be in accordance with such a contract, otherwise competition issues and even distrust over the flexibility may happen. The formulation of standard contracts templates can encourage the closure of bilateral agreements and help with regulatory and monopoly control.

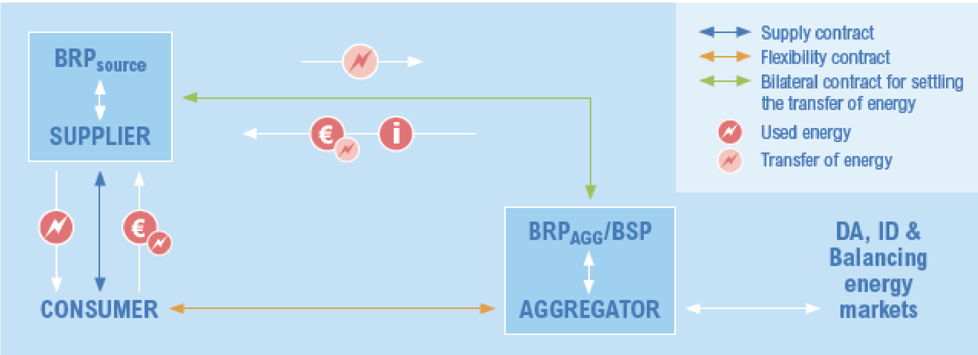


Figure 10. Bilateral Agreement Model (Source: ENTSO-E 2015)

Market designs without a bilateral agreement are dealing in a different way with the energy transfers and compensations between its players, providing a certain independency to the aggregator from the suppliers. The BRP_{source} imbalancing risk can be address by neutralizing the activated energy, which means the BRP in association with the independent aggregator is in charge of the balancing between requested and sold energy from DSR activation. Also, the independent aggregators must inform the TSO of the planned DSR activations to avoid problems in grid balancing. Then the TSO provides the BRP_{source} with the requested flexibility activation to prevent counter-balancing actions. In this framework, the following two market designs can be considered.

[13] BRP_{source} is the BRP to which the consumer providing the flexibility is associated to

- **Supplier settlement for DSR Activations Model**: In this market design, **the consumer pays directly to the energy supplier for the energy sold by the independent aggregator when DSR is activated** (Figure 11). Thus, the energy transfers remain between the supplier and consumer, at the supply cost stipulated in the contract. There must be **financial compensation from the aggregator to the consumer** for the energy sold during DSR activation. An agreement between both parties regulates the compensation transactions. A metering entity, for example the TSO or DSO, provides the supplier with the information about the consumed energy and the DSR application: This information may be provided without distinction between consumed energy and DSR activation, in a so-called **single billing** situation. There is some price complexity attached to this approach due to differences between consumed and sold energy taxations. On the other hand, there is the option of **double billing**, where the metering entity provides the separate values of consumed and DSR activation energy. Thus, the tariffs and taxation become simpler to calculate.

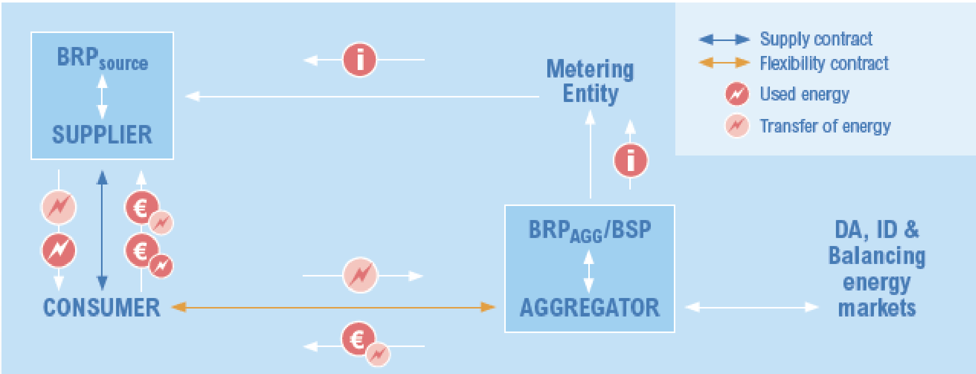


Figure 11. Supplier settlement for DSR activations model (Source: ENTSO-E 2015)

- **Central Settlement for DSR Activations Model**: For this configuration, a **neutral central entity** (that can be the DSO, TSO or a third party) **carries out the settlement of the transfer of energy between supplier and independent aggregators** (Figure 12). There must be a wholesale settlement price agreement between the parties. This price can be either the supply price set for activated consumers or a reference price approved by regulatory institutions. This market design is effective in assuring confidentiality for aggregators, but it can cause imbalances between the transfer price stipulated and the real supply price.

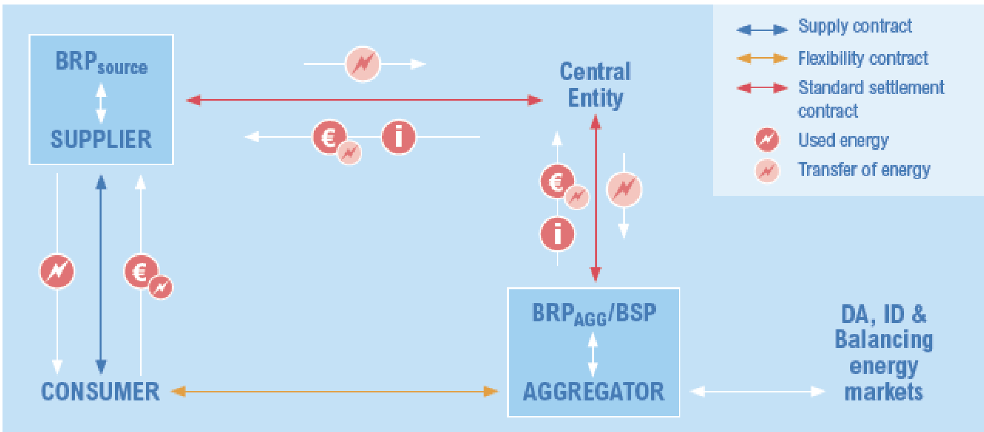


Figure 12. Central settlement for DSR activations model (Source: ENTSO-E 2015)

3.4.2 Bilateral Agreement Model – Flow Chart

Going more into detail, the flow chart presented in Figure 13 shows the flows of energy, money and data in the simplest independent aggregator model: the **bilateral agreement model**. In this example, the flexibility requesting party is the TSO, procuring flexibility on the balancing market.

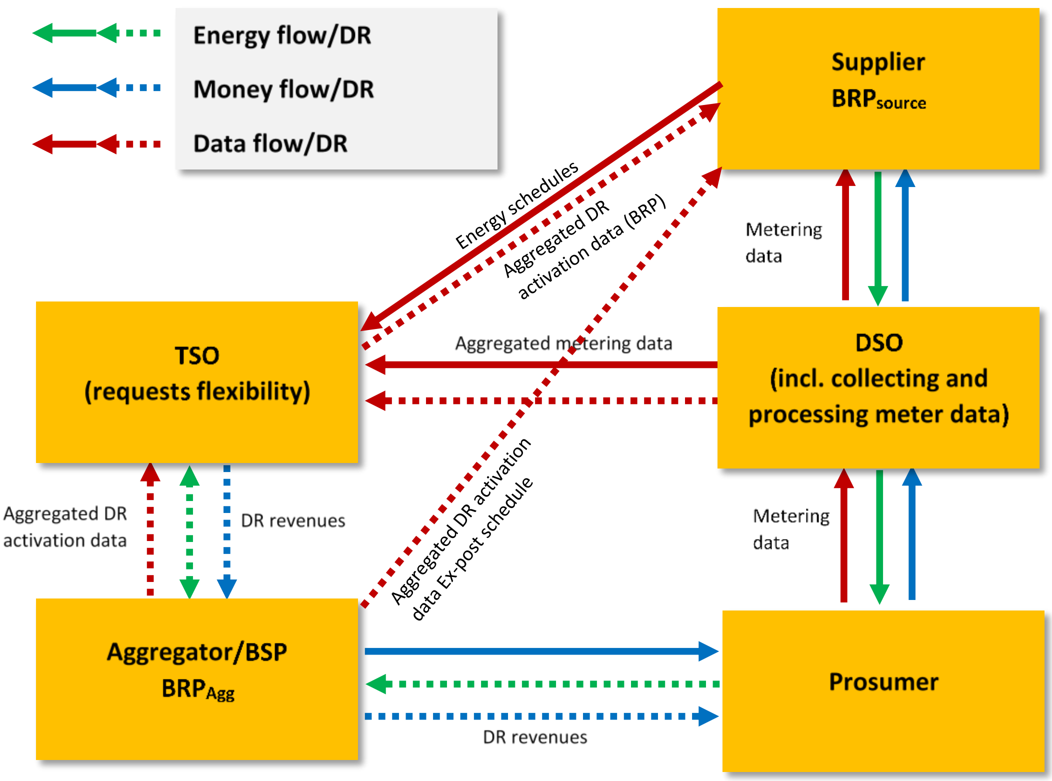


Figure 13. Detailed flow chart of the bilateral agreement model (Source: own diagram, based on ENTSO-E 2015)

Description of the DR activation and data processing:

Upstream processing

- An independent aggregator (member of BRP_{Agg}) closes a contract with the energy supplier (member of BRP_{source}). This contract includes remuneration for DR as well as data exchange and further processes.
- Flexibility is tendered by the TSO (via the dedicated MO), depending on the market this may take place weekly, daily or for any other time period.
- Aggregator acts as balancing service provider (BSP) and offers its flexible loads to the TSO (typically with a price for availability of power, and a price for energy for the case of activation).
- After successful tendering the load has to be available for the offered time period.
- Availability will be rewarded with the bid-price for power.

Demand Response (DR) activation

- TSO requests the activation of flexibility from the Aggregator/BSP.
- The Aggregator communicates with its clients (automatically or manually) and controls the DERs accordingly.
- The Aggregator/BSP aggregates all activated power and reports these data to the TSO (in real time).
- DR activation data are aggregated along balance groups and sent to BRP_{source} by TSO.

- In order to prevent contradictory balancing of the BRP which would remove the effect of the DR activation, the Aggregator/BSP informs the BRP_{source} on the DR activation (in real time). BRP_{source} has agreed not to counterbalance the DR activation.

Ex post processing

- Aggregator/BSP provides a correction of the schedule that allows the BRP_{source} to be compensated for changes in energy consumption (due to DR activation) and any occurred imbalance costs. This corrected schedule (ex-post schedule) will be used for final imbalance settlement.
- The Prosumer is billed by the supplier for the energy consumption that would have occurred in the case of no DR was activated. This means: Metering data have to be corrected on the side of the energy supplier and DSO (grid charges).
- Revenues for accepted DR offers and their activation are separated from energy billing and are processed by the aggregator based on a bilateral agreement with the client.

The following Table 2 summarises all the relevant tasks achieved by each party in the example.

Table 2. Activities per role in the bilateral agreement model (Source: based on ENTSO-E 2015)

Stakeholders involved	Tasks
TSO	Collecting energy schedules from BRPs; Tendering of control energy; Re-calling control energy; Processing of aggregated metering data; Providing DR activation data to BRP
Supplier, BRP_{source}	Providing schedules to TSO; Providing energy to final consumers; Billing energy supply
DSO	Collecting and processing of metering data from final consumers; Providing metering data to supplier; Providing aggregated metering data to TSO;
Aggregator/BSP	Collecting, aggregating and processing DR events (from different Prosumers); Providing aggregated DR data to TSO Providing aggregated DR activation data to BRP_{source} (real time); Providing corrected schedule to BRP_{source} (ex post)
Prosumer	Operation of DERs

3.4.3 USEF Market-based Coordination Mechanism

Introduced by USEF (2015), the **Market-Based Coordination Mechanism** (**MCM**) is intended to be a supplement to the existing liberalised market by optimising the flexibility value for all stakeholders involved. The MCM sets **guidelines and practices to manage and trade flexibility**, unlocking potentials through the value chain. An essential aspect of this approach is that **flexibility can be used by the DSO to avoid significant grid infrastructure investments and constraint violations**.

Grid Operating Regimes

The MCM establishes four possible grid operating regimes, indicated by colours ranging from Green to Red (Figure 14). **These operating regimes indicate if the DSO allows flexibility trading between different partie**s. The Green operating regime implies that the flexibility is available without limitations for the BRPs to manage. In the Yellow stage, the DSO will restrict flexibility and may use it to reduce congestions at specific grid points. The Orange regime is an alternative if there is insufficient flexibility to deflect interruption. The DSO will overrule the market by limiting connections to prevent outages. The DSO can favour connections that are critically dependent on energy over less critical ones. The Red regime is an extreme case where the grid protection system is enabled to avoid significant structural damages.

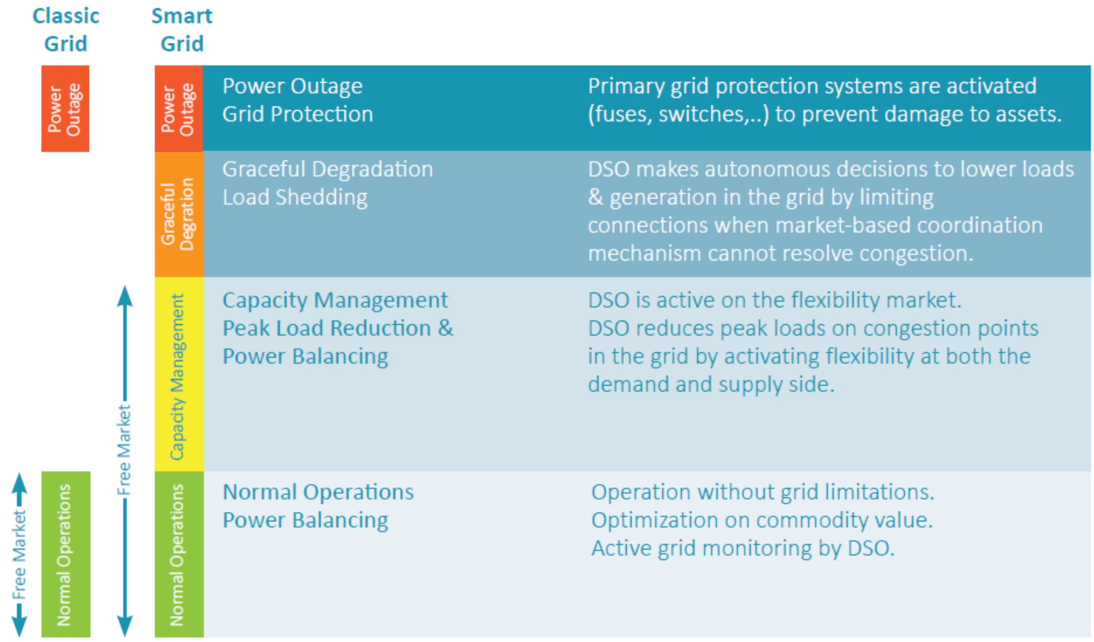


Figure 14. Operating regimes for Smart and Classic Grids (Source: USEF 2015)

For the **Yellow and Green operating regimes, independent aggregators can integrate flexibility management**. Specifically, when there are congestion points in the grid (Yellow regime activated), **the aggregator may provide the DSO with the flexibility needed to manage the constraint violations** in the congested locations. Thereby a so-called Common Reference Operator (CRO) is established to provide information about the grid connections, available aggregators and congestion points for the interested parties.

The MCM plan and phases

USEF established a five-phase plan (Figure 15) to promote optimal use of the grid and expand stakeholders' freedom of trading before the energy is supplied to the consumer. The time scales may vary from years up to hours before the “Operate” phase begins. This broad time range enables load trading in different markets and also changes in the grid capacity. Each phase of the MCM plan is detailed below.

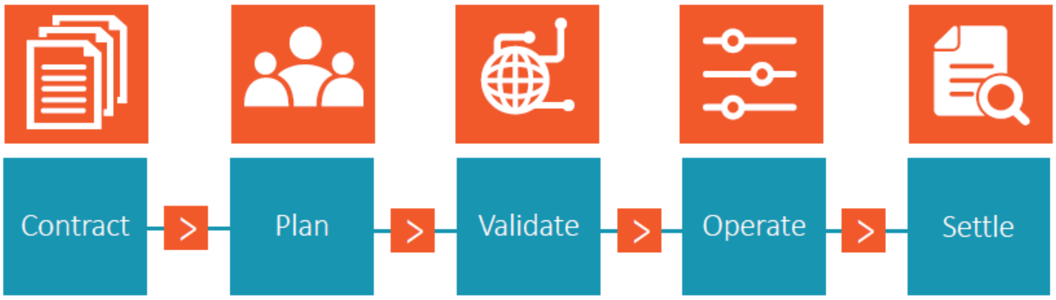


Figure 15. MCM five-phase plan (Source: USEF 2015, adapted)

Phase 1: Contract

In this phase, the **contractual agreements are established** between the different entities involved. The aggregator sets up a flexibility purchase contract with the prosumer, setting the operating terms for the DR activation. A framework contract between the aggregator and the supplier is settled for all prosumers aggregated. This contract specifies the conditions of DR execution. A flexibility service contract between the BRP and aggregator outlines how the aggregator may submit the flexibility offer to the BRP and how imbalances will be settled.

There is no need for the aggregator and DSO to establish a contract once the **MCM covers the operating terms for flexibility trading**. In the case a flexibility service contract is set, the **DSO may procure flexibility from the aggregator to secure the grid**. Also, in these contracts, prosumers' data privacy handling must be adequately addressed.

Phase 2: Plan

The purpose of this phase is to **build an economically optimized program that meets the aggregator and BRP flexibility portfolios for a given time**. First, the aggregator gathers forecasts for the prosumers in its portfolio. With this information, the aggregator optimizes and plans how to maximise the flexibility opportunities, thus creating an initial A-plan that will be sent to the BRP. If there is a change in the aggregators forecast, then the A-plan can be updated with the new predictions. The BRP optimizes its portfolio similarly, consisted of aggregators, suppliers etc., to achieve also an economically optimized program. Thus, the BRP may ask the aggregator to modify parts of its A-plan, based on prices for specific locations or a required flexibility potential. Once the aggregators A-plan complies with BRP requests, an E-program is created by the BRP, which will be the foundation for the imbalance resolution process between the BRP and TSO.

In the planning phase, **the DSO is responsible for identifying where the congestion points may occur**. The DSO records this information in the Common Reference, operated by the CRO. The Common Reference can be accessed by **aggregators, to verify if they can offer flexibility to the DSO in the location of the congestion** points. The DSO usually determines these points only a few times a year.

Phase 3: Validate

In this phase, the **DSO defines if the demand and supply forecasted will be safely distributed by the grid.** First, the aggregator creates a D-Prognosis, that shows the energy consumption of its portfolio at a given congestion point, using the A-plan created in the Plan phase. The DSO gathers D-Prognoses from aggregators and compares them to its forecast for connections not served by aggregators. This results in a T-prognosis created by the DSO and sent to the TSO. This allows the DSO to perform a network security analysis to determine whether the planned energy can be safely distributed. If not, the grid operating regime changes to Yellow and the **DSO requests flexibility on the market to solve the congestion**. If there is not enough flexibility available, then the Orange regime is activated.

The DSO's acquisition of flexibility can affect an aggregator's A-plan. Therefore, the Validate phase is iterative with the Plan phase. The aggregator may often adjust its A-plan as long as the bilateral agreement with BRP allows. It is a responsibility of the aggregator to assure that when the gate closes, all problems are resolved and A-plan and D-prognosis are aligned.

Phase 4: Operate

For this phase, the effective distribution of energy and flexibility occurs through operational interactions between the parties. In short, aggregators provide the flexibility sold to BRPs (for portfolio balancing) and DSOs (for grid management). The energy system will remain balanced as long as no variations between operation and A-plan/D-prognosis/E-programs happen. Despite that, deviations can arise from many different sources, such as weather changes or a prolonged football match. These variations on demand cause significant imbalances and possibly congestions, affecting the entities involved directly.

During operation, the responsibilities are:

- **Aggregator**: Its main goal is to stick to the A-plan and D-prognosis approved. It can obtain the net demand of its portfolio and detect possible load deviations through smart meter devices. In this case, the aggregator will reoptimize the demand response activations.
- **BRP**: Its primary concern is to avoid imbalance costs. If by any chance the operation deviates from the E-program, the BRP may seek extra flexibility from aggregators for instance.
- **DSO**: The DSO will continuously monitor the grid status and possible congestion points. If congestions issues are detected, the DSO can ask aggregators directly for flexibility potentials. By doing so, the BRP portfolio will unbalance. Thus, the aggregator may charge the DSO extra fees to cover the imbalance risk caused. If the flexibility available is not sufficient, then the Orange regime is activated.
- **TSO**: Its major responsibility is the energy system stability. In case of unexpected events that may threaten this stability, the TSO can use primary/secondary/tertiary controls to secure the system. The TSO is also allowed to procure flexibility from other entities.

Phase 5: Settle

After energy and services have been delivered, it’s time to **settle all transactions from previous phases**. The settlement includes all parties involved in the flexibility value chain. The MCM determines the following settlement procedures:

- **Aggregator → Prosumer**: The aggregator will reward the prosumer for the flexibility provided to the system. The MCM does not stipulate a strict model to follow. Therefore, aggregators may choose in which way prosumers will be compensated.
- **DSO →Aggregator**: Based on the final D-Prognosis, the DSO will calculate the flexibility procured from each aggregator. The DSO will validate the flexibility delivered using metering data and stipulate the compensation or penalties applicably.
- **BRP →Aggregator**: Similar to the DSO, the BRP will compensate or penalize aggregators for the flexibility provided in contrast to the final E-program.
- **Orange regime**: In this case, the DSO has complete control of the system, being able to curtail prosumer energy generation or consumption directly. The impact of these actions should be settled between prosumers and DSO: The MCM does not specify a particular practice for this negotiation.

4. Current Relevant Technologies

The aim of this chapter is to examine current relevant cutting-edge technologies and solutions that may enable the implementation of Local Flexibility Markets (LFMs) as intended by the PARITY project. Against the background of the market concepts at DSO level analytically described above (section 3.3.2.2), here, local market platforms in general are addressed, including LFMs and LEMs (P2P transactive energy exchange). The concepts of LFM and LEM are discussed and clarified in detail in chapter 6.3.2.

Several technologies and approaches for designing and implementing LFMs have been proposed in the literature. As LFMs involve energy trading among actors of different goals and priorities, various technical topics such as architecture, methods for flexibility estimation and market clearing etc. have to be addressed. The literature review presented in this chapter focuses on LFM architectures, P2P technologies for energy trading, and algorithmic approaches for flexibility estimation and optimization.

4.1 LFM Architectural View

Inspired by the four-layer system architecture for P2P energy trading by Zhang et al. (2018) and the Smart Grid Architecture Model (SGAM) (Smart Grid Coordination Group 2012) for providing several architectural views regarding the layers of the smart grid, Jin, Wu and Jia (2020) present a four-layer structure for LFMs to showcase the potential key elements and technologies used. Each layer is described as follows:

(1) The *power grid layer* is composed of all the physical components of the electric distribution system, including components providing supply-side flexibility (e.g., various DGs, energy storage units, etc.) components providing demand-side flexibility (e.g. prosumers, aggregators, etc.) and components providing grid-side flexibility (e.g. Soft Open Points, Static Var Compensators, Static Var Generators, smart meters, etc.). These components compose the electric distribution system where local flexibility trading is conducted.

(2) The *ICT* (information and communication technologies) *layer* is composed of communication devices, protocols, applications and information flow to support local flexibility trading (Zhang et al. 2018). The ICT layer enables the distribution system monitoring, control and management of all components. It also provides ICT infrastructure for local flexibility trading.

(3) The *control layer* is mainly composed of the control functions for the supply-side, the demand-side and the grid-side of the distribution system. Supply-side control strategies are facilitated in this layer to control and optimize the operation of various DGs and energy storage units for providing supply-side flexibility. Demand side strategies are defined in this layer to control and manage the demand-side resources for providing demand-side flexibility. Furthermore, grid side strategies are defined in this layer to control the power flow, the voltage and the network topology for preserving the quality and reliability of the distribution system. Different control-based methods including active network management (ANM), price-based control and transactive energy are also implemented in this layer. The control layer is also responsible for the management of the flexibility orders.

(4) The *market layer* determines how flexibility is traded locally among the participants in the LFM. The participants mainly include DSO, aggregator, BRP and market operator. The market layer is responsible for the management of flexibility transactions in the LFM. Various business models can be integrated in this layer to facilitate different kinds of local flexibility trading.

4.2 Technologies for P2P Transactive Energy Exchange

With regard to the topology, every transaction in traditional power systems is centrally managed for tracking consumed/produced energy, calculating energy prices, and recording transactions-related information. On the contrary, in a Peer-to-Peer (P2P) context, management is decentralized and regulated among the peers participating to the energy network. Centralized architectures are not easily scalable to account for an exponential increase of prosumers, which in turn produce high volumes of data (Siano et al. 2019).

According to Tushar et al. (2018), P2P network can be divided into two layers: 1) virtual layer and 2) physical layer. The virtual layer provides a secured connection for participants to decide on their energy trading parameters. It ensures that all participants have equal access to a virtual platform, in which buy and sell orders are created, an appropriate market mechanism is used to match the buy and sell orders, and finally, financial transactions are carried out upon successful matching of the orders. On the other hand, the physical layer, is essentially a physical network that facilitates the transfer of electricity from sellers to buyers once the financial settlements between both parties are completed over the virtual layer platform. Different key elements of P2P network are shown in Figure 16.

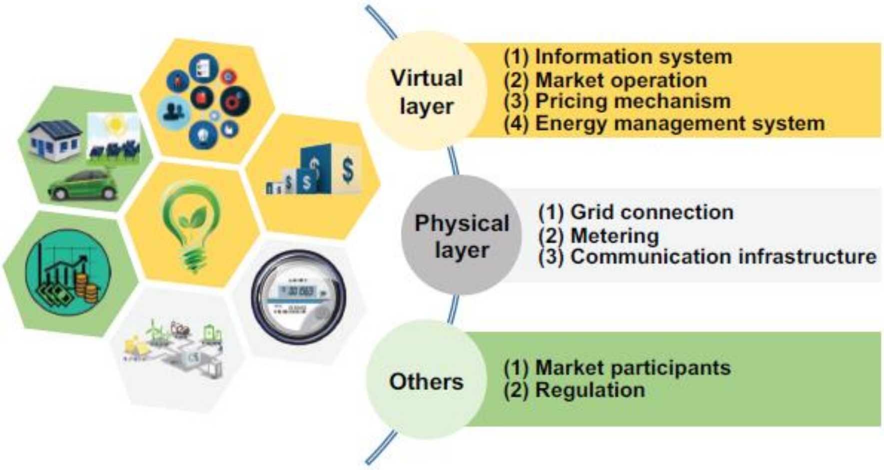


Figure 16. Elements of P2P network (Source: Tushar et al. 2018)

A P2P system might incorporate blockchain technologies to keep track of the electricity amount traded and have a transparent automated settlement system (Lüth et al. 2018). In a P2P scenario, energy matching based on users' preferences is possible through multidirectional trading, and thus, advanced information and communication technology-based online services are used to support the implementation of P2P energy trading. The existing P2P energy trading platforms are nearly always designed using conventional database technologies, which causes problems of transaction intractability, privacy protection, and data modification (Han et al. 2020). The emergence of blockchains has brought about the opportunity to securely automate the procedure of P2P energy trading. A blockchain is an open and distributed ledger that records transactions between two parties efficiently and in a verifiable and permanent manner (Dinh et al. 2018). It is noteworthy that a smart contract is one of the key elements in executing the procedure of the blockchain platform without a human interface (Thomas et al. 2019). Smart contracts are well suited to autonomously conduct rules for direct end-to-end transactions of energy based on local consumer preferences. The blockchain-based smart contract has the potential to enhance security and ensure fairness for decentralized energy systems' management (Li et al. 2019).

There are several studies in the literature that propose the use of blockchain technology in P2P energy trading. For instance, in study (Noor et al. 2018), a game-theoretic approach for the demand side management model that incorporates storage components is suggested, and blockchain technology is applied for efficiency and trustworthiness. Brooklyn microgrid is the first applied engineering program of energy blockchain in the world (Zhao et al. 2019). The whole project is based on P2P energy trading with blockchain, and doesn't need the third party-traditional electricity utility company (Nguyen 2016). Brooklyn microgrid proves blockchain can really be used in practical P2P electricity trading. In addition, consumers can cut electricity bills and gain more power selling profits through this project. Third-party involvement always increases the cost of operation drastically and paves the way for erroneous transactions. This is where blockchain offers a promising solution to these existing issues of the smart grid (Andoni et al. 2019).

A blockchain-based trading infrastructure offers a decentralized platform that enables the P2P trade of energy between consumers and prosumers in a secure manner. The identity privacy and security of transactions is higher in the decentralized platform compared to the traditional system. The P2P energy trading finds purpose in many applications including the Industrial Internet of Things (IIoT) and enhances the possibility of developing micro-grids leading to sustainable energy utilization (Li et al. 2017; Mengelkamp et al. 2018). The computational time and the power consumption needed under normal operations of Internet of Things (IoT) devices are important challenges that may restrict the application of blockchain in IoT and smart grids. Li et al. (2019b) proposed a decentralized on-demand energy supply architecture for miners in the IoT network, using microgrids to provide renewable energy for mining in the IoT devices. On the other hand, with the development and popularization of artificial intelligence, the network application of wireless sensors is gradually scaled up and industrialized, so Zhang (2020) proposes a regional energy balance routing algorithm based on intelligent chaotic ant colony.

The main blockchain based technologies for P2P trading are virtual currency, credit-based transactions and smart contracts (Alladi et al. 2019). Using blockchain, a virtual currency can be created for representing each unit of electricity. Surplus energy available to the prosumer can be sold by engaging in transactions with other peers within the blockchain network and transferring this electrical energy into the grid. The prosumer can earn virtual currency for the energy sale at a specified price while the consumers with deficit can buy energy for their requirement with the virtual currency. The true identity of both the buyer and the seller do not need to be disclosed in such transactions using virtual coins (Mengelkamp et al. 2018; Leonhard 2016).

Since there is some latency in the validation and addition of transactions into the blockchain, which in turn delays the release of virtual currency for the respective user, users might face a shortage of virtual currency temporarily. A credit-based transaction system helps such users in purchasing the required energy without actual possession of virtual currencies at that moment. Li et al. (2017) utilized a credit-based payment scheme where each node is allotted an identity, a set of public and private keys, a certificate for unique identification, and a set of wallet addresses upon a legitimate registration onto the blockchain. Upon initialization, the wallet integrity is checked and its credit data are downloaded from the memory pool of the supervisory nodes (which store records on credit-based payments). The request from each node for the release of credit-based tokens is validated by the credit bank managed by the supervisory nodes and released if the requesting node meets the specified criteria. These tokens which are then transferred to the wallet of the node can be used to buy the required energy from other selling nodes (Buterin 2020).

Smart contracts are computer codes consisting of terms of agreements under which the parties involved should interact with each other. They implement predefined instructions upon meeting a particular set of conditions or certain specified actions. Smart contracts associated with the smart meters in the grid are deployed in the blockchain. They ensure secure transactions by allowing only authentic data transfers between the smart meters and the supervisory nodes and report if any unauthorized and malicious tampering of data has occurred (Delmolino et al. 2016). Implementations of blockchain-based smart contracts in the energy domain are emerging. For example, NRGcoin (Mihaylov, Razo-Zapata and Nowe 2018) is an industry-academia project that was originally developed at Vrije Universiteit Brussel and is currently being up-scaled in an industrial context by Enervalis. NRGcoin replaces traditional high-risk renewable support policies with a novel blockchain-based Smart Contract, which better rewards green energy.

4.3 Algorithmic Approaches

As the amount of energy that is traded in an LFM depends on the flexibility that can be provided by each prosumer, flexibility estimation is a key process for LFM operation. Several methods for flexibility estimation have been proposed in the literature.

In Torbaghan et al. (2016), two planning and scheduling mechanisms are introduced, that enable harnessing the prosumers flexibility in an economically efficient way: Ahead-markets planning (Day-Ahead, Intra-Day) and Real-time dispatching. The difference between the two mechanisms lies in the objective, the time horizon, and the time elapsed between the closure of the decision-making process and the actual energy delivery. The main objective of ahead markets planning is to provide a platform to trade flexibility to adjust the energy program before it will be submitted to the wholesale energy market, while the main objective of the real time dispatching is to maintain the security of the grid at minimum costs. The ahead, market-based planning includes two mechanisms, day-ahead (DA) and intra-day (ID), which are operated by the LFM operator. Each local market seeks to adjust the energy programs before they will be forwarded to the wholesale energy market such that, if accepted, the programs will result in no congestion issues in the distribution grid. The real-time dispatching consists of a set of control actions that are determined and implemented by the DSO to resolve a network congestion issue, should the market-based planning fail.

The ahead-markets scheduling provides a trading platform that allows market participants to reflect their need(s) for flexibility and to monetize flexibility services in a fair and competitive manner. It enables flexibility trades which will eventually facilitate network management for the system operator. In Torbaghan et al. (2018), the authors present the steps that should be taken in DA and ID scheduling mechanisms in accordance with time.

The emerging technologies of the IoT and big data can be utilized to derive knowledge and support applications for effective prediction. In Luo et al. (2019), 4-layer IoT-based big data platform is developed for day-ahead prediction of building energy demands, while the core part is the hybrid machine learning-based predictive model.

In the paper of Sun et al. (2020), a DA economic dispatch strategy which can solve mixed integer programming problem based on game theory is proposed. In Zhao et al. (2015), a model predictive control (MPC)-based strategy using nonlinear programming (NLP) algorithm is proposed to optimize the scheduling of the energy systems under DA electricity pricing.

Use of electric vehicles (EVs) and EV charging are also taken into account in recent studies. When the EV penetration level is high in the power system, the EV charging demand will have a significant impact on electricity spot prices and consequently an influence on the EV charging strategies. According to Liu et al. (2018), the EV charging behaviour forms a noncooperative game in the day-ahead market. The demand of EV day-ahead energy plans can be put together by aggregators and forwarded to the electricity wholesale market.

Cloud-based solutions can address the non-trivial tasks related to storage, real-time computation and optimization of the expected large amount of data (Meloni et al. 2017). Using technologies adopted in the IoT domain (Atzori et al. 2010; Farris et al. 2015), which combine cloud and edge properties in a virtualized environment, fulfils the remaining requirements. Through resources virtualization (Nitti et al. 2016), which is a common trait of recent IoT architectural solutions, it is possible to address appropriately the key data handling and communication needs of the Smart Grids.

A common representation of flexible loads has to be defined and used, in order to exchange information about energy flexibility among different actors. The EU project MIRABEL proposed flex-offer (Šikšnys and Pedersen 2018), which is a format to encode this information. Flex-offer supports aggregation as well as different types of flexibility (e.g. amount flexibility, time-shift flexibility), where each type is characterized by energy-based and time-based constraints. Flex-offer has been used in several projects such as GOFLEX, ARROWHEAD, and TOTALFLEX.

4.4 Techniques for P2P Energy Trading

Based on the approaches proposed in recent studies, four techniques can be identified as the main contributors to the design of P2P energy trading systems (Tushar et al. 2020). These are (a) game theory, (b) auction theory, (c) constrained optimization, and (d) blockchain. Game theory is a mathematical tool that analyses the strategic decision-making process of a number of players in a competitive situation, in which the decision of action taken by one player depends on and affects the actions of other players. A double auction involves a market of a number of buyers and sellers seeking to interact. In a double auction, which is usually a step-by-step process, potential buyers submit their bids to an auctioneer, while potential sellers simultaneously ask prices to the auctioneer. A number of constrained optimization techniques have been used to design P2P energy trading schemes. Examples of some techniques include linear programming (LP) (Lüth et al. 2018), mixed integer linear programming (MILP) (Nguyen et al. 2018), alternating direction method of multipliers (ADMM) (Morstyn and McCulloch 2018), and nonlinear programming (NLP) (Long et al. 2018). A summary is presented in Table 3. Apart from the methods mentioned above, other emerging methods are becoming popular, such as graph theory (Nikolaidiset al. 2018)., heuristic multi-agent simulation (Zhou et al. 2018), artificial intelligence (Chen and Su 2018), and activity-based models (Alvaro-Hermana et al. 2016).

Table 3. Summary of approaches to enable P2P energy trading (Source: Tushar et al. 2020).

Technical approach	General focus of the approach	Main methods
Game theory	To capture the competition and cooperation between different participants of P2P energy trading market to deliver a solution that is stable, sometime optimal, and mutually beneficial for all involved parties	Stackelberg game, coalition formation game, canonical coalition game, noncooperative Nash game, generalized Nash game
Auction theory	To capture the interaction between a number of sellers and buyers of a P2P market so as to enable them to trade their electricity in a step-by-step fashion	Double auction
Constrained optimization	To use mathematical programming technique for optimizing the parameters of P2P trading under different hard and soft constraints imposed by the market and power system	LP, MILP, ADMM, NLP
Blockchain	To provide a data structure that can be replicated and shared among members to enable secured, transparent, and decentralized energy trading in a P2P network	Smart contract, Elecbay, consortium blockchain, Hyperledger, Ethereum

It is worthwhile to mention that clearing methods for LFMs are similar to that for Local Electricity Markets (LEMs), which are facilitating P2P trading among prosumers. A recent overview of the state-of-the-art computational intelligence methods applied to the optimal operation of Local Electricity Markets is provided by Georgilakis (2010). Some of the methods included are Genetic Algorithm, Fuzzy Sets, Multi agent systems, Particle Swarm Optimization, Reinforcement Learning, and Artificial Neural Networks.

5. Related Research and Pilot Projects

In this chapter, previous research and pilot projects that are relevant for and related to the PARITY concept are reviewed. This is performed on the one hand from the perspective of market structures implemented and on the other hand with a focus on the technical solutions applied.

At first, an introduction is given on Flexibility Market Platforms in general, then the projects that have been reviewed are summarised and classified in an overview table. Finally, each of the projects is described in detail.

5.1 Introduction on Flexibility Market Platforms

The environment where all the flexibility processes take place is an IT platform known as flexibility platform. USEF defines a flexibility platform as "an IT platform where the trading, dispatch and/or settlement of flexibility is facilitated or coordinated (De Heer and Van der Reek 2018). Based on this conception and considering that a flexibility platform can have different functions and purposes, several types of flexibility platforms can be categorised, as portrayed in Figure 17.

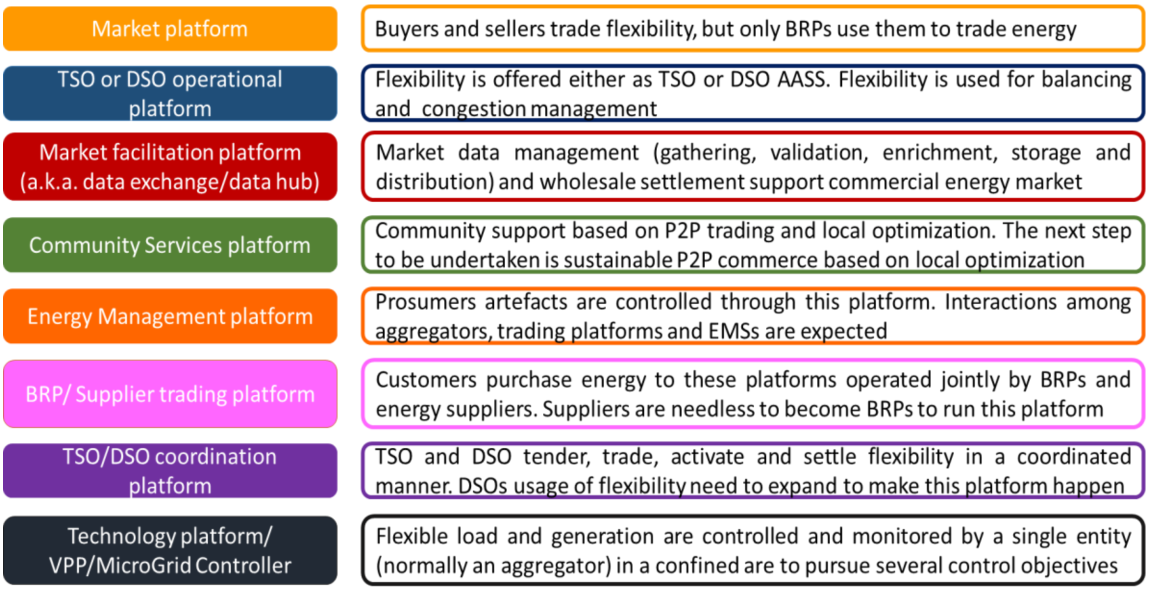


Figure 17. Demand side flexibility platforms (Source: De Heer and Van der Reek 2018)

As the PARITY local market framework focusses on establishing a market platform (c.f. chapter 6), the following projects examined here, mainly implement platforms for local flexibility markets, local energy markets or both.

5.2 Summary of Related Projects

Project	Market(s) implemented			Market operator	Flexibility services provided to the DSO, TSO or both	Flexibility/energy providers	Flexibility market horizons (day ahead, intraday, others)
	LFM	LEM	Participation in AS/WS market				
Nodes	√		√	Third party	DSO and/or TSO	Mainly aggregators	Intraday
EPEX Spot Local Flex	√		√	Third party	DSO and/or TSO	Aggregators and large power plants	Day ahead and intraday
GOPACS	√		√	Third party	DSO and/or TSO	Aggregators, small energy produces and any market party that can have a worthnoting influence electricity generation or consumption	Intraday (through ETPA market platform)
Piclo Flex	√		√	Third party	DNO (Distribution Network Operator)	Aggregators, small residential prosumers (EV and stationary battery owners), as well as industrial and commercial prosumers.	Long-term auctions
INTERFLEX	√	√	√	DSO	DSO, also proposed to TSO. Congestion management and balancing	Mainly small residential consumers, but open to others	Day ahead, intraday. Near real time update.
DRIvE	√	√		Aggregator	DSO (grid support a secondary objective the main is DR and bill optimization)	Residential and tertiary buildings	Intraday. Near real time update.
CATALYST	√	√	√	Third party	DSO Congestion management	Data centres, mainly from climate systems	Day ahead and intraday

eDREAM	√	√		LFM – DSO LEM – All market participants through block chain	DSO Ancillary and balancing services	Different kind of DERs	Day ahead and intraday. Near real time update.
SmartNet	√		√	TSO, DSO and/or independent third party	TSO and DSO	Different kinds and sizes of DERS (consumers, generators and storage systems)	Day ahead, intraday. Near real time update.
Brooklyn Microgrid		√	√	Microgrid Service Provider	DSO Capacity, balancing, frequency response	Residential and local business prosumers	Near real time
INVADE	√			Aggregator	DSO Congestion management, voltage control, controlled islanding	Electric vehicles and batteries	Day ahead and intraday

5.3 Detailed Description of Related Projects

5.3.1 Nodes Market Platform

NODES corresponds to an independent marketplace open to all flexibility providers and grid operators (flexibility requesters) with the main target to make accessible the value of local flexible power resources and facilitate the optimal use of flexibility in the grid (NODES MARKET LIMITED 2020, Whitepaper, NODES MARKET LIMITED 2020, case). NODES marketplace is investigated in different use cases: Engene, IntraFlex, FlexLab, NorFlex and Mitnetz are some of them, each one using the NODES market platform for different purposes like grid investments, renewable curtailment, auto-rebalancing, availability of local flexibility to TSO for manual frequency response restoration etc.

5.3.1.1 Market Overview

From a market aspect, NODES corresponds to a fully integrated marketplace for flexibility. It proposes a new market design, as depicted in Figure 18, with a twofold purpose; i) NODES market identifies and puts a value to local flexibility, putting local DSOs in the market and giving the flexibility buyer the right to change consumption or production according to a contract and ii) bridges a market gap giving the opportunity to flexibility not used locally to be sold to the TSO in the reserve market and/or BRPs at the intraday/day ahead market. Finally, the flexibility offers in NODES are in a different way, incorporating information coming from new parameters which are location, availability, time, profile and order.

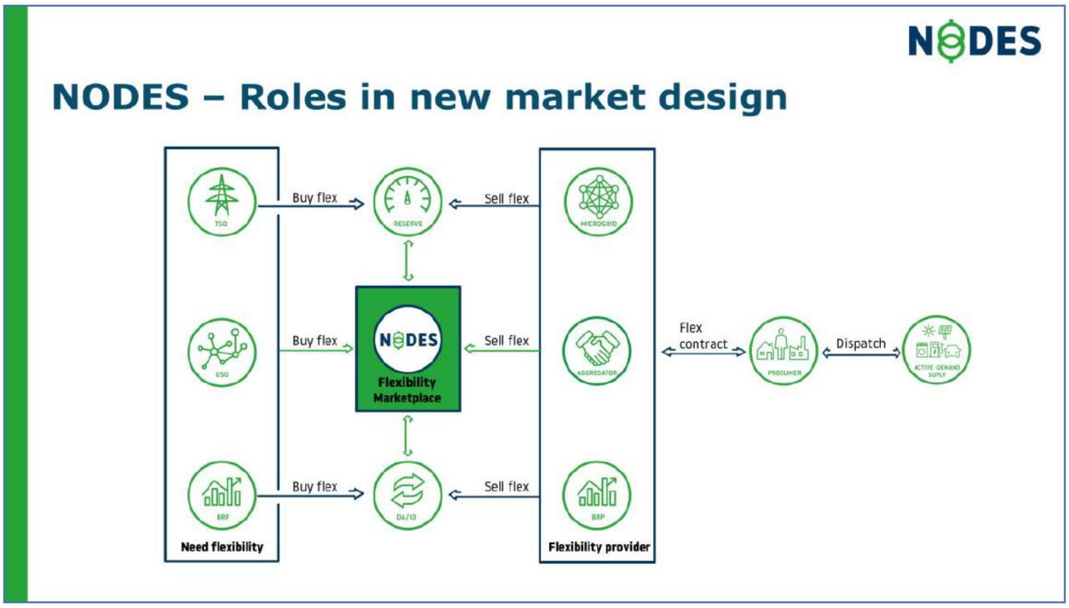


Figure 18. NODES market design (Source: NODES MARKET LIMITED 2020, case)

5.3.1.2 Technological Overview

From a technological view, NODES uses several APIs to communicate and interface with other market parties like system operators (TSOs - DSOs), BRPs, Retailers and others. The NODES market platform is based on real-time communication and automated control signals dispatch with the support of Microsoft Azure cloud services, while smart systems monitor continuously and in real-time the available power in the grid. For measuring the local flexibility, the loads that are measured through installed smart meters and used for flexibility estimation include:

- electricity production from solar PV and wind turbines,
- energy storage in EVs and large stationary batteries and
- residential loads induced in a building level.

Currently NODES marketplace is active in two pilot projects: One is located in Germany and is operated by the DSO “Mitnetz Strom”. The other one is located in Norway and is called “Engene pilot project”

(NODES MARKET LIMITED 2020). It is coordinated by Agder Energi DSO. In the latter, Engene project demonstrates a solution on how to use DERs as flexibility assets and to test DER forecasting for a power company. More specifically, the project's main objective is to show how to reduce peak load in certain hours in order to avoid overload in a 25MW sub-station transformer. To achieve that, demand response and stationary batteries are utilized for optimal peak shifting. In the other active project in Germany the proposed technology in NODES marketplace is used to optimize non-dispatchable power production, improving the use of DERs in local areas where distributed generation is high.

5.3.2 EPEX SPOT Local Flexibility Market Platform

EPEX SPOT local flexibility market constitutes an open and voluntary platform developed to resolve mostly market-based congestion management issues induced by intermittent renewable energies. This flexibility market platform centralizes local flexibility offers with critical physical impact for the TSOs and DSOs, helping them to address grid congestions.

5.3.2.1 Market Overview

EPEX SPOT acts as the market operator - an intermediary between FRPs and flexibility providers, while it is responsible also for the price formation and to guarantee transparency among transactions (Figure 19). In general, EPEX SPOT is in charge of defining flexibility product specifications and the rules of the market. The main target of EPEX SPOT is to operate a local flexibility market platform in the intraday timeframe and in parallel with the global market like the intraday and the day-ahead wholesale markets. For this purpose, all flexibility offers are recorded in locational order books and the platform is responsible for the efficient coordination of the flexibility trading.

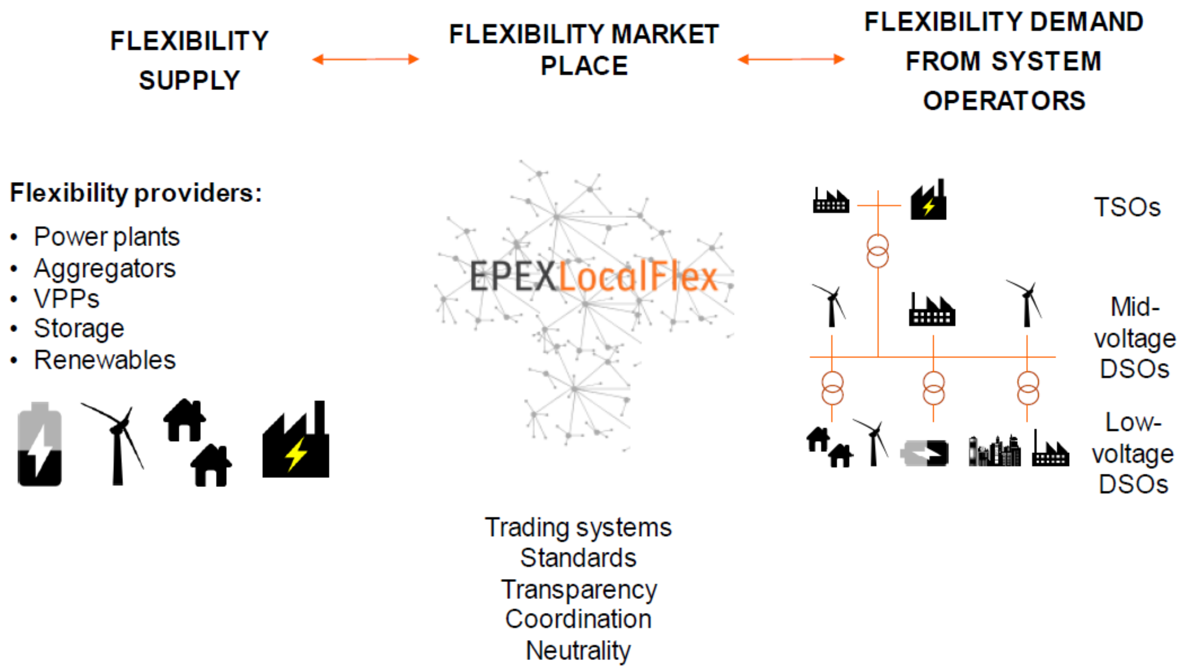


Figure 19. EPEX SPOT Local Flexibility Market Platform concept (Source: EPEX SPOT 2019)

Finally, the interactions between the market and the grid congestion management are based on the traffic light concept depicted below in Figure 20.

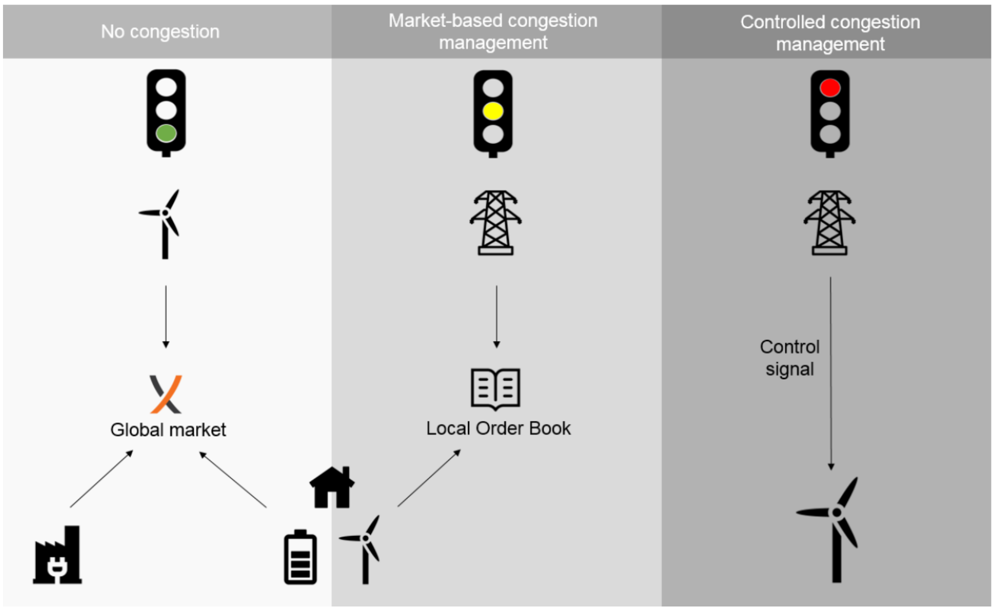


Figure 20. The traffic light concept for market-based congestion management (Source: Niessen et al. 2019)

5.3.2.2 Technological Overview

From a technological aspect, EPEX SPOT local flexibility market platform is based on real-time communication systems providing APIs for fast and optimum interface among system operators (TSOs/DSOs) for enhanced coordination among different voltage levels. The loads utilized in this local flexibility market platform are coming from small electricity assets on residential building level like EVs from a single household through loads induced from large industries like power-to-gas devices. Also, grid loads produced by renewables and stationary batteries are used as flexibility assets. EPEX SPOT platform is utilized in pilot projects active in SINTEG (Federal Ministry for Economic Affairs and Energy (Germany) 2018) – a German funding programme consisting of several use cases all addressing the energy transition concept from a different perspective.

Two of the most worthnoting projects are Enera and C/sells (Federal Ministry for Economic Affairs and Energy (Germany) 2018), both still active in Germany. In Enera project, the main target is the digitization and improvement in terms of technical flexibility of the current energy system, considering all the actors ranging from small prosumers on a single household level to large industrial prosumers. For this purpose, the energy supply system has been equipped with digital technologies including:

- smart electricity meters installation in households and companies,
- digital metrology in power grid junctions,
- smart transformers in the local grid for automated grid fluctuations balance,
- smart control technology for large industries to increase production when there is a surplus in green electricity,
- electricity storage units to automatically provide electricity when needed.

Finally, in the C/sells project, the main goal is to build cellular energy systems using a large share of renewables. A cell could be a large city, a district, a street or a single building. Firstly, the goal is that each cell is able to produce, distribute and use energy as an autonomous energy system. Secondly, the cells should be connected to each other with digital technology achieving automated energy trading at higher levels. C/sells basic structure consists three basic elements. The first is an Infrastructure Information System (IIS) which ensures the data/information exchange among cells is efficient, interoperable and secure. The IIS comprises sensors and actuator technology as well as communication systems. The second element– called reconciliation cascade – is responsible for the fast and automated grid communication among all levels, while the third element is addressing regional flexibility products.

5.3.3 GOPACS/IDCONS Local Flexibility Market Platform (ETPA Market Platform)

GOPACS (GOPACS 2019, Radecke et al. 2019) is a platform developed for grid congestion management issues mitigation and is based on IDCONS (Intraday congestion spreads) product. It was initially developed to investigate the flexibility assets coming from small-scale energy resources and in parallel provide the distribution grid operators with innovative congestion management tools. Currently, is in operational use in Netherlands by Dutch TSOs/DSOs.

5.3.3.1 Market Overview

GOPACS platform is integrated into the intraday marketplace of ETPA (Energy Trading Platform Amsterdam) and is based on IDCONS product, which is a combination of two orders; a flexibility sell order (on local level) and a buy order (Figure 21). These orders are in opposite directions, include information like location (specified with an EAN code), the volume of flexibility, the duration and the starting time, while there are no specific limitations regarding the pricing and volumes of flexibility (although there is a minimum requirement of 0.5MW to participate in the market). The orders are processed by GOPACS platform operated by the Dutch TSO/DSOs and they decide for the most suitable of them, ensuring also that the order will not cause disruptions in the electricity grid. GOPACS at the moment can support a limited number of orders.

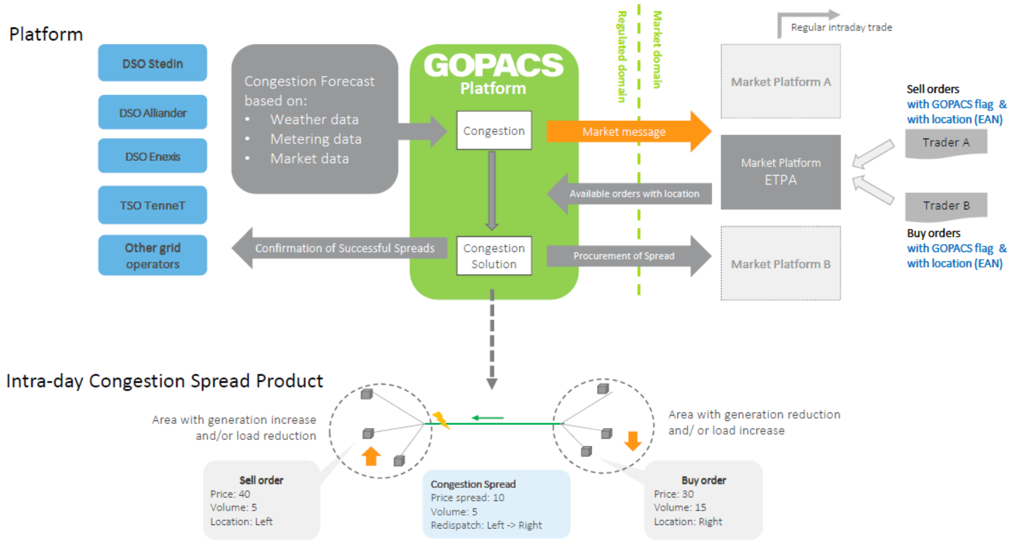


Figure 21. GOPACS Platform design and IDCONS product (Source: GOPACS 2019)

5.3.3.2 Technological Overview

Examining the GOPACS platform from a technological point, the platform in connection with ETPA has developed several APIs in order to facilitate the connections and the information flows among all the market parties. As the platform is open for large and small players, loads that demonstrate a key-role in flexibility trading include heavy industrial loads (i.e. induced by Combined Heat Pump systems), generation loads coming from renewables (PVs and Wind Turbines), storage loads (stationary batteries) and small-scale demand assets from small companies or households. Moreover, smart meters are installed to measure the data flows (load flows, energy trading) for delivery verification purposes. Finally, several smart apps are provided to the platform participants (i.e. power wallets) for the better tracking and monitoring of information like financial settlements and current energy tradings and others.

5.3.4 Piclo Flexibility Marketplace (Piclo Flex)

Piclo Flex (Radecke et al. 2019, Open Utility Ltd. 2020, Piclo 2019) is an independent marketplace for online flexibility trading, currently active in UK. It has been developed with the main scope to standardize and facilitate transactions and flexibility procurement coordination by DNOs (Distribution Network Operators) and reduce the need for grid reinforcement. Piclo's target is to address use cases like grid reinforcement deferral in constrained areas where long-term demand forecast remains unknown, abnormal network conditions management and rural networks improvement.

5.3.4.1 Market Overview

Piclo's marketplace most prominent actors are DSOs and aggregators, as shown in Figure 22. The method upon which the flexibility through Piclo Flex is procured is an open-competition concept. Specific local areas are predetermined by local DNOs, containing prequalifying flexible assets. In order for the assets to be activated there is a prequalification/testing process. The market parties that can take part in Piclo's marketplace are ranging from traditional demand response aggregators, battery/EV operators and operators with dispatchable generators to industrial and commercial customers. Finally, it is worth to be mentioned that the whole market concerns long-term bids/auctions and seems that it is not connected to intraday or day-ahead markets.

Figure 22. Piclo's market design (Source: Open Utility Ltd. 2020)

5.3.4.2 Technological Overview

From a technological perspective, Piclo Flex is based on a digital online platform for auction. The loads that can be utilized as flexibility assets are loads induced from DERs, storage, generation and industries while it is not known whether there is a verification process with smart measurements for the flexibility delivery.

5.3.5 INTERFLEX (InterFlex 2018)

5.3.5.1 System Architecture

The project implemented this system in diverse demonstrators (France, The Netherlands, Sweden, Germany, Czech Republic), with the aim of allowing DSOs to obtain flexibility at local markets for grid management optimization purposes. Figure 23 portrays the general scheme of the Local Flexibility Markets (LFM) implemented in the French and Dutch demos (InterFlex 2018).

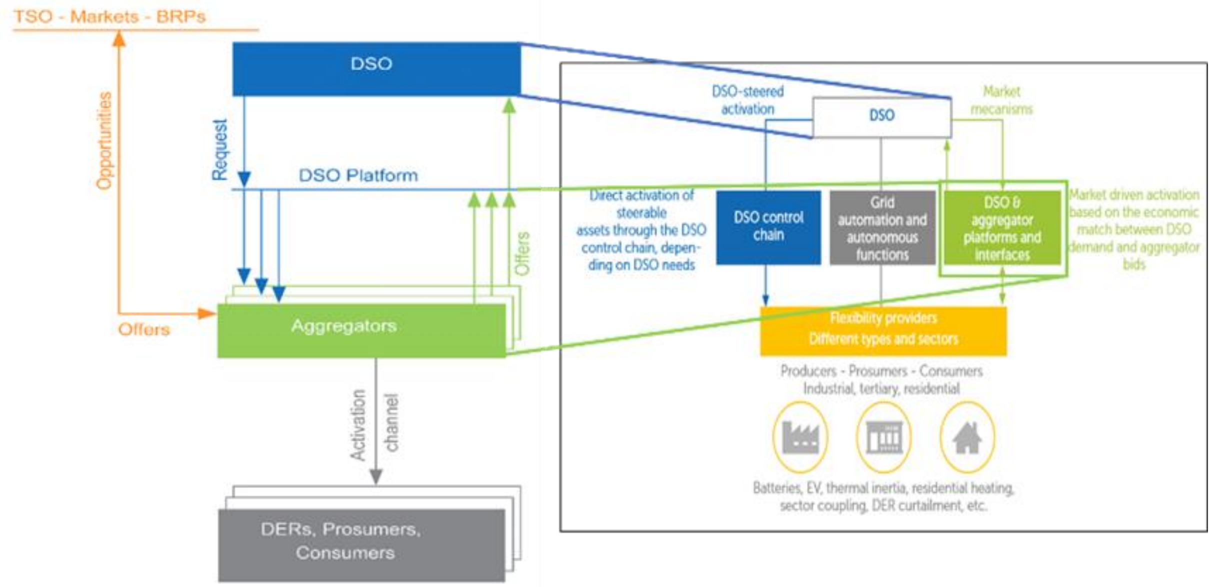


Figure 23. INTERFLEX Flexibility Platforms (Source: InterFlex 2018)

The main actors of the INTERFLEX LFMs are the DSO, which plays the role of Grid constraint manager, the aggregator, which acts as flexibility service provider, and the prosumers as the source of the flexibility. DSOs make a flexibility service request to the aggregators and after the respective analysis, choose the most suitable one(s). Immediately after, aggregators determine the respective availability to send bids towards the DSO. The activation request is later sent by the DSO if there is a match between DSO demand and aggregator bids. The exchange of flexibility between aggregators and the DSO is jointly carried out by their respective platforms (InterFlex 2018).

Sources of flexibility vary according to the demo. In the French demo, the flexibility is provided by domestic appliances, bi-vector assets (gas, electricity), stationary batteries, V2G-EVs, and industrial process control, whereas the Dutch demo sources its flexibility from controllable PV systems, stationary batteries and EVs whose charging sequence is smart-controlled. All the flexibility processes are channelled by both platforms along with their interfaces (InterFlex 2018).

5.3.5.2 Market Structure

The Use Case 4 of the INTERFLEX project includes the development of a peer-to-peer (P2P) market platform and a DSR program for facilitating micro grid customer flexibility. This P2P platform was developed by Lumenaza and helps to visualize the energy data coming from operational LV customers (consumption, impact on the grid, contribution through balancing technologies, and so on) (Pokorná 2017).

The design and development of the pilot trial as the demonstrator of this UC is known as the SIMRIS project and was implemented in the locality of Simris (Sweden).

With regard to the technologies employed for transactive exchange, several balancing technologies are accounted for, such as Hot Tap Water Boiler, Heat Pumps, and PV + Battery. As a part of the P2P platform, there is a User Interface (UI) that let customers visualize how their flexibility is utilized and the incentives they are prone to receive for this (Figure 24). Lastly, there is the billing platform, in charge of undertaking the billing process and performing the payment of incentives based on the percentage of contribution of each customer to the flexibility service (Pokorná 2017, Wilms et al. 2018).

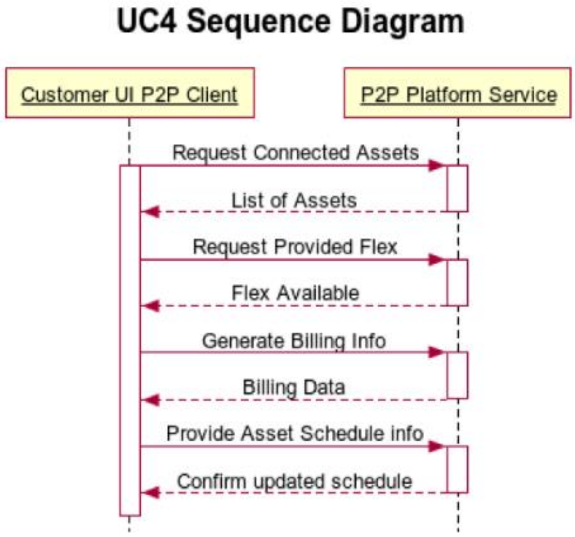


Figure 24. P2P Market Diagram (Source: Pokorná 2017)

5.3.5.3 Methods for Flexibility Estimation

INTERFLEX defines the flexibility estimation as the process where algorithms operate with external information to ameliorate flexibility calendars previously created (InterFlex 2018). Based on this, several advanced algorithms have been developed to estimate flexibility (Wilms et al. 2018, Tamadon et al. 2018, Mildt et al. 2019, Fonteijn et al. 2018, The Strijp, Dumbs and Jarry 2018, Fonteijn et al. 2018, Flexibility for). Some of them are briefly described hereinafter.

In (Wilms et al. 2018), several objective functions were proposed and evaluated by Aachen University, whose equations are shown in Table 4:

Table 4. Objective functions evaluated by RWTH Aachen University (Wilms et al. 2018)

$\min\left(\sum_{t=1}^{T} Cost_{power\_import}(t) - \sum_{t=1}^{T} Revenue_{power\_export}(t) + \sum_{t=1}^{T} Cost_{all\_assets}(t)\right)$ Operational Cost Minimization	$\min\left(\sum_{t=1}^{T} \sum_{(i,j)\in\varepsilon} P_{i,j,loss}\right)$ Loss Minimization
$\max\left(\sum_{t=t_{island}}^{T} \delta_{PCC}(t)\right), \quad s.t.\ \delta_{PCC}(t+1) \geq \delta_{PCC}(t)$ Maximization of Possible Islanding Time After t_{island}	$\min\left(\sum_{t=1}^{T} P_{import}(t) - P_{export}(t)\right)$ Minimization of Power Exchange with the Main Grid

In Tamadon et al. (2018), two types of balancing flexibility were deployed, namely heat pumps and Electric Energy Storage (EES), with the objective to locally balance load and generation at LV grids. Load, generation, and temperature forecasts serve as input data to create day-ahead schedules with three iterative-loop based scheduling algorithms (these are not based in objective functions). These algorithms are for EES charging, EES discharging and heat-pump activation, and were executed step-by-step and consecutively feedbacked. Three simulation cases were considered: for the day with the highest PV generation, and for two winter weekdays. Each simulation was undertaken for a 24-hours period of 15-min time interval. Deploying this scheduling algorithm, balancing of LV grids at local level is achieved with the help of balancing flexibility. This is independent from generation costs and price signals, entailing a diminished exchange among LV networks and towards upstream MV and HV networks.

Finally, authors in (Mildt et al. 2019) implement an Energy Management System (EMS) that deploys a Model Predictive Control (MPC) with a discrete time-step control horizon. The EMS works with four different objective functions and their interaction among them for trade-off purposes. These objective functions are the maximization of potential islanding time (PIT), as well as the minimization of several KPIs, such as the energy exchanged with the main grid, resistive losses, and operational cost. The grid where the EMS system is tested is assumed to be radial, the problem is posed as Mixed-Integer Second-Order Cone Programming (MISOCP), the optimization problems are set in the YALMIP toolbox (Löfberg, J., 2004), and the GUROBI solver is used (Gurobi Optimization - LLC, s.a)

5.3.6 DRIvE (DRIvE s.a.)

5.3.6.1 System Architecture

The DRIvE Project promotes the creation of a flexibility platform where several EMSs for residential and tertiary buildings interoperate among them to allow DR at the distribution network (Loureiro et al. 2018). Figure 25 depicts the logical architecture of a demo case of the project, where community and aggregator platforms operate jointly. The demonstrator, located in the Netherlands, consists of (Denysiuk et al. 2020, Multiagent system):

a) 16 households, with each house having connected to a 2kW heat pump, a 200l hot water buffer, a 7kW PV installation, and a 7.8kWh battery
b) A 220kW district BESS

The multi-model of the community platform is sorted out in two agents deployed on a bipartite energy network: device agents and net agents (Denysiuk et al. 2020, Multiagent system). Device agents are referred to either physical or abstract devices encompassed in the community platform. Examples of these agents are external ties, batteries, PV panels, connectors, fixed loads, etc (Denysiuk et al. 2020, Multiagent system). Net agents belong to the aggregator platform, a virtual zone aimed for the exchange of energy among devices. Example of these are the local energy market, as well as the decomposed battery model (Denysiuk et al. 2020, Multiagent system).

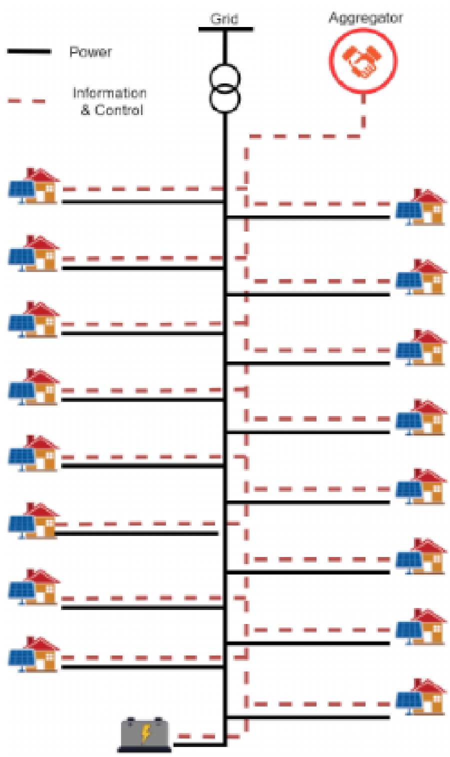


Figure 25. DRIvE Flexibility Platform (Source: Denysiuk et al. 2020, Multiagent system)

5.3.6.2 Market Structure

Authors in (Lilliu et al. 2019, Denysiuk et al. 2020, Peer-to) modelized a problem with a game-theory perspective with the aim of determining how agents would be affected by incentive mechanisms. To do so, a game with the notation G=(U,S,Q), was defined, where U represents the set of players, S the set of players strategies, Q the payoff function for each player, and the players are the grid users.

Hence, for each user, the difference between the energy consumption c_i and the energy production p_i is computed, and the result is a vector whose size is a 24-h time horizon of 15-min time interval. The utility function for this vector is given by (Denysiuk et al. 2020, Peer-to):

$$q_i(t) = g(\boldsymbol{p_i}(t), t_p, t_c) - h(\boldsymbol{c_i}(t), t_p, t_c)$$

Where g and h are a set of pre-defined functions representing the reward for the energy produced and the cost for the energy consumed, respectively, such that $g(0, a, b) = h(0, a, b) = 0$ for each $a, b\epsilon\boldsymbol{R}$, whereas $\boldsymbol{p_i}$ and $\boldsymbol{c_i}$ are the total production and consumption over the network as a function of time, respectively. Three strategies for the players have been set: fixed production, fixed consumption and shiftable loads (Denysiuk et al. 2020, Peer-to).

The aforementioned perspective served as a base to formulate a Peer-to-peer trading mechanism based on NRG-X-Change, a mechanism that does not rely on any energy market and incentivizes both consumers and producers depending on the energy balance that these are capable of achieving (Lilliu et al. 2019, Denysiuk et al. 2020, Peer-to, Mihaylov et al. 2014). The incentives are payed with the energy trading currency known as NRGcoin (1kWh=1NRGcoin) (NRGcoin 2020). The proposed NRG-X-Change Incentive Mechanism is based on a selling function and buying function given by the next formulas (Denysiuk et al. 2020, Peer-to):

Selling function:

$$g(x, t_p, t_c) = P_{max} * g_1(t(x, t_p^{-i}, t_c^{-i})) - g_1(t(0, t_p^{-i}, t_c^{-i})) - P(x, t_p^{-i}, t_c^{-i})$$

Buying function:

$$h(y, t_c^{-i}, t_p^{-i}) = Q_{max} * h_1\left(\frac{t_c^{-i} + y + t_p^{-i}}{B} + 1\right) * y + P(y, t_c^{-i}, t_p^{-i})$$

The buying and selling functions later allow to rewrite the utility function from a game theory perspective, as (Denysiuk et al. 2020, Peer-to):

$$q_i(t) = x * \frac{q}{e^{\frac{(t_p - t_c)^2}{a}}} \qquad if\ y = 0$$

$$q_i(t) = -y * \frac{r * t_c}{t_p + t_c} \qquad if\ x = 0$$

The critical points that have been improved with this NRG-X-Change mechanism and the simulated cases as well are detailed in (Denysiuk et al. 2020, Peer-to). It is noteworthy to mention that despite being completely structured, this P2P market mechanism has not been yet tested when diverse balancing flexibility such as heating, and storage systems are connected to the grid (Denysiuk et al. 2020, Peer-to).

5.3.6.3 Methods for Flexibility Estimation

According to authors in (Loureiro et al. 2018), the DRIvE Project was conceived for the development of a fully-integrated platform for aggregators so that the Demand Response Management can be secure and interoperable. The methods that have been proposed for flexibility estimation are optimization techniques, advanced forecasting strategies, fast-response capabilities, improved user participation components and cyber-security platforms' implementation (Lilliu et al. 2019, Denysiuk et al. 2020, Peer-to).

The DRIvE Project aims to develop novel algorithmic (prediction, control and cyber-security) and frame approaches (MAS, blockchain) that integrate with existing technologies to undertake building energy management. Enervalis[14] is the technical coordinator of the project and makes the middleware available where the DRIvE optimization platform resides (Robbe et al. 2018, Meng et al. 2018, Espeche et al. 2019, Loureiro et al. 2019, Wang et al. 2019).

One of the key flexibility estimation methods consist of the development of an iterative negotiation agent based on potential islanding time (PIT) (Loureiro et al. 2018, Robbe et al. 2018). The optimization

[14] https://www.enervalis.com/

problem that has been carried out uses a splitting technique with the purpose of minimizing the energy bill generated by both device agents (D) and net agents (N), as represented in the next equation (Loureiro et al. 2018):

$$minimize_{x_i \in \Omega_i, z_i \in \Theta_i} \sum_{i \in D} f_i(x_i) + \sum_{i \in N} g_i(z_i)$$

The tests for the proposed market scenarios were carried out with input data corresponding to a winter day of 15-min time interval.

This algorithm was fully funded by the DRIvE project, whereas a partial funding was employed to undertake an algorithm which seeks to minimize the total economic cost, being the problem formulated as an optimal coordination of DSM of plug-in electric vehicles (PEVs) jointly with unit commitment for a time horizon of 24 hours. In the Case Study 3, PEV's charging load type and flexibility allowed to define a charging factor ω to acknowledge how PEVs charging load affects the power system (Wang et al. 2019).

5.3.7 CATALYST (CATALYST Project 2020)

5.3.7.1 System Architecture

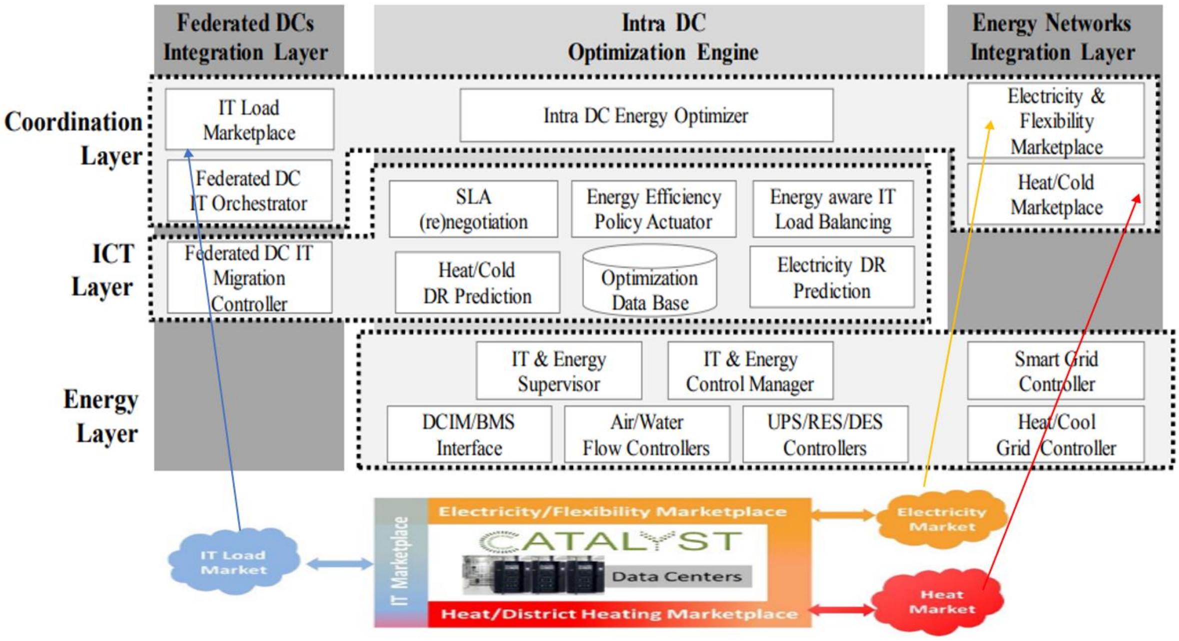


Figure 26. CATALYST Architecture – 1 (Source: Anghel et al. 2020)

As can be seen in Figure 26, there are horizontal and vertical layers of coordinated optimization depending on diverse Data Centres (DC) disciplines can be addressed. These are shown in Table 5.

Table 5. Layers of the CATALYST Architecture (Source: Anghel et al. 2020)

Horizontal Layers	Vertical Layers
Energy: includes both electricity and heat/cool energy generated by distributed sources throughout the supply chain.	Federated DCs Integration integrates the data network of federated DCs.
ICT: includes ICT load of either a single DC or a group of federated/distributed DCs.	Intra DC Optimization: where each DC is optimized to provide energy flexibility services
Coordination: an access where energy and IT loads communicate among each other	Energy Networks Integrator: where smart energy grids are integrated

White rectangles and cylinders represent the main components of each vertical tier, whose brief description is encountered in (Anghel et al. 2020).

5.3.7.2 Market Structure

From Figure 27 can be noticed that there are four marketplaces which help to undertake the transactive exchanges of several values: Electricity Marketplace (where electricity trading among DCs and other prosumers take place), Flexibility Marketplace (where flexibility services are traded among aggregators, the enrolled prosumers with their respective DCs and DSO), Heat/Cold Marketplace (where heat and cooling are traded the DC operators and heat aggregators) and IT Load Marketplace (where workload relocation among DCs in carried out for obtaining financial revenues).

The first two are local, whereas the other two have a higher action field (Cioara et al. 2020).

How these marketplaces operate is better noticed from Figure 27Figure 27. CATALYST Architecture – 2 (Source: Cioara et al. 2020). Such diagram corresponds to the “Scenario 7: Workload Federated DCs Providing Both Thermal and Electrical Energy Flexibility”, which seeks to “exploit migration of traceable ICT-load between federated DCs to deliver: (i) heat to the surrounding thermal grids and (ii) energy flexibility to the surrounding power grids” (Cioara et al. 2020).

In there, the committed DCs interchange IT load through the IT Workload Marketplace. Besides, these are connected to electricity and flexibility aggregators, which in last instance trade both the flexibility and electricity gathered from the DCs associated to the prosumers. Lastly, these DCs trade heat at the Heat/Cold Marketplace (Cioara et al. 2020).

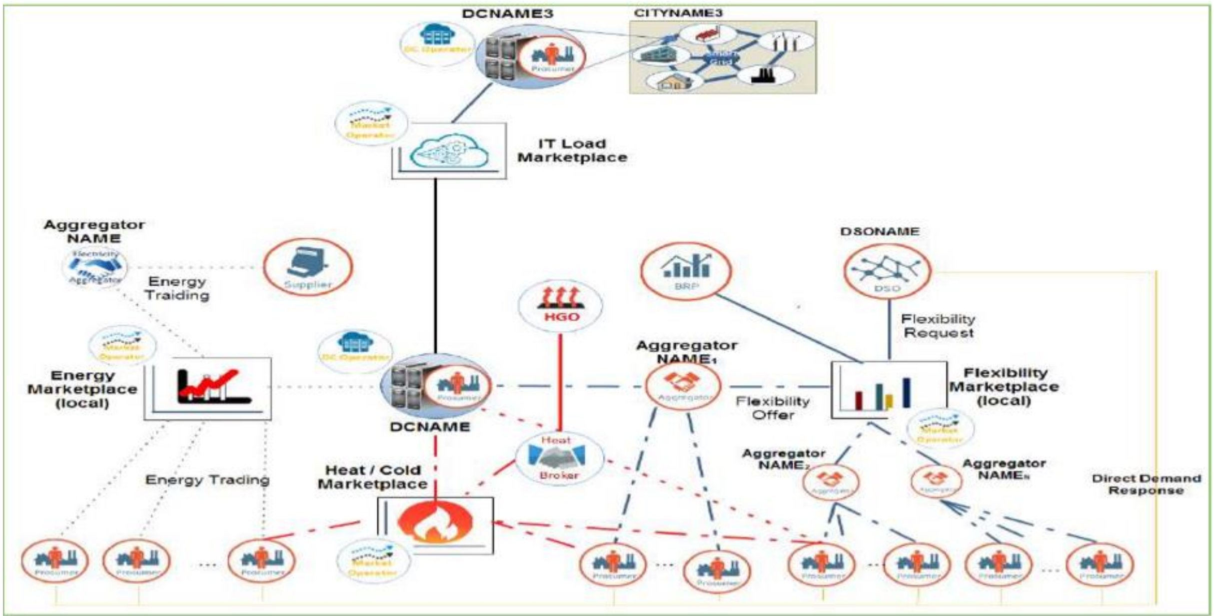


Figure 27. CATALYST Architecture – 2 (Source: Cioara et al. 2020)

5.3.7.3 Methods for Flexibility Estimation

The main purpose of the CATALYST Project is to employ Data Centres (DCs) as facilities for providing electrical, thermal and IT data, which later serves to undertake energy flexibility supply by means of applying several optimization techniques (Anghel et al. 2020, Cioara et al. 2018).

In this regard, one of these approaches seeks to minimize the deviation between the total energy demand accounted for each data centre and the objective demand curve that such data centres ought to track at a time span $t \in [0, T]$ when discrete time modelling techniques are utilized, as depicted in the next equation (Cioara et al. 2018).

$$min\left(\sum_{t=1}^{T}(E_{DC}^{adapted}(t) - E_{goal}(t))\right)^{1/2}$$

The flexibility estimation is carried out by means of modelling each DC component as a transfer function depending on time, where the energy flexibility variables (electrical, thermal and workload relocation) pass through an internal state process to turn these into energy demand. The input data is mapped to a Mixed-integer Nonlinear Programming (MINLP) problem, and the combinatorial problem is intended to solve through the employment of complex branch-and-bound algorithms, whereas among the techniques to delimit the search spaces are interval analysis, convex analysis, constraint propagation, NLP relaxation, feasibility sub-problem, and so on. The energy flexibility techniques and the sources employed for carrying them out are described in Table 6.

Table 6. Energy flexibility techniques carried out in (Source: Cioara et al. 2018)

Component	Energy flexibility technique
IT servers	*Time shifting of delay tolerant workload*, in the same DC. The DC energy demand is reduced at timestamp t with the amount of energy needed to execute the delay-tolerant load that is shifted at timestamp $t+u$, $u \in [1, T-t]$ while the DC energy demand at timestamp $t+u$ is increased with the amount of energy needed to execute the delay-tolerant load shifted from t.
Electrical cooling system and TES	*Dynamic usage of non-electrical cooling systems* (TES) to precool the DC and to compensate the electrical one. At timestamp t the TES is charged, its coolant (water based thermal tanks) is overcooled by using the electrical cooling at higher capacity resulting in an increased energy demand. At timestamp $t+u$, $u \in [1, T-t]$ the TES is discharged; the DC is cooled down using the pre-cooled coolant and the electrical cooling is used at low intensity resulting in a decrease of DC energy demand.
ESD	The DC energy demand is reduced at timestamp t by the amount of energy discharged from batteries and increased at timestamp $t+u$, $u \in [1, T-t]$ by the amount of energy charged in batteries.

Another optimization process was undertaken, but for a different energy vector. That is, instead of creating a framework to gather electrical flexibility, was created a DC Cloud Architecture which constitutes an improvement of CloudSim framework. Such improvement, known as CoolCloudSim, has the purpose of optimizing the consumption of cooling systems and IT resources, developing for this several strategies aiming to allocate several thermal aware Virtual Machines (VM) (Cristian et al. 2018). Among the proposed algorithmic approaches are accounted Worst Fit Decreasing (WFD), First-Fit Decreasing using Decreasing Host Available MIPS (FFDDHAM), Thermal Aware Best Fit Decreasing (TASBFD), and Best Temp Difference or Worst Power Difference (BTDWPD). All of these demonstrated their capability of outperforming the default CloudSim Power Aware Best-Fit Decreasing (PABFD), because they can reduce the energy consumption greater than 10% as well as a considerable reduction of VM migrations (Anghel et al. 2020).

5.3.8 eDREAM (eDREAM s.a.)

5.3.8.1 System Architecture

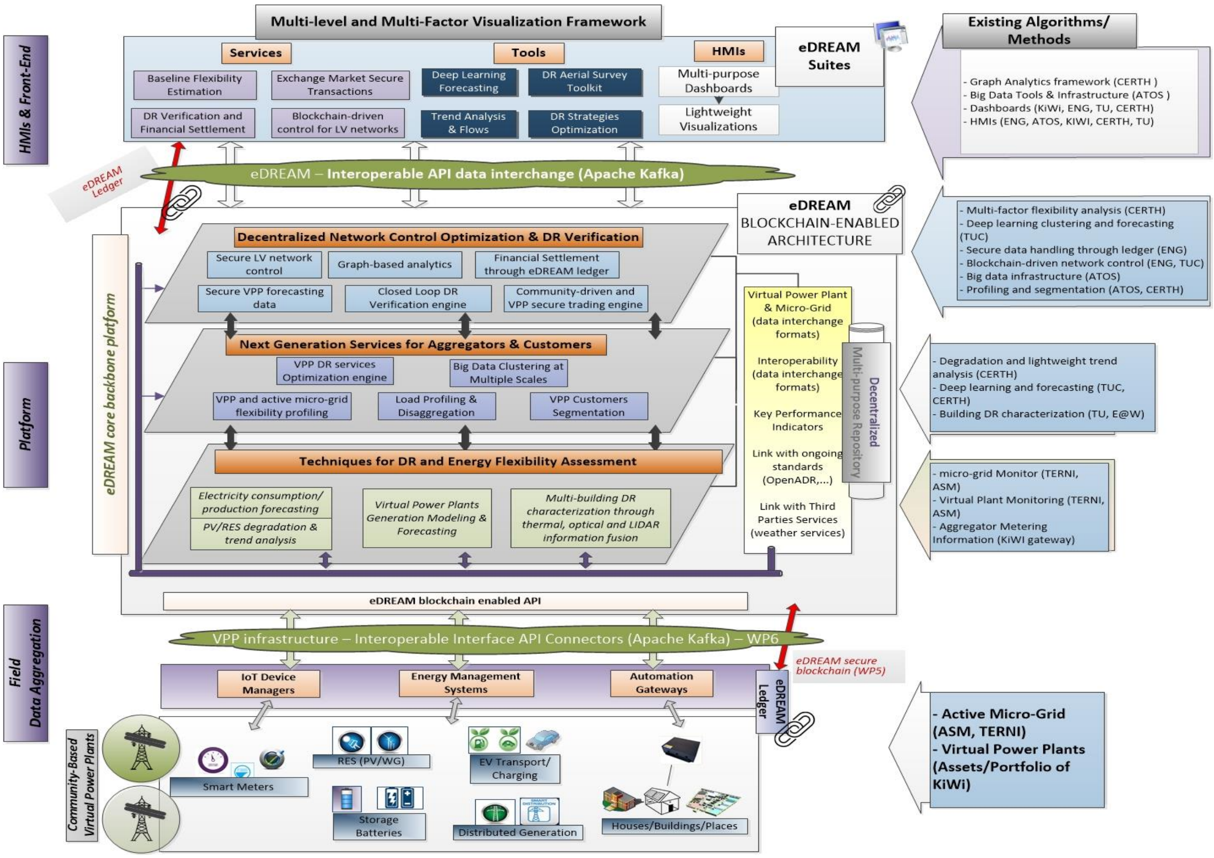


Figure 28. eDREAM Conceptual Architecture (Source: eDream 2018, D2.4)

Figure 28 depicts the eDREAM Project's Overall Architecture (eDream 2018, D2.4). It consists of a technological environment encompassed by several layers, sub-layers, and the corresponding architectural components. The objective of this project is to automatically estimate, aggregate and manage the flexibility provided by Distributed Energy Resources, consumers, and storage systems (eDream 2018, D2.4). Each of the layers will be briefly described in Table 7.

Table 7. Layers of the eDREAM Architecture (Source: eDream 2018, D2.4)

Layer	Description	Additional information
Field Data Aggregation	Where smart metering devices and communication interfaces help to establish a bridge with the physical structures. This layer sends real-time information towards the upper layers, and its inner components perform analysis and calculation processes right after.	The information transference with the other layers is carried out through the IoT device managers and will be based on open communication standards.
Core Backbone Platform	Comprises all the mechanisms and components needed for providing enhanced services to the stakeholders. In this layer, the components provide support to the structures encompassing a decentralized ecosystem dedicated to closed-loop DR programs. This layer is comprised by three sub-layers connected with a Decentralized Multi-purpose Repository:	Energy consumption and production forecasts were improved for allowing small-scaled household to participate in DR programs. Machine Learning Techniques and Big Data Analytics Engine were investigated.

	a) Technologies for DR and Energy Flexibility Assessment b) Next Generation Services for Aggregators and Customers c) Decentralized Network Control Optimization & DR Verification	DR modelling, control and validation were undertaken by means of employing Blockchain platforms.
HMIs & Front-end for end-users and operators	Layer purposely envisioned for data visualization, analysis and interpreted. The data comes from the outputs obtained at the Core Backbone Platform, and the data flow between this layer and the immediately below layer is bidirectional.	The available Human-Machine-Interfaces (HMIs) for both operators and end-users enable two types of collaboration: a) Horizontal: community based VPPs b) Vertical: from DSOs/Aggregators to consumers/prosumers

Table 8 displays most of the functional architecture components and their high-level dependencies, especially those dedicated to flexibility functionalities per se. The functional components are defined as parts of the system having a specific task and carry out diverse functions, while disposing interfaces that connects them among each other. The dependencies can be defined as channels through which the components' functions availability for other components is made upon request (eDream 2018, D2.4):

Table 8. eDREAM's Functional Architecture – Main components and dependencies (Source: eDream 2018, D2.4)

Component	Brief Description/functions	Dependencies to other components
Graph-based Analytics	The main functionalities of this component are: a) Offering output data viz b) Allows to visualize either energy transactions or financial settlements, etc.	Capable of interacting with all the components located in its same layer and those place at the front-end part, as well as with the Decentralized Repository
Secure data handling through ledger	Also known as blockchain distribution layer, stores both energy transactions and DR flexibility services. Among its main functionalities are authorizes access to data only to those end-users allowed to, allows a secure way to store energy transactions, and so on.	Capable of interacting with all the components located in its same layer
Blockchain-driven control for LV networks (Flexibility Management)	Self-enforcing smart contracts allow this module to intervene when it comes to undertake functionalities such as: detection of grid congestion points, selection of flexibility offers from aggregators, and so on.	Secure data handling through ledger, Field Middleware, Electricity Consumption/Production Forecasting, Baseline Flexibility Estimation, Closed loop DR Verification Engine, Decision Support System & DR Strategies Optimization
Closed loop DR Verification Engine	DSO-Prosumer and DSO-VPP Manager matches for services such as production/load modulation are monitored and verified by this component, specifically outputs related to matched prices, penalties, and services	Blockchain-driven control for LV networks, HMIs
Secured Blockchain-driven Energy Market	Self-enforcing smart contracts allow this module to provide market sessions for registering demand/offer/matching actions and clearing price computations	Secure data handling through ledger, HMIs, Closed loop DR Verification Engine
VPP&DR Services Optimization Engine	DR optimization mechanisms are supplied by this component. Among its functionalities, there are: consumption/production forecasting,	Electricity Consumption/Production Forecasting, PV Degradation & Trend Analysis and Baseline Flexibility Estimation, Decentralized Repository, Virtual Power Plants

	average baseline calculations, estimation of end-user's potential incentives, employment of Trend Analysis Algorithm for carrying out forecasting improvements	Generation, Modelling & Forecasting, VPP and active Microgrid Flexibility Profiling, Decision Support System & DR Strategies Optimization, HMIs
Load profiling & disaggregation	Detects patterns on load profiles and gathers these profiles considering hindcasted load consumption	Decentralized Multi-purpose Repository, Field Middleware, Electricity Consumption/Production Forecasting, Big Data Clustering at Multiple Scales
VPP and active Microgrid Flexibility Profiling	Allows to get prosumers' generation assets' flexibility margins. Production assets can serve for supplying flexibility services either directly or through aggregators, with the latter giving the possibility of exploding both VPPs and MGs flexibility to manage DSO's instabilities	Virtual Power Plants Generation, Modelling & Forecasting, Baseline Flexibility Estimation, Big Data Clustering at Multiple Scales, VPP & DR Services Optimization Engine, Blockchain-driven control for LV networks (flexibility management)
PV/RES Degradation and Trend Analysis	Calculates the degradation rate (Rd) of PV plants and other RES for long/term energy production estimation purposes, as well as for short/term generation forecasting	Electricity Consumption/Production Forecasting, Decentralized Multipurpose Repository, Virtual Power Plants Generation Modelling & Forecasting, Forecasting Tool, VPP & DR Service Optimization Engine
Electricity Consumption & Production Forecasting	Detects the patterns of energy consumption and production of prosumers to deliver precise supply/demand energy forecasts at different granularity levels. The prediction platform implemented in GEYSER project will allow to create diverse prediction models and to provide prediction for selected DERs	Decentralized Multi-purpose Repository, Virtual Power Plants Generation, Modelling & Forecasting, PV/RES Degradation & Trend Analysis, Blockchain-driven control for LV networks (flexibility management), Load Profiling & Disaggregation, Forecasting Tool, VPP & DR Services Optimization Engine, Decision Support System & DR Strategies Optimization
Virtual Power Plants Generation, Modelling & Forecasting	Develops models for diverse generation sources, such as PV, wind turbines, back-up generators and so on, aimed to create VPPs capable of providing a more reliable power supply at the aggregation node	Electricity Consumption/Production Forecasting, PV/RES Degradation & Trend Analysis, Field Middleware, Multibuilding DR characterization through thermal, optical and LIDAR information fusion
Multi-Building DR characterization through thermal, optical and LIDAR information fusion	Estimates the potential of DR by means of employing images gathered from optical, thermal and LIDAR scanners placed on drones appropriately designed for undertaking several tasks	Virtual Power Plants Generation, Modelling & Forecasting, Baseline Flexibility Estimation, Big Data Clustering at Multiple Scales, Decentralized Multi-purpose Repository, DR Aerial Survey Toolkit
Baseline Flexibility Estimation	Calculates the flexibility of prosumers based on several profiles (smart metering data, energy demand) obtained when these intervene in diverse DR programs, such as economic/energy tariff, balancing/ancillary services, and resource adequacy/capacity	Decentralized Multi-purpose Repository, Multi-building DR characterization through thermal, optical and LIDAR information fusion, VPP and active Microgrid Flexibility profiling, VPP & DR Strategies Optimization Engine, Blockchain-driven control for LV networks (flexibility management), Forecasting Tool, DR Aerial Survey Toolkit
Field Middleware	Bottom layer of the system. Communicates interfaces with field devices. Gets raw data from smart meters, EV chargers and so on for undertaking primary information processing and serving as interface with the physical world.	Field Devices (Smart meters, EV charger), Core Backbone Platform, Decentralized Repos.

5.3.8.2 Market Structure

eDREAM has created a mechanism known as "Peer-to-peer local energy trading market", which constitutes one of the High-Level Use Case 02 elicited by the members of the consortium (eDream 2018, D2.4, D'Oriano et al. 2018) and was tested at E.ON Future Lab back in 2016 (Pop et al. 2018). It is a decentralized price-driven platform where prosumers establish peer-to-peer transactive direct exchanges with the energy sellers, or with the intermediation of an aggregator when their infrastructure is not big enough, being the smart contracts based on Blockchain the technology chosen for (eDream 2018, D2.4, D'Oriano et al. 2018, eDream 2019, D3.2).

Figure 29 represents the blockchain-based distributed ledger for energy transactions at microgrid level, along with the architecture for decentralized management of power systems based on Blockchain Technology (eDream 2019, D5.1, Pop et al. 2018).

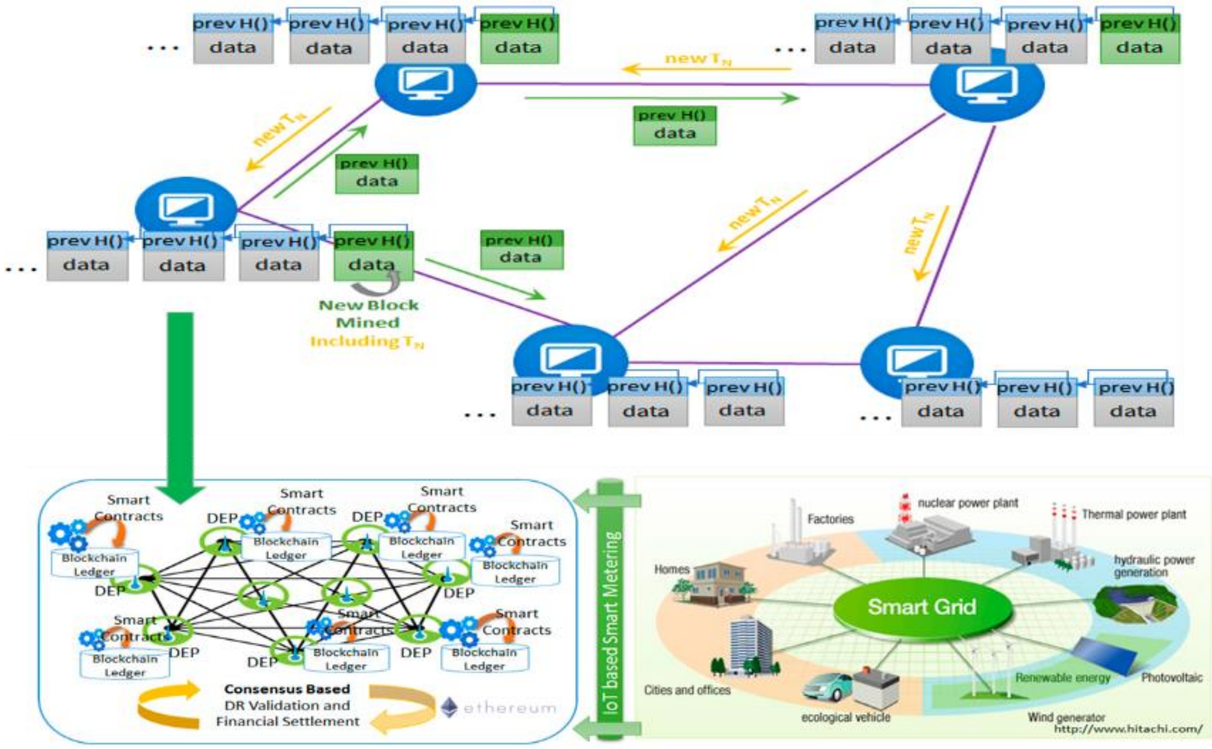


Figure 29. eDREAM Peer-to-Peer Architecture (Source: eDream 2019, D5.1, Pop et al. 2018)

In this scheme, each one of the participants (prosumers, DERs, energy aggregators, DSOs, or any other showing interest in microgrid management) is modelled as a node inside the P2P network.

Either the peer-to-peer local trading is undertaken directly among the stakeholders or by means of an aggregator, the transactive process is the one described next (eDream 2018, D2.4):

a) Prosumers registration with the energy trading platform: prosumers provide their information on the energy market to proceed with its registration and later, a self-enforcing smart contract, whose aim is to track and control energy transactions and DER flexibility services, is subscribed in a decentralized manner after validation. Energy tokens are needed for energy transaction and prosumers must be capable of affording them.
b) Prosumers bids/offers submission: Prosumers concur to the next market session by means of employing forecasted data that helps to build the bid/offers. These are submitted by association with the tokens equivalence with the amount of energy to be traded, that is, 1 token = 1kW.
c) Energy clearing price determination: the intersection between the curves corresponding to energy supply offers and energy demand bids allow to determine the energy trading price.
d) Validation and financial settlement: "The energy transactions are validated, and the prosumer accounts settled allocating tokens to the prosumers accounts/wallets".
e) The energy-driven data is recorded at prosumer level and later stored as immutable energy purchasing for a posterior aggregation in blocks to be replicated in the ledger (Pop et al. 2018).

The registration, validation and propagation of every single new transaction is carried out among all the peer nodes. Due to a lack of a centrality in the nodes peering, consensus algorithm happens to be the most appropriate technique for ensuring an agreement among nodes that let them to concur towards a valid ledger state (eDream 2019, D5.1).

The rules radically change when a new market participant is incorporated to the peer-to-peer scheme. That is, a new node must be created once a new prosumer joins the blockchain network, and when the connection with the seed nodes is achieved, these send information to the new node about its neighbouring peers to update the network. The result of this updating is an append-only data structure that could lead to inconsistencies if the blocks are not properly rehashed during the update of the ledger, what can cause the interruption of any transaction until the inconsistency is solved (Pop et al. 2018).

Lastly, a blockchain-architecture for control, distributed management, and DR programs validations in LV/MV smart grids has been envisioned. The same is aimed for implementing identifiable-tamper-proof energy flexibility trading and close-to-real-time DR validation, what allows the assurance of grid operative stability (eDream 2019, D5.1).

5.3.8.3 *Methods for Flexibility Estimation*

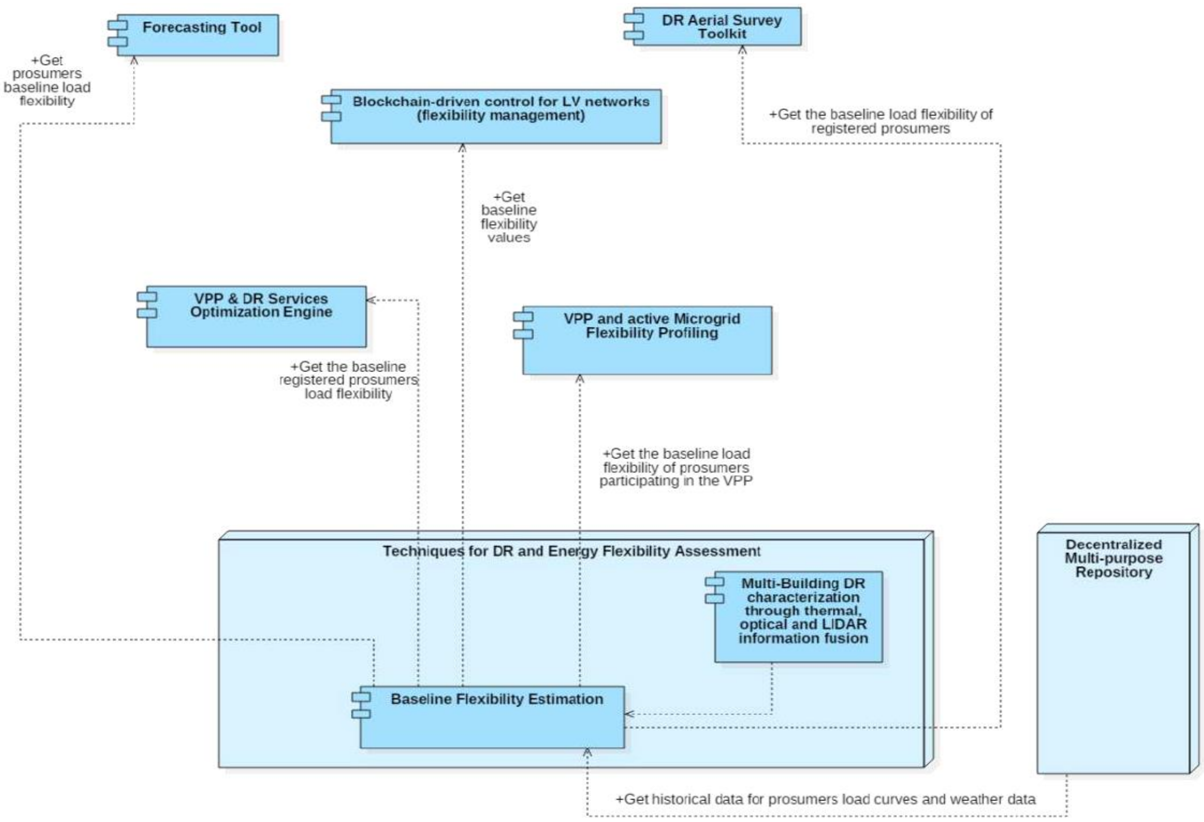


Figure 30. Baseline Flexibility Estimation Component (Source: eDream 2018, D2.4)

The Flexibility Estimation is undertaken through a component inside the eDREAM Architecture named Baseline Flexibility Estimation. This is a service supported as one of the eDREAM suites inside the upper layer (Figure 30), and its main function is to calculate the flexibility of prosumers based on several profiles (smart metering data, energy demand) obtained when these intervene in diverse DR programs, such as economic/energy tariff, balancing/ancillary services and resource adequacy/capacity. The comparison of such baseline load curves will be executed for all the demonstrators and will be subjected to either historic weather records or a natural meteorological time span (e.g., one year) (eDream 2018, D2.4).

Taking a look closer at the picture above, it is noticeable that the Baseline Flexibility Estimation Block takes as input data, on the one hand, the one coming from the Decentralized Multi-purpose Repository (registered prosumers load curves and weather data), and on the other hand, the one coming from Multi-building DR characterization through thermal, optical and LIDAR information fusion (e. g. analysed images and data). Inside this block, calculations, and evaluation of baseline load flexibility of potential prosumers are performed altogether by means of the employment of techniques that allow to assess energy flexibility and DR. The output data of this block is categorized based on their inner sub-components (Table 9).

Table 9. Output Blocks of the eDREAM Baseline Flexibility Estimation Component (Source: eDream 2018, D2.4)

Sub-component	Output Data
VPP and active Microgrid Flexibility profiling	Baseline load flexibility of those prosumers that participate in the VPP, that later serves to calculate the profiling of VPP flexibility
VPP & DR Strategies Optimization Engine	Baseline registered prosumers load flexibility, which allows to plan the DR programs
Blockchain-driven control for LV networks (flexibility management)	Baseline flexibility values of registered prosumers. It helps to determine the actual flexibility that can be delivered upon DSO's request
Forecasting Tool	Prosumers baseline load flexibility, which is later correlated with the depicted estimated consumption
DR Aerial Survey Toolkit	Baseline load flexibility of both, registered prosumers (for evaluation with aerial survey) and new potential prosumers (based on analysed gathered illustrations).

Dynamic coalitions with the purpose of aggregating DERs according to the type of VPPs were modelled at micro-grid level as a part of the consumption flexibility models and aggregation techniques undertaken on the eDREAM project. The types of VPPs considered are Distributed Energy Generators (CHP systems, PV units and wind turbines, etc.), Energy Storage Systems (UPS, batteries) and Flexible Energy Demand Assets. Optimization techniques aimed to enhance the profit of each VPP participants are depicted in Table 10.

Table 10. Formulation of the optimization problem for VPPs modelled at the eDREAM project (Source: eDream 2019, D3.3)

VPP energy trading: Seeks to optimize the prosumers' coalition, such that these can be able to trade aggregated generation while considering energy price signals. The output of this optimization is the number of prosumers capable of meeting the optimization objective once their individual constraints have been fulfilled. $$maxVPP_{profit}^{trading}(t) = \sum_{t=1}^{T} E_{VPP}^{generation}(t) * price(t) + R_{ESS}(C_{ESS}, D_{ESS}, price) - (risk_{uncertainty} + risk_{diversity} + Gen_{Cost})$$	**Capacity bidding service:** the optimal prosumers set capable of forming a coalition for supplying a fixed energy capacity over time is determined by means of the dual objective function depicted next, and seeks to impose a target aggregated capacity coming from prosumers as increase the profit of the VPPs. $$\min\left(\sqrt{\sum_{t=1}^{T}(E_{VPP}(t) - Target_{capacity})^2}\right),$$ $$maxVPP_{profit}^{capacity}(t) = Compensation * \sum_{t=1}^{T} E_{VPP}(t) - (risk_{uncertainty} + risk_{diversity} + Gen_{Cost})$$
VPP demand response: the twofold optimization problem in this case selects a subset of a clustered energy prosumers for fulfilling DSO demand at the same that diminishes the risks caused by predictions' uncertainty as well as by	**Reactive power compensation device:** clustered prosumers around a point placed at the local grid allow to create a dynamic such that, after the occurrence of a reactive power imbalance, new VPPs are called to optimally address local

generation systems' diversity. In addition, seeks to maximize the profits gathered by the VPPs when participate in DR programs. $\min \sqrt{\sum_{t=1}^{T}((E_{VPP}^{generation}(t) + E_{VPP}^{flexibility}) - DSO_{demand}(t))^2}$ $maxVPP_{profit}^{DR} = \left(\left(\left(\sum_{k=1}^{N}\sum_{t=1}^{T}\left\|E_{uncertain}^{k}(t) - E_{K}^{baseline}(t)\right\| * price(t)\right) - DSO_{reward}\right) - (risk_{uncertainty} + risk_{diversity} + Gen_{Cost})\right)$	reactive power oscillations while grid voltages are balanced. In such sense, the objective function seeks to minimize the deviation between the actual power factor ad the target one, whereas maximizes the profit that VPPs obtain after conveying the reactive power compensation service. $\min(\sqrt{\sum_{t=1}^{T}(PF_{target}(t) - PF_{grid}(t))^2}$ $maxVPP_{profit}^{PF} = Service_{Reward} - Gen_{Cost}$

All the objective functions presented in table above consider that the producers' coalition for VPP optimization purposes are Constraint Satisfaction Problems placed at the category of NP-complete. All of them were addressed in such way that they have the general form presented in Figure 31.

Determine $x \in R^n, y \in Z^m$

$$minimize(f(x,y)), f: R^n \times Z^m$$

Such that

Constraints: $c_i(x,y) \leq d, i \in \{1..K\}, d \in R$

Variable Bounds: $x_L \leq x \leq x_H$

$$y_L \leq y \leq y_H$$

Variable Types: $x \in X \subseteq R^n$

$$y \in Y \subseteq Z^m$$

Figure 31. General form of the optimization problems presented in (Source: eDream 2019, D3.3)

Exact solutions are not easy to find when the problem is addressed as NP-complete. Hence, the problem complexity was approached according to the correlation among the variable types, as shown in Table 11 (eDream 2019, D3.3):

Table 11. Problem approaching by correlating variable types (Source: eDream 2019, D3.3)

x	y	*f-differentiable*	Problem Class	Algorithms
$x \in X \subseteq R^n$	$y \in \emptyset$	*yes*	NLP	Gradient-based
$x \in \emptyset$	$y \in Y \subseteq Z^m$	*no*	ILP	Heuristic-based
$x \in X \subseteq R^n \emptyset$	$y \in Y \subseteq Z^m$	*no*	MINLP	Hybrid Approach

A gradient-based algorithm, such as the ADAM algorithm, is well suited for calculating an approximate solution when the problem is comprised by continuous variables only and the function is differentiable, whereas a space search can be performed with the aim of looking for all the feasible solutions when heuristic methods are applied to when the problem only contains integer variables and the function is not differentiable. By taking advantage of both gradient-based and heuristic-based algorithms, a hybrid approach has been proposed, where a function f is minimized by applying heuristic methods tendent to determine a candidate solution for y, and later the constraints associated to the winner solution y are set within the function f, being the last step the one in which, by means of performing gradient-based algorithms, the derivative given by $\frac{df(x,y_{solution})}{dx}$ is computed. The whole hybrid approached is symbolized in Figure 32.

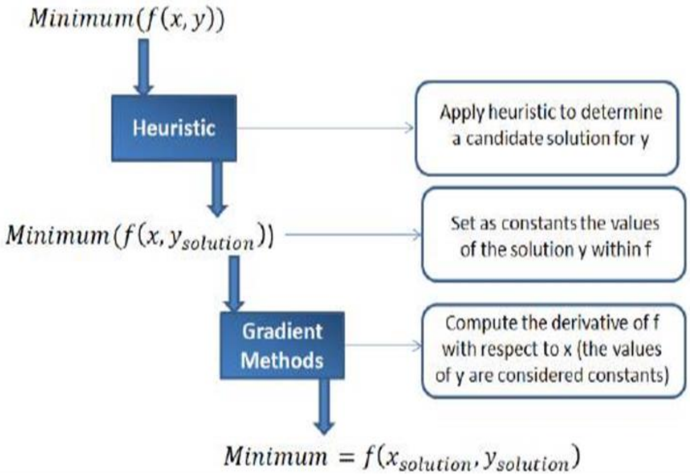


Figure 32. Hybrid optimization approach proposed in (Source: eDream 2019, D3.3)

After addressing the appropriate approach for handling with the optimization problem and determining its class (MINLP), an augmented objective function is introduced that at the same time deals with the issue of having to verify the set of constraints according to those variables whose value help to minimize the objective function (eDream 2019, D3.3).

$$f_{objective}: R^n x Z^m, f_{objective}(x,y) =< f_{constraint}(x,y), f_{barrier}(x,y) >$$

The new twofold objective functional is featured as next (eDream 2019, D3.3):

a) First component (constraints not met by any solution):

$$C_V = \{i | c_i(x,y) > d\}$$

$$C_x = \{i | x^i < x_L^i \vee x_H^i < x^i, i \in \{1..n\}\}$$

$$C_y = \{i | y^i < y_L^i \vee y_H^i < y^i, i \in \{1..m\}\}$$

$$f_{constraint}: R^n x Z^m, f_{constraint}(x,y) = |C_V| + |C_x| + |C_y|$$

b) Second component (considers those constraints not being met from the C_V subset):

$$f_{barrier}: R^n x Z^m, f_{barrier}(x,y) = f(x,y) + \mu \sum_{i=1}^{K} g_i(x)$$

5.3.9 SmartNet (SmartNet Project 2018)

5.3.9.1 System Architecture

SmartNet Project seeks to provide optimum coordination among TSOs and DSOs by means of comparing possible architectures, as well as the information interchange for serval purposes (SmartNet Project 2018, Migliavacca et al. 2017):

a) Acquisition of ancillary services, such as reserve and balancing, congestion management and voltage balancing control.
b) Monitoring flexible load and distributed generation upon local and central power systems' request.

The aim of this project is to develop a platform which will serve to perform ad/hoc simulation for modelling the three layers: physical layer, bidding and dispatching layer and market layer (Migliavacca et al. 2017, Viganò et al. 2019), whose overall architecture of the SmartNet Project is the one depicted in Figure 33, and will serve to evaluate how impactful DERs operation will be in terms of (Migliavacca et al. 2017):

a) Dispatching
b) Market layout and sequencing
c) Signals exchanged among TSOs and DSOs
d) ICT inquiries
e) Legal connotations

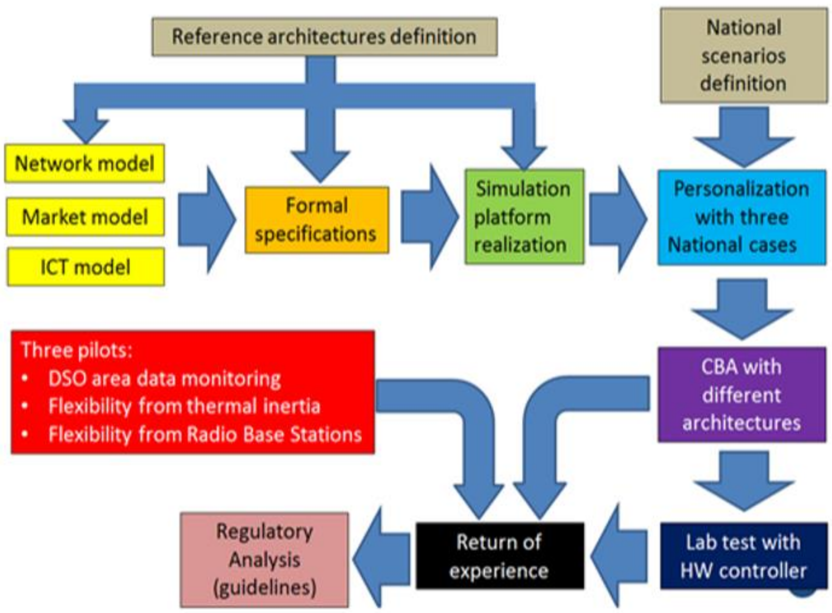


Figure 33. SmartNet overall Architecture (Source: SmartNet Project 2018, Migliavacca et al. 2017)

To undertake the simulations, three modelling schemes will be performed for network, market, and ICT platforms, and three pilots were built at the same locations object of national scenarios definition (Migliavacca et al. 2017).

- The Italian Pilot monitored DSO's area data to evaluate the technical expediency of such process in terms of participating in frequency and voltage regulation. The pilot was mounted in the region of Ahrntal, whose main feature is the hydro sources high penetration, and allowed to demonstrate the "Aggregation of information in real-time at the TSO/DSO interconnection point, Voltage regulation by generators connected at HV and MV and the Power-frequency regulation (Frequency Restoration) by generators connected at MV" (Migliavacca et al. 2017).
- The Danish Pilot was framed for providing flexibility coming from indoor swimming pools for ancillary services supply purposes. It sought to demonstrate how predictable demand could

contribute to the operation of T&D power systems, with special emphasis on the usage of price signals to manipulate swimming pools thermostats' set-points.

- The Spanish Pilot was aimed to get flexibility from distributed energy storage systems located at telecommunication base stations. This pilot conceived how to demonstrate that mobile phones base stations were capable of providing the flexibility needed to diminish congestions in distribution power systems on the one hand, and to maintain TSO's energy balance by means of imposing an exchange calendar at the TSO-connection border knot on the other hand.

The architecture of each pilot is portrayed in Figure 34, Figure 35 and Figure 36 respectively (Migliavacca et al. 2017).

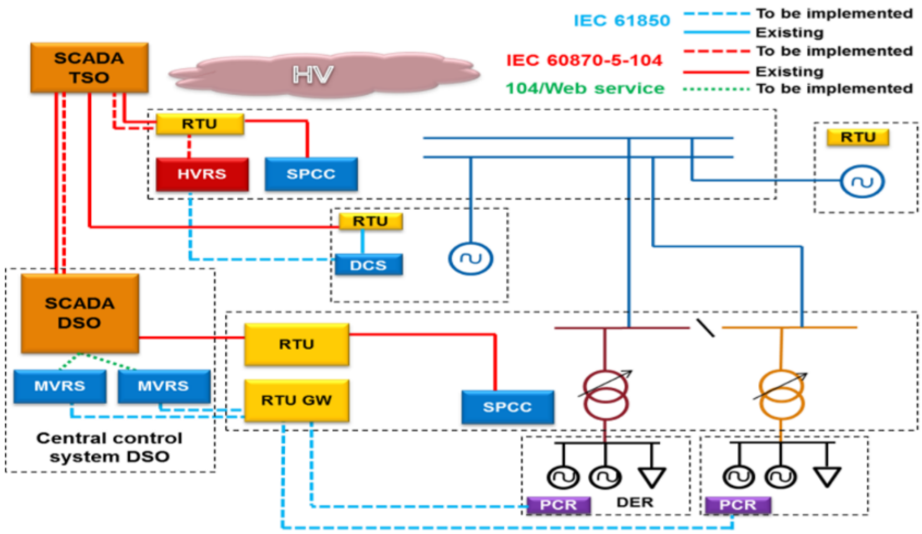


Figure 34. SmartNet Project – Italian Pilot (Source: Migliavacca et al. 2017)

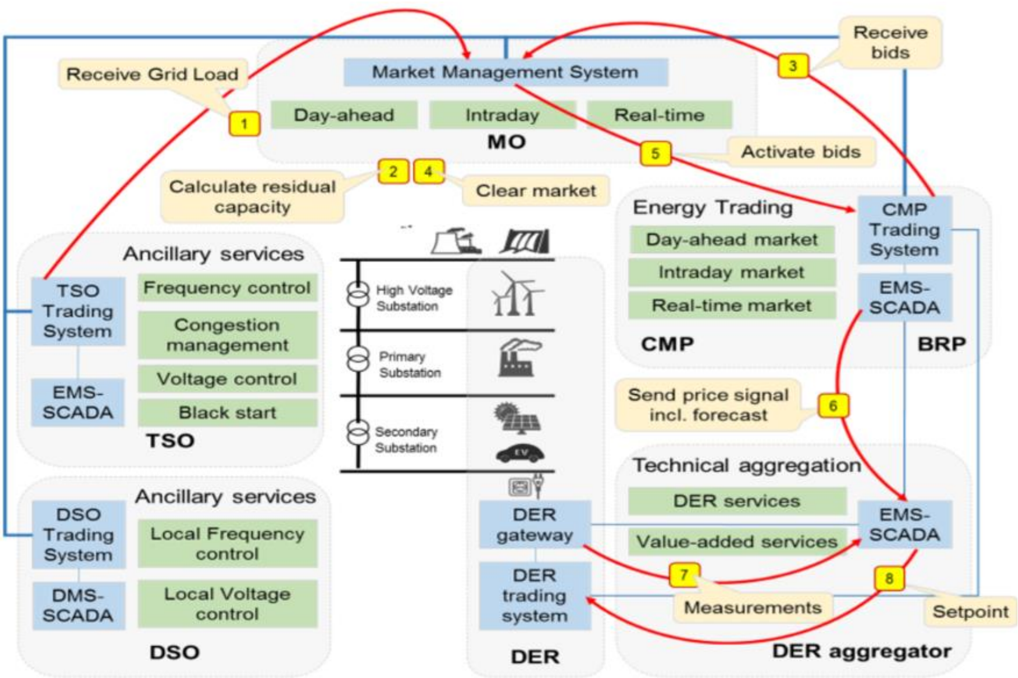


Figure 35. SmartNet Project – Danish Pilot (Source: Migliavacca et al. 2017)

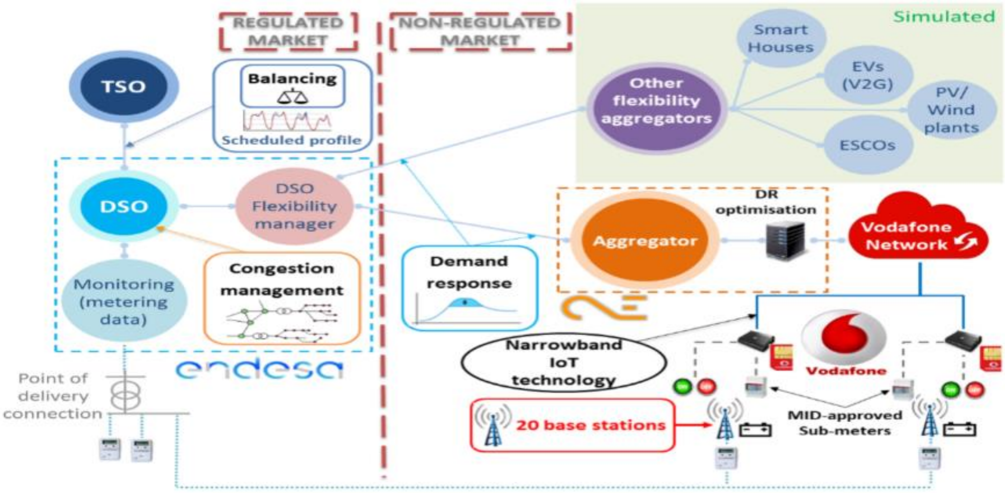
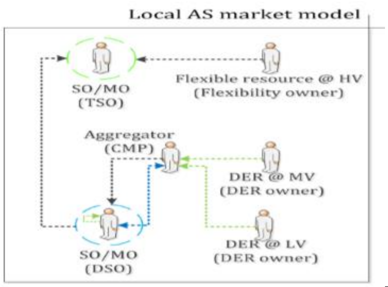
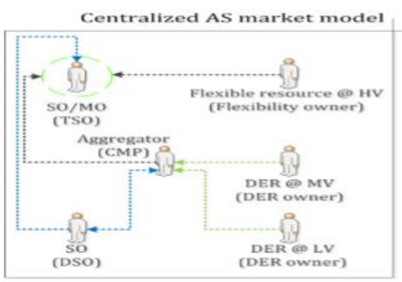
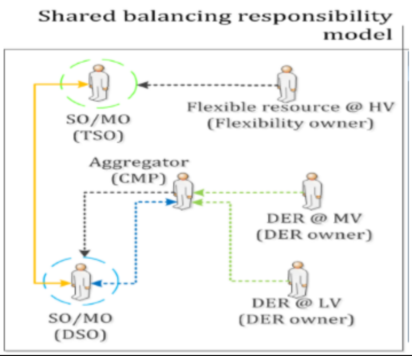
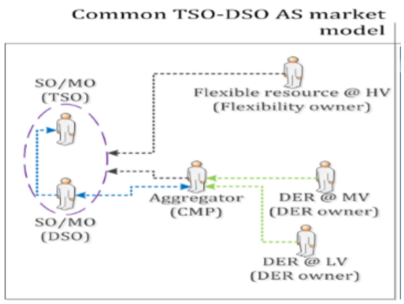


Figure 36. SmartNet Project – Spanish Pilot (Source: Migliavacca et al. 2017)

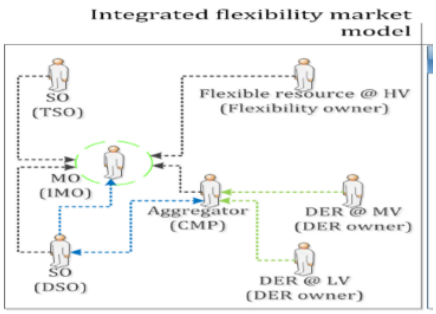
With the aim of establishing a proper coordination among DSOs and TSOs, five coordination schemes have been proposed (Table 12).

Table 12. Coordination schemes of SmartNet Project for the three demo cases (Source: Gerard et al. 2017, Gerard et al. 2018, Madina et al. 2019, Morch et al. 2019)

Market architecture	Description
	DSOs trade AS with DERs at DSO level and offers to TSOs the bids left after local grid constraints have been solved. It is a beneficial coordination scheme for small-scale DERs, due to its local markets can lower the barriers to let these in. Besides, gives DSOs the priority in terms of local flexibility usage, which significates that these can actively procure AS. However, an extensive communication platform among TSO and local DSO markets is still a drawback.
	TSO purchases AASS provided by the DERs connected to the DSO's power system. Among its advantages are accounted that the scheme is efficient in those cases where TSOs are the buyers, and its operational costs are low, and the regulatory framework compliance is guaranteed. It has however some disadvantages, such as that DSOs are not participating in the process, what may entail a recurrent violation of grid constraints at distribution level.
	Balance responsibility is transferred from the TSO to the DSO at the distribution grid, in accordance to a pre-determined calendar. Procurement of curtailed AS from the TSO, local markets for small-scaled DERs, and fair bounds among DSOs and TSO are some of the advantages obtained with this CS. Some attention points about the implementation of the same are that the procured AS among system operators are higher, the BRPs deal with higher balancing costs, lack of liquidity of small-scaled markets, and that the definition of schedules among TSOs and DSOs to share balance responsibilities could be a huge task to accomplish.

<table>
<tr>
<td>
</td>
<td>Both TSO and DSO concur in a common flexibility market to contract DER, with the purpose of decreasing the costs about the total procurement of their contracted flexibility.

This CS is advantageous in terms of minimizing costs of AS for TSOs while lowering the local services needed by DSOs, implying an optimal utilization of flexibility sources.

Nevertheless, when compared to other schemes, individual costs might be higher, what at the same time possess a difficulty when allocating costs among TSOs and DSOS.</td>
</tr>
<tr>
<td>
</td>
<td>Regulated and non-regulated market entities, such as TSOs, DSOs, and Commercial Market Parties (CMPs), have open letter to participate in the market.

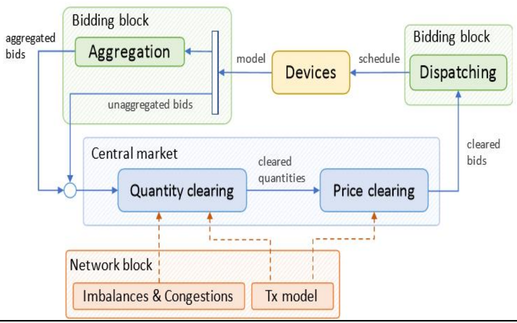
It offers BRPs more capability for solving imbalances and guarantees a higher liquidity with better prices as well.

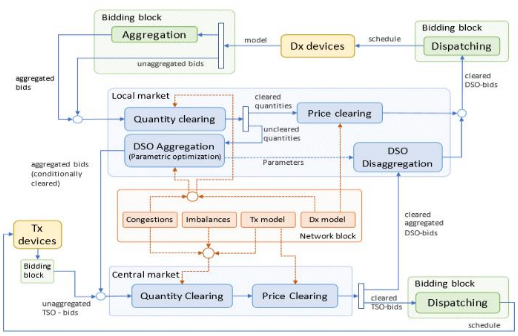
Nonetheless, an independent market party is required for neutral trading purposes. Besides, when concurring on intraday markets, liquidity may be affected negatively. Lastly, a privacy concern can arise since TSOs and DSOs must share data with Independent Market Operator (IMO).</td>
</tr>
</table>

5.3.9.2 *Market Structure*

The Coordination schemes previously stated served as the base for creating five market platforms adapted to these, although it is noteworthy to point out that none of them are peer-to-peer type (Table 13).

Table 13. Market schemes based on Coordination schemes proposed by SmartNet (Source: SmartNet Project 2018, Smart TSO)

<table>
<tr>
<th>Block diagram</th>
<th>Algorithmic specificities</th>
</tr>
<tr>
<td>
</td>
<td>Centralized AS Market:

The market operator runs a market clearing algorithm, aiming to optimize the social welfare (SW) subjected to the next constraints:
a) Bids constraints
b) Operational constraints at Tx level
c) Avoiding undesired activations
d) Active power balance on nodes at Tx level</td>
</tr>
<tr>
<td>
</td>
<td>Local AS Market:

The objective is to maximize the social welfare subjected to the next constraints:
a) Bids constraints
b) Operational constraints at Dx level
c) Avoiding undesired activations
d) Active and reactive power balance on nodes at Dx level
e) Forecast flow at the HV-MV transformer kept unaltered (imbalance not changed by LMA)</td>
</tr>
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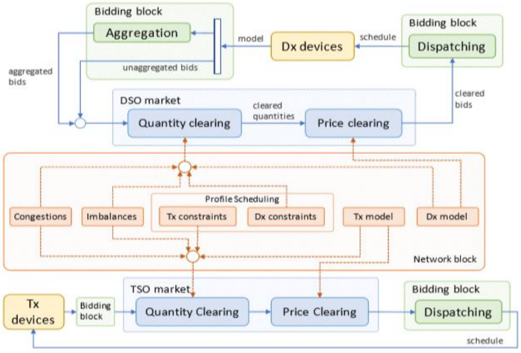
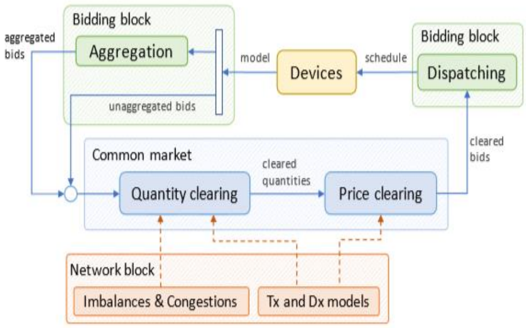
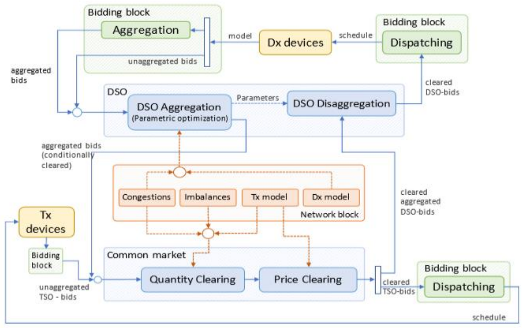
	**Shared Balanced Responsibility:** Maximizes SW subjected to: a) Active power balance on nodes at MO level b) Reactive power balance on nodes (only applicable to DSO MO) c) Bids constraints d) Avoiding undesired activations e) Operational constraints at MO level f) “Respect the agreed schedule at HV-MW connecting edge”
	**Common Centralized TSO-DSO AS Market:** Maximizes SW (including both TSO and DSOs), and subjected to the next constraints: a) Bids constraints b) Avoiding undesired activations c) Reactive power balance on nodes at Dx level d) Active power balance on nodes at both Tx level and Dx level e) Operational constraints at Tx and Dx level
	**Common Decentralized TSO-DSO AS Market:** The objective is to maximize social welfare while solving both imbalances and congestion problems at Tx and Dx level. Both system operators coexist in a common market and the DSO addresses a conditional clearing method (i.e. parametric optimization) to solve local congestions without clearing bids. On the other hand, an a posteriori DSO disaggregation process clears aggregated DSO’s bids. Summarizing, the imbalance and congestion problems are solved by the common market in one clearing.

The previous market architectures were envisioned by means of formulating an Ancillary Services Market Objective which, summarized, is comprised by the market objective function that seeks to, on the one hand, minimize the activation cost, and on the other hand, maximize the social welfare whether the time horizon is short or long (SmartNet Project 2018, Smart TSO).

Such objectives functions are addressed next (SmartNet Project 2018, Smart TSO):

a) Minimization of activation cost

The activation costs are minimized when operators solicit either up or down regulation, as portrayed in Figure 37.

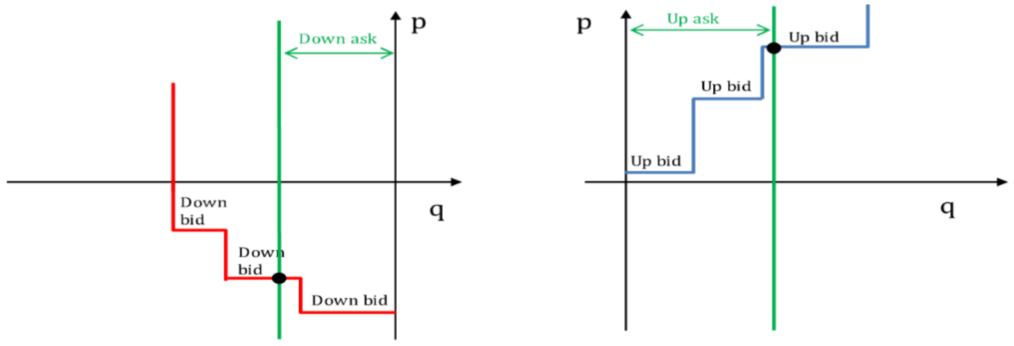


Figure 37. Down bids and up bids clearings. Black dots symbolize the clearing point for a cleared quantity (q) and price (p) (Source: SmartNet Project 2018, Smart TSO)

Thus, and attending the recommendations of the European Balancing guidelines, it is necessary to define an objective function that minimizes the activation costs while maximizing the social welfare. Hence, the activations costs, that is, the product of the absolute values corresponding to both cleared price and cleared quantity, are minimized with the next set of objective functions (SmartNet Project 2018, Smart TSO):

$$UP\ regulation: min \sum_{\beta \epsilon\ set\ of\ upward\ bids, q>0} f(p_{\beta,0}, p_{\beta,1}, q_\beta, x_\beta)$$

$$DOWN\ regulation: min \sum_{\beta \epsilon\ set\ of\ downward\ bids, q<0} f(p_{\beta,0}, p_{\beta,1}, q_\beta, x_\beta)$$

However, there must exist the possibility of activating bids in the same path followed by the imbalance when congestions are present. In such case, the previous twofold objective function can be turned into one over the whole set of bids (SmartNet Project 2018, Smart TSO):

$$min \sum_{\beta \epsilon\ set\ of\ downward\ bids, q<0} f(p_{\beta,0}, p_{\beta,1}, q_\beta, x_\beta)$$

b) Maximization of Social Welfare – First approach

Contrary to the previous objective function, this one addresses the maximization of social welfare. In such case, all bids are considered as a single objective function. The way of doing this is to merge both down bid curve and up bid curve and apply the curve-crossing technique, as observed on the left side of the

Figure 38. As can be noticed, this technique is not well suited since the bids are not placed in the same half-planes. To solve such problem, the easiest way is to rotate the crossed curves to the other side for obtaining the clearing point that allows to maximize the social welfare, as portrayed on the right side of the figure (SmartNet Project 2018, Smart TSO).

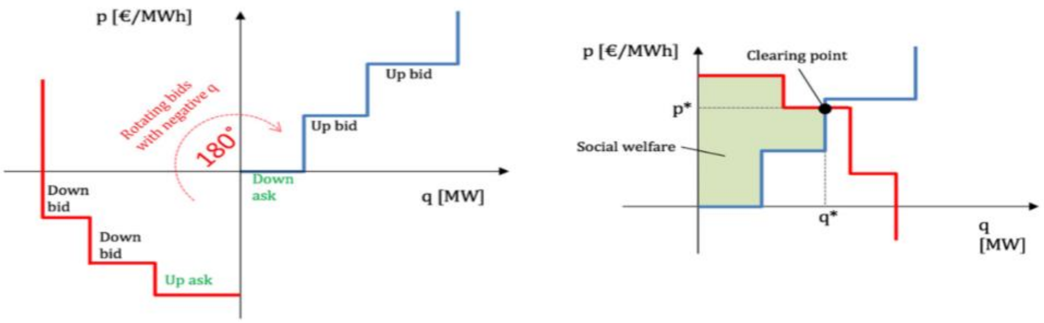


Figure 38. Social welfare because of the rotation of bids (Source: SmartNet Project 2018, Smart TSO)

Hence, the objective function for social welfare (SW) is defined as (SmartNet Project 2018, Smart TSO):

$$SW(t) = -\sum_{\beta \epsilon\ set\ of all\ bids} f(p_{\beta,0}, p_{\beta,1}, q_\beta, x_\beta)$$

c) Maximization of Social Welfare – Second approach

When the forecast accuracy gets worst over time, the most suited objective function is the one defined next (SmartNet Project 2018, Smart TSO):

$$SW = \sum_{t \epsilon T} \gamma_t SW(t)$$

5.3.9.3 *Methods for Flexibility Estimation*

The performance of the five Coordination Schemes (CSs) has been tested and furtherly compared among them. To achieve this, a large-scaled simulator capable of simulating complex power systems has been built. Its three-layered structure is shown in Figure 39 (Rossi et al. 2019).

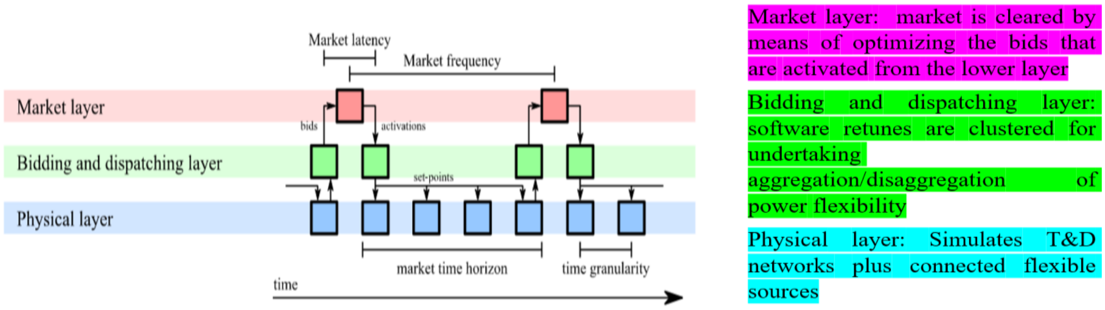


Figure 39. SmartNet's simulator layers (Source: Bompard et al. 2017)

Throughout this simulator, several algorithms are applied for estimating flexibility (Rossi et al. 2019):

a) At the bidding layer, algorithms for converting DERs' power flexibility into ancillary services market bids are executed, i.e., an availability concept algorithm is applied to manage stationary and mobile energy storage systems, whereas an aggregation algorithm is used to curtail generation and load at the same that avoids rebound effect, resulting on the available flexibility calculation depicted next.
b) At the market layer, the market clearing algorithm serves to code T&D power systems for solving current congestions and prevent future ones during the balancing mechanism.
c) At physical layer, several computations are undertaken, such as the modelling of the set/point given by the aggregator by employing zero-order or first-order dynamic models, whereas dedicated optimization functions are in charge of controlling those assets that do not intervene in market decision makings.
Lastly, network operators deal with unwanted measures derived from mFRR, so these need manually re-dispatching flexible resources in case of network congestions.

It is noteworthy to mention that these CSs were studied to determine their feasibility for providing ancillary services, and the following ancillary services (AASS) provided by flexibility sources from distribution grid by the TSO were acknowledged based on how each CS impacts on the processes of prequalification, procurement, activation and settlement of such services (Gerard et al. 2017):

a) Frequency restoration/balancing and congestion management
b) Frequency control
c) Voltage control of the transmission power system

Even though there are more flexibility services prone to be purchased, they were not considered for mapping the coordination schemes with the ancillary services. This mapping procedure allowed to determine whether a CS is compatible with an ancillary service or not, as can be noticed from Figure 40 (Le Baut et al. 2017).

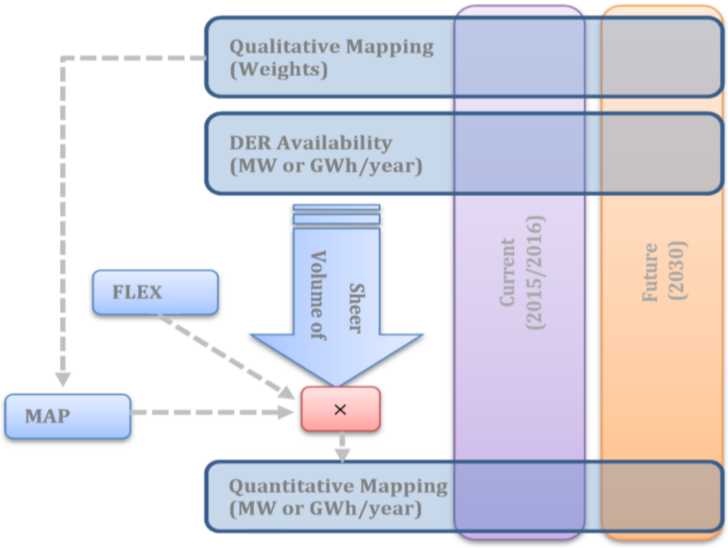


Figure 40. Procedure for mapping flexibility sources (Source: Mazza et al. 2019)

5.3.10 Brooklyn Microgrid

Brooklyn Microgrid (BMG) is a community-driven initiative that began in April 2016 when it allowed the first peer-to-peer energy transactions (Brooklyn Microgrid 2019). BMG was created by parent company LO3 Energy to introduce the concept of a communal energy network in which residential and commercial users can buy and sell renewable energy, which is generated locally. BMG is a network that connects people in New York City who own solar arrays (prosumers) with people who are willing to purchase local solar energy (consumers). Solar energy transactions through BMG support the local economy and result in the reduction in greenhouse gas emissions. Moreover, BMG allows users to control where their energy is sourced.

5.3.10.1 Market Overview

According to the peer-to-peer energy trading use case (Figure 41), participants access the local energy marketplace through the Brooklyn Microgrid mobile application. The application allows the users to choose to buy local solar energy credits (these tokens are called XRG). Prosumers make their excess solar energy available to the marketplace where consumers can purchase the available solar energy via an auction process. Through the use of the mobile application, consumers are able to select their energy sources and set their daily budget. On the other hand, prosumers can select if they want to sell their excess solar energy to the marketplace or continue to net meter.

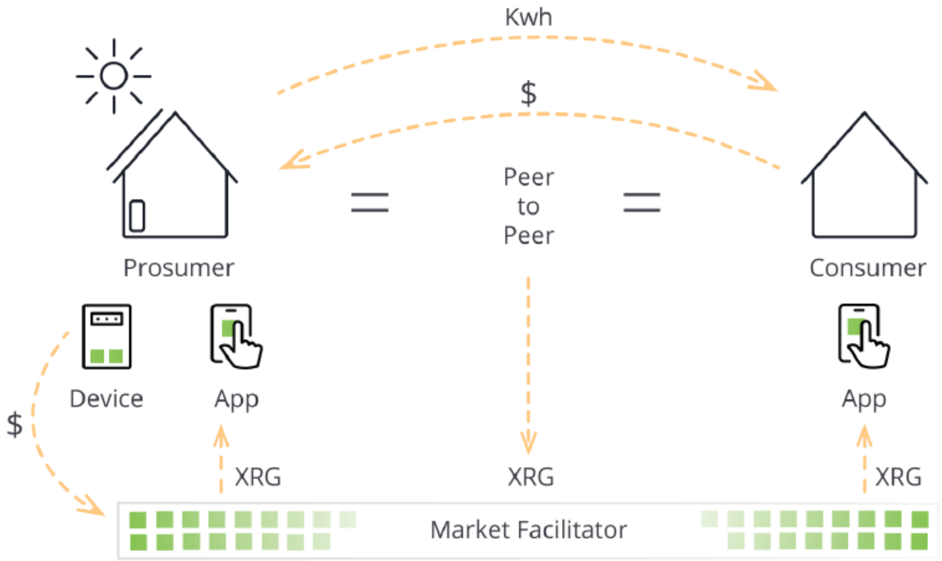


Figure 41. Peer-to-peer energy trading case (Source: Orsini et al. 2018)

Apart from the consumers and prosumers, other participants such as the DSO and Microgrid Service Provider are involved in extended use cases. DSO is granted access to consumer data, and manages energy use, load balancing and demand response. DSO receives payment for physical transfer of electricity across the network (between microgrids). Microgrid Service Provider allows local value-added services and is paid to run settlements between prosumers and consumers.

5.3.10.2 Technological Overview

A blockchain-based energy platform, named Exergy, has been developed and used in BMG. The platform creates localized energy marketplaces for transacting energy across existing grid infrastructure. Blockchain technology allows devices at grid edge to securely and directly transact for PV-generated energy sale among microgrid participants. Exergy runs on a private, permissioned blockchain through a network of globally distributed nodes. The implemented token approach aims to enable a common extensible platform that can facilitate valuable network utility from diverse but synergistic use cases.

Regarding the equipment installed, residential and business prosumers are equipped with TAGe smart meters that facilitate connectivity and support all necessary functionalities (Figure 42). As already mentioned, users are able to set their preferences and perform actions through the mobile application.

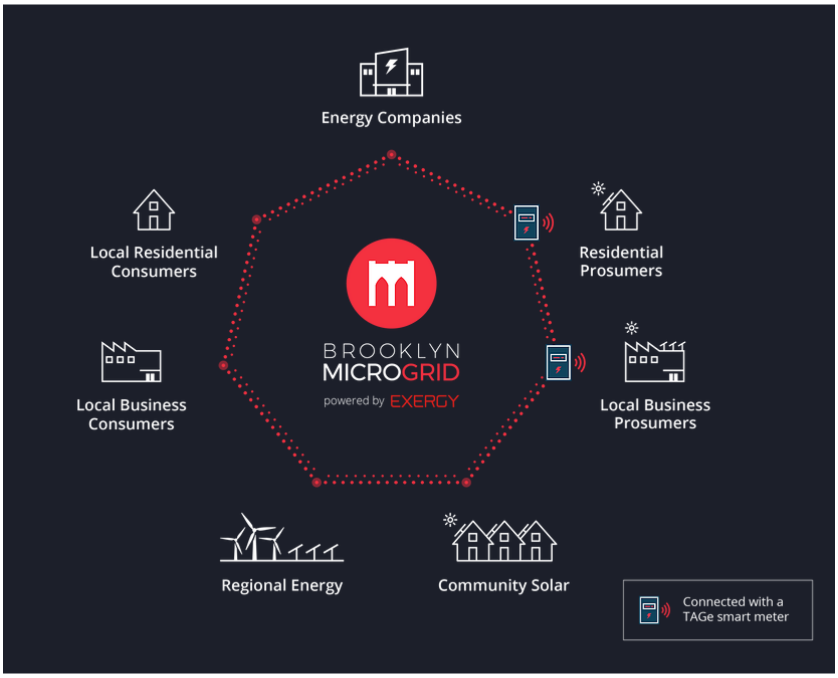


Figure 42. Consumers and prosumers participating in energy transactions (Source: Brooklyn Microgrid 2019)

Lastly, BMG also supports Electric Vehicle (EV) smart charging. In case a public or private charging station or an EV has a surplus of energy, it is made available for sale on the microgrid. Consumers can set budgets via a mobile application, which also provides notifications about the availability of offered charging opportunities.

5.3.11 INVADE (Invade 2020)

5.3.11.1 System Architecture

The consortium took as reference the overall architecture presented in Figure 43 to propose five pilots located in Norway, The Netherlands, Bulgaria, Germany, and Spain. The flexibility operator, that is the Balance Responsibility Party (BRP), oversees undertaking the aggregation and operation functions after gathering the flexibility resources provided by prosumers. Such functions are carried out around the operation zone inside the SGAM model depending on the pilot, and it is up to the demonstrators to let the BRPs be their own flexibility marketer or not (Lloret et al. 2017).

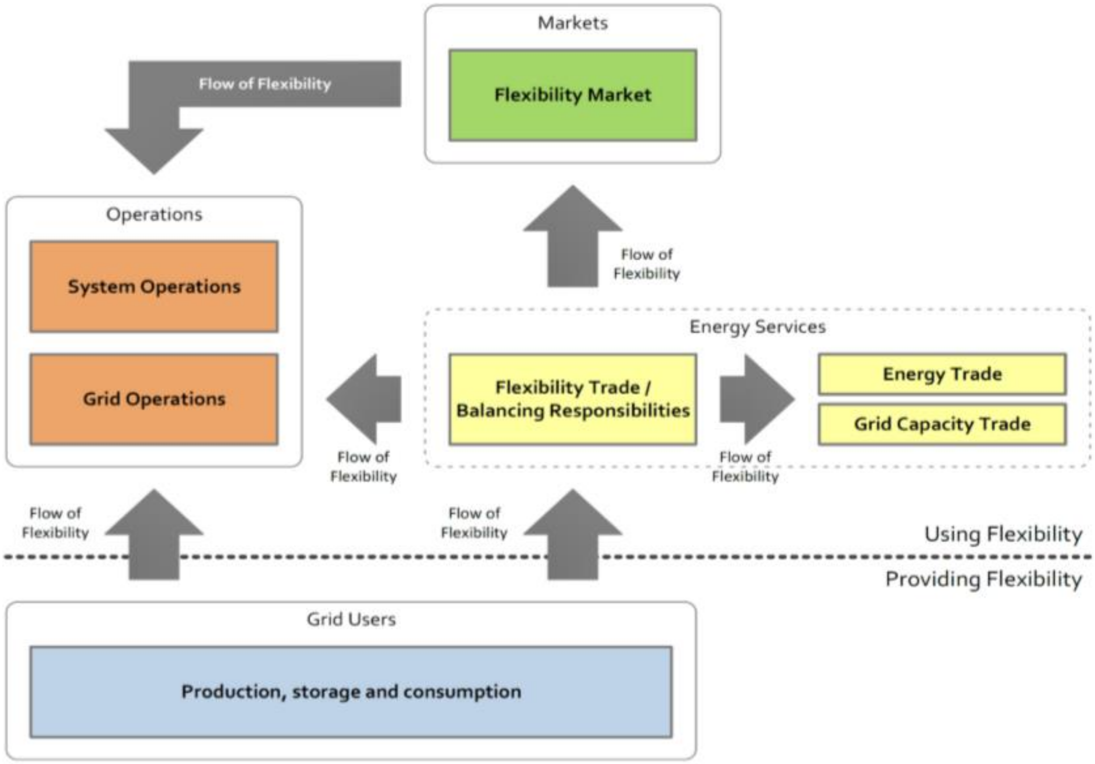


Figure 43. General flexibility architecture proposed in (Source: Lloret et al. 2017)

5.3.11.2 Market Structure

There was the necessity of conceiving a general business framework to be replicated the most of its functionalities on the pilots envisioned for the project. The general model created for INVADE can be even escalated to other markets and industries, what makes it more generic as its applicability widens. Such framework is portrayed in Figure 44 (Wåge et al. 2018), whereas the flexibility services associated to each pilot in accordance to the generic model are portrayed in Figure 45 (Wåge et al. 2018, Ottesen et al. 2017).

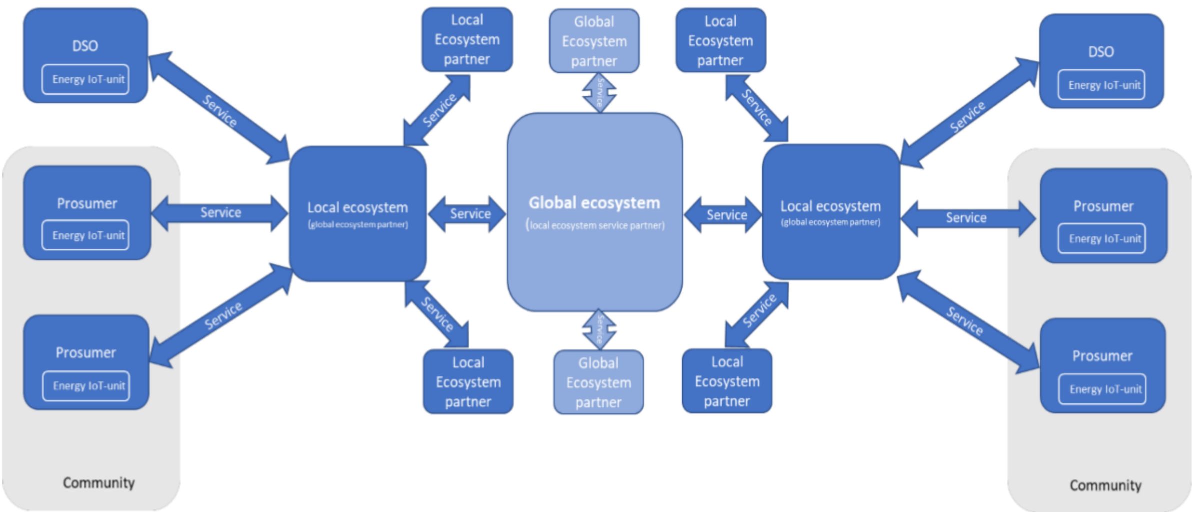


Figure 44. INVADE's Generic Business Model (Source: Wåge et al. 2018)

Flexibility customer	Flexibility services INVADE	Norwegian pilot	Dutch pilots	Bulgarian pilot	German pilot	Spanish pilot
DSO	Congestion management	N	Y	N	Y	Y
	Voltage / Reactive power control	N	Y	N	Y	Y
	Controlled islanding	N	N	N	TBD	Y
BRP	Day–ahead portfolio optimization	N	Y	TBD	N	TBD
	Intraday portfolio optimization	N	Y	TBD	N	Y
	Self-balancing portfolio optimization	N	Y	TBD	TBD	Y
Prosumer	ToU optimization	Y	Y	Y	Y	TBD (phase 2)
	kWmax control	Y	Y	Y	Y	TBD (phase 2)
	Self-balancing	Y	Y	Y	Y	TBD (phase 2)
	Controlled islanding	TBD	N	TBD	Y	N

Figure 45. INVADE Pilot's Flexibility Services (Source: Ottesen et al. 2017)

6. Local Market Design

The aim of this chapter is to find a suitable market design for the local market framework in PARITY. At first, concepts for local markets and various controversies associated with this topic are discussed based on scientific literature in this field as well as the related projects described in chapter 5. Then a scheme is developed, describing the most important local market design parameters. Finally, this scheme is used to define the PARITY market design.

6.1 Local Market Concepts

6.1.1 Energy and Flexibility Services

In the context of local communities and local markets, there are novel energy and flexibility services arising in addition to the existing ones described in the conventional electricity market models (chapter 3). USEF (Klaassen and Van der Laan 2019) introduces 7 of such services that may be requested (or offered) in Citizen Energy Communities (CECs). Note, that USEF considers these services to be provided potentially by the CEC itself. These services are described as follows and illustrated in Figure 46.

1. **Services to increase energy awareness** of prosumers; e.g. by providing energy consumption monitoring, dissemination of knowledge on energy saving or offering benchmarks and challenges (gamification).
2. **Joint purchase and maintenance of (shared) assets**; overcoming the financing barrier for investments in DERs for prosumers.
3. **Supply of (shared) energy;** offering the role of a supplier for the local prosumer making use of community DERs.
4. **Peer-to-peer supply;** facilitating P2P- trade among prosumers of the community. Either by taking the role of a supplier or by running a shadow administration (in the role of an ESCo). For detailed discussion see chapter 3.
5. **Optimize individual prosumers' energy profiles;** controlling prosumers' DERs and facilitating individual self-balancing and implicit DR.
6. **Provide explicit demand-side flexibility services;** by contracting with an aggregator as a whole pool of flexibility sources.
7. **Optimise the community energy profile;** controlling prosumers' and shared community DERs and facilitating community self-balancing and implicit DR.

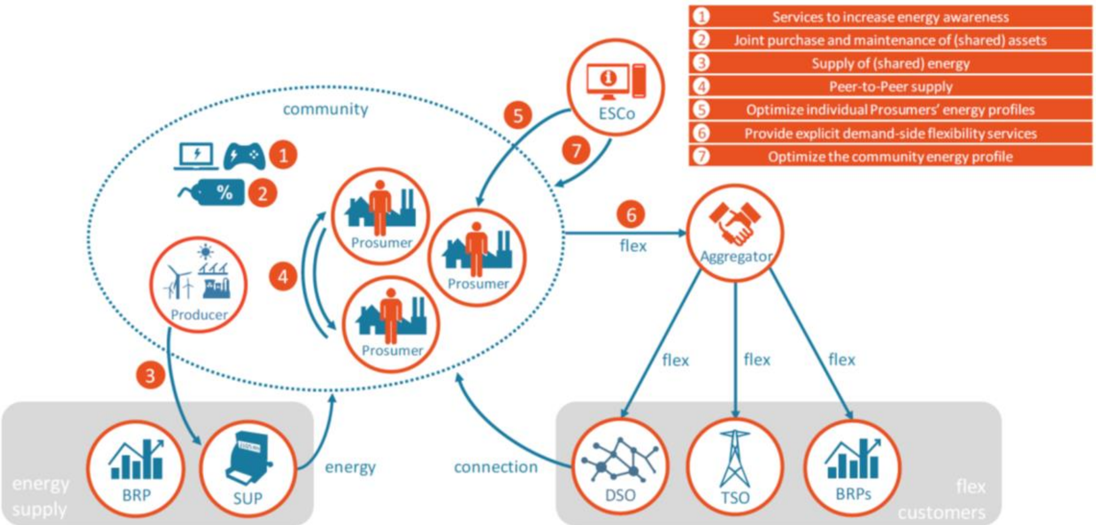


Figure 46. Illustration of energy and flexibility services that can be provided within a CEC (Source: Klaassen and Van der Laan 2019)

6.1.2 Instruments and Markets

For providing these flexibility services for the DSO, different instruments or methods are proposed in the literature. The instruments can be either control-based or market based. According to Jin, Wu and Jia (2020), control-based instruments mainly include Active Network Management (ANM) and Virtual Power Plants (VPP), whereas the following 4 market-based instruments are distinguished:

- **Local Energy Market (LEM):** An LEM is a concept that encourages localized energy trading. In a LEM prosumers can decide to sell their surplus electricity production and other local prosumers can buy this surplus by increasing their loads. This increases local usage of energy produced by DERs and as a result, indirectly may reduce voltage fluctuations and solve congestions in the distribution grid (Jin et al. 2020, Siano et al. 2019). Concepts for local energy trading can be characterised in three groups (Khorasany et al. 2018): direct P2P trading, trading through a mediator/broker, and a combination of both approaches. As LEMs are only dealing with trade of electrical energy they can also be referred to as Local Electricity Markets.
- **Transactive energy (TE)**: The concept of TE is closely related to the LEM. TE is broadly defined as “a set of economic and control mechanisms that allows the dynamic balance of supply and demand across the entire electrical infrastructure using value as a key operational parameter” (Grid Wise Architecture Council 2015). In this sense, ‘value’ means price. The intent of TE is to guarantee that all DERs of local prosumers operate in an optimal situation. This means that equilibria are reached applying a microeconomic utility function. For instance, TE looks for the benefits of all prosumers as a collective and not for the benefit of individual prosumers (Siano et al. 2019, Hu et al. 2017). The implementation of the TE concept is also often referred to as Transactive Control. In comparison to the P2P trading on an LEM, TE is therefore more viewed as a control method, whereas a P2P market is defined by freely sharing and trading energy among prosumers (Abrishambaf et al. 2019). Often, TE and LEM are proposed in an integrated concept such as Transactive Energy Exchanges in Local Energy Markets (Siano et al. 2019).
- **Price-Based Control (PBC)**: In this concept, the DSO forecasts potential congestions and the respective congestion point. Based on that, the DSO also publishes a congestion price (as a dynamic tariff), according to which aggregators and prosumers can schedule their flexible loads in an optimal way. This local grid prices are also referred to as Distribution Locational Marginal Price (DLMP) (Abrishambaf et al. 2019).
- **Local Flexibility Market (LFM)**: LFMs aim to provide a direct market-based tool for the DSO to solve voltage violations and congestions. In case the DSO forecasts a constraint, it will send a flexibility request to the LFM operator (maybe the DSO itself or a third party) and in this way place an order on the LFM. As a response to that, aggregators will bundle flexibility offers from local prosumers and make a flexibility offer at the LFM. Once the LFM is cleared, the flexibility is provided to the DSO and the grid constraint violations are solved (Jin et al. 2020 and Siano et al. 2019).

Among these concepts, the LFM is the only explicit marketplace where flexibility can be procured by the DSO. In this context, LEM, TE and PBC are market-based instruments that are implicitly integrated in the electricity retail market and may solve grid constraint violations via price signals indirectly there. As a result, here it is proposed to refer to PBC, LEM and TE concepts that specifically tackle local constraint violations in the distribution system (congestions and voltage violations) also as **implicit LFMs**. Note, that the LEM (and TE) can also be applied with a purpose other than solving distribution grid constraint violations, e.g. for virtually matching supply and demand of prosumers. In this case LEM (and TE) represent explicit markets for this purpose (but not for solving DSO problems) and therefore can not be classified as implicit LFMs.

6.1.3 Market Participants and Operators

The **market participants** involved in a local market depend on the type of market or market-based instrument that is implemented (section 6.1.2).

In an **LEM** and also in **TE** frameworks, the prosumers are the main market participants, trading electricity peer-to-peer. Additionally, aggregators may participate in trading on the LEM and in this way provide a link between the LEM and other markets such as the AS and WS markets.

In a **PBC** framework, which is not an explicit market but a market-based instrument implicitly integrated in the retail market, the DSO has the key role by determining the localised dynamic grid price. The actual market participants are the typical retail market participants.

In the context of **LFMs**, the market participants are discussed frequently in the literature. First of all, there is the DSO who is the main beneficiary procuring flexibility on the LFM. The entities offering flexibility on the LFM are the aggregators, bundling loads from prosumers and their DERs. Often also the BRP is defined as a market participant procuring flexibility on the LFM, for instance in the works of Olivella-Rosell et al. (2018) as well as Jin, Wu and Jia (2020). Direct participation of prosumers and their DERs in an LFM are not considered due to two reasons (Jin et al. 2020): Firstly, an individual prosumer has limited negotiating power in an LFM because of its relatively small volume of flexibility (Burger et al. 2017). Secondly, the direct participation of prosumers would overstrain the LFM in terms of communication burden for information exchange between market participants and computation burden for market clearing (Bahrami and Amini 2018).

Finally, the role of the **Market Operator (MO)** needs to be discussed. The MO provides the trading platform and is also responsible for market clearing. Market clearing is the process that collects flexibility offers and flexibility requests, and determines trading results (i.e., price and quantity of flexibility to be traded) (Jin et al. 2020). In general, explicit markets (such as LEM and LFM) require the role of a MO, whereas market-based instruments that are implicitly included in the retail market (such as PBC) don't need a specific MO.

For **LEMs**, there are basically two options of how the role of the MO can be implemented (Klaassen and Van der Laan 2019). Firstly, the MO who provides the trading platform can assume the role of a supplier (and the respective BRP role), sourcing the energy from a prosumer and selling it to another prosumer. Secondly, the MO can have an ESCo role, running a shadow market administration which has no official role in the organisation of the electricity system and is separate from the administration of a supplier and the respective BRP.

In **LFMs** the role of the market operator can be assigned to different entities, as highlighted by Jin, Wu and Jia (2020). The LFM can be operated by the DSO itself, by an aggregator, or independent third parties.

The controversy about the question, if the MO should be merged with another role or should remain independent has already been raised by many scientific authors and stakeholder organisations for the context of flexibility markets (Schittekatte and Meeus 2020). Burger et al. (2019), Stanley et al. (2019) and Ramos et al. (2016) point out that to ensure transparency the MO should not be a market participant simultaneously. Gerard et al. (2018) and USEF (De Heer and Van der Reek 2018) state that the entity assuming the role of the MO depends on whether the market is separated or integrated with other markets (such as WS or AS markets). ENTSO-E et al. (2019) take the position that network operators should act as neutral market facilitators.

The main arguments for independent MOs or in contrast "merging the role" are as follows (Schittekatte and Meeus 2020):

- In the case of a DSO as a MO, the experience might not always be present in-house to set up market platforms. Stanley et al. (2019) highlight that an engagement with a specialised third party can allow for a faster development of the procurement mechanism.
- When deploying an independent third-party MO, neutrality between buyers and sellers can be ensured. If DSOs operate the market platform for flexibility procurement, the platform will be monopolistic by nature. In case a third party operates the platform, this might not be the case.
- An argument against having a third party as a market operator is the cost for the additional interface between the DSO and the MO, when unbundling these activities.

6.1.4 Local Scope

When describing a local market concept, the question arises of *how to define the local scope?* In order to implement technical solutions, the term *local* needs to be defined by technical means. From the perspective of PARITY, a definition should be derived preferably from the grid's topology.

It is an important feature of such concepts (especially LFMs) to activate flexibility for the DSO in order to solve grid constraint violations. Therefore, a basic common denominator for the understanding of the term local is a DSO domain, meaning a medium voltage (MV) and the connected low voltage (LV) grids. As this may not be a sufficient definition, a more in-depth discussion is required.

Assuming the markets should consist of a homogenous market area, following requirements can be found:

- From the perspective of an **LEM** facilitating P2P trade, it is expected that a certain level of liquidity may be required in order to ensure a well-functioning market that can be cleared properly. This could mean the more prosumers are participating in an LEM, the more liquidity is reached. As a result, a rather large market area is preferable.
- In an **LFM** the granularity of the market (and in a homogenous market this means size of the market) needs to be suitable for solving specific constraint violations (congestions, voltage violations). In case the constraint violation appears at a high-level node (e.g. MV to LV transformer), the market should be rather large, while it should be rather small, if it appears at a low-level node (e.g. LV line).

These are two contrary requirements for an LEM and an LFM. When integrating these markets into a single market area, this leads to a trade-off when defining the local scope.

The aspect of local scope has been discussed in scientific literature only very rarely. However, Kouzelis et al. (2015) addressed the geographical aspect of flexibility in distribution grids and discussed to which extent flexibility offers should be aggregated or disaggregated. They also highlight two basic conflicting features, similar to the trade-off above. On the one hand, an aggregator wants to disaggregate its offers as much as possible in order to provide attractive flexibility services to the DSO with a high locational granularity. On the other hand, more aggregated offers are better to facilitate market processes and also forecasting errors can be minimised through risk diversification. The authors deploy an optimisation problem for solving this trade-off and present a methodology to systematically define flexibility offer areas. As a result, they conclude, that a "supermarket" framework should be considered as the most promising option. This means, that the DSO forecasts the grid location that requires demand side flexibility (such as a load reduction), but these locations will not be published to the aggregators. This avoids overpricing of flexibility at specific nodes and so the DSO can choose the most appealing offers.

6.1.5 Coordination Mechanisms

As discussed in detail in chapter 3, flexibility can be used for a variety of services for Flexibility Requesting Parties (FRPs). Therefore, it is crucial to consider coordination mechanisms prioritising the need for flexibility in order to avoid conflicts of interest among market parties or even grid damages.

A widely discussed approach for prioritising flexibility needs is the so-called **Traffic Light Concept** (TLC). Especially for coordinating congestion management on DSO level in a market based-way, the TLC (or a variation of it) is proposed in many models (Bontius and Hodemaekers 2018). How the TLC is applied in the framework of USEF has already been described above (cf. operating regimes in chapter 0). Olivella-Rosell et al. (2018) also apply the TLC in their local market concept and highlight that the price for flexibility should also be displayed in the TLC. For instance, in a yellow phase the flexibility services for the DSO may have the highest priority, but are also highly rewarded.

Another important aspect affecting the coordination between FRPs is the **separation or integration** of local markets in existing markets (such as AS/WS markets). In general, local markets either can be implemented as a separate standalone platform (e.g. where DSO can procure flexibility) or they can be integrated into other market platforms (e.g. DSO procures flexibility on the TSO's balancing market or the wholesale spot market). This affects the coordination between FRPs as in separate platforms, there is only one buyer, whereas in integrated platforms several buyers compete for the best offers. A very much debated aspect in this respect is the TSO-DSO cooperation. This determines the priority for obtaining flexibility in an integrated market where TSO and DSOs jointly procure their flexibility services. Schittekatte and Meeus (2020) analysed the advantages and disadvantages of having an integrated vs. separated market platforms:

- The main advantage of separate local platforms is that differences between products (e.g. locational information) can be highlighted and transparency on price levels is created.
- However, in integrated markets higher liquidity can be ensured.
- Integrating platforms can reduce complexity for market participants and reduce costs.
- Allowing network operators and other parties to procure flexibility in the same market, creates a kind of secondary market for flexibility providers.

6.1.6 Further Controversies

Of course, there are many more elements and controversies for designing local markets. However, one crucial issue needs to be addressed here in this discussion about overall market design options, which only apply specifically for LFMs as explicit markets. It is the question about **market product definition**, or in other words if there should be a reservation payment for keeping available flexibility capacities in LFMs or not. Schittekatte and Meeus (2020) conclude following two arguments in favour and two arguments against reservation payments:

- Firstly, reservation payments in the sense of long-term contracts can ensure that sufficient flexibility capacities are available for offering on the market at all times.
- Also, “gaming” can be mitigated by reservation payments. This means, that sometimes only very few market participants are able to offer flexibility at a specific location and therefore, those could offer their flexibility for arbitrarily high prices. By applying long-term contracts with a predefined activation payment this could be avoided.
- However, if latter is the case, the short-term efficiency of the market could be hampered.
- Finally, long-term contracts with reservation payments may represent a market entrance barrier for small-scall flexibility resources such as DERs from prosumers, due to forecasting difficulties.

6.2 Local Market Design Parameters

Based on the various concepts and controversies for implementing local markets as introduced above, now a set of local market design parameters is derived. These parameters highlight the most important aspects that need to be defined for the local market structure in PARITY. Table 14 shows the five key parameters with guiding questions respectively.

Table 14. Local Market Design Parameters

Key parameter	Guiding questions
Market participants	Which roles need to be defined for describing the local market in PARITY?
Instruments for providing flexibility	What kind of flexibility needs are solved? Which instruments are applied for solving these flexibility needs? Which markets are introduced as a result?
Market operator(s)	Which activities are performed by the market operator(s) and what are the responsibilities? Which entity is assuming the role of the market operator?
Definition of local scope	How is the term “local” defined in the context of PARITY?
Coordination between flexibility requesting parties	What is the main priority for providing flexibility services for in PARITY? What practical schemes are introduced to manage such priorities?

Note, that this set of parameters is not an exhaustive list as not all aspects for fully describing the PARITY market structure can be included at this stage of the market design. Before the PARITY market framework will be ready for application, there are many more aspects to consider, e.g. time horizons of the markets or contract specifications. However, these issues will be tackled in a later stage of the PARITY project such as in WP5.

6.3 PARITY Market Design

Finally, in this chapter, the PARITY market design will be determined and described. This is achieved by discussing each of the aforementioned local market design parameters and answering the guiding questions. The foundation for the market structure defined here, has been laid by the description of the initial PARITY market concept in the proposal of the PARITY project. Against this background the local market design parameters have been discussed with the consortium partners. The outcome of this discussion process is described in the following sections.

6.3.1 Market Participants

Generally, the following roles need to be defined for PARITY, representing the most important stakeholders in this framework: **DSOs, prosumers, aggregators, suppliers, BRPs, TSO, Market operator (MO)**.

When defining only the **participants on the local market**[15], meaning those who actually trade energy and flexibility on a local platform, the list can be narrowed down to the **DSO, prosumers** and **aggregators.** As the aggregator is only an intermediary between flexibility source and requesting party, only flexibility needs for the DSO and flexibility as well as energy services for prosumers are addressed in the local market framework of PARITY.

Eventually, we can define the **TSO, BRPs** and **aggregators** as participants of the **overlay AS and WS markets**. The TSO acting as a buyer on the (TSO-level) AS market and the BRPs as participants in the wholesale market. For allowing the participation of prosumers to these markets the aggregators function as intermediaries also here.

In the PARITY framework, the **suppliers** can be only seen as market participants on the local market, if they also assume the aggregator role. This is the same for the AS market. For the WS market, a supplier can participate as an aggregator or as BRP.

The role of the **market operator (MO)** is defined in section 6.3.3 and depends on the specific market implemented in PARITY (section 6.3.2).

6.3.2 Instruments for Providing Flexibility

PARITY implements both market-based as well as control-based instruments for providing flexibility services and energy services.

As a **control-based instrument** within PARITY the application of active network management (ANM) tools by the DSO (e.g. 4-Leg D-STATCOM) can be considered. A further control-based element in PARITY is the application of the TLC, as in its red phase market-based activities are overruled and control is enforced by the DSO. The application of the TLC in PARITY is explained in section 6.3.5.

In contrast, following **market-based instruments** are applied and integrated in PARITY.

- Local Electricity Market (LEM)
- Local Flexibility Market (LFM): either as an explicit or implicit market
- Participation in overlay ancillary services and wholesale markets (AS/WS markets)

The **local market** in PARITY therefore comprises two novel markets: the **LEM** and the **LFM**.

Local Electricity Market (LEM)

On the LEM, **prosumers can trade electricity with each other (P2P trading)**. This is facilitated by a fully automated and smart contract-based LEM platform. Generally, there are three main benefits arising from the deployment of an LEM in PARITY:

- First of all, **prosumers** in an LEM could benefit from a reduced grid tariff for the energy supplied from local peers. This means, that the energy purchased on the LEM is only subject to a local grid tariff (fee for using the distribution grid) whereas the energy obtained from a centralised supplier is subject to the usual grid tariff (fee for using distribution and transmission grid). However, the cost reduction depends on the definition of this local grid tariff which may vary between EU member states. Currently, only a few countries are developing such tariffs (Frieden et al. 2019).
- Secondly, the **attractivity of investing in DERs may increase** for prosumers, if they engage in an LEM. This is due to the fact, that through P2P trade prosumers could achieve a higher price for their surplus electricity from PV production, than they would earn from classical feed-in-tariffs. Also, flexible loads, such as EVs, could be charged at a lower price using locally produced surplus energy.
- Finally, the **DSO** may benefit from having LEMs in its grid area. The idea is, that by encouraging local trading, a high penetration of DERs can be managed in a way that congestions

[15] Consisting of LEM and LFM, see section 6.3.2

and voltage violations in the distribution grid can be avoided indirectly. This may be the case, if P2P trade leads to effective self-balancing of a local community of prosumers and therefore avoids high power flows at higher level nodes such as transformer stations. However, self-balancing could also lead to new problems in the grid. For instance, if a few prosumers with a high capacity of flexible loads purchase a high amount of surplus electricity from local peers in a short time frame, this could lead to congestions at single LV lines. Note, that P2P trade as such does not influence physical power flows, but rather virtual allocation of consumption. Therefore, the benefits for the grid can only be achieved, if prosumers can react to local power supply and adapt their consumption profile accordingly by making use of their DERs.

Local Flexibility Market (LFM)

The only purpose of an LFM is to **provide flexibility for the DSO** in a market-based manner in order to solve grid constraint violations (congestions and voltage violations). For implementing an LFM in PARITY, two options are considered: either an explicit or an implicit LFM.

Explicit LFM

The explicit LFM represents a standalone market platform where the DSO procures flexibility for its own needs from a range of competing aggregators. Single prosumers placing offers on an explicit LFM are also possible in theory, but due to their small individual flexibility potential, it is not likely that they participate in the explicit LFM as a flexibility provider. In line with the literature discussed above, prosumers are not included as direct market participants in the explicit LFM.

The explicit LFM can be seen as an analogue to the AS markets at TSO level, such as the balancing market where the TSO procures the desired AS (in this case frequency control) from a range of pre-qualified flexibility providers. However, in the explicit LFM the DSO is the one procuring flexibility for the AS, in this case congestion management and voltage control.

The market activities on the explicit LFM in PARITY can be described similarly to the typical LFM concept found in the literature. Firstly, the DSO forecasts potential constraint violations in its grid area and based on that will place a request on the LFM platform. However, it remains open for discussion if the flexibility products traded on the explicit LFM in PARITY are ***unconditional*** or ***conditional***, meaning if there are ***long-term reservation payments*** for keeping available flexibility resources or not (cf. chapter 3.1). In the literature, both approaches are discussed, both having advantages and disadvantages (cf. detailed discussion in Schittekatte and Meeus 2020). For reasons of simplicity and in order to make sure aggregators bundling many small scale DERs can participate in the explicit LFM, it is expected that reservation payments won't be applied in PARITY. However, this is an open issue that needs to be determined in later stages of the market design, after it is clear whether the LFM will be implemented as an explicit or implicit market.

Implicit LFM

The implicit LFM is an alternative option, where the activation of flexibility for the needs of the DSO is implicitly achieved in the LEM and therefore in the retail market. This means, other than above, there is no market platform for the LFM. The implicit LFM in PARITY is designed as a **Price-Based Control (PBC) mechanism**. This means, that again the DSO starts with forecasting potential constraint violations and the location of the respective congestion points. In contrast to the explicit LFM, here the DSO does not publish a flexibility request, but determines locationally differentiated grid prices. By doing so, the DSO is imposing a price signal to the prosumers that reflects the grid constraints. If the prosumers are reacting to this price signal by altering their load and/or generation profile (by making use of their flexible DERs), constraint violations can be solved indirectly. The alteration of the load profile goes along with changed trading behaviour of the prosumers on the LEM and the retail market in general. For example, a consumer facing a significant increase of the grid price will decrease the current load and as a result will purchase less energy in this specific situation from the peers (LEM) or the traditional supplier (retail market). Meanwhile, another prosumer may face a reduction in the grid price and will try to increase its load for charging its EV, for instance. By doing so, this prosumer purchases more energy from peers or the traditional supplier in this situation.

As this basically represents an implicit DR model, the ***typical aggregator role is*** also ***not required***. There is no explicit market for flexibility in this concept, so the market participants involved here are the same as in the LEM (the prosumers) or the retail market in general (prosumer and suppliers). Aggregators can only play an auxiliary role here, by assuming the role of an ESCo that provides the flexibility service of load control for tariff optimisation. However, this ESCo role can also be assumed by any other private competitive entity, of course.

Finally, it needs to be mentioned that this implicit LFM is only feasible if there is a ***regulatory framework*** enabling the DSO to impose such locationally varying grid prices. The grid prices are highly regulated and usually set by the NRA, and not by the DSO. This would need to be changed by introducing a variable element in the grid price that can be determined by the DSO reflecting its grid constraints.

Participation in AS/WS markets

The third pillar in the market framework of PARITY is the participation of prosumers in ancillary services markets at TSO level and in the wholesale market. The role providing the link from the prosumers to the FRPs on the AS and WS markets is the aggregator role. Therefore, the prosumers are not direct market participants in these markets, only the aggregators are on their behalf.

This means, that PARITY prosumers have the free choice either to trade their energy (production or demand) on the LEM or to sell their flexibility to the aggregator (for AS/WS participation). If the priority from the perspective of the prosumers lies on LEM participation or aggregator delivery, ultimately depends on the financial benefit that can be achieved in both options. However, the electricity supplied from local peers at the LEM may be subject to a reduced grid tariff where only charges for the local grid apply. This won't be the case for the flexibility delivered to the aggregator. If this difference in the grid price is significantly large, it can be expected, that the first priority of prosumers will be LEM participation, as the price here is more attractive. In this case only the residual flexibility will be offered to the aggregator.

6.3.3 Market Operator

The role and the activities of the market operator need to be defined for the two novel markets introduced in PARITY: the LEM and the LFM.

Local Electricity Market Operator (LEMO)

The purpose of the LEMO role is to provide and administrate the LEM platform and to clear and settle the LEM:

- As a **platform provider**, the LEMO has to provide the technical infrastructure enabling the market participants to offer and make bids on the LEM, fully automated and based on smart contracts. In this respect, the LEMO is not necessarily the technology developer, but an entity that has acquired the licenses and the know-how to operate such a platform. The LEMO also needs to make sure that the prosumers' DERs are connected properly to the platform from a technical perspective. Therefore, also the PARITY Oracle (which is the gateway controlling and communicating with the Prosumers' DERs) can be provided by the entity assuming the LEMO role.
- In terms of **LEM administration**, the LEMO is registering new market participants and represents the point of contact for participants' inquiries.
- The LEMO is **clearing and settling the LEM**, which is the core activity of a market operator. The LEM is cleared and settled between the prosumers offering and bidding on the LEM. For P2P trading as facilitated on the LEM, different clearing methods may apply. Khorasany, Mishra and Ledwich (2018) classify clearing methods for LEMs into Distributed methods (Decomposition methods, Networked optimisation, Game theoretic methods and Multi-agent systems) and Auction-based methods (Multi level optimisation and others). However, defining a clearing method for the LEM in PARITY is out of the scope of this report. This aspect will be

closer analysed and defined in WP5. Finally, settlement of the LEM means the validation of all the transactions in the market and the according actual exchange of money. In this context, the LEMO is responsible for invoicing the electricity traded among prosumers.

The role of the LEMO can be assumed by any **private competitive entity**, such as an aggregator, supplier or independent LEMO. In PARITY, it will depend on the specific business model, which entity is assuming this role. The business models will be determined in T4.4. However, for each type of entity assuming this role, there will be advantages and disadvantages. For example, an aggregator in the role of a LEMO has to make sure, that the prosumers are maximising their profit both through P2P trade on the LEM as well as through aggregated participation on AS/WS markets.

Local Flexibility Market Operator (LFMO)

A LFMO is only required, if the LFM is implemented as an explicit market, while an implicit LFM is included in the LEM. Similar to the LEMO above, the purpose of the LFMO role is to provide and administrate the LFM platform and to clear and settle the LFM:

- The LFMO **provides the technical platform**, where the DSO on the one hand and the aggregators on the other hand can trade flexibility.
- **LFM administration** mainly includes the prequalification process, making sure the aggregators meet all the requirements from the DSO for providing flexibility services.
- In terms of the core activity, **LFM clearing and settlement**, the LFMO matches the flexibility offers from the aggregators with the requests from the DSO. As mentioned above, theoretically also large prosumers could make offers on their own on the LFM, if they meet the prequalification criteria. For LFM clearing, also a range of methods can be applied. Jin, Wu and Jia (2020) find that clearing methods for LFMs are similar to those for LEMs and roughly distinguish between centralized optimization, decomposition methods and bi-level optimization. However, defining a market clearing method is out of scope of this report.

The role of an LFMO in PARITY can be assumed by a **regulated entity,** that has been granted the authorisation by the NRA. This could either be the DSO or another regulated (independent) entity. The scientific discussion on that is vivid, with significant advantages and disadvantages for each option. On the one hand, it is argued that an independent LFMO should be preferred, ensuring neutrality and avoiding the DSO exploiting its monopsony position. On the other hand, an independent LFMO could lead to higher overall costs and would also require an additional interface between LFMO and DSO. For PARITY both options are considered feasible: the DSO as LFMO or an independent regulated entity as LFMO.

6.3.4 Definition of Local Scope

As existing literature is quite vague about this issue, an in-depth discussion has been launched in this respect for defining the local scope of the PARITY market framework. Taking into account the contrary requirements for an LEM and an LFM (described in section 6.1.4), the **initial question raised** can be summarised as follows: *If both the LFM and LEM are designed as two homogenous markets, what is the most suitable local extent for each of them, in terms of hierarchical nodes in the grid?*

To find a fitting answer to that, a range of detailed questions has been discussed with the DSO partners in the consortium as an expert group to understand the needs and possibilities from their perspective. Two of those questions will be discussed in the following paragraphs in detail.

Firstly, it is necessary to evaluate, **at which locations** or nodes in the distribution grid, **DSOs typically install monitoring devices** and therefore can detect grid constraint violations. The responses show that in following locations in the distribution grid topology measurements are performed:

1. At HV/MV transformer stations (voltage and current measurement)
2. At MV/LV transformer station (voltage and current measurement at the MV as well as at the LV side)
3. At each feeder at the LV side of MV/LV transformers (voltage and current measurement)

4. At prosumers' smart meters (measurement of active and reactive power, also current and voltage if possible)

Figure 47 shows these measurement points mapped in a simplified and exemplary distribution grid.

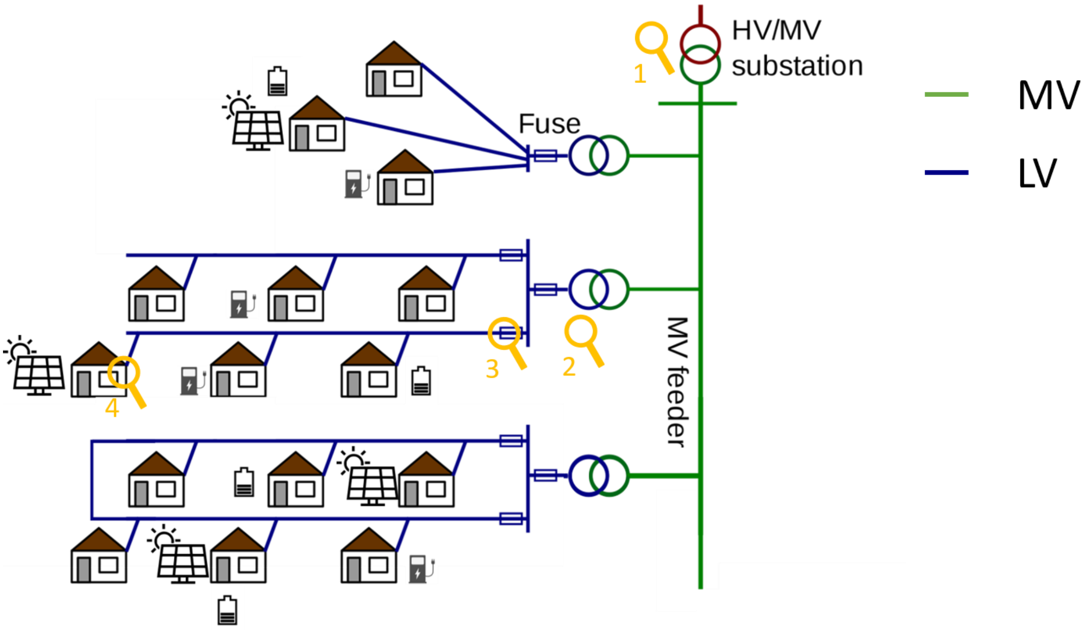


Figure 47. Typical locations of measurement points in distribution grids (Source: adapted from Wikimedia commons)

As an analogue to that, the expert group analysed, **where in this topology grid constraint violations** (congestions and voltage violations) **typically occur**. Following main locations have been identified and mapped in the exemplary grid topology (Figure 48):

1. At HV/MV transformer stations
2. At MV/LV transformer stations
3. At LV feeders from MV/LV transformer stations
4. At power lines between prosumers

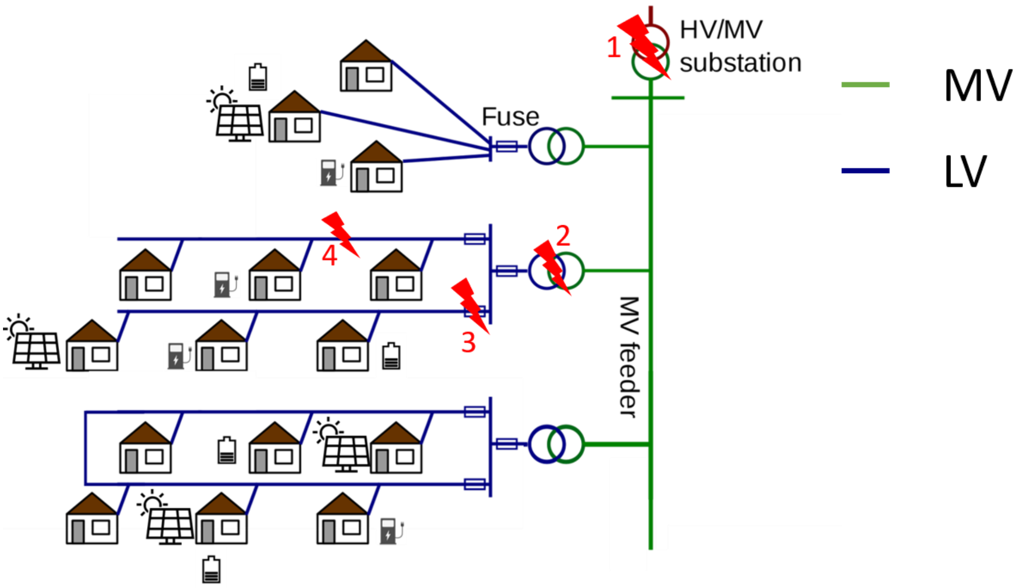


Figure 48. Typical locations of constraints in distribution grids (Source: adapted from Wikimedia commons)

Concluding from this analysis, the expert group found that **constraint violations at power lines between prosumers (type 4)** are the most critical ones. Generally, constraint violations can occur at all of these points, but constraint violation types 1-3 can be solved relatively easy by the DSO itself, e.g. by changing the tap configuration at a transformer station. In contrast, type 4 constraint violations are the most challenging ones for the DSO as LV power lines traditionally have been planned and built for distributing electricity among consumers and not for feeding back fluctuating loads from distributed generation such as PV. Therefore, the discussion concluded, that the PARITY market framework should aim at tackling these type 4 constraint violations.

However, constraint violations at power lines between prosumers (type 4) are also the most challenging ones to solve in a market-based way. That's because these constraint violations could occur literally at any location in the LV grid and not at a specific node. This makes a **homogenous market** with a defined group of flexibility providers **obsolete**.

As a result, in the PARITY market framework the **following solution is proposed**:

The local scope of both the LEM and the LFM include **the whole distribution grid** operated by the DSO. In this way, the liquidity on the LEM is safeguarded, as all the prosumers connected to the DSOs MV or LV grid can participate in the market at all times.

However, the local granularity that is necessary to solve these specific constraint violations in the LFM can be achieved as follows, depending on the design option for the LFM:

- In an **explicit LFM**, the granularity is achieved through a **locational attribute that is attached to each offer** on the LFM. Then the DSO chooses from offers with the fitting locational attribute, that can solve the specific constraint violation.
- In an **implicit LFM**, the local granularity is determined by the DSO imposing **locationally differentiated grid prices** in situations when critical constraint violations are forecasted. Based on this price signal, prosumers can react and adapt their trades on the LEM accordingly.

6.3.5 Coordination between Flexibility Requesting Parties

Finally, the coordination mechanisms for prioritizing the requests from the different FRPs is defined. PARITY applies the Traffic Light Concept (TLC) governing market activities in the four different grid regimes GREEN, YELLOW, RED and BLACK (Outage). These grid regimes can be described as follows:

- **GREEN**: There are no constraint violations detected in the distribution grid: DSO performs active grid monitoring
- **YELLOW**: It is a temporary state, when constraint violations have been forecasted by the DSO
- **RED**: It is a temporary state, when distribution grid stability is in danger due to constraint violations such as congestions and voltage violations
- **BLACK**: Means a grid outage

Which markets are active in each of these grid regimes depends on the design of the LFM as an explicit or implicit LFM.

In case an **explicit LFM** is implemented (Table 15), the LEM is active in GREEN regime and also participation in AS/WS markets through an aggregator is possible for prosumers in the GREEN regime only. Once the YELLOW regime is imposed, LEM and AS/WS participation is paused and the explicit LFM is activated. Now aggregators can provide flexibility to the DSO. Finally, in RED and BLACK regime, all market-based activities are paused and the DSO takes over control. As the black regime represents a grid outage, it will not be further addressed in PARITY. However, it is mentioned here for consistency reasons.

Table 15. Grid regimes in case of an explicit LFM

Reg.	LEM	Explicit LFM	AS/WS markets	Activities
GREEN	active	paused	active	LEM is cleared by LEMO Aggregator bundles flexibilities and trades on AS/WS markets
YELLOW	**paused**	active	**paused**	Explicit LFM is activated and cleared LFMO
RED	paused	paused	paused	DSO is allowed to override market-based contracts and to perform direct load control forcing loads to be switched off or reduced. This may be enforced through the aggregators' or the DSO's own infrastructure
BLACK	paused	paused	paused	All connections in the constrained area are disconnected for grid safety reasons. Hierarchical coordination for system restoration

In contrast, if an **implicit LFM** is implemented (Table 16), the LEM is active both in GREEN and YELLOW grid regime. The same applies for participation in AS/WS markets through aggregators. Here, the only thing that differentiates these two grid regimes are the locationally varying grid prices imposed by the DSO in YELLOW regime. In RED and BLACK regime, again all market-based activities are paused.

Table 16. Grid regimes in case of an implicit LFM

Reg.	LEM	Implicit LFM	AS/WS markets	Activities
GREEN	active	paused	active	LEM is cleared by LEMO Aggregator bundles prosumers' flexibilities and trades on AS/WS markets
YELLOW	**Active**	active	**active**	DSO imposes locationally varying grid prices LEM is cleared by LEMO Aggregator bundles flexibilities and trades on AS/WS markets
RED	paused	paused	paused	DSO is allowed to override market-based contracts and to perform direct load control forcing loads to be switched off or reduced. This may be enforced through the aggregators' or the DSO's own infrastructure
BLACK	paused	paused	paused	All connections in the constrained area are disconnected for grid safety reasons. Hierarchical coordination for system restoration

6.3.6 Summary of PARITY Market Design

In the PARITY market framework, two novel markets are introduced: The Local Electricity Market (LEM) and the Local Flexibility Market (LFM).

The **LEM** is facilitating P2P trading among prosumers and the platform is operated by the Local Electricity Market Operator (LEMO), a private competitive entity.

The **LFM** has the purpose to activate flexibility for the DSO's needs. As a first option, it can be implemented as an **explicit** market with a dedicated market platform, that is operated by the Local Flexibility Market Operator (LFMO), a regulated entity. On this platform aggregators can offer flexibility services to the DSO only.

As a second option, the **LFM** can also be **implicitly** integrated in the LEM. This means, that there is no market platform for the LFM and hence no LFMO. However, for activating this implicit LFM, the DSO imposes locationally varying grid prices to the prosumers. Those can react to this price signals by adapting their load and/or generation profile and their trades on the LEM accordingly and as a result avoid grid constraint violations.

The PARITY market framework is governed by the Traffic Light Concept (TLC). In the GREEN phase the LEM is active as well as participation of the prosumers in ancillary services (AS) and wholesale (WS) markets through aggregators. In the YELLOW phase, the LFM is activated. In case of an explicit LFM, the dedicated market platform is opened and all other market activities (LEM, AS/WS participation) are paused. In an implicit LFM, those market activities continue, but the DSO imposes the locationally varying grid prices. Finally, in RED and BLACK state, the DSO takes over control and all market activities are stopped.

Figure 49 shows the PARITY market role model, mapping all the roles involved and their interactions.

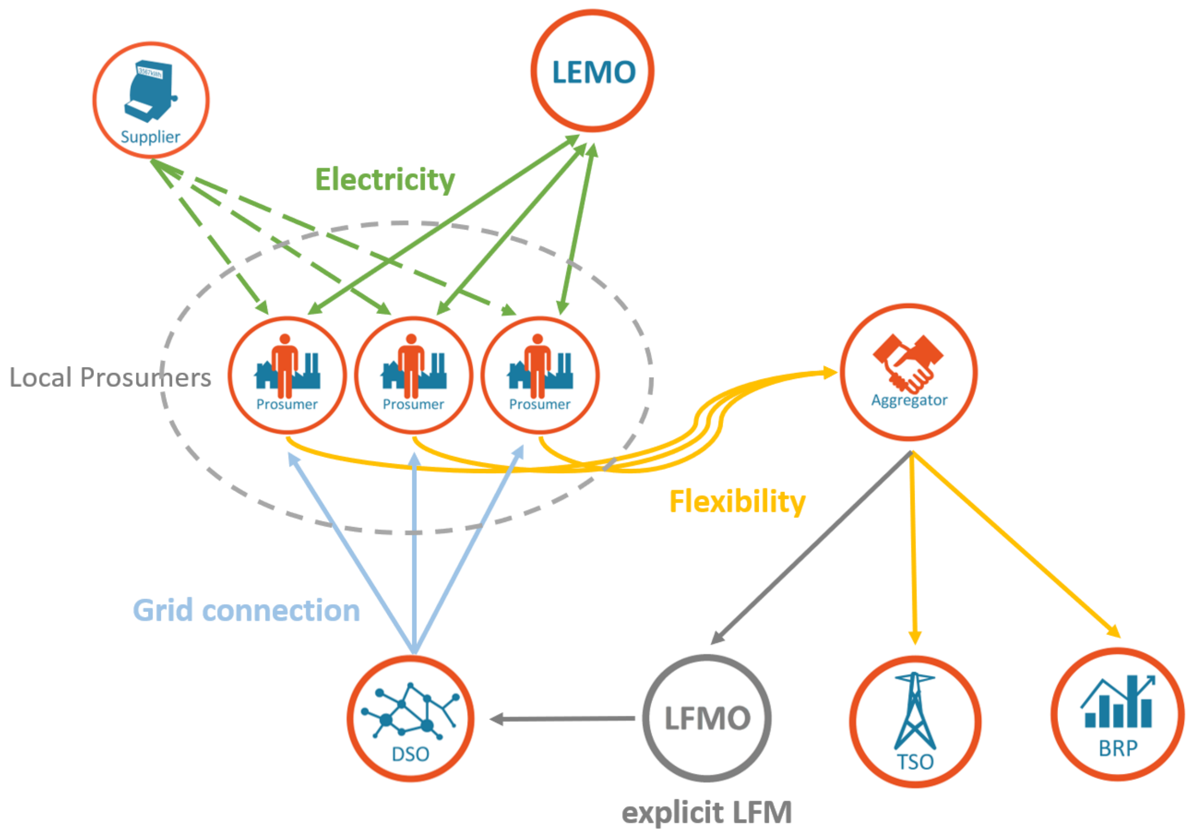


Figure 49. PARITY market role model

7. Gap Analysis

7.1 Structural Gap

Increased activity within energy electricity model development in recent years has led to several new models and capabilities, motivated by the need to better represent the integration of fluctuating renewables. The purpose of this section is to make a market participants-oriented analysis in order to investigate the structural gap between the conventional electricity market models and the proposed local market model in PARITY. To do so, an extensive SWOT analysis[16] is performed focusing on the market participants' perspectives, identifying the gap and finally providing recommendations for bridging the gap.

7.1.1 Comparison between Conventional Model and Proposed Local Market Model

The key difference between the proposed local market model and the conventional ones (e.g. wholesale market models), lies in the fact that local markets include additional information such as locational information and some technical requirements. Technology-driven improvements apply, among other things, to consumers who have access to in-house energy systems that can produce and store energy and control their consumption profiles. In comparison with the conventional electricity models, technological advance facilitates a move towards a smarter local market model, described as a combination of enabling technologies, hardware and software that collectively make the grid delivery infrastructure more scalable, safe, accommodating, resilient and ultimately useful to consumers. The proposed local market model of the PARITY project empowers users to take an active price-based decision on their electricity consumption. Consumers also have access to emerging technologies such as solar panels, batteries, heat storage systems and smart metering devices. The consumer is becoming an active decision-maker instead of a price-maker. Within conventional models load profiles are taken for granted and generation has to be changed to preserve system balance. Although conventional systems concentrate on a market where generation meets demand needs, the proposed local market framework sets out new market mechanisms to take advantage of the emerging innovations available (e.g. game theory, auction theory, constrained optimization and blockchain) in both consumption and generation domains. The manner in what markets are structured, determines what entities have access to flexibility tools at different times and locations. Market design improvements are important to allow flexible service providers access to customers that value the services provided. Table 17 presents some major distinctive differences between conventional models and the proposed local market model within the PARITY project.

Table 17. Comparison between conventional models and proposed local market models

Conventional Electricity Market Models	Proposed Local Market Model
Wholesale /Ancillary services Market	Local Flexibility Market, Local Electricity Market
One-way communication	Multi-way communication
No collaboration between consumers	Prosumers are involved in the local market, managing their energy consumption and production resources, they can also participate in traditional wholesale/ancillary services markets
Focus on traditional electricity sources	Focus on renewable energy generation resources
Centralized electricity generation	Distributed electricity generation
Sensors are not widely used	Sensors are widely used
Manual market monitoring	Digital automatic monitoring
Limited energy efficiency and flexibility	Optimal balance of energy efficiency and flexibility
High degree of vulnerability of the market	Flexibility and fast restoration of the market

[16] SWOT stands for Strenghts, Weaknesses, Opportunities and Threats

7.1.2 Identifying the Gap: SWOT Analysis

From the aforementioned comparison it is obvious that there are key differences between the conventional electricity market model and the one proposed within PARITY, considering the structural parameters of the models. In order to identify possible conflicts of interest, a SWOT analysis was conducted, taking into consideration the market participants involved in the PARITY project consortium. Each market participant has conducted an individual SWOT analysis emphasizing on structural parameters and identifying the structural gap, considering the market models described in the previous sections of this deliverable. During the SWOT analysis, the identified strengths and weaknesses were focussed on the conventional framework, while the opportunities and threats were focussed on the new framework proposed within PARITY. It is worth mentioning that the individual SWOT analyses were combined into a final one, providing a holistic view of the market participants on possible structural gaps. The results are presented in Table 18.

Table 18. Structural model SWOT analysis

Internal Conventional Framework		
	Strengths	***Weaknesses***
Legislation/ Regulation	• Established integration between technological aspects and social/legal aspects • Knowledge and expertise of regulatory aspects	• Dynamical adjustments regarding changing policies and developments are slow • Specific legislation provisions for promotion of local energy communities aren't available
Economical Aspects	• Strong economic development mainly driven by investments	• Overpriced schemes • Customer are not in control of their spending • Development of electricity market/market prices - competitiveness of flexibility solution
Prosumers Involvement	• Flexibility products beneficial economically for prosumers and market participants • Strong connection to end users, with good ability to handle large capacity of energy data from prosumers.	• New balance services, products provided by TSO not known by no huge prosumers/consumers. Expenses in advertising new balance/services provided. • Fault of engagement by prosumers to participate due to the huge costs in adapting the measuring and control of the load appliances. • Difficulty to adapt friendly interfaces for prosumers.
Security	• No ties to grid operators or suppliers ensuring safe-guarding of prosumer interests.	

Flexibility Market	• Well-established network with technology providers, decision-makers and customers • Low complexity in business that helps the market participants optimize their operations • Easing DER deployment and integration into the standard business model • Flexibility will improve the quality performance of the grid, reducing the SAIDI (System Average Interruption Duration Index) & SAIFI (System Average Interruption Frequency Index)	• The DSO might misuse DERs to avoid grid issues, and the supplier may not be as interested in energy efficiency services shrinking their market • Limited market's-based access (use of flexibility mostly used for serving public interest) • Lack of ability in planning DER penetration and contemporary flexibility engagement • Risk is to get too much production which must be (partially) switched off for avoiding over-voltage • Multiple brand DER integration requires a complex optimization system, and comprises a challenge to the aggregator.
	External New Framework Proposed in PARITY	
	Opportunities	***Threats***
Legislation/Regulation	• To integrate DSO legal constraint into a flexibility free market shaped environment • European policies generally support the proposed framework • To develop a consistent platform that can be ran in different countries with common rules and actors.	• Changes in regulatory schemes, uncertain short- to long-term national regulation • Competitors are building DC grids to bypass regulation on distribution grid concession, which is highly ineffective from a resource perspective.
Economical Aspects	• Flexible network energy prices and network charges • Cheaper energy storage solutions. • Prioritize the DER owners' economic interests before for example grid operation, in order to earn trust necessary to be let into people's houses • capturing the correct value of flexibility services	• Despite the use of flexibility, long-term investments cannot be avoided as the penetration of RES increases. • Increased complexity in calculation of network charges (especially for P2P transactions). • Huge costs involved to adapt prosumers to the new smart devices having a smaller data time to be registered and real time acting from flexibility algorithm. • DSO´s infrastructure should be adapted to Local Flexibility Scenarios by deploying devices to have real time data.

Prosumers Involvement	• enhanced prosumers role • Willingness of customers to achieve additional benefits from their installed equipment • Perceived rising energy awareness among prosumers and willingness to contribute and work with the system rather than against it • New model of Energy Communities as base for a cooperation between user/prosumers-local authorities-DSO • This local flexibility market will allow to sell electricity excess to another DSOs or TSO.	• Part of the society will not feel to participate at the energy transition • Several prosumers are not interested in taking (key) energy distribution decisions • A malfunction of the Local Flexibility market can produce congestion and voltage deviation problems such as overvoltage or undervoltage
Trust/Security	• Human centric approach safeguards prosumer satisfaction and justified intrusion, bettering the relationship between aggregator and prosumer	• Significant improvements in cybersecurity are essential for the DSOs and the other stakeholders. • Lack of trust from the prosumers side to start providing flexibility as their benefits and consequences are not clear enough at this stage.
Flexibility Market	• Use of new technologies (artificial intelligence, blockchain) and, consequently, business models for enhancing optimisation of dispersed flexibility • Reduction of energy transactions through the rest of the grid, as more energy will be consumed locally • wrapping flexibility into a broader energy plan, connecting flexibility with other business goals such as energy efficiency, sustainability and cost reduction • Implementing PPAs (power purchase agreement) models, which might provide greater certainty on the realization of benefits • Proliferation of decentralized RES as i.e. PV, heat pumps and EV(-chargers) • High volumes of decentralized, controllable, interconnected generation and consumption with comparatively high power/energy specifications • Offering flexibilities/flex-services to support the DSO • P2P trading: reducing losses and imbalance risks/saving transmission fees thus reducing overall costs	• Need for more investment in order to increase the smartness of the grid. • Private market valorisation of flexibility may be contradictory with public interest of an optimized load profile at coupling point between MV/HV grid (this means between local and wholesale market) • Technology have to be coupled with new organisation and function; the risk is to implement new technology into the old frame • Competitors lobbying to become completely independent from the BRP

7.1.3 Conflicts of Interest between Market Stakeholders

Since the above SWOT analysis is market participant oriented, different views and opinions are depicted, examining whether one variable affects another and identifying possible conflicts of interest. During the SWOT analysis several challenges and threats were identified that different market participants are facing or they have the potential to face in the future, leading to possible conflicts between them.

7.1.3.1 DSO – Retailer: Profits optimization between sold and acquired energy

While the DSO is responsible for maintaining the distribution grid and avoiding congestions etc., the retailer needs to optimize the profit between sold and acquired energy. Thus, conflicts may arise, considering that price signals (e.g. in a ToU pricing scheme) or DR interventions coming from the electricity supplier don’t reflect the grid status and therefore might create congestions in the distribution grid.

7.1.3.2 DSO – Retailer: Reliable data exchange increases DSO costs

The collection and processing of data is a responsibility of DSOs. In the new proposed market model, data processing will be required in higher time resolution. This will place pressure on the processes of DSOs, while retailers may benefit from this pattern.

7.1.3.3 DSO – Aggregator: Hesitation to disclose sensitive data

Information sharing is not the primary focus of DSOs, in comparison with data collection that is necessary. When it is required to transmit the data to the aggregator, the DSO may be reluctant or unable to do so because of privacy and data ownership issues.

7.1.3.4 DSO – Aggregator: Higher market price

The aggregator may leverage the flexibility prices higher than market prices if it offers services towards the DSO, in order to minimize excess capacity scenarios.

7.1.3.5 Aggregator – Retailer: Losing share of the market

The challenge between these two market participants is that their customer segment may overlap. For instance, where an aggregator operates on the wholesale and retail markets, it does not differentiate in any way from the retailer's role.

7.1.3.6 Aggregator – Retailer: Forecasting errors on the energy demand

An aggregator that spreads energy consumption to different and contradictory times than retailer forecasts, may create conflicts in the market model.

To sum up, during the SWOT analysis that was conducted, structural gaps were identified leading to conflicts of interests between the different market participants. In a nutshell the main conflicts were identifies between a) the DSO and the Retailer (e.g. pricing, use of energy storage), b) the DSO and Aggregator (e.g. regulations, data sharing, grid stability) and finally c) the Aggregator and Retailer (e.g. energy forecasting errors).

7.2 Technological Gap

7.2.1 Technological Barriers - State of the Art Analysis

The incorporation of renewable energy resources within a smart grid has made considerable progress towards production and deployment since the beginning of the 21st century. The European Commission set out the goal that energy production will be 100% carbon-free by 2050 (EC 2018)[17]. Much of this capacity will be installed at the customers' premises, and will be completely incorporated into the market to ensure cost-effectiveness of RES. These innovations provide a structure for Local Flexibility Markets to be developed, which can be described as market places that allow prosumers to exchange energy within their local communities (Mendes et al. 2018). While green smart homes and smart grids have grown rapidly, there are still some open technological challenges that need to be addressed, even considering the issues of technology readiness. An extensive technological barriers analysis was conducted within D4.1, but here an overview of the identified technological barriers is presented, as also depicted in Figure 50. The identified technological barriers are classified in seven types: a) Integration of renewable energy into the grid, b) Lack of technology standardization, c) Privacy, security and data sharing, d) Interoperability, e) Networking and f) Infrastructure.

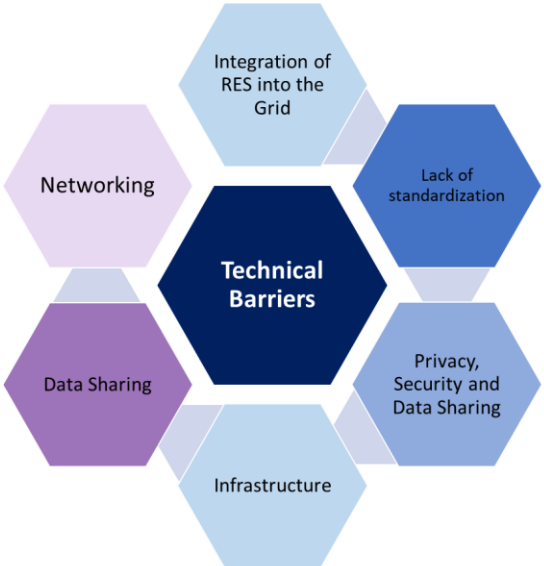


Figure 50. Identified technical barriers (Source: PARITY 2020, D4.1)

Several DER technologies, which are crucial to LFMs/LEMs, are not fully technically mature and have not yet been widely adopted yet. Additionally, technical obstacles exist for the incorporation of renewable energy into the grid, where the infrastructure for data collection and actuation (e.g. smart meters) is missing or incomplete. Additionally, the traditional centralised top-down energy model has not been built in the light of new smart technology.

Moreover, cyber security is one of the most important issues about the changing requirements surrounding the implementation of the smart grid. Energy IoT systems are inherently vulnerable to most common wireless network attacks due to the way the data is transmitted. Ambiguity of data security and privacy as well as access to information (e.g. data access rights) impede the implementation of smart grid technologies. The smart grid information technology (IT) spectrum has expanded to include devices that had previously been outside the grid, producing valuable data but also raising new safety issues (AM Conservation Group 2020).

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[17] Communication from the Commission to the European Parliament, The European Council, the Council, the European Economic and Social Committee, the Committee of the Regions and the European Investment Bank. A Clean Planet for all - A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy, Brussels 28.11.2018

Moving forward, in terms of interoperability, the presence of incompatible standards and protocols used by various manufacturers of energy devices (e.g. smart meters, batteries) is a significant barrier, making the seamless integration of vendor hardware a complicated process (Kamilaris and Pitsillides 2013).

Networking is another technical barrier. Specifically, with an increasing number of energy IoT products, large amounts of data have been generated in recent years, resulting in widespread bandwidth requirements in modern smart homes, leading to major network issues (Sujin Issac Samuel 2016). Also, resource levels and flexible loads responding to flexible demand signals trigger technical problems. Smart controllers transfer huge parts of power consumption to the lowest price times, overloading network assets and causing voltage problems.

Last but not least, the infrastructure of the local flexibility sector consists of different technologies, which again differ widely in maturity, condition and capability. The entry of emerging innovations and energy resources is threatened by factors including cost, potential technological risk and significant learning curves. However, it is still uncertain how this new infrastructure can be better exploited to support distribution processes and how these technologies can be accounted for in the network planning process (National Institute of Standards and Technology (NIST) 2012).

7.2.2 Technological Gap Analysis: Definition and Proposed Methodology in PARITY Project

The main scope of a gap analysis is to make a comparison between an actual state or performance and the desired state or performance in order to identify the added-value of a solution and infer useful conclusions. The output of the method is twofold; i) identify the desired state and ii) provide and infer some conclusions or possible actions regarding what is needed to reach the desired state. In PARITY a similar methodology has been implemented from a technological perspective which is defined as the PARITY's technological gap analysis.

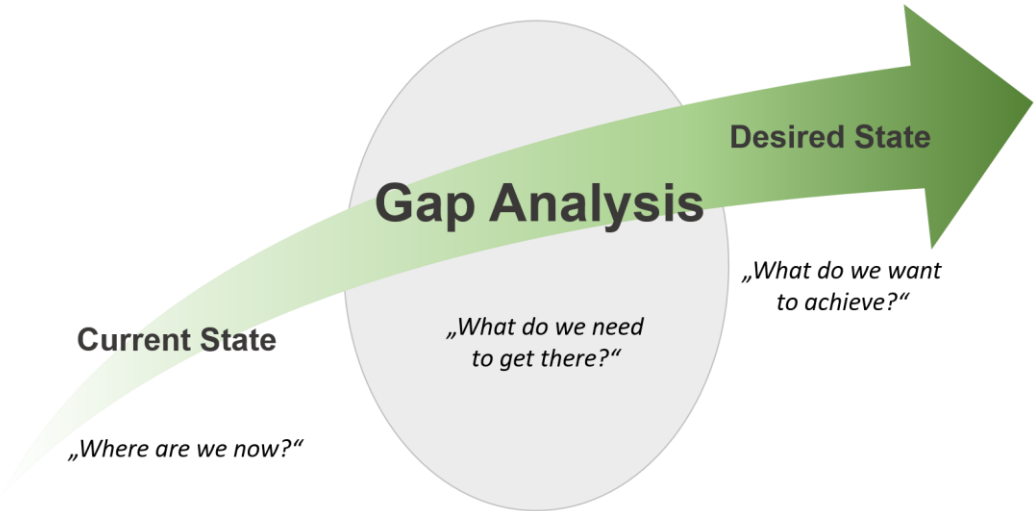

Figure 51. The basic states of the gap analysis process

The main purpose of the technological gap analysis is to analyse technological solutions related to local energy of flexibility trading from other relevant projects. More specifically, the methodology for the technological gap analysis that has been developed and proposed in PARITY is the following:

1) Identify all the relevant frameworks that are related to local energy trading
2) Make a taxonomy of the identified frameworks in two main categories:

    a. Local Flexibility Platforms (LFM) which are in near-commercial stage and are currently being implemented in a large scale in several EU countries.
    b. Prototype and highly innovative energy transactive frameworks, being deployed at pre-pilot stage with a focus on Peer-to-peer (P2P) energy trading.

3) Definition of the main technological aspects (indicators) under which the identified energy frameworks will be compared and evaluated within PARITY. These indicators coincide with the six basic technological aspects that PARITY aims to address:

    a. EV flexibility and smart charging
    b. Smart contract enabled transactions
    c. Human centric demand flexibility profiling and control
    d. Power-to-heat technologies for virtual thermal energy storage
    e. Smart grid monitoring and management
    f. Communications and networking

The aforementioned indicators have been specified taking into account the main objectives and technologies that will be developed in the PARITY project. For the technological gap analysis, the most relevant energy frameworks from previous related projects have been analysed and compared to PARITY, based on the six technological indicators.

Table 19 classifies these previous projects according to the two broad categories. In the first category the NODES, EPEX Local Flex, GOPACS and Piclo Flex LFM platforms are analysed and evaluated, while in the second category projects like BROOKLYN, GOFLEX, INTERFLEX, DRiVE, CATALYST, eDREAM and SmartNet have been chosen to make an in-depth technological gap analysis.

Table 19. Classification of the projects that are being investigated in two classes: i) LFM and P2P energy trading frameworks

Projects	LFM (near-commercial stage)	P2P energy trading (pre-pilot, research oriented)
Nodes	√	
EPEX Local Flex	√	
GOPACS	√	
Piclo Flex	√	
BROOKLYN		√
GOFLEX		√
INTERFLEX		√
DRiVE		√
CATALYST		√
eDREAM		√
SmartNet		√

7.2.3 LFM Platform (Near-commercial Stage) Frameworks

In the following Table 20 some basic information including key features, general details and projects for each of the aforementioned near-commercial LFM platforms are presented.

Table 20. Key features and basic details from LFM frameworks

Framework	Key Features	General Details	Related projects
NODES	• Utilizes a rulebook to determine how to cope with cases where flexibility providers do not deliver according to buyer expectations. • Commercial Platform released on 2019	NODES is an independent marketplace for decentralized flexibility and energy trading among grid owners, prosumers and consumers established at 2018. Its main target is to identify and give value to local flexibility.	• FLEXGRID (est. 2019) • IntraFlex (est. 2019) • NorFlex (est. 2019) • Engene (est. 2018) • sthlmflex (est. 2020)
EPEXSPOT local flex	• Utilizes locational orderbooks to centralize flexibility offers that can be used by flexibility requesters (DSO/TSO) in order to avoid or reduce grid congestions • EPEX local flex platform implemented for enera project with starting time on 2017	EPEX SPOT Local Flexibility Market platform is a voluntary market-based platform which has been developed as an efficient tool for DSOs/TSOs aiming at giving a smart solution to the grid congestion problems emerged from the everyday operation of renewable energy sources.	• SINTEG/Enera (est. 2017) • Other relevant projects under SINTEG initiative are: • SINTEG/CSELLS • SINTEG/New 4.0 • SINTEG/WindNODE • SINTEG/DESIGNETZ
GOPACS	• Utilizes location data in order to evaluate flexibility offers through an EAN code • There are no limitations (maximum or minimum) regarding the prices of the flex offers • Currently support limit orders • Connected with national Dutch intraday platform called Energy Trading Platform Amsterdam (ETPA) for market clearing • Established in 2019	GOPACS is the acronym for Grid Operator Platform for Congestion Solutions and is a platform that has been developed to be operated by Dutch TSOs and DSOs for the optimal and efficient managing and coordination of grid congestions issues.	• ETPA market platform
Piclo Flex	• It is an independent flexibility marketplace • It is based on a live auction mechanism to procure flexibility • Flexibility is evaluated through locational, technical and temporal requirements published by Distribution Network Operators (DNOs) • Launched in 2017	Piclo Flex is an independent marketplace that provides online flexibility services in terms of trading between requested parties through actions. Its main scope is the management of local network constraints in order grid reinforcement to be deferred.	• Piclo Flex is active only in UK with the participation of the six major distribution network operators.

As regards the LFM platform frameworks, these are analysed in terms of the aforementioned technological indicators. The analysis is presented in the following Table 21 where the comparison between the LFM frameworks through the specified technological indicators is provided. The main scope of this comparison is several useful conclusions to be deducted, regarding the potential technological novelty of the PARITY project as well as the technological issues that PARITY will try to address through a concrete and smart solution.

Table 21. LFM platform technological analysis under PARITY main technological indicators

Indicator	Sub-indicators	NODES	EPEX local flex	GOPACS	Piclo Flex
EV flexibility and smart charging	**EVs as flexible loads**	EVs used as flexible loads	EVs used as flexible loads	EVs used as flexible loads	EVs used as flexible loads
	Smart charging strategies information	G2V and V2H charging strategies	G2V and V2G charging strategies	Smart charging strategies are not provided and are not in the main scope of the project	Smart charging strategies are not provided and are not in the main scope of the project
	Flexibility profiling based on implicit and/or explicit information	Explicit charging preferences provided by the user	Explicit charging preferences provided by the user	Explicit charging preferences provided by the user	Explicit charging preferences provided by the user
	Geo-charging vs stationary profiles	Charging profile based only on charging point power data	Charging profile based only on charging point power data	N/A (are not considered in this project)	N/A (are not considered in this project)
	P2P charging services	Retailer-to-prosumer charging services	Retailer-to-prosumer charging services	N/A	N/A
Smart contract enabled transactions	**Level of energy/flexibility transactions**	Peer-to-aggregator and Peer-to-retailer energy transactions	Peer-to-aggregator and Peer-to-retailer energy transactions	Peer-to-aggregator and Peer-to-DSO energy transactions	Peer-to-DNO energy transactions and Aggregator-to-DNO energy transactions
	Type of SLAs	SLAs based on fixed parameters (static contracts)	SLAs based on fixed parameters (static contracts)	SLAs based on fixed parameters (static contracts) using other market platforms (e.g. ETPA)	SLAs based on fixed parameters. Long term contracts - e.g. flexibility auctions 4 months ahead
	Grid constraints incorporated into the market conditions	Grid constraints incorporated into the market conditions	Grid constraints incorporated into the market conditions	Grid constraints incorporated into the market conditions	Grid constraints incorporated into the market conditions

Indicator	Sub-indicators	NODES	EPEX local flex	GOPACS	Piclo Flex
Human Centric demand flexibility profiling and control	**Level of intrusiveness**	Demand management based on predefined agreements and without violating prosumers preferences	Demand management based on predefined agreements and without violating prosumers preferences	Demand management based on predefined agreements	Demand management it is not based on predefined agreements – each prosumer denotes its available flexibility
	Demand flexibility profiling and control considering prosumer's profile in a dynamic manner	Explicit preferences provided by the prosumer	Explicit preferences provided by the prosumer	Explicit preferences provided by the prosumer	Explicit preferences provided by the prosumer
	Level of automation	Fully automated control	Fully automated control	Manual actions required by the prosumer	Manual actions required by the prosumer
Power2Heat technologies for thermal energy storage	**Devices/loads that are being used**	Electric HVACs, Domestic Hot Waters (DHW)	Electric HVACs, Domestic Hot Waters (DHW)	Electric HVACs, Domestic Hot Waters (DHW), CHP plants	Electric HVACs, Domestic Hot Waters (DHW)
Smart Grid monitoring and management	**Grid management tools utilized to operate DSO grid assets and others**	No specific ANM, maintain current grid operation systems adding flexibility markets in different time horizons to improve grid operation.	No specific ANM, maintain current grid operation systems adding flexibility markets in different time horizons to improve grid operation. Proposes using a "traffic light concept" approach and direct control of the SO of some resources in red light (operation not directly linked to market results). Forecasted congestions and its solution are an input for LFM.	No specific ANM, maintain current grid operation systems adding flexibility markets in different time horizons to improve grid operation.	No specific ANM, maintain current grid operation systems adding flexibility markets in different time horizons to improve grid operation.

	Sub-indicators	NODES	EPEX local flex	GOPACS	Piclo Flex
	Grid state monitoring in LV level	DERs and current SO monitoring. DERs and grid monitoring to calculate flexibility capabilities/needs, billing and others	DERs and current SO monitoring. DERs and grid monitoring to calculate flexibility capabilities/needs, billing and others	DERs and current SO monitoring. DERs and grid monitoring to calculate flexibility capabilities/needs, billing and others	DERs and current SO monitoring. DERs and grid monitoring to calculate flexibility capabilities/needs, billing and others
Communication and networking	**Reliability and security of data exchange protocols used**	Microsoft Azure B2C authentication	Specific communication protocols are used without being specified, while the platform ensures transparency and confidentiality.	N/A	N/A
	Interoperability of the different flexibility assets	N/A	N/A	N/A	N/A

7.2.4 P2P Energy Trading (Pre-pilot) Frameworks

Following the same approach as implemented in the previous section for the LFM platform frameworks, in the following tables, Table 22 and Table 23, some basic details and key features for the selected P2P energy trading frameworks are presented, sharing similar technological aspects as PARITY project does.

Table 22. Key features and basic details for P2P energy trading frameworks

Framework	Key Features	General Details	Related projects
Brooklyn Microgrid (BMG)	• BMG marketplace allows prosumers to sell the excess solar energy they generate to NYC residents • Community-driven initiative created by LO3 Energy parent company	BMG is an energy marketplace for locally generated, solar energy. In April 2016, the first ever P2P energy transaction was carried out by two Brooklyn residents that were participating in BMG.	-

Framework	Key Features	General Details	Related projects
GOFLEX	• The project develops solutions providing more flexibility for automatic trading of general, localized, device-specific energy as well as flexibility for trading aggregated prosumer energy. • GOFLEX solution is tested at three European demonstration sites in Germany, Switzerland and Cyprus involving over 400 prosumers from industry, buildings and transport • Horizon 2020 research project	GOFLEX aims to enable the cost-effective use of demand response in distribution grids, increase the grids' available adaptation capacity and support an increasing share of electricity generated from renewable energy sources.	• FLEXICIENCY (est.2015) • InterFLEX (est.2017) • DRIvE (est.2017)
eDREAM	• Provides ancillary services to the DSOs allowing to optimize network operations • Direct trading of the aggregated flexibility through self-enforcing smart contracts • Horizon 2020 research project	eDREAM develops and validates novel technologies and tools for commercial and industrial near real time closed loop DR optimized flexibility management.	-
InterFLEX	• Exploration of new solutions that foster the development of DERs, including e-mobility • Six demonstration sites tested the flexibility of distribution networks utilizing innovative IT solutions for increased network automation • Horizon 2020 research project	InterFLEX investigates the use of local flexibilities to relieve the distribution grid constraints.	• DRIvE (est.2017) • GOFLEX • (est. 2017)
DRIvE	• Combination of Multi-Agent Systems (MAS), forecasting and cyber security technologies, aiming at market penetration in EU DR markets. • Horizon 2020 research project	DRiVE aims at moving closer to real time operations and progress from a limited number of assets toward decentralized management of a larger number of assets providing DR services to prosumers, grid stakeholders and DSOs.	• InterFLEX (est.2017) • GOFLEX • (est. 2017)
Catalyst	• Data centers assess their thermal, electric and IT workload flexibility that can be provided to other stakeholders • DC centers and many other flexibility prosumers can trade their offers • Horizon 2020 research project	Catalyst aims to adapt, scale up, deploy and validate an innovative technological and business framework that enables data centers to offer a range of mutualized energy flexibility services to both electricity and heat grids.	• GEYSER (FP7) • Dolfin (FP7 est. 2013)
SmartNet	• Develop an ad hoc simulation platform to model physical network, market and ICT • Different TSO-DSO coordination schemes are compared with reference to three selected national cases • Horizon 2020 research project	SmartNet project aims to provide optimized instruments and modalities to improve the coordination between the TSOs and DSOs as well as the exchange of information for monitoring and for the acquisition of ancillary services from subjects located in the distribution segment (flexible load and distributed generation).	-

Table 23. P2P energy trading frameworks technological analysis under PARITY main technological indicators

Indicator	Sub-indicators	BROOKLYN	GOFLEX	INTERFLEX	DRIVE	CATALYST	eDREAM	SMARTNET
EV flexibility and smart charging	**EVs as flexible loads**	EVs used as flexible loads	EVs used as flexible loads	EVs used as flexible loads	EVs used as flexible loads	EVs are not considered as flexible loads	EVs used as flexible loads	EVs are not considered as flexible loads
	Smart charging strategies information	G2V charging strategies	G2V charging strategies	V2G charging strategies	G2V charging strategies	EVs are not considered as flexible loads	G2V charging strategies	EVs are not considered as flexible loads
	Flexibility profiling based on implicit and/or explicit information	Explicit charging preferences are provided by the user	Explicit charging preferences are provided by the user	Explicit charging preferences are provided by the user. Control charging power in case of emergency after receiving signal from DSO.	N/A	EVs are not considered as flexible loads	N/A	EVs are not considered as flexible loads
	Geo-charging vs stationary profiles	Charging profile based on driving schedule information	Charging profile based only on charging point power data	Charging profile based only on charging point power data	N/A (monitoring and control are implemented in order to lower the peak-load)	EVs are not considered as flexible loads	Geolocation information used for EV fleet monitoring	EVs are not considered as flexible loads
	P2P charging services	Prosumer-to-prosumer charging services (token-based)	Retailer-to-prosumer charging services using flexible credits	Retailer-to-prosumer charging services	No P2P charging services	EVs are not considered as flexible loads	Retailer-to-prosumer charging services	EVs are not considered as flexible loads

Indicator	Sub-indicators	BROOKLYN	GOFLEX	INTERFLEX	DRIVE	CATALYST	eDREAM	SMARTNET
Smart contract enabled transactions	**Level of energy/flexibility transactions**	Peer-to-peer and peer-to-DSO transactions	Peer-to-peer and peer-to-aggregator transactions	Peer-to-peer and peer-to-aggregator transactions	Peer-to-aggregator transactions	Peer-to-peer and peer-to-aggregator transactions	Peer-to-peer and peer-to-aggregator transactions	Peer-to-aggregator transactions
	Type of SLAs	Consumers purchase the available energy from prosumers via auction.	SLAs based on fixed parameters. Human-centric parameters incorporated into SLAs	SLAs based on fixed parameters	N/A	SLAs based on dynamic parameters (Marketplace as a Service)	SLAs based on fixed parameters (Human-centric parameters incorporated in SLAs)	Flexibility trading bids, market clearing algorithms and grid physical state are simulated
	Grid constraints incorporated into the market conditions	N/A	N/A	Grid constraints incorporated into the market conditions	Grid constraints are taken into account	Grid constraints incorporated into the market conditions	Constraints of the installed field devices and operational constraints of DER are considered	Grid constraints are taken into account (but may not be incorporated into the market conditions)
Human Centric demand flexibility profiling and control	**Level of intrusiveness**	Demand management within prosumer preferences	Demand management based on predefined agreements and within the prosumer preferences	Demand management based on predefined agreements	Demand management based on predefined agreements	Demand management based on predefined agreements	Demand management based on predefined agreements	Demand management through bidding for congestion management (not based on predefined agreements)
	Demand flexibility profiling and control considering prosumer's profile in a dynamic manner	Explicit preferences are provided by the prosumer	Explicit preferences are provided by the prosumer	Explicit preferences are provided by the prosumer (but only for the EV case)	Explicit preferences are provided by the prosumer	N/A	Explicit preferences are provided by the prosumer	N/A

	Sub-indicators	BROOKLYN	GOFLEX	INTERFLEX	DRIVE	CATALYST	eDREAM	SMARTNET
	Level of automation	Manual actions required by the prosumer	Fully automated control	Fully automated control or manual actions depending on the use case	Fully automated control	Semi-automated control approved by the prosumer	Fully automated control	Fully automated control
Power2Heat technologies for thermal energy storage	**Devices/loads that are being used**	N/A	Electric water heaters, HVACs, Electric storage heaters	Electric HVACs, Coupling of urban thermal networks, Thermal Household storage devices, Gas/Electricity hybrid heating systems, Micro CHP units	Electric HVACs, Heat Pumps, Heat provided by CHP, biomass, and gas boilers	Thermal Storage, Heat Pumps, District Heating network, Waste Heat Pumps from flywheels	No Power2Heat technologies are being used	Thermal inertia of indoor swimming pool, CHP and thermostatically control loads (electric boiler and HVACs)
Smart Grid monitoring and management	**Grid management tools utilized to operate DSO grid assets and others**	No active network management is implemented	No active network management is implemented	Grid management tools for intraday and day-ahead flexibility markets management. Autonomous management in real time of different devices	No active network management is implemented	No active network management is implemented	No active network management is implemented	No active network management is implemented

	Sub-indicators	BROOKLYN	GOFLEX	INTERFLEX	DRIVE	CATALYST	eDREAM	SMARTNET
	Grid state monitoring in LV level	DERs and current SO monitoring. DERs and grid monitoring to calculate flexibility capabilities/needs, billing and others	DERs and current SO monitoring. DERs and grid monitoring to calculate flexibility capabilities/ needs, billing and others	LV monitoring using DSO RTUs and smart meters for intraday, day ahead and near real time management and for autonomous DERs management	Smart meters as input for P2P trade and flexibility management in intraday markets	DERs and current SO monitoring. DERs and grid monitoring to calculate flexibility capabilities/needs, billing and others	DERs and current SO monitoring. DERs and grid monitoring to calculate flexibility capabilities/needs, billing and others	DERs and current SO monitoring, mainly in HV and MV
Communication and networking	**Reliability and security of data exchange protocols used**	The blockchain – based cryptographically secure platform TransActive Grid is used	Data are transferred to the cloud after anonymization. User authentication and authorization	Findable, Accessible, Interoperable, Reuseable (FAIR) data. Data is categorized to different levels of confidentiality	User authentication and authorization. Privacy protection and anonymization and GDPR compliance.	Token-based authorization along with a custom, permissions, and filtering scheme. Data access for registered users is restricted based on permissions	Byzantine fault tolerant protocol is used for handling possible malicious behaviours.	Market data exchange with TCP/IP network, Modbus protocol used for batteries. Use of digital certificates is advisable. Different levels of authentication.
	Interoperability of the different flexibility assets	N/A	Flex-offer concept	XMPP, CIM Market protocols used for flexibility management (no use of openADR or M2M)	OpenADR	REST for synchronous communication among the components through common HTTP API and pub/sub messaging for asynchronous communications	OpenADR	Common encoding scheme for information that facilitate information exchange. M2M.

7.2.5 Technological Gap Identification

As an outcome of the analysis of all the projects that were investigated from a technological viewpoint and under the specific six technological indicators that have been defined and presented in the previous sections, the identification of the technological gap that exists in the current technological solutions is presented in this subsection. More specifically the conclusions for each indicator is presented as follows:

- EV flexibility profiling and smart charging:
    - While most of the projects consider EV as a flexible load, none of the investigated projects infers implicitly the charging profiling from an EV user. This means that each EV user must be aware of and declare its charging preferences and also to update this information in a continuous manner.
    - None of the investigated projects addresses G2V, V2G and V2H charging strategies under a unified framework.
    - Most of the LFM and P2P projects which have been examined do not provide smart geocharging services in terms of considering dynamic driver profiles. Only BROOKLYN project takes into account driving schedule information while the other projects extract a charging profile for the driver using only power data acquired from a stationary charging point.
    - Prosumer-to-prosumer charging services are not considered to any of the investigated LFM projects, while only NODES and EPEX local flex platform considers retailer-to-prosumer EV charging services. Only BROOKLYN project has made an attempt to provide prosumer-to-prosumer charging services.

- Smart contract enabled transactions:
    - Almost all the investigated projects utilize static contracts and service-level-agreements (SLAs) based on fixed parameters. That means that the current technological solutions presented in the investigated projects do not consider the dynamic behaviour or the variable preferences of a prosumer.
    - Most of the examined energy trading frameworks have incorporated grid constraints into the contracts.

- Human-Centric and demand flexibility profiling and control:
    - Most projects extract information for the prosumer’s demand flexibility profiling based on the prosumer explicit preferences. That means that in the current technological solutions the dynamic individual end-user’s comfort preferences are not automatically inferred (dynamically, in a continuous manner), requiring additional actions or specific knowledge from the end-users and probably are not in the main aspect of the investigated projects.
    - Some of the projects using fully automated actions to properly control DERs and acquiring the desired level of flexibility. This means that currently there are some serious attempts that expect to reduce the number of actions required by the prosumer side, developing less intrusive control systems.

- Power2Heat technologies for thermal energy storage:
    - Almost all the projects that have been examined consider power-to-heat technologies utilizing mostly HVAC and DHW devices. Therefore, no gap is identified.

- Smart grid monitoring and management:
    - In all the current frameworks which have been examined, there is no specific active network management (ANM) management identified. The current implemented strategies lie mostly on the addition of flexibility markets in different time horizons in order to improve grid operations.

- Communication and networking:
    - Regarding LFM platforms that are in near-commercial stage, it is quite hard to acquire specific and detailed information regarding this indicator, although NODES and EPEX Local Flex frameworks mention tools or actions implemented to ensure privacy, security and communication among the responsible parties. In the second category where P2P energy trading frameworks belong, there is much more information identified. As presented in Table 23, there are several different standards and protocols used in the P2P energy trading frameworks like XMPP, CIM, OpenADR, M2M while for the security and the reliability of data exchange, blockchain, Modbus and token-based authorization tools are mostly preferred among others.

8. Conclusion

In this report the development of the PARITY market design has been described, as performed in T4.3. The main purpose of this task is to clearly disentangle the PARITY market concept and create a common understanding among the project partners. For achieving this goal, firstly a thorough analysis of conventional electricity market models, relevant technologies and related research and pilot projects has been performed. Based on that, the novel market design proposed in PARITY has been defined based on carefully selected key parameters. Then, a technological gap analysis has been carried out in order to specify the technological innovation potential of PARITY. Finally, a structural gap analysis collected the viewpoints of actual market participants in order to compare existing market models with the proposed one and to identify possible conflicts of interest between market actors.

In this chapter, conclusions are derived from the PARITY market design (chapter 6), followed by those from the structural gap analysis (chapter 7.1) and finally the technological gap analysis (chapter 7.2).

8.1 PARITY Local Market Design

Based on a review of concepts for local markets and the associated controversies discussed in scientific literature, a scheme is developed, highlighting the **most important parameters** for defining a local market structure in PARITY. These include:

- Market participants
- Instruments for providing flexibility
- Market operator(s)
- Definition of the local scope of the market
- Coordination between flexibility requesting parties

This scheme is then applied for defining the PARITY market design.

In PARITY, two novel markets are introduced: The Local Electricity Market (LEM) and the Local Flexibility Market (LFM). The **LEM** is facilitating P2P trading among prosumers and the platform is operated by the Local Electricity Market Operator (LEMO), a private competitive entity.

The **LFM** has the purpose to activate flexibility for the DSO’s needs. As a first option, it can be implemented as an **explicit** market with a dedicated market platform, that is operated by the Local Flexibility Market Operator (LFMO), a regulated entity. On this platform aggregators can offer flexibility services to the DSO only.

As a second option, the **LFM** can also be **implicitly** integrated in the LEM. This means, that there is no market platform for the LFM and hence no LFMO. However, for activating this implicit LFM, the DSO imposes locationally varying grid prices to the prosumers. Prosumers can react to these price signals by adapting their load curve and their trades on the LEM accordingly and as a result avoid grid constraint violations.

An in-depth discussion about the **local scope** of the PARITY market framework has been performed with market participants, especially DSOs. In the explicit LFM local tags are assigned to each flexibility bid in order to enable the DSO to solve grid constraint violations precisely when procuring flexibility. For the implicit LFM, this is tackled by the locationally varying grid prices.

The PARITY market framework is **governed by a Traffic Light Concept (TLC)**. In the GREEN phase, the LEM is active and prosumers are also allowed to participate in ancillary services (AS) and wholesale (WS) markets through aggregators. In the YELLOW phase, the LFM is activated. In case of an explicit LFM, the dedicated market platform is opened and all other market activities (LEM, AS/WS participation) are paused. In an implicit LFM, those market activities continue, but the DSO imposes the locationally varying grid prices. Finally, in RED and BLACK state, the DSO takes over control and all market activities are stopped.

8.2 Structural Gap

During the first phase of the structural gap analysis, a **comparison between conventional models and the proposed model** was presented. The major observation lies in the fact that under the PARITY project, the new local market model empowers customers to take proactive price-based decisions on their energy usage, while consumers also have direct access to advanced technologies such as solar panels, batteries, heat storage devices and smart meters. Another major difference between conventional models and the proposed one is related to electricity generation. While conventional electricity market models are focusing mainly on traditional energy sources and centralized generation, the PARITY market model propose the wide adoption of renewable energy sources focusing on distributed generation. Moreover, it was identified that through the proposed model, optimal balance between energy efficiency and flexibility is becoming a reality, avoiding the high degree of vulnerabilities in traditional markets.

Once the comparison was accomplished, it became apparent that key differentiation exists between the conventional and the proposed model. Thus, in order to identify possible conflicts of interest derived from the structural gap, a **SWOT analysis** was conducted, taking into consideration the PARITY market participants. The SWOT analysis that was used in order to obtain and analyse the outcomes, was a result of the aggregation of individual SWOT tables, created by the market participants. The holistic SWOT analysis identified strengths and weaknesses, focusing on the conventional framework, while the opportunities and threats concentrated on the new framework proposed within PARITY.

Since the implemented SWOT was oriented towards the market participants and focused on the structural parameters, different views and opinions were depicted. The goal was to recognize that various market players are facing, or that they may face possible conflicts between them in the future. In short, the **main conflicts of interest were reported** between i) the DSO and the Retailer (e.g. prices, energy storage use), ii) the DSO and the Aggregator (e.g. rules, data exchange, grid stability) and iii) the Aggregator and Retailer (e.g. energy forecasting errors).

8.3 Technological Gap

In section 7.2, the gap analysis from a technological perspective has been presented. The methodology that has been followed is based on the analysis of the current technological state of projects that share similar goals with PARITY, similar technological aspects and implement similar technological solutions. The initial step of the methodology was a high-level classification of the projects that have been presented in section 5. Two broad classes were identified: i) LFM platform frameworks in near-commercial stage and ii) P2P energy trading framework in pre-pilot stage. The next step in the technological gap analysis was the identification of the indicators and sub-indicators under which this analysis was performed. These indicators have been derived from the basic technological objectives and the main aspects that PARITY aims to address, as defined in the proposal of the project. They are relevant to EV flexibility, transactions based on a smart contract framework, demand flexibility profiling through a human-centric aspect, usage of power-to-heat technologies, smart strategies for grid monitoring and management and finally communications and networking framework. The analysis of all the projects under the specified indicators concluded to the technological gap identification for each technological indicator. As presented in the *7.2.5 Technological Gap Identification* subsection, a **serious technological gap** derived **for almost all the specified indicators**. For each identified gap, the final and probably the most important outcome of the technological gap analysis is to provide recommendations and give further technological directions that the PARITY project could follow in order to make an attempt and explore the feasibility of covering the identified gaps. These recommendations are provided and analysed in the next section (section 9).

9. Recommendations

At the time of publishing this report, the PARITY project has been running for about one year. However, as the total project duration is 42 months, the PARITY local market framework is still in a rather early stage. Therefore, at this point it is crucial to give further directions for the project work based on the findings and definitions in this Deliverable.

In the following sections a list of recommendations is derived. These are targeted to all consortium partners involved in upcoming tasks, further specifying the market structure, developing tools or identifying suitable business models. At first recommendations arising from the definition of the PARITY market design (chapter 6) are presented, followed by those from the structural (chapter 7.1) and finally the technological gap analysis (chapter 7.2).

9.1 PARITY Local Market Design

Considering the design of the PARITY market structure, following recommendations are derived:

- **Recommendation #1:** This report proposes two possible concepts for implementing the LFM: an **implicit and an explicit LFM**. For the further development of the PARITY market platform(s) it is essential to **decide on one of these competing concepts** and adapt the tools and approaches accordingly. This is a key decision for the further project progress as both approaches require different development routes which might overstrain the scope and resources of this project. For this decision, it is recommended to consider a range of different aspects such as
    - **Regulatory feasibility:** Especially the implicit LFM requires far reaching regulatory changes enabling the DSO to set locationally varying grid prices. The PARITY approach should be as much as possible in line with current and planned legislation in order to have a fair chance of widespread adoption.
    - **The readiness of the demand side:** Demand side flexibility can only be activated, if a significant amount of controllable DERs with a relevant flexibility potential are deployed in the distribution grids. Against this backdrop, an implicit LFM might be a promising solution if DERs are widely available, while an explicit LFM could enable the participation of a few significant flexibility providers while keeping others unaffected in their tariff structure.
    - **Fitting end-users' preferences:** Prosumers should be encouraged to provide their flexibility. While the explicit LFM requires active involvement in a DR programme, the implicit LFM would affect prosumers by default. However, this should not lead to a state where "inflexible" consumers and prosumers increasingly face disadvantages.
    - **Incentive for DER investments:** Finally, the option implemented should incentivise prosumers to make investments in DERs.

- **Recommendation #2:** A newly developed market can be established as a standalone marketplace or can be integrated into an existing marketplace. Integrating the PARITY LFM into other marketplaces (e.g. balancing market operated by TSO) or bundling several LFMs/LEMs in one market place could be attractive in order to cut down costs related to the operation of the marketplace. In the development phase in this project, PARITY will be developed as a standalone market place. However, the **possibility of marketplace integration should be considered throughout the projec**t as a promising option for the real-life deployment of the PARITY concept.

- **Recommendation #3:** The possible **interactions between stakeholders** in the PARITY market structure and the resulting conflicts of interest need to be further clarified for practical implementation based on a set of different **Business Models**.

- **Recommendation #4:** The PARITY markets should aim at solving constraint violations in the LV grid, especially on specific lines between prosumers, as those are considered the most critical ones in the future. Therefore, the LFM needs to be able to solve constraint violations with **high local granularity**. In the explicit LFM we propose to add local tags to each flexibility bid in order to ensure this high resolution. For the implicit LFM, the locationally varying grid prices should be set at rather low-level nodes. However, it is expected that this will be the LV transformer as any lower node would discriminate prosumers by their location in the grid topology. Generally, grid **tariffs with a high power (kW) component** should be considered as this penalizes high power peaks by default.

- **Recommendation #5:** The **Traffic Light Concept (TLC)** drafted in this deliverable should be further refined in order to also enable LEM transactions as well as transactions towards AS/WS markets in yellow grid regime that are not interfering with the needs of the DSO. That is also because constraint violations in the yellow regime could be very local (for example in one specific LV line), leaving free grid capacities in other parts of the grid. This applies to the concept of the explicit LFM.
- **Recommendation #6:** further elements that need to be defined regarding the market design include:
  - **Product standardization:** A common definition of flexibility products that can be traded on the LEM/LFM
  - **Time horizons:** Determine if LEM/LFM transactions are performed on a day-ahead or intraday basis, for instance.

9.2 Structural Gap

A significantly higher proportion of RES and DERs will be used in the PARITY project. The proposed market model would allow the incorporation of emerging technologies like blockchain and smart contracts with existing and new smart grid technologies. Although, during the structural gap analysis presented in section 7.1, several challenges and threats were identified that different market participants are possible to face. In the current section, high level recommendations are going to be provided addressing open issues that need to be considered for the next steps in PARITY project.

9.2.1 Recommendations on tackling threats for market participants

Recommendation #7: Standardisation

- Prosumers should have direct access to their energy-related data (through smart meters) in order to make an accurate decision when changing suppliers or providers and to make the most of off-chain technological solutions, provided by the PARITY project. Customers should also have control over the use of their personal data by third parties (GDPR compliance).

Recommendation #8: Data access and data sharing

- Better access to accurate data is essential to the market from the relevant market players. It is important to ensure data access and data sharing for equal market competition, while at the same time protecting the privacy of consumers through GDPR compliance.

Recommendation #9: Market accessibility

- A system will be built to ensure a fair and open playing field for all service providers offering explicit or implicit demand response and flexibility services operating in the markets. At least the following problems and values need to be addressed:
  - The market-based approach should be considered, considering all forms of versatility. All market participants should compete under fair remuneration.
  - The functions and obligations of the various parties (especially the new ones) need to be explained and clearly defined.

<u>Recommendation #10:</u> Market efficiency

- Market processes should have appropriate synchronization functions between them for economic efficiency and reliability of supply, particularly where the same assets will provide different services to different market processes. In this way, entirely different business mechanisms should be avoided.
- TSOs and DSOs shall pay particular attention to the application of communication between the various market processes under which they work, such as balance and congestion management.
- The guidelines for the allocation of bids (technical and economic approach) should be straightforward and transparent.

9.2.2 Recommendations on tackling conflicts of interest

<u>Recommendation #11:</u> DSO – Retailer

- **Profits optimization between sold and acquired energy:**
    - Establish a business process that would consider the signals from both the market and system itself, managing possible trade-off in an optimal way.
    - This could be facilitated by communicating an accurate day-ahead load profile forecast to the DSO.
- **Reliable data exchange increases DSO costs:** If the demand for quicker sharing of data derives from the legislation, the reimbursement must be adequate to prevent unreasonably high costs that the DSO faces. Investment costs for the introduction of an effective data sharing network can be difficult to estimate.
    - The regulation relevant to faster data sharing should be more sufficient to avoid high costs faced by DSO (e.g. by establishing a central platform for allowing timely data distribution among the different stakeholders).

<u>Recommendation #12:</u> DSO – Aggregator

- **Hesitation to disclose sensitive data:** Information collection is not the central activity of DSOs, but it is important to gather information. If it needs to transmit the data to more than one participant, DSO may be hesitant to do so because it requires additional effort.
    - Suitable regulations should be established in order to securely share information between DSOs and aggregators.
- **Higher market price:** If the DSO does not need to validate the energy load, the aggregator can increase the price to unfairly high values. DSO would buy it in order to fulfil its responsibilities on grid stability.
    - Provide mechanisms that would maintain a price cap on the services provided to the DSO, managing possible trade-off in an optimal way.

<u>Recommendation #13:</u> Aggregator – Retailer

- **Losing share of the market:** An aggregator can also be a participant in the market. Thus, the need for cooperation vanishes and the aggregator becomes a retailer-aggregator. Both participants will have the same customer base, which means that competition in energy markets is getting stronger, leading to possible market share loses for one of them.
    - Emphasis should be given to the incorporation of aggregators into the LFM in order to enhance the functionality of the system.
- **Forecasting errors on the energy demand:** The retailer's priority is to remain on balance for energy consumption. The retailer purchases the estimated quantity of energy from the market. The margin between the purchasing of energy by the distributor and the selling of energy must be determined by means of imbalance control. Uncertainty in imbalanced electricity markets causes potential risks and costs for retailers.
    - Retailer and aggregator efficient collaboration is required for keeping the balance groups (and therefore production and consumption) in balance.

9.3 Technological Gap

Considering the overall work and the analysis performed under the technological gap analysis section and mainly taking into account the technological gap that has been identified as a result from this analysis, some main technological recommendations can be proposed for the PARITY project. The description of these recommendations is provided below and constitutes a technological path that PARITY may follow with the main goal to provide innovative tools and make a serious attempt to bridge the technological gaps that exist in the conventional energy trading frameworks on a Pan-European level:

- **Recommendation #14:** EV charging profiling of an end-user should be inferred implicitly and dynamically updated, without any previous knowledge of the end-user's charging preferences and without any requirement for the end-user to update its charging preferences in a periodic manner. Additionally, standard charging profiles from the literature and experiences from previous projects could be considered.
- **Recommendation #15:** In the EV concept, G2V, V2G and V2H charging strategies should be provided under a unified framework and a holistic technological solution to the end-user but also for optimized flexibility trading purposes. The current and expected future availability of V2G-ready vehicles on the market needs to be considered.
- **Recommendation #16:** From the overall technological analysis can be concluded that the concept of providing accurate and useful geocharging services considering dynamic EV driver profile is still in its infancy. Thus, PARITY should investigate this concept in-depth and make an attempt to provide smart charging services to an EV user considering its dynamically variable location.
- **Recommendation #17:** Prosumer-to-prosumer EV charging services should be considered for implementation during the runtime of the PARITY project and be evaluated in terms of flexibility services under a Local Flexibility Market scale.
- **Recommendation #18:** The dynamic behaviour and the variable preferences (prosumer's comfort dynamics in combination with contextual characteristics) of a prosumer should be reflected under specific service-level-agreements (SLAs) and clearly described with dynamic contract parameters.
- **Recommendation #19:** Demand management strategies should be based on fully automated control frameworks and taking into account the variable prosumers comfort preferences.
- **Recommendation #20:** Prosumers preferences should be automatically inferred, extracting demand flexibility profiling dynamically and in a continuous manner.
- **Recommendation #21:** Most current technological solutions do not consider smart active network management (ANM) tools for ensuring grid stability and quality on the low-voltage level. Therefore, it can be mentioned that the integration of new sensing and actuating tools and devices, responsible for enhancing the stability and the grid quality, is highly recommended.
- **Recommendation #22:** There are many different utilized frameworks and tools responsible for reliability and security of data exchange as well as for the interoperability among the various flexibility assets as regards the P2P (pre-commercial) energy trading projects, while for the LFM frameworks it seems (from the little information extracted for this technological indicator) that no secure conclusion can be deducted. As an outcome of this investigation could be inferred that there is an opportunity for PARITY to examine and decide which could be the most suitable, secure and robust framework for data exchange and communication among the flexibility assets.

10. References

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ANNEX A: Market Participants' Individual SWOT Analyses

DSOs:

HEDNO

Market Participant Description:

HEDNO is the main DSO in Greece and one of the largest in Europe. HEDNO's tasks comprise the operation, maintenance and development of the electricity distribution network in Greece in order to ensure transparent and non-discriminatory access of all consumers and more generally of all users of the network.

HEDNO as a DSO is an industry partner within PARITY and end-user that provides support for the deployment of technical solutions in operational environment. Furthermore, HEDNO supports the design of technical solutions and based on its experience provids consulting, networking and cooperation with industry.

HEDNO's SWOT analysis is performed from a DSO perspective.

SWOT Analysis:

Internal	
Strengths	***Weaknesses***
Strong economic development mainly driven by investments	No reduction of network charges due to investments
Capable to support all connection requests	Low level of smartness of the grid
Easy and fast grid planning	
Low complexity in business that helps the DSO optimize its operation	
External	
Opportunities	***Threats***
Short-term investment avoidance	Despite the use of flexibility, long-term investments cannot be avoided as the penetration of RES increases.
Flexible network energy prices and network charges	Need for more investment in order to increase the smartness of the grid.
Engagement of new IT technology in the energy sector	Significant improvements in cybersecurity are essential for the DSOs and the rest stakeholders.
Reduction of energy transactions through the rest of the grid, as more energy will be consumed locally	High complexity in grid monitoring and operation.
DSO can access ancillary services market	Increased complexity in calculation of network charges (especially for P2P transactions).

CUERVA

Market Participant Description:

Cuerva acts as DSO in the PARITY project with a pilot which consists in a portion of the grid owned by Cuerva. Cuerva will collaborate in the PARITY project by analyzing the flexibility that can be provided to avoid congestion and/or voltage deviation problems and how this flexibility could be exchanged in Local Flexibility Markets.

SWOT Analysis:

Internal	
Strengths	***Weaknesses***
Flexibility will improve the quality performance of the grid, reducing the SAIDI (System Average Interruption Duration Index) & SAIFI (System Average Interruption Frecuency Index)	DSO´s infrastructure should be adapted to Local Flexibility Scenarios by deploying devices to have real time data.
From the DSO side the investments in grid reinforcements will be postponed	There is a need for a huge quantity of DERs in the grid to cover the flexibility demand that currently are not deployed.
Better opportunities for the customers to reduce their billings and adjust their consumption to the market price	Costs should be considered for the prosumers, currently Pay-Back period are high and solutions to reduce this cost must be deployed.
	It’s complicated to engage prosumers if there are not friendly interfaces to manage the DERs
External	
Opportunities	***Threats***
To provide new energy services for the consumers that will help to the community engagement.	Difficulty to adapt to different European legislations.
This local flexibility market will allow to sell electricity excess to another DSOs or TSO.	A malfunction of the Local Flexibility market can produce congestion and voltage deviation problems such as overvoltage or undervoltage…
To develop a consistent platform that can be ran in different countries with common rules and actors.	Lack of trust from the prosumers side to start providing flexibility as their benefits are not clear enough at this stage.

AEM

Market Participant Description:

Azienda Elettrica di Massagno (AEM) is a DSO, managing a high voltage (HV) grid (two MV/HV transformers 20 MV/A and two bars on the HV side), 63km medium voltage (MV) grid (mainly in ring), 66 transformers MV/LV (standards 400 or 630 MV/A) and 233km low voltage (LV) lines (mainly radial without redundancies). AEM, as a retailer, is supplying roughly 50 GWh/y to roughly 9’450 customers, mainly residential (captive market) in a territory belonging to 3 municipalities within an area of 49 square km.

Within the PARITY project AEM is offering the demo site of Lugaggia, an Energy Community (Lugaggia Innovation Community) ranging 22 households connected by LV lines and enjoying a 90kW photovoltaic installed capacity (in 5 sites) and a centralised district battery (50kWh and 50kW bidirectional). Power supplied from the grid is measured by a meter located at the coupling point between the district LV line and the distribution grid (electrical cabinet).

AEM's SWOT analysis is performed from a DSO perspective.

SWOT Analysis:

Internal	
Strengths	***Weaknesses***
Easing DER deployment and integration into the standard business model	Limited market's-based access (use of flexibility mostly used for serving public interest)
Local use of the local flexibility to serve a public interest (grid control and management and optimized tariff's costs)	Flexibility reward, which is mainly reflected into a) self-consumption and b) optimized tariff's costs
Integration between technological aspects and social/legal aspects	Still lack of ability in planning (for the future) DER penetration and contemporary flexibility engagement; risk is to get too much production which have to be (partially) switched off for avoiding over-voltage
Planning cables/lines/transformer upgrade when needed and not as a preventive action	"Silent stakeholders" engagement ("digital divide")
External	
Opportunities	***Threats***
Increase role and function of domestic automatization, to be integrated into the "smart grid", enhancing prosumers role	Public campaigns that promote DER are not considering its grid impact, sending a contradictory message to the public
To integrate DSO legal constraint into a flexibility free market shaped environment	Private market valorisation of flexibility may be contradictory with public interest of an optimized load profile at coupling point between MV/HV grid (this means between local and wholesale market)
Use of new technologies (artificial intelligence, blockchain) and, consequently, business models for enhancing optimisation of dispersed flexibility	Under-evaluation of "digital divide" and "silent stakeholders, which means part of the society will not feel to participate at the energy transition
Better defined DSO's role and function in a more shaped free market environment	Technology have to be coupled with new organisation and function; the risk is to implement new technology into the old frame
New model of Energy Communities as base for a cooperation between user/prosumers-local authorities-DSO	
DER are local (narrow) based, even just by the fact that they are supplying into the LV grid. Therefore, new technologies would provide narrow based solution. Edge computing intelligence is already showing the mainstream	

Retailers/Suppliers:

E.ON

Market Participant Description:

Within PARITY, E.ON's main contribution will be in the development/research by providing customer insight, test subjects for pilot sites and the relevant business perspective of the electricity retailer.

E. ON's SWOT analysis is performed from an electricity retailer's/solution provider's perspective.

SWOT Analysis:

Internal	
Strengths	***Weaknesses***
developed customer platform	Depending on the company's maturity/age dynamical adjustments regarding changing policies and developments might be slow
contacts to broad bandwidth of stakeholders, well-established network with technology providers, decision-makers and customers	
knowledge and expertise of market mechanisms, regulatory aspects, energy solution development, sales, marketing, customer service	
External	
Opportunities	***Threats***
Becoming also an aggregator/LEMO to maximize value	One barrier might be metering requirements and missing standards
wrapping flexibility into a broader energy plan, connecting flexibility with other business goals such as energy efficiency, sustainability and cost reduction	changes in regulatory schemes, uncertain short- to long-term national regulation
Implementing PPAs (power purchase agreement) models, which might provide greater certainty on the realization of benefits	Development of electricity market/market prices - competitiveness of flexibility solution
Willingness of customers to achieve additional benefits from their installed equipment	lower revenues than anticipated and uncertain outlook, difficult prediction of auxiliary market revenue
Proliferation of decentralized RES as i.e. PV, heat pumps and EV(-chargers)	capturing the correct value of flexibility services
High volumes of decentralized, controllable, interconnected generation and consumption with comparatively high power/energy specifications	Unfamiliar and complex subject to communicate to stakeholders
Offering flexibilities/flex-services to support the DSO	complex and fast-changing legislative landscape, product offering and commercial dynamics
P2P trading: reducing losses and imbalance risks/saving transmission fees thus reducing overall costs	uncertainty about future flexibility market landscape - wait, be aware and adopt to what comes up

Aggregators

URBENER

Market Participant Description:

URBENER, S.L. is an aggregator who aggregates prosumer flexibility acting as BSP and BRP to manage aggregated flexibility into the wholesale market. URBENER, S.L. will collaborate in the PARITY project with a pilot plant where a flexibility algorithm will act over the appliances loads by means a semi-automatic human centric system.

URBENER's SWOT analysis is performed from an aggregator perspective.

SWOT Analysis:

Internal	
Strengths	***Weaknesses***
Flexibility products beneficial economically for prosumers and market participants such as aggregator.	Fault of P2P platform that would need to be develop in the company, development of new technologies as Blockchain that need specialist developers that are difficult to find in the job market at huge prices. Difficulty in building decentralized P2P platform provided that databases are prosumer depending.
A new balance energy product provided that will compete in the electrical energy market reducing the electrical energy price.	New balance services, products provided by TSO not known by no huge prosumers/consumers. Expenses in advertising new balance/services provided.
Higher flexibility achieved in adjusting the electrical energy demand by means of balancing products bought for smaller periods of time.	Fault of engagement by prosumers to participate due to the huge costs in adapting the measuring and control of the load appliances.
	Difficulty to adapt friendly interfaces for prosumers.
External	
Opportunities	***Threats***
Platform constructed taking in account the legislation of different countries in the EU.	Difficulty to adapt to different European legislations.
Blockchain technology involved to verify systematically the authenticity of contracts by hassing and register energy trading. Reducing the interpersonal dependence with lawyers and associated costs.	Huge costs involved to adapt prosumers to the new smart devices having a smaller data time to be registered and real time acting from flexibility algorithm. OS and DSO should adapt technologically their infrastructure. OS and DSO will tend to postpone the initial date to trade flexibility.
The platform takes in account the different roles involved in the electrical system such as OS, DSO, aggregator and human-centric approach focused in prosumer comfort preferences. The aggregator role allows aggregated demand and flexibility availability reducing deviations in the programming unit.	Fault of trust by prosumers to start being flexibility providers considering unknown consequences.

CWATT

Market Participant Description:

CheckWatt's responsibilities within PARITY are in the scope of a flexibility aggregator. CWATT's main contribution within PARITY is to provide demand response services to prosumers for DER control and integrate multiple DER interfaces for total building energy optimization. Moreover, CWATT is responsible for the aggregation of capacity to meet requirements and enable operation on different parts of the electricity market (including LFM, TSO ancillary services market, wholesale market)

CheckWatt's SWOT analysis is performed from an aggregator perspective.

SWOT Analysis:

Internal	
Strengths	***Weaknesses***
Ability to go to competing flexibility markets enabling market-based pricing. (No natural monopoly)	Multiple brand DER integration requires a complex optimization system, and comprises a challenge to the aggregator. Many end up with strong brand loyalty and lose benefits (see strengths)
No ties to grid operators or suppliers ensuring safe-guarding of prosumer interests. (it is a very important advantage to prioritize the DER owners' economic interests before for example grid operation, in order to earn trust necessary to be let into people's houses)	
The option to an independent aggregator is if aggregation would be done by DSO or supplier. As mentioned above, conflicts of interest could emerge in those cases. The DSO might misuse DER to avoid grid issues, and the supplier may not be as interested in energy efficiency services shrinking their market.	
Strong connection to end users, with good ability to handle large capacity of energy data from prosumers.	
External	
Opportunities	***Threats***
Human centric approach safeguards prosumer satisfaction and justified intrusion, bettering the relationship between aggregator and prosumer.	Low trust in small scale solutions for large scale energy system problems. (meaning attitudes that flexibility markets and solutions cannot replace rotating mass and other existing components ensuring system stability)
Perceived rising energy awareness among prosumers and willingness to contribute and work with the system rather than against it.	Competitors are focusing on large prosumers.

Market participant discussion about local energy communities, which would be an additional driving factor for DER integration. (partly similar to the PARITY proposed LEM)	Competitors are building DC grids to bypass regulation on distribution grid concession, which is highly ineffective from a resource perspective.
Cheaper energy storage solutions.	Competitors lobbying to become completely independent from the BRP
Modern DER devices have built in smart technology and are ready for integration.	