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TSO-DSO-Consumer INTERFACE aRchitecture to provide innovative Grid Services for an efficient power system

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D2.2 Existing tools and services report

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Abbreviations

DoW	Description of Work
EU	European Union
GA	Grant Agreement
HW, H/W	Hardware
IDEB	Innovation, Dissemination & Exploitation Board
IDEM	Innovation, Dissemination & Exploitation Manager
IP	Intellectual Property
IPR	Intellectual Property Rights
KPI	Key Performance Indicator
PC	Project Coordinator
PCT	Project Coordination Team
PI	Principal Investigator
PSC	Project Steering Committee
QAS	Quality Assurance Supervisor
QMP	Quality Management Plan
SAB	Security Advisory Board
SW, S/W	Software
TL	Task Leader
TM	Technical Manager
TSC	Technical & Scientific Committee
WP	Work Package
WPL	Work Package Leader

Executive Summary

This deliverable called "Existing tools and services report" is the second deliverable of the INTERRFACE project Work Package (WP) 2 "SOTA Analysis/Assessment and End-User Requirements". Within this deliverable, an analysis of existing tools and services and a thorough survey were conducted to provide in-depth insights on the various developments of tools and services used by different operators and other actors of the energy value chain for data collection and delivery. According to the state-of-the-art analysis and the survey results, different tools and services were listed and analysed to ensure that their use through the Interoperable pan-European Grid Services Architecture (IEGSA) will meet the transparency needs of new actors (DER, Prosumers, ESCOs) and DSOs. This paper also provides an evaluation which aims to establish whether the relevant tools and services can facilitate the needs of the actors, while also identifying improvement areas given the current status quo.

In state-of-the-art analysis, the most common services provided by different stakeholders of the energy value chain for data collection and delivery are listed and analysed from different viewpoints. The most commonly used tools are also listed, representing grid and market tools.

In preparation for this analysis, a survey on existing tools and services within market and grid fields was carried out in order to identify the relevant issues and pain points across various European experiences. Particular emphasis was placed on the perceived needs of various energy actors. Findings revealed major concerns with regards to the integration of different platforms used for different purposes (for example, operational planning and real time systems) and how to exchange information/data between parties in an expedited and standardized way. The survey results notably enable the identification of key improvement areas for existing tools and processes. Survey participants see the future energy system as a system where energy storage systems, smart metering, online voltage regulation and Demand Response services will be prevalent services in the years to come. Therefore, existing tools will have to be adapted in order to fulfil the needs that these foreseen services will require. Regarding the market landscape, it is noteworthy that the creation of a limited number of fully integrated and regulated markets is seen as the most popular solution to avoid the usage of flexibility in too many different markets and products.

The analysis made in this document will be fruitful for Task 3.1 and Task 3.3 where services design and reference architecture design are studied, as well to Task 4.4 for the implementation of the interfaces of these tools into the IEGSA platform.

1 Introduction

1.1 Background

The present Deliverable 2.2 titled "Existing tools and services report" corresponds to Task 2.2 "Collection of existing tools/services (joint pan-European toolset)" of the INTERRFACE Working Package (WP) 2"SOTA Analysis/Assessment and End-User Requirements". The objectives of WP2 are:

- To make a thorough review and comparative analysis of the project's technologies, toolsets and services;
- To carry out the requirements analysis based on the stakeholders' input
- To execute a study of applicable international, European and national law/ regulation framework to identify relevant regulatory aspects that need to be taken into account related to the operational framework to be defined for the IEGSA platform

Task 2.2 focuses on the analysis of existing tools and services used by different operators and other actors of the energy value chain for data collection and delivery (e.g. ENTSO-E IT platforms, data hubs, data management systems, etc.). The expected result of this activity is to develop a coherent and fact-based review of the following issues:

a) Which existing services are most relevant and important for different actors of the energy value chain
b) Which services currently are not used by different companies, but are expected to gain prevalence in the future
c) What tools are used for relevant services
d) What can be improved with regards to currently used tools

To achieve these goals, Task 2.2 includes the following steps:

- State-of-the-art analysis of existing tools and services currently used by different companies
- The survey analysis of existing tools and services used by different actors of the energy value chain and whether these services fulfil the needs of the actors or not.

1.2 Report structure

Following the Executive summary and Introduction in Chapter 1, the State-of-the-art analysis is described in Chapter 2. It is divided in 2 subchapters: Services and Tools. Services subchapter is divided in 3 sections: Grid, User and Market. In these sections the services provided by grid, user and market companies are listed respectively. Tools subchapter is divided in 2 sections: Grid and Market. The most commonly used tools are listed in this subchapter.

The Chapter 3 represents the survey analysis of existing tools and services. The survey was divided in 2 parts, Grid and Market, and the detailed analysis of the answers is shown in Grid's tools and services and Market's tools and services subchapters respectively.

Finally, a conclusion in Chapter 4 summarizes the main accomplishments of the deliverable and gives an outcome of Task 2.2, which will be handed over to Task 3.1 and Task 3.3 to further describe new services envisioned as well as the dependencies and connection between tools and datasets, to adjust the data granularity and enable a proper market integration, as well as to Task 4.4 for the implementation of the interfaces of these tools to the IEGSA platform.

2 SOTA analysis

2.1 Services

2.1.1 Grid services

In this chapter, TSO and DSO grid services are described from a flexibility viewpoint. Flexibility has been defined as "the modification of generation injection and/or consumption patterns in reaction to an external signal (price signal or activation) to provide a service within the energy system." [1]. Both provided and utilized services are considered.

Services that TSOs are providing are DataHUB and flexible grid connection contract. At the same time, TSOs use flexibility services in frequency control and reserves, balancing of power system, capacity reserves (peak load capacity), voltage control (reactive power management), and congestion management. DSOs are providing services like metering data, load control via smart meters, voltage control, and flexible grid connection contract. DSOs are utilizing flexibility services in voltage control (reactive power management), congestion management, and backup power. However, as mentioned in D2.1, there are a number of new use cases in which DSOs foresee the use of flexibility, namely: controlled islanding, operation under severe circumstances, restoration control and local grid balancing (often referring to redispatch).

A flexible grid connection contract is a TSO and DSO service to grid customers. If deep connection costs are applied to customers willing to connect into a weak grid, the cost of connection might become extremely expensive. In this kind of cases, a flexible grid connection contract might be an interesting option to reduce grid connection costs. The idea behind flexible connection is to avoid or postpone grid reinforcement while connecting a new customer who is willing to behave in a flexible way. In practice, this may occasionally result in production curtailment or peak demand management.

DataHUB (national metering data HUB) is an emerging service provided by TSOs, DSOs or third parties to collect and share smart meter data. DSOs (or those who are responsible of metering) submit metering data to DataHUB where it becomes accessible for the relevant (and authorised) actors. The value of this service resides in the fact that retailers no longer need to communicate with several DSOs, but rather with a unique system operator. Some limitations related with General Data Protection Regulation (GDPR) are hindering the common practice of national data hubs. A possible way forward is to work on the interfaces between market players in order to find standardization and communication protocols that will facilitate the data exchange, and by that way solve privacy issues.

Metering data is provided to end-customers as well. Some smart meters provide an interface (e.g. Zigbee of Z-wave) for real-time reading of energy for home or building automation usage. Other technologies like M-bus or light pulses are utilized as well for real-time reading of a meter. DSOs' or Suppliers' web-portal may also provide energy saving hints for a customer in addition to providing access to past consumption data. Furthermore, some DSOs (or the retailer) are also capable of sending notifications (e.g. email or text message) to customers concerning planned or unplanned outages at their connection point [2].

Load control via smart meters is DSO's service to aggregators to get an access to demand response resources [3]. Smart meter may have a relay to control load (e.g. electric hot water boiler, electric space heating, cooling device, etc.) on and off. Smart metering infrastructure (which includes the IT systems, meter reading system and the meter itself) is utilized to deliver the control command from the aggregator to the load. In this case, the DSO is a service provider for an aggregator, and the aggregator needs to have a contract with the end-customer to realize demand response.

TSOs utilize flexibility for multiple purposes. Frequency control is based on harmonized services in Europe, which are visualized in Figure 2-1 [6]. The aim of Frequency Containment Reserve (FCR) is

to maintain the frequency as close to 50 Hz as possible. It can be divided in two parts: normal (FCR-N) and disturbance (FCR-D) reserves (mostly in Nordic region). The difference between them are the frequency thresholds for activation and the requirement for activation time. Figure 2-2 [7] provides a visualization of the utilization of reserves. Thresholds for other regions are different, but the principle of reserve utilization is the same. FCR-N is activated immediately when frequency deviates from 50 Hz and it must be fully activated when frequency has dropped to 49.9 Hz. If the frequency decreases further, FCR-D will be activated and it must be fully activated at 49.5 Hz. In different part of Europe FCR is provided by different participants, only by generators in Iberian peninsula and most Eastern European countries, Generators & Load & Pump Storage & Batteries in UK, Ireland, France, Switzerland, Germany, in Nordic countries FCR is typically located in generating units (hydro power units), large-scale industrial demand response, aggregated small-scale demand response or HVDC links going outside the region [4][40].

Frequency Restoration reserve (FRR) has two purposes: to free activated FCR to take care of next frequency deviation, and to restore frequency back to normal variation range. FRR may be realized automatically (aFRR) or manually (mFRR). Like visible in Figure 2-2, the activation of FRR increases frequency gradually back to normal variation range. While doing that, the output from FCR decreases, i.e. they are deactivated. Typical resources for FRR are generating units (hydro power units), large-scale industrial demand response or aggregated small-scale demand response in Nordic case[5], generators (only for Iberian peninsula) and most Eastern European countries[40]. Replacement Reserves (RR) release activated FRRs back to a state of readiness in case of new disturbances (not used in the Ireland, Belgium, Netherlands, Germany, Denmark and some Eastern European countries[40]).

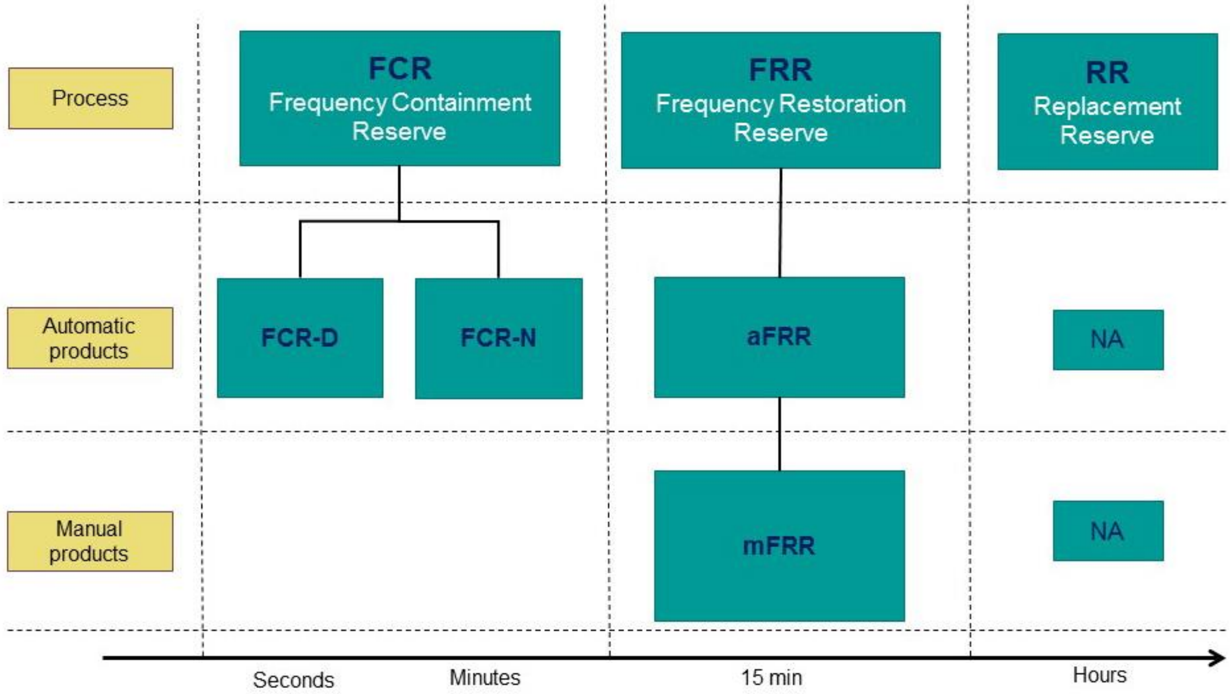

Figure 2-1 – Frequency control processes [6]

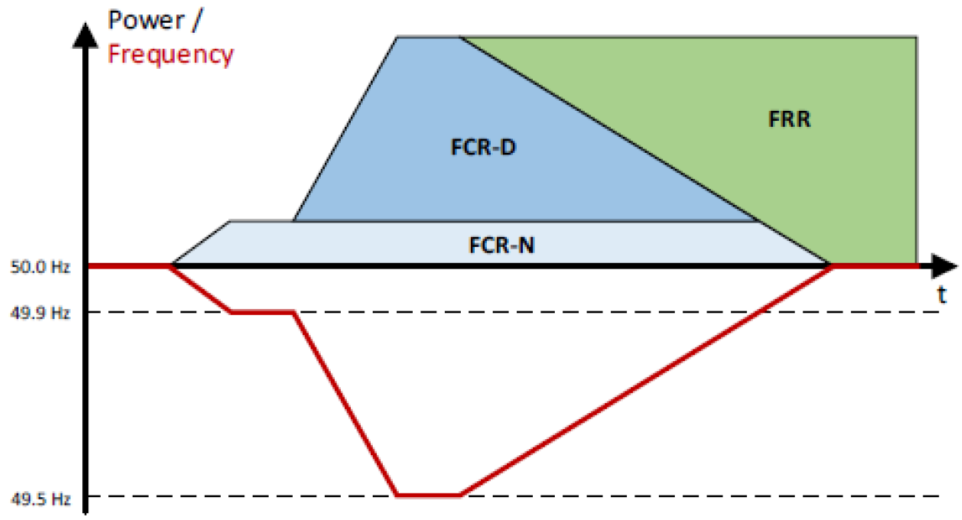

Figure 2-2 – Utilization of FCR and FRR in under-frequency situation [7]

Market participants mainly maintain power system balance by following their production and consumption plans. Every market participant needs to have an open supplier who handles the party's power imbalance. Open suppliers may create a chain and the market participant whose open supplier is the TSO is called Balance Responsible Party (BRP). BRPs submit generation and load schedules to the TSOs and are financially accountable for deviations from their schedules. In the case of deficit imbalance (in the system), the TSO activates upward imbalance power, and in case of surplus (in the system), the TSO activates downward imbalance power. The price of imbalance power is defined in balance power market, which is utilized by TSOs to keep the system balance.

Congestion management at transmission grids is mainly realized in the zonal day-ahead energy market. Zonal prices are defined in such a way that power flow according to traded energy will be within allocated transmission capacities. Internal congestion within a zone may be removed by re-dispatching or by reducing cross-border transmission capacity provided for market (by moving internal congestion to a border of zone). A more long-term solution would be the splitting of zone to two or more zones to solve internal congestion problem.

Distribution grid-level congestion may occur as well although it is much less common than transmission grid congestion and it has naturally local consequences only. However, since the local dimension (aggregators, prosumers, storage, DER, EVs…) is becoming increasingly prevalent in the energy sector, it is expected that in a near future, DSOs will need to adapt their core systems so that they are prepared to deal with an increase in the appearance rate of congestions. Typical reason for congestion in the distribution grid is a high penetration of renewable energy resources, which leads to over-current or over-voltage in the grid. Because DSOs typically do not have other possibilities to remove the congestion, production curtailment is applied. Active network management methods [8] and local flexibility markets [9] might be utilized in specific cases. However, these are still mainly in demonstration phase and therefore do not represent the state-of-the-art.

In rural distribution grids, supply reliability is typically much weaker than in urban areas. In addition to traditional distribution grid reliability enhancement options (e.g. replacing overhead line with cables, distribution automation), the reliability may be enhanced by flexibility by providing backup power, supporting restoration process, or islanding. Backup generators have traditionally been utilized for that purpose, but renewable energy sources, storage and demand response provide an interesting alternative because aggregators may provide them for other purposes when grid is in normal situation [10].

Some other examples in which the DSOs use flexibility are the power quality management, controlled islanding, among others. While the power quality issues related to voltage and continuation of service are already addressed by voltage control and congestion management, other issues like milliseconds of voltage drops, flicker or harmonics compensation are also topical problems for the DSOs to monitor and solve. Indeed, in a consultation regarding DSO use of flexibility, CEER found that along with congestion management and load shape flattening, flexibility services were also seen to enable DSOs to handle power quality issues [11].

For the controlled islanding, the DSOs should adapt to new ways of operating the grid, which can prove to be useful for example in managing the grid under severe circumstances. There is already some field work on this subject, particularly in the H2020 project Sensible, in which the first LV islanding operation in Portugal was tested.

The local dimension has emerged in the electrical system and is as relevant as the central dimension due to the new framework of the power sector, the so-called web of energy. DSOs, as a part of their neutral market facilitator role, will be the entity responsible for validation of traded flexibility related to assets connected to the distribution grid. This process, described in the report [1], will prove its usefulness in using local assets in TSO-balancing as well as in TSO- and DSO congestion management, especially now that DSOs will be posed with many local grid constraints. These issues should be solved through cooperation between the DSOs and the market parties (aggregators, energy communities, single end users) that can solve the grid constraint. There is already some field work on this subject, particularly through innovative projects. Two examples are: TransPower V2G, led by UK Power Networks and InterFlex, an H2020 project.

In addition to frequency and constraint management, TSOs and DSOs need to maintain appropriate voltage levels in the grid as well. Voltage is mainly maintained by generators, which have an obligation to provide voltage control service for grid companies according to the EU network code SOGL [12]. System voltage is determined by the balance of reactive power production and absorption. However, voltage control becomes more challenging with increasing shares of variable renewable energy sources and the decrease in generation from conventional plants. In addition to direct voltage control, generators and customers like large industry may also provide services for reactive power management of grids.

2.1.2 User services

According to a study by the Smart Energy Demand Coalition (SEDC) [15][16][17][18], an efficient regulation of the roles of the subjects involved in the ancillary services markets can promote new business models and enable the full activity of markets by enhancing the efficiency of demand-offer combination schemes (Figure 2-3).

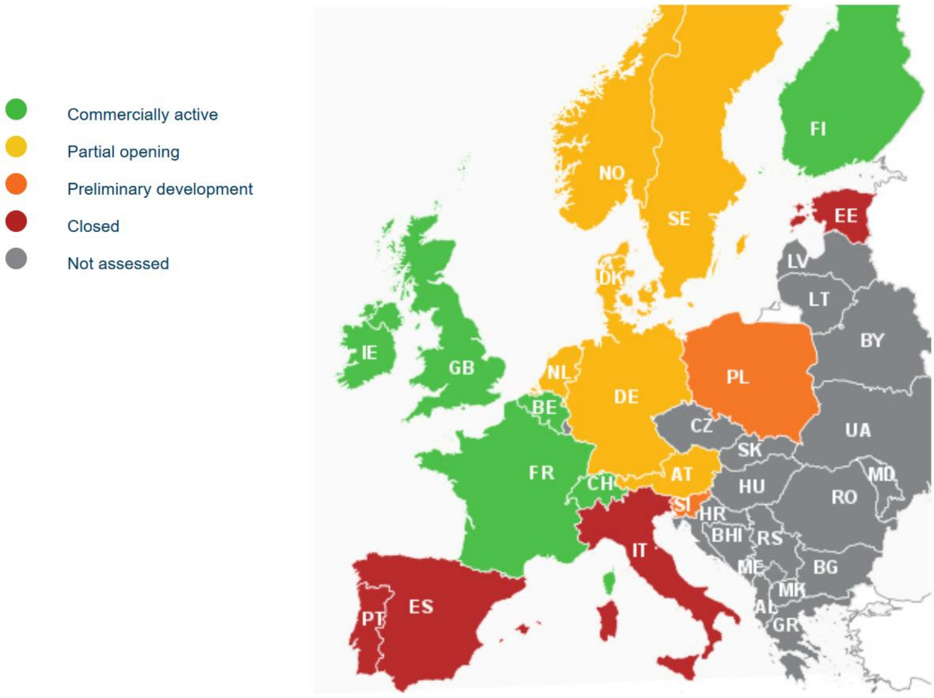

Figure 2-3 – State of the art of the demand participation in the ancillary markets (end of 2016)

In particular, the research study investigates the following four issues:

1. The amount of demand enabled as a resource within the different national electricity markets (wholesale energy market, balancing market and ancillary services market).
2. The definition of roles and responsibilities of the parties involved in the markets. In particular, the study investigates which countries have implemented regulated and standard agreements between BRP, electricity suppliers and aggregators.
3. The technical requirements of the different programs/products that enable the demand participation in the ancillary services markets (e.g. maximum number of activations allowed, operational constraints for participation of the plant).
4. The degree of standardization of regulations and the presence of transparency measures regarding the measurement and the remuneration of flexibility services offered by the demand side.

The results of the investigation highlighted one key aspect for the implementation of a competitive market, namely the promotion of a flexible demand in such a market framework that protects consumers' interests and creates conditions of transparency for all operators. As previously discussed, consumers willing to earn from their flexibility services should be able to choose freely their service provider (aggregator) independently from the aggregator associated to or approved by their energy supplier [19]. Also from a technical point of view the potential of demand flexibility is sometimes unexpressed: the requirements for providing ancillary services may discourage the participation of consumers even in an aggregated form, mainly because they are often unable to regulate their energy consumption for periods as long as sometimes required by the existing products on the market.

Another relevant feature emerging from the SEDC study is that in countries where the role of the independent aggregator is well defined (e.g. France, Switzerland), the opening up of aggregate demand to new services can lead to interesting earning prospects for the end user [20][21]. To date,

the European countries showing a potentially favorable framework for the creation of an independent aggretator are Belgium, Switzerland and Great Britain, where however regulatory barriers are still present [22][23]. In fact, in these countries the aggregator has first to obtain permission from the energy supplier to manage the customer load and then compensate the former for the energy not supplied to the end user who is providing the flexibility service. In order to remove those barriers, in February 2017 the European Commission expressed the need to encourage a non-discriminatory entry of the independent aggregator in the markets [24]. As a consequence, Germany, the Nordic Countries and Austria started a reform to regulate this operator, while France has outlined the financial relationship between the energy supplier and the independent aggregator, by establishing an economic compensation through an administrative agreement defined at national level for the regulation of imbalance charges [25].

In the rest of Europe situations still occur in which the demand participation is limited to single large-scale consumption units (as is the case of Slovenia and Poland) or in which the inclusion of aggregate demand is typically almost non-existent (e.g. Estonia, Spain and, so far, Italy), although there is an emerging interest in exploring its potential [25]. Table 2-1 summarizes the level of demand access and participation to the wholesale markets both in single and aggregate form. The term *access* here stands for a sufficient level of regulation that allows the potential participation of the demand in the provision of a service, while *participation* means the actual enabling of the demand to provide the service. It should be noted that, in some countries, flexibility can be offered not only for "global" services to the transmission network operator but also for "local" services to the distributor.

Table 2-1 - The access of demand to wholesale markets in the different countries

Country	France	Switzerland	Belgium	Great Britain	Ireland	Finland
Day-ahead market						
Access and participation of demand	√	√	√	X	√	√
Aggregated load acceptance	√	√	X	X	√	√
Aggregated generation acceptance	√	√	–	√	√	√
Intra-day market						
Access and participation of demand	√	√	X	X	√	√
Aggregated load acceptance	√	√	X	X	√	√
Aggregated generation acceptance	√	√	–	√	√	√
Legend √: access of demand; X: closed market √: open market but not sufficiently regulated ; –: no information available.						

Table 2-2 - Access of demand to ancillary and balancing services in the EU countries

Access of demand

Service	France	Switzerland	Belgium	Great Britain	Ireland	Finland
Primary reserve	√	√	X/√	√	X	√
Secondary reserve	√	√	X	√	X	√
Tertiary reserve	√	√	X/√	√	X	√
Tertiary reserve by interruptible loads	-	-	√	-	√	√
Voltage and reactive power control	√	√	X	√	X/√	√
Other ancillary services: re-dispatching	-	-	-	X/√	√	√
Capacity market	-	√	-	√	√	√
Strategic reserve	-	√	X/√	√	-	√
Services for DSO congestion management	-	-	-		X	√
Aggregated load acceptance						
Service	France	Switzerland	Belgium	Great Britain	Ireland	Finland
Primary reserve	√	√	X/√	√	X	√
Secondary reserve	√	√	X	√	X	X
Tertiary reserve	√	√	X/√	√	X	√
Tertiary reserve by interruptible loads	-	-	√	-	√	-
Voltage and reactive power control	√	√	-	√	X	√
Other ancillary services: re-dispatching	-	-	-	X/√	√	-
Capacity market	-	√	-	√	√	-
Strategic reserve	-	√	X/√	√	-	√
Services for DSO congestion management	-	-	-		X	-
Aggregated generation acceptance						
Service	France	Switzerland	Belgium	Great Britain	Ireland	Finland
Primary reserve	√	√	-	√	X	√
Secondary reserve	√	√	-	√	X	√
Tertiary reserve	√	√	-	√	X	√
Tertiary reserve by interruptible loads	-	-	-	-	X	√
Voltage and reactive power control	√	√	-	√	X	√
Other ancillary services: re-dispatching	-	-	-	X/√	√	√
Capacity market	-	√	-	√	√	√
Strategic reserve	-	√	-	√	-	√
Services for DSO congestion management	-	-	-	X/√	X	√

The main features of the new operators enabled to provide flexibility services, with particular attention to load and generation aggregates, as well as the relationships between market players can

be summarized by what is already implemented by the three main European aggregators, which are presented below through summary sheets reporting the resources involved and the services offered.

Example 2-1: flexibility from generation.

NEXT KRAFTWERKE	
COUNTRY	Germany – Austria – Belgium – France – Netherlands – Poland – Switzerland – Italy
Starting year	Germany (2009) – Austria (2014) – Belgium (2014) – France (2015) – Netherlands (2016) –Poland (2016) – Switzerland (2016) – Italy (2017 only Day-ahead)
Services	Secondary frequency control (FRR) Tertiary frequency control (RR) Other services: customer portfolio optimization – market trading
Resources	Biogas, biomass, wind, photovoltaic and CHP power plants, standby generators.
Minimum single unit size	Dependent on the regulatory context in the country
Minimum aggregated unit size	Dependent on the regulatory context in the country
BSP	They operate both as BSP and BRP
BSP Remuneration (estimated values)	Dependent on the regulatory context in the country

Example 2-2: flexibility from customers in the residential and tertiary sectors

tiko	
COUNTRY	Switzerland
Starting year	2012
Services	Primary frequency control (FCR) Secondary frequency control (FRR) Tertiary frequency control (RR) Other services: Peak shaving
Resources	End users in the residential, tertiary and industrial sectors
Minimum single unit size	5 MW
Minimum aggregated unit size	5 MW
BSP	Yes, independent aggregator or combined aggregator
BSP Remuneration (estimated values)	FRR:25.68 CHF/MW RR: 5.45 CHF/MW (Weekly +), 3.57 CHF/MW (Weekly -), 2.60 CHF/MW (Daily +), 2.18 CHF/MW (Daily -)

Example 2-3: flexibility from complex sites.

Flexitricity	
COUNTRY	Great Britain
Starting year	2004
Services	Primary frequency control (FCR) Primary frequency control by energy storage systems (EFR) Frequency control by demand management (FCDM) Other services: capacity market, network congestions management.
Resources	**Airports and commercial buildings:** heating, ventilation, and air conditioning (HVAC) systems, hot water storage systems. **Refrigeration in commercial buildings:** air conditioning in supermarkets, cold rooms, fridges **Hospitals and Universities:** heating, ventilation, and air conditioning (HVAC) systems, hot water storage systems **Industrial clusters:** heating, ventilation, and air conditioning (HVAC) systems, boilers, fan coil, heat pumps, variable speed drives on fans and other motors **Generators** (hydroelectric and renewable energy power plants, CHP, standby generators) **and energy storage systems**
Minimum single unit size	1 MW (FFR), 1MW (EFR), 3MW (FCDM) 3MW (STOR[1])
Minimum aggregated unit size	FFR: 1 MW (FFR), 3MW(STOR), 1MW(EFR), 3MW (FCDM)
BSP	Yes, independent aggregator
BSP Remuneration (estimated values)	FFR: – remuneration for availability: £1.47 /MW – remuneration for use: £3.39 /MW FCDM: £4/MW EFR: £7/MW - £12/MW DSBR: 15.000-16000 £ per MW of capacity STOR: – remuneration for availability: £5.6/MW (fixed), £1.83/MW (flexible) – remuneration for use: £158/MWh (fixed), £91.04/MWh (flexible)

2.1.3 Market services

2.1.3.1 Standard ancillary services

Ancillary services are all services required by the transmission or distribution system operator to enable them to maintain the integrity and stability of the transmission or distribution system as well as the power quality.

2.1.3.1.1 Frequency regulation

2.1.3.1.1.1 Frequency Containment Reserve

The Frequency Containment Reserve displaces the earlier primary control reserve with similar parameters. Its aim is to stabilize the frequency at a steady-state value within the permissible maximum steady-state frequency deviation after disturbances in the internationally connected high-

[1] STOR falls under tertiary frequency control services (RR)

voltage grid regardless of the cause and location of disruptions. The process is realized by a joint action of local automatic devices in the synchronous area within 30 s.[28][35]

2.1.3.1.1.2 Frequency Restoration Reserve

Frequency Restoration Reserves are active power reserves aiming to restore the system frequency to its nominal value and the power balance to the scheduled value and in the meantime to free up the FCR. FRR can be activated automatically or manually. Their full activation time is 15 min. The automatic FRR replaced the earlier secondary while the manual FRR replaces the tertiary (minute) reserve [28].

2.1.3.1.1.3 Restoration Reserve

The Restoration Reserve is used to restore or support the FRR in order to be prepared for any further system imbalances. The RR is activated in the disturbed LFC area. The RR displaces the older hourly tertiary reserve. The balancing process for frequency restoration can be followed in Figure 2-4 [28].

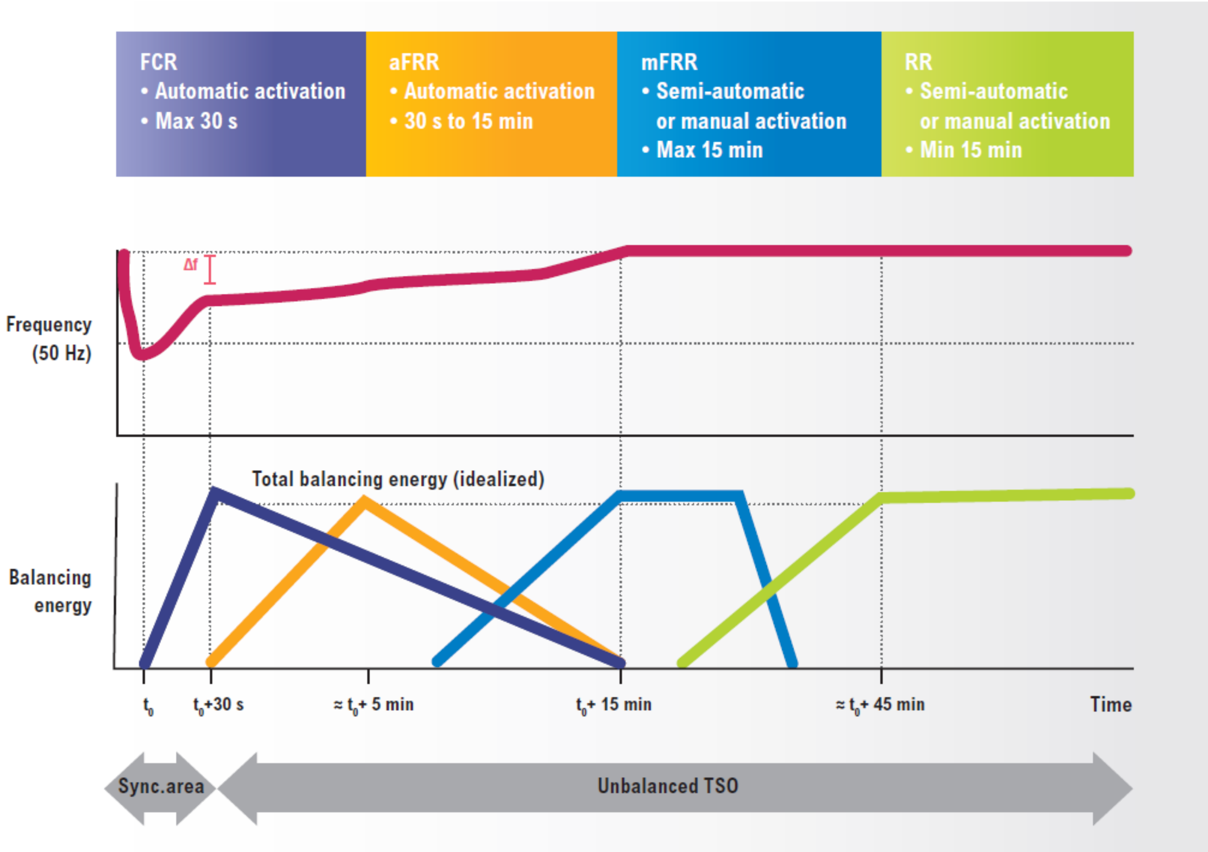

Figure 2-4 – Balancing market process for frequency restoration [28]

2.1.3.1.1.4 Black start capability

Black start reserve is provided by power plants with the ability of starting up the own power plant shutdown without the use of external power supply. Therefore the power plant can support the start-up of the electricity system after a black-out.

2.1.3.1.1.5 Reactive power and voltage control

Reactive Power and Voltage Control support the TSOs and DSOs to maintain the steady-state voltage at the connection points within the operation security limits. [29]. Keeping the voltage within the values prescribed in network codes is one of the biggest challenges for the DSOs. Especially in the

case of long low-voltage network sections, without physical development, there is an inability to control the voltage changes.

2.1.3.2 Special ancillary services in the UCTE

This chapter focuses on special ancillary services used in the UCTE but the use of standard reserves are also mentioned by country.

2.1.3.2.1.1 The Czech Republic

In the Czech Republic, more types of tertiary reserves (RZMZ) are in use apart from the standard primary (PC, activation time 30 s) and secondary reserves (SC, full activation in 10 min, symmetrical) [28]:

- **Minute reserve available within 5 min, symmetric**
  - Minimum value is 30 MW (unless otherwise contracted with the TSO).
  - The minimum guaranteed duration of the provision of this reserve within 5 minutes is 4 hours even if the service is activated at the end of its reservation interval.
  - It can be fulfilled by changing the output of a pumped storage hydro power plant of by load control, too.
- **Minute reserve available within 15 min positive**
  - Minimum amount is 10MW.
  - Maximum unit power output is 70 MW (unless otherwise contracted with the TSO),
  - The duration of the provision of the services is not limited.
  - The positive minute reserve can be provided in the form of an increase in power plant output as well as by the discontinuation of pumping in a pumped storage hydro power plant, the non-utilization of the pre-planned pumping or the disconnection of load.
- **Minute reserve available within 15 min negative**
  - Minimum amount is 10MW.
  - The maximum unit power output is 70 MW (unless otherwise contracted with the TSO)
  - The negative minute reserve can be provided by either power output reduction or load increment.
  - The duration of the provision of the services is not limited.

Apart from the above ancillary services, the Rapid Unloading Reserve (RUR) can be also purchased at the day-ahead market or through tender. RUR is a downward reserve provided by generating units. The minimum offer is 30 MW and the minimum time during which its delivery must be guaranteed following its enabling is 24 h. It is only used in case the above close-to-standard services are not sufficient.

Secondary Voltage and Reactive Power Control (SUQC), Island Operation Capability (IO) and Black Start (BS) capability is procured via direct contracts between the TSO and the provider.

- SUQC is an automatic control. The entire regulating range of each unit is used.
- Regarding the IO provider, the unit must be capable of switching to island operation, operating in island mode (with expected significant frequency and voltage fluctuations), re-connecting the island to the system and being available for service. Such a generating unit must have a high regulation capability to prevent and manage islanding.
- A generating unit that can start up without an external power supply, reach the set voltage value, connect to the grid and supply an island, is able to provide BS service.

2.1.3.2.1.2 Germany

In Germany, there are four TSO areas owned by TenneT, Amprion, 50Herz and Transnet. They use the standard products for frequency control (primary, secondary and minute reserve) and they procure them through a common internet platform (regelleistung.net). The call for tenders are published at this site and the bids are processed and the bidders are informed about acceptance or rejection here, too. However, a special product is introduced for demand-side management, the so-called Interruptible load [31].

Primary Control Reserve (PCR) is procured through shared calls for tenders since 1st December 2007 in Germany. The connecting TSO (the source TSO area of the service provider) is responsible for the prequalification procedure of generating units but also controllable loads and is the sole contracting party of the supplier. The PCR can be offered for other TSO control areas through a framework agreement. The PCR product is symmetrical. Since 27 June 2011 the tendering is weekly instead of the earlier monthly tenders. The minimum PCR lot size has been reduced to ±1 MW on 27 June 2011 compared to the ±5 MW applied before. Germany is partner in the international PCR cooperation jointly with Belgium, the Netherlands, France and Austria [32].

The framework for marketing Secondary Control Reserve (SCR) in Germany, is similar to the PCR rules and the joint procurement on the common platform has been introduced together with the PCR in 2007 The minimum lot size for bidding SCR is 5 MW. Although 1 MW, 2 MW, 3 MW and 4 MW bids are also allowed provided that only one offer is submitted per product time slice of positive or negative SCR per control area. The supplier of SCR in Germany, automatically takes part in the entire German secondary reserve market because of the Grid Control Cooperation (GCC). Germany and Austria procure SCR jointly since 2019 under the International Grid Control Cooperation (IGCC). They apply imbalance netting, Country-specific core shares and the available cross-border capacities are taken into account. The amount of available cross-zonal capacities (CZC) will be determined in a weekly cost-benefit analysis and reserved accordingly [32].

German TSOs use the internet platform for shared Minute Reserve (MR) since 1st December 2006. The tendering period for MR is daily for the next day. There are separate products for positive and negative MR and the daily offer is divided into 6 times 4 hour long time slices. The minimum lot size is 5 MW but like in case of the SCR, 1 MW, 2 MW, 3 MW and 4 MW bids can be also submitted if a BSP (Balancing Service Provider) submits only one offer per product time slice of positive or negative MR in the respective control area. Therefore the minimum prequalified MR must be at least 1 MW. The maximum indivisible block offer size is 25 MW. The activation of MR is automatic.

There are two Interruptible Load types in Germany:

- Immediately Interruptible Load (SOL): automatically frequency-controlled within 350ms when the frequency drops below a predefined value and remotely controlled without delay by the TSO
- Quickly Interruptible Load (SNL): remotely controlled within 15 min by the TSO

Interruptible loads are consumer who can reliably reduce their demand for a fixed capacity upon request of the German TSOs. This product is designed flexibly: suppliers have the possibility to submit tenders individually according to the characteristics of their load. The duration of switch-off must be minimum one and maximum 32 quarter-hour included in the tender. There are weekly tenders to acquire 750 MW of each. Prequalified immediate interruptible loads can also qualify as quickly interruptible loads but only one can be used per week. The minimum tender size is 5 MW and the maximum offer size is 200 MW. The operational communication is between the load management server of the TSO called "LaMaS" and the client "Aladin" of the provider. The latter will be further on provided free of charge. There are 4 SOL and 11 SNL framework agreements at the time of writing this report with a total capacity of 933 MW and 1370 MW respectively.

The ancillary services in Germany:

- Frequency Control
    - FCR
    - FRR
    - RR
- Voltage Control
    - dynamic (fault-ride-through)
    - steady-state
- System Restoration
    - Black Start Capability
    - House Load Operation
    - Grid Energizing Capability

The voltage control is a local service compared to the global frequency control. Bilateral agreements exists as well as regulator approved prices.

2.1.3.2.1.3 Belgium

The Belgian TSO, ELIA uses the standard frequency control services apart from that they differentiate two types of tertiary reserves, both activated manually [33]:

- Tertiary Production Reserve: for producers
- Tertiary Off-take Reserve: reduction of consumption by grid users who have signed interruptibility contract

Grid losses can be purchased also from foreign suppliers. Black start is used, too.

2.1.3.2.1.4 The Netherlands

The ancillary services used by Tennet, the Dutch TSO are [34]:

- Balancing reserves (FCR, aFRR, mFRRda and mFRRsa)
- Reactive power
- Redispatch
- Black start facility
- Compensation of losses and sustainability of grid losses through Guarantees of Origin (GoOs)

The FCR of the Dutch TenneT control area is conducted through the German internet platform, "regelleistun.net" since 13 January 2014. 30% of the Dutch FCR need is procured in a separate auction for Dutch BSPs only (PRL-NL) and 70% of the FCR need of the Netherlands is procured in a common auction with other TSOs [35].

The specialty in the Dutch mFRR is that two types are in use:

- mFRRda: directly activated
    - This emergency power is contracted between Tennet and suppliers. The supplier is obliged to be available over the entire contract period. It is purchased per quarter and per month.
- mFRRsa: scheduled-activated
    - not contracted bids
    - The bid has a call time of one Program Time Unit (PTU) instead of a ramp rate. The call is the offered volume per PTU.
    - There are no requirements on minimum volumes.

Reactive power is procured through a yearly tender by Tennet from producers connected to the extra high voltage (EHV: 380 kV or 220 kV) or the high-voltage (HV: 150 kV or 110 kV) grid.

Producers give bids for redispatch purposes under the name of „Reserve Power for Other Purposes". These bids can be adjusted to 3 PTUs. Redispatch usually means the shifting of in-feed and take-off of electricity from the grid) to solve transport problems (e.g. N-1 overload) in the high-voltage grid. Therefore it normally means feeding in less power in one place and more (equivalent amount) in another place. As the location of the provider is important, bilateral contracts are in use.

Black Start is contracted only every so many years with a contract period spanning multiple years because of the required investments.

The procurement of losses on the TSO grid is also listed among ancillary services. Three such products are procured:

- Grid losses (Extra) high voltage: the total grid loss is procured annually
- Cable losses: loss on the HVDC cable to Norway called NorNed. The loss on this cable is considered by a fix formula in the market coupling process and the resulting deficit or surplus is procured or sold separately. It is contracted annually.
- Guarantees of Origin (GoO): Tennet buys GoO in order to minimize the environmental impact of the consumption and to excite RES. GoO is tendered annually.

2.1.3.2.1.5 Austria

Austria uses primary, secondary and tertiary control (minute) reserves [36].

2.1.3.2.1.6 France

All standard products are used in France as frequency ancillary services [37]. The provision of frequency AS is open to any prequalified source in continental France, irrespective of the technology and the grid connection point. FCR is procured through cross-border auction at regellaistung.net. The minimum FCR bid is ±1 MW, symmetric [38].

There is an obligation to provide aFRR for a regulated price of about 18 €/MWh. Bilateral exchange between frequency AS providers is allowed.

Tertiary reserves – both mFRR are RR – are tendered each year, 1000 MW and 500 MW respectively. The mFRR need to be activated within 13 min while the RR activation time is 30 min. The remuneration for such an available capacity is an annual bonus depending on the offered volume and activation time [39][40].

Regarding voltage regulation, RTE, the French TSO differentiates primary and secondary voltage regulation as well as a specific synchronous compensation. The remuneration for voltage regulation comprises of a fix and a variable part and depends on the oversizing of the alternator, the type of voltage regulation and the geographical area. Sources of voltage regulation must connect to the transmission grid. The primary voltage regulation is a local automatic control while the secondary is a centralised, the latter coordinating zonal and regional (comprising of several zones) voltage control. The secondary voltage regulation means a continuous adjustment of the reactive power output in function of the TSO (RTE) command [41].

2.1.3.2.1.7 Denmark

Western and Eastern Denmark belongs to different regional groups. Denmark West (DK1) corresponds to the Regional Group Continental Europe while Denmark East belongs to the Nordic Regional Group. Because of this, slightly different rules apply for AS providers in these two zones.

DK1 is responsible for the procurement of [42]:

- FCR
- aFRR reserve and supply ability
- mFRR
- Properties required to maintain power system stability

The following AS are delivered in DK2:

- Frequency-controlled disturbance reserve (FCR-D)

- Frequency-controlled normal operation reserve (FCR-N)
- aFRR supply ability
- mFRR
- Properties required to maintain power system stability

Wind turbines are not allowed to bid for AS themselves only pooled with other production to guarantee supply in case that the wind turbines are not available.

In DK1, FCR can be also provided by consumers and import/export of FCR is allowed but limited to neighbouring TSOs or TSOs within the same control block like the German ones provided that there is an agreement between the TSOs concerned. FCR auction are held day-ahead for 4 hour long time periods (blocks) separately for the positive and negative direction. Bids must be submitted to Energienet until 15:00 each day. The minimum FCR bid is 0.3 MW.

Both DK1 and DK2 procures aFRR but the technical conditions differ slightly: the Nordic rules require full response in 5 min while the standard response time in DK1 as in Continental Europe is 15 min. In both zones, aFRR is symmetric and procured at monthly auctions. Bids must be valid for the entire month. The minimum bid size is 1 MW and the maximum is 50 MW.

2.1.3.2.1.8 Switzerland

Swissgrid also employs the standard primary, secondary, tertiary control reserves. Other ancillary services include the voltage control, black start and island operation capability[43].

2.1.3.2.1.9 Poland

In the operation rules of the Polish TSO ([44]), primary, secondary and tertiary control are used. According to [28] ENTSO-E survey, these correspond to FCR, aFRR and RR reserves, respectively.

2.1.3.2.1.10 Italy

Italy applies primary, secondary and replacement tertiary reserves as in the Grid Code of Terna [45]. The ENTSO-E survey also classifies these to the FCR, aFRR and RR categories. Black start capability and reactive power reserve for voltage control are also in use in Italy.

GME operates the ancillary services market (MSD) on behalf of Terna, the Italian transmission system operator [46]. The procurement is organized in six substages: MSD1…MSD6 as in the Figure 2-5 .

Reference Day	D-1				D															
	MGP	MI1	MI2	MSD1	MB1	MI3	MSD2	MB2	MI4	MSD3	MB3	MI5	MSD4	MB4	MI6	MSD5	MB5	MI7	MSD6	MB6
Preliminary information	11.30	15.00	16.30	n.d.	n.d.	23.45*	n.d.	n.d.	3.45	n.d.	n.d.	7.45	n.d.	n.d.	11.15	n.d.	n.d	15.45	n.d.	n.d
Openingof sitting	08.00**	12.55	12.55	12.55	°	17.30*	°	22.30*	17.30*	°	22.30*	17.30*	°	22.30*	17.30*	°	22.30*	17.30*	°	22.30*
Closing of sitting	12.00	15.00	16.30	17.30	°	23.45*	°	3.00	3.45	°	7.00	7.45	°	11.00	11.15	°	15.00	15.45	°	19.00
Provisional results	12.42	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Final results	12.55	15.30	17.00	21.45	#	0.15	2.15	#	4.15	6.15	#	8.15	10.15	#	11.45	14.15	#	16.15	18.15	#

*the time refers to the day D-9
**the time refers to the day D-1
°use is made of bid/offers entered into the MSD1
#Dispaching Rules

Figure 2-5 – The timeline of activities on the Italian electricity market [46]

2.1.3.2.1.11 Spain

Spain applies standard primary, secondary, tertiary, voltage control and deviation management as ancillary services. Offering secondary reserve is optional while bidding tertiary is compulsory for active generators. The tertiary should be activated within 15 min and maintained for at least 2 hours [47].

The mechanism of deviation management is an optional service managed and remunerated by market mechanisms. Its aim is to resolve the deviations between generation and demand higher than 300 MWh which could appear in the period between the end of one intraday market and the beginning of the next intraday market horizon.

There is an Interruptibility Service advertised at RED's website. It is about a demand-side management (DSM) tool considering both technical and economic aspects in order of the TSO. Large industrial consumers mostly provide demand reduction. There are two types of interruptible capacity products allocated at descending price computerised auctions: 5 MW and 40 MW [48].

2.1.3.2.1.12 Portugal

In Portugal, primary, secondary and regulating reserves are used as ancillary services [49]. According to the ENTSO-E survey, regulating reserve covers also mFRR and RR[28].

2.1.3.2.1.13 Hungary

In Hungary, symmetric FCR, aFRR and mFRR reserves are procured however RR is also defined in the rules. Loads with quarter-hourly schedule are also allowed to bid for control reserves. Voltage and reactive power control as well as black start capability are procured via yearly tenders.

2.1.3.2.1.14 Romania

Transelectrica, the Romanian TSO applies primary, (frequency-power) secondary and tertiary control reserves. Fast and slow tertiary control reserves are differentiated. The fast tertiary reserve

providers are capable of load synchronization and charging in maximum 30 min. Slow tertiary reserve providers are able to start-up and load have a takeover time smaller than 7 h.

Voltage control is done by reactive power control and a startup service is also used. [50]

2.1.3.2.1.15 Bulgaria

In Bulgaria, the standard primary, secondary, tertiary control reserves, voltage and reactive power control (VAR control) and black start reserves are procured by ESO (Electricity System Operator)[51].

2.1.3.2.1.16 Croatia

Croatia uses primary, secondary, tertiary, reactive power and voltage control, black start as well as island operation as ancillary services. The island operation reserve enables the establishment of island operation of parts of the power system in case of disturbance, major maintenance or reconstruction work. Its purpose is to minimize the unsupplied time of customers.

2.1.3.2.1.17 Greece

In Greece, FCR, aFRR and mFRR control reserve products are used in the Grid Code already but RR is not used [40][53].

The summary of active power regulation is shown in Table 2-3.

Table 2-3 - Summary of active power regulation

Country	FCR	aFRR	mFRR	RR	special products
Germany	√	√	√	-	Immediately and Quickly Interruptible Load
Netherlands	√	√	mFRRda, mFRRsa	-	-
Austria	√	√	√	-	-
Belgium	√	√	tertiary production and offtake	-	-
France	√	√	√	√	-
The Czech Republic	√	√	5 min symmetric, 15 min asymmetric	-	-
Denmark- DK1	√	√	√	-	-
Denmark – DK2	FCR-D, FCR-N	√	√	-	-
Spain	√	√	√	-	Interruptible Service
Portugal	√	√	√	√	-
Poland	√	√	-	√	-
Romania	√	√	√	√	-
Italy	√	√	-	√	-
Switzerland	√	√	√	√	Island operation capability
Hungary	√	√	√	-	-
Greece	√	√	√	-	-
Croatia	√	√	√	-	Island operation

2.1.3.3 Ancillary services in the GB

GB TSO procures frequency response through a number of routes:

1. The Mandatory market for those parties who have a Mandatory Service Agreement (MSA), typically large transmission-connected generators. This market is accessed within the day by the TSO to manage short-term variability in requirement driven by changes in the generation mix. The products available are Primary, Secondary and High dynamic response. The market arrangements are set out in the Charging and Use of System Code (CUSC). Providers are able to submit availability ('holding') prices on a monthly basis; utilization payments (Response Energy Payment) are based on a methodology in the CUSC, which aims to net a provider's energy position using a basket of market indices.

2. The Firm Frequency Response market (FFR) for parties with a Framework Agreement; these could be any asset or combination of assets that can provide the relevant product. This market is accessed monthly by the TSO to lock in a committed level of frequency response on a longer term basis (1–24 months). The products available are Primary, Secondary and High dynamic response, and Secondary static response. The market arrangements are set out in the Standard Contract Terms and the Market Information Report.

3. Specific contracts, such as Frequency Control by Demand Management and Enhanced Frequency Response (EFR). These contracts are used where there are technical or operational reasons why parties cannot participate in the existing markets. The majority of these are legacy arrangements, and the TSOs are no longer actively pursuing them as they are committed to moving towards transparent and competitive market solutions.

The amount of frequency response that the TSOs procure through each route varies considerably depending on the conditions on the day and what has been economically procured in the FFR market. Figure 2-6 shows how TSO's frequency response requirements are met by a mix of mandatory market, FFR and bilateral contracts. The cost associated with each market can be found in Monthly Balancing Services Summary reports, or the annual C16 Procurement Report [59].

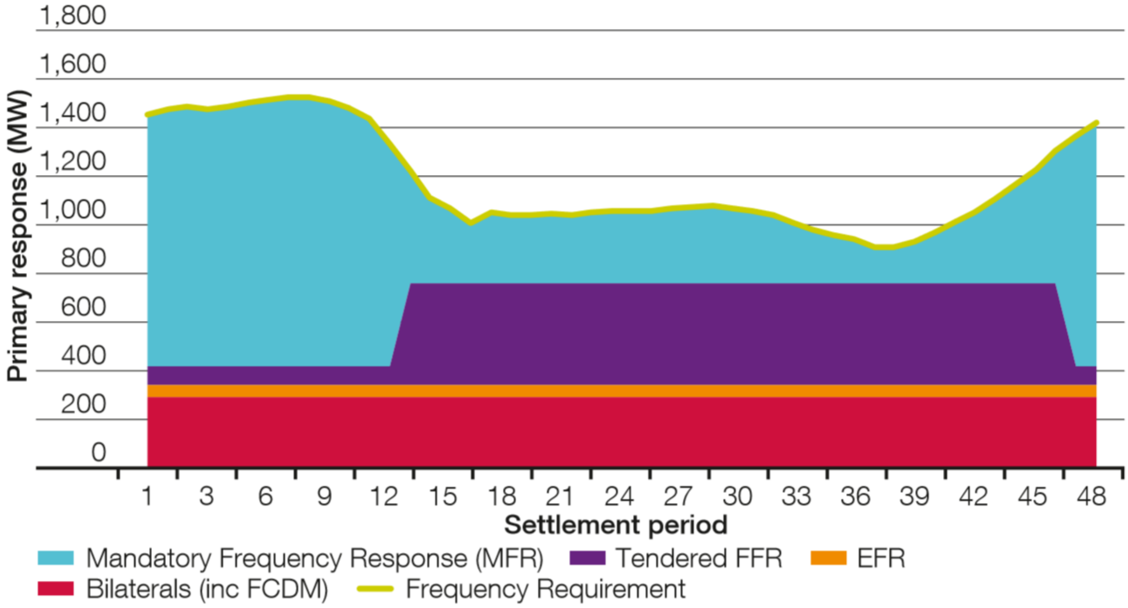

Figure 2-6 – Illustration of typical frequency response requirement components

TSO is forecasting that while the baseline frequency response requirement will remain broadly the same over time, there will be an increase in the variability of TSO's requirement closer to real time.

This variability will also increase in size as system inertia decreases and demand behavior becomes increasingly reactive to market signals.

TSOs have already made a number of improvements in their frequency response products over the past two years:

- a reduction of the minimum participation size in FFR from 10 MW to 1 MW;
- allowing parties to stack two different FFR contracts so virtual power plants can grow;
- an increase in transparency with the information provided through TSO's Market Information Report;
- reviewing and clarifying testing guidance for Distributed Energy Resources (DER) providers.

TSO implements daily windows to align with EFA blocks (Electricity Forward Agreement), the timings for which are every four hours starting from 23:00 (Figure 2-7). This also aligns with the wholesale energy market, where standardized timeframes for delivery of energy are the norm. TSO is retaining the ability for parties to provide different availabilities on weekdays, Saturday, and Sundays/Holidays as these have an effect both on the operational need for response as well as providers' operational schedules and availability.

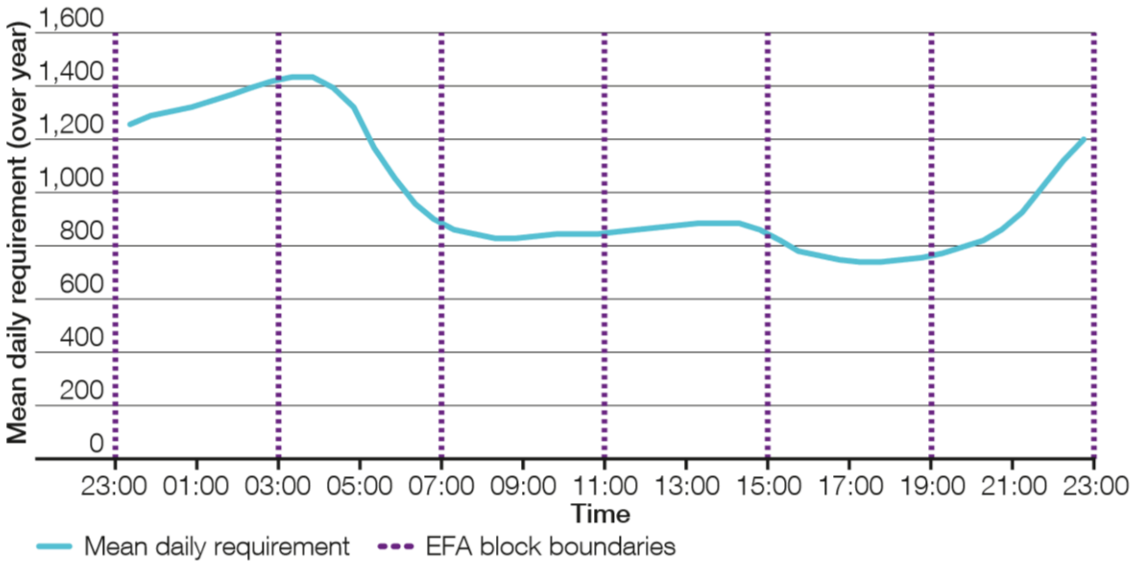

Figure 2-7 – Electricity Forward Agreement blocks

2.1.3.4 Ancillary services in Nordics

Nordic synchronous power system consists of the Finnish, Swedish, Norwegian and Eastern Denmark's power systems. The Western Denmark is connected to the Central European synchronous system. Sweden has four bidding zones, Norway five, Denmark two and Finland one, definitions reflecting the structural internal congestions. The Nordics have long cooperation in relation to

electricity market development and harmonisation. The electricity market structure is shown in Figure 2-8.

Figure 2-8 – Electricity market structure in Nordics

2.1.3.4.1 mFRR (including balancing and congestion management)

The Nordic mFRR energy market was the first international balancing energy market in Europe. The Nordic TSOs run a common market with a common Nordic merit order list. The balancing model is currently based on forecasted common frequency deviation and the common Nordic system imbalance, meaning the most economic bid in the whole Nordic area is activated, given that there are no grid constraints. This differs from the area control error (ACE) approach used widely in Europe where each bidding zone is balanced individually. However, a change into ACE balancing model is planned in Nordics in the early 2020's.

The minimum bid size of Nordic mFRR is 5 MW currently, but a shift to 1 MW is seen when joining the European mFRR energy market if not earlier. It is possible although not mandatory for the Nordic TSOs to procure mFRR capacity. In principle, the capacity means an obligation to bid in the mFRR energy market for the procured capacity period. The capacity market rules are national and the delivery period varies.

The Nordic mFRR market and the TSO congestion management markets are combined as mFRR bids can be utilized for congestion management as well. The bids that are used for congestion management do not impact the balancing price determination, which is based on marginal pricing, nor do they impact the imbalance price determination, which is derived from the balancing price. The bids that are used for congestion management are remunerated as pay-as-bid.

The majority of the balancing resources are from hydro generation. However, industrial consumption represents a significant share of the Finnish mFRR energy bids.

2.1.3.4.2 aFRR

aFRR capacity is currently not procured for every hour in Nordics, as mFRR is the main balancing product. aFRR capacity is activated pro-rata currently.

aFRR energy markets are under development and aFRR volumes will increase in future as the volatility of the power system increases and more automation is needed.

2.1.3.4.3 FCR

Nordic countries have two Frequency Containment Reserve products: FCR-N and FCR-D. The Nordic TSOs are going to introduce an upward-FCR-D product in 2020, to ensure system security when large HVDC cables trip from full export.

The specifications and dimensioning of the FCRs are done jointly in the Nordic synchronous area. There is a minimum requirement for capacity that each TSO procures nationally, but some FCR

trading between countries is possible. Cross-border FCR exchange ensures cost-efficiency and fosters competition. Demand side response represents a major part of the Finnish FCR-D market.

2.1.3.4.4 FFR

With the decreasing thermal generation and increasing RES generation, inertia in the Nordic power systems is decreasing. In summer 2018, the largest nuclear generation unit had to be curtailed to ensure system security. In future, low inertia situations will be handled with a faster reserve (faster than FCR-D) called Fast Frequency Reserve (FFR). Faster reserve, procured only for low inertia situations, copes with faster drop in frequency after the dimensioning failure [61].

The Nordic TSOs are defining the technical details of the new FFR reserve during 2019. It is estimated that potential technologies capable of proving such fast response is relay-connected demand, electricity storages, HVDC links and wind power.

2.1.3.4.5 Retail markets

The Nordic countries are all advanced in the retail market development and competition. All Nordic countries have started their smart meter roll out (Finland being the first one, 100 % completed in 2013). All Nordic countries are also building a central datahub for more efficient retail market data exchange (Denmark being the first one to launch) [62]. The overview of retail markets is based on Electricity Retail Market Models [40] and presented in Table 2-4.

Table 2-4 – Overview of the retail markets

Characteristic	Finland	Sweden	Norway	Denmark
Total electricity consumption (GWh)	85 100	120 000	120 000	31 000
Metering points (million)	3.5	5.2	2.9	3.3
Number of active suppliers	72	122	140	51
Market concentration index (HHI)*	1250	1250	n/a	1350
Number of DSOs	77	151	146	61
Number of legally unbundled DSOs	48/77	151/151	7/146	61/61
Switching rate	11.4%	10.3%	13.7%	7.1%
Most common supply contract type**	Variable price, 55%	Variable price, 48%	Spot price, 33%	Fixed price
Status of automated meter reading	~100%	>90% monthly reading	~50% by August 2017; due 1.1.2019	~60% hourly reading; due 31.12.2020
Status of datahub	2019	2021	2018	Online
Retailing Subject to License	-	-	+	-
Standard Compensation for Outages	+	+	+	-

Despite the long cooperation of the Nordic TSOs and the Nordic regulators, the retail market models[2] are still not completely harmonised. After the commission of the datahubs, developing interoperability of datahubs and data models provide for more integrated retail markets and enhanced competition, which will benefit the customers and foster innovation.

2.1.3.4.6 Settlement

[2] meaning roles and responsibilities of different actors as well as the processes in between them

A common Nordic settlement company, eSett, does the imbalance settlement jointly for Finland, Sweden and Norway. Denmark will join the common imbalance settlement in the future [63]. Settlement is done for 1-hour periods but a change to 15-min periods will be established in early 2020's.

2.1.3.4.7 Future changes in short-term markets

On top of the above mentioned changes, the Nordic short term markets are going to face larger reforms in the 2020's. There are two main drivers: the European harmonisation of the market design to foster competition, and the energy transition that changes the physics of the power system.

The Nordic TSOs have long history of developing market rules for more distributed assets and new participants, including independent aggregators, to participate in ancillary services markets. A flexibility report summarises some of the pilots [64] (Table 2-5), but it is important to highlight that industrial consumers have a long tradition of participating in different markets in the Nordics.

Table 2-5 – Overview performed and planned Nordic TSO pilots enabling aggregation

What?	Where?	2014	2015	2016	2017	2018
Demand response pilot	NO4 in Norway	X	X			
Enabling aggregation of bids in 10 MW volumes in mFRR	NO1 in Norway				X	
Enabling aggregation of bids in 5MW/10MW volumes in mFRR	NO1 in Norway					X
Large scale demand response pilot	NO4 in Norway					X
Pilot of flexible households in FCR-N	SE3 Sweden			X	X	
Testing new solutions in FCR-D	Sweden				X	X
Demand response pilots in different balancing products	Finland	X	X	X		
Pilot of independent aggregators and multi-BRP aggregation in FCR-N	Finland			X		
Independent aggregators and multi-BRP aggregation in FCR-D	Finland				X	
5 MW bid size in mFRR	Finland				X	
Aggregation of generation and load in mFRR	Finland				X	
Pilot of independent aggregator and multi-BRP aggregation in mFRR	Finland					X
Independent aggregators and multi-BRP aggregation allowed in FCE-N	Finland					X
Market Model 2.0 testing e.g. third-party aggregators and sub-meters	Denmark	X	X			
Electric vehicle validation for FCR-N	Denmark			X	X	X
Heat pump project testing e.g. sub-meter and hub communication	Denmark			X	X	
Battery project testing mFRR	Denmark			X	X	
Flexibility from industries developing measurements, baseline, pricing, etc.	Denmark			X	X	X

Implementation of the European network codes, deriving from the third energy package, mean significant changes in the Nordics. Electricity Balancing Guideline is currently under implementation and will be finished by early 2020's, including joining to the European aFRR and mFRR balancing markets, shift to ACE balancing model, shift to 15-min imbalance settlement period and 15-min market period in the intraday market, and changes in imbalance pricing. The timeline for the Nordic Balancing Model changes is shown in Figure 2-9.

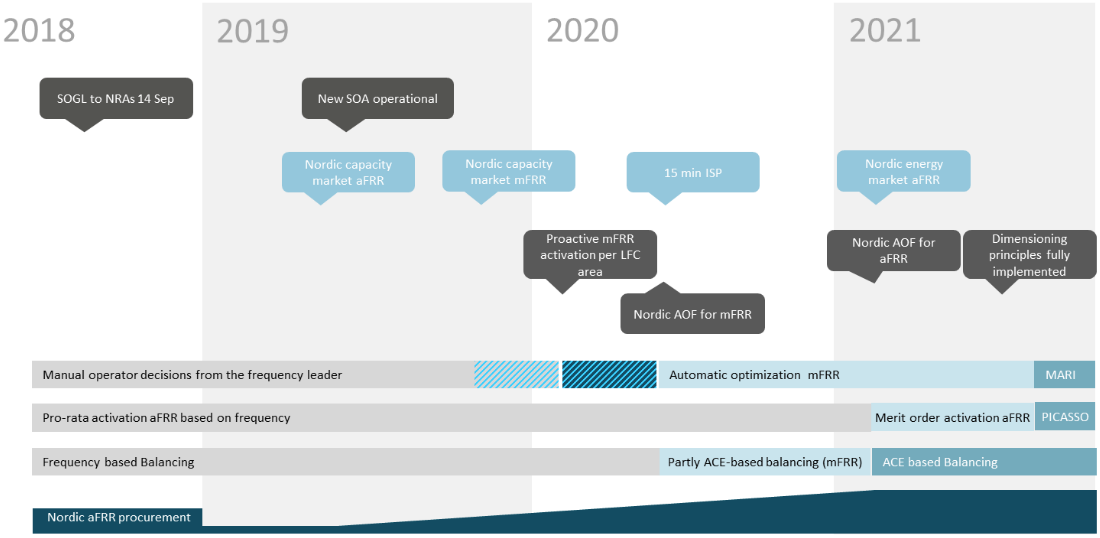

Figure 2-9 – Timeline for the Nordic Balancing Model

The Nordic power system, like many other power systems across the globe, are undergoing a significant transformation. The generation and flexibility become more distributed, while also a large nuclear unit and HVDC links are commissioned. These changes challenge the existing operating models to ensure the security of supply as the Nordic power system faces more fluctuating power flows and decreased predictability.

The future topics to be improved are TSO-DSO cooperation, increased transparency and data availability, interoperability of different platforms as well as efficient transmission capacity allocation between different markets. It is of extreme importance to provide easy access for the market participants to enter the markets and to provide their flexibility where it has most value. The Nordic TSOs have commissioned discussions with their stakeholders to design market towards 2030, the indicative timetables are shown in Figure 2-10 [65].

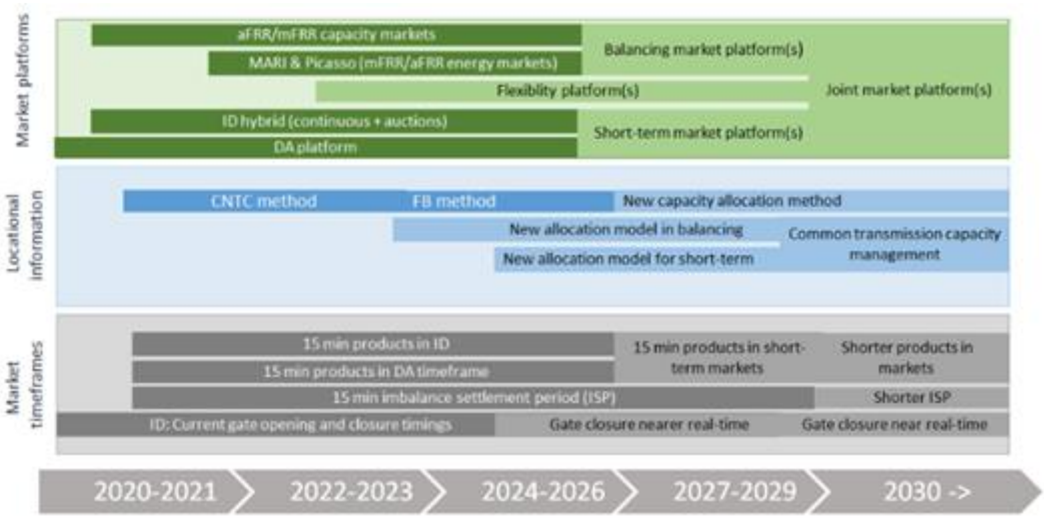

Figure 2-10 – Indicative timetables identified by Nordic TSOs (darker colours indicate already planned initiatives and lighter colours indicate new possible arrangements)

2.1.3.5 International co-operations

2.1.3.5.1 Primary control - PCR

Primary Control Reserve (PCR) is a cooperation for primary control procurement on a Central Clearing System (CCS) platform. It was initiated in 2015 between the Swiss and German TSOs. Swissgrid procured 25 MW of its primary control need on joint tender with the German TSOs. Since 7 January, 2014 Tennet NL also participates in the joint tenders, currently purchasing about 70% of the Dutch primary control reserve need on the shared internet platform called regelleistung.net. As of 7th April 2015, the international cooperation is linked to the Austrian-Swiss PCR tendering procedure. The Belgian Elia joined on August 1st 2016, then the French RTE on 16 January 2017. These coupled PCR markets reached a total demand over 1350 MW. The Danish Energienet.dk is already planned to join the platform. The map of the cooperating countries is shown in Figure 2-11.

Figure 2-11 – The map of PCR partners [30]

The joint call for tenders by Germany, Belgium, the Netherlands, Austria and Switzerland uses the tendering systems that are already in place and is open to all pre-qualified suppliers. The weekly call for tender takes place every Tuesday at 15:00. The allowed PCR export is capped in maximum 30% of the country's PCR need but not less than 100 MW. This concludes to the following limits: 100 MW for Belgium, the Netherlands, Austria and Switzerland, 181 MW for Germany and 158 MW for France. Core portions are also considered for the following countries: Austria 20 MW, France 159 MW, Germany 182 MW and Switzerland 19 MW. [30]

2.1.3.5.2 Secondary control

2.1.3.5.2.1 IGCC

International Grid Control Cooperation exists since 2012. It realizes imbalance netting to avoid simultaneous activation of reserves in opposite directions. Consequently it reduces the volume of control reserve activation that leads also to cost reduction. The procurement of the control power stays at national level according to [66]. The IGCC member states are shown in Figure 2-12.

2.1.3.5.2.2 Picasso

PICASSO is a common platform for aFRR activation. It will probably take over the role of IGCC, too. It is meant to realize a common merit order list for aFRR activation in order to reduce minimize the control energy cost on European level. It is expected to go-live by the end of 2021.

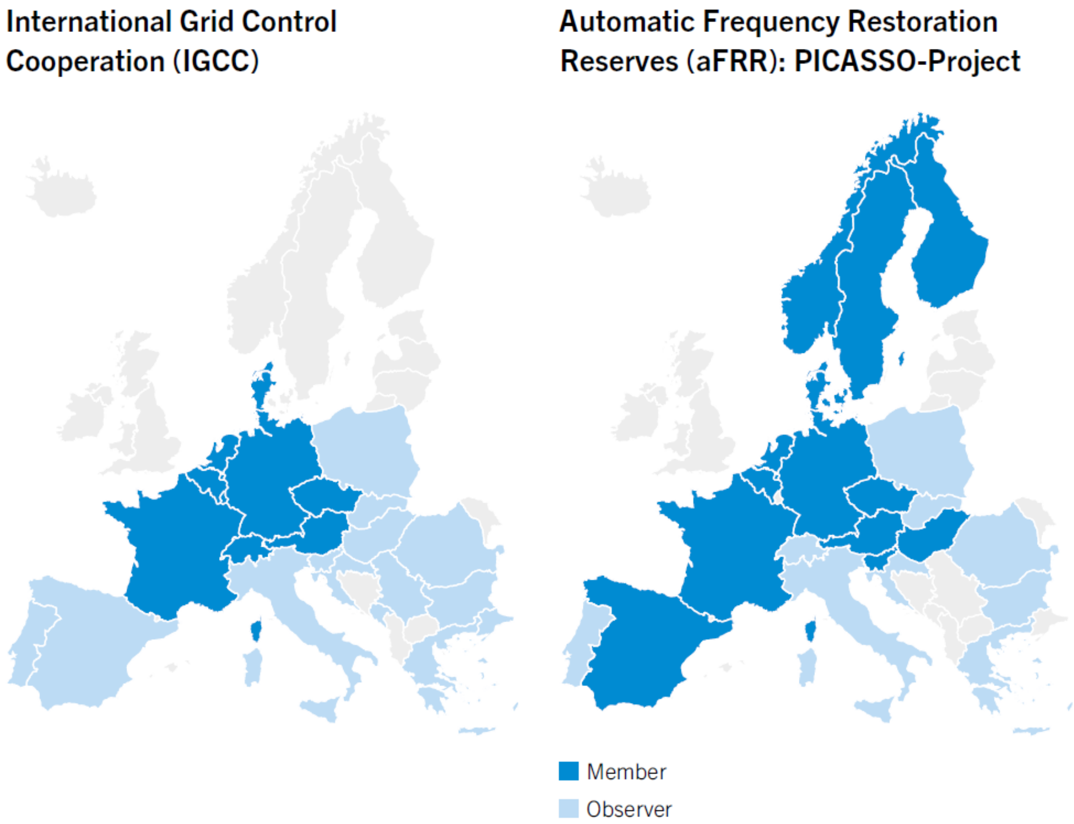

Figure 2-12 – The map of international secondary control cooperation partners

2.1.3.5.3 Tertiary control

2.1.3.5.3.1 MARI

The Guideline on Electricity Balancing defines tasks and a timeline for the implementation of a European platform for the exchange of mFRR [56]. A memorandum of understanding has been formed by 19 countries to establish a common platform for mFRR activation. Its name is MARI that abbreviates Manually Activated Reserves Initiative. The procurement of the mFRR will stay under national regulation but the product has to be unified in the member states. The launch of the MARI platform is expected by the end of 2021 according to [56].

2.1.3.5.3.2 TERRE

TERRE is a central clearing platform for RR in Europe. It is expected to go live by the end of 2019. The RR provision and procurement will take place at national level [56]. For this purpose, the TSOs are developing an IT platform and algorithmic optimisation called LIBRA [57].

The member and observer partners of the MARI and TERRE projects are shown in Figure 2-13.

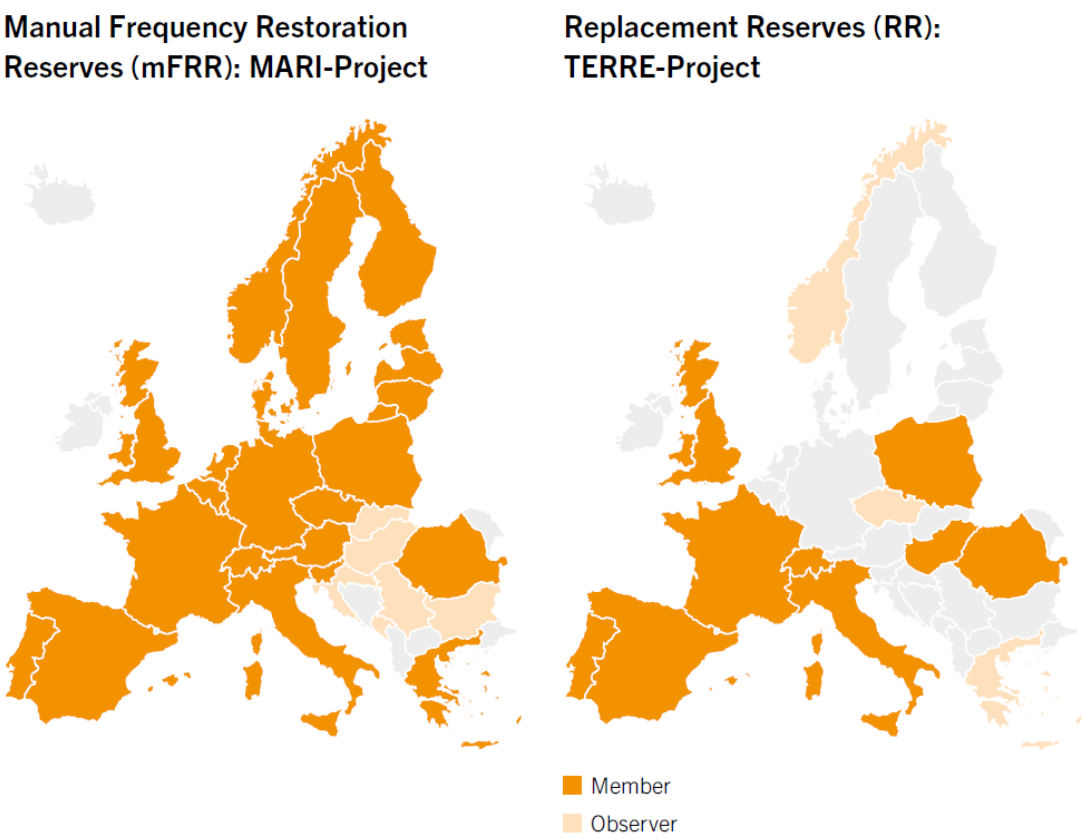

Figure 2-13 – The map of international tertiary control cooperation partners

2.1.3.6 Wholesale market services

Spot markets (Day – ahead and Intraday)

The European Target Model for Electricity provides top-down guidance for regional market integration projects. The model is implemented bottom-up through regional market coupling projects and top-down through the network codes that ACER, the European Commission and ENTSO-E have developed. The implementation of the target model is equivalent to the completion of the Internal Energy Market for electricity which is one of the long term goals for the European Union. The integrated market for Day-Ahead and Intraday market coupling shall be fully implemented by mid-2021 according to the projects timelines.

The target model gives guidance for each timeframe, Day-ahead (DA), Intraday (ID), Balancing and Forward Market.

Key elements of the target model:

- Day Ahead: Single price coupling - implicit auctions

European main implementation project: Price Coupling of Regions -PCR (Now transformed to Single Day Ahead Coupling – SDAC)

- Intra Day: Single price coupling – continuous trading

European main implementation project: Cross Border Intra Day Trading (XBID)

- Key network code: Capacity Allocation and Congestion Management (CACM)

Opens competition for Power Exchanges - henceforth Nominated Electricity Market Operators (NEMOs). The network code assigns tasks to NEMOs and TSOs for implementation of single day ahead and intra-day market coupling.

CACM requirements for Day-ahead markets:

- Gate opening latest at 11:00 CET
- Gate closure in each bidding zone at 12:00 CET (can be different in certain regions until the market couples to MRC and PCR)
- Market participants needs to submit their orders to relevant NEMO before gate closure at 12:00 CET
- Each NEMOs shall submit orders to the central system before agreed timeline
- Orders matched in the central system are firm and binding
- Central system needs to ensure anonymity of the orders

Day Ahead Market (DAM)

Market Coupling (MC) is a way to join and integrate different energy markets into one coupled market. In a coupled market, demand and supply orders are no longer confined to the local territorial scope. On the contrary, in a market coupling approach, energy transactions can involve sellers and buyers from different areas, only restricted by the electricity network constraints.

The main benefit of the Market Coupling approach resides in improving the market liquidity with the beneficial side effect of less volatile electricity prices. Market coupling is beneficial for market players too. They no longer need to acquire transmission capacity rights to carry out cross-border exchanges, since these cross-border exchanges are given as the result of the MC mechanism. They only have to submit a single order in their market (via their corresponding PX) which will be matched with other competitive orders in the same market or other markets (provided the electricity network constraints are respected).

Price Coupling of Regions (PCR) project is an initiative of eight Power Exchanges (PXs): EPEX SPOT, GME, HEnEx, Nord Pool, OMIE, OPCOM, OTE and TGE covering the electricity markets in Austria, Belgium, Czech Republic, Croatia, Denmark, Estonia, Finland, France, Germany, Hungary, Italy, Ireland, Latvia, Lithuania, Luxembourg, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and UK. PCR is implemented in both the MRC region as well as the 4M Market Coupling (4M MC). The map of countries using PCR is shown in Figure 2-14.

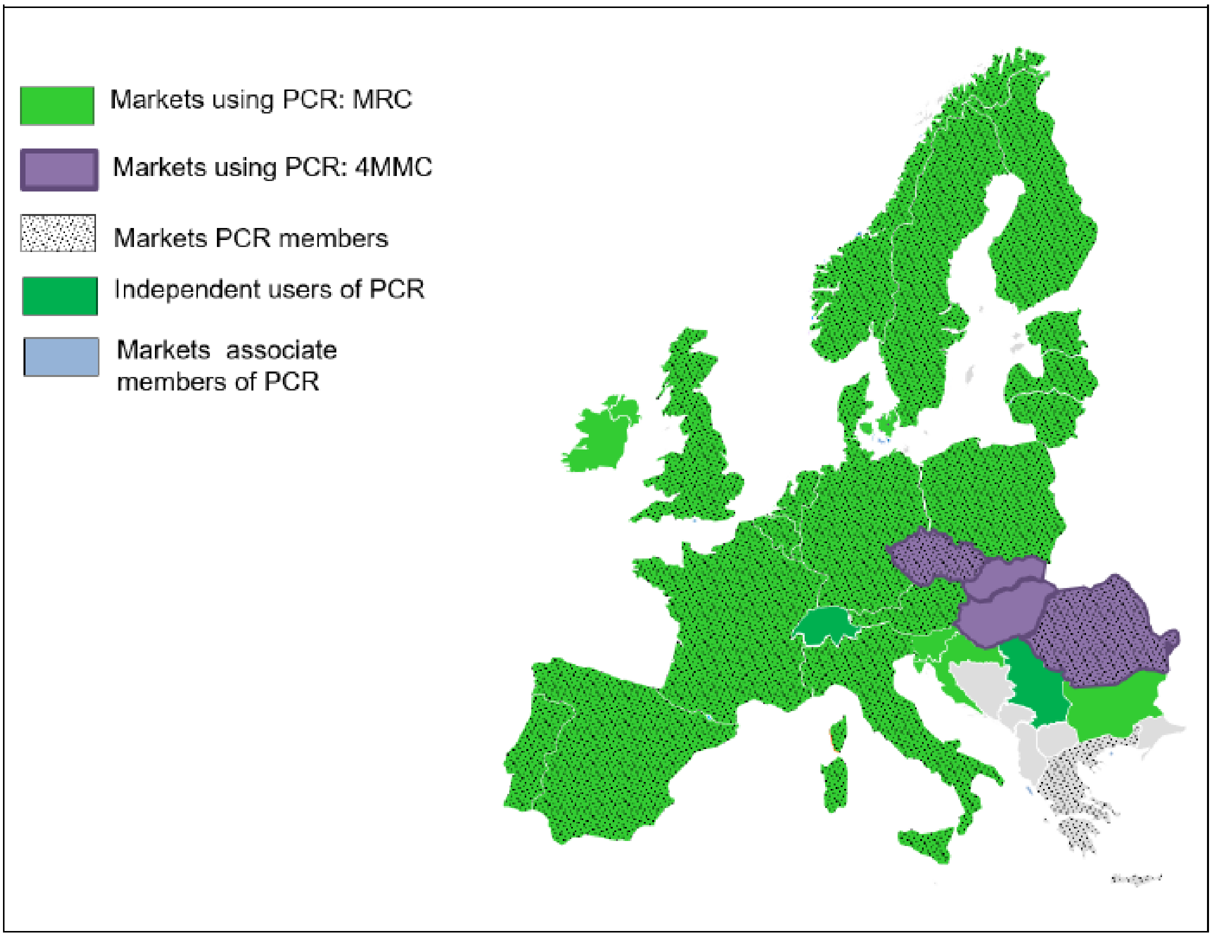

Figure 2-14 – The map of countries using PCR

One of the key achievements of the PCR project is the development of a single price coupling algorithm, commonly known as EUPHEMIA (acronym for Pan-European Hybrid Electricity Market Integration Algorithm).

Day-ahead prices are always calculated and published for each hour of the coming day for each day of the year. In the DAM electricity market, the individual market participant's supply and demand bids are the two most important factors for determining the electricity price. A demand bid describes the willingness to buy power at a price the consumer can afford. The generic theory behind a demand bid is that while other factors stay as constant, the higher the price of the product is, the less demand there is for it and the other way around, the lower the price is, the higher the demand will be. The demand curve is therefore typically descending due to the fact that the consumer-received benefit from another unit of product is always less than the gained benefit from previous unit, which is called the marginal utility. In electricity markets demand originates from the electricity consumers such as large-scale customers like energy-intensive industries or retail sellers. Demand in theory is affected by electricity consumers' desire to maximize their benefit with their available budget. In addition, demand is affected by the variable and fixed costs of the production and by the delivery obligations. However, usually demand in electricity markets is quite inelastic due to the essentiality of the sufficient electricity supply. In other words, demand is not affected much by the market price and consumers are willing to buy electricity almost at any price. Eventually, the aggregated demand curve is compiled by summing up all the demand curves of the single consumers.

Supply describes the willingness of selling power at different prices and thereby has the possibility to gain profits from the sales. The law of supply states that while other factors stay as constant, the

higher the price of power is, the more is produced. Following the same logic, the lower the price is, the less there is willingness to produce power will be. Opposite to demand, supply curve is typically ascending as each incrementing utility provides less profit. In other words, the production costs are increasing for each additional produced unit. In the electricity markets supply originates from power producers. Supply is affected by multiple factors such as weather conditions, production method and fuel prices. Also free competition in the markets affects the pricing of the supply. Eventually, the aggregated supply curve for the market is compiled by summing up all the individual supply curves of each power producer.

In the DAM the aim is to maximise the welfare for all EU by finding an optimal price and volume for electricity for every hour of the next day. In a market situation the optimal situation is always found at the intersection of the supply and demand curves, at market equilibrium. In generic market Theory the price at this point is called equilibrium price and the volume as the equilibrium volume. Therefore, the markets automatically move towards the market equilibrium to maximize the overall welfare.

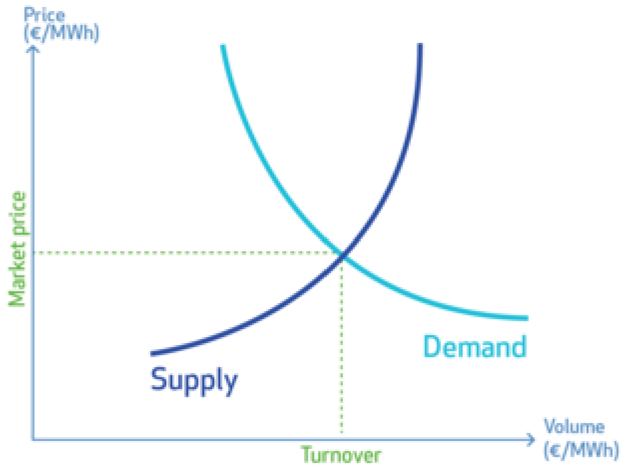

Figure 2-15 – Price formation in Day Ahead markets

In the European market model price is formed by finding the intersection of the aggregated supply and demand curves as described earlier. All the market participants, both producers and consumers settle with same price within each bidding zone (market area). This price is called Marginal Price. Due to the market model based on merit order of the production in the supply curve based on price, producers typically offer their production based on the short-term marginal costs. Therefore, the production units with the lowest marginal cost of the production are activated first. As result, the economically most efficient production units will earn the most.

Intra Day Market

In the Intraday market (IDM) market place the market participants can place purchase and sales orders continuously throughout the day close to the actual physical delivery of power. This is done on a continuous market where a trade will be done whenever two orders match in price and quantity[3]. In other words, each placed order can be matched independently whenever suitable counter offer is found. Due to the possibility of trading close to the delivery period, intraday market provides market participants a good way to balance out their positions after the Day Ahead market results are published. In addition, after the Day Ahead market results are published and physical

[3] CACM, Art. 63 also provides that, next to continuous trading, complimentary regional intraday auctions may also be implemented if approved by the regulatory authorities

power transfers between countries are defined through the implicit auction, the remaining cross-border capacity can be allocated to the intraday market for cross-border trading.

Intraday market is becoming more and more important while more and more intermittent renewable energy resources are emerging in the power system. Wind and solar power generation (but also demand) forecasts are more accurate closer to real-time, thus enabling a better adjustment of binding production schedules in the Intraday market than in the Day-Ahead market. This would reduce the overall balancing costs for the power system as well as being a trading opportunity for these resources. This can typically be observed in the areas with high penetration of intermittent production.

The market coupling of the intraday markets across Europe is driven by the Cross-Border Intraday initiative (XBID).

An integrated intraday market will promote effective competition and pricing, increase liquidity and enable a more efficient utilisation of the generation resources across Europe. With the increasing amount of intermittent production, it becomes more and more challenging for market participants to be in balance after the closing of the Day-Ahead market. Therefore, interest in trading in the intraday markets is increasing. Being balanced on the network closer from delivery time is beneficial for market participants and for the power systems alike by, among others reducing the need of reserves and associated costs.

Introduction to the balancing mechanism

In the EU target market model, the BM pricing is tightly related to the DAM spot prices in order to reduce market manipulation and abuse.

In the BM, BRP should be able to place offers for up-regulation (increase in production or decrease in consumption) or for down-regulation (decrease in production or increase in consumption). Then the TSO(s) should activate the orders based on the balancing needs of the power system. Thus, the pricing will be based on DAM spot prices. On the hours where up-regulation is needed, the closing price for each up-regulation offer will be the price of the most expensive up-regulating offer used. The tight coupling that should be implemented could be based on the solution that is implemented in the Nordics where the price will be at least the spot price (DAM) for the regarding hour. On the hours where down-regulation is needed, the closing price for each down-regulation offer will be the price of the cheapest down-regulation offer. The same way the price will be at the most the spot price for the regarding hour. Balancing power pricing method is illustrated in Figure 2-16.

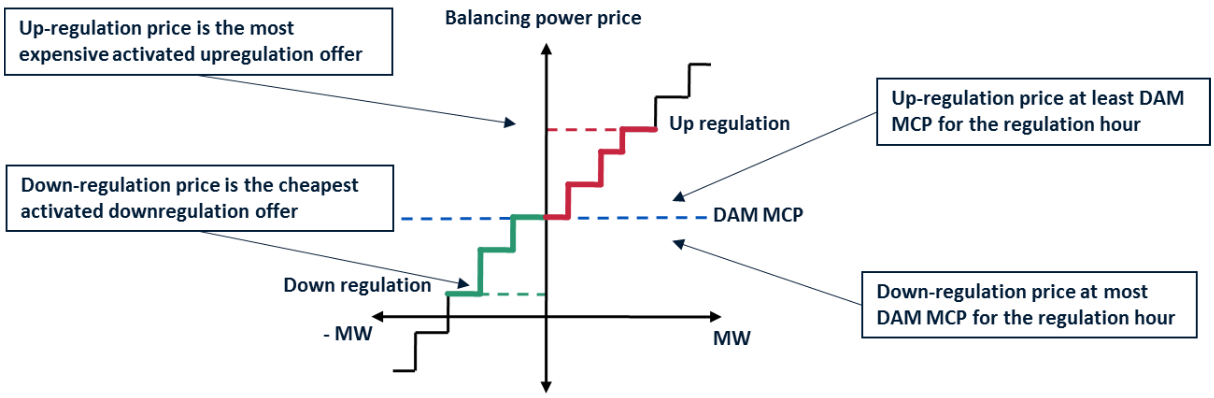

Figure 2-16 – Balancing power pricing

Typically, the balancing power pricing method is designed to attract market participants to take part also in the balancing power market with their spare capacity. In case of up-regulation TSO should

buy up-regulation power from the market participants at least on the respective Day Ahead Market Clearing Price (MCP). This should ensure that the market participants will receive at least same profits as they would have got from the Day Ahead market, and in most cases the balance power purchase price should be higher than spot price. Therefore, if market participants were not able to sell all their capacity to Day Ahead and Intraday markets, they can submit the remaining capacity to balancing power market without the risk of losing profits.

In the same way, when down-regulation is needed TSO will sell the down-regulation power to the market participants so that they can either consume more or produce less (countertrading). In this case the balancing power that the market participants will buy is at the same price than power purchased from DAM or even cheaper. Due to the pricing mechanism this is also attractive method for market participants to fix their trading portfolio imbalances after Day Ahead and Intra Day markets.

Imbalance power settlement

When moving further with the conceptual market design and after the real time operations for the power system are ran, each BRP' consumption or production balance is checked. In other words, it is calculated whether the participant will have an imbalance between its scheduled (planned) commitments and its actual metered generation/consumption.

Since the planned production or usage of electricity might not end up in the same amount of what was planned, there will occur imbalances. Essentially BRP is paying for the actions taken by the TSO to maintain the frequency and stability in the network.

In Nordic model, for instance, the so called two-price system is applied for these purchases. In the two-price system, separate prices are calculated for purchase and sales imbalance power. The price is coupled to the balancing power market. For the sales of the imbalance power, the price is the up-regulation price of the concerning hour. However, if the concerning hour was down-regulation hour, then Nord Pool spot price for the concerning hour is used as the sales price of the imbalance power. On the contrary, for the purchases of the imbalance power the down-regulation price for the concerning hour is used. However, if the concerning hour was upregulation hour, then Nord Pool spot price for the concerning hour is used for imbalance power purchases. These pricing methods are further elaborated in Table 2-6.

In the one-price system, the purchase and sales prices of imbalance power are identical. During an up-regulating hour, the price of imbalance power is the up-regulating price, and during a down-regulating hour, the price of imbalance power is the down-regulating price. If no regulations have been carried out during an hour, the price of imbalance power is the spot price. Two-price and one-price system and price formation is illustrated in Table 2-6, where first one is numerical illustration and second one graphical from the same pricing method.

Table 2-6 – Two-price and one-price system in table format

	2-price			1-price		
€/MWh	Up-regulating hour	No regulation	Down-regulation hour	Up-regulating hour	No regulation	Down-regulating hour
Up-regulating price	**100**	50	50	**100**	50	50

Spot price	50	50	50	50	50	50
Down-regulating price	50	50	**20**	50	50	**20**
Purchase price for balance power	**100**	50	50	**100**	50	**20**
Sales price for balance power	50	50	**20**	**100**	50	**20**

Both one- and two-price systems have advantages and drawbacks. In some cases, for example in Germany, the one-price system price is not determined as marginal cost. Instead, the price is calculated based on the average cost of the activated reserves. When the imbalance and balance power prices are not coupled to the Day Ahead Market spot prices so called passive balancing can occur. In this case the market participants can intentionally deviate from their planned production or consumption plans if they have forecasted more attractive imbalance prices. In addition, when imbalance and balancing power price is calculated and determined separately from the Day Ahead market, it lacks some transparency. Moreover, when single pricing method is used the TSO will purchase and sell power with the same price and further has little possibility for profits which could be allocated to lowering the grid tariffs.

Since the two-price system is directly coupled to balancing power pricing and Day Ahead prices it effectively prevents incentives to deviate from the planned schedules. Due to the pricing method there is no gain to intentionally deviate from schedules but at the same time no gain to worsen the system imbalance. This imbalance power pricing method also increased the price formation transparency. However, two-price system gives bigger Balance Responsible Parties possibility to net their portfolios and avoid higher imbalance casts. At the same time, smaller market participants are more often directly subjected to imbalance prices and thus this might steer them to outsource their balancing and join bigger Balance Responsibility pools.

Generally, in Europe different countries have different amount of imbalance portfolios. Imbalance portfolio term is used to refer on the number of imbalance volumes to be calculated, attributed and charged to BRP's per settlement time unit. Usually when two imbalance portfolios are issued, one portfolio is for consumption and the other one is for production. Figure 2-17 shows which number of imbalance portfolios each country has.

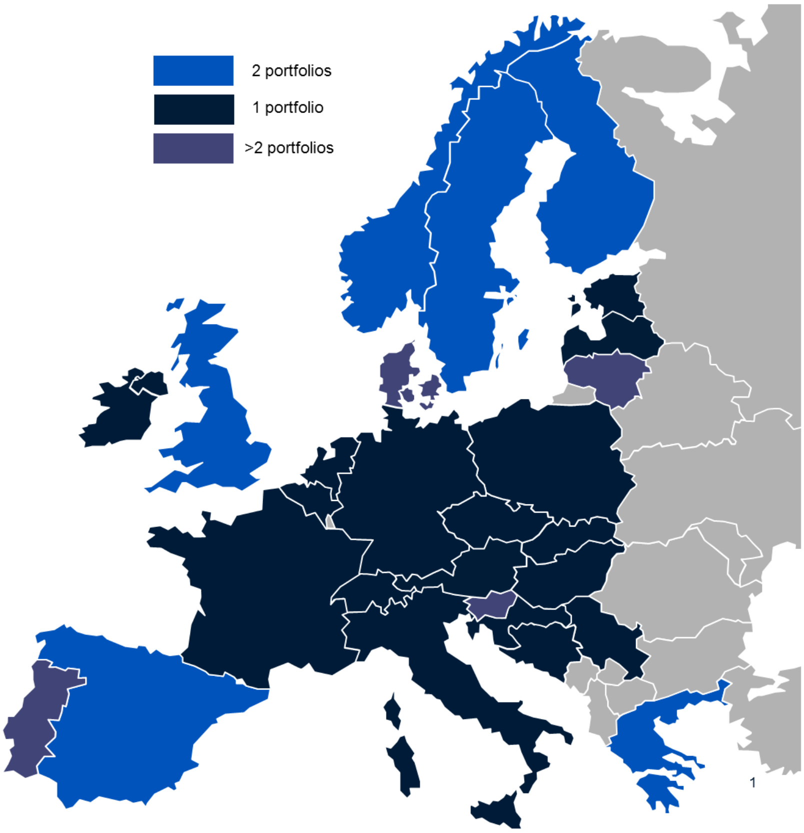

Figure 2-17 – Imbalance portfolios in European countries

The Bulgarian balancing market is taken as an example.

<u>Bulgarian balancing market</u>

The Bulgarian liberalized market set up [65] is illustrated in the diagram below:

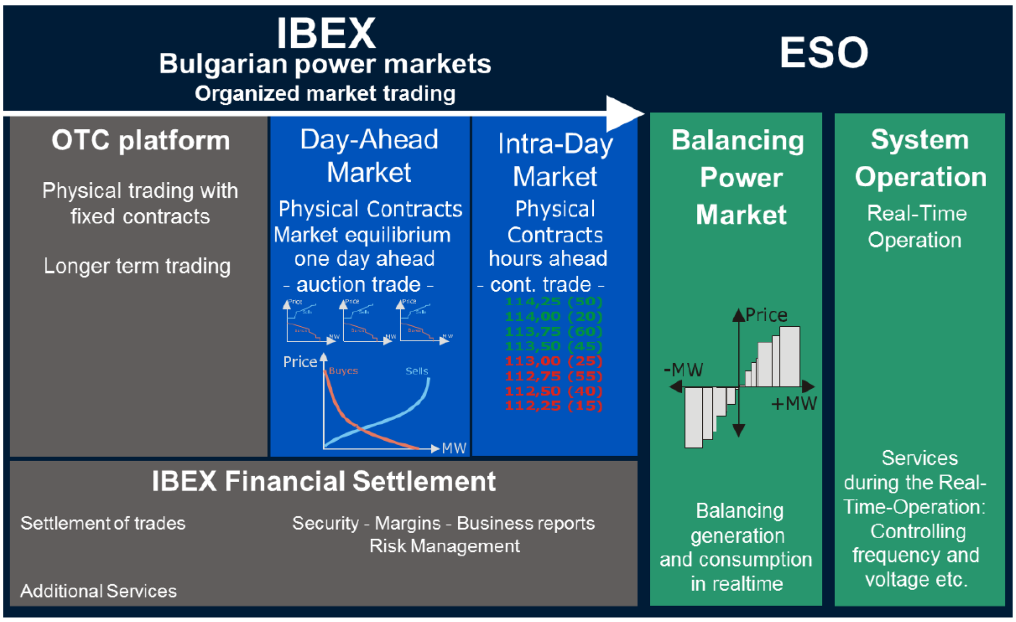

Figure 2-18 – Structure of Bulgarian market set up

The Bulgarian balancing market was launched in July 2014 as a two-price system and it is fully compliant with the general EU requirements. In the beginning it was not related to the DAM prices, simply because the Bulgarian DAM went live later, on the 19.01.2016. With the increase of the Bulgarian DAM liquidity, the necessity of correlation between the prices for imbalances and the DAM prices became more and more relevant. There were plenty of situations in 2016 and 2017 in which the competition between the two segments occurred. This led as from 01.02.2018 to the decision of the national regulatory authority (Energy and Water Regulatory Commission – EWRC) to link the prices for balancing energy procurement with the IBEX Base daily price that was one important step in the right direction.

The imbalance prices calculation method, as well as the legal base of the Bulgarian balancing market is included in the dedicated Electricity Trading Rules (ETR).

On the TSO web site, the information for the hourly imbalance prices and the balancing energy providers' prices could be derived.

The services offered by the Bulgarian TSO are listed below:

1. Balancing;
2. Auxiliary services - primary, secondary and tertiary control services, where the tertiary reserve is market procured (through the auction where the generators and big industrial consumers could participate);
3. Cold reserve – required by law and contracted by the TSO.

Because of the balancing market opening process, all market participants are balance responsible and manage their imbalance risk towards the TSO.

The expected developments are related to the tighter interrelation with the DAM prices, by inclusion of the DAM hourly prices into the calculation methodology.

2.2 Tools

2.2.1 Grid's tools

Services provided or utilized by TSOs and DSOs may be realized as a mandatory requirement (e.g. defined by grid code) to interconnect to the electricity system, as a voluntary bilateral contract, or as a market-based solution. Voltage control is a mandatory requirement for generating units belonging to type D according to network code on requirements for grid connection of generators [12], which defines the technical requirements for different kinds of generating technologies like synchronous generators and inverter-based units. The network code defines also multiple other requirements related to generation units' frequency stability, remote operation, automatic connection, robustness like fault-ride-through capability, system restoration, general system management, automatic disconnection, etc. Network code should ensure non-discriminatory access to the electricity system for everyone in such a way that power system security is ensured in a cost-effective way. Therefore, the network code as a tool to define utilized services should be considered carefully and agreed in wide acceptance. Network code is agreed on European level and it may have some minor modifications at national level. In addition to network code needed at transmission level, there are also DSO level connection requirements, which are less harmonized than network codes discussed previously.

Provided services of TSO and DSO may also be mandatory. Provision of metering data and datahub are examples of topics where this may be applied. These services in European context are still under development. As an example, the Transparency Platform is a mandated tool available online (https://www.entsoe.eu/data/transparency-platform/) developed by the European Network of Transmission System Operators for Energy (ENTSO-E) and specified by regulation 543/2013

{Commission Regulation No 432/2013 (2013). Submission and publication of data in electricity markets and amending Annex I to Regulation (EC) No 714/2009 of the European Parliament and of the Council Text with EEA relevance. [Online]. Available: https://eur-lex.europa.eu/eli/reg/2013/543/oj}. Currently, 43 TSOs from 36 countries, members of ENTSO-E, publish their data into the Transparency Platform, together with non-TSO providers. All technical procedures and definitions are specified in a handbook named Manual of Procedures for the ENTSO-E Central Information Transparency Platform", v2.0, May 2014. [Online]. Available: https://www.entsoe.eu/fileadmin/user_upload/_library/resources/Transparency/ENTSO-E%20Manual%20of%20Procedures%20V2R0-2014-05-01.pdf}, available at ENTSO-E webpage, presenting the data to be published and available to download.

Voluntary bilateral contracts are utilized for services, which are not mandatory for security reasons and are inefficient to require from everyone, and where there does not exist a market-based solution for such service. In such case, TSO or DSO and the owner of flexibility resource make a bilateral contract to utilize the flexibility. Flexible grid connection contract is a typical example of such contract, where rules for service utilization, requirements for technical performance of flexibility, and financial compensation of availability and utilization of flexibility are defined. There are different methodologies to determine the order of production curtailment for generating units for example in case of distribution grid congestion. These methodologies are for example "last in first out" principle where the curtailment is realized for a unit connected to system as a last. This might not always be technically very effective and therefore sharing of curtailment for all units will be more effective. Curtailment based completely on technical reasons might lead to unfair conditions, if curtailment is always done in the same units.

In a similar way, there might be a contract between DSO and generating unit to provide reactive power services for coordinated voltage control of active network management or for reactive power management of distribution grid. DSO and a service company providing backup power or islanding may also contract to enhance distribution supply reliability in specific location. The third option is to have a contract between DSO's service business and an aggregator to utilize smart meter controllability for communicating demand response commands to customer premises [13].

Market-based solutions are more common for services, which are national or even international in some cases. Reserves, balancing and congestion management services are commonly organized as a market-based solution. Resources participating in these markets need to fulfil prequalification tests, specific technical requirements and requirements on reporting and verification [14]. Most of FCR have to be provided within TSO region to maintain frequency in isolated operation as well. Some of FCR may be located in neighbouring TSO's region if transmission capacity is allocated for it. Cross-border HVDC links may be utilized for FCR-N procurement as well. In countries, where FCR is market-based, FCR markets are maintained by TSOs. aFRR has hourly market, but it is utilized only in morning and evening hours when load demand changes fastest. In Nordic region, the activation of aFRR is operated together with all Nordic TSOs. mFRR are procured from balancing power market and balancing capacity market. Reserve power plants owned by Nordic TSOs are used for critical situations, not for normal market condition. Some TSOs (Nordic, Baltic) have common balancing power market. When there is enough transmission capacity available between bidding areas, bids are accepted in price order.

For congestion management and voltage control most TSOs and DSOs use power system simulation and analysis tool (either 3rd-party or in-house platform), which allows them to perform a wide variety of analysis functions, including: power flow, dynamics, short circuit, contingency analysis, optimal power flow, voltage stability, transient stability simulation, and much more.

For data exchange between TSOs, ENTSO-E Communication and Connectivity Platform (ECCo SP) constitute a value-added platform enabling communication between business applications. It is currently made of two main components: ECP (Energy Communication Platform) and EDX (Energy

Data eXchange). ECP provides message delivery capabilities with security, compliant with technical specification IEC 62325-503 {"ENTSO-E, "MADES Communication Standard, IEC IS 62325-503: 2018", Edition 1. 2018. [Online]. Available: https://webstore.iec.ch/publication/60690&preview"} for transparent message exchange. For EDX, its distributed messaging system allows the transfer of messages between ECCo SP network participants, support the integration through MADES, FTP, AMQP or web-services. ECCo SP is currently applied by a list of more than 30 projects or partners for data exchange in the energy sector.

2.2.2 Market's tools

Day-ahead market

EUPHEMIA is the algorithm that has been developed to solve the problem associated with the coupling of the day-ahead power markets in the PCR region.

First, Market participants start by submitting their orders to their respective power Exchange. All these orders are collected and submitted to Euphemia that has to decide which orders are to be executed and which orders are to be rejected in accordance with the prices to be published such that:

• The social welfare (consumer surplus + producer surplus + congestion rent across the regions) generated by the executed orders is maximal.

• The power flows induced by the executed orders, resulting in the net positions do not exceed the capacity of the relevant network elements.

Euphemia handles standard and more sophisticated order types with all their requirements. It aims at rapidly finding a good first solution from which it continues trying to improve and increase the overall welfare. EUPHEMIA is a generic algorithm: there is no hard limit on the number of markets, orders or network constraints; all orders of the same type submitted by the participants are treated equally.

The development of Euphemia started in July 2011 using one of the existing local algorithms COSMOS (being in use in CWE since November 2010) as starting point. The first stable version able to cover the whole PCR scope was internally delivered one year later (July 2012). Since then, the product has been evolving, including both corrective and evolutionary changes. On the 4th of February 2014, Euphemia was used for the first time in production to couple the North Western Europe (NWE) in common synchronized mode with the South-Western Europe. One year later, on the 25th of February 2015, GME was successfully coupled. On the 21st of May 2015, the Central Western Europe was coupled for the first-time using Flow-based model. On 20 November 2014 the 4M MC coupling was launched coupling the markets of Czech Republic, Hungary, Romania and Slovakia.

As mentioned previously, EUPHEMIA is the algorithm that has been developed to solve the Day-Ahead European Market Coupling problem. EUPHEMIA matches energy demand and supply for all the periods of a single day at once while taking into account the market and cross-border constrains. The main objective of EUPHEMIA is to maximize the social welfare, i.e. the total market value of the Day-Ahead auction expressed as a function of the consumer surplus, the supplier surplus, and the congestion rent including tariff rates on interconnectors if they are present. EUPHEMIA returns the market clearing prices, the matched volumes, and the net position of each bidding zone as well as the flow through the interconnectors. It also returns the selection of block, complex, merit, and PUN orders that will be executed. For curtailable blocks the selection status will indicate the accepted percentage for each block.

By ignoring the particular requirements of the block, complex, merit and PUN orders, the market coupling problem resolves into a much simpler problem which can be modelled as a Quadratic Program (QP) and solved using commercial off-the-shelf solvers. However, the presence of these orders renders the problem more complex. Indeed, the "kill-or-fill" property of block orders and the

minimum income condition (MIC) of complex orders requires the introduction of binary (i.e. 0/1) variables. Moreover, the strict consecutiveness requirement of merit and PUN orders adds up to the complexity of the problem.

In order to solve this problem, EUPHEMIA runs a combined optimization process based on the modelling of the market coupling problem. EUPHEMIA aims to solve a welfare maximization problem (also referred to as the master problem) and three interdependent sub-problems, namely the price determination sub-problem, the PUN search sub-problem and the volume indeterminacy sub-problem.

In the welfare maximization problem, EUPHEMIA searches among the set of solutions (solution space) for a good selection of block and MIC orders that maximizes the social welfare. In this problem, the PUN and merit orders requirements are not enforced. Once an integer solution has been found for this problem, EUPHEMIA moves on to determine the market clearing prices.

The objective of the price determination sub-problem is to determine, for each bidding zone, the appropriate market clearing price while ensuring that no block and complex MIC orders are paradoxically accepted and that the flows price-network requirements are respected. If a feasible solution could be found for the price determination sub-problem, EUPHEMIA proceeds with the PUN search sub-problem. However, if the sub-problem does not have any solution, we can conclude that the block and complex orders selection is not acceptable, and the integer solution to the welfare maximization problem must be rejected. This is achieved by adding a cut to the welfare maximization problem that renders its current solution infeasible. Subsequently, EUPHEMIA resumes the welfare maximization problem searching for a new integer solution for the problem.

The objective of the PUN search sub-problem is to find valid PUN volumes and prices for each period of the day while satisfying the PUN imbalance constraint and enforcing the strong consecutiveness of accepted PUN orders. When the PUN search sub-problem is completed, EUPHEMIA verifies that the obtained PUN solution does not introduce any paradoxically accepted block/complex orders. If some orders become paradoxically accepted, a new cut is introduced to the welfare maximization problem that renders the current solution infeasible. Otherwise, EUPHEMIA proceeds with the lifting of volume indeterminacies.

<u>Intraday Market</u>

The **XBID** Programme started as a joint initiative by Power Exchanges and TSOs from 11 countries, to create a coupled integrated intraday cross-border market. Meanwhile the XBID Platform has been confirmed as the Single Intraday Coupling (SIDC) which shall enable continuous cross-border trading across Europe. XBID is based on a common IT system with one Shared Order Book (SOB), a Capacity Management Module (CMM) and a Shipping Module (SM). This means that orders entered by market participants for continuous matching in one country can be matched by orders similarly submitted by market participants in any other country within the project's reach as long as transmission capacity is available. The intraday solution supports both explicit (where requested by NRAs) and implicit continuous trading and is in line with the EU Target model for an integrated intraday market. The purpose of the XBID initiative is to increase the overall efficiency of intraday trading.

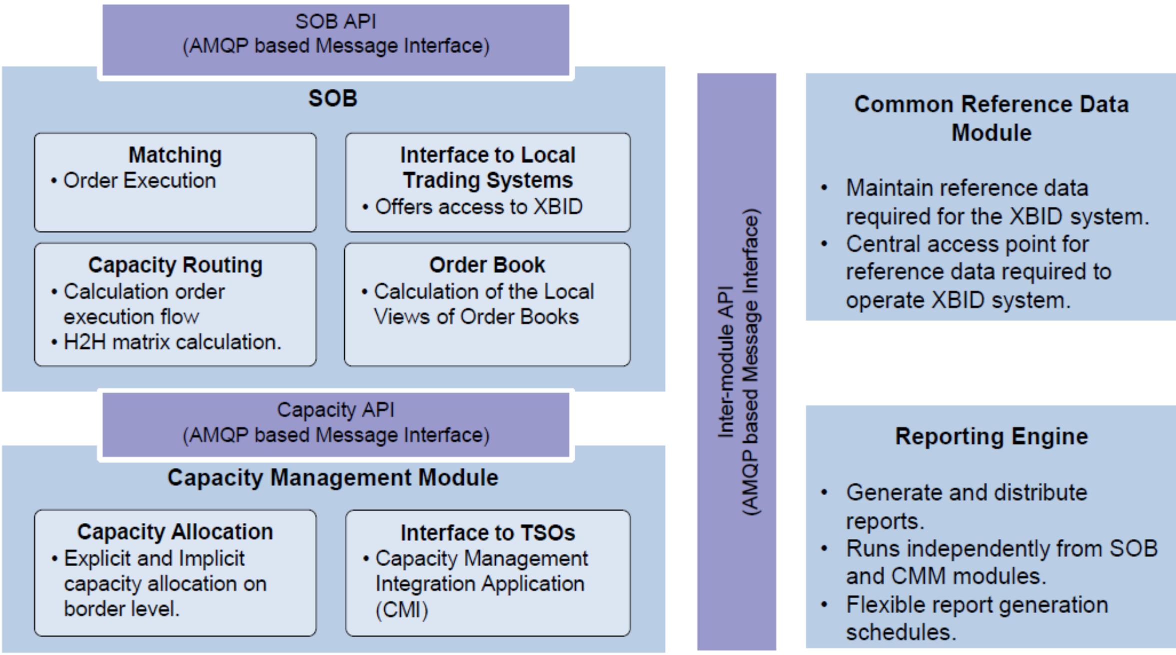

Figure 2-19 – Structure of intraday cross-border market

The orders submitted by the market participants of each NEMO via the Local Trading Solution (LTS) of the respective NEMO will be centralised in the SOB. Similarly, all the intraday cross-border capacities are made available by the TSOs in the CMM.

It is important to clearly distinguish between Local Trading Solutions (LTSs) and XBID Solution:

• LTSs represent an interface (the only interaction point) between the Implicit Market Participants and Single Intraday Coupling (SIDC) Solution. In other words the Implicit Market Participant may access the SIDC only via the LTS of a particular NEMO.

• XBID Solution is a so called backend process which does not interact with the Implicit Market Participants. XBID Solution provides, among others, a functionality of the Shared Order Book via interaction with the connected LTSs.

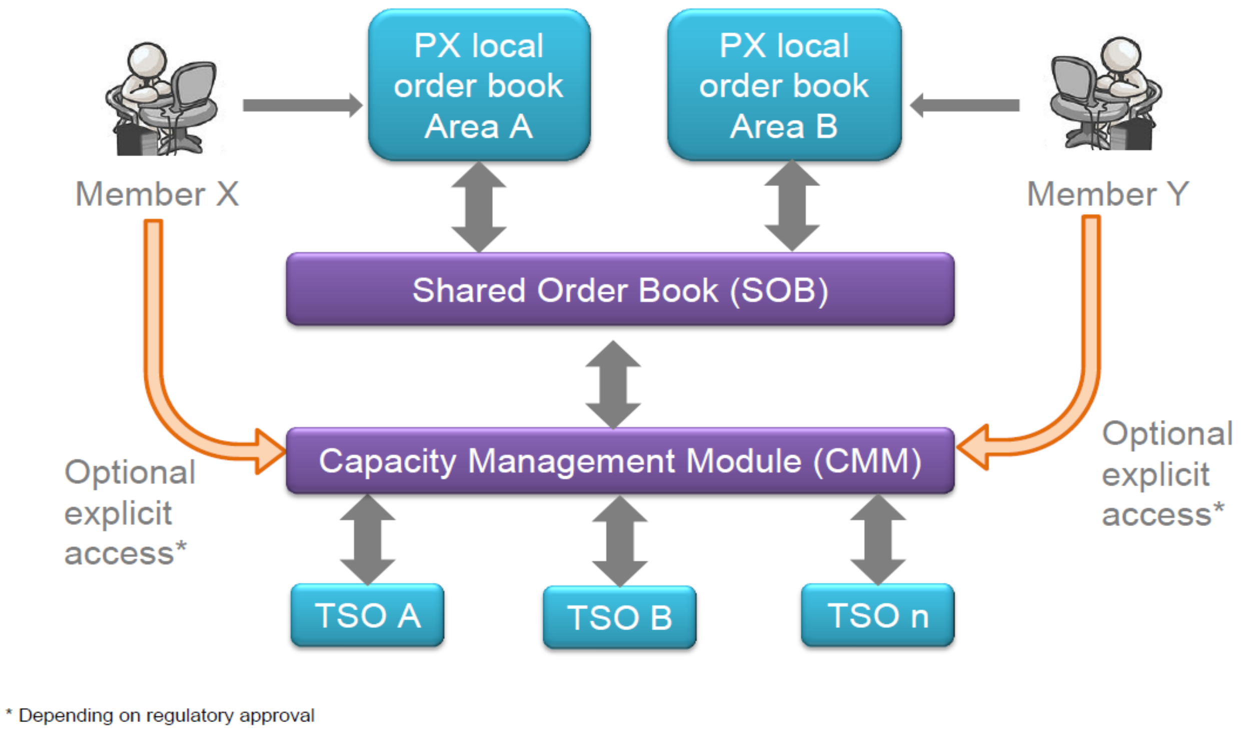

Figure 2-20 – Connection between members of intraday cross-border market

The orders submitted by the market participants of each PX are centralised in one shared order book (SOB). Similarly, all the intraday cross-border capacities are made available by the TSOs in the Capacity Management Module (CMM).

Order books displayed to the market participants via the usual NEMOs' trading systems contain orders coming from other participants of the concerned NEMO and also orders coming from other NEMOs for cross-border matching, provided there is enough capacity available.

Orders submitted for different market areas can be matched provided there is enough capacity available. In such a case, the order matching is associated with implicit capacity allocation. Concretely, when two orders are being matched the SOB and CMM is updated immediately. Trade is done on a first-come first-served principle where the highest buy price and the lowest sell price get served first. The update of SOB means that the orders that were matched are removed, and consequently that the available transmission capacity in the CMM is updated. For how many borders the capacities are updated depends on where the matched orders were located geographically.

For borders where NRAs requested for it, explicit allocation is made available to Explicit Participants (currently only at the FR-DE border).

During the trading period, available capacities and order books are simultaneously updated on a continuous basis.

The Shipping Module (SM) of the XBID Solution provides information from trades concluded within XBID to all relevant parties of the post-coupling process. The SM receives data from the SOB about all trades concluded:

- Between two different Delivery Areas
- In the same Delivery Area between two different Exchanges

The data from the SOB and the CMM are enhanced with relevant TSO, Central Counter Party (CCP) and Shipping Agent data from the SM and transferred to the parties at the configured moments.

3 Survey analysis

The aim of this survey, disseminated by the consortium partners across Europe, is to understand, from the customers' perspective, the tools and the services that would prove to be most useful and necessary for the future power systems and electricity market setting.

A survey on existing tools and services within market and grid fields was carried out. The survey was disseminated within the consortium but also to external experts, taking advantage of the wide network of the INTERRFACE consortium. The aim was to identify the shortcomings and relevant issues across Europe, focusing on the needs of relevant energy actors. A key issue was identified in relation to the integration of different platforms used for different purposes (for example, operational planning and real time systems) and how to exchange information/data between parties in an expedited and standardized way. The survey results notably enable the identification of key improvement areas for existing tools and processes. Survey participants see the future energy system as a system where energy storage systems, smart metering, online voltage regulation and Demand Response services will be prevalent services in the years to come

3.1 Grid's tools and services

The grid tools and services survey brought together a total of thirty-eight (38) answers spread from 20 different European countries. ENTSO-e made a good effort in dissemination of the grid survey to all TSO and RSC in Europe. In the Figure 3-1 it is possible to find the distribution among Europe map of the countries that answered to this survey.

Figure 3-1 – Countries that answered the grid's tools and services survey

The fact that this survey gathered responses from 20 different European countries ensures a good coverage of Europe. Therefore, these survey results represent in a good rate the European perspective about the actual grid's tool and services landscape.

The next table shows the sharing of answers according the role of the participants in the energy sector.

Role in the energy sector	Number of answers
Aggregator	3
Consumer	1
DSO	10
Regulator	1
RSC	2
Software Manufacturer	1
Supplier	1
TSO	19
Total	**38**

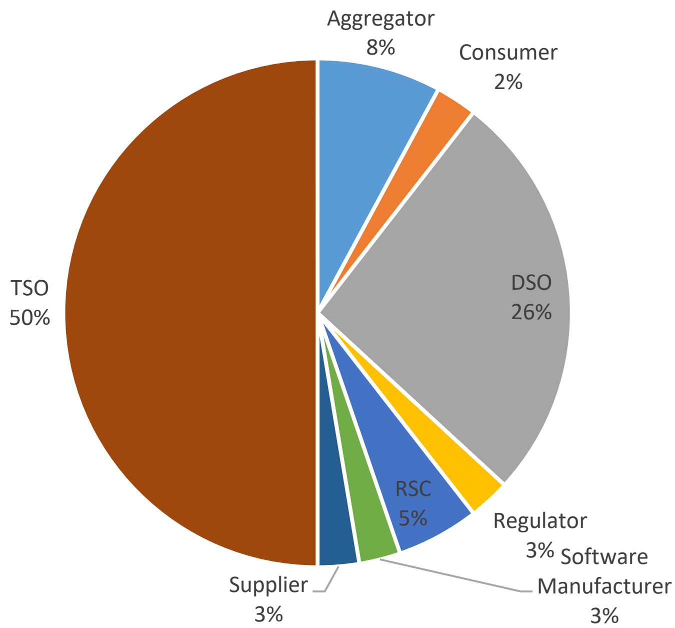

Figure 3-2 – Survey participants roles

Half of the survey participants are TSOs (19) and more than one quarter are DSOs (10). The remaining participants are from other parties like consumers, suppliers, aggregators, regulators, RSCs and manufacturers.

In this survey a set of questions is included that are related with the tools and/or platforms that are being used by the different stakeholders in the energy sector for different system/grid needs. For each of these needs, the survey tries to identify the list of tools used and what is the purpose for which they are being used. For reasons of confidentiality, the name of the tools will not be revealed in this report, so the analysis will be mainly focused on the applications in which the tools referred are employed. Additionally the survey shows, if the platforms/tools used per application are made in-house or by a 3rd party company.

In Figure 3-3 the analysis of the answers according to the origin of the tools that are

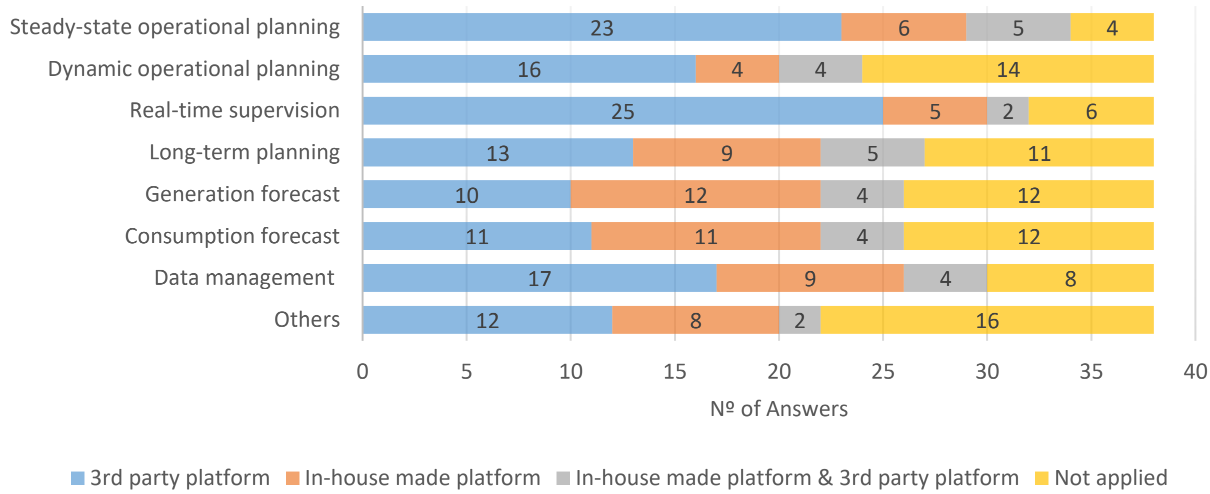

Figure 3-3 – Origin of the tools/platforms used by the participants for different purposes

used by the participants in diverse grid categories/services as operational planning, forecast or data management, among others is demonstrated.

For the steady-state operational planning purposes most of the participants stated that their tools are made by other companies (3rd party platforms/tools). The real time supervision activities are the ones from the categories proposed in the survey, where more participants answered that their dedicated tools are developed by 3rd parties.

One interesting outcome of this chart analysis, is the fact that the forecast activities are the ones where most the tools used are designed by the same company which uses it.

The Table 3-1 shows the different purposes that were mentioned in the survey answers for each platform/tool used by the survey participant.

Table 3-1 - Applications in which the different tools are used for each service

Service	Applications
Steady-state operational planning	State Estimator, Security Analysis based on SCADA data. DACF and IDCF process and analysis. Day-ahead and long-term capacity calculation. Offline analysis like load flow and contingency analysis. Short-circuit calculation. Network modeling. Congestion management.
Dynamic operational planning	Dynamic stability calculations (off-line). Supervision of voltage and frequency stability.
Real-time supervision	Interconnector Monitoring. Control Center's SCADAs. Substation Automation. Security Analysis. Dispatching control. Trading.
Long-term planning	Grid planning. Network simulation for steady-state and dynamic modelling and analysis. Market modelling and studies. Outage planning.
Generation forecast	Solar generation forecast. Wind generation forecast. Balance Management System incl. for collection, validation and synchronization of planning data (balance plans, forecasts etc.).
Consumption forecast	Short Term Load Forecast. Day-ahead and intraday grid losses forecast. Long-term predictions.
Data management	Remote metering Development of CGMES models and merging Preparation of data for the dispatching control Common grid data exchange CIM modelling

In the survey it is also asked if there are any others relevant services that are not mentioned and for which the tools used should be mentioned due to their importance. Balancing Services, Demand response, Smart Metering and outage management systems were the main services revealed.

In order to try to foresee what will be the future energy system, participants were asked to rate the relevance of different equipment/services in the future, from their point of view. The rating suggested is from 1 to 5, being 1 not relevant and 5 essential for the future energy system. Figure 3-4 presents the answers given by the participants about the rating of the grid services foreseen as relevant in the future.

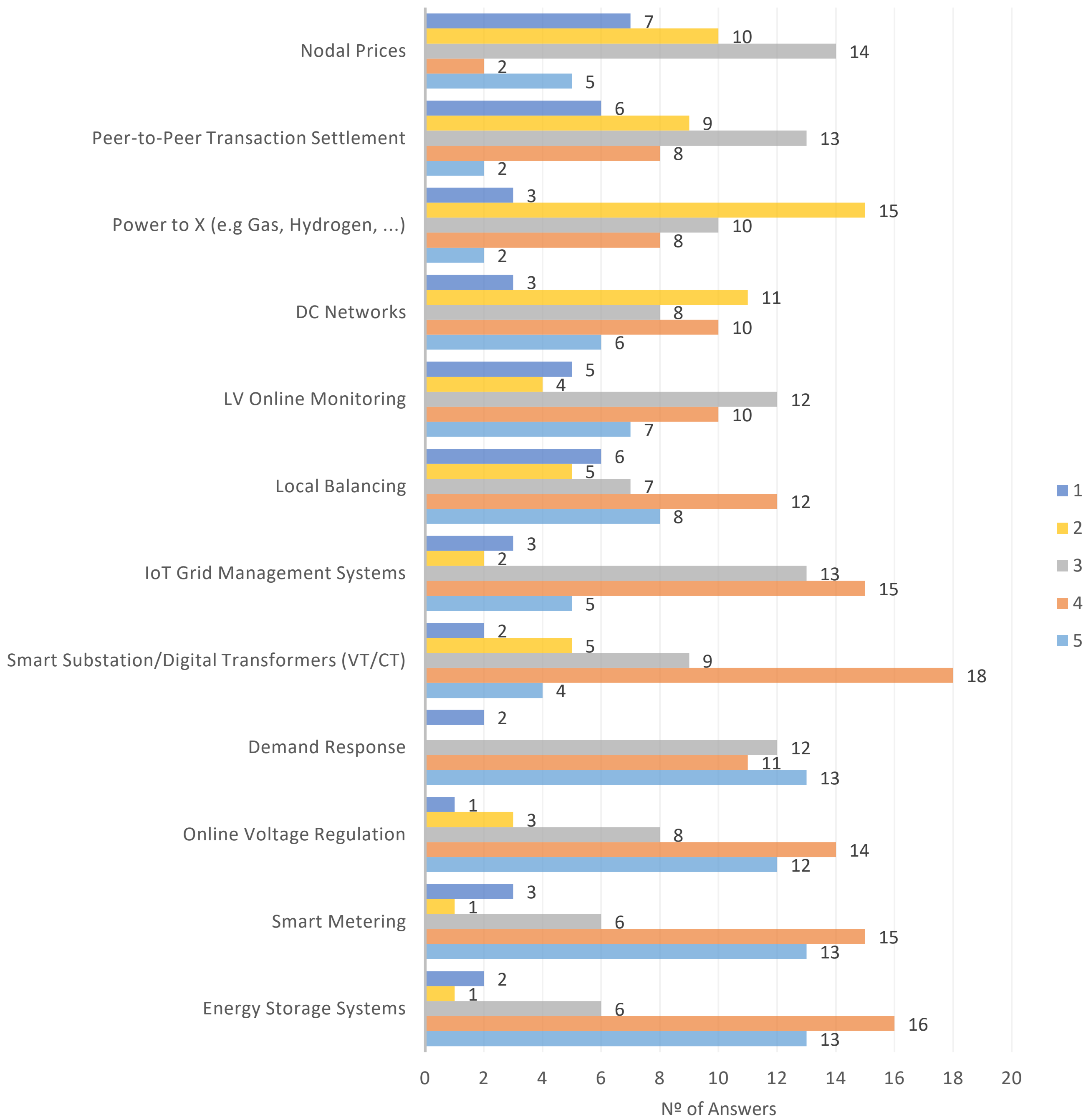

Figure 3-4 Rating of the importance of grid services in the future energy system

By summing up the rate given by all the participant presented in the Figure 3-4, it's possible to establish the importance of each service as presented in the following table.

Table 3-2 – Sum of the rating of each grid service

Services	Sum up rating
Energy Storage Systems	151
Smart Metering	148
Online Voltage Regulation	147
Demand Response	147
Smart Substation/Digital Transformers (VT/CT)	131
IoT Grid Management Systems	131
Local Balancing	125
LV Online Monitoring	124
DC Networks	119
Power to X (e.g. Gas, Hydrogen,…)	105
Peer-to-Peer Transaction	105
Nodal Prices	102

According to the results the majority of participants think that the Energy Storage Systems will be the most important service in the future energy system. The top 3 is completed by the Smart Metering and Online Voltage Regulation in *ex aequo* with Demand Response. The less important grid service was considered the nodal pricing.

Another interesting analysis is to try to understand if there is any pattern between the answers to this question and the roles of the participants in the energy sector. In the Table 3-3 it is presented the top 3 answers only for the Aggregators, DSOs and TSOs, because they are the single ones that have more than one answer given by different partners for the same energy role in the system.

Table 3-3 - TOP 3 grid services considered most relevant for the future energy system by role

Role	1st	2nd	3rd
Aggregator	Energy Storage Systems	Smart Metering	Demand Response
DSO	Smart Metering	Demand Response	LV online monitoring; Online Voltage Regulation; Smart Substation/Digital Transformers; IoT Grid Management Systems
TSO	Energy Storage Systems	Online Voltage Regulation	Smart Metering

Additionally the questionnaire investigated whether the partners are fully satisfied with the tools that they are actually using for their operation, and if they fulfill entirely their needs. The results are presented in the Figure 3-5

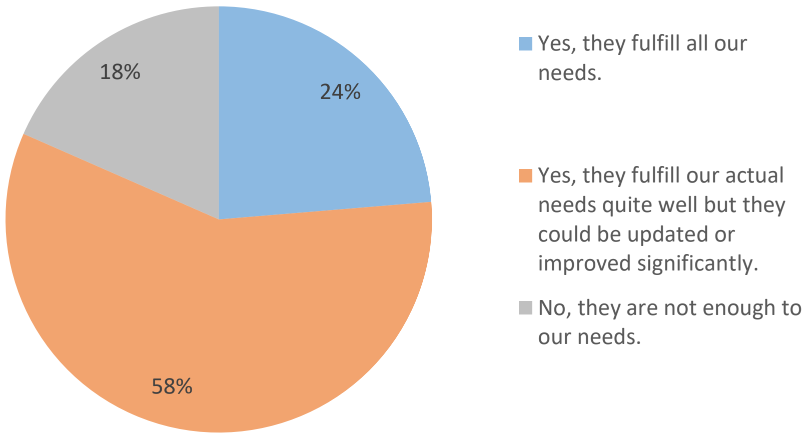

Figure 3-5 - Fulfilment of the needs with the actual tools used

By analyzing the results it is possible to notice that the majority of the participant consider that the tools that they are using fulfill their actual needs (82%) however, 58% of them consider that the actual tools are not prepared for the future needs and they have free room to be improved. This interesting result supports the need to reexamine the actual platforms in order to adapt them to the challenges that the future grid service will present to the different network players.

For the participants in the survey, the most important improvements that will be needed in a near future are:

- Integration of different platforms used for different purposes (for example, real time and operational planning systems);
- Facilitate the exchange of information/data between parties;
- Tools should be extended in order to accommodate more data according to the constant development of the electric system (more DER, etc.);
- Follow data exchange standards.

Focusing on the existing data exchange platforms, participants were asked on their opinion about some platforms and which of them are actually being used. Transparency platform, Electronic Highway, ENTSO-E Communication & Connectivity Service Platform (ECCo SP) and Energy Communication Platform (ECP) were the platforms that were asked in the survey regarding their usage among the participants. The use of standard models were also questioned, namely CIM/CGMES model. In Figure 3-6 the answers to each of these data exchange platforms are presented.

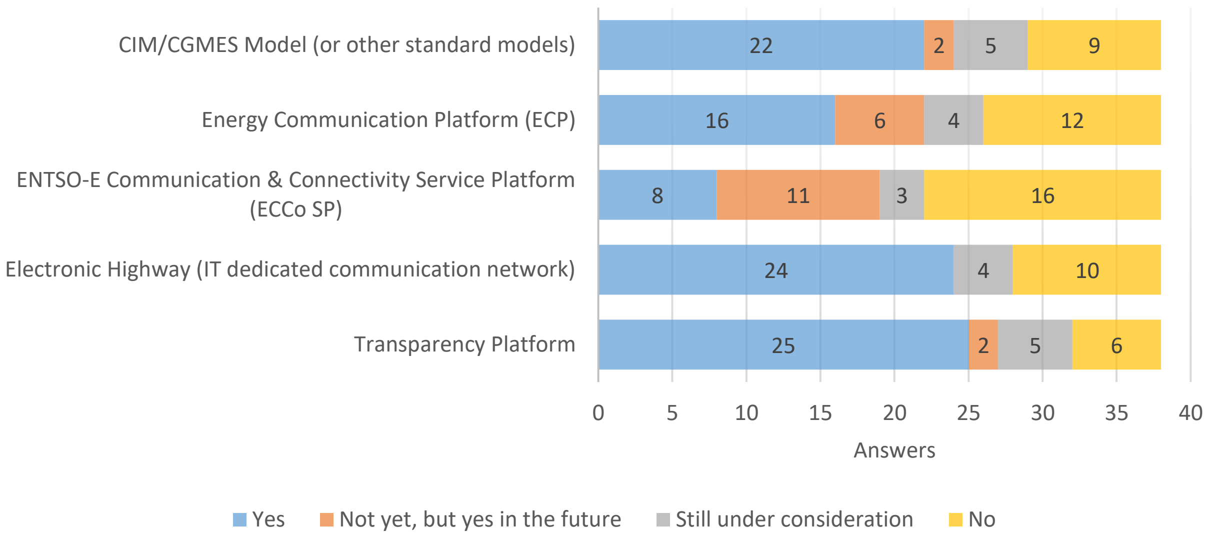

Figure 3-6 – Data exchange platforms usage

Most of the respondents are actually using the Electronic Highway and the Transparency Platform as a communication platform. Around 60% of the survey participants are using standard models to exchange data between different stakeholders. The ECCo SP platform is the one that less participants are using, however is the one that more participants are considering to use in the near future. Some other platforms that the respondents are using are: OPDE, Estfeed, ARIS, Generis, CONVERGENCE and DAMAS.

3.2 Market's tools and services

In this section, the current existing market tools and services were identified based on the survey, which was carried out with participants from various European countries. Six countries took part in the survey (see Figure 3-7).

Figure 3-7 – The participated countries in the market tools and services survey.

A total of 32 answers were received. The bar chart illustrated in Figure 3-8 shows the received answers based on the type of the stakeholders. As it can be noticed from this chart, the majority of the responses come from retailers and DSOs. The other energy stakeholders which are illustrated in the bar chart include: software manufacturer, power exchange, association, energy flexibility solution provider (IT), delegated operator, OEM of electric vehicle charging infrastructure, and electricity production and trading.

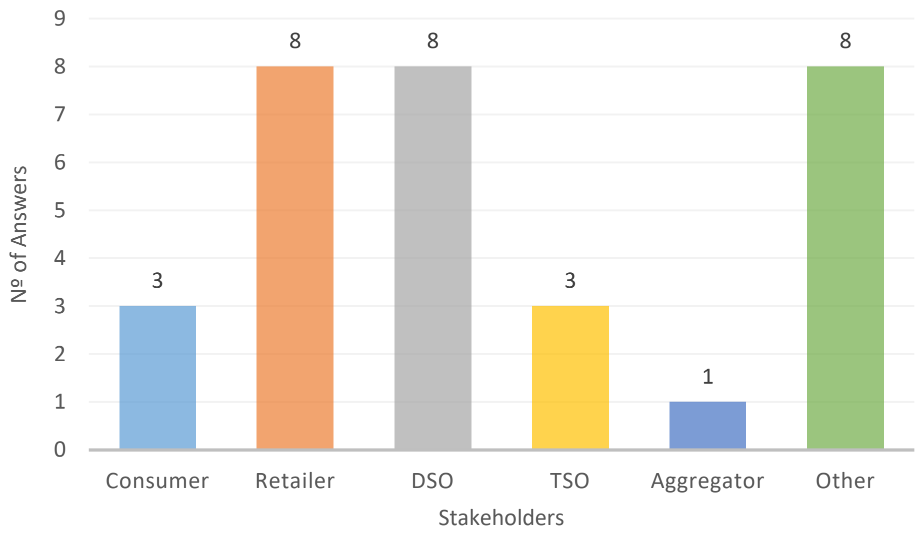

Figure 3-8 – The participated energy stakeholders and their corresponding number of answers in the market tools and services survey.

According to the survey, the function of each market platform was classified into three categories i.e. in-house made, 3rd party, and not applied. Some used functions use more than one platform. The percentage usage of each function according to its platform category is listed in Figure 3-9.

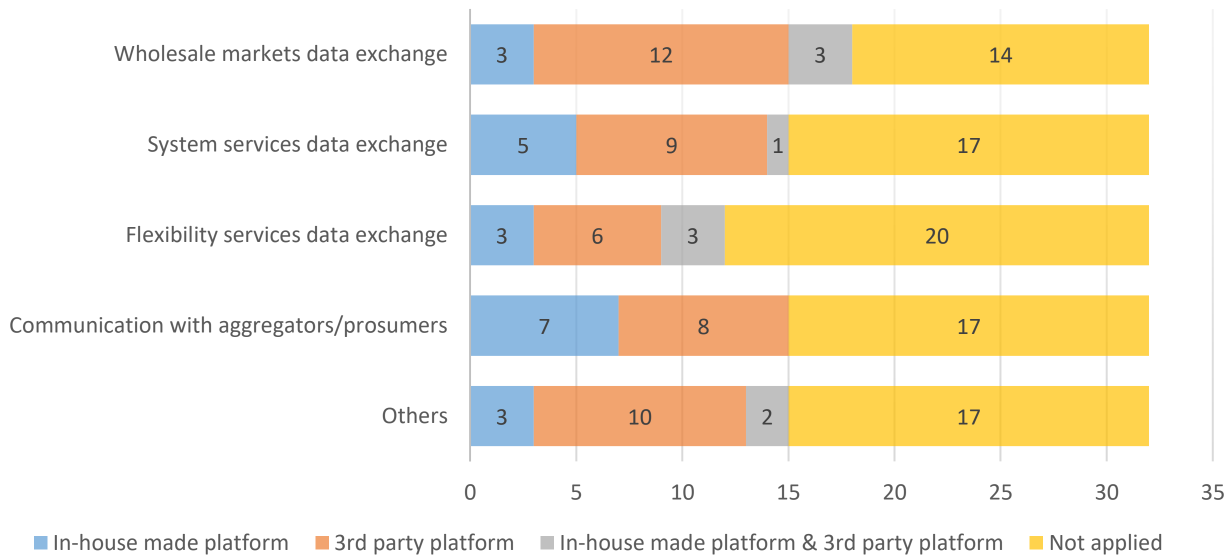

Figure 3-9 – The actually used platforms for market tools & services.

As can be observed from Figure 3-9, all the functions are implemented mostly using not paid platform. However, the tools and services of the in-house made and 3rd party platforms and their corresponding purposes were identified in the survey. Based on the received answers, the purposes of the wholesale markets data exchange functions involve; EMS, settlement, out-systems billing of producers, billing and collection of customers, buying energy for recovery of losses, intraday market,

day-ahead market, reporting to ACER as RRM for market participants, and collecting data from market.

Regarding the system services data exchange, the survey identifies the following purposes; IXS, communicate with SAP, receive load curves and aggregate consumption and production, auction platform and system services activation, primary and secondary frequency regulation, electronic data exchange, exchange of DSO and TSO data for imbalance settlement, balancing client, metering data exchange, metering point data, supplier switching, and system services data exchange.

Similarly, based on the survey answers, the purposes that are included in the flexibility services data exchange are: IXS, communicate with SAP, receive load curves and aggregate consumption and production, for demand side management, auction platform and system services activation, and Flexibility services data exchange. The purposes which are included in the Communication with aggregators/prosumers are; EDM, Telia data exchange, communicate with SAP, receive load curves and aggregate consumption and production, frequency regulation, EV charging control center and receiving charging requests from prosumers, sending flexibility offers to higher levels, receiving requests for flexibility activation, aggregators own platform, and private communication network for contract partners that provides system services to TSO. However, the other functions include the following; EMS, energy information open portal, communicate with SAP, receive load curves and aggregate consumption and production, scheduling system (Congestion management), power flow regulation, and common office for secure energy system operation.

However, the flexibility can be used in many different markets and products. For example, if every user (or buyer) of demand side flexibility organizes its own market, this could lead to market fragmentation and lack of transparency as well as to problems with the coordination between different market processes (e.g. double activation, etc.). Based on the survey, to overcome these problems in the future, the following four options were suggested; one single integrated market at regional or EU level; fully fragmented markets with robust coordination procedures in place; limited/regulated number of fully integrated markets; and other. The received answers from questionnaire are represented in Figure 3-10.

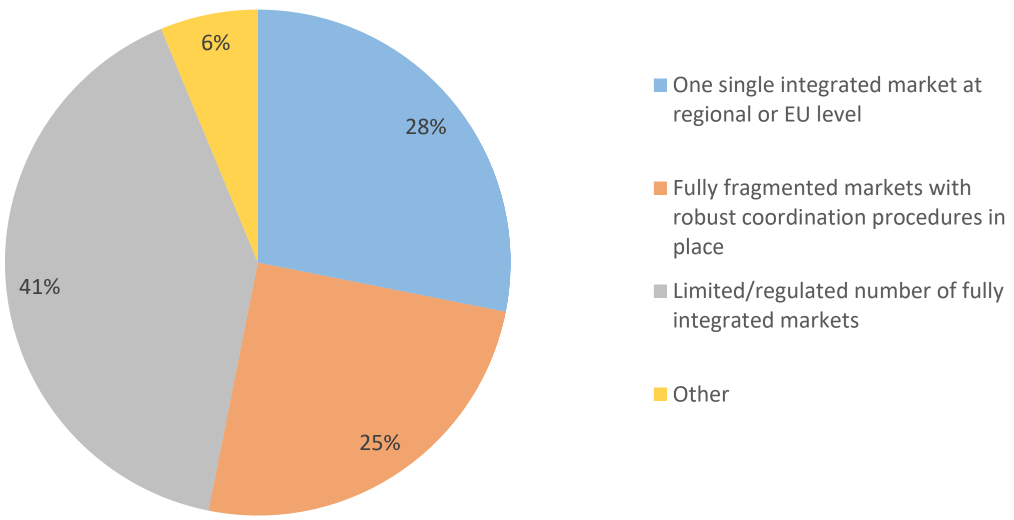

Figure 3-10 – The percentage of available options to deal with the flexibility problem which can be used in many different markets and products.

As it can be seen from Figure 3-10, as many as 41% of energy stakeholders mentioned that the best way to overcome the problem of using flexibility in many different markets and products is by developing limited/regulated number of fully integrated markets. While very close percentages of answers i.e. 28%, 25% reported that the best way to overcome the mentioned problem is by using one single integrated market at regional/EU level, and by using fully fragmented markets with robust coordination procedures in place, respectively. On the other hand, only 6% of the energy stakeholders have their own perspective to deals with the problem.

The energy stakeholders that took part in the survey were asked on their opinion if the target market model should be implemented based on one of the existing frameworks on common integral market designs for the trading of flexible energy use; the results are shown in Figure 3-11. As it can be seen from this figure, the majority of the responses are neutral followed by strongly agree, agree, disagree, and strongly disagree.

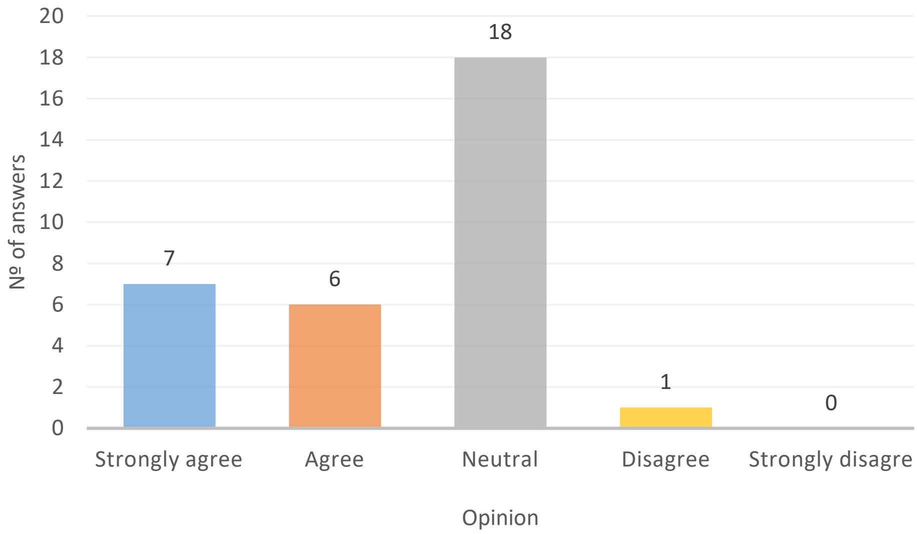

Figure 3-11 – Answers related to the target market model.

Explicit demand side flexibility in the market requires quantification of the amount of flexibility delivered. Since flexibility by its definition cannot be measured, a baseline is needed to quantify the delivered flexibility. Chosen baseline methodology should be accurate, simple, transparent, unbiased, disabling gaming-options by design in order to assure proper functioning of explicit demand side flexibility. Based on this, it was asked about the optimal approach for choosing the baseline methodology was examined through the survey. The received answers are illustrated in Figure 3-12.

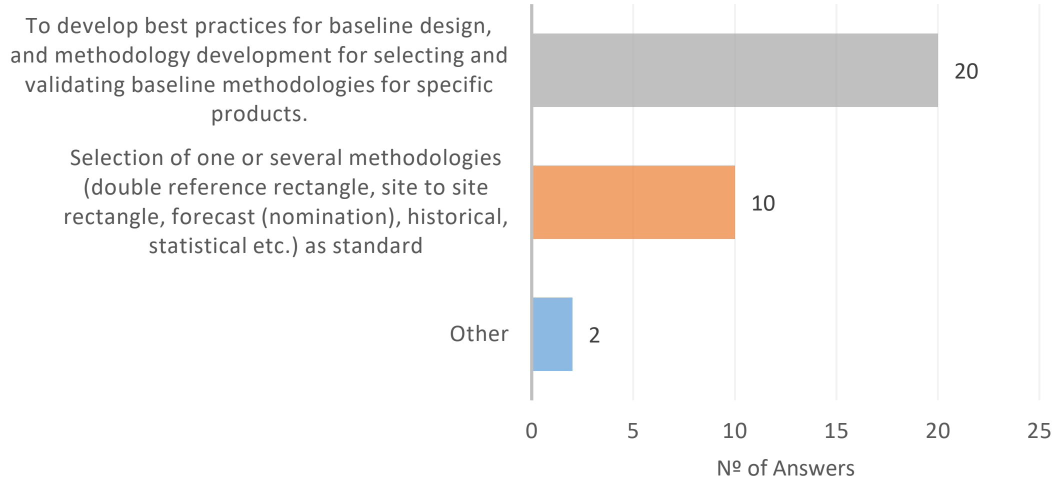

Figure 3-12 – Number of answers for optimal approach to choose the baseline methodology.

Based on the EU specifications which were defined in 2012, the roll out of smart meters will be finalized by 2020 in the majority of the European countries. Consequently, it was expected that the market will develop rapidly after 2020, and the energy system will undergo a major transformation. New requirements on real time data require much more flexible AMI architecture so new (even not yet known today) requirements can be smoothly implemented when they become relevant. In the survey, it was asked about the best way to assure that. The obtained answers are illustrated in Figure 3-13.

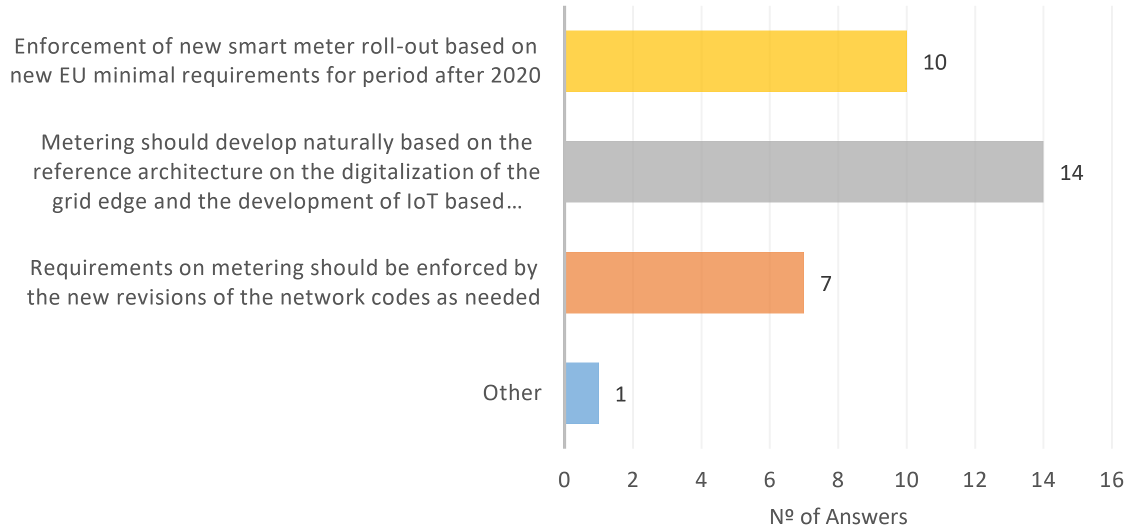

Figure 3-13 – The received answers for the requirements of flexible AMI architecture in the real time data.

As it can be seen from the Figure 3-13, a 44% of answers mentioned that the metering should develop naturally based on the reference architecture on the digitalization of the grid edge and the development of IoT based ecosystems. 31% of the responses were in line with the enforcement of new smart meter roll-out based on new EU minimal requirements for the period after 2020. On the other hand, a 22% of the responses stated that the requirements on metering should be enforced by the new revisions of the network codes as needed. However, only 3% of participants responded differently.

Due to the connected technologies and renewables, which turn consumers into prosumers the world of energy, is quickly changing from a top down to a distributed model. The emerging distributed model creates many additional challenges to the existing ones. Despite the fact that block chain technology is to be the key enabler of this revolution there is, amongst others, one big challenge addressing cybersecurity (interconnected smart grid) and data privacy (GDPR). In the context of understanding the complexities regarding the new block chain technology, the rating of the key issues was examined in the survey. The key issues and their corresponding received answers are depicted in Figure 3-14.

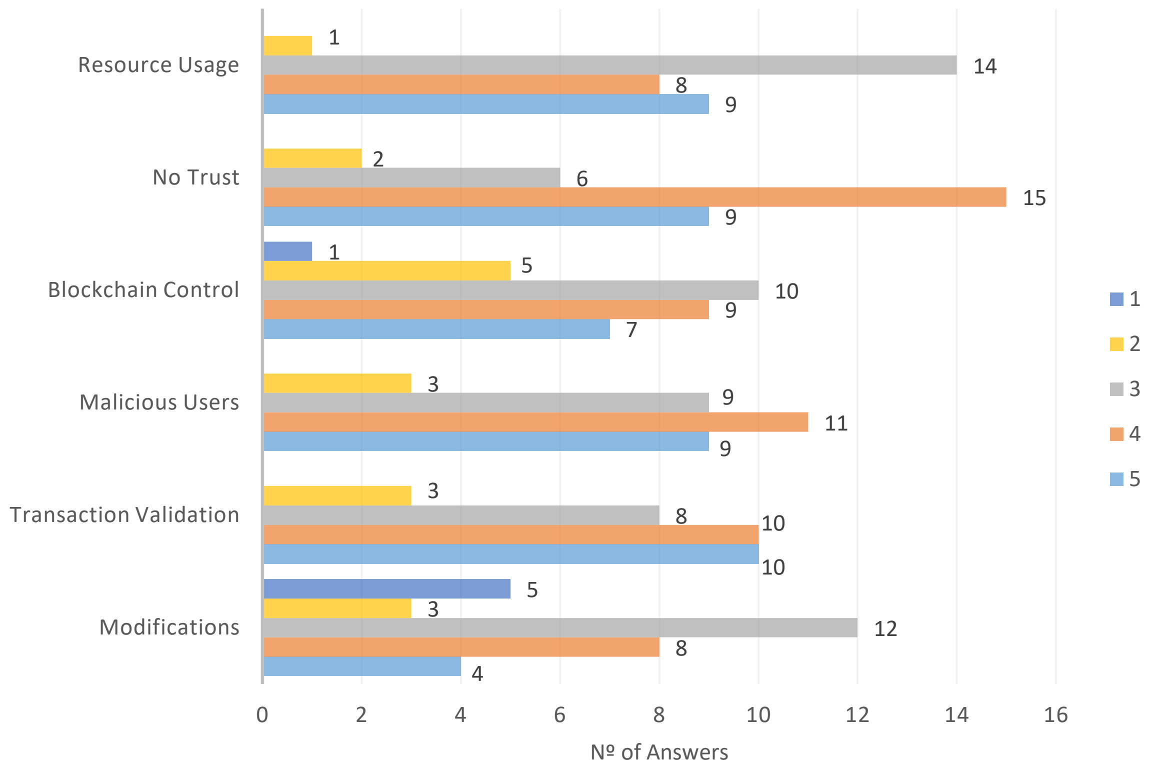

Figure 3-14 – The key issues of the new block chain technology and their corresponding answers.

4 Conclusions

The present document is the second deliverable of the INTERRFACE project Work Package (WP) 2 “SOTA Analysis/Assessment and End-User Requirements”. The main contribution of this deliverable is the listing and description of existing tools and services, which will be handed over to Task 3.1 and Task 3.3 to further describe new services envisioned as well as the dependencies and connection between tools and datasets, to adjust the data granularity and enable a proper market integration, as well as to Task 4.4 for the implementation of the interfaces of these tools to the IEGSA platform.

The most common services provided by different stakeholders of the energy value chain for data collection and delivery are listed in Chapter 2.1. Grid services are presented from the flexibility viewpoint, describing frequency control processes as well as congestion management and voltage control. User services are presented from aggregators and end-users viewpoint with examples of services, provided by three main European aggregators. In the Market services chapter the standard ancillary services and special services for UCTE, GB and Nordics are presented as well as retail market services. The most commonly used tools are listed in Chapter 2.2, including grid and market tools.

As mentioned, a survey about the actual tools and services was carried out in order to identify the current European landscape from the grid and market point of view. For that reason the survey was split in two surveys, one dedicated to grid tools and services and other to the market tools and services.

The grid tools and services survey had a total of 38 answers from different energy stakeholders covering 20 different European countries. This survey has focused in the identification of the tools that are being used for different purposes/services (operational planning, real time, data exchange, etc.) and in the services that the participants foresee as crucial in the future energy system.

From the results it was interesting to identify that most of the tools used are 3rd party platforms/tools unless for the forecasting tools where it’s possible to see that most of the tools are developed in house by each company that needs this kind of services. The vision of the future energy system, from the participants’ responses, presents the Energy storage systems as the most important grid service in a near future, giving also attention to the Smart Metering and Demand response. Analyzing the results it is also possible to notice that most of the participants are aware that the actual tools can fulfil their actual needs, however, they consider that the actual tools are not prepared for the future needs and for the upcoming grid services. This is an interesting result that supports the need to rethink and improve the actual platforms/tools in order to adapt them to the imminent challenges that the future energy system can bring.

A survey based on the tools and services of the market players has been carried out within Europe. A total of 32 answers from a variety of energy stakeholders have been received from six participating countries. The survey has focused mainly on the currently used platforms and their functions, flexibility, and target market.

The results outcomes have shown that all the functions are implemented mostly using a not paid platform. Regarding the problem of using flexibility in many different market and products, the majority of energy stakeholders stated that the best way to overcome this problem is by developing a limited/regulated number of fully integrated markets. However, most of the received answered have pointed out to neutral opinion in terms of if the target market model should be implemented based on one of the existing frameworks on common integral market designs for the trading of flexible energy use.

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