ReDREAM

change your energy

D2.5 Connection with Electricity Market Software

March 2022

Technical References

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[1] PU = Public

PP = Restricted to other programme participants (including the Commission Services)

RE = Restricted to a group specified by the consortium (including the Commission Services)

CO = Confidential, only for members of the consortium (including the Commission Services)

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Review

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V0.2	20/01/22	*Rubén Rodríguez*	*Addition of explanations of national energy markets.*
V0.3	27/01/22	*Olga Rico*	*Addition of connection with OMIE and annexe with SOAP explanation. IREMEL and self-consumption in Spain.*
V0.4	10/02/22	*Francisco Martín* *Rubén Rodríguez*	*Minor changes explaining further the OMIE connection and explanation of the flexibility markets. Add API connection details with ESIOS.*
V0.5	20/02/22	*Francisco Martín*	*Add connection with ENTSOE, Elexon, Octopus Energy and design of Retail Markets.*
V0.6	28/02/22	*Olga Rico* *Rubén Rodríguez*	*Add details in Flexibility markets for each demo*
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Summary

ReDREAM Project

The energy market is rapidly transforming, and so is the role of the Consumer. Yesterday's passive consumers are central actors in today's energy markets. As new prosumers, energy markets can benefit from their generation, consumption and storage capabilities. The EU-funded ReDREAM project will enable the effective participation of consumers and prosumers in the energy market. The project will develop a strategy for creating a value generation chain based on a revolutionary service-dominant logic in which services are exchanged. The project will foster the demand response tools and energy/non-energy services that enable consumers to participate in the energy market. This will lead to the establishment of a new concept: a connected user-centred energy ecosystem.

Deliverable Summary

How have the tools been developed to connect with the electricity markets?
How are the electricity markets involved in REDREAM demo countries?
How are the electricity tariffs in these countries?
Does collective self-consumption to make peer-to-peer exchanges exist?

The aim of Deliverable 2.5 is to develop a tool to connect the electricity markets of the demo countries to obtain price cleared and send bids to take part in the different markets. Before explaining the tool developed, a description of the markets is done.

The first part of the deliverable defines the different markets analysed, distinguishes between energy and ancillary and local flexibility markets. This differentiation is developed in Section 1. Energy markets analysed in Section 2 are mainly wholesale markets at a national level, retail markets and (collective) self-consumption at a local level. Regarding ancillary and local flexibility markets, ancillary services and capacity markets are considered at a national level. In contrast, distribution constrains markets at a local level, also known as local flexibility markets. All these markets are defined in Section 3. Special attention is given to retail tariffs, (collective) self-consumption and local flexibility markets, as national markets were widely defined in deliverable 1.3 [1].

Country	Energy Market		Ancillary and Local Flexibility Market	
	National	Local	National	Local
Spain	Day-ahead, intraday auctions, intraday continuous	Retail, collective self-consumption	aFRR, mFRR, RR, Capacity market	IREMEL
United Kingdom		Retail	DC, DM, DR, STOR, RR, ODFM	Flexible Power
Croatia	Day-ahead, intraday continuous		mFRR, aFRR	-

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Italy	Day-ahead, intraday auctions, intraday continuous	Retail, collective self-consumption	Ex-ante and Balancing Market (FCR, mFRR and RR), UVAM project.	-

As a starting point for the above-described objectives, this report describes the creation of an interface that connects to the different markets at the national and local levels. Thanks to this and the defined ecosystem, consumers can exchange flexibility and energy at the national and local levels.

The software developed in this document permits the connection with the Spanish national energy market through the API of OMIE (Spanish market operator). It enables a download of the daily market matching prices and uploading offers to the daily market. Still, it also opens the door to additional developments depending on future requirements and different countries.

On the other hand, a software is developed that connects to the ENTSO-E API that obtains information from the European energy markets as well as the connection with the API of ELEXON, a UK portal that allows obtaining operational data related to balancing and settlement agreements for electricity in the UK, and data from Octopus Energy (a British company that offers a tariff that depends on the wholesale energy market in Great Britain). This data is obtained through Agile Octopus API, downloaded and stored for the efficiency and demand response tool.

Downloading data from local flexibility markets in Spain will be obtained from IREMEL, which has not been done in this deliverable because their tool is not developed yet, and there is a lack of information. Prices for auxiliary markets in Spain are managed by Red Eléctrica de España (REE), and OMIE controls the prices and production of the energy markets. The ESIOS platform with which a connection tool is being developed through its API. And finally, for the connection with the flexibility markets, in this case, there is WPD in the United Kingdom, with which software is developed that achieves the connection through its API.

For clarification purposes, the following summary table shows the connections made and those pending to be made in the four demo countries, shown in the rows. The first two columns of the table show the connection with the national energy markets and collective self-consumption. The next two columns refer to the ancillary services and local flexibility markets, and in the last column the connections with different platforms to obtain the CO_2 emitted by each country due to energy generation.

	Energy markets		**Ancillary and local flexibility markets**		**CO_2**
	National	**Collective self consumption**	**Ancillary services**	**Local flexibility market**	
Spain	Implemented the connection with the Spanish national operator (OMIE)	No necessary interface for T2.4 task.	Implemented for aFRR, mFRR and RR balancing markets. ESIOS	There is no available interface yet. It will be implemented as soon it is available.	Implemented with ENTSOE

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United Kingdom	Implemented with Octopus and ELEXON	No necessary interface for T2.4 task.	Not implemented. A simulation with Spanish markets will be carried out	Implemented for local congestions (WPD)	Implemented witn ELEXON
Croatia	Implemented reading from ENTSOE		Not implemented. A simulation with Spanish markets will be carried out		Implemented with ENTSOE
Italy	Implemented reding from ENTSOE	No necessary interface for T2.4 task.	Not implemented. A simulation with Spanish markets will be carried out		Implemented with ENTSOE

The implemented results shown in the table in highlighted colour, are the ones that are developed and the rest are in the process of development or not available.

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Table of Acronyms

Acronyms	Description
aFRR	automatic Frequency Restoration Reserve
AP(s)	Action Point(s)
API	Application Programming Interface
BRP	Balance Responsible Party
BSP	Balance Service Provider
CA	Consortium Agreement
CHP	Combined Heat and Power
CMZ	Constrain Management Zone
DA	Day-ahead market
DER	Distributed Energy Resource
DNO	Distribution Network Operator
DR	Demand Response
DSF	Demand-Side Flexibility
DSO	Distribution System Operator
EBGL	Electricity Balancing Guidelines
EC	European Commission
ECP	Electric Charging Post
ECR	European Commission Reporting
EE	Energy Efficiency
ENTSO-E	European Network of Transmission System Operators for Electricity
EPOV	Energy Poverty Observatory
EV	Electric Vehicle
FCR	Frequency Containment Reserve
FSP	Flexibility Service Providers
GA	Grant Agreement
GDPR	General Data Protection Regulation
H2020	Horizon 2020 programme
HBS	Household Budget Survey
HH	Half-Hour
ID	Intraday market

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LTP	Linked Third Party
mFRR	manual Frequency Restoration Reserve
NEMO	Nominated Electricity Market Operator
NRA	National Regulation Agency
OAuth 2	Open Authorization
PC	Project Coordinator
PMB	Project Management Board
PTC	Project Technical Committee
PVPC	Voluntary Price for the Small Consumer
RES	Renewable Energy Sources
RR	Restoration Reserve
SDAC	Single Day-Ahead Coupling
SIDC	Single Intraday Coupling
SILC	Survey on Income and Living Conditions
SME	Small and Medium Enterprise
SO	System Operator
SOC	State of Charge
T&C	Terms & Conditions
TPR	Ten Percent Rule
TSO	Transmission System Operator
UC	Use Case
UML	Unified Modelling Language
VRE	Variable Renewable Energy
WP(s)	Work Package(s)
WPD	Western Power Distribution

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1 Introduction

Deliverable D2.5 of ReDREAM project, "Connection with electricity market", aims to carry out the connection with the national and local energy markets, as well as Ancillary and Local Flexibility Markets within the framework of task T2.4.

For this purpose, tools have been developed to connect STEMY platform with OMIE (Iberian market operator) trading platform to get the Spanish market prices directly when they are published after each auction and send offers to the platform through this system. This connection has been possible thanks to the development of API that allows us to generate two main calls, implemented in java code: one call to obtain electricity prices automatically and the other to send offers, both available as .bat executables for any software.

Tools have also been developed for the connection with ENTSO-E that allows obtaining the prices of European national markets, furthermore the connection with the British national market: ELEXON; and finally, with the British Flexibility market: WPD and with the Spanish Flexibility market: IREMEL.

In this sense, the **main objective** of this document is to describe in detail how the connections with the national, local, and flexible energy market have been made.

Objective 1: Definition of the retail markets present in each member country of the project, differences and peculiarities.

Objective 2: Detail the local flexibility markets available in the four project member countries.

Objective 3: Description of the national energy markets based on the relevant information obtained from deliverable D1.3.

Objective 4: Definition of the different self-consumption models present in the four project member countries and specification, if available, of shared collective self-consumption models for peer-to-peer energy exchanges.

Before developing the tools, throughout this document, there will be a clear differentiation between the different markets analysed. First of all, a differentiation between the type of energy traded has been done.

Electricity markets explained in Task 1.3 were: day-ahead and intraday markets, Balancing Markets, Capacity markets, and Local Flexibility Markets. Throughout this document, these markets have been grouped into two markets: **Energy markets** and **Ancillary and Local Flexibility markets**.

It has been considered as **Energy Market** those in which energy is traded between generators and consumers (usually represented by energy suppliers); these are the wholesale markets, composed of day-ahead and intraday markets. Most of the energy consumed and generated is procured in this market.

The other type of market described is the **Ancillary and Local Flexibility Market**. We have considered as flexibility markets those in charge of maintaining the proper conditions of working the electricity system as a whole, from the transmission to distribution grids. These markets are: balancing markets, capacity markets and local flexibility markets.

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Table 1: Summary of services and markets available in demo countries.

Sections in the deliverable	Category	Managed by	Services
2. Energy Market	**Wholesale Markets (WM)**	Market Operator	Day-Ahead (DAM) Intraday Markets (IDM)
3. Ancillary and Local Flexibility Markets	**Ancillary Services (ASM)**	Transmission System Operator	**Frequency Restoration – Balancing Services:** FCR: <30s, up to 30min aFRR: <5min, up to 30min mFRR <15min, up to 4h RR <30 min up to hours
		Transmission System Operator, Distribution System Operator	Constraint Management Services: Voltage Control Grid Capacity Planning Congestion Management
	Adequacy Services	Transmission System Operator or 3rd parties depending on the regulation.	Capacity Markets Capacity Payments
	Local Flexibility Market	It depends on the country (Transmission System Operator, Distribution System Operator, Market Operator, Independent agent…)	Local Flexibility Market

Another differentiation carried out has been the scope of applicability of each of the markets aforementioned. The **National market** has been considered as that market in which the localisation of the asset participant does not matter (while it is in the same country), e.g. there is no limitation for the localisation of the generator in the wholescale market. In contrast, section 3 it has been defined **Local flexibility markets,** which are markets in that assets can only take part in flexibility procurement

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in a specific zone, usually limited by the distribution grid or distance limitation. Section 2 has also described how **retail markets** and how it is **self-consumption** and **the collective self-consumption** (if it exists in the country analysed).

Most information about energy and ancillary markets has been obtained from ReDream Deliverable 1.3. [1]. On the other side, there has been researched about the operation of local markets. Special attention has been given to how retail markets/tariffs work, the possibility of collective self-consumption, and available local flexibility markets in each country analysed in this document.

To obtain information from these markets, different connectivities have been developed. All of them have been done through remote APIs. Remote APIs are designed to interact over a communications network. The word remote indicates that the resources managed by the API are located outside the computer sending the request. Since the most widely used communications network is the Internet, most APIs are designed according to web standards. Web APIs typically use HTTP for request messages and provide a definition of the structure of the response messages. These response messages are usually XML or JSON files, which are the preferred formats because they present the data so that other applications can easily manipulate it. The connection using SOAP and REST APIs have been made in task 2.4.

The paper is structured in such a way that it starts with a review of the national and collective self-consumption energy markets of the four demo countries. At the end of this section is the connection made with these national markets: Spain (OMIE), United Kingdom (Octopus and SPOT), Croatia and Italy (obtained from ENTSOE); and the connection with the collective self-consumption markets (no interface for T2.4 task).

The following section will go into the ancillary and local flexibility markets, and their respective connections made for this deliverable. Ancillary services: Spain (ESIOS), United Kingdom, Croatia and Italy connections will be simulated with Spanish market; and Local Flexibility market: Spain (Iremel) which is under development, and United Kingdom (WPD).

In this derivable it will be also defined how is the connection with the different platforms to obtain the CO_2 emission and then be able to calculate the GHG emissions of customers at the moment they are using the electricity. So, a connection with Spain (ENTSOE), United Kingdom (ELEXON), Croatia (ENTSOE) and Italy (ENTSOE) is done to obtain this data.

The following table (Table 2) shows a summary of the connections made throughout the document, highlighted in colour, and those that are pending or will not be made with white background.

Table 2: Summary of connections with the different markets

	Energy markets		Ancillary and local flexibility markets		CO_2
	National	Collective self consumption	Ancillary services	Local flexibility market	
Spain	OMIE	No necessary interface for T2.4 task.	ESIOS	There is no available interface yet.	ENTSOE

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				It will be implemented.	
United Kingdom	ELEXON and Octopus	No necessary interface for T2.4 task.	Not implemented. A simulation with Spanish markets will be carried out	WPD	ELEXON
Croatia	Implemented reading from ENTSOE		Not implemented. A simulation with Spanish markets will be carried out		ENTSOE
Italy	Implemented reding from ENTSOE	No necessary interface for T2.4 task.	Not implemented. A simulation with Spanish markets will be carried out		ENTSOE

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2 Energy market

This section will describe how is the connection with the different electricity market platforms, describing the process done to obtain data and send offers to the platforms for the national markets of the demo countries. Before defining this, a description of the markets in which energy is procured for each demo country has been done. These markets have been divided into two different fields: national and local markets.

In national markets is where most of the energy is procured. Most of the electricity markets are based on marginal-cost pricing. Generators and energy retailers send their bids and offer to the market operator for each hour (or half-hour) traded in the market (e.g., the day-ahead market is the 24 hours of the following day). Then, generation offers are stacked in ascending price order, and demand is stacked in descending price. The market "clears" when the amount of electricity offered matches the amount demanded, then it is at this point when the cost of the electricity (€/MWh) is determined for that hour. This process is repeated for each hour of the market.

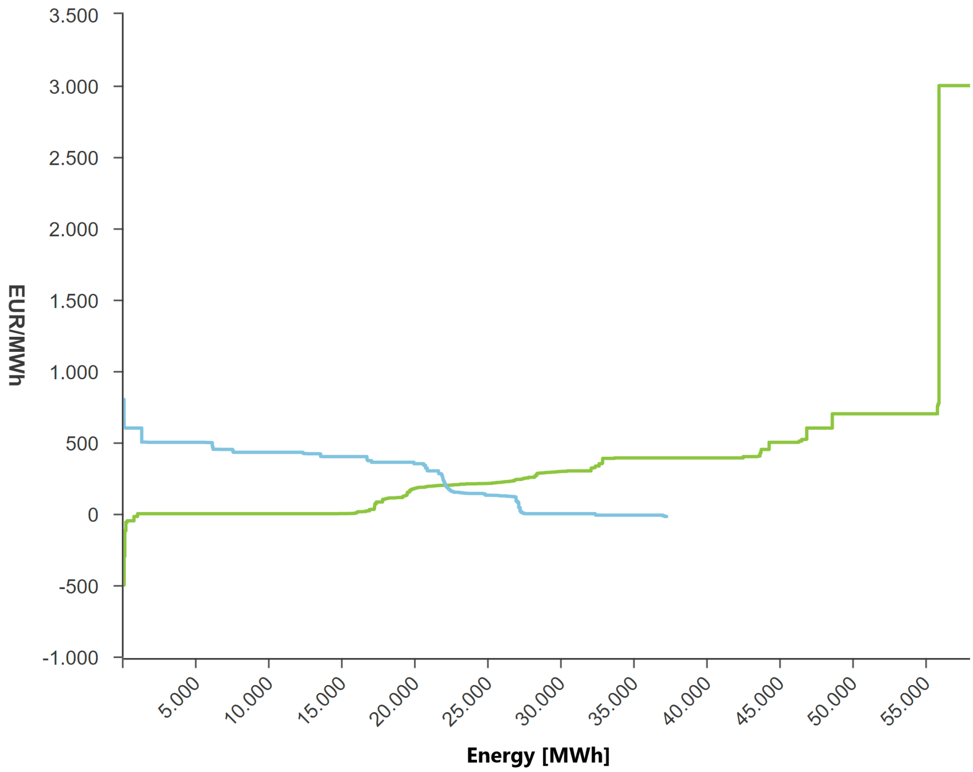

Figure 1 Aggregated supply and demand curves in the Iberian Electricity Market (MIBEL) for the first hour of 22/02/2022 [2]. The green line is the selling offers of energy (made by generators) and the blue line is the buying offers (made by energy suppliers).

National energy markets are composed of the following markets:

- **Day-ahead market**: electricity for the 24 hours (or 48 half-hours) of the following day is sold and bought. It is in this market in which most of the electricity is procured. Generators and consumers – represented by energy retailers – submit their bids in this market until noon. Most European countries are connected to the Single Day-Ahead Coupling (SDAC), which aims

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to create a pan European cross zonal day-ahead market; more information about this market can be found in D1.3 [1].

- **Intraday auction market**: electricity agents can adjust their portfolio after the day-ahead market in the intraday market. These changes could be due to a shift in the forecast of generation or consumption, biding strategy. The number of intraday market sessions varies from country to country, e.g. in Spain, there are six sessions while in Italy there are 3. Most intraday markets in Europe are within the Single Intraday Coupling (SIDC) system, creating a single EU cross-zonal intraday market, both for the auction and continuous markets. More information about intraday markets and SIDC can be found in D1.3 [1].
- **Intraday continuous market**: is similar to the previous one, but agents can benefit from the liquidity available in markets in other areas of Europe, given that cross-border transportation capacity is available between the zones, and also adjustments can be made up to 15 minutes before the moment of the delivery of energy. In D1.3 [1], a more detailed description of this market can be found.

After defining national energy markets, it has been described how retail tariffs are in each country of the project, pointing out the tariffs, the fees and taxes paid by customers, and if it is also available a regulated tariff controlled by a central institution. Furthermore, self-consumption and collective self-consumption has been described if available in the country studied.

After defining both types of markets, the connexion with different markets platforms available has been performed. First of all, it has been defined how the connection with the Spanish National market has been through OMIE, using an API SOAP and developing java classes to get the prices of the Spanish day-ahead send offers to the market. Other connectivities have been developed through REST API explained in D1.6. Thus, the connection of the API SOAP is more technically described. Second, the connectivity has been carried from the ENTSO-E transparency platform for Croatian and Italian markets, from which market data will be obtained. For the British market, data from the Balancing Mechanism Reporting Service (BMRS) of Elexon has been used to download and store information on the status of British markets. Finally, the design of retail tariffs has been done to be able to model any kind of tariff with a special connection to those tariffs that depend on the national energy market. One of them is the connection with a British retailer present in Bath end-users, and the other is the indexed tariff in the Spanish demo.

2.1 Spain

In the following table, we can see which are the main actors in the Spanish electricity system:

Table 3: Main Spanish actors in the electricity system

Actors	Description
NRA CNMC	**CNMC** – Comisión Nacional de los Mercados y la Competencia

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NEMO	**OMIE** – Iberian Market Operator (Spain and Portugal)
TSO	**REE** – Red Eléctrica de España
DSOs	There are more than 300 DSOs. 5 DSOs have 60-80% of distribution power (Endesa, Iberdrola, Naturgy, EDP, Viesgo)
Energy Suppliers	More **than 680** energy suppliers in the free market and eight energy suppliers in charge of marketing the regulated tariff (PVPC).

2.1.1 National Market

Spanish national electricity market can be divided into five markets:

- Organized and unorganized forward markets
- ***Mercado diario*** **(MD): Day-ahead market.**
- ***Mercado Intradiario*** **(MI): intraday market.**
- *Servicios de balance*: Balancing (Ancillary) markets.
- *Mercado de capacidad*: capacity market.

Day-ahead and intraday markets are where most of the energy is procured, while the last one is used for balancing (this one will be considered in this deliverable as a flexible market).

Spain's most important national energy market is the day-ahead and intraday markets (known as Spot Market), acquiring more than 70% of the energy consumed in Spain in 2020. Then, forward markets only account for 28% of the energy in 2020 [3]. Day-ahead and intraday markets are operated by the Spanish market operator OMIE, while OMIP operates forward markets. In this section, we are going to focus on Spot markets.

The Spanish day-ahead market is where most of the energy is assigned. Energy production and consumption are cleared every day at noon, and the hourly price is determined for the following day. The characteristics of the electricity bids are the following ones:

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Table 4: Characteristics of energy products for the day-ahead market in Spain [1].

Characteristics	Description
Gate opening time (GOT)	No limit
Gate closure time (GCT)	Day before at 12:00 CET
Granularity product (hourly, 30 mins, 15 mins)	Hourly
Minimum Quantity to bid	0,1 MW
Maximum Quantity to bid	No limit
Price Tick	0,1 €/MWh
Minimum bid price	- 500 €/MWh
Maximum bid price	+ 3,000 €/MWh

Regarding intraday market in Spain is structured by two contractual formats: continuous intraday market coupled with Europe and intraday action market.

Spanish intraday auction markets are divided into six bidding sessions for adjusting agents' portfolios for the following day and the same day for the case of Session 2:

Table 5: Spanish intraday auction markets timetable [4]. PIBCA is "Programa Intradiario Base de Casación Acumulado" (Intraday programme Cumulative Basis of Clearance), this programme is generated as a result of the clearing process of each of the intraday market sessions. PHF is "Programa Horario Final" (Final Programme Schedule), this programme is the result of the aggregation of all firm transactions concluded for each negotiable programming period.

	SESSION 1º	SESSION 2ª	SESSION 3ª	SESSION 4ª	SESSION 5ª	SESSION 6ª
Auction Opening time	14:00	17:00	21:00	1:00	4:00	9:00
Auction Closing time	15:00	17:50	21:50	1:50	4:50	9:50
Matching Process	15:00	17:50	21:50	1:50	4:50	9:50
Results publication (PIBCA)	15:07	17:57	21:57	1:57	4:57	9:57
TSOs Publication (PHF)	16:20	18:20	22:20	2:20	5:20	10:20
Schedule Horizon (Timing periods included in the horizon)	24 hours (1-24 D+1)	28 hours (21-24 y 1-24 D+1)	24 hours (1-24 D+1)	20 hours (5-24)	17 hours (8-24)	12 hours (13-24)

The opening of the negotiation of all contracts of the continuous intraday market for the next day (D + 1), in the price areas of Spain and Portugal, will be made after the end of the first auction of the current day (D). Market agents can negociate in this markets up to one hour before the delivery of energy (H-1).

In Section 2.5 has been developed a java class to obtain all data results from the different markets defined above and others to send offers to these markets.

2.1.2 Retail and Self-consumption in Spain

2.1.2.1 Retail tariffs

Spanish electricity sector was liberalised on the 1st of July 2009, separating all electricity activities in Spain: The end consumer can now contract an electricity tariff with any retail company and does not need to do so directly with the distribution company that supplies the electricity.

The electricity bills in Spain are divided into five components:

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A) Cost of energy: considers the cost of power in the day-ahead market (85.4% of the total cost of energy), cost of balancing services (7.3%), capacity payments (6.5%) and payment to the market and system operator, OMIE and REE (<1%).
B) Regulated costs: costs of transmission grid (10.1% of total regulated costs in 2020), distribution grid (31.4%), costs associated with the promotion of renewable energies (37.4%), production cost differential in non-peninsular territories (4.6%), annuities to recover prior years' deficits (16.4%) and CNMC (0.1%).
C) Commercialization margin: payment to the retailer for the services it renders (depending on whether the tariff is regulated or not).
D) Rental of measuring equipment.
E) Taxes: electricity tax (5.1127% applied to total costs) and VAT (21%)[1].

The only costs that are not regulated are the cost of the energy in the day-ahead market and the cost of the balancing services.

Consumers' bills are paid based on the energy consumed and the maximum contracted power. The maximum power is used only to calculate the transmission and distribution costs (€/kW), which are regulated. On the other hand, the energy consumption is paid at a price determined by the customer's tariff (a day-ahead market price or fixed price defined by the supplier) plus transport and distribution costs, also paid according to the energy consumed (€/kWh).

Transmission grid and distribution grid costs, known as tolls (*Peajes* in Spanish), are regulated and vary depending on the hour. For residential customers (low voltage and up to 10 kW), there is one unique toll, 2.0 TD, which has three different time bands for the energy consumed and only two for the power.

The three different time bands for energy consumption **tolls** are:

- The **peak period** (*Periodo de punta*) is where the highest toll price occurs. It ranges from 10 a.m. to 2 p.m. and from 6 p.m. to 10 p.m. on weekdays.
- The **flat period** (*Periodo de llano*): Price between peak and off-peak periods, from 8 a.m. to 10 a.m., 2 p.m. to 6 p.m. and 10 p.m. to 12 p.m., on weekdays.
- The **off-peak period** (*Periodo de Valle*) is the lowest toll price. It ranges from 12 p.m. until 8 a.m. on weekdays, and all hours of Saturday, Sunday and public holidays.

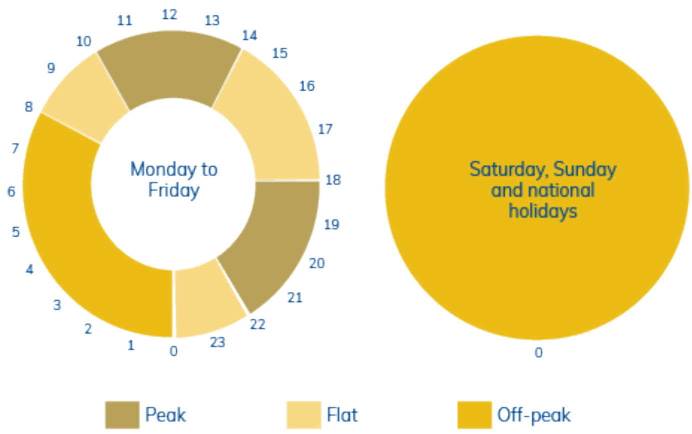

Figure 2 Time bands for energy consumption in 2.0 TD tariffs in Spain [5].

[1] Because the current high prices of electricity in Europe taxes have been reduced: hydrocarbon taxes to 0.5% and VAT to 10%.

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And the two different time bands for power tolls are:

- The peak period: from 8 a.m. to 12 p.m. on weekdays.
- The off-peak period: from 12 p.m. to 8 a.m. on weekdays, and every hour of Saturday, Sunday and public holidays.

SME customers (toll 3.0TD, low voltage and more than 15 kW) and industrial customers (toll 6.0 to 6.4 TD, high voltage) have six different time bands depending on the hour, day of the week and the month of the year. Period 1 has the highest toll that decreases until Period 6. In the following table appears the distribution of the periods during a year:

Table 6: Time bands SME and industrial customers. The most expensive hours are the P1 periods and the less expensive are the P6 periods.

Hours	January	February	March	April	May	June	July	August	September	October	November	December	Weekends and holidays
00:00 - 01:00	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6
01:00 - 02:00	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6
02:00 - 03:00	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6
03:00 - 04:00	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6
04:00 - 05:00	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6
05:00 - 06:00	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6
06:00 - 07:00	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6
07:00 - 08:00	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6	P6
08:00 - 09:00	P2	P2	P3	P5	P5	P4	P2	P4	P4	P5	P3	P2	P6
09:00 - 10:00	P1	P1	P2	P4	P4	P3	P1	P3	P3	P4	P2	P1	P6
10:00 - 11:00	P1	P1	P2	P4	P4	P3	P1	P3	P3	P4	P2	P1	P6
11:00 - 12:00	P1	P1	P2	P4	P4	P3	P1	P3	P3	P4	P2	P1	P6
12:00 - 13:00	P1	P1	P2	P4	P4	P3	P1	P3	P3	P4	P2	P1	P6
13:00 - 14:00	P1	P1	P2	P4	P4	P3	P1	P3	P3	P4	P2	P1	P6
14:00 - 15:00	P2	P2	P3	P5	P5	P4	P2	P4	P4	P5	P3	P2	P6
15:00 - 16:00	P2	P2	P3	P5	P5	P4	P2	P4	P4	P5	P3	P2	P6
16:00 - 17:00	P2	P2	P3	P5	P5	P4	P2	P4	P4	P5	P3	P2	P6
17:00 - 18:00	P2	P2	P3	P5	P5	P4	P2	P4	P4	P5	P3	P2	P6
18:00 - 19:00	P1	P1	P2	P4	P4	P3	P1	P3	P3	P4	P2	P1	P6
19:00 - 20:00	P1	P1	P2	P4	P4	P3	P1	P3	P3	P4	P2	P1	P6
20:00 - 21:00	P1	P1	P2	P4	P4	P3	P1	P3	P3	P4	P2	P1	P6
21:00 - 22:00	P1	P1	P2	P4	P4	P3	P1	P3	P3	P4	P2	P1	P6
22:00 - 23:00	P2	P2	P3	P5	P5	P4	P2	P4	P4	P5	P3	P2	P6
23:00 - 24:00	P2	P2	P3	P5	P5	P4	P2	P4	P4	P5	P3	P2	P6

Customers in Spain have the chance to choose between electricity tariffs in the liberalised or market and regulated market.

In the regulated market, there is a unique tariff known as PVPC (Voluntary Price for the Small Consumer). This tariff, offered by regulated retailers, has its prices established by the government, except for the energy price, determined by the price cleared in the day-ahead market.

Only residential consumers (up to 10 kW) can contract this tariff and, depending on their socio-economic situation, can access a discount of up to 50% of the total bill (known as *Bono Social Eléctrico*) depending on the socio-economical status of the consumer.

More than 10 million consumers have contracted a tariff in the regulated market (39% of the consumers in the retail market), of which 1 million benefits from the discount of the *Bono Social Eléctrico* [6].

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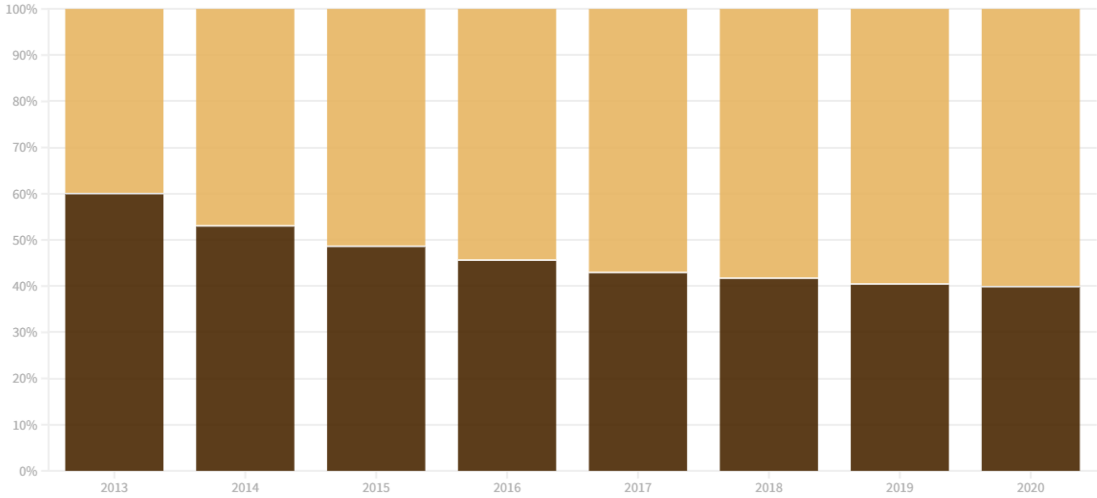

Figure 3 Percentage of consumers contracting electricity on the liberalised market (light brown) and the regulated market (dark brown) [6].

Regarding the liberalised market, Spain has 689 retailers at the national or regional level that offer different modalities of tariffs: fixed price in one or two time periods, indexed price to day-ahead market, flat fee tariffs, etc. The most important retailers in Spain are Endesa (32%), Iberdrola (24%) and Naturgy (9%).

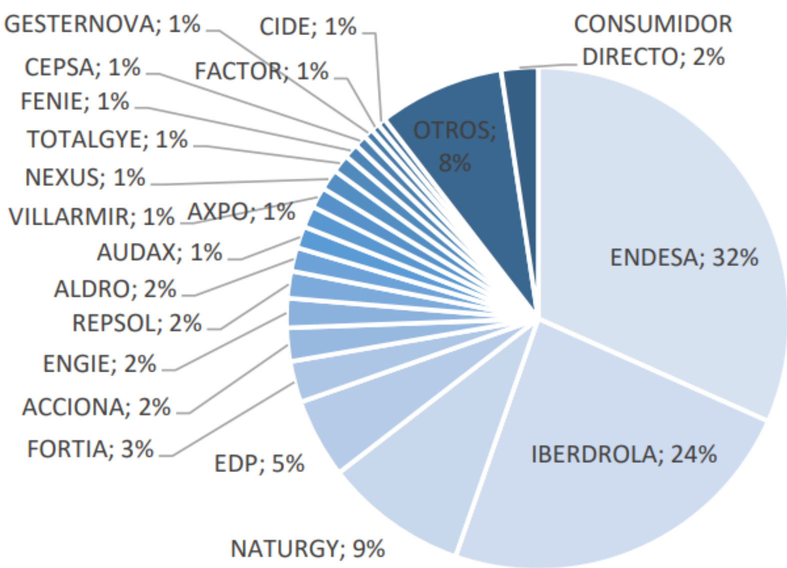

Figure 4 Percentage of energy supplied in Spain by each energy retailer [7].

2.1.2.2 Self-consumption

In Spain, the decree-law 244/19 regulates the administrative, technical, and economic conditions for self-consumption [8]. This Decree completes the regulatory framework in this area, driven by Royal Decree-Law 15/2018, which repealed the "sun tax" and provides greater certainty and security to users. This decree-law allows individual and collective self-consumption to reduce administrative formalities and establishes a simplified mechanism for compensating the energy discharged into the public grid.

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The installation models in Spain [9] are self-consumption facilities without surplus, self-consumption facilities with surplus under-compensation, and self-consumption facilities with a surplus without compensation. In this section, all of them are going to be defined:

1. **Self-consumption facilities without surplus**

There are self-consumption installations, which, although connected to the internal network, do not transfer energy to it. They are provided with an anti-dumping system.

2. **Self-consumption facilities with surplus**

This type of installation can inject surplus energy into the transmission and distribution networks in addition to self-consumption.

The production facilities close to and associated with the consumption facilities (both in the internal network and those that use the distribution or transport network) belong to this group. Within this group, there are two types: Self-consumption facilities with surplus under-compensation and self-consumption facilities with a surplus without compensation.

a) In **self-consumption installations with surpluses under-compensation**, both the producer and the consumer benefit from the surplus compensation system, which means that the consumer uses the energy coming from the self-consumption installation when required and buys energy from the grid at times when the energy coming from the self-consumption facility does not satisfy its electricity demand. In addition, when not all the energy from the self-consumption installation is consumed, it can be injected into the grid, and in each billing period (maximum one month), the cost of the invoice for the energy purchased from the grid will be compensated with the surplus energy poured at the average price of the hourly market minus the cost of deviations (PVPC) or at a price agreed with the marketer.

    a. In order to be eligible for this compensation system, a series of conditions must be met, as described below: The primary energy has to be of renewable origin, the total installed power of associated production may not exceed 100 kW, the consumer has had to sign a single supply contract for associated consumption and for auxiliary consumption with a marketing company, in addition, both the producer and the consumer have had to associate a self-consumption surplus compensation contract defined in article 14 of Royal Decree 244/2019, and finally the production facility must not be subject to the perception of a different or specific retributive regime.

b) In the case of **self-consumption with surpluses not subject to compensation**, all self-consumption with surpluses that do not meet any of the requirements of the previous modality will belong to this modality. In this case, the surpluses will be sold in the electricity market.

3. **Collective self-consumption**

Spain has also regulated **collective self-consumption** [10], also known as “peer-to-peer”, so that several consumers can be associated with the same generation plant, which will promote self-consumption in homeowners' communities. This possibility has been facilitated by the production facilities close to the consumption facilities and associated with them.

The Royal Decree 244/2019 aforementioned, of April 5, which regulates self-consumption, provides for the existence of coefficients to distribute energy in collective self-consumption. The value of these distribution coefficients depends on the agreement between the participants, with the only requirement that they are constant values. These criteria and coefficients must be included in the agreement between the parties, which each consumer must send to the distributor directly or through its commercialization company. As a last resort solution, and if the participants do not submit different values, the regulation provides distribution coefficients calculated based on the maximum power

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contracted by the participating consumers. The project has considered these virtual solar plants for individuals where the production corresponds with the coefficient multiplied by the total production.

It is also important to know that in Spain, collective self-consumption using the public grid is physically and geographically limited by the following conditions:

- Participating entities must be located within the low voltage distribution network derived from the same transformation centre.
- The maximum distance between production and consumption meters is 500 meters.
- The participating entities must be located in the same cadastral zone.

2.2 United Kingdom – Great Britain (GB)

In the following table, we can see which are the main actors in the British electricity system:

Table 7: main British actors in the electricity system

Actors	Description
NRA ofgem	**Ofgem** – Office for Gas and Electricity Markets
NEMOs epexspot NORD POOL	The two NEMOs for GB are **European Market Coupling Operator AS** and **EPEX Spot SE.**
TSO nationalgridESO	**NGESO** - National Grid ESO
DSOs	There are **14 DNOs** owned by six groups licensed by Ofgem to distribute electricity in GB
Energy Suppliers	There are **118 licensed domestic/non-domestic electricity suppliers** and **50 licensed suppliers of non-domestic** electricity in GB.

2.2.1 National Market

GB electricity markets fall into the following categories:

- **Wholesale market: day-ahead and intraday (auction and continuous)**

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- Ancillary balancing services: Dynamic Containment, Firm Frequency Response, Short Term Operating Reserve and Replacement Reserve.
- Balancing mechanism.
- Capacity market.
- Local flexibility.

For this section, we will focus on the markets that trade most of the energy, which is the wholesale market in the case of the United Kingdom.

British day-ahead market is managed for two different NEMOs: Nord Pool and EPEX Spot. In each NEMO, generators and suppliers can make bids for energy. In both NEMOs, there are three energy products for the day-ahead market:

- Hourly auctions: with 24-hourly delivery periods for the following day.
- Half-hourly (HH) auctions: 48 half-hourly delivery periods for the next day.
- Day-ahead explicit auctions on interconnections: transmission capacity between France, Belgium, and the Netherlands are auctioned.

The intraday market is structured in two different markets: intraday auction markets and continuous markets. **Intraday auctions market** is divided into two separate sessions: IDA1, in which can be traded electricity for the 24 hours of the flowing day and is closed at 18.30 the day before the delivery and IDA2, in which can be traded electricity for the same day, from 12.00 p.m. to 12.00 a.m, and is closed at 9.00 a.m. of the delivery day. The **continuous intraday market** is based on constant trading of products with up to half-hour granularity and is organized by Nord pool and EPEX Spot.

2.2.2 Retail and Self-consumption in the United Kingdom – Great Britain

2.2.2.1 Retail tariffs

British electricity bill is divided into six parts:

A) Wholesale costs: is the cost of buying the energy. This electricity could be purchased from the day-ahead market or buy this energy in advance.
B) Network costs: transmission and distribution operators charge energy suppliers and customers for the use of their grids. These costs are regulated by the regulatory institution Ofgem (Office of the Gas and Electricity Markets).
C) Social and environmental obligation costs: part of the bill that is intended to fund government programmes for energy efficiency (rollout of Smart meters), secure energy supply (capacity market), deliver lower carbon electricity (Feed-In tariffs) and provide direct financial support to the fuel poor (Warm Home Discount).
D) Operating costs: these are the costs of running a retail energy company (metering operations, building rents and providing customer service).
E) Other direct costs: includes sales commissions and brokerage, administration from data and settlement services, wider smart metering programme costs, among others.
F) Taxes: They consists of 5% of VAT for household and non-profit organisations and 20% for the rest of customers.

All costs defined above are charged only based on the energy consumed and, depending on the energy supplier, also based on fixed annual tariffs (prorated over the billing periods). For residential consumers, there are no payments according to the contracted or consumed power, as is the case in Spain.

Only customers who have half-hourly meters (typically medium or large industrial and commercial businesses) have to pay according to the power consumed. Each year, National Grid determines three Triads to compute an organization's Transmission Network Use of System (TNUoS) charges. A triad is one of the three highest electricity demand peaks between November and February, usually between 4 pm and 6 pm on weekdays (when industrial demand coincides with residential demand). Then, with

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the three triads measured from an organization, TNUoS are calculated based on the power consumed in these triads and then charged to the customer.

Energy suppliers can compete with each other only in energy and operational costs. The rest of the costs are regulated by Ofgem or the government.

British electricity suppliers offer different types of tariffs. These are:

- Standard variable tariffs (SVTs): is an energy supplier's default tariff. Prices in these tariffs can vary to reflect changes in the wholesale energy market prices (not directly, if wholesale prices go up or down, SVT may do the same, but not always happen).
- Fixed-rate tariffs: the price of the electricity consumed by the customer is fixed for a set amount of time, usually 12 to 24 months.
- Prepayment tariffs: also known as pay-as-you-go tariffs, the energy supply is based on a pre-pay basis, instead of paying by direct debit or on receipt of a bill.
- Economy 7: it measures electricity usage based on two different prices per kilowatt; an on-peak rate and an off-peak one. The off-peak hours apply for seven hours of the night (hence its name). Customers can only contract it with an energy meter that can measure the energy in this way.
- Economy 10: it is the same as the previous tariff, but instead of having cheaper energy for 7 hours, this tariff has more affordable energy for 10 hours (split into seven hours overnight and three hours during the day, usually in the afternoon).
- Tracker tariffs: price in this type of tariffs follow a price index, e.g. wholesale costs. Prices are updated daily based on the price index.

Standard variable tariffs are a specific type of tariff in which Ofgem defines a price cap that electricity suppliers are not allowed to exceed, which could be considered a regulated tariff. The prices of this type of tariff can be lower but not higher than this cap. This cap is defined every six months. This tariff has to be offered mandatory to some energy suppliers.

According to Ofgem data, 60% of domestic electricity customers have contracted a standard variable tariff, 38% have a fixed tariff and the 2% remaining have other tariffs [11].

The most important electricity suppliers in the UK are British Gas, EDF Energy, E.ON, Scottish Power and OVO. The graph below shows the evolution of the share of customers per electricity supplier from 2004 to 2021.

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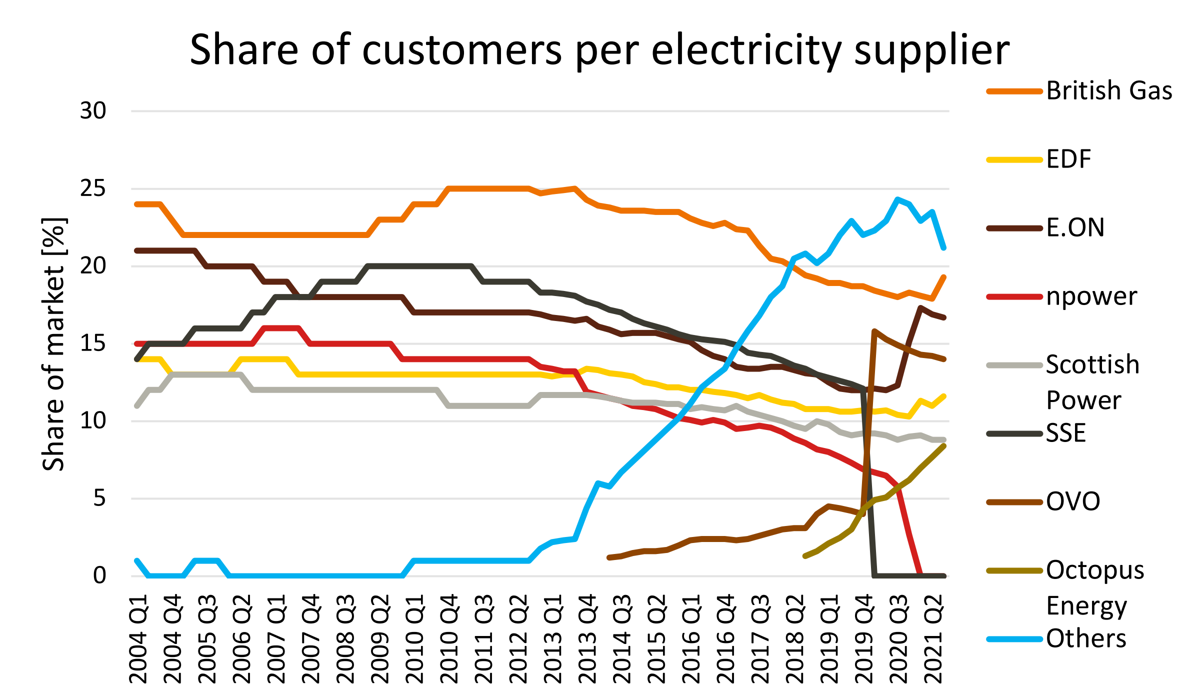

Figure 5 Evolution of the percentage of customers by electricity supplier from 2004 to 2021 [11].

2.2.2.2 Self-consumption

At the end of 2021, over 12 GW of solar photovoltaics had been deployed in the UK, of which roughly 2.8 GW comes from small < 4 kW units associated with homes and small businesses and a further 4.7 GW from 4 kW to 5 MW arrays [12], most of this capacity is dedicated to self-consumption for households and commercial buildings.

Until 2019, a feed-in-tariff for renewable and low-carbon self-consumption was established. Prosumers were given a fixed payment for the energy injected into the grid. The payment changed between different technologies and power installed (e.g. 16.58 p/kWh for micro CHP or 4.7 p/kWh for PV).

Feed-in-tariff incentives ended, and **Smart Export Guarantee (SEG)** initiative was launched on 1 January 2020. In SEG, prosumers with solar PV, wind, micro-CHP, hydro or anaerobic digestion installations can participate in this incentive. The maximum installed capacity can not be higher than 5 MW, except for Micro-CHP, which has to be lower than 50 kW.

The SEG requires certain licensed electricity suppliers (SEG Licensees) to offer a tariff and pay eligible generators for electricity that they export back to the National Grid. Licensed electricity suppliers are required to provide at least one SEG compliant export tariff to any generator with an eligible installation SEG Licensees can choose the tariff rate, contract length and some other relevant terms that they will offer Generators as part of their SEG contract. The tariff rate must always be above zero. Some electricity suppliers with a mandatory offering of SEG are British Gas, E.ON, Octopus Energy, etc. Then, the conditions of the tariffs are determined by electricity suppliers.

Even though the regulatory framework does **not allow collective self-consumption** nor permit power trading between consumers, several peer-to-peer local markets have been authorised as “regulatory sandboxes” by the regulator.

2.3 Croatia

In the following table, we can see which are the main actors in the Croatian electricity system:

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Table 8: main Croatian actors in the electricity system

Actors	Description
NRA	**HERA** - Croatian Energy Regulatory Agency
NEMO	**HROTE -** Croatian Energy Market Operator
TSO	**HOPS -** Croatian Transmission System Operator
DSOs	HEP ODS performs the public electricity distribution service as the distribution system operator.
Energy Suppliers	The latest information (18 October 2021) reports only seven **electricity suppliers**[2].

2.3.1 National market

After adopting the new regulation about energy markets, the Croatian electricity market is divided into two markets — the first one based on a balance group model and bilateral contracts. The second market is organized by the Croatian Power Exchange company (CROPEX) and is formed by the day-ahead and intraday markets. This section will focus on the second market organized by CROPEX.

Croatian Day-Ahead Market (*Dan Unaprijed Tržište*) allows market members to submit orders to buy or sell electricity for 24 hours of the following day. This market is coupled with the European SDAC market via the Croatian-Slovenian border.

The intraday market in Croatia is a market for continuous trading in products during trading hours where transactions are matched automatically. Transactions may be registered up to 30 minutes

[2] https://www.hera.hr/hr/html/aktivni_opskrbljivaci_ee.html

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before delivery. This market has been connected with the European SIDC market since November 2019.

Characteristics of the bids for the day-ahead and intraday market in Croatia can be found in the following table:

Table 9 Characteristics of the bids in Croatian day-ahead and intraday market [1].

Markets	DM	IM
Trading Hours	The coming 24 hours starting from 00:00 CET.	Trading starts 15:00 D-1 day
Gate Closure	12:00 CET	Trading ends D-30 minutes.
Trade Lot	0.1 MW	
Tick Size	Euro 0.1/MWh	
Currency	Orders can be submitted in EUR. Price calculation in EUR.	
Order Types	Hourly Orders, Block Orders, Linked Block Orders, Profile Block Orders	Fill, All-or-Nothing, Fill-or-Kill (FoK), Iceberg Order (IBO), Block Order
Minimum Volume Limit	0,1 MW	
Block Order Volume Limit	500 MW	999 MW
Minimum number of consecutive hours in Block Orders	3 hours	*NA*
Maximum number of Block Orders	Orders: 4 per Trading Portfolio	*NA*
Linked Block Orders	The linking of blocks is limited on portfolio level. The linking is limited to three levels, and a total limitation of 4 blocks per family shall be applied.	*NA*
Price Steps	The number of Price Steps is 200 per day (including the upper and lower Order Price Limits)	*NA*
Minimum Price Limit	Euro - 500	Euro - 9999
Maximum Order Price Limit	Euro + 3000	Euro + 9999
Delivery	As specified in the Order	

2.3.2 Retail and Self-consumption in Croatia

2.3.2.1 Retail tariffs

The country had to harmonise its legislation with EU standards to enable Croatia's accession to the European Union, including the electricity market. The first reforms of the electricity sector started in 2001, with the abolition of monopoly ownership and the introduction of competition, but formal liberalisation began in 2008.

The Croatian electricity bill consists of three parts:

A) Energy costs: defined by the energy retailer or the government (depending on the tariff), expressed in kn/kWh.
B) Cost of the use of the transmission and distribution network. Regulated by the government, it varies according to the customer's tariff model. Expenses are paid according to the energy consumed (kn/kWh), a monthly fee (kn/month) and the power in red tariff models (kn/kW).
C) Taxes and fees: a separate fee to encourage electricity production from renewable energy sources (0.105 kn/kWh) and VAT (13%).

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Competition between energy retailers only takes place on energy costs. All other costs are regulated and defined by HERA (Croatian Energy Regulatory Agency, in Croatian). For example, distribution costs for household customers range from 0.08 to 0.24 kn/kWh, depending on the tariff model and time slot.

The time bands used for transmission and distribution costs are different depending on the timeband. These are:

- VT: most expensive time band, in the wintertime from 7 a.m. – 9 p.m. whereas in the summertime from 8 a.m. – 10 p.m.
- NT: cheapest time band, in the wintertime from 9p.m – 7 a.m. whereas in the summertime from 10 p.m. – 8 a.m.
- JT: if a tariff has only a single band.

Customers have access to different tariffs models according to the type of meter (single-tariff or multi-tariff meters) and also the kind of consumer (household and enterprises). The different tariffs models and characteristics to access them are:

- Tariff model Blue (*Plavi*): low-voltage customers who have a single-tariff (only JT) or multi-tariff meter (NT and VT).
- Tariff model White (*Bijeli*): low voltage customers with a multi-tariff meter.
- Tariff model Red (*Crveni*): users with more than 20 kW connected power.
- Tariff model Yellow (*Žuti*): tariff used for public lighting.

Since 2008, Croatian customers can choose the energy retailer freely. Currently, in Croatia, there are seven: HEP – Opskrba, HEP ELEKTRA, GEN-I, E.ON, PETROL, MET and ENNA. All of them offer electricity tariffs in the liberalised market except for HEP – Opskrba, which is the one that provides a regulated tariff for households (known as Universal service) and for industries (known as Guaranteed supply). HERA regulates this service, but the price of electricity is not determined by them and is freely defined [13].

Of the total electricity sold to households in 2020, 12% was sold outside the universal service, while the share of supply outside the guaranteed supply for industrial consumers amounted to 92%. Regarding industrial customers, 92% of the electricity sold was outside of the guaranteed supply service, and only 8% of the energy was from the public service. Overall, 58% of the energy consumption in Croatia is in the liberalised market, while the 42% remaining are in the regulated tariffs.

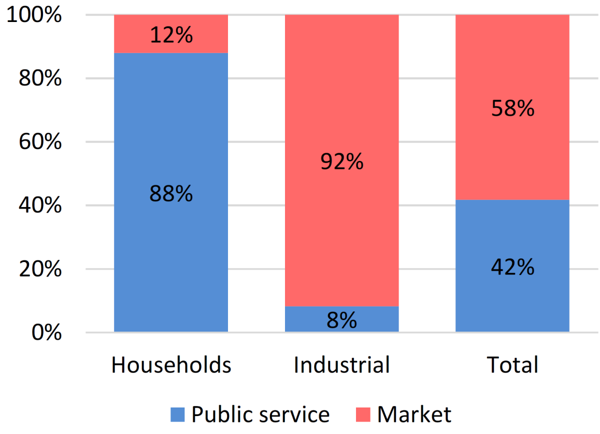

Figure 6 Proportions of energy sold to household and industrial final customer categories in 2020 [13].

Out of the seven suppliers in Croatia, the three largest will account for 99% of the energy supply to residential customers and 94% of industrial customers in 2020. Among these three, the two from the HEP group (HEP-Opskrba and HEP ELEKTRA) stand out, accounting for 92% of residential and 88% of

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industrial energy. The type of tariffs offered by Croatian suppliers to households are only fixed price tariffs, with or without time bands. There are no tariffs indexed to the day-ahead market or flat fee rates. The possibility of contracts with dynamic electricity prices was introduced in the law at the end of 2021, so information on the implementation of such tariffs is not yet available.

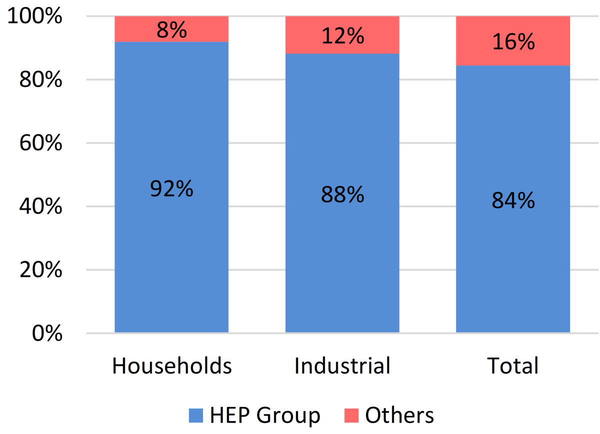

Figure 7 Percentage of energy supplied by HEP Group to household and industrial customers in 2020 [13].

2.3.2.2 Self-consumption

At the end of 2020, 1495 users had self-consumption in Croatia, representing 2% of the total installed capacity of producers located in Croatia (84 MW). At the household level, the average size of the PV installation is 6 kW, meanwhile for commercial customers is 43 kW for facilities connected at low-voltage and 677 kW connected at medium voltage [14].

Since January 2016, self-consumption has been allowed for renewable generation and high-efficiency cogeneration with less than 500 kW. At this time, energy suppliers were obligated to purchase the excess electricity injected into the grid by prosumers at the 90% price of the supply tariff (net-billing). The power of the installation had to be lower than the power contracted by the prosumer.

In 2019 regulation changed, and net-metering was limited only to households with self-generation. The annual injected energy by the prosumer has to be lower than the electricity consumed from the grid, being this electricity injected bought by the energy supplier at a price 80% of the supply tariff.

Collective self-consumption schemes are not yet regulated, so making peer-to-peer transactions with this method is not possible.

2.4 Italy

In the following table, we can see which are the main actors in the Italian electricity system:

Table 10: main Italian actors in the electricity system

Actors	Description
NRA	**ARERA** - Autorità di Regolazione per Energia Reti e Ambiente

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NEMO	**GME** - Gestore dei Mercati Energetici
TSO	**Terna** - Rete Elettrica Nazionale
DSOs	There are **120 DNOs** in Italy. E-distribuzione has 86% of the market
Energy Suppliers	There are about **70 electricity suppliers** that operate in the free market and at least five companies in the protected market.

2.4.1 National market

Italian electricity market can be divided into two different markets:

- Mercato a termine (MTE): forward markets.
- **Mercato a pronti (MPE): Spot markets, which in turn is divided into four further markets:**
    - **Mercato del Giorno Prima (MGP): day-ahead market.**
    - **Mercato Infragiornaliero (MI): intraday market.**
    - **Mercato dei prodotti giornalieri (MPEG): Daily products market.**
    - Mercato per il Servizio di Dispacciamento (MSD): ancillary services.

Table 11: Italian electricity acronym summary

Acronym	Description
MGP	Day Ahead Market – *Mercato del Giorno Prima*
MI	Intraday Market – *Mercato Infragiornaliero*
MPEG	Daily Products Market – *Mercato dei Prodotti Gionalieri*
MSD	Ancillary service market – *Mercato per il Servizio di Dispacciamento*

This section will analyse the three first Spot markets: MGP, MI, and MPEG. The MSD market will be examined in the following sections of this deliverable.

Italian day-ahead market trades energy for the next day, divided into 24 periods (one for each hour), and trading electricity for each geographical zone (North, Central North, Central South, South, Calabria, Sicilia and Sardegna). In each region, a price is defined, but then all energy is valued at a Unique National Price (PUN), being this the average price of all zones weighted for the quantities purchased in these zones. MGP uses the market coupling process of the Single Day-Ahead Coupling (SDAC) platform. The characteristics of the bids in MGP are:

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Table 12 Characteristics of energy products for the day-ahead market in Italy [1].

Characteristics	Description
Gate opening time (GOT)	The MGP sitting opens at 8 a.m. of the ninth day before the day of delivery.
Gate closure time (GCT)	Day before at 12:00 CET
Publication of results	The results of the MGP are made known within 12.55 p.m. of the day before the day of delivery.
Granularity product (hourly, 30 mins, 15 mins)	Hourly
Minimum bid price*	0 €/MW
Maximum bid price	+ 3,000 €/MW

Intraday auction markets, in which Italian market participants can modify their portfolios, are divided into three different sessions; the first one (MI-A1) takes place after closing the day-ahead market (12:55 p.m.) and ends at 3 p.m. of the same day (D-1). MI-A2 is also opened at 12.55 p.m. but ends at 10.00 p.m. on the same day (D-1). The last auction (MI-A3) starts at 12.55 p.m. and is closed at 10.00 a.m. the following day, which is the day of physical delivery (D).

The continuous intraday market, known as MI-XBID, is divided into three phases, in which, at the same time as the negotiation of offers to buy and sell, intraday interconnection capacity is allocated between all areas of the Italian market and other interconnected geographical regions active in the XBID. MI-XBID phase I opens at 3.30 p.m. the day before the delivery (D-1) and closes at 9.40 p.m. D-1, MI-XBID phase II begins at 10.30 p.m. and closes depending on the period traded (first 12 hours of day D, closes one hour before each period (h-1); for the second twelve hours of day D is closed at 9.40 a.m. of day D), and MI-XBID phase III opens at 10.30 a.m. and closes before the start of each period (h-1).

The last electricity market available in Italy is the Daily Products market (MPEG). In MPEG, two different products are traded:

- Unite price differential: The price indicated in the preparation of bids/asks and so the price determined on completion of the trading phase is the differential expression compared to the PUN, to which Participants are willing to trade such products.
- Full unit price: The price is indicated in the preparation of bids/asks. The price determined as a result of the trading phase is the expression of the unit value of electricity exchange subject to the traded contracts.

Two different delivery profiles are available for these two types of products: peak load (Monday to Friday, from 9 a.m. to 9 p.m.) and baseload (energy delivered during every hour belonging to the day being traded). The sessions of the MPEG take place on weekdays, between two or one day before, depending on whether there are public holidays.

2.4.2 Retail and Self-consumption in Italy

2.4.2.1 Retail tariffs

Legislative decree n.79 of 1999 implemented the European directive on electricity 96/92/CE for the liberalisation of the Italian Electricity sector. In 2007 the deregulation of the Italian energy market was completed opening it to new suppliers and allowing users to choose the operator freely.

Italian electricity bill is divided into four cost items:

A) Cost of energy: includes the amounts invoiced concerning the various activities carried out by the seller to supply electricity to the end customer. The total price charged in the bill is the sum of the costs of energy (PE), dispatch (PD), equalisation (PPE), marketing (PCV), dispatch component (DispBT). Is paid a fixed fee (Euro/year) and an energy fee (€/kWh), with prices that time bands can differentiate.

B) Cost for transport and meter management: includes the amounts invoiced for the various activities that enable sellers to deliver electricity to end customers. The overall price consists of the components of the transmission, distribution and metering tariff and other tariff components. Is paid a fixed fee (euro/year), a power quota (euro/kW/year) and an energy quota (euro/kWh).

C) Expenditure on system charges: includes amounts invoiced to cover costs related to activities of general interest to the electricity system, which are paid by all end customers (incentives for renewable sources, promotion of energy efficiency, nuclear charges, etc.). Is paid an energy quota, a power quota (not for dwellings) and a fixed fee (not applied to homes where the person is registered).

D) Taxes: Electricity taxes for residential (0.0227 €/kWh depending on power and energy consumed) and no-residential customers (0.0125 €/kWh consumption less than 200 MWh/month, 0.0075 €/kWh consumption higher than 200 MWh/month) and VAT (10% for dwellings and 22% for other uses).

As in the Spanish electricity system, competition between commercial offers in the free market is only linked to the cost of energy, i.e., the energy quota and marketing services. System charges, meter management and transport costs, as well as taxes and VAT, are the same for all electricity suppliers because they are costs established by ARERA (Italian Regulatory Authority for Energy, Networks and Environment).

Regarding the costs related to transport and distribution, these costs are not differentiated in time bands. There is only one cost per unit of energy, power or year. For example, in 2019, residential consumers had a fixed quote of 20.28 €/year, a power quote of 21.29 €/kW/year and an energy quote of 0.00798 €/kWh.

Customers are divided into residential and no-residential customers. No-residential customers, in turn, are differentiated regarding their voltage (low-voltage: BTA, medium voltage: MTA, high voltage: ALTA, very high voltage AAT) and power (BTA1: power output less than 1.5 kW, BTA5 less than 10 kW, etc.).

In Italy, customers can choose freely their energy retailer, which offers different types of tariffs. Like in Spain, there are tariffs in the liberalised market, but ARERA offers a regulated tariff, known as *Servizio di Maggior Tutela* (Higher Protection Service).

Servizio di magior tutela is an option provided in the Italian energy market, which guarantees the consumer the supply of electricity and gas at the economic and contractual conditions established by the ARERA. This service is offered to small final customers (households and micro companies with a committed capacity of up to 15 kW) who have not yet chosen a seller in the free market. The regulated tariff is planned to end in January 2023 for micro-companies. Meanwhile, for households will be in January 2024. Once the service is closed, customers who had not yet chosen a free-market supplier will be assigned to the graduated protection service at that time to guarantee the continuity of the electricity supply.

The energy price is defined by ARERA that sets and updates the price every three months, considering the costs of *Acquirente Unico* (the body in charge of purchases for customers in *Servizio di magior tutela*) to buy energy on the market.

The regulated tariff has three different time bands:

- *Fascia 1* (Band 1): the most expensive, from 8 a.m. to 7 p.m. on Mondays to Fridays, excluding public holidays.
- *Fascia 2* (Band 2): 7 a.m. to 8 a.m. and 7 p.m. to 11 p.m. on Mondays to Fridays and 7 a.m. to 11 p.m. on Saturdays, excluding public holidays.

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- *Fascia 3* (Band 3): from 11 p.m. to 7 a.m. on Mondays to Saturdays and all hours on Sundays and public holidays.

For residential customers, energy prices are divided into only two-time slots (F1 and F23), while micro-enterprises follow the three-time slots for energy. As noted above, transport and distribution cost have no time bands. It is paid the same independently of the hour. More than 12 million residential customers (42.7% of residential customers) have contracted the regulated tariff.

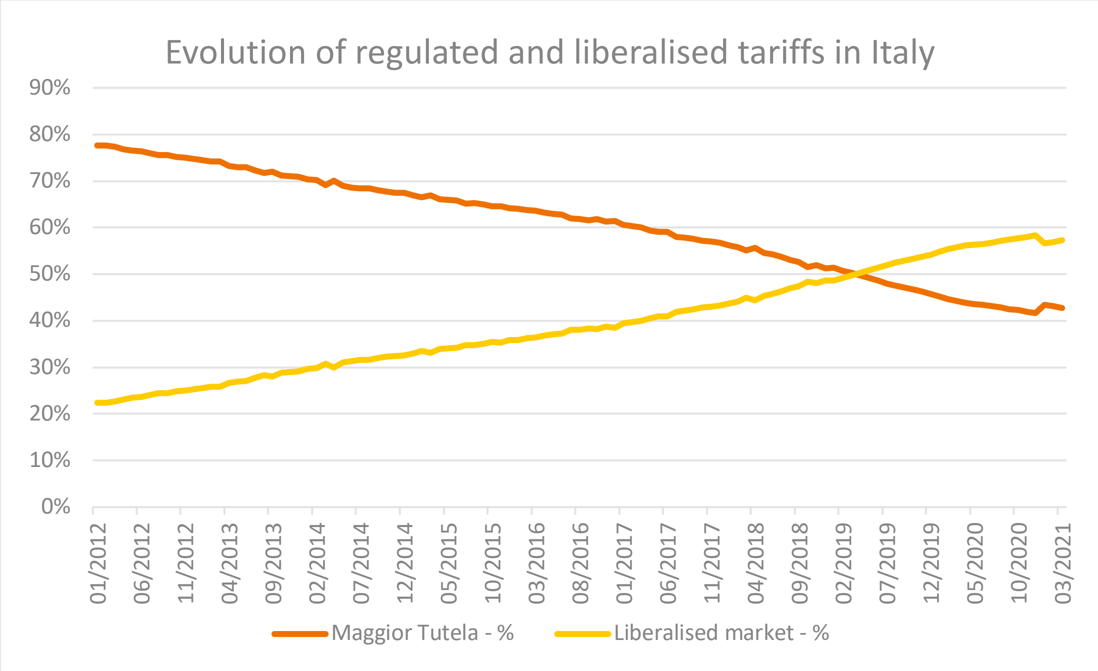

Figure 8 Share of regulated and liberalised tariffs in Italy (low voltage) since 2012. [15].

Tariffs in the liberalised market can determine the energy prices that offer and the marketing margin. There are different types of tariffs: unique or time banded (2 or 3 bands) fixed price of energy, indexed price of energy with the day-ahead market, fee tariffs and PLACET tariffs (tariff calculated with a procedure determined by the ARERA). The most important retailers in Italy are: Enel (36%), Edison (6%), A2A (5%), Hera (5%), Axpo Group (5%), Eni (4%).

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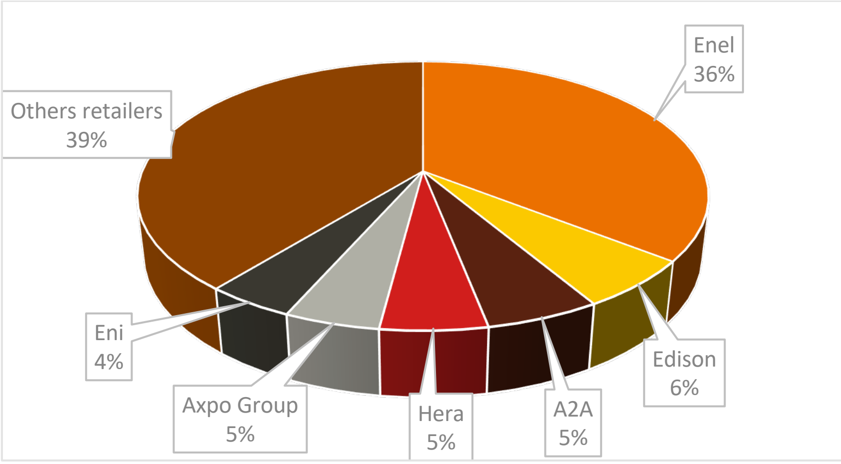

Figure 9 Percentage of customers per energy retailer in Italy [16].

2.4.2.2 Self-consumption

According to the Statistical Report of the GSE (*Gestore Servizi Energetici*) on solar photovoltaics in 2020 [17], self-consumption in Italy will amount to 4,735 GWh, representing 19.0% of the total production of photovoltaic installations.

Currently exists the possibility to inject energy generated by prosumers and not consumed to the grid and obtain revenues from this. Prosumers can sell their energy adhering to *Scambio sul Posto* (net metering) or use *Ritiro Dedicato*, options offered by GSE.

The first case is a **net metering mechanism, *Scambio sul Posto***. Net metering allows you to inject into the grid the electricity produced by a private electricity production plant for the portion not immediately self-consumed and then withdraw it at a later date to meet your electricity consumption.

Therefore, it uses the electricity system as a tool for the virtual storage of electricity produced but not simultaneously. To take part in this mechanism, the maximum power of installations with renewable sources is 500 kW (for a new facility), and for high efficiency, CHP is 200 kW.

If the value of the energy fed into the grid is greater than the value of the energy withdrawn from the grid, there is a surplus at the end of the year. These can, on request, be settled by the GSE.

For the case of ***Ritiro Dedicato***, the user, on the one hand, withdraws energy from the grid (when not self-producing) and, on the other hand, sells the energy produced to the grid (to the GSE).

In this case, all the energy withdrawn from the grid will be paid for in the bill at 'full price' without any form of reimbursement (as is the case with on-site exchange).

Therefore, prosumers pay your bills at full price. On the other hand, you receive income from the sale of the energy fed into the grid. The advantage here is that the selling prices are regulated by a resolution of the Electricity and Gas Authority. The sale prices are "guaranteed minimum prices", which protect producers from renewable sources.

Finally, Italy now has the option of **collective self-consumption** thanks to the execution of Legislative Decree 162/19. Collective self-consumption systems need participants to be in the same building or condominium, and the renewable plant's power cannot exceed 200 kW. It is also available to share energy with members from a Renewable Energy Community (*Comunità di Energia Rinnovabile*). Instead of being limited to the same building o condominium, the limit of the energy community is that the production plants and withdrawal points forming part of a Community are connected to the low-voltage electricity grid via the same MV/LV transformer substation.

Residential structures (for example, apartment buildings in huge cities), tertiary sector buildings (offices, hospitals and nursing homes, commercial properties, etc.), industrial properties, or public

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administration buildings (authorities, schools, hospitals and nursing homes, facilities for sports activities) can all benefit from collective self-consumption systems.

To participate in the collective self-consumption, participants must establish a private law contract that governs their connections and name a scheme manager who will represent all activities. The methodology for calculating the allocation of the virtual self-consumption is the result of contractual agreements between the owners and can be:

a) on an energy criterion, e.g. in proportion to the withdrawals of each user in each measurement time interval;
b) on a fixed criterion, e.g. a millesimal criterion, not related to the energy consumption of individual households.

2.5 Connectivity with Spanish National market through OMIE

This section will detail the whole process of connecting with the Spanish national market. This connection has been carried out through the OMIE´s API (Operador del Mercado Ibérico de la Electricidad, OMI Polo Español S.A. (OMIE)). To this end, we will first focus on the architecture and technology of the web service, then it will be described in detail the development carried out for downloading prices from the market, and finally, the procedure carried out for sending bids to the market.

2.5.1 Web Service OMIE´s Architecture

A web service is a software system designed to support interoperable machine-to-machine interaction over the network. Web Services present a service-oriented architecture that allows creating an abstract definition of a service, providing a concrete implementation of that service, publishing and locating the service, selecting an instance of the service, and using that service with high interoperability.

The OMIE Web Service architecture is composed of three main components: Provider, Client and Service Registry. The interactions between them are reflected in the following diagram (Figure 10). The protocol or standard used for each operation is indicated in the chart below.

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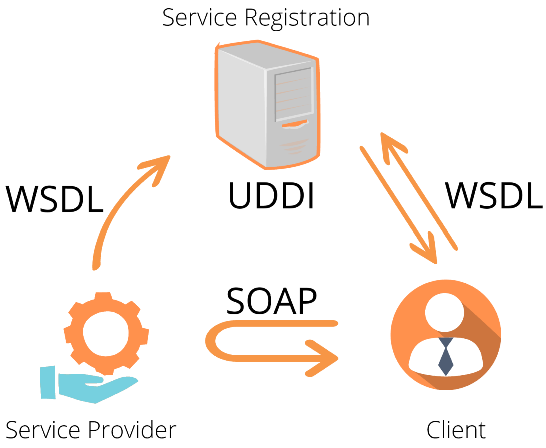

Figure 10 OMIE´s Web Service diagram. The main communication protocols and languages that compose the OMIE architecture are WSDL (Web Services Description Language) and SOAP (Simple Object Access Protocol).

The above general scheme describing the interaction pattern of a web service is summarized in the following steps:

1. The Service Provider generates the integration contract using a Web Services Description Language (WSDL), where the Web Service specification is described. This WSDL contract is registered in the UDDI (Universal Description Discovery and Integration) directory or Service Registry.
2. A client requests a Web Service through the UDDI, locates it in the Service Registry, and has its physical location.
3. Through the descriptor specification (WSDL), the service client sends a "Request" for a particular service to the Web Service Listener, which is responsible for receiving and sending messages in SOAP format.
4. The Service Provider receives the SOAP message from the consumer and executes the operation related to that "Request". The result of the operation is returned as a SOAP message to the consumer (Response).
5. The client receives the SOAP with the "Response" and/or result of the operation and processes it.

The messaging and service description technologies are discussed in detail in Annex 1:

2.5.2 API SOAP and WSDL development in OMIE

OMIE, as mentioned in the previous section, presents an architecture with SOAP protocol and XML-based message exchange. OMIE provides the agents with an application that simulates the connection to the energy market, both daily and intraday, to get started with its operation. It also provides an endpoint to test the requests. The SIOM2 Client provided by OMIE has some technical requirements: Virtual Java Machine JVM 1.7.0 (the last version supported), Windows operating system (Windows 7,8 or 10), Memory RAM of 1GB or higher, and Intel Core i3 or higher.

For running the application, it is needed to access the folder where the application was installed, then follow the steps in the "User Manual - SIOM2 Client". Once in the directory, run the .bat file called "ExecuteClient", a screen appears asking for the digital certificate provided by OMIE, which must be previously installed, as well as the application file directory and if everything is correct, click accept (Figure 11), and the application will start running, whose main window is shown in Figure 12.

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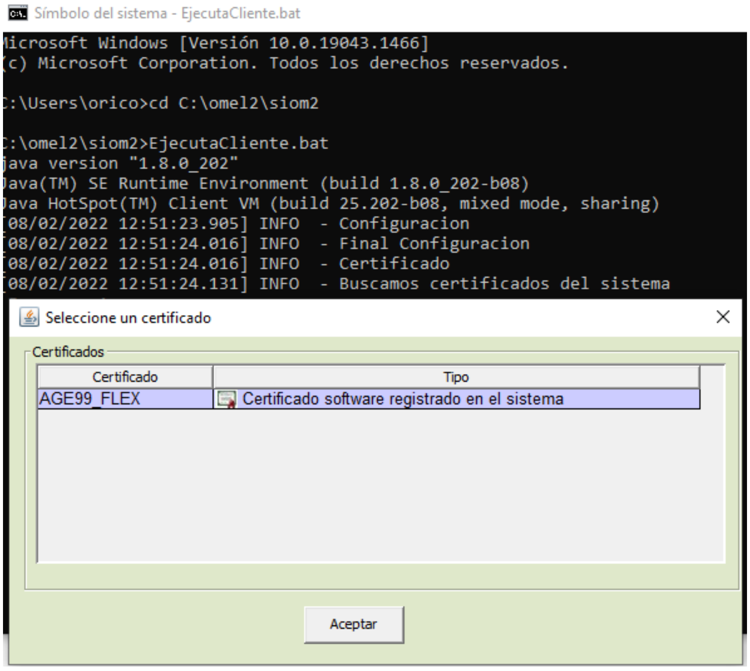

Figure 11 OMIE´s test application

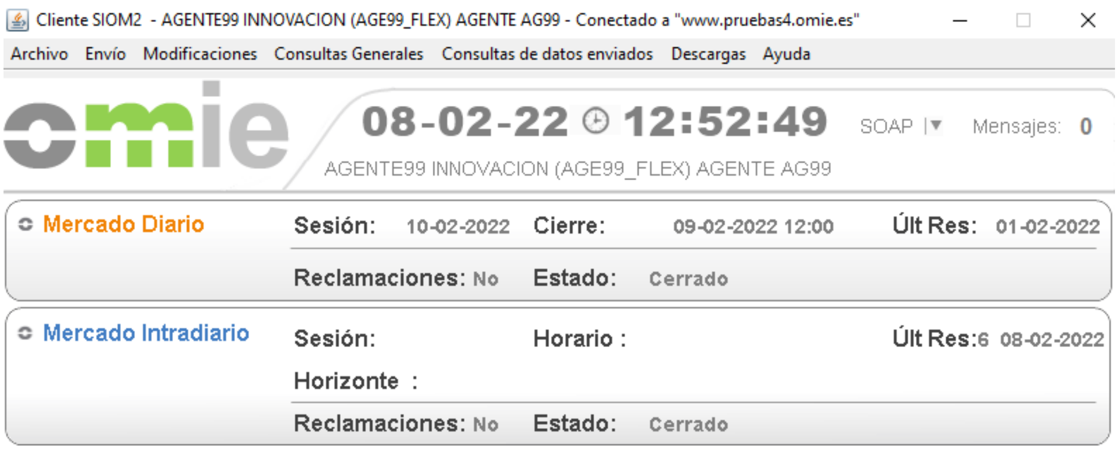

Figure 12 OMIE´s application main window

This application makes requests to the OMIE SOAP API and displays the sending transactions of these SOAP messages (Figure 13). They also provide code information in WSDL classes with the possible Web Service calls, which will be described in the next section because they are helpful in programming the connection to the API.

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Ofertas por Defecto Válidas


```
<soapenv:Envelope xmlns:xml="http://www.w3.org/XML/1998/namespace" xmlns:soapenv="http://schemas.xmlsoap.org/soap/envelope/" xmlns:xsd="http://www.w3.org/2001/XMLSchema"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  <soapenv:Body>
    <ns1:ServicioEjecucionConsultaEncolumnada xmlns:ns1="http://www.omel.es/Schemas">
      <MensajeEjecucionConsulta>
        <CodConsulta v="5161"/>
        <Parametros/>
      </MensajeEjecucionConsulta>
    </ns1:ServicioEjecucionConsultaEncolumnada>
  </soapenv:Body>
</soapenv:Envelope>
```

```
<SOAP-ENV:Envelope xmlns:xml="http://www.w3.org/XML/1998/namespace" xmlns:SOAP-ENV="http://schemas.xmlsoap.org/soap/envelope/" xmlns:op="http://www.omel.es/Schemas">
  <SOAP-ENV:Body>
    <op:ServicioEjecucionConsultaEncolumnadaResponse>
      <EjecucionConsultaEncolumnada>
        <op:RespuestaEjecucionConsultaEncolumnada>
          <op:CodConsulta v="5161"/>
          <op:Parametros/>
          <op:Fila>
            <op:Num n="Oferta" v="101"/>
            <op:Num n="Version" v="0"/>
            <op:Txt n="Casacion" v="NORMAL"/>
            <op:Txt n="UOfertante" v="HID99"/>
            <op:Fec n="Anulada"/>
            <op:Feh n="FechaAnulacion"/>
            <op:Feh n="FechaAlta" v="2022-02-01T13:59:04"/>
            <op:Txt n="" v="10/02/2022"/>
            <op:Num n="Ofertada" v="0.1"/>
          </op:Fila>
          <op:Fila>
            <op:Num n="Oferta" v="126"/>
            <op:Num n="Version" v="0"/>
            <op:Txt n="Casacion" v="NORMAL"/>
            <op:Txt n="UOfertante" v="TER99"/>
            <op:Fec n="Anulada"/>
            <op:Feh n="FechaAnulacion"/>
            <op:Feh n="FechaAlta" v="2022-02-01T13:59:04"/>
            <op:Txt n="" v="10/02/2022"/>
            <op:Num n="Ofertada" v="0.1"/>
          </op:Fila>
        </op:RespuestaEjecucionConsultaEncolumnada>
      </EjecucionConsultaEncolumnada>
    </op:ServicioEjecucionConsultaEncolumnadaResponse>
  </SOAP-ENV:Body>
</SOAP-ENV:Envelope>
```


Principal SOAP

Figure 13 Soap messages transaction

OMIE also provides:

- A .xsd code with the application's schema received and facilitated in its messages and responses.
- A "SIOM2 Technical Manual", which describes the operation and the use of the SIOM2 client core modules, and API implemented in Java.
- A "Manual of information exchange format between OM and AM" provides information on the .xml structure that the formats for sending files to the SOAP API must follow between the Market Agent and the Market Operator.
- A set of compiled and documented Java libraries, ready to be used, both from the User Interface (modified or not by the agents) and from any other system to be developed or adapted by the Agents.

It is necessary to know that as a client, when an HTTP request is sent to the server, the response is received and contains status information about the request, and may also include the requested content. The two most common HTTP methods are GET and POST. GET is used to request data from a specific resource. POST sends data to a server to create/update a resource. For this reason, two requests are selected to download the cleared price and send bids to the daily market. A GET request is chosen for the first transaction and a POST request for the second.

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2.5.3 Sending Queries

With all the information and classes provided by OMIE (Market Operator), the implementation of the java classes can be started, which will make the requests to the OMIE SOAP API (The following steps need to be followed:

In the first step, as the Market Operator delivers an electronic certificate (for this specific project is "AGE99_FLEX"), it needs to be configured and installed in the project directory where the classes that invoke the Web Service will be created. Once the certificate is installed and operative, its call must be implemented from the java class (new WindowsSoftwareCertificateManager ("AGE99_FLEX")).

In the second step, the documentation to know which Service to invoke must be analyzed to make the desired request. For this purpose, the WSDL classes (Annex 1:b) are used with all the possible queries and calls to the Web Service. These classes specify the abstract interface through which a client can access the Service and see how to use it. The best way to analyze the information in these classes provided by OMIE is by invoking them from the SOAPUI [18] application, Figure 14Figure 1, where all the available Services can be examined, and after the execution of each one, its response to choose the one that better fits the concrete needs.

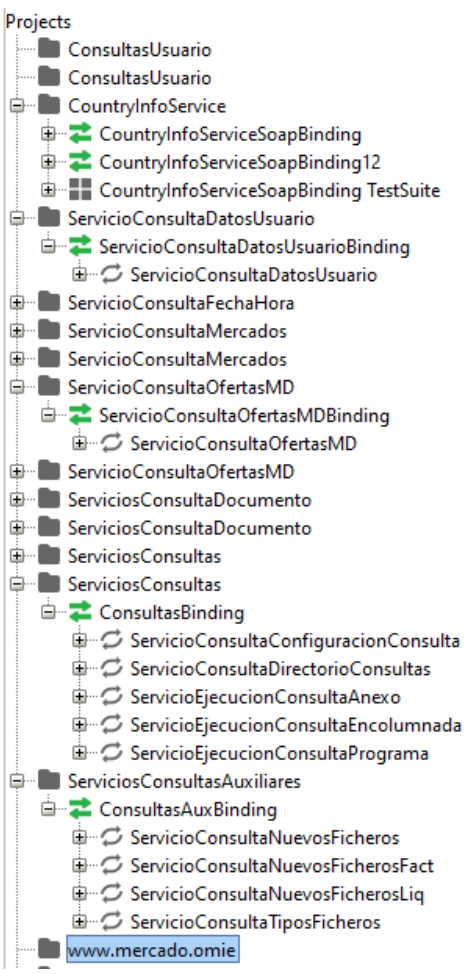

Figure 14 List of WSDL queries

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2.5.4 GET – Daily market prize

Due to download data of the energy price value resulting from the matching in the Daily Market [19], a GET request must be made to the OMIE SOAP API. This section describes how the connection with the Market Operator has been made to download the energy price information in the matching for a day that is passed as a parameter.

Once the procedure described in the previous section (Sending Queries) has been carried out to know the Web Service to invoke for downloading market prices, it is decided, first of all, to call the service "ServicioConsultaDirectorioConsultas" Figure 15, which contains the information of all available queries as well as a short description of what each of them is. The request is executed, and among all the possible queries, the following one is obtained (Figure 16), being the one that best suits the desired, due to the description it provides, which says "Prices resulting from matching", i.e., the daily market price established as a result of clearing.

Relevant information is obtained from this response: The query code (5202) and the type of query (ENCOL). But to know the parameters to be passed to this query, the information obtained from another request called "ServicioConsultaConfiguracionConsulta " Figure 15 is needed. The call to this service is made, getting the result is shown in Figure 17, which describes as parameters for the query 5202, the clearing date.

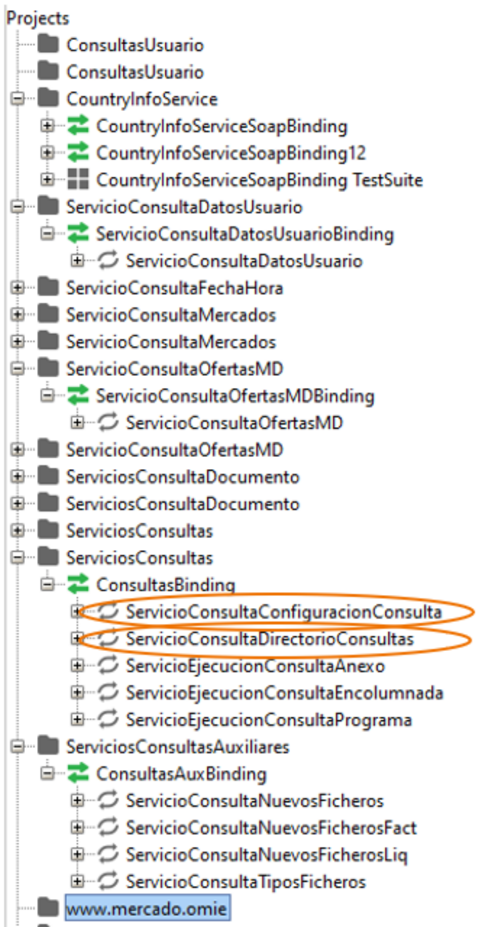

Figure 15 WSDL queries selected -GET

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```
</op:Seccion>
<op:Seccion v="Mercado Diario. Resultados de la Casación">
  <op:Consultas>
    <op:CodConsulta v="5202"/>
    <op:Titulo v="Precios resultado de la Casación"/>
    <op:TipoConsulta v="ENCOL"/>
  </op:Consultas>
  <op:Consultas>
```


Figure 16 Query directory service response 5202.


```
<SOAP-ENV:Envelope xmlns:SOAP-ENV="http://schemas.xmlsoap.org/soap/envelope/" xmlns:op="http://www.omel.e
  <SOAP-ENV:Header/>
  <SOAP-ENV:Body>
    <op:ServicioConsultaConfiguracionConsultaResponse>
      <ConfiguracionConsulta>
        <op:RespuestaConfiguracionConsulta>
          <op:Cabecera>
            <op:CodConsulta v="5202"/>
            <op:Titulo v="Precios resultado de la Casación"/>
            <op:TipoConsulta v="ENCOL"/>
            <op:Seccion v="Mercado Diario. Resultados de la Casación"/>
          </op:Cabecera>
          <op:Parametros>
            <op:Fec desc="Fecha Casación" n="FechaCasacion"/>
          </op:Parametros>
          <op:Columnas>
            <op:Num desc="Hora" long="65" n="Hora"/>
            <op:Num desc="Precio España EUR/MWh" long="90" n="PrecioES"/>
            <op:Num desc="Precio Portugal EUR/MWh" long="90" n="PrecioPT"/>
            <op:Txt desc="Splitting" long="50" n="Spliting"/>
            <op:Num desc="Energía" long="90" n="Energia"/>
          </op:Columnas>
        </op:RespuestaConfiguracionConsulta>
      </ConfiguracionConsulta>
    </op:ServicioConsultaConfiguracionConsultaResponse>
  </SOAP-ENV:Body>
</SOAP-ENV:Envelope>
```


Figure 17 All query parameters service response 5202. These are the parameters needed "Fecha de Casación" or clearing date.

With this data, the GET request can be structured, which is of type ENCOL, which means "*encolumnada*". According to the OMIE documentation "Siom2 Client Guide - Technical Manual," there are three GET types of queries depending on the response format generated by each one:

- ServicioEjecucionConsultaEncolumnada: the result is returned in an XML format with row and column definition.
- ServicioEjecucionConsultaAnexo: the result is a file sent attached to the answer in any format (CSV, PDF, ZIP, etc.).
- ServicioEjecucionConsultaPrograma: the result is an XML file, but it is not sent attached to the response but inside the SOAP response itself. In this case, the user is also asked for the file's destination to be saved locally.

With all this data obtained, you can continue the implementation of the java class with the declaration of:

1) The call to the target Web Service or EndPoint: "ServicioExecuciónConsultaEncolumnada".
2) The query code is 5202.
3) The parameters passed to the Web Service: clearing date (YYYYY-MM-DD).

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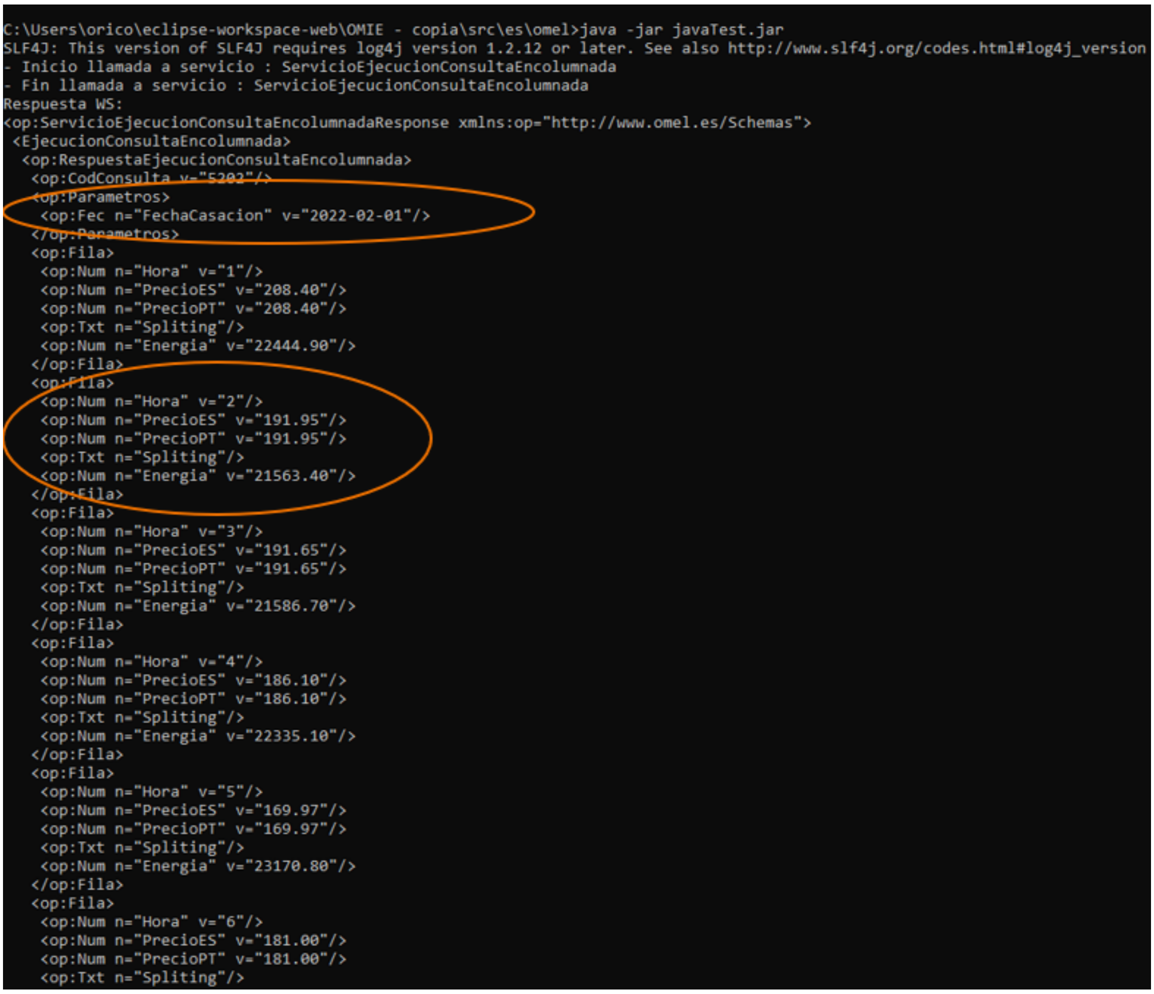
To manage this call to the server, the class JavaTest.jar, an executed java class, has been created to get the information from the OMIE API. These commands need to be done to run it (for example, using the cmd windows console).

1) The root where the .jar file is created needs to be found.
   The command is **cd** "project path in the computer."
2) The .jar file is executed.
   The command is **java -jar javaTest.jar**.

The response received (Figure 18) described the prize of the day set at parameter for the Spanish and Portugal market as well as the energy cleared, up to hour 24. But the figure only shows up to hour 6 as an example.



```
C:\Users\orico\eclipse-workspace-web\OMIE - copia\src\es\omel>java -jar javaTest.jar
SLF4J: This version of SLF4J requires log4j version 1.2.12 or later. See also http://www.slf4j.org/codes.html#log4j_version
- Inicio llamada a servicio : ServicioEjecucionConsultaEncolumnada
- Fin llamada a servicio : ServicioEjecucionConsultaEncolumnada
Respuesta WS:
<op:ServicioEjecucionConsultaEncolumnadaResponse xmlns:op="http://www.omel.es/Schemas">
 <EjecucionConsultaEncolumnada>
  <op:RespuestaEjecucionConsultaEncolumnada>
   <op:CodConsulta v="5202"/>
   <op:Parametros>
    <op:Fec n="FechaCasacion" v="2022-02-01"/>
   </op:Parametros>
   <op:Fila>
    <op:Num n="Hora" v="1"/>
    <op:Num n="PrecioES" v="208.40"/>
    <op:Num n="PrecioPT" v="208.40"/>
    <op:Txt n="Spliting"/>
    <op:Num n="Energia" v="22444.90"/>
   </op:Fila>
   <op:Fila>
    <op:Num n="Hora" v="2"/>
    <op:Num n="PrecioES" v="191.95"/>
    <op:Num n="PrecioPT" v="191.95"/>
    <op:Txt n="Spliting"/>
    <op:Num n="Energia" v="21563.40"/>
   </op:Fila>
   <op:Fila>
    <op:Num n="Hora" v="3"/>
    <op:Num n="PrecioES" v="191.65"/>
    <op:Num n="PrecioPT" v="191.65"/>
    <op:Txt n="Spliting"/>
    <op:Num n="Energia" v="21586.70"/>
   </op:Fila>
   <op:Fila>
    <op:Num n="Hora" v="4"/>
    <op:Num n="PrecioES" v="186.10"/>
    <op:Num n="PrecioPT" v="186.10"/>
    <op:Txt n="Spliting"/>
    <op:Num n="Energia" v="22335.10"/>
   </op:Fila>
   <op:Fila>
    <op:Num n="Hora" v="5"/>
    <op:Num n="PrecioES" v="169.97"/>
    <op:Num n="PrecioPT" v="169.97"/>
    <op:Txt n="Spliting"/>
    <op:Num n="Energia" v="23170.80"/>
   </op:Fila>
   <op:Fila>
    <op:Num n="Hora" v="6"/>
    <op:Num n="PrecioES" v="181.00"/>
    <op:Num n="PrecioPT" v="181.00"/>
    <op:Txt n="Spliting"/>
```

Figure 18 GET response from OMIE´s API

Finally, the storage of the response to this request in a local XML file, as seen in Figure 19, is being programmed.

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957837.

consultandoPrecios.xml


```xml
<ns1:ServicioEjecucionConsultaEncolumnadaResponse xmlns:ns1="http://www.omel.es/Schemas">
<EjecucionConsultaEncolumnada>
<ns1:RespuestaEjecucionConsultaEncolumnada>
<ns1:CodConsulta v="5202"/>
<ns1:Parametros>
<ns1:Fec n="FechaCasacion" v="2022-02-01"/>
</ns1:Parametros>
<ns1:Fila>
<ns1:Num n="Hora" v="1"/>
<ns1:Num n="PrecioES" v="208.40"/>
<ns1:Num n="PrecioPT" v="208.40"/>
<ns1:Txt n="Spliting"/>
<ns1:Num n="Energia" v="22444.90"/>
</ns1:Fila>
<ns1:Fila>
<ns1:Num n="Hora" v="2"/>
<ns1:Num n="PrecioES" v="191.95"/>
<ns1:Num n="PrecioPT" v="191.95"/>
<ns1:Txt n="Spliting"/>
<ns1:Num n="Energia" v="21563.40"/>
</ns1:Fila>
<ns1:Fila>
<ns1:Num n="Hora" v="3"/>
<ns1:Num n="PrecioES" v="191.65"/>
<ns1:Num n="PrecioPT" v="191.65"/>
<ns1:Txt n="Spliting"/>
<ns1:Num n="Energia" v="21586.70"/>
</ns1:Fila>
<ns1:Fila>
<ns1:Num n="Hora" v="4"/>
<ns1:Num n="PrecioES" v="186.10"/>
<ns1:Num n="PrecioPT" v="186.10"/>
<ns1:Txt n="Spliting"/>
<ns1:Num n="Energia" v="22335.10"/>
```


Figure 19 XML file response stored

2.5.5 POST – Send Offers

In order to send offers to the Daily Market, a connection to the OMIE SOAP API must be made, similar to the one described in the previous section. The difference is that now, it is a POST request, i.e. data is not downloaded from the API but sent. For this purpose, another Java class has been developed to load .xml files with the offers of the Daily Market energy prices.

Before developing the java class, an XML file should be created to send the offer to the market. This file is created with the help of the guide provided by OMIE "Intercambio de información entre OM y AM". Here, the structure and predefined parameters that the file must follow can be found to be able to send the offers. This is an example of the XML file implemented following the guide (Figure 20). Where the value 180.3 is the price offered (€/MWh), and the value "1.9" and "2.4" is the energy in terms of MWh. In this example, only two offers are going to be sent, but more can be added.

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957837.

```xml
<?xml version="1.0" encoding="UTF-8"?>
<MensajeOfertasMD xmlns="http://www.omel.es/Schemas">
<IdMensaje v="Mensaje_ofertas_MD_20110308"/>
<VerMensaje v="1"/>
<FechaMensaje v="2022-02-08T10:14:53"/>
<IdRemitente v="AG99"/>
<Oferta>
<IdOferta v=" Oferta_1"/>
<IdUnidad v="COM99" tipo="UO" area="1"/>
<Validez>
<TipoMercado v="MD"/>
<Sesion fecha="2022-02-08"/>
</Validez>
<ClaseOferta v="C"/>
<UniPrecio v="EURO/MWh"/>
<Detalle>
<Dia v="2022-02-08"/>
<Blq num="1">
<Per v="1"/>
<Ctn v="1.9"/>
<Prc v="180.3"/>
</Blq>
<Blq num="1">
<Per v="2"/>
<Ctn v="2.4"/>
<Prc v="180.3"/>
</Blq>
</Detalle>
</Oferta>
</MensajeOfertasMD>
```


Figure 20 XML file with the offers to be sent. It presents a couple of offers: the energy and price per MWh.

Once the XML file and the procedure described in the previous section (Sending Queries) has been carried out, determining the appropriate Web Service is needed. In this case, among the services described in the WSDL classes, the Service "ServicioAltaOfertasMD" (Figure 21) is identified as the one in charge of uploading files to send offers to the Daily Market.

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957837.

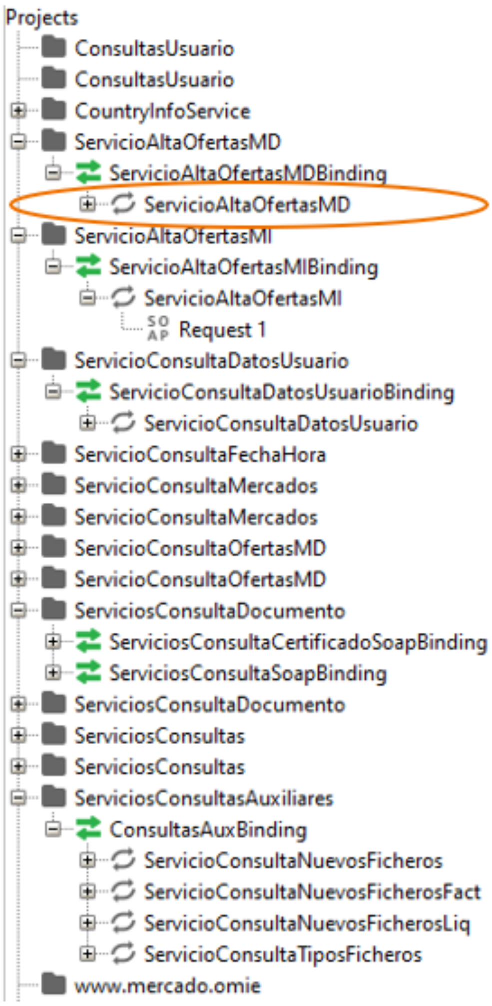
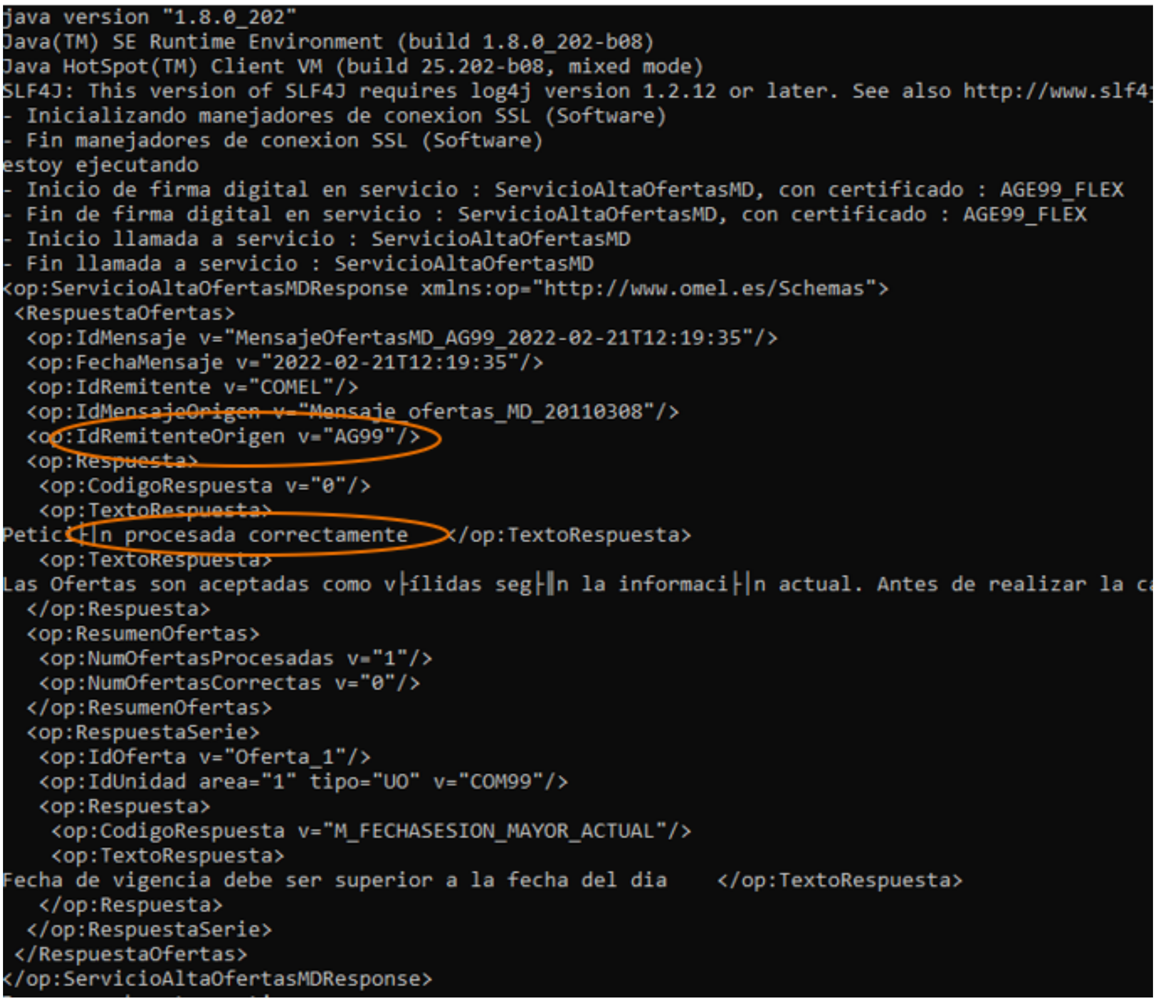


Figure 21 WSDL queries selected -POST

With all this data obtained and developed, it is possible to continue the implementation of the java class sending a request to the Web Service, which is invoked and signed, and the result obtained is returned to the console, which would inform if the POST request has been carried out correctly. As it can be observed in Figure 22, it has been correctly processed ("correctamente procesada") for AGE99_FLEX and will pass to a review process for subsequent acceptance in the Daily Market.

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957837.



```
java version "1.8.0_202"
Java(TM) SE Runtime Environment (build 1.8.0_202-b08)
Java HotSpot(TM) Client VM (build 25.202-b08, mixed mode)
SLF4J: This version of SLF4J requires log4j version 1.2.12 or later. See also http://www.slf4j
- Inicializando manejadores de conexion SSL (Software)
- Fin manejadores de conexion SSL (Software)
estoy ejecutando
- Inicio de firma digital en servicio : ServicioAltaOfertasMD, con certificado : AGE99_FLEX
- Fin de firma digital en servicio : ServicioAltaOfertasMD, con certificado : AGE99_FLEX
- Inicio llamada a servicio : ServicioAltaOfertasMD
- Fin llamada a servicio : ServicioAltaOfertasMD
<op:ServicioAltaOfertasMDResponse xmlns:op="http://www.omel.es/Schemas">
 <RespuestaOfertas>
  <op:IdMensaje v="MensajeOfertasMD_AG99_2022-02-21T12:19:35"/>
  <op:FechaMensaje v="2022-02-21T12:19:35"/>
  <op:IdRemitente v="COMEL"/>
  <op:IdMensajeOrigen v="Mensaje_ofertas_MD_20110308"/>
  <op:IdRemitenteOrigen v="AG99"/>
  <op:Respuesta>
   <op:CodigoRespuesta v="0"/>
   <op:TextoRespuesta>
Petici├│n procesada correctamente   </op:TextoRespuesta>
   <op:TextoRespuesta>
Las Ofertas son aceptadas como v├ílidas seg├║n la informaci├│n actual. Antes de realizar la ca
  </op:Respuesta>
  <op:ResumenOfertas>
   <op:NumOfertasProcesadas v="1"/>
   <op:NumOfertasCorrectas v="0"/>
  </op:ResumenOfertas>
  <op:RespuestaSerie>
   <op:IdOferta v="Oferta_1"/>
   <op:IdUnidad area="1" tipo="UO" v="COM99"/>
   <op:Respuesta>
    <op:CodigoRespuesta v="M_FECHASESION_MAYOR_ACTUAL"/>
    <op:TextoRespuesta>
Fecha de vigencia debe ser superior a la fecha del dia    </op:TextoRespuesta>
   </op:Respuesta>
  </op:RespuestaSerie>
 </RespuestaOfertas>
</op:ServicioAltaOfertasMDResponse>
```

Figure 22 Console response to the request sent. The message "petición procesada correctamente" means that the offer is correctly sent and waiting for acceptance.

The response should be also similar to the example below, Figure 23, where you can see that it returns the ID of the offer sent ("Código de oferta") and the version.

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957837.

Respuesta

Código: 0
- Petición procesada correctamente
- Las Ofertas son aceptadas como válidas según la información actual. Antes de realizar la casación se volverán a validar con la última información disponible.

Detalle

Número de ofertas procesadas: 1
Número de ofertas correctas: 1

Id.Oferta: Oferta_1 **Unidad:**COM99 **Código Oferta:** 7280920 **Versión:** 0

Código: TSD-002074
- Oferta Oferta_1 (UO. COM99, Cod.Ofer. 7280920, Ver. 0 dia 2022-02-09) correcta. Fecha 2022-02-08T08:52:32
- La oferta es aceptada de forma provisional. Antes de realizar la casación se verificará de nuevo la disponibilidad de garantias con la última información disponible vigente al cierre del periodo de recepción de ofertas. Podrá consultar su estado de garantias y valoración de la oferta en la consulta de estado de garantias para la sesión.

Figure 23 Response to the offer sent. The Code of the offer is relevant data that will be needed to check out the offers sent, reviewed and approved; this is "Codigo Oferta".

2.5.6 Consultation of our offers sent to the daily market.

A java class has also been developed to consult every offer sent. This class is similar to the one deployed for downloading the market prices, but with the difference that it invokes the Service "ServicioConsultaOfertasMD" Figure 24, and that a query parameter is needed, which is the "offerID," obtained from Figure 23.

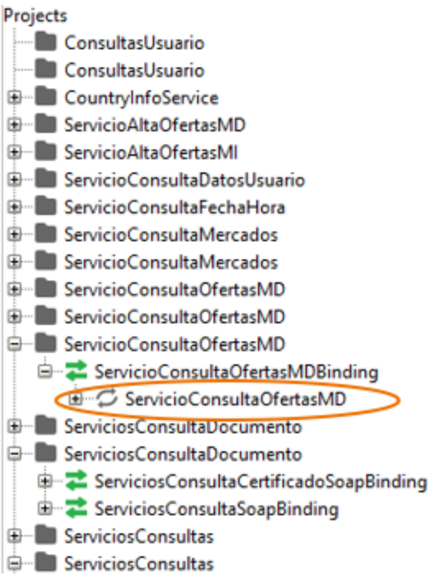
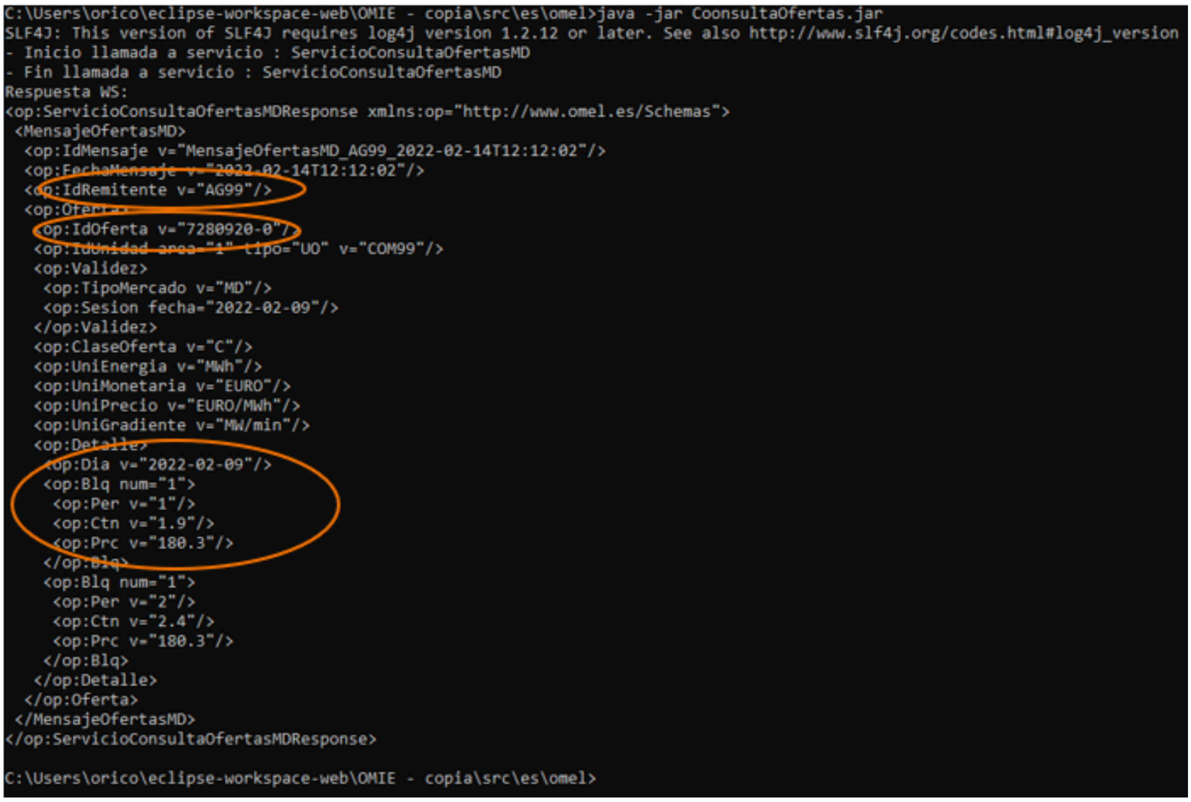


Figure 24 WSDL queries selected -Consulting offers sent

Once the previous steps are done, the java class is implemented and executed, obtaining the following (Figure 25), identifying the agent that sends the offer, the date for which it is sent, the energy in MWh and the price of the energy in €/MWh.

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957837.



```
C:\Users\orico\eclipse-workspace-web\OMIE - copia\src\es\omel>java -jar CoonsultaOfertas.jar
SLF4J: This version of SLF4J requires log4j version 1.2.12 or later. See also http://www.slf4j.org/codes.html#log4j_version
- Inicio llamada a servicio : ServicioConsultaOfertasMD
- Fin llamada a servicio : ServicioConsultaOfertasMD
Respuesta WS:
<op:ServicioConsultaOfertasMDResponse xmlns:op="http://www.omel.es/Schemas">
 <MensajeOfertasMD>
  <op:IdMensaje v="MensajeOfertasMD_AG99_2022-02-14T12:12:02"/>
  <op:FechaMensaje v="2022-02-14T12:12:02"/>
  <op:IdRemitente v="AG99"/>
  <op:Oferta>
   <op:IdOferta v="7280920-0"/>
   <op:IdUnidad area="1" tipo="UO" v="COM99"/>
   <op:Validez>
    <op:TipoMercado v="MD"/>
    <op:Sesion fecha="2022-02-09"/>
   </op:Validez>
   <op:ClaseOferta v="C"/>
   <op:UniEnergia v="MWh"/>
   <op:UniMonetaria v="EURO"/>
   <op:UniPrecio v="EURO/MWh"/>
   <op:UniGradiente v="MW/min"/>
   <op:Detalle>
    <op:Dia v="2022-02-09"/>
    <op:Blq num="1">
     <op:Per v="1"/>
     <op:Ctn v="1.9"/>
     <op:Prc v="180.3"/>
    </op:Blq>
    <op:Blq num="1">
     <op:Per v="2"/>
     <op:Ctn v="2.4"/>
     <op:Prc v="180.3"/>
    </op:Blq>
   </op:Detalle>
  </op:Oferta>
 </MensajeOfertasMD>
</op:ServicioConsultaOfertasMDResponse>

C:\Users\orico\eclipse-workspace-web\OMIE - copia\src\es\omel>
```

Figure 25 Offers sent by us to the electric market. In the message shown, there are some fields "IdRemitente" which means sender id, "IdOferta" which indicates Offer id, and also relevant the date, the energy offer and the price.

2.5.7 Consultation of all the agents' offers sent to the daily market.

If all agents' offers to the market need to be consulted, another java class has been developed. First, to find out the Query Code, the same procedure described in GET – Daily market prize section is carried out, i.e., the query to the "ServicioConsultaDirectorioConsulta" service to find out the type and code of query, in this case, the one that best suits the desired is number "5161" of type "ENCOL" (

Figure *27*), which request the valid offers sent pending for approval. Once this data is known, the service "ServicioConsultaConfiguraciónConsulta" is called to find out what parameters the call should take, which in this case, as shown in Figure 28, does not need parameters.

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957837.

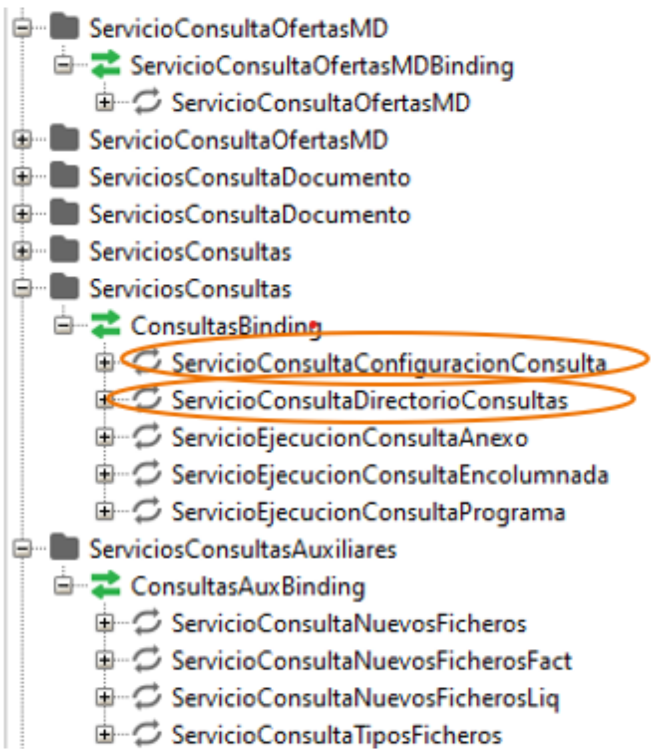


Figure 26 WSDL queries selected -Consulting ALL offers sent.

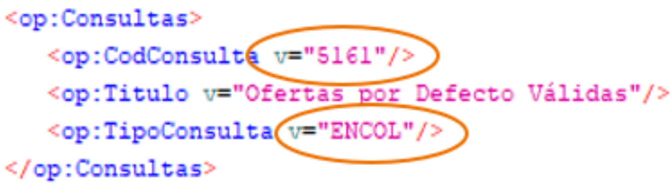


Figure 27 Query directory service response 5161.

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957837.

```xml
<SOAP-ENV:Envelope xmlns:SOAP-ENV="http://schemas.xmlsoap.org/soap/envelope/" xmlns:c
   <SOAP-ENV:Header/>
   <SOAP-ENV:Body>
      <op:ServicioConsultaConfiguracionConsultaResponse>
         <ConfiguracionConsulta>
            <op:RespuestaConfiguracionConsulta>
               <op:Cabecera>
                  <op:CodConsulta v="5161"/>
                  <op:Titulo v="Ofertas por Defecto Válidas"/>
                  <op:TipoConsulta v="ENCOL"/>
                  <op:Seccion v="Mercado Diario. Ofertas"/>
               </op:Cabecera>
               <op:Parametros/>
               <op:Columnas>
                  <op:Num desc="Oferta" long="65" n="Oferta"/>
                  <op:Num desc="Ver." long="30" n="Version"/>
                  <op:Txt desc="Casación" long="65" n="Casacion"/>
                  <op:Txt desc="U. Oferta" long="65" n="UOfertante"/>
                  <op:Fec desc="Anulada" n="Anulada"/>
                  <op:Feh desc="Fecha Anulación" n="FechaAnulacion"/>
                  <op:Feh desc="Fecha Alta" n="FechaAlta"/>
                  <op:Txt long="0" n=""/>
                  <op:Num desc="Energía total ofertada" long="40" n="Ofertada"/>
               </op:Columnas>
            </op:RespuestaConfiguracionConsulta>
         </ConfiguracionConsulta>
      </op:ServicioConsultaConfiguracionConsultaResponse>
   </SOAP-ENV:Body>
</SOAP-ENV:Envelope>
```


Figure 28 All query parameters service response 5161. For this service, there is no need for params.

Next, the service to be called in this "ENCOL" type query is "ServicioEjecucionConsultaEncolumnada," the same as downloading the market prices in the above section. Finally, a .jar file is created, the executable of the java class called "ConsultaOfertas.jar." It is executed, obtaining the response shown in Figure 29, where other offers from different agents can be observed, with the offerID, the agentID, and the date when it was sent.

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957837.

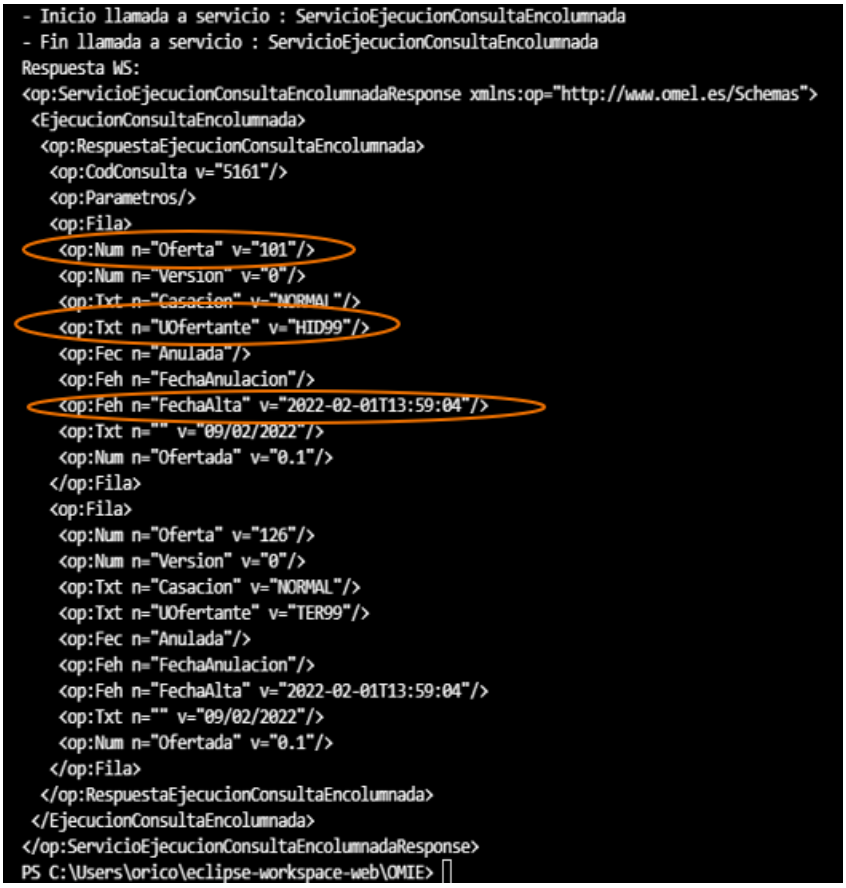


Figure 29 Offers stored in the OMIE´s database. The "n Oferta" means the number of the offer sent. "UOfertante" is the agent sending the offer, and "FechaAlta" is the date when the offer was approved. There are more agent offers shown bollow in the image.

2.6 Connectivity with ENTSO-E for the European market and CO2 emissions

In other European Countries[3], ENTSOE can be used to obtain information about electricity markets. This platform is called ENTSOE Transparency, and it has a web portal [20] that can be accessed to get this information, as can be seen in Figure 30.

[3] Great Britain was in this platform until Brexit so a new platform is being searched.

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957837.

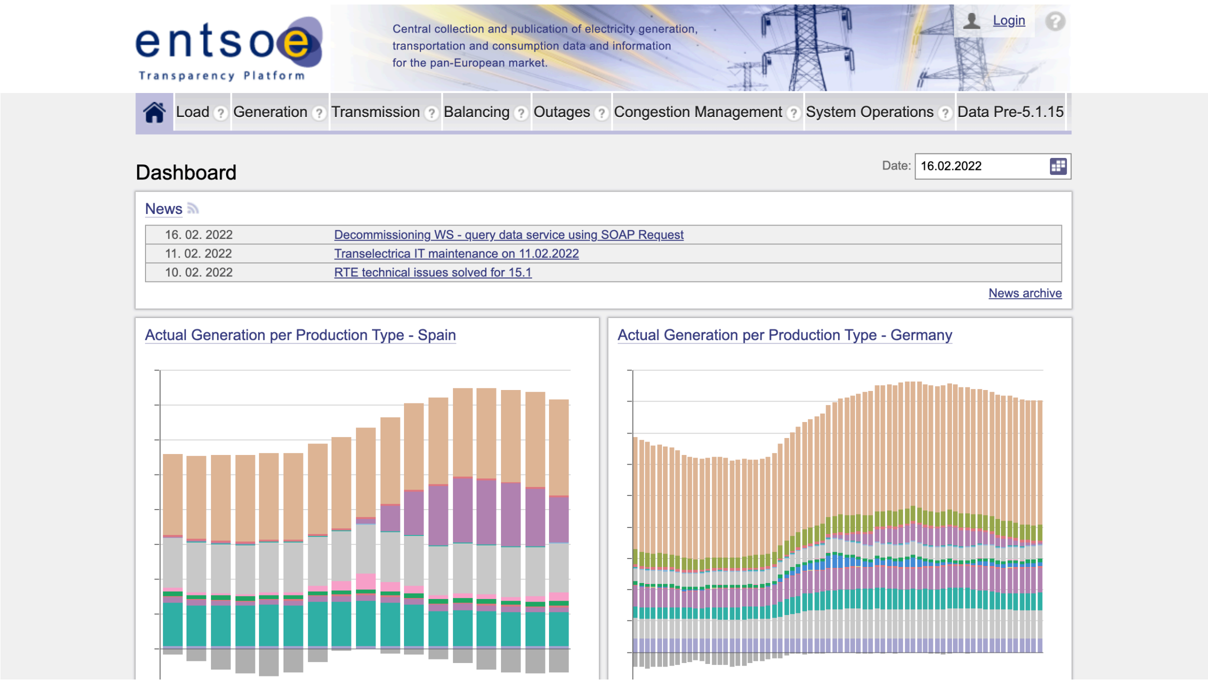


Figure 30 ENTSOE Web Portal.

ENTSO-E platform also offers an API that is fully documented in [21]. To request access to the Restful API, please register on the Transparency Platform and send an email to transparency@entsoe.eu with “Restful API access” in the subject line.

The REST API is an asynchronous interface. There are two methods to query for desired data:

- HTTP **Get** - parameters are a part of URI string: https://transparency.entsoe.eu/api? followed by Parameter Name = Parameter Value, where each pair of parameter name and value are separated by &
- HTTP **Post** - Status Request Document with parameters are included as XML in the request body: Content-Type: application/xml required in request header

In our case, only the get method will be used using the different parameters listed in [21] with the objective of achieving production by technology to estimate the CO2 emissions or the price of the energy. This has been implemented as a class in C++.

The project leading to this application has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 957837.

Table 13: Example of request and response of the ENTSOE API.

Requests	
Header	Host: transparency.entsoe.eu/api
Route	**Production by technology.** https://transparency.entsoe.eu/api?documentType=A75&in_Domain=10YES-REE------0&processType=A16&securityToken=token&timeInterval=2022-02-16T15%3a00Z%2f2022-02-16T16%3a00Z **Price of the electricity market.** https://transparency.entsoe.eu/api?documentType=A44&in_Domain=10YES-REE------0&out_Domain=10YES-REE------0&processType=A16&securityToken=token&timeInterval=2022-02-16T15%3a00Z%2f2022-02-16T16%3a00Z
Query Parameters	documentType: "A44" (Price), "A75"(Production) in_Domain: Area code eg: "10YES-REE------0"; out_Domain: Area code eg:"10YES-REE------0"; processType: Realised "A16" securityToken: "token"; periodStart: periodStart; periodEnd: periodEnd;
Response: XML	
Body	<StatusRequest_MarketDocument xmlns="urn:iec62325.351:tc57wg16:451-5:statusrequestdocument:4:0"> <mRID>SampleCallToRestfulApi</mRID> <type>A59</type> <sender_MarketParticipant.mRID codingScheme="A01">10X1001A1001A450</sender_MarketParticipant.mRID> <sender_MarketParticipant.marketRole.type>A07</sender_MarketParticipant.marketRole.type> <receiver_MarketParticipant.mRID codingScheme="A01">10X1001A1001A450</receiver_MarketParticipant.mRID> <receiver_MarketParticipant.marketRole.type>A32</receiver_MarketParticipant.marketRole.type> <createdDateTime>2016-01-10T13:00:00Z</createdDateTime> <AttributeInstanceComponent> <attribute>DocumentType</attribute> <attributeValue>A75</attributeValue> </AttributeInstanceComponent> <AttributeInstanceComponent> <attribute>ProcessType</attribute> <attributeValue>A16</attributeValue> </AttributeInstanceComponent> <AttributeInstanceComponent> <attribute>PsrType</attribute> <attributeValue>B02</attributeValue> </AttributeInstanceComponent> <AttributeInstanceComponent> <attribute>In_Domain</attribute> <attributeValue>10YCZ-CEPS-----N</attributeValue> </AttributeInstanceComponent> <AttributeInstanceComponent> <attribute>TimeInterval</attribute> <attributeValue>2015-12-31T23:00Z/2016-12-31T23:00Z</attributeValue> </AttributeInstanceComponent> </StatusRequest_MarketDocument>

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957837.

2.7 Connectivity with Elexon for the British market and CO2 emissions

Electricity prices for the UK are obtained from the Elexon website. Elexon is responsible for managing the Balancing and Settlement Code (BSC), and it is also responsible for the Balancing Mechanism Reporting Service (BMRS), which is the primary channel for providing operational data relating to the GB Electricity Balancing and Settlement arrangements.

The BMRS has a web portal [22] and a REST API [23] to obtain the data. In order to use the API, you need a key that can be obtained after the registration in the Elexon Portal. The file format by which the API will return data is CSV or XML. This has been implemented as a class in C++.

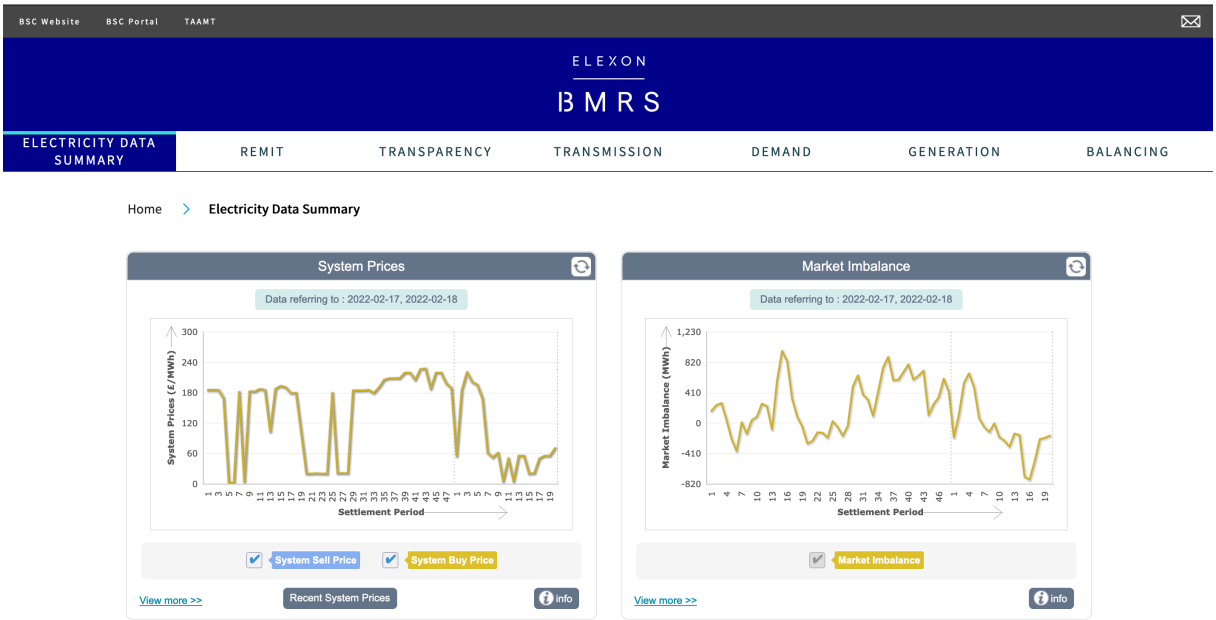


Figure 31 Elexon-BMRS Web Portal

Table 14: Example of request and response of the ELEXON API

Requests	
Header	Host: api.bmreports.com/BMRS/database/v1
Route	**Production per type** https://api.bmreports.com/BMRS/B1620/v1?APIKey=keyUK &Period=19&SettlementDate=2022-02-18 **Past Prices** https://api.bmreports.com/BMRS/DERSYSDATA/v1?APIKey=keyUK &FromSettlementDate=2022-02-16&ToSettlementDate=2022-02-17
Query Parameters	APIKey: keyUK SettlementDate: date Period: speriod ServiceType: "xml"
Response: XML	
Body	<response> <responseMetadata> <httpCode>200</httpCode> <errorType>Ok</errorType> <description>Success</description> <cappingApplied>No</cappingApplied> <cappingLimit>1000</cappingLimit> <queryString>SettlementDate=2022-02-18,Period=19</queryString>

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957837.

```
</responseMetadata>
<responseBody>
<dataItem>B1620</dataItem>
<responseList>
<item>
<documentType>Actual generation per type</documentType>
<businessType>Solar generation</businessType>
<processType>Realised</processType>
<timeSeriesID>NGET-EMFIP-AGPT-TS-21929846</timeSeriesID>
<quantity>1290</quantity>
<curveType>Sequential fixed size block</curveType>
<resolution>PT30M</resolution>
<settlementDate>2022-02-18</settlementDate>
<settlementPeriod>19</settlementPeriod>
<powerSystemResourceType>"Solar"</powerSystemResourceType>
<activeFlag>Y</activeFlag>
<documentID>NGET-EMFIP-AGPT-06401181</documentID>
<documentRevNum>1</documentRevNum>
</responseList>
</responseBody>
</response>
```


2.8 Design of retail markets in the project

In this project, we are dealing with four different ways of tariff design. We can conclude tariffs could have:

- fix costs per month €/month
- cost depending on the power that can be consumed (€/kW-day)
- the cost that depends on the energy consumed (€/kWh).

Fix cost can be translated into a price of €/kW-day since both are fixed. The most important part is the energy part (€/kWh) that could depend on the date (season, day of the week, month…), the price of the energy market (indexed tariffs in Spain), the hour of the day….

For being able to model the energy part of tariff that does not depend on the price of the energy market, three lists are defined:

- a list with the name of the tariff indicating if it depends on the market or not
- a list with the day type (winter, summer, weekend…)
- a list of the period type obtained as the possible combination of the €/kW and €/kWh (low price, high price, fixed…) that a tariff could have.

In the service that calculates the tariff, the date is used to determine the day type for each tariff. Once the day type is specified, another two tables are needed. One where the period type of each hour is stored and a second one that allocates, as shown in Figure 32, the current value of €/kW-day and €/kWh of a tariff and period type. The profile can be easily obtained by crossing both tables.

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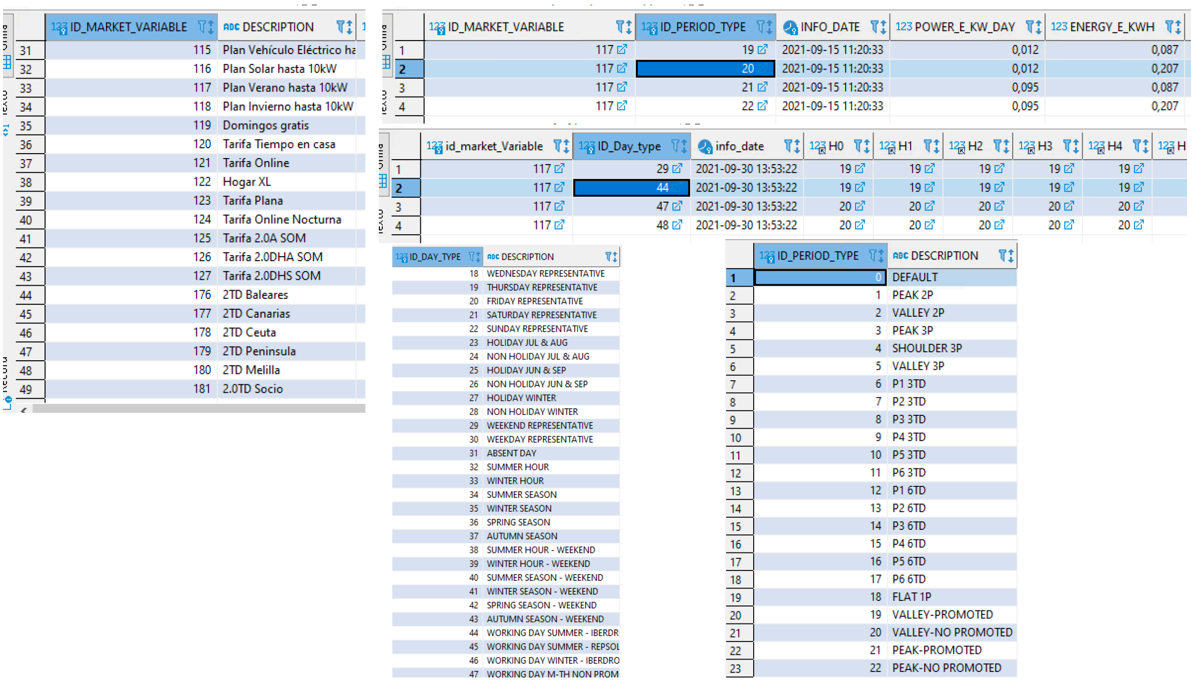

Figure 32 Database structure implemented.

On the other hand, the final price of tariffs that depend on the energy of the market is based on a formula that includes taxed and fixed charges per period. This formula can be applied once the energy market price is obtained, as explained in section 2.5 or section 3.5.

2.9 Connectivity with Octopus Energy

Octopus Energy is a British company that offer a tariff that depends on Great Britain's wholesale energy market. Data from Agile Octopus will be downloaded to store it and used for the efficiency and demand response tool. This tariff has been chosen because some ReDREAM customers already have contracted this tariff. Agile Octopus can only be obtained through an API request.

Table 15: Example of request and response of the Octopus API

Requests	
Header	`Host: api.octopus.energy`
Route	`https://api.octopus.energy/v1/products/AGILE-18-02-21/electricity-tariffs/E-1R-AGILE-18-02-21-A/standard-unit-rates/`
Response: JSON	
Body	JSON Datos sin procesar Cabeceras Guardar Copiar Contraer todo Expandir todo Filtrar JSON count: 89997 next: "https://api.octopus.ener…ndard-unit-rates/?page=2" previous: null results: 0: value_exc_vat: 25.2 value_inc_vat: 26.46 valid_from: "2022-02-18T22:30:00Z" valid_to: "2022-02-18T23:00:00Z" 1: value_exc_vat: 32.55 value_inc_vat: 34.1775 valid_from: "2022-02-18T22:00:00Z" valid_to: "2022-02-18T22:30:00Z"

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3 Ancillary and Local Flexibility markets

After defining the energy markets and connecting with all markets in the demo countries, it will now be developed the Ancillary and Local Flexibility markets. In this case, it will be defined how is the communication process with the Spanish ancillary services through an API. Part of the information of ancillary services have been obtained from Deliverable 1.3 [1], for more information about these markets can be found in this document.

Flexibility can be defined as "the degree to which a power system can adjust the electricity demand or generation in reaction to both anticipated and unanticipated variability" The significant inclusion of variable renewable energy (VRE) generation provokes a reduction of stability in the electricity grid, creating the need for new sources of flexibility.

In the past, flexibility was obtained from the thermal generation side by producing more or less electricity (consuming more or less fuel) and buying it at the national (transmission) level. With the reduction of big thermal generation plants, switching to a more distributed and renewable generation, demand-side flexibility (DSF) and energy storage appears as alternatives to procure flexibility to the system at the local (distribution) level.

In this section, it will be explained how this flexibility can be procured at local level and how ancillary service works in each country. It has been done a difference between national and local markets.

We have considered as national flexibility markets those in which an electricity system agent can sell or buy services at every level; SOs, TSOs, DSOs, generators, BRPs, BSPs, consumers can offer/buy their services. It does not matter whether they are located in the same area where the need is located or whether they are connected at high or low voltage. Large consumers and generators are usually the leading players in these markets.

The primary services in national markets are balancing services (Frequency Containment Reserves FCR, Replacement Reserves), capacity markets and constrain management services.

Balancing services are used to maintain the balance between electricity generation and demand. If generation and demand are balanced, electricity frequency will be constant at 50 Hz (in Europe); if not, this will vary, and all electrical equipment will not work correctly. ENTSO-E (European Network of Transmission System Operators) determines that frequency must be in a predefined stability range; it shall not go below 47.5 and above 51.5 Hz [24]. At the European level, there are defined specifics services for balancing the electricity system; these are:

Table 16: Definition of balancing products at European level [25] and [26].

FCR – Frequency Containment Reserve	FCR instantaneously balances out frequency deviations and is activated automatically. Assets that provide FCR need to **react within 30 seconds to the steering signals fully.**
aFRR – automatic Frequency Restoration Reserve	aFRR is automatically activated after FCR, replacing the assets triggered by FCR. aFRR has to be **fully activated within 5 minutes.**
mFRR – manual Frequency Restoration Reserve	mFRR is activated to substitute assets involved in aFRR. This service is manually activated and has to deploy all its capacity in **less than 15 min**.

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RR – Restoration Reserve	The reserve replacement process replaces the activated mFRR. Activation time varies between different European countries **(30 minutes to hours).**

The Electricity Balancing Guidelines (EBGL) [27] target the establishment of common European platforms and, as a result, the standardisation of European balancing market processes. For each balancing service, the EBGL requires the definition of a European platform. These platforms are: Platform for the International Coordination of Automated Frequency Restoration and Stable System Operation (PICASSO) – for aFRR process; Manually Activated Reserves Initiative (MARI) – for mFRR process and Trans-European Restoration Reserves Exchange (TERRE) – for RR process.

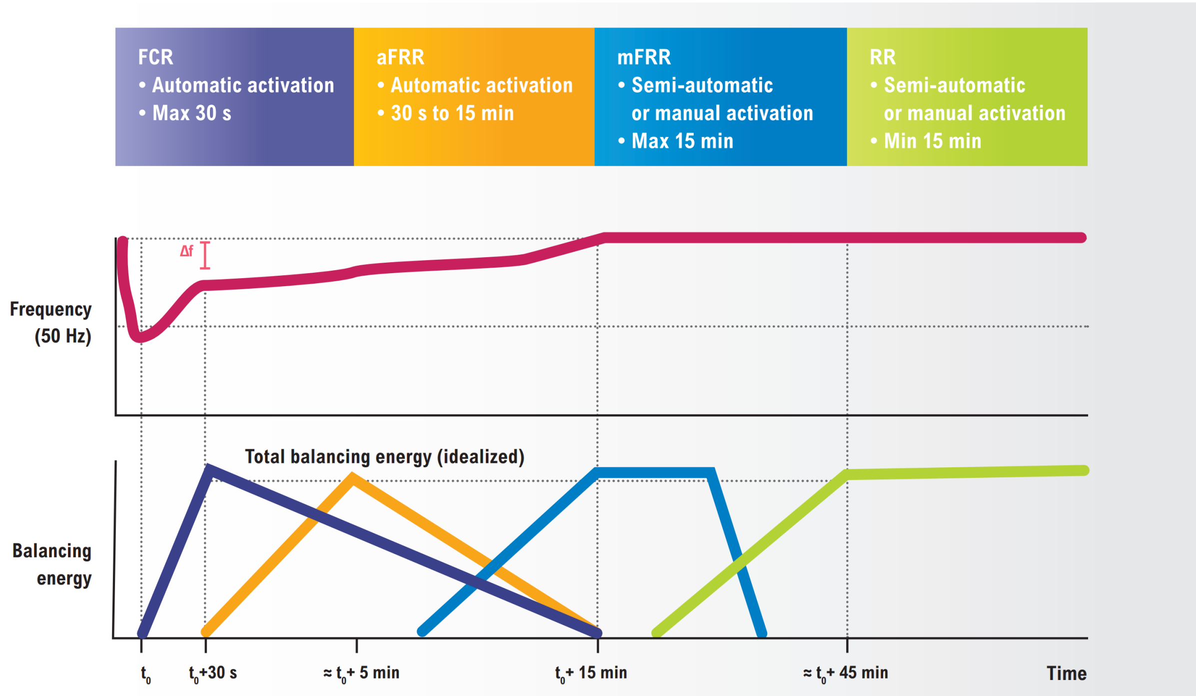

Figure 33 Timeline of balancing service activation [25]. It can be seen that in the first moment after the deviation of frequency, FCR service is automatically activated, after FCR, aFRR is activated to replace FCR, then mFRR substitute aFRR if it is required.

Capacity markets are used to procure capacity through long-term contracts to ensure security supply, enabling power plants to be available for generating electricity when needed. In exchange, the mechanisms provide payments to these power plants. These capacity payments are in addition to the earnings power plants gain by selling electricity on the energy market. This market is not present in all countries in Europe; 11 countries of the European Union have this market.

Constrain management services are used at the transmission and distribution level to solve the possible problems on the grid due to physical constraints in interconnections or transmission/distribution lines. This service can be procured via market procurement.

On the other hand, are the local flexibility markets. These markets are focused on supply flexibility requirements at a local level (in a specific city or region). DSOs usually procure this flexibility to avoid congestions in the distribution grid and ensure the quality of the electricity.

These markets are still in the stage of development. The leading players in local flexibility markets are Distributed Energy Resources (DER), e.g. small-scale generation (renewable), demand response (DR), electric vehicles, energy storage systems, among others; which, usually, are connected to the

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distribution grid, not like big generators, which are connected to the transmission grid. The aggregator's role is necessary to join the market with DERs; more detail about this role can be found in the deliverable D3.2. [28]

An analysis of the different flexibility markets will be carried out in this section, defining national and local flexibility markets in the four demo countries in ReDREAM. Local flexibility markets are not available in all countries, so they will only be described in those with open local markets.

3.1 Spain

The most developed markets in Spain are at national level, although an important initiative is being developed for local markets. Both are addressed below.

3.1.1 National market

To provide auxiliar services to the Spanish electricity system, Spanish TSO, *Red Electrica de España* (REE), has a total of three services available, these are:

- *Mercado de Balance*: Balancing markets. This market is divided into four different services:
  - *Regulación Primaria*: Primary regulation (FCR):
  - *Regulación Secundaria*: Secondary regulation (aFRR).
  - *Regulación Terciaria*: Tertiary regulation (mFRR).
  - *Reservas de substitución*: Replacement Reserves (RR).
- *Mercado de capacidad:* Capacity market.
- *Restricciones técnicas*: Technical Constraints Resolution Market.

Primary regulation service (FCR) is obligatory and not remunerated, while secondary regulation capacity and additional upward regulation capacity are procured through market mechanisms. The TSO publishes the secondary regulation reserves requirements for the following day before 16:00 of the day ahead (D-1). After posting these requirements, REE opens a process to receive bids to provide the **secondary regulation service (aFRR)**. This service is paid through market mechanisms for two concepts: availability (regulation band) and use (energy):

- Reserve assignation price [€/kW]: the regulation band is remunerated as the result of the marginal cost.
- Effective net energy [€/kWh]: secondary regulation energy used because of the real-time monitoring of the regulation requirements. This energy is valued at the marginal price of the tertiary regulation energy that would have been necessary to program each hour, both to go up and down, to replace this net use of secondary regulation energy.

Once the secondary requirements are assigned, if it is necessary**, tertiary regulation requirements (mFRR)** are published by the TSO at 9.00 p.m. Tertiary regulation energy is paid at a marginal price through a scheduled allocation process (15 min before the scheduling period) and when it is appropriately caused by direct activations, within the hour.

Red Eléctrica de España has foreseen the inclusion of aFRR and mFRR market in the European platforms PICASSO and MARI at the end of 2024 [29].

It is necessary to have a regulatory zone to participate in the aFRR, which needs at least 200 MW habilitated to participate in this market. This is a significant barrier for some agents to participate in this market (especially demand units). On the other side is mFRR and RR, whose requirements are not so demanding; it is not necessary to have a regulation zone, but also with programming units with more than 1 MW is enough.

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Since last March 2020, the allocation of balance energy from **replacement reserves (RR)** has already been carried out from the European LIBRA-TERRE platform. This service, which can be manually activated in a time equal to or less than 30 minutes, is managed through the European platform LIBRA. More information about balancing markets can be found in D1.3 [1].

Spanish Government activated a public consultation to create a **Capacity Market** in the Spanish electricity system. This new capacity market aims to minimize the volatility of electricity prices and ensure the technical viability of the system due to the growing penetration of renewable technologies.

The new market will be constituted as a centralized system where the Spanish System Operator will contract the required firm power (power that an installation will be able to offer at times of peak demand, depending on the needs that it detects from analysis of demand coverage).

- It will be contracted through competitive bidding procedures managed by the operator of the "pay-as-bid" auction system.
- Participants may be consumers, generation, or storage facilities, including self-consumption facilities. They meet several technical requirements.

The first model of market analyses two modalities of capacity auctions:

- The main auctions with a maximum "grace period" of five years, and a service provision period of 1 or 5 years, depending on whether they are existing facilities or new facilities.
- The adjustment auctions with a maximum "grace" period of 12 months and a service provision period of 12 months. The purpose of these last auctions is to resolve eventual coverage problems that the firm power of the principal will not cover.

Finally, the Technical Constraints Resolution Market focuses on carrying out redispatches to solve system constraints, including network constraints, security considerations, coal production quotas (a transitory mechanism), etc. These markets are systematically run after each energy market session (day-ahead and intraday auction market) but can also be called at any time based on the TSO criterion. The TSO takes the declared programs derived from bilateral contracts, and the day-ahead market results check their technical feasibility and makes necessary adjustments (redispatches).

Connection with this market has been done using the platform of the Spanish TSO in section 3.5.

3.1.2 Local Flexbility market in Spain – IREMEL

In this section, the objective is to define the operating model of the local flexibility markets of electricity (described in section 3), a project called IREMEL to be developed as a collaboration of Instituto para la Diversificación y Ahorro de la Energía (IDAE) and the Operador del Mercado Ibérico de la Electricidad, OMI Polo Español S.A. (OMIE).

The primary purpose of this project and the operating model designed is to facilitate the incorporation and participation in the removable installation production markets and consumption from the grids, promoting the integration of removable energy and consumer empowerment besides taking advantage of better prices in the electricity markets because of its flexibility.

This objective mentioned is aligned with the European legislation derived from the so-called "clean energy package", and in particular with the Directive on the promotion of the use of renewable energy sources (Directive 2018/2001) and the Directive on standard rules for the internal market in electricity (Directive 2019/944) [30]. In the first regulation, the role of the citizen and of renewable distributed energy resources is enhanced through the promotion of self-consumption, and in the regulation relating to the internal electricity market, the bases are laid for active participation in the different electricity markets of the citizen energy communities, the figure of the aggregator is defined.

In addition, incentivizing DSOs (distribution system operators) to acquire flexibility services, including congestion management, would improve grids' operational efficiency and development, avoiding unnecessary investments in grid expansions.

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Under the proposed approach, distribution systems operators have three mechanisms at a local level to deal with potential congestion and problems that may occur in their grids.

1. Establish limitations to the programs and bids presented in local markets by the distributed resources in their area, decreasing the possibility of such problems occurring.
2. To face this foreseeable congestion or operational problems, use the Local Products to promote the modification of the production programs and consume manageable resources in the area.
3. Facing a recurring problem that would be very onerous to solve by investing in the distribution grid, defining flexibility services or agreements with the owners of specific distributed resources to ensure their availability, and the presentation of offers to the local products to solve such problems, if they occur.

This model has the advantage to allow the different agents and distributed resources to freely participate in the markets in case there are no congestions or problems in the areas where they are located, and just for those periods when these problems occur, be partially limited or be called upon to participate through the Local Products in the mechanisms established for their resolution.

IREMEL foresee those two different solutions [30] proposed below:

- Using Local Products to solve these eventual congestions. (eventual solution)
- Creation of specific flexibility services or signing agreements between the distribution grid operator and the distributed resources that establish their behaviour, ideally via their participation in the markets, in the face of a series of situations that may arise and for which the grid operator needs to have available resources in a given area with a commitment to modify production or consumption. i.e., agreement of changing the generation or demand that could be done if necessary. (consistent solution)

Both solutions will be explained more deeply.

The first one, using **Local Products** to solve the eventual congestions or grid problems: The Market Operator, in collaboration with the distribution network managers, will define the Local Delivery Products in the distribution network areas where congestion or technical problems may occur.

Once the products that would be necessary to help solve the congestion through modifications in their production or consumption have been defined, the distribution network operator is the one who monitors that the operating parameters of the network are adequate, and in case of congestion forecast (with enough time for the distributed resources to manage their production/consumption during the coming), the grid operator indicates to the market operator this situation, the need to open to negotiation the associated Local Product and the amount of energy dumped that it wishes to increase (or decrease the consumption) or reduce (or increase the consumption) in these facilities. The Local Product will be open to negotiation. The affected installations will be notified of this eventuality to make their offers competitively, selecting those most competitive bids up to the limit established by the grid operator.

Among the negotiation mechanisms for Local Products, two main ones are being established: Continuous and Auction markets. As a result of the negotiation, the set of resources will be obtained that will modify their production or consumption plans up to the required limit in the necessary periods.

In this image (

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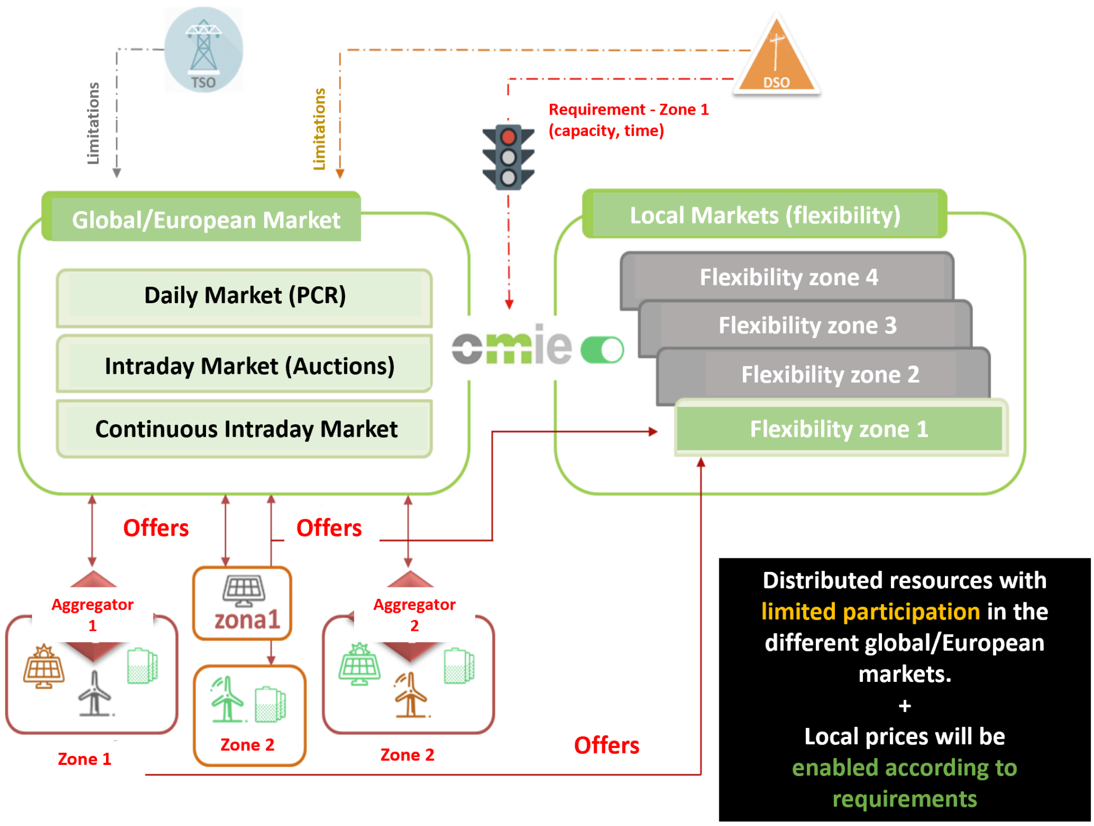

Figure 34), you can see a global state of the congested grid; the market operator enables the requested flexibility market in zone1. The distributed resources seen on the left side of the image can participate in the existing global/European and also in the flexibility market that has been activated.

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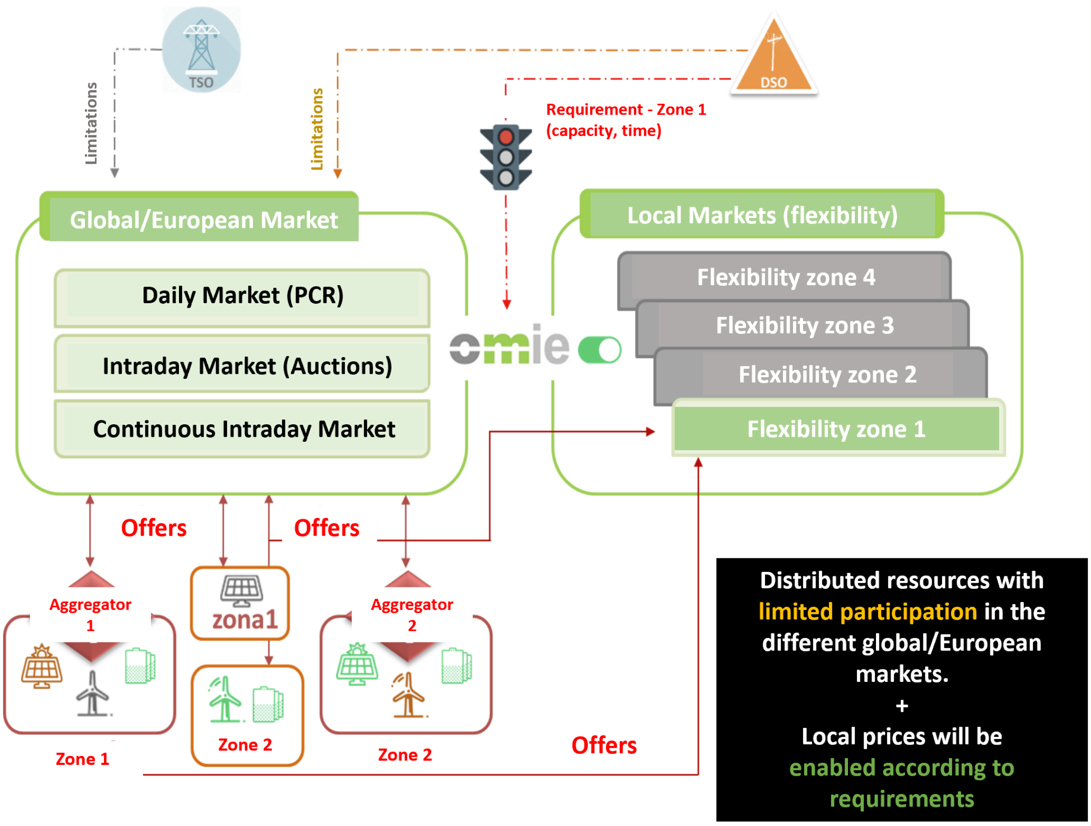

Figure 34: Local Products (eventual solution) [30] It presents an overall state of the congested network, and at the request of the distribution network manager, the market operator enables the requested flexibility market in zone1. On the left side of the image, distributed resources can participate in existing global/European markets either on an individual free basis or via aggregator on a limited basis, and in addition, the resources allocated to zone1 can also participate in the flexibility market that has been activated.

The second one is the **Creation of specific flexibility services**: the distribution grid operator could consider it convenient, due to the persistence of congestions and problems in the area, to have a series of resources that are committed to modifying their productions or consumptions in case of need. Intending to have the security that those behaviours will occur, the distribution grid operator reaches an agreement or contracts a specific service with the resources involved, who, in exchange for a particularly established remuneration, undertake to carry out the indicated action; not being necessary to invest in the improvement of elements of the distribution grid.

The remuneration of the resources for these services would be made up of a fixed amount (market result, auction) and a variable amount (the result of each time the Local Product associated with said service is activated or matched). The participation of the distributed resources in the Flexibility Services that are convened does not prevent their involvement in the global or local products that are being negotiated; it is the owner of the resource, who, in the event of having acquired a flexibility commitment, must ensure that its participation in the different markets does not prevent it from complying with the obligations previously received.

In the following image (Figure 35), a global state of congestion in the grid can be observed. The market operator habilitates the flexibility market in zone 2. In the left of the image, it can be seen that the distributed resources can participate on the global market or European market, and also the resources assigned to zone 2 can participate in this flexibility market, but in this case, they have a commitment with the DSO of offering to the flexibility market the restrictions defined in their contract.

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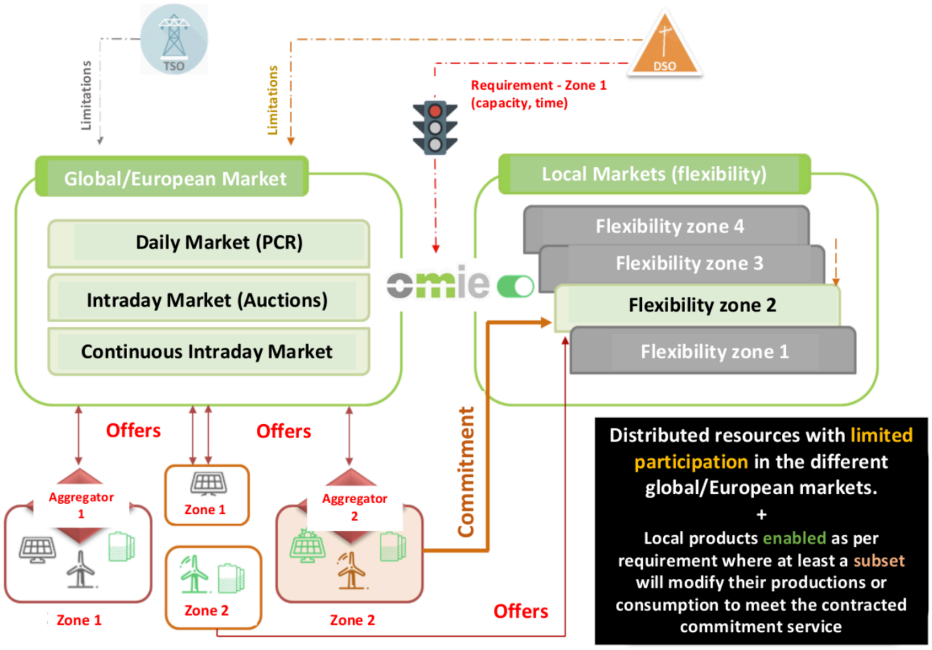

Figure 35: Creation of specific flexibility services (consistent solution) [30]. It presents a global state of the congested network, and at the request of the distribution network operator, the market operator enables the requested flexibility market in the zone2. In the left part of the image, the distributed resources can participate in the existing global/European markets either freely, individually or via aggregator in a limited way. In addition, the resources assigned to zone 2 can also participate in the flexibility market that has been activated. In this case, additionally, the resources that have contracted the flexibility service with the DSO have a commitment to bid into the flexibility market according to the constraints defined in the contract.

By way of summary, the following Table 17 shows the negotiation possibilities available for the distributed resources:

Table 17: Negotiation possibilities for distributed resources

Geographic area	Congestion level	Model	Market
Global European	Distribution grid without congestions or restrictions	Participation in the actual markets without restrictions	Diary Intraday Auctions Intraday Continuous
	Distribution grid with congestions or restrictions	Participation in the current markets may be limited to the facilities' performance due to network conditions.	Diary Intraday Auctions Intraday Continuous
Local area	Eventual or punctual congestion that requires action	Local products differentiated per zone	Specific local products with continuous market trading or auctions.

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	Persistence congestion that requires available resources with a commitment to act	Ex-ante contracting of flexibility services by the DSO Local products on a daily basis	Use of local products Commitment to the participation of facilities with which the flexibility service is contracted.

In addition, an **integrated platform** is proposed to operate through the trading platforms offered by the market operator, allowing owners of distributed resources to access, according to their needs or in response to price signals, either global or zonal markets with the same security standards and through a centralized platform that integrates the different trading modalities. This model guarantees greater transparency and cost efficiency, and greater liquidity in the offer of flexibility, as opposed to other models of independent, non-centralized platforms that tend to fragment the offer.

IREMEL was scheduled to be launched in the third quarter of 2022, but at the moment, there is no information on the final market design nor what the connectivity with this platform will be. Since OMIE is a consortium partner, the connectivity will be similar to the one developed in 2.5 and will be created when ready to make tests.

3.2 United Kingdom – Great Britain

In the UK, the most developed markets are at the local level, whereas the national markets are being reformulated and discussed. Both are addressed below.

3.2.1 National market

From the markets described in Section 2.2.1, Ancillary balancing services, operating and replacement reserve, capacity market and balancing mechanism are considered as national markets. Regarding the standard balancing products presented at the beginning of Section 3, the UK does not follow these products (only partially RR), but they have access to their products, these are: Future Response Products, STOR, FR, RR and ODFM.

British TSO National Grid Electricity System Operator (NGESO) has different options to keep the network balanced. One of them is the **Future Response Product** Suite, with three frequency response services: Dynamic Containment (DC), Dynamic Moderation (DM) and Dynamic Regulation (DR). These services substitute the old FCR services Enhanced Frequency Response, Mandatory Frequency Response and Firm Frequency Response.

These new services are procured to manage system frequency within Security and Quality of Supply Standard (SQSS) limits around 50 Hz. Currently is only on service DC, but DM and DR will be released during 2022. The characteristics of these three services are the following ones:

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Table 18: Product characteristics – for DC, DM, and DR [1].

	Dynamic Containment (DC)	Dynamic Moderation (DM)	Dynamic Regulation (DR)
Product Characteristics	Designed to arrest the change in frequency following a sudden imbalance. The aim is to contain frequency within SQSS limits (for unacceptable frequency conditions).	Designed to assist frequency management following large imbalances. The aim to contain frequency within operational limits of +/-0.2Hz.	Designed to slowly correct small continuous deviations in frequency. The aim is to continually regulate frequency around the target of 50Hz
Renumeration	Pay-as-bid		
Procurement	Day-ahead		

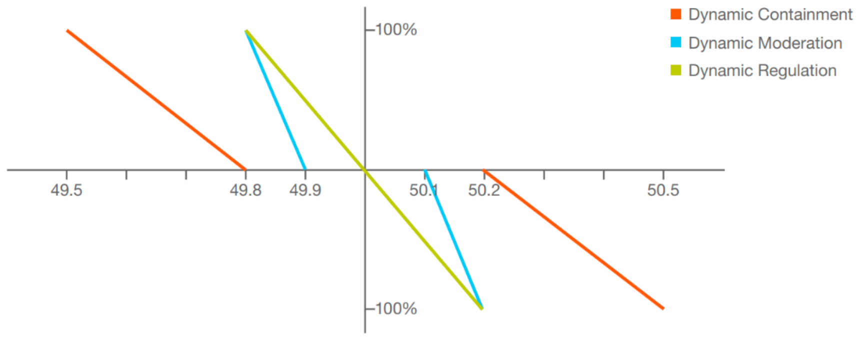

Figure 36 Frequency range of Future Response Product Suite services [1].

DC is an optional ancillary service to protect the system from large deviations from the nominal frequency of 50 Hz, responding automatically to any variations outside the Deadband of +/- 0.015 Hz. DC requires a complete response in under 1 second, with output sustained for 15 minutes. DC is procured day-ahead and is renumerated based on an availability fee [£/MW/hr].

The main parameters of this service are: payment for service availability (£/MW/h), minimum of 1MW per Response Unit; can take part generation, demand and energy storage; Aggregation possible where assets behind same Grid Supply Point. The Dynamic Containment service is procured through an auction process the day before the delivery, with contract lengths of 24 hours and single price and volume submissions.

Another frequency response service is **Short Term Operating Reserve (STOR).** STOR is procured to meet some of our reserve requirements through balancing services when it is economical to do so. This requirement provides additional energy in megawatts (MW) in short timescales. The service is open to any technology to increase generation or reduce demand by at least 3 MW. Providers must respond to an instruction within 240 minutes, although response times within 20 minutes are preferred. The service is remunerated based on formulae, and bidding is mandatory for contracted STOR units. Each STOR Bid will represent a single offered MW capability, and accompanying price (£/MW/h), for all of the committed windows on a working day.

From 1 April 2021, STOR is procured through a daily pay-as clear auction process. The auction closes at 05:00 for service delivery the following day (05:00-05:00). Providers submit their availability prices and MW offering before the day-ahead auction, which is then cleared to secure capacity for STOR at the lowest available cost. A STOR bid is accepted when NGESO considers that the total costs of securing and operating the system are lower with the bid than without it.

Another service provided by NGESO is **Fast Reserve** (FR). Fast Reserve is a contractual Balancing Service in which the service provider supplies a contracted level of power when National Grid instructs it, while

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staying within pre-determined boundaries. This is comparable to the STOR service, except the supplier must respond in a considerably shorter timeframe. The characteristics of this service are: active power delivery must start within two minutes of the dispatch instruction; a delivery rate over 25MW/minute; the reserve energy should be sustainable for a minimum of 15 minutes; and must be able to deliver a minimum of 25 MW.

For Fast Reserve, there are three types of payment: Availability fee (£/hour, paid for the hours a provider has tendered to make the service available), Nomination/positional fee (£/hour, paid for being called upon to provide the service within a fast reserve nomination window) and Utilisation fee (£/MWh paid based upon the actual level of energy delivered in a given nomination window).

Short Term Operating Reserve (STOR)	Fast Reserve (FR)
■ 3 tender rounds per year, for a **committed or flexible** service. ■ **Min. entry size is 3MW**, from an single or aggregated unit. ■ Asset(s) must be able to respond to an instruction within **20 mins** and sustain the response for **up to 4 hours**. ■ More info: STOR Interactive Guidance Document	■ Procured via monthly tender. ■ **Min. entry size is 25MW**, from an single or aggregated unit. ■ Ramp up rate is 12.5MW/min so an asset should be at an output of 25MW in 2 minutes. ■ The response must be sustained for **15 mins**.

Figure 37 Comparative table between STOR and FR [31].

The **Replacement Reserve (RR)** service is in the process of being discussed for implementation in the UK, but with the country's exit from the European Union, different possibilities are being considered. According to the latest information, NGESO is considering three implementation scenarios; GB operates a TERRE-like mechanism in standalone mode, access to European RR via bilateral agreement or an agreed position between the UK and European Commission (EC) on balancing market arrangements, including access to TERRE and MARI. At the moment, the most likely scenario, according to NGESO, would be the first one [32].

Optional Downward Flexibility Management (ODFM) was introduced in 2020 as a negative-reserve service designed specifically for distributed assets to help manage low demand periods, which is an effect of coronavirus lockdowns in Great Britain.

Providers of ODFM must not be registered as a Balancing Mechanisms Unit and must not have a connection agreement subject to an active network management system. The total capacity of assets must be at least 1 MW. Aggregation is permitted for smaller units, providing all individual assets are connected behind the same grid supply point and the same technology type. Delivery of the service must be sustained for a minimum of 3 hours, during which generation assets are required to reduce their output to 0 MW.[112]

Prospective providers of ODFM are required to submit their availability to provide the service and utilisation fee on a week-ahead basis. During the summer operational period, submission deadlines were each Wednesday at 15:00 for delivery for the week starting Friday at 23:00. National Grid ESO calls on providers when a downward reserve is required. Instructions are made by email the day before service delivery is required

However, all these markets are experiencing a transformation, so the final conditions of some of them are still to be known:

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Response Product	In 2020	In 2025
Enhanced Frequency Response (EFR)	EFR is an ESO legacy product which was procured through a one-off tender event in 2016. Eight new-build battery storage sites were awarded 4-year EFR contracts which will end in 2022.	EFR will no longer exist in 2025. EFR providers will be able to offer their services into DC or DM.
Mandatory Frequency Response (MFR)	MFR covers the mandatory provision of 'Primary', 'Secondary' and 'High' Response as defined in the Grid Code and governed through a payment schedule in the CUSC. It is instructed through the BM in real time. Almost all Large Generators must have response capability. This is defined in their Mandatory Service Agreements (MSAs).	In 2025 we will still require a real-time (intra-day) procured response service. It is likely that MFR will still exist, but we will be exploring options for further development.
Firm Frequency Response (FFR)	FFR monthly tenders allows us to procure Primary, Secondary and High response from BM and non-BM providers as well as smaller volumes of non-dynamic response. FFR tenders are pay-as-bid and provide revenue certainty for the month for successful contract holders.	FFR monthly tenders will have been phased out and providers can move into the new response products or new reserve markets in accordance with their technical capabilities.
Weekly Auction Trial (DLH and LSF)	The Auction Trial, which is hosted on an EPEXSPOT built and owned bespoke auction platform, is trialling closer to real time procurement and exploring price formation in pay-as-clear auctions. It is funded through an Network Innovation Allowance (NIA) innovation project which will end in December 2021.	The Auction Trial will have ended and learnings from the trial will have been incorporated into the development of the new product suite which will use a pay-as-clear auction procurement approach.
Dynamic Containment (DC)	The first of our new response product suite, DC, was launched in October 2020. DC requires a response time from providers within one second of a deviation in frequency outside dead-band limits. It is currently procured through a pay-as-bid day ahead auction for 24-hour long contracts.	DC volumes will have increased and the market matured. We will have separated procurement of High Frequency and Low Frequency. We will be procuring the product through a day-ahead pay-as-clear auction. DC auctions will include a range of providers.
Dynamic Moderation (DM)	DM technical specifications are still in development and we will be looking to co-create these with industry. The product will need to be fast acting (1 second response) and support the ESO in managing sudden imbalances.	We expect to be procuring DM in the same timescales and through the same platform as DC.
Dynamic Regulation (DR)	DR will have a slower response time (around 10 seconds to maximum active power output) and will therefore be open to most existing response providers. It will support us to correct continuous but small deviations in system frequency.	We expect to be procuring DR in the same timescales and through the same platform as DC. DR will be an option for some of the technologies with a slower response time like wind.

Reserve Product	In 2020	In 2025
Short Term Operating Reserve (STOR)	STOR is a well-established service providing extra power to meet extra demand at certain times of day or if there's an unexpected drop in generation. We aim to procure 1700MW of STOR to cover our largest loss.	Standardised products created during Reserve Reform must ensure we retain the capability to fulfil our SQSS obligations. The future of STOR is dependent on the delivered outcomes from Reserve Reform.
Fast Reserve	Fast Reserve provides the rapid and reliable delivery of active power through an increased output from generation or a reduction in consumption from demand sources, following receipt of an electronic dispatch instruction. We currently have three categories of Fast Reserve: Firm Fast Reserve, Optional Fast Reserve and Optional Spin Gen.	In July 2020 we published a letter to industry confirming that we would no longer be procuring Firm Fast Reserve in its existing form. By 2025 all Fast Reserve services will have been replaced by a new standardised product suitable for Day-Ahead procurement timescales.
Operating Reserve	Operating Reserve provides access to injections of active power through the BM, forward trades or SO-SO services.	This is anticipated to continue; our ambition is that all dispatch occurs from one location to aid optimisation.
Replacement Reserve (RR)	This pan-European reserve product is harmonised across participating TSOs. It allows the TSO to access upwards or downwards injections of active power. The full activation time of the RR standard product is 30 minutes.	The UK will not have access to the LIBRA platform to access the standardised European RR product however we are going to be exploring more standardisation in our products through Reserve Reform.
Negative Reserve	A negative reserve service is one which provides the ESO with flexibility to reduce generation or increase demand and is usually instructed in the same way as operating reserve.	Access to negative reserve is an important tool to manage expected future system conditions. The Reserve Reform programme will result in both upwards and downwards products.

Figure 38 Expected changes of national response products by National Grid [33].

There is no way of connecting to a platform to obtain prices, requirements and activation since they are pay-as-bid markets.

3.2.2 Local Flexibility market – Flexible Power

Flexible power is an initiative from five British Distribution Network Operators (Western Power Distribution, Northern Powergrid, Scottish and Southern Electricity Networks, SP Energy Networks, and Electricity North West) to procure flexibility from customers in order to avoid constraints in distribution networks using assets at all voltage levels. Flexible power uses a customer-facing portal in which Flexibility Service Providers (FSPs) can declare their flexible assets' availability, receive dispatch signals, and view performance and settlement reports.

Flexibility requirements are located in specific geographical locations, known as Constraint Management Zones (CMZs). Flexibility is procured from three different services aligned with the definition given by the Open Networks Project [4]. These services are Secure, Dynamic and Restore.

Secure service is used to control network peak demand loading and minimize network load in advance. As these restrictions are predictable, payments of this service consist of an arming fee when the service is assigned to a flexibility provider and a utilization fee when the service is delivered (based on the amount of flexibility provided).

[4] https://www.energynetworks.org/assets/images/Resource%20library/ON-WS1A-P3%20Active%20Power%20Services%20-%20Final%20Implementation%20Plan-PUBLISHED.23.12.20.pdf

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957837.

The following week's secure service requirements are announced in advance. When FSPs are not required to participate in the Secure service, the week-ahead declarations are scheduled to allow them to participate in alternative services.

In the following table can be seen the different approaches that each DNO have for Secure service:

Service Parameter	ENWL	NPG	SSEN	UKPN	NIE	SPEN	WPD
Minimum Non-Aggregated Declarable Capacity	50kW	100kW	50kW	50kW	70kW	50kW	No Min
Minimum Aggregated Declarable Capacity	100kW	100kW	50kW	50kW	70kW	50kW	No Min
Minimum Utilisation	30 mins	3 hours	30 mins	N/A	30 mins	30 mins	1 hour
Minimum Utilisation Duration Capability	30 mins	30 mins	30 mins	30 mins	30 mins	0	30 mins
Maximum Ramping Period	30 mins	30 mins	30 mins	30 mins	30 mins	30 mins	15 mins
Availability Agreement Period	Contract Stage	Contract Stage	1 Week Ahead	Contract Stage	1 Week Ahead	Contract Stage	1 Week Ahead
Utilisation Instruction Notification Period	Contract Stage	Contract Stage	24 hrs	Real Time	Real Time	1 day ahead	1 Week Ahead

Figure 39 Technical requirements for each DNO for Secure services [34].

Dynamic service has been developed to support the network in specific fault conditions, such as during maintenance work. Payments in this service consist of an availability fee and utilisation fee. If an FSP offer is accepted, it is expected that this FSP is ready to respond to utilisation calls within 15 minutes.

Utilisation time is expected to have a longer duration than the secure service. As in the secure service, dynamic service availability is determined in advance for the following week.

In the following table can be seen the different approaches that each DNO have for Dynamic service:

Service Parameter	ENWL	NPG	SSEN	UKPN	NIE	SPEN	WPD
Minimum Non-Aggregated Declarable Capacity	50kW	100kW	50kW	50kW	70kW	50kW	No Min
Minimum Aggregated Declarable Capacity	100kW	100kW	50kW	50kW	70kW	50kW	No Min
Minimum Utilisation	30 mins	3 hours	30 mins	N/A	30 mins	30 mins	1 hour
Minimum Utilisation Duration Capability	30 mins	30 mins	30 mins	30 mins	30 mins	0	30 mins
Maximum Ramping Period	3 mins	3 mins	3 mins	30 mins	30 mins	3 mins	15 mins
Availability Agreement Period	Contract Stage	Contract Stage	1 Week Ahead	Contract Stage	1 Week Ahead	Contract Stage	1 Week Ahead
Utilisation Instruction Notification Period	Real Time	Real Time	3 mins	Real Time	Real Time	Real Time	1 Week Ahead

Figure 40 Technical requirements for each DNO for Dynamic service [34].

Restore service is designed to assist with network restoration in a rare network failure alleviating network stress.

This service is based on a premium 'Utilisation only' price since the necessity is fundamentally uncertain. There are no pays for Arming or Availability, only is rewarded for utilisation. Like in the dynamic service, it is expected that FSP has to be ready to activate their flexibility within 15 minutes after the utilisation call.

In the following table can be seen the different approaches that each DNO have for Restore service:

Service Parameter	ENWL	NPG	SSEN	UKPN	NIE	SPEN	WPD
Minimum Non-Aggregated Declarable Capacity	50kW	100kW	50kW	N/A	70kW	50kW	No Min
Minimum Aggregated Declarable Capacity	100kW	100kW	50kW	N/A	70kW	50kW	No Min
Minimum Utilisation	30 mins	3 hours	30 mins	N/A	30 mins	30 mins	1 hour
Minimum Utilisation Duration Capability	30 mins	30 mins	30 mins	30 mins	30 mins	0	30 mins
Maximum Ramping Period	3 mins	3 mins	3 mins	N/A	30 mins	3 mins	ASAP
Availability Agreement Period	Contract Stage	Contract Stage	N/A	N/A	N/A	Contract Stage	N/A
Utilisation Instruction Notification Period	Real Time	Real Time	3 mins	N/A	Real Time	Real Time	Real Time

Figure 41 Technical requirements for each DNO for Restore service [34].

On the Flexible Power website, a projection of requirements for the following month is updated by different DNOs for Secure and Dynamic services every month. The table below illustrates one example of how monthly forecasted conditions are shown:

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CMZ_T2A_SWE_0001					
Plymouth/South Hams					
Product	Date		MWh Forecast Availability Requirement	£ Value of our requirement	Availability Windows
Dynamic	w/c 7 Feb 2022	M			17:00 - 19:00 20:30 - 21:30
		T	3.1	£16	
		W			
		T			
		F			
		S	3.1	£16	
		S			
Dynamic	w/c 14 Feb 2022	M			17:00 - 19:00 20:30 - 21:30
		T	3.1	£16	
		W			
		T			
		F			
		S	3.1	£16	
		S			
Dynamic	w/c 21 Feb 2022	M			17:00 - 19:00 20:30 - 21:30
		T	3.1	£16	
		W			
		T			
		F			
		S	3.1	£16	
		S			
Dynamic	w/c 28 Feb 2022	M			00:30 - 01:30 06:30 - 22:30
		T	359.4	£1,797	
		W	359.4	£1,797	
		T	359.4	£1,797	
		F	359.4	£1,797	
		S	359.4	£1,797	
		S	359.4	£1,797	
Total Forecast	Availability		2,175.0	£10,875	
	Utilisation		17.9	£5,370	

CMZ_T2A_SWE_0002					
Exeter City					
Product	Date		MWh Forecast Availability Requirement	£ Value of our requirement	Availability Windows
Dynamic	w/c 7 Feb 2022	M	8.7	£44	08:30 - 14:00 15:30 - 19:30
		T	8.7	£44	
		W	8.7	£44	
		T	8.7	£44	
		F			
		S			
		S			
Dynamic	w/c 14 Feb 2022	M	8.7	£44	08:30 - 14:00 15:30 - 19:30
		T	8.7	£44	
		W	8.7	£44	
		T	8.7	£44	
		F			
		S			
		S			
Dynamic	w/c 21 Feb 2022	M	8.7	£44	08:30 - 14:00 15:30 - 19:30
		T	8.7	£44	
		W	8.7	£44	
		T	8.7	£44	
		F			
		S			
		S			
Dynamic	w/c 28 Feb 2022	M	8.7	£44	08:30 - 14:00 15:30 - 19:30
		T			
		W			
		T			
		F			
		S			
		S			
Total Forecast	Availability		113.1	£566	
	Utilisation		5.1	£1,530	

CMZ_T3A_EM_0003					
Woodhall Spa					
Product	Date		MWh Forecast Availability Requirement	£ Value of our requirement	Availability Windows
Dynamic	w/c 7 Feb 2022	M	1.0	£5	06:30 - 13:30 15:30 - 20:30
		T	1.0	£5	
		W	1.0	£5	
		T	1.0	£5	
		F	1.0	£5	
		S	1.0	£5	
		S	1.0	£5	
Dynamic	w/c 14 Feb 2022	M	1.0	£5	06:30 - 13:30 15:30 - 20:30
		T	1.0	£5	
		W	1.0	£5	
		T	1.0	£5	
		F	1.0	£5	
		S	1.0	£5	
		S	1.0	£5	
Dynamic	w/c 21 Feb 2022	M	1.0	£5	06:30 - 13:30 15:30 - 20:30
		T	1.0	£5	
		W	1.0	£5	
		T	1.0	£5	
		F	1.0	£5	
		S	1.0	£5	
		S	1.0	£5	
Dynamic	w/c 28 Feb 2022	M	1.0	£5	06:30 - 13:30 15:30 - 20:30
		T	0.1	£1	09:00 - 14:00 15:00 - 21:00
		W	0.1	£1	
		T	0.1	£1	
		F	0.1	£1	
		S	0.1	£1	
		S			
Total Forecast	Availability		22.5	£113	
	Utilisation		0.6	£180	

Figure 42 Forecasted requirements made by West Power Distribution for February 2022 [5].

Three services defined above have been the only ones available in Flexible Power, but in the following months, new long-term services will be opened to bring new opportunities for different assets to enter. These new services are Sustain, Secure (long term) and Dynamic (long term).

Sustain service is a scheduled constrain service, managing peak demand loading on the network and pre-emptively reducing network loading. Behaviour is determined ahead of time is a scheduled service, generally with a contract, requiring less technical integration to participate and making it easier for households to participate in it.

This service is procured months in advance for two different delivery periods on weekdays for two seasons (winter daytime and evening, summer daytime and evening). Each period has 4 hours, in which the FSPs has to reduce their aggregated demand to a level at or below a Target demand.

Remuneration in this market is fixed, based on the power reduced (£/kW), the payment score of the FSP (Indicates whether the agreed power to be reduced has finally been reduced) and a de-rating factor (reflects data uncertainties).

In the following table can be seen the characteristics determined by each DNO for Sustain service:

[5] https://www.flexiblepower.co.uk/downloads/1035

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Service Parameter	ENWL	NPG	SSEN	UKPN	NIE	SPEN	WPD
Minimum Non-Aggregated Declarable Capacity	50kW	100kW	50kW	10kW	70kW	50kW	No Min
Minimum Aggregated Declarable Capacity	100kW	100kW	50kW	10kW	70kW	50kW	No Min
Minimum Utilisation	30 mins	3 hours	30 mins	N/A	30 mins	30 mins	N/A
Minimum Utilisation Duration Capability	30 mins	30 mins	30 mins	30 mins	30 mins	0	30 mins
Maximum Ramping Period	30 mins	30 mins	30 mins	30 mins	0 minutes	30 mins	N/A
Availability Agreement Period	Contract Stage	Contract Stage	Contract Stage	N/A	Contract Stage	Contract Stage	N/A
Utilisation Instruction Notification Period	Contract Stage	Contract Stage	3 mins	M / W Ahead	Contract Stage	1 day ahead	N/A

Figure 43 Technical requirements for each DNO for Sustain service [34].

Secure and Dynamic long-term services are the same as those defined above, but instead of having the flexibility requirements each week, requirements and energy trade are made months in advance. With the addition of the three new products, six products are available in the Flexible Power market. It has been decided to allocate zone as Secure or Dynamic zones to simplify the number of products available in each zone. Sustain and Restore would be available in both zones. The allocation is shown in the table below:

Products	Secure Zone	Dynamic Zone
Sustain	Yes	Yes
Secure (long term)	Yes	No
Secure	Yes	No
Dynamic (long term)	No	Yes
Dynamic	No	Yes
Restore	Yes	Yes

Figure 44 Allocation of services based on the products offered [35].

The price determination for the services mentioned above depends on the type of services. For example, Sustain and Restore prices are fixed, but arming and utilisation fees are pay-as-clear in Secure service. In the following table are the pricing methods for each service:

Service	Pricing (once market is liquid)			
	Secure Zone		Dynamic Zone	
	Arming	Utilisation	Availability	Utilisation
Sustain		Fixed Price		Fixed Price
Secure (long term)	Pay As Clear. Cleared at the Trade months ahead	Pay As Clear. Cleared at the Trade months ahead		
Dynamic (long term)			Pay As Clear. Cleared at the Trade months ahead	Prices Capped months ahead. Final Price set through the Joint Utilisation Competition at week ahead stage which is Pay As Clear
Secure	Pay As Clear. Cleared at the Trade at the week ahead	Pay As Clear. Cleared at the Trade at the week ahead		
Dynamic			Pay As Clear. Cleared at the Trade at the week ahead	Final Price set through the Joint Utilisation Competition at week ahead stage which is Pay As Clear
Restore		Fixed Price		Fixed Price

Figure 45 Pricing method for each service offered in Flexible Power [35].

Fixed price is used for services that do not have enough flexibility to provide a competitive market, as is the case for Sustain and Restore services. For some fees from Dynamic and Secure services, prices are determined as pay-as-clear, which means that all energy is paid at a marginal cost.

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For Dynamic utilisation fees, price is determined by Join Utilisation Competition (JUC). JUC is made for encouraging competition between long term and Dynamic weekly services. Long term participants will automatically be entered into the competition at a capped rate but will be encouraged to update their pricing to reflect any efficiencies that can be made closer to real-time.

Prices at Secure and Dynamic services are submitted in a single value, which considers arming/availability and utilisation fees, using a standard split between these fees (Secure: arming 41.5% and utilisation 58.5%, Dynamic: availability 1.6% and utilisation 98.4%). Dynamic services will drop the split and allow free bids for both Availability and Utilisation.

Once determined which are the services of Flexible Power and how are they priced, it will be explained how the process is to participate in this market.

To participate in the Flexible Power market, interested parties must first register their interest via Periodic Indicative Notice (PIN). All parties will be requested to complete the Pre-Qualification Questionnaire (PQQ) following the PIN. Parties that pass the PQQ step will be added to the Dynamic Purchasing System (DPS), which holds records of all potential suppliers. All DNO demand response needs will be sent out as an Invitation to Tender (ITT) to all interested parties.

All parties who have successfully been added to the DPS will be notified of all CMZs that are open for tender. Parties having an eligible site inside the CMZ that need flexibility should reply to the ITT within the timeframes specified in the ITT.

After that, sites that have been successful at the tender stage are expected to have an API in place before the first service window of the CMZ becomes operational. Once this API is tested by the DNO and checks that the customer can receive stop/start signals and send meter readings, the site will be ready to participate in the services offered.

To offer flexibility, FSP declares availability on the Flexible Power portal by midnight on Wednesday. On Thursday morning, offers are accepted or rejected by the DNOs. The following figures show how availability and acceptance appear in the Flexible Power portal:

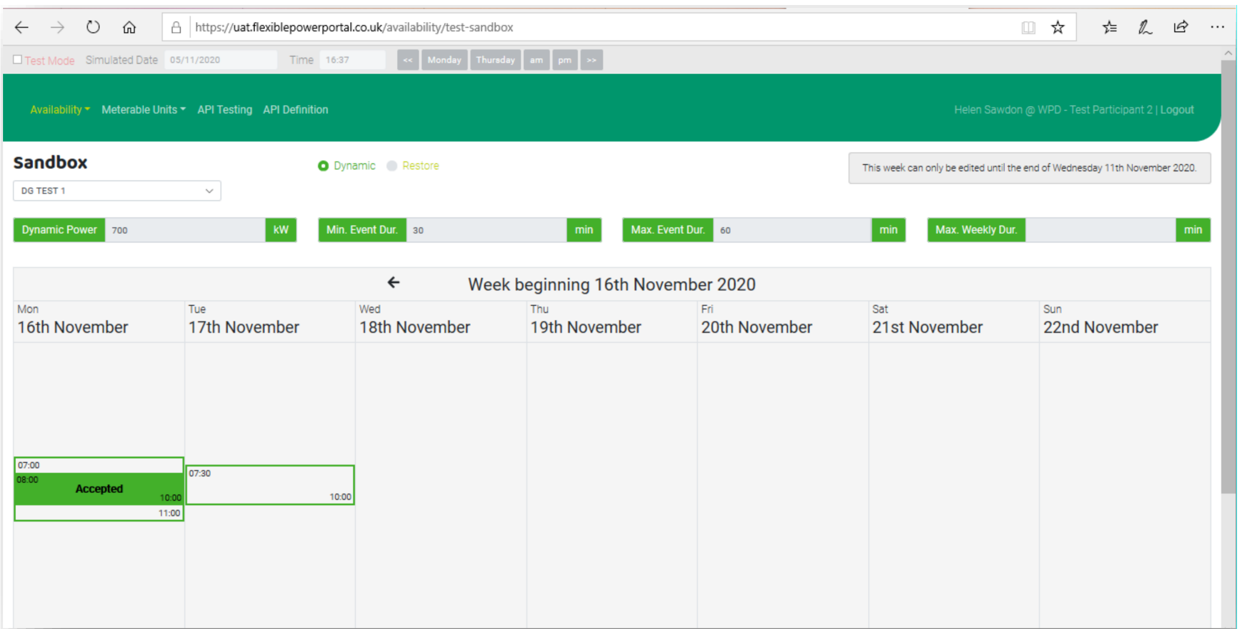

Figure 46 Definition of flexibility availability (green edge of the rectangle) and accepted flexibility in the Flexible Power portal [36].

In section 3.6, the connectivity with Flexible Power API to access the Western Power Distribution flexibility market has been described. Different prices and periods could be studied.

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3.3 Croatia

In Croatia there is only balancing markets, there are no capacity markets nor local markets in this country. Ancillary services that grid users provide to the TSO are defined as Automatic or Manual frequency restoration reserves (aFRR & mFRR) and power limitations/load shedding as demand response services for grid congestion management.

mFRR service is based on a market schema, in which the marginal procedure defines the price. For upward energy (generate more or consume less), bidders have a collection right, while for downward energy (generate less or consume more), there is a payment obligation. Units intending to participate in this market must pass a prequalification process before entering. Balancing service providers can be all individual network users and aggregators who have signed Balancing Service Agreement with TSO.

Public tenders are published for units that signed the balancing agreement to procure mFRR balancing capacity and/or energy. Balancing service providers who have received confirmation on the selection of the mFRR balancing capacity bid are required to submit a balancing energy bid in an amount equal to or greater than the agreed amount of the power reserve. Bidders who have not received confirmation on the selection of the mFRR balancing capacity bid may submit a voluntary balancing energy bid. The minimum power that providers can offer is 1 MW, and the time to full activation is 15 minutes.

The balancing energy bidding procedure starts two days before the delivery, opening the market at 15.00 D-2 and closing it at 13.00 D-1.

The other frequency restoration reserve service, **aFRR**, is based on a market schema, remunerating for the energy activated (the marginal price of the tertiary energy price €/MWh) and a reserve assignation price (for the regulation band assigned €/MW). TSO defines the needs for each day ahead. Balancing capacity bids accepted are required to submit a balancing energy bid in an amount equal to or greater than the agreed amount of the power reserve like in mFRR. The minimum power that providers can offer is 1 MW, the time to full activation is 5 min, and the activation is automatically on the order of the central regulator.

No connection developed since there is no platform to get prices, requirements and availabilities. In fact, D3.1 remarks that Croatia needs to continue to work to cope with new electric directives. Tests with other country markets could be done.

3.4 Italy

The Italian TSO, Terna, purchases resources from the Ancillary Services Market (MSD) to manage and monitor the system, relieve intra-zonal congestions, create energy reserves, and perform real-time balancing. Terna serves as a central counterparty in the MSD, and approved offers are compensated at a price offered (pay-as-bid).

The MSD comprises a scheduling substage (ex-ante MSD) and a market balancing stage (MB). As specified in the dispatching rules, the ex-ante MSD and MB occur in various sessions.

In the ex-ante MSD, Terna accepts energy demand bids and supply offers to relieve residual congestion and create reserve margins. MSD1, MSD2, MSD3, MSD4, MSD5, and MSD6 are the six scheduling substages of the ex-ante MSD. There is only one seating for bid/ask submission into the ex-ante MSD.

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The Balancing Market consists of the continuous submission of offers, with hourly readings for the 24 hours of flow day D. Opening of the session for the submission of offers for the Balancing Market is at 10.30 pm on the day before flow day D. Market Participants may submit offers up to 60' before the start of the hour H to which these offers refer.

In both the ex-ante MSD and the MB, power reserves are traded in four ways: *Regolazione secondaria* (aFRR), *Regolazione terziaria* (mFRR), replacement reserve (RR) and UVAM.

Primary regulation, *Riserva primaria* (FCR), is outside of a market scheme like in Spain, is not remunerated, and is mandatory for all eligible units.

Participation in the secondary power reserve market (aFRR) is mandatory for eligible units. It can vary the injection of electricity within 5 min of the initiation of the requested variation. It needs to provide the band within 200 s and at least 2 hours. The remuneration is based on a market- scheme pay-as-bid (€/MWh) accepting the offers submitted by market operators according to an order of economic merit, minimizing the costs for the electricity system. Only can offer energy to this market programmable generation units with more than 10 MW. The necessity of this power reserve is scheduled at 17.00, the day ahead of the delivery.

Tertiary regulation (mFRR) in Italy, as in aFRR, is mandatory for eligible units. mFRR can be divided into a "ready reserve" (*riserva pronta*) (within 15 minutes with a gradient of 50 MW / min) and "replacement reserve RR" (*riserva di sostituzione*) (within 120 minutes with a gradient of 0.67 MW / min). Programmable generation units with a power higher than 10 MW are eligible, with a preparation period of 15 min.

Terna (Italian TSO) started a project to facilitate the participation of new resources in the ancillary services market; this is known as the **UVAM project** (Virtually Aggregated Mixed Units in Italian). UVAM allow participation not only generation, but also demand and energy storage systems, mainly distributed resources. Remuneration is linked to the energy activated (€/MWh) and availability (€/MW) and is pay-as-bid, like in the previous markets.

Finally, the last market considered as a ancillary market is the Italian **capacity market**. Terna uses this market to procure long-term procurement contracts awarded through competitive bidding. Participation is voluntary and technology-neutral, so demand and generation can participate in this market.

Units selected in this market will have to offer their capacity on the energy and services markets, receive an annual fixed fee (€/MW/year) from Terna, and they must repay Terna the difference, if positive, between the price of the electricity realized on the energy and services markets and the strike price defined by Area (this is not applied for demand). Units participating in this market cannot join in the UVAM project.

At the time of writing this report, there is not local flexibility market deployed in Italy.

3.5 Connectivity with Spanish National Ancillary Service through ESIOS – REE

In the Spanish case, REE has an advanced public platform where anyone, totally free, can view and download information on the electricity system. This platform can obtain prices and productions of the energy markets controlled by OMIE and the ancillary markets managed by REE. This platform is

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called ESIOS [37] and has a web portal that can be accessed to get this information, as can be seen in Figure 47.

Figure 47 ESIOS Web Portal

In this case, REE also offers an API that is fully documented in [38]. In this case, we are requesting specific indicators that can be easily obtained from the URL of the web (

Figure 48):

https://www.esios.ree.es/en/analysis/IndicatorNumber

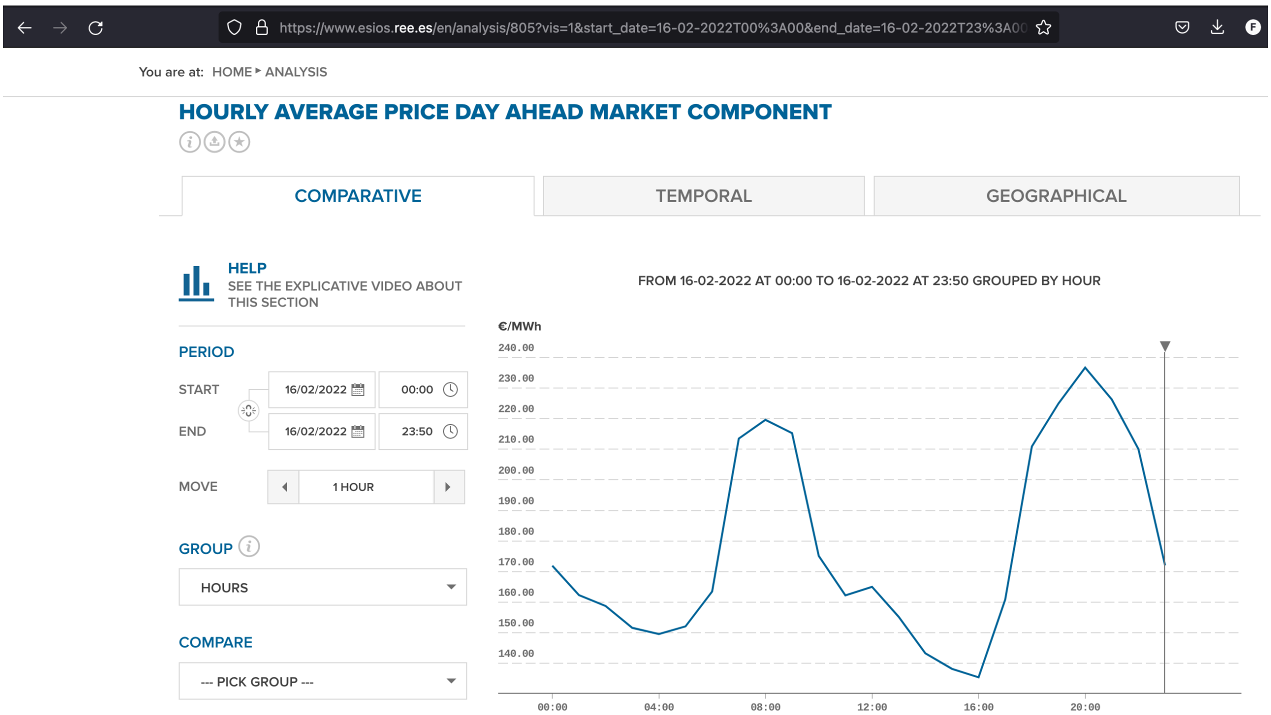

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Figure 48 Example of Indicator in the ESIOS Web Portal

Table 19: Indicator requested in the ESIOS API

Indicator Number	geo_id	Description
1001	8743	getTwoTdBaleares (PVPC)
1001	8742	getTwoTdCanarias (PVPC)
1001	8744	getTwoTdCeuta (PVPC)
1001	8741	getTwoTdPeninsula (PVPC)
1001	8745	getTwoTdMelilla (PVPC)
1739		getExcedente (PVPC)
634		get_aFRR_up_reserve_price_e_kw/get_aFRR_down_reserve_price_e_kw
682		get_aFRR_up_activation_price_e_kwh
683		get_aFRR_down_activation_price_e_kwh
632		get_aFRR_up_reserve_kw
633		get_aFRR_down_reserve_kw
680		get_aFRR_up_activation_kwh
681		get_aFRR_down_activation_kwh
677		get_mFRR_up_activation_price_e_kwh
676		get_mFRR_down_activation_price_e_kwh
675		get_mFRR_up_activation_kwh
674		get_mFRR_down_activation_kwh
1788		get_mFRR_up_requirement_kw
1789		get_mFRR_down_requirement_kw
672		get_mFRR_up_need_kw
673		get_mFRR_down_need_kw
762		get_RR_energy_kwh
666		get_RR_up_activation_kwh
667		get_RR_down_activation_kwh
669		get_RR_down_activation_price_e_kwh
668		get_RR_up_activation_price_e_kwh
10211		get_spot_price_e_kw

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Table 20: Example of request and response of the ESIOS API

Requests	

Header	`Accept: application/json; application/vnd.esios-api-v1+json`
	`Content-Type: application/json`
	`Host: api.esios.ree.es`
	`Authorization: Token token="…"`
	`Cookie:`

Route	`GET/indicators/`**`682`**`?start_date=2022-02-14T00%3A00%3A00Z&end_date=2022-02-14T00%3A00%3A00Z&time_agg=avg&time_trunc=hour`
Indicator No	It is the variable to obtain values in the response. In this case: 682.

Query Parameters	`start_date=2022-02-14T00%3A00%3A00Z`
	`end_date=2022-02-14T00%3A00%3A00Z`
	`time_agg=avg`
	`time_trunc=hour`
	`geo_id: - (in some cases)`

Response: JSON	
Body	(see below)

Body


```
{
    "indicator": {
        "name": "Precio de Regulación Secundaria subir",
        "short_name": "Regulación Secundaria subir",
        "id": 682,
        "composited": false,
        "step_type": "linear",
        "disaggregated": false,
        "magnitud": [
            {
                "name": "Precio",
                "id": 23
            }
        ],
        "tiempo": [
            {
                "name": "Hora",
                "id": 4
            }
        ],
        "geos": [
            {
                "geo_id": 8741,
                "geo_name": "Península"
            }
        ],
        "values_updated_at": "2022-02-15T01:55:01.000+01:00",
        "values": [
            {
                "value": 165.49,
                "datetime": "2022-02-14T01:00:00.000+01:00",
                "datetime_utc": "2022-02-14T00:00:00Z",
                "tz_time": "2022-02-14T00:00:00.000Z",
                "geo_id": 8741,
                "geo_name": "Península"
            }
        ]
    }
}
```


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3.6 Connectivity with WPD for Flexible Power market

As explained in section 3.2.2, WPD has a web portal where bids must be introduced each Wednesday manually. On Thursday morning, offers are accepted or rejected by the DNOs.

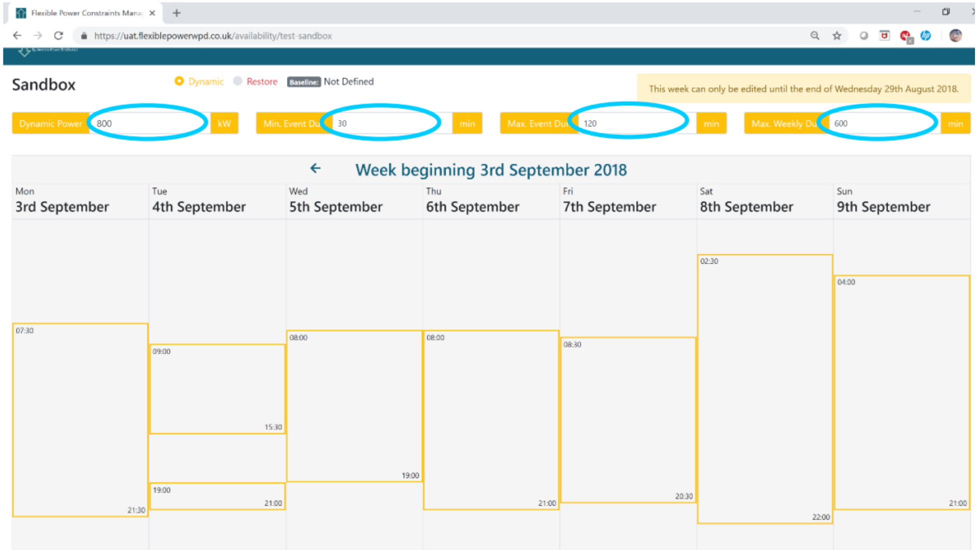

Figure 49 WPD Flexible Web Portal to introduce bids.

Then, WPD will send to an endpoint request to start (*/dispatch/start*) or to stop (*/dispatch/stop*) an activation. This has been done to be able to test this kind of market. Then, the participants should send minute by minute power readings (*/readings*). Participants can also send emergency stop signals (*/stop*). These requests had also been implemented.

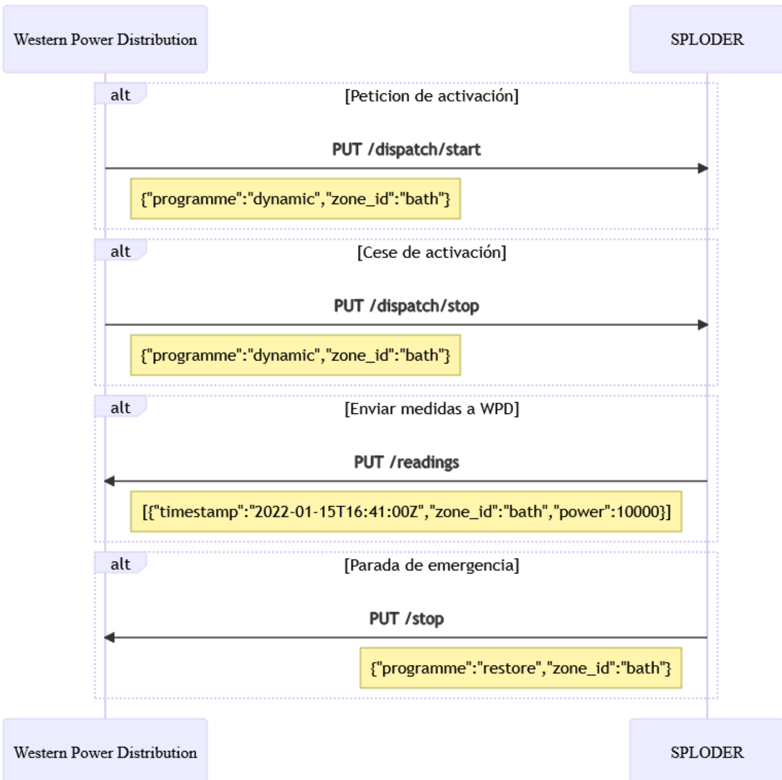

Figure 50 WPD requests implemented from/to its platform.

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4 Conclusion

Thanks to D1.3 [1], how different markets work and in which there are ancillary services described, but in this deliverable has been defined how is the retail market in each market, designing how to consider each type of tariff and how to connect with variable tariffs like PVPC or Octopus Agile and collective self-consumption. Also, it has been a detailed definition of the connexion with energy markets, balancing markets and Local flexibility markets in Spain. Meanwhile, the definition of the connectivity in the rest of the countries has been descriptive.

Before defining how is the system developed, it has been described how are the markets in each country of the project, differentiating between energy markets and ancillary and local flexibility markets.

Energy markets have been considered those in most of the energy traded between generators and suppliers, mainly the wholesale market, composed of day-ahead and intraday markets. Ancillary and local flexibility markets have been treated as those that help with the stability of the system, ancillary (balancing) services, capacity market, technical constraints and local flexibility market has be considered of this group of market.

Then, other market differentiation has been carried out, distinguishing between national and local markets. National markets have been considered those where there is no limit to the location of a generator or consumer, but where energy or flexibility was managed at the overall country level. Local markets then are those in which there is a limit due to the location of the assets, especially for flexibility markets and collective self-consumption. Most of the information used for this section has been extracted from D1.3 [1].

Particular attention has been done to retail tariffs in each country. Tariff structures and fees are different between the four countries analysed, so a detailed description has been defined to understand the operation of these. Also, it has been remarked the existence of regulated tariffs and the different types of tariffs in the liberalised market (fixed price, indexed price, variable tariff, flat fee tariff). Finally, in the energy markets section, it has been stated how the different models of self-consumption exist with energy injection into the grid and if collective self-consumption exists (that can be considered as peer-to-peer exchanges) in each country.

Table 21: Summary of markets analysed in D2.5.

<table>
<tr><th rowspan="2">Country</th><th colspan="2">Energy Market</th><th colspan="2">Ancillary and Local Flexibility Market</th></tr>
<tr><th>National</th><th>Local</th><th>National</th><th>Local</th></tr>
<tr><td>Spain</td><td rowspan="2">Day-ahead, intraday auctions, intraday continuous</td><td>Retail, collective self-consumption</td><td>aFRR, mFRR, RR, Capacity market</td><td>IREMEL</td></tr>
<tr><td>United Kingdom</td><td>Retail</td><td>DC, DM, DR, STOR, RR, ODFM</td><td>Flexible Power</td></tr>
</table>

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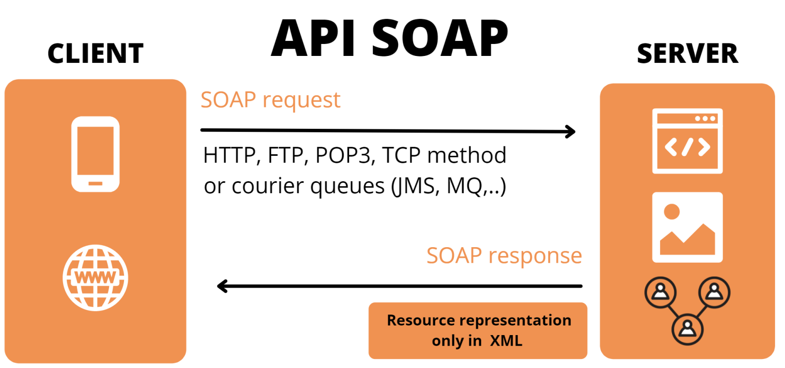
Croatia	Day-ahead, intraday continuous		mFRR, aFRR	-
Italy	Day-ahead, intraday auctions, intraday continuous	Retail, collective self-consumption	Ex-ante and Balancing Market (FCR, mFRR and RR), UVAM project.	-

Once analysed the markets, it has been described in detail the connection that has been possible to develop. For instance, it has been defined how is the connection with the Spanish market operator, OMIE. A description of the OMIE's web service architecture and how what is an API SOAP and WSDL has been done. It has described in detail the connection system made with the Spanish electricity market by means of a SOAP API so that it allows the downloading of prices and energy cleared (GET) and sending of offers (POST). In sections 2.5.4 and 2.5.5 are developed both Java classes. This java class that allows the connection with OMIE could be replicated for the rest of the markets. Other connections have been made through API REST using a transparency platform where the information can be obtained.

For clarification purposes, the following table (Table 22) shows the main differences between REST and SOAP APIs used to connect to the marketplaces throughout the document:

Table 22: Different APIs connections.The two main different APIs connections used through this deliverable: API SOAP (Simple Object Access Protocol) and API REST (Representational State Transfer).

<table>
<tr><th>Connection type</th><th>Connection Schema</th><th>Connection list</th></tr>
<tr><td>API SOAP</td><td>
</td><td>OMIE</td></tr>
</table>

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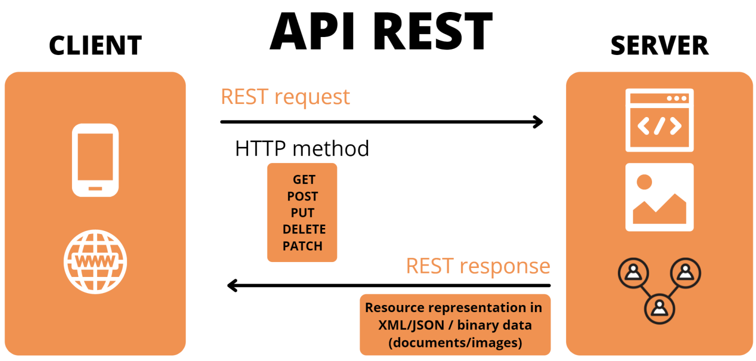
<table>
<tr><td>API REST</td><td>
</td><td>ENTSOE, ELEXON,
Agile Octopus,
ESIOS,
WDP</td></tr>
</table>

Some of the differences observed in the table, and other notable ones, are the fact that in REST APIs the services are organized hierarchically, while in SOAP APIs, they are organized by collections of business methods. API REST uses only one communication protocol (HTTP) while API SOAP has several (HTTP, HTTPS, SMTP, FTP, JMS, POP3, TCP, MQ). API REST has a smaller communication message size, and its communication must be synchronous, while API SOAP can be synchronous or asynchronous. API REST simplifies client development, does not require state maintenance and has the ability to represent resources in JSON, XML, or binary data formats (documents, images). In contrast, the SOAP API can only represent resources in XML format.

With the development of the tool for the OMIE market platform, the foundations have been laid for the further development of the other systems for accessing the other European market platforms. In particular, the IREMEL platform will be developed by OMIE in 2022 and the connection will be detailed in following deliverables of ReDREAM project.

Together with task 5.5, different trials can be defined to test different markets during the project. Although some countries do not have available information of the national markets in Spain and British local markets could be used as a reference for that. In addition, the development of local markets in Spain could present a good opportunity to test in reality this market.

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Annex 1: API SOAP and WSDL

a) API SOAP

It is a protocol derived from XML used to exchange information between applications. SOAP is typically used to connect to a service and invoke remote methods, although it can be used in a more generic way to send any type of content. We can distinguish two types of messages according to their content:

- Document-oriented messages: they contain any type of content that we want to send between applications.
- RPC-oriented messages: This message will be used to invoke procedures remotely (Remote Procedure Calls). We can see it as a more specific type within the previous type since, in this case, the content of the message will specify the method we want to invoke together with the parameters we pass to it, and the server must return a SOAP message with the result of invoking the method.

This protocol establishes a transport layer over HTTP, which acts as a wrapper for the data, called "envelope". The XML document that defines SOAP is composed of four elements:

- Envelope: document root.
- Header: (optional). It provides information on how the message should be processed.
- Body: Body of the message that contains the information related to the call and its response. In the case of RPC messages, a convention is defined on how this content should be, specifying the method to be invoked and the values passed as parameters.
- Fault: information related to errors occurring during processing.

An example of a SOAP message is the following:

```
<soapenv:Envelope
xmlns:soapenv="http://schemas.xmlsoap.org/soap/envelope/"xmlns:sch="http:/www.omel.es/Schemas">
  <soapenv:Header/>
  <soapenv:Body>
    <sch:ServicioConsultaMercados/>
  </soapenv:Body>
</soapenv:Envelope>
```

In this example, the method gets “ServicioConsultaMercados” has been called to obtain information of the electricity markets, if there are some claims, if the claims to match period is open or if the claims to bid period is open.

b) WSDL

WSDL (Web Services Description Language) is an XML-based language used to describe the functionality provided by a Web service. A WSDL description or WSDL file of a Web service provides machine-readable information about the Web service interface, indicating how the service should be called, what parameters it expects, and what data structures it returns.

WSDL describes a service using various elements (XML tags). These elements can be classified as either abstract or concrete. The abstract WSDL part describes the operations and messages in detail. In other

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words, the conceptual part of a WSDL specifies what the service does: the available operations, the inputs, outputs, and error messages that the operations have, and the type definitions for the input, output, and error messages. The concrete WSDL part describes the how and where of the service, i.e., how a client has to call the service, which protocol to use, and where the service is available

The WSDL elements are shown below in more detail:

- definitions: This is the root element and allows you to specify the namespace of the document target namespace, the name, and other prefixes used in the WSDL document.
- Types: It is used to define the data types to be exchanged in the message. We can define these types directly within this element or import the definition from a schema file (XSD file).
- Message: Defines the different messages that will be exchanged during the service invocation process. The input and output messages must be defined for each operation offered by the service.
- PortType: Contains a collection of one or more operations. For each process, it indicates which are the input and output messages, using the messages defined in the previous section.
- Binding: Indicates the network protocol and data format for the operations of a portType. Bindings are concrete definitions of portTypes. A portType can have multiple bindings associated with it.
- Service: Defines the service as a collection of port elements that can be accessed. A port is defined by associating a network address with one of the bindings defined in the document. This network address is the address (URL) where the service acts, and therefore, it will be the address that applications must connect to in order to access the service. This is an example, Figure 51, of one of the classes provided by OMIE.

```
<wsdl:definitions xmlns:typens="http://www.omel.es/Schemas" xmlns:xsd="http://www.w3.org/2001/XMLSchema" xmlns:soap="http://schemas.xmlsoap.org/

    <wsdl:types>
        <xsd:schema xmlns="http://www.w3.org/2001/XMLSchema" targetNamespace="http://www.omel.es/Schemas">
            <xsd:include schemaLocation="../xsd/MensajeOfertasMD.xsd"/>
            <xsd:include schemaLocation="../xsd/RespuestaOfertas.xsd"/>
        </xsd:schema>
    </wsdl:types>
    <message name="serviceRequest">
        <part name="MensajeOfertasMD" type="typens:tMensajeOfertasMD"/>
    </message>
    <message name="serviceResponse">
        <part name="RespuestaOfertas" type="typens:tRespuestaOfertas"/>
    </message>
    <portType name="ServicioAltaOfertasMDPort">
        <operation name="ServicioAltaOfertasMD">
            <input message="typens:serviceRequest"/>
            <output message="typens:serviceResponse"/>
        </operation>
    </portType>
    <binding name="ServicioAltaOfertasMDBinding" type="typens:ServicioAltaOfertasMDPort">
        <soap:binding style="rpc" transport="http://schemas.xmlsoap.org/soap/http"/>
        <operation name="ServicioAltaOfertasMD">
            <soap:operation soapAction="urn:ServicioAltaOfertasMD"/>
            <input>
                <soap:body use="literal" encodingStyle="http://schemas.xmlsoap.org/soap/encoding/" namespace="http://www.omel.es/Schemas"/>
            </input>
            <output>
                <soap:body use="literal" encodingStyle="http://schemas.xmlsoap.org/soap/encoding/" namespace="http://www.omel.es/Schemas"/>
            </output>
        </operation>
    </binding>
    <service name="ServicioAltaOfertasMDService">
        <port name="ServicioAltaOfertasMDPort" binding="typens:ServicioAltaOfertasMDBinding">
            <soap:address location="https://www.mercado.omie.es/jsiom/webServices/SIOMServiceRouter"/>
        </port>
    </service>
</wsdl:definitions>
```

Figure 51 ServicioAltaOfertasMD wsdl code example

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