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THE ELECTRIC POWER INDUSTRY IN SPAIN

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Abstract

The following study has the intention of introducing the reader to the Spanish electric power industry from an understandable point of view for somebody who does not have any knowledge of engineering matters and seeking, ultimately, to shed light on a sector that many people do not have great acknowledge of. Many times, we do not fully understand why variations in the price of our electricity bills are due to, as well as the different concepts for which we pay or if there are any external conditions that influence our consumption.

Putting the reader in context, we begin with a brief summary of the historical background of the industry going back to the mid-20th century, when projects were carried out under direct government supervision. Although the Spanish electricity sector dates back many years, that period is essential to understand the handicaps that the sector suffered during the 1980s, ending with its liberalization, and later the rate deficits and the irruption of renewable generation technologies.

We will take a look at the agents involved in the generation, transmission, distribution and commercialization of electricity. Going through the companies that are dedicated to produce and sell electricity, to the market and the electricity grid operators. We will also overview the working method of the electricity market in its daily, intraday and forward aspects, in addition to the products sold in that market.

It must be emphasized that electricity is a staple good in today's society, so we will see what generation sources are in Spain and how they operate throughout the year. We will analyze an electricity bill in order to see in what concepts the final consumers of that service are charged. We will also see the different pricing options that customers have when hiring an electricity supply to cover their power needs and schedules.

Finally, we will analyze how the contributions affect to the grid of the different generation sources, the climate, the price of oil and the price of gas have on the marginal prices of the intraday electricity market, in addition to a section of conclusions in which we will see the results obtained during the study.

In order to complete this work, we have resorted to the official pages of the market and electrical network operators, the web archive of the Official State Gazette (BOE in Spanish) and different specialized pages of the sectors of engineering, market and marketing issues. It has also been made an extensive use of the data offered by *Red Eléctrica de España* regarding the demand by hours, assuming it is a valuable source of information to understand the particularities of the demand for electricity.

Although the text does not abound in statistical and econometric analyzes, in the last section econometrics are used to explain broadly the behavior of the marginal price in the intraday market, using as independent variables the power contributions of the different sources of energy generation. The model does not have a large number of observations due to the scarcity of data tables in which power is disaggregated by source of generation, having to resort to the data from *Red Eléctrica de España* cited in the previous paragraph.

Historical background of the Spanish electricity sector

Some of the reasons why the electricity sector in Spain is made up by a few companies that grab a large part of electricity production can be explained if we take a look back in time. We cannot understand the phenomena such as the rate deficit or the high maintenance costs that generation companies have without taking into account a series of events that already went back to the Francoist Spain years.

Although the Spanish electricity sector dates back many years (around the second middle of the 19th century), and electricity was widely used during the first half of the 20th century, we probably found the most relevant information the second half of 20th century.

Rise and crisis of the electrical industry (1960-1978):

Starting in the 1960s, with the approval of the Stabilization Plan (1959), a favorable institutional framework was created for foreign investment and the adoption of technology of international source. During that period, energy dependence on oil increased, which later would pose a serious problem as we will see.

That institutional framework would match with the years of greatest growth of the Francoist regime, in which energy demand did not stop growing and new technologies began to be adopted in order to increase the electricity generation park (such as nuclear power). In the 1960s, the projects of the **First Generation** of nuclear power plants began to be undertaken in Spain, with the Garoña and Vandellos plants. Those plants were built through the cooperation of the Francoist regime with the United States government, which eased the transfer of patent pending designs registered by North American energy companies.

The State already reserved the exploitation of national uranium deposits even before the use of this productive source. At the beginning of the 1970s, the first projects of what was known as the **Second Generation** of nuclear power plants began to be executed. Most of these projects were carried out by private initiative and were financed in US Dollars, since national financing was more expensive than foreign loans denominated in that currency.

Second generation plants:

- Nuclear power plant of Almaraz (1981 and 1983) PWR[1] type
- Nuclear power plant of Ascó (1984 and 1986) PWR type
- Nuclear power plant of Cofrentes (1984) LWR[2] type
- Nuclear power plant of Lemóniz (Never start to operate) PWR type

Some of the companies involved in the construction of those plants:

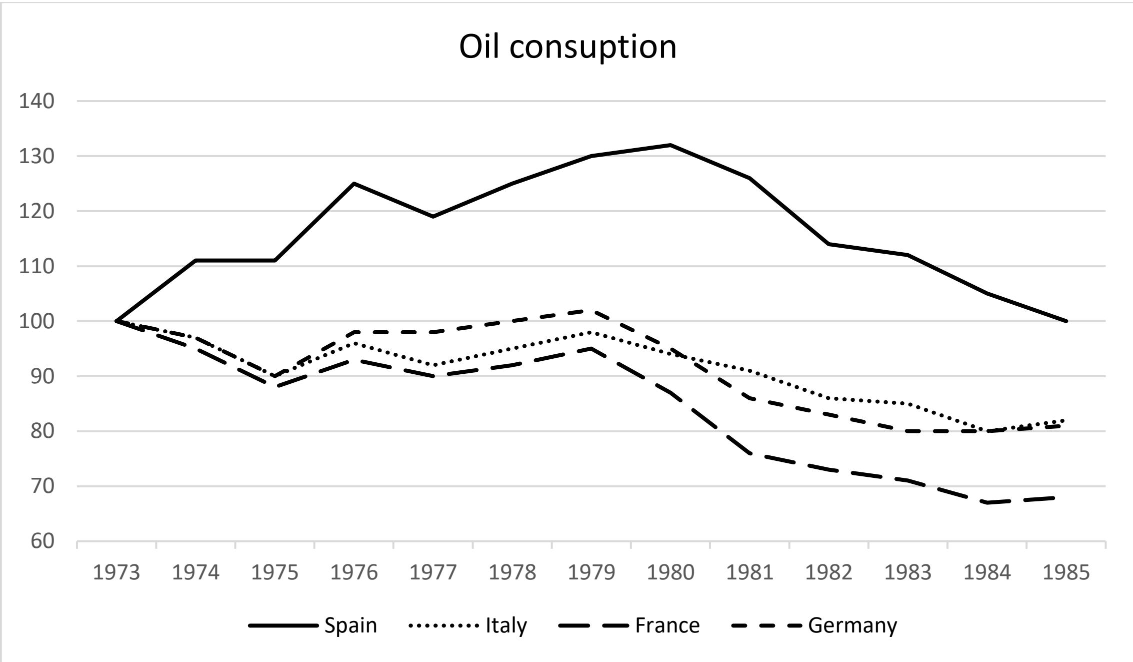
- Hidroeléctrica Ibérica (Iberduero): private
- Hidroeléctrica Española (Hidrola): private
- Fuerzas Eléctricas del Noroeste (Fenosa): private

[1] Design of Pressurized Water Reactor: http://large.stanford.edu/courses/2017/ph241/kraus1/
[2] Design of Light Water Reactor: http://large.stanford.edu/courses/2018/ph241/leis-pretto1/

- Empresa Nacional de Electricidad (ENDESA): public

The 1970s were a shock for the Spanish energy sector. Oil prices quintupled in the 1973 crisis, and later tripled again in 1979. The State made the ill-advised decision to compensate the increase in crude prices with a reduction in the special tax on hydrocarbons[3] in order to avoid a general increase in prices. For that reason, in Spain oil continued to be consumed although oil prices soared, increasing dependence on that resource. In the next graphic we can see the evolution of the oil consumption since the first oil crisis in four countries of Europe:

Graphic 1: Oil consumption evolution at different countries between 1973 and 1985 (1973=100%)



Source: International Energy Agency (IEA)[4]

Many of the nuclear power plants were still under construction and some projects would end up being cancelled directly during the government of Felipe González as a result of his nuclear moratorium policies. The last nuclear power plant to come into operation was the Trillo nuclear power plant in 1988.

National Energetic Plan and Stable Legal Framework (1978-1997)

During this stage, the State takes part in practically all decisions concerning the sector, and implements a plan designed to attend a growing demand with the background of the oil crises of the 1970s. Those plans showed a strong supply bias and, although they reduced dependence on foreign energy and significantly improved the guarantee of supply, they presented serious financial problems.

[3] Page 373. Historia económica de la España contemporánea. A. Carreras & X. Tafunell
[4] https://www.iea.org/subscribe-to-data-services/oil-statistics

In just five years (between 1980 and 1985), 5.112 MW of power were added to the generation park in new coal-fired thermal power plants and 4.695 MW in nuclear power plants. Given the deadlines for the execution of the works for the commissioning of such facilities, we can deduce that a strong investment effort was made in the previous years, just at the moments of greatest impact on the Spanish economy of the oil crises.

That effort was carried out by the electricity companies that, unlikely what happened in neighboring countries where it started earlier and where the dominant model was the public monopoly (such as ENEL in Italy), formed a vertically integrated oligopoly with a majority proportion of private capital. The investment was basically carried out through indebtedness, and that ended up triggering serious financial problems in the companies. Those companies maintained a sustained dividend distribution policy and domestic financing became scarcer and more expensive, which led to the search for credits abroad denominated in foreign currency. That was a serious problem in the early 1980s when there was a strong devaluation of the Peseta, in addition to the fact that the rates regulated by the state did not reflect all the electricity generation costs.

In other words, the oil crises caused the need to pass on to a generation that would avoid excessive dependence on oil derivatives, increasing the facilities of national coal, imported and incorporating new nuclear technology, which entailed a strong investment process bound by the content of the PEN (National Energy Plan acronym in Spanish) in adverse conditions. The process was carried out without a corresponding increase in rates, subject to state regulation, since the objective of reducing inflation determined that rate increases were almost always lower than the general increase in prices. Thus, it was possible to reduce dependence on oil, but, at the same time, **the generation of an accumulated deficit in rates was promoted, which called into question the very viability of the electricity system as its whole.**

Briefly, the issues of electric sector in those years were:

- Inadequate size and structure.
- Low level of income as a result of insufficient demand and rates.
- Large number of ongoing projects (Power plants under construction).
- High indebtedness (In foreign currency, aggravated by the devaluation of the peseta).
- Serious financial problems due to the increase in interest rates.

The government and the electricity companies reached some agreements to try to solve the precarious situation of the Spanish electricity industry. Those agreements would be reflected in the following **National Energy Plan (1983-1992)** approved by **Law 49/1984, of December 26[5],** which would incorporate the following measures:

- Intervention by the Ministry of Industry and Energy in the rate policy of electricity companies. The objective of this measure was to ensure sufficient profitability to companies that would allow them to amortize their own projects (Including those canceled by the nuclear moratorium such as Lemoniz I and II).

[5]Official State Gazette (1984) Law 49/1984, of December 26, on unified exploitation of the national electricity system: *https://www.boe.es/buscar/doc.php?id=BOE-A-1984-28282*

- Nationalization of the high voltage network through the majority participation of the public sector in a mixed company (*Red Eléctrica de España*), which aimed to optimize the network over and above the individual interests of the electricity companies that had built the infrastructure.

- Medium and long-term coordination of the development of the electricity sector through energy plans. Investments in new infrastructure would be subordinated to the decisions of the State in order to focus them more on national needs and less on the criteria of the electricity companies.

- Stricter requirements to public and private companies in order to favor their self-financing so in the future they could undertake new investment projects, in order to meet a growing energy demand.

Those standards were applied between 1984 and 1997, although in recent years, in order to integrate European regulations into the Spanish electricity sector, there was a drastic turn in its institutional framework towards a liberalization of a large part of the sector. Those changes would materialize with the **Law 54/1997 of November 27.**

Law of 1997: Liberalization of the electric power sector:

It is enough to read a brief fragment of **Law 54/1997 of November 27**[6] to understand the institutional change of the electricity sector as of 1997:

La presente Ley tiene, por consiguiente, como fin básico establecer la regulación del sector eléctrico, con el triple y tradicional objetivo de garantizar el suministro eléctrico, garantizar la calidad de dicho suministro y garantizar que se realice al menor coste posible, todo ello sin olvidar la protección del medioambiente, aspecto que adquiere especial relevancia dadas las características de este sector económico. Sin embargo, a diferencia de regulaciones anteriores, la presente Ley se asienta en el convencimiento de que garantizar el suministro eléctrico, su calidad y su coste ***no requiere de más intervención estatal que la que la propia regulación específica supone****. No se considera necesario que el Estado se reserve para sí el ejercicio de ninguna de las actividades que integran el suministro eléctrico. Así,* ***se abandona la noción de servicio público****, tradicional en nuestro ordenamiento pese a su progresiva pérdida de trascendencia en la práctica, sustituyéndola por la expresa garantía del suministro a todos los consumidores demandantes del servicio dentro del territorio nacional.* ***La explotación unificada del sistema eléctrico nacional deja de ser un servicio público de titularidad estatal*** *desarrollado por el Estado mediante una sociedad de mayoría pública* ***y sus funciones son asumidas por dos sociedades mercantiles y privadas****, responsables respectivamente, de la gestión económica y técnica del sistema. La gestión económica del sistema, por su parte, abandona las posibilidades de una optimización teórica para basarse en las decisiones de los agentes económicos en el marco de un mercado mayorista organizado de energía eléctrica.*

La planificación estatal, por último, ***queda restringida a las instalaciones de transporte****, buscando así su imbricación en la planificación urbanística y en la ordenación del territorio.* ***Se abandona la idea de una planificación determinante de las decisiones de inversión de las empresas eléctricas****, que es sustituida por una* ***planificación indicativa de los parámetros bajo***

[6] https://www.boe.es/buscar/doc.php?id=BOE-A-1997-25340

los que cabe esperar que se desenvuelva el sector eléctrico en un futuro próximo*, lo que puede facilitar decisiones de inversión de los diferentes agentes económicos.*

Therefore, what we can make clear from the fragment is the following:

- The State ceases to intervene in the prices of electricity companies, now establishing prices in the market. However, electricity tolls (rates that account for most of the consumer bills as we will see below) continue to be established administratively (they are subject to regulation).

- The state no longer conditions investment decisions within the electricity sector, and private companies are the ones that will make the decision to invest in the infrastructure they deem most convenient, although the state reserves the right to create indicative planning that channels investment decisions.

- The management of *Red Eléctrica de España* goes from being public to private. That became a reality in 1999 with its IPO, with the State Industrial Participation Company (SEPI in Spanish) reserving 20% of the company's shares.

- State planning is limited to the facilities of the National Electric Network, in order to preserve control of the transport and distribution of electricity.

- The State will also guarantee the electricity supply, the quality of the supply, the lowest possible cost and the protection of the environment.

This law aimed the vertical disaggregation of the different activities of the electricity industry, separating those of natural monopoly, such as transmission and generation (due to their high costs in terms of capital investments), from those that developed a regime of free competition such as distribution and selling.

It also liberalized the access of third parties to the electricity grid (Transmission and Distribution Networks), forced the accounting separation of the different activities of the sector (Generation, Transport, Distribution and Selling) and gave consumers freedom to choose the desired supplier of electricity.

Two electricity markets were created as of the approval and promulgation of that law, which would function as follows:

Short-term wholesale market (Spot Market): It is a sequence of 24 auctions carried out the day before the supply, which is an auction for every hour of the next day. The day of supply a sequence of 6 auctions are made again to adjust more precisely the supply and demand positions (Intraday coupling). The operator allocates quantities at the price determined by matching the supply and demand for electricity, and is set marginally, being the last unit added in market supply and demand who determinates the price for every Kw negotiated in the market previously. 80% of the wholesale market is traded on the Spot market.

Long-term market: In this market, contracts are signed bilaterally with different durations in which terms such as quantity of electricity, hour discrimination, price, etc. are precisely determined. Those contracts can be signed through the market operator or through OTC (Over The Counter) contracts, outside of the organized market.

Today, electricity markets continue to function in a similar way, with very few major companies generating electricity.

Tariff Deficit, Irruption of new renewable technologies and Law 24/2013, of December 26:

The transition to the liberation of the electricity sector was carried out during the years following the approval of the 1997 law. However, final consumers (individuals) had the possibility to choose whether they wanted to continue with a rate that included all electricity costs (full rate) or contract a price agreed with the marketers.

Those rates were agreed in such a way that they were not taking market prices as a reference, and in 2005 and forward many consumers chose to resort to this system, which transferred increases in electricity prices much more slowly.

Starting in 2006, electricity generation costs increased dramatically. Those costs were not offset by an increase in tariffs, and were further compounded by excessive subsidies for some renewables that were still in an earlier stage of development.

To solve that problem, in 2009, the Last Resort Rate (TUR or Tarifa de Último Recurso in Spanish) was established, which could be used by all consumers who so desired and who did not exceed a certain power. The price of electricity that was included in this rate was the one agreed by the CESUR[7] auctions (Quarterly), and also included the costs of electricity and marketing tolls.

The establishment of targets set by the renewable energy plans was the main cause of the onerous policy of subsidies (which were especially favourable for some technologies that did not contribute any efficiency to the system). According to the Bank of Spain's electricity sector report, system costs increased 168% due to premiums, regulated costs and the payment of interest on debts contracted to finance new projects, which in 2013 was 30,000 million of euros. In any case, it should be noted that some technologies had a very rapid development process and it is now considered that they could provide a solution to energy dependence.

Law 24/2013 of the electricity sector tried to put an end to the rate deficit with the establishment of new taxes, a reduction in remuneration for distribution and transport, and a reduction in investment incentives (payments for capacity, which went from 26,000 € to 10,000 € per MW). The Special Regime for renewable energies was eliminated and although premiums continued to exist, they were much lower. The price setting mechanism for consumers who have a counter with hour discrimination is also modified, which would be established as follows:

- **Variable part:** It includes the cost of electricity at the prices established in the wholesale electricity market at each hour of the day (before they were fixed quarterly).

- **Fixed part:** It includes the cost associated with the installed power and access to the electrical network (this part is increased by an increase in the rates for access to the network).

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[7] The CESUR auctions (Energy Contracts for the Supply of Last Resort acronym in Spanish) were auctions that were held on a quarterly basis to establish the price of electricity in the TUR (Last Resort Rates).

In 2015, the backup tolls were established, which would be better known as the sun tax and which would be charged to consumers in 2 concepts:

- **Charge for installed power:** Is charged to installations above 100kw or if accumulation batteries are installed to conserve the surplus energy that is produced. The registration of facilities with powers less than 100kw was required.

- **Charge for energy dumped into the grid:** It is a price charged for the energy dumped into the electricity grid.

That tax was intended for small self-consumers to contribute to the maintenance costs of the electrical infrastructure. However, it aroused great unpopularity by assuming that facilities with such a generating source were ultimately more expensive than if electricity was consumed directly from the grid. This measure was eliminated almost 2 years ago by Royal Decree-Law 15/2018, of October 5, on urgent measures for the energy transition and the protection of consumers[8].

The electricity power sector nowadays:

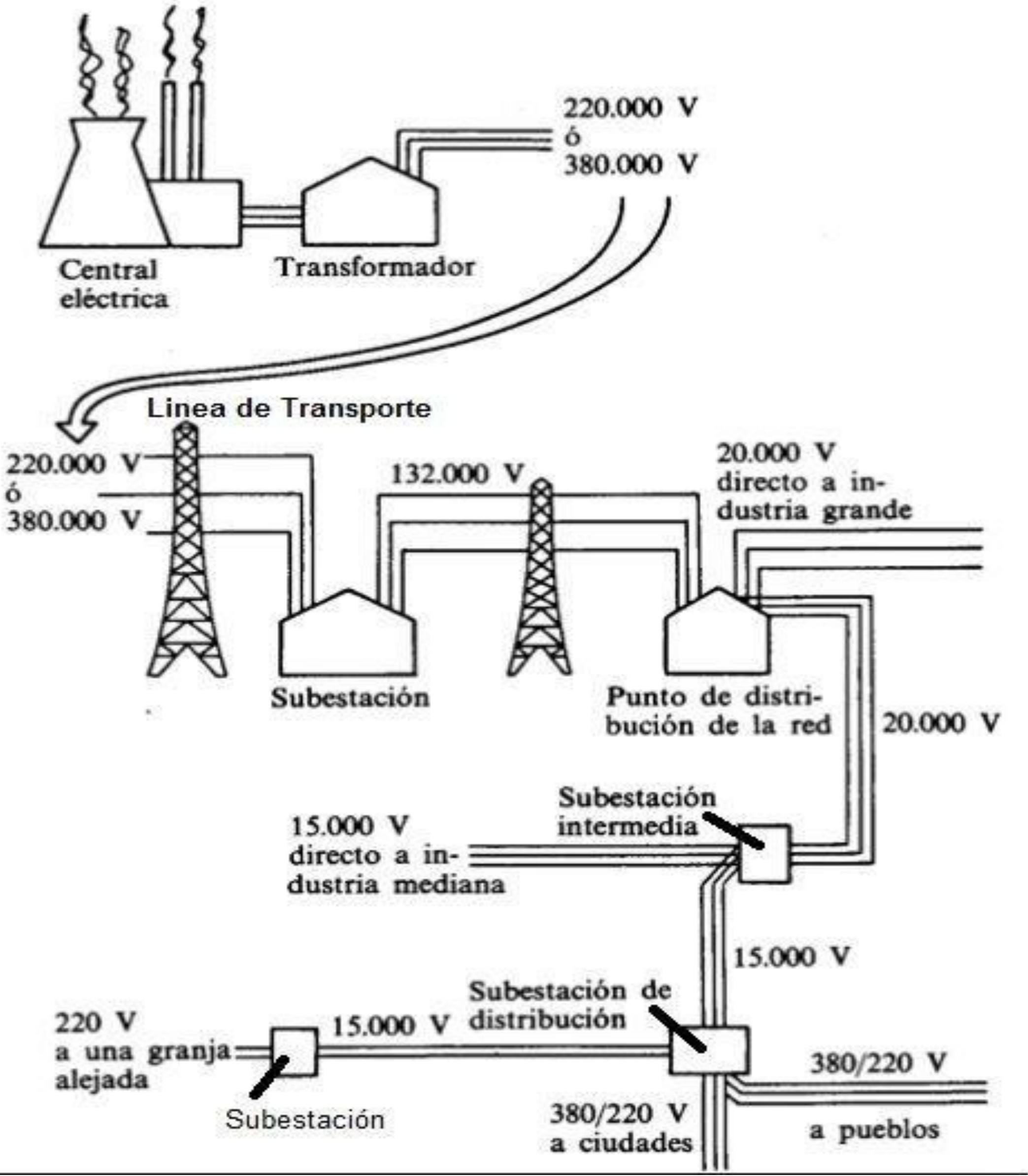
The electricity market has a particularity that makes it different from the rest, and it is that the good that it is marketed is not mostly storable (in the amounts traded in the Iberian electricity market) and must be consumed instantly. Therefore, an attempt is made to find the best possible adjustment between the supply and demand of electricity for each moment of the day.

Agents involved in the electricity market:

In this section we are going to analyse the different agents that are part of the Spanish and Iberian electricity market, in addition to their characteristic features.

[8] https://www.boe.es/buscar/doc.php?id=BOE-A-2018-13593

Illustration 1: Schema of the electrical network components



Source: Área Tecnología: How is distributed the electricity power[9]

In figure 1 we can see how the electrical network is configured, in addition to the process that follows until it reaches our homes and businesses. Electric energy is generated from some type of chemical, mechanical or thermal process, passing through the different high voltage lines and substations, until it reaches the consumption points in different voltage measurements depending on the consumption needs.

Following the previous scheme, and as a result of the 1997 electricity sector liberalization law, we can summarize that the electricity sector in Spain is divided into 4, namely:

Generation: Production of electricity using primary sources of energy. (CNAE codes 3515: **Hydroelectric**, 3516: **Conventional Thermal**, 3517: **Nuclear Thermal**, 3518: **Wind** and 3519: **Of other types**).

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[9] https://www.areatecnologia.com/como-se-distribuye-energia-electrica.htm

Transportation: It is the transmission of electrical energy through the network, used in order to supply the different subjects and to carry out international exchanges (CNAE Code 3512). Although it is true that there are other companies with this activity code in the market, ***Red Eléctrica de España*** is the one that performs this function mainly.

Distribution: Transmission of electrical energy from the transmission networks or from the generation point itself (if it is connected to the distribution network), to the points of consumption (CNAE Code 3513). The 6 companies with bigger incomes are:

- **E-Distribución S.L. (Endesa Group)**
- **UFD S.A. (Union Fenosa)**
- **Iberdrola Redes España S.A.**
- **CHC Energía (EDP Group)**
- **Viesgo Distribución S.L. (Parent company bought by EDP this same year)**
- **Hidrocantábrico Distribución S.A.U. (EDP Group).**

Selling: Activity developed by electrical energy trading companies that, by accessing the transmission or distribution networks, have the function of selling electrical energy to consumers and other subjects according to current regulations (CNAE Code 3514). In this sector the 6 companies with bigger incomes are the these ones:

- **Endesa Energía S.A.U.**
- **Iberdrola Clientes S.A.**
- **Energy XXI (Endesa Group)**
- **Curenergía S.A. (Iberdrola Group)**
- **AXPO Iberia S.L.U.**
- **EDP Energía S.A.U.**

In addition to the agents who are dedicated to the 4 tasks that underpin the sector, there are others who intervene in the electricity market in order to make it work properly.

MIBEL, OMI, OMIE Y OMIP:

The Iberian Electricity Market (**MIBEL** in its acronym in Spanish[10]) is a common market in which all the electricity necessary to cover the demand of the Iberian Peninsula is traded. It is the result of the collaboration between Spain and Portugal with the aim of creating a common market in which it could operate both; between states and at the European level. Within this market we have a couple of operators, which are:

OMI is the acronym for **Iberian Market Operator** (*Operador del Mercado Ibérico* in Spanish), and its function is to manage both the intraday and daily markets, as well as the forward market through its subsidiaries **OMIE** and **OMIP.**

OMIE[11] is the **Iberian Energy Market Operator - Spanish Pole** (*Operador del Mercado Ibérico de Energía - Polo Español* in Spanish) for daily and intraday operations. These designated operators

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[10] https://www.mibel.com/es/home_es/
[11] https://www.omie.es/es/sobre-nosotros

are called NEMOs (Nominated Electricity Market Operator), and each member state of the European Union has a counterpart operating in its territory. Its function is to manage the purchase and sale orders within the Iberian market in such a way as to match the supply and demand of electricity for the different hours of the day in the spot market mentioned above.

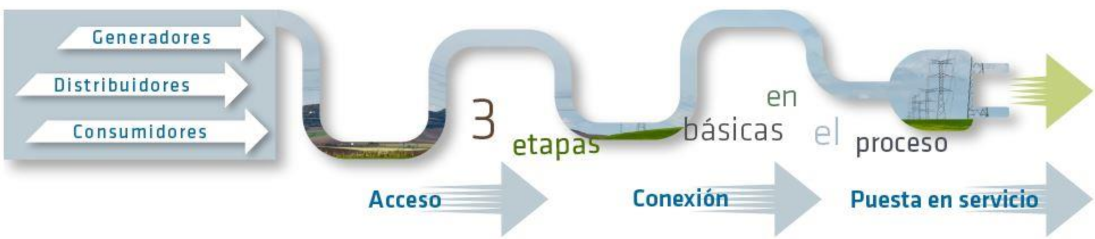
OMIP[12], on the other hand, is the **Iberian Energy Market Operator - Portuguese Pole** (*Operador del Mercado Ibérico de Energía - Polo Portugués* in Spanish) for forward operations. This operator manages the electricity derivatives and performs the functions of intermediary between the agents that operate in the forward market that we have described above.

The **National Commission of Markets and Competition** (**CNMC** Spanish acronym) supervises the operation of the market in both the retail and wholesale markets, in addition to labeling energy from renewable sources[13].

The **CNMC** is also in charge of supervising compliance with REMIT[14] agreements on the integrity and transparency of wholesale electricity markets. Those agreements establish certain rules such as the prohibition of manipulating the market and operating taking advantage of the use of privileged information, as well as the obligation to publish any relevant information for the proper functioning of the market.

Anyone who wants to and who meets the requirements (Small renewable energy generators, for example) can connect their installation to the electrical transport grid. REE assesses the installation to see if it meets the requirements regarding the viability of the technical project and, if it meets them, grants permission to commission the installation after carrying out some relevant tests, as we can see in the next illustration.

Illustration 2: Scheme of the network access process



Source: Activities of REE: Access, connection and commissioning

Energy planning process: REE is also part of the energy planning process through its plans for the electric power transmission network. In those plans they collaborate with the General Administration of the State and the territorial communities in order to cover the needs that are foreseen for the future, and how to configure the electrical network to cover those needs. They are currently preparing the plan for the period 2021-2026.

REE publishes on its website a real-time graph of the estimated, real and forecast electricity demand for each moment of the day. The forecasts are made in collaboration with the CECOE

[12] https://www.omip.pt/es/sobre-nosotros-omip
[13] https://www.cnmc.es/ambitos-de-actuacion/energia/mercado-electrico
[14] Regulation (EU) n ° 1227/2011 of the European Parliament and of the Council, of October 25, 2011, on the integrity and transparency of the wholesale energy market.

(Electric Control Center in its acronym in Spanish) based on statistical background of the weather, historical and even economic data.

Illustration 3:Estimated, scheduled and real electricity demand graphic in the system (08/06/2020, 3:30 p.m.)

Source: *Red Eléctrica de España*, https://demanda.ree.es/visiona/peninsula/demanda/total

Electricity power market: How does it work?

Once we know the agents that take part on the electricity market in Spain, we will see how it is transacted in the different types of market that currently exist. The transactions carried out in those markets have a direct effect on electricity prices, as we will see later, and ultimately, on the final bill paid by both small private consumers and companies.

There are basically 3 types of markets depending on the term in which it operates: The forward market, the daily market and the intraday. However, recently a system has been put on to operate in the intraday market in a continuous platform and at a European level (until now the intraday only operated through auctions for specific hours as we will see later), so the operators of the market can transact with other countries if the connection lines are not saturated.

Daily Market:

In this market (also known as electricity pool) electricity is traded every day for each hour of the following day at a specific price. Electricity providers must be accredited to operate in the MIBEL, and they can offer electricity from different sources (Combined Cycle, Nuclear, Coal, Renewable ...). Electricity enters the system in a different order due to its origin, being the first kW to enter the grid those from renewable sources, as it is not possible to control the primary source of energy (unlike the thermal power plants).

On the demand side, marketers and certain consumers who have the accreditation to operate in the MIBEL will make acquisition offers. This negotiation process is carried out through a series of auctions for each hour of the following day, and the maximum amount that can be bid is 180€ per megawatt / hour. OMIE receives the purchase and sale orders, and using software based on a mathematical algorithm called **Euphemia**[15], performs a coupling process between supply and demand, resulting in a **coupling price**. This price, which is obtained marginally, is applied to all the MW that are traded on the grid for that hour, and in many cases, it is usually determined by the **combined cycle and coal thermal power plants**, which are the last to offer their electricity.

Sell offers are divided into simple and compound, while takeover offers can only be simple.

Simple sale / purchase offer: Offers consist of pairs of quantities and prices that are divided between 1 and 25 tranches. For each tranche, the seller or buyer sets a price, with a higher seller's price for each additional block offered and a lower buyer's price for each additional block demanded.

Compound sale offer: They have the same characteristics as a simple sale offer, but with some special conditions:

- **Indivisibility:** If a buyer acquires the tranche that an offeror sells him under this condition, at the time of coupling it cannot be divided into fractions, the entire tranche must be coupled.

- **Minimum Income:** If a bidder makes an offer for a tranche and it is purchased, he can establish a minimum price that, if is not reached during the coupling process, gives him the option of withdrawing that energy from the pool (He is not interested in supplying it below that price). This is interesting for plants that have a known fix operating cost, since they can establish that fix operating cost of the plant as a minimum income condition.

- **Scheduled stop:** This occurs when a sale offer for a specific hour is rejected as it does not reach the minimum price in the coupling.

- **Variation in production capacity:** This condition is useful for plants that have a considerable variation in their production capacity, as it allows them to establish minimum and maximum deviation between 2 consecutive scheduling periods.

However, we must not forget that electricity is a physical good that must be transported, and that is why after awarding electricity through the auctions that we have just mentioned, REE must analyze the viability of transporting electricity from the different points from generation to distribution, for their subsequent commercialization in what they call **management of the technical restrictions of the system**[16]. In this market, the planned energy program is modified and minimum / maximum power limits are applied, giving rise to a new energy program called the **Provisional Viable Daily Program (PDVP).**

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[15]Euphemia is a mathematical algorithm developed by the company N-SIDE that aims to maximize the surpluses of the agents participating in the European electricity market, taking into account the physical limitations of the network. https://www.n-side.com/pcr-euphemia-algorithm-european-power-exchanges-price-coupling-electricity-market/

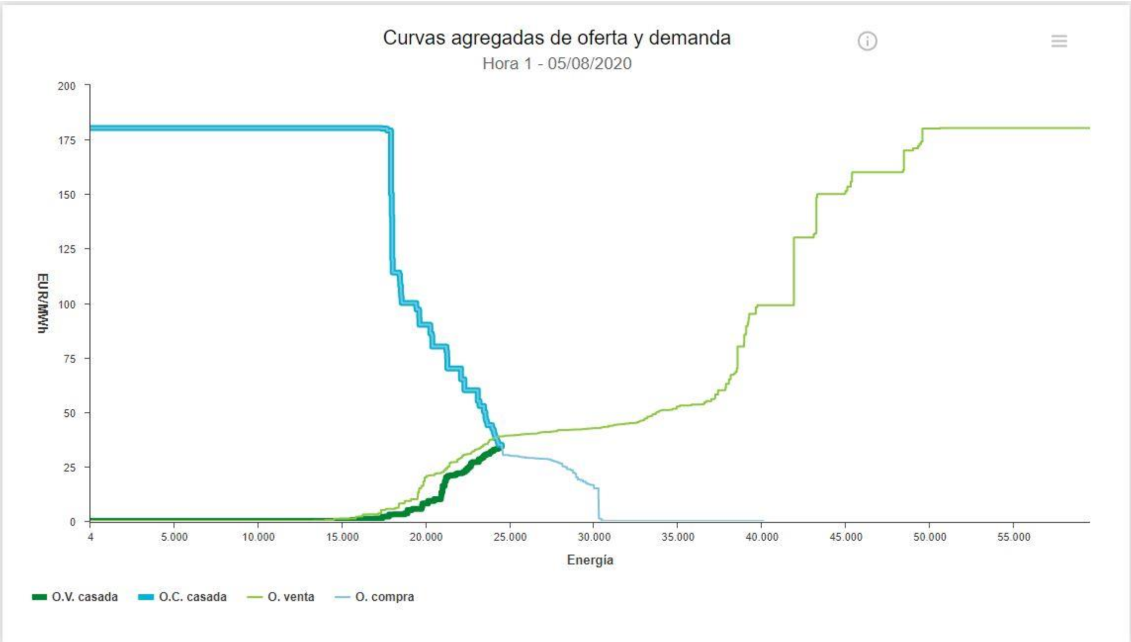
[16] Red Eléctrica de España (2013) *La Operación del Sistema Eléctrico para Dummies*

Here the generators can make simple sale offers (generally Surplus) that will be acquired by the pumping consumer units[17]. Generators that produce electricity from a thermal process can make complex offers in this tight market. They will specify the cost to compensate for:

- Maintenance of the generating unit per hour
- Unit of energy produced
- By cold start
- By hot start

Once the pertinent modifications to the PDVP are made by the agents that intervene in the restriction market, and the necessary reserves of power to raise or lower are established, the **Definitive Viable Daily Program (PDVD)** is republished, which will be the one referenced by the agents that operate in the intraday market.

Illustration 4: Aggregate supply and demand curves (08/05/2020)[18]



Source: https://www.omie.es/es/market-results/daily/daily-market/aggragate-suply-curves

Intraday Market:

In this market, authorized agents can operate again to suit better their needs, since in many occasions there are deviations from what was traded on the daily market the day before and what was published in the **PDVD**. In this market there are several components, since although

[17] A pumping consumption plant is nothing more than a hydraulic plant that pumps water from its base to the upper reservoir. Complying with a basic thermodynamic principle, it is evident that this process consumes more electricity than it generates, thus being able to regulate the overloads of the electrical system.

[18] There are 24 of these for each day (24 hours a day). We can see the supply before the coupling process and the equilibrium point after the coupling. The first tranche of the supply it offered at 0 marginal price because of the generation source (renewable and nuclear), as it is mentioned before in this document.

the MIBEL continues to operate through auctions that are held in 6 sessions throughout the day, other market operations with connected countries are carried out in the **continuous intraday market**. This continuous market is the commitment to the integration of the European electricity market as a **common market**.

Auctions in the intraday market:

In this intraday market, the electricity and the capacity of the interconnections between Spain-Portugal, Spain-Andorra and Spain-Morocco are negotiated. This market works in a similar way to the daily one, setting the price also in a marginal way by coupling the supply and demand of electricity for each hourly section. Agents operating in the intraday market must:

1- **Having previously operated in the daily market**. However, if a broker has traded on the daily market, he does not have to return to intraday trading (he may not do anything if everything goes according to planned).

2- Possessing **bilateral contracts** that have been negotiated before in the forward market.

In addition to the aforementioned, the agents that operate in this market must justify the adjustment they wish to make. At the close of each session, the **Final Schedule Program (PHF)** is published for each corresponding scheduling horizon, and this program is used as a reference for the next session (Except for the first one, which reference is taken from the PDVD). The 6 sessions are held at specific hours set by the market operator (OMIE) as we can see in the following table:

Table 1: Intraday market and fixed hours for the sessions

	Session 1	Session 2	Session 3	Session 4	Session 5	Session 6
Opening of the session	14:00	17:00	21:00	1:00	4:00	9:00
Closing of the session	15:00	17:50	21:50	1:50	4:50	9:50
Coupling	15:00	17:50	21:50	1:50	4:50	9:50
PIBCA publication	15:07	17:57	21:57	1:57	4:57	9:57
PHF publication	16:20	18:20	22:20	2:20	5:20	10:20
Programming horizon	24h (1-24 of the next day)	28h (21-24 and 1-24 of the next day)	24h (1-24 of the next day)	20h (5-24 of the same day)	17h (8-24 of the same day)	12h (13-24 of the same day)

Source: OMIE https://www.omie.es/es/mercado-de-electricidad

In this market, sale offers can be made by both electricity generators and marketers and distributors who have acquired electricity through the daily market or through bilateral contracts in the forward market. The supply curve is composed of the adjustments of the supply of electricity negotiated in the daily market. In any case, the agents that operate in this market for speculative purposes are very few.

The acquisition offers are made by distributors and traders who want to adjust their position, and the demand curve is made up of those adjustments in addition to the electricity that has already been negotiated in the daily market.

The way in which the sale and purchase offers are made is very similar to that of the daily market, but with 5 tranches per purchase and sale offer instead of 25. In this case, the sale offers are also divided by simple and composite, although with some different conditions than those we find in the daily market, and those who make purchase offers can also establish certain conditions, such as a maximum payment condition:

- **Maximum payment condition:** Buyers can include a condition that establishes a limit on what they are willing to pay for electricity at the time of coupling, so they can withdraw they purchase offer from the aggregate demand curve.

However, the conditions imposed on complex offers on the intraday market are not applicable to offers for the purchase and sale of electricity on the daily market. The OMIE evaluate the buy and sell orders in this market, and if it considers that they do not meet the necessary requirements or have an irregularity, they can reject them before they enter the Euphemia algorithm. Once the coupling is done, OMIE publishes the solution and the price for each hour of the day, the **Intraday Base Incremental Matching Program (PIBCI)** and the **Intraday Base Accumulated Matching Program (PIBCA)**. Those programs contain information on committed energy (PIBCI) and allocated (PIBCA) for each agent, and are strictly confidential.

Finally, the system operator (REE) and the market operator (OMIE) publish the **Final Hour Program (PHF**) for the corresponding scheduling horizon. This process is repeated in each of the 6 intraday sessions with a shorter time horizon in each session.

Continuous intraday market:

This market, like the intraday market, aims to improve the precision which electricity supply and demand are adjusted. The difference about the intraday auction market is that the adjustment can be made in a faster way (with a limit of one hour before the energy delivery time), and it is the way that the Iberian market agents have to operate with the rest of Europe. This market is also called SIDC (Single Intraday Coupling).

In the intraday market agents operate in one-hour intervals across the 24 rounds of the day, with a different scheduling horizon depending on the round of day in which it is trading. In the following graphic we can see the hours of the day traded and what scheduling horizon they have.

Table 2: Continuous intraday market sessions (SIDC)

Rondas continuo para el día D y D+1					
Día	**Apertura**	**Cierre**	**Ronda**	**Periodos en negociación**	**Subastas**
D	14:00	15:00	17	17 18 19 20 21 22 23 24	**MI1 14:00-15:00 (1-24)**
D	15:00	15:10	18	18 19 20 21 22 23 24	
D	15:10	16:00	18	18 19 20 21 22 23 24 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24	
D	16:00	17:00	19	19 20 21 22 23 24 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24	
D	17:00	17:50	20	20 21 22 23 24 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24	
D	17:50	18:00	20	20	**MI2 17:00-17:50 (21-24, 1-24)**
D	18:00	19:00	21	21 22 23 24 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24	
D	19:00	20:00	22	22 23 24 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24	
D	20:00	21:00	23	23 24 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24	
D	21:00	21:50	24	24 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24	
D	21:50	22:00	24	24	**MI3 21:00-21:50 (1-24)**
D	22:00	23:00	1	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24	
D	23:00	0:00	2	2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24	
D+1	0:00	1:00	3	3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24	
D+1	1:00	1:50	4	4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24	
D+1	1:50	2:00	4	4	**MI4 1:00-1:50 (5-24)**
D+1	2:00	3:00	5	5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24	
D+1	3:00	4:00	6	6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24	
D+1	4:00	4:50	7	7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24	
D+1	4:50	5:00	7	7	**MI5 4:00-4:50 (8-24)**
D+1	5:00	6:00	8	8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24	
D+1	6:00	7:00	9	9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24	
D+1	7:00	8:00	10	10 11 12 13 14 15 16 17 18 19 20 21 22 23 24	
D+1	8:00	9:00	11	11 12 13 14 15 16 17 18 19 20 21 22 23 24	
D+1	9:00	9:50	12	12 13 14 15 16 17 18 19 20 21 22 23 24	
D+1	9:00	10:00	12	12	**MI6 9:00-9:50 (13-24)**
D+1	10:00	11:00	13	13 14 15 16 17 18 19 20 21 22 23 24	
D+1	11:00	12:00	14	14 15 16 17 18 19 20 21 22 23 24	
D+1	12:00	13:00	15	15 16 17 18 19 20 21 22 23 24	
D+1	13:00	14:00	16	16 17 18 19 20 21 22 23 24	

Source: OMIE https://www.omie.es/es/mercado-de-electricidad

Forward market:

In this market, electricity supplies are negotiated beyond the daily market, either for a specific day in the future or for a longer period in time (for example, an agreed electricity supply service for 2 years and with certain conditions). In this market we have the following modalities:

Pool indexed billing[19]:

Electricity consumers can choose to contract with the marketer for a supply that bases its price on the market. Although each marketer will have a different billing system, we can say that roughly the form of indexed billing is based on two different types:

1- **Pass Pool:** The marketer offers the consumer a fixed price per hour based on the market price published by the OMIE. In this way, the client is less exposed to market fluctuations, and the operator must set a price that guarantees coverage against such fluctuations.

2- **Pass Trough:** In this billing modality, the client pays a fix component for Third Party Access to the Network and capacity payments (These rates are regulated by the state[20]), and a variable component based on the final price of market published by the OMIE. In

[19] https://www.smarkia.com/es/blog/factura-indexada-pool-i-principales-caracteristicas
[20] https://www.boe.es/buscar/doc.php?id=BOE-A-2013-13645

this case, the customer is the one who is exposed to price fluctuations rather than the marketer.

Trading companies also tend to include other items in their invoices such as municipal taxes, market surcharges, operating and financial costs, in addition to a trade margin established by each trading company.

Non-indexed billing and consumers with access to market:

Some consumers may choose to negotiate a fixed price with the marketer in order to reduce uncertainty. The marketer will offer you a price that covers all costs, both regulated and those derived from the electricity market. Generally, it is usually higher than the cost of electricity if this consumer chooses to purchase it in the market, which leads us to think that certain consumers might prefer to purchase electricity directly in the market.

These consumers must meet some requirements established by law to adapt to the supply activities, in addition to undergoing REE supervision to see if the installation meets the minimum safety and technical feasibility (similar to what we have seen before in the case of small generators that are connected to the grid), and the supervision of OMIE to ensure that it meets the necessary conditions to operate in the market.

Power Purchase Agreement (PPA):

These sales contracts, known as PPAs, are bilateral contracts that are signed between a buyer of electricity (it does not have to be a consumer) and a generator for the supply of electricity by an extended period in time. A series of conditions intervene in the contract that, in many cases, go beyond the price and quantity of electricity exchanged, although the ultimate purpose of these contracts is to guarantee a stable supply of electricity at the agreed price. The terms of the contract specify at least:

1- Volume of electrical energy

2- Price of electricity in € / MWh

3- Period during which electricity will be provided in that volume and price (Start date and end date)

4- Origin of the electrical energy (And generally the type of generation source)

These types of contracts give consumers the opportunity to make cost forecasts more accurately and eliminate the uncertainty that can arise from variations in electricity prices in the long term. Generators in the other part have a constant income flow that allows them to undertake new investment projects with some sort of security. Additionally, a company may require that the electricity supplied to it be from a renewable source.

There is a form of PPA that is traded as a financial derivative in the form of futures contracts whose underlying asset is the price of electricity. An agent (who may even be outside the electricity system in which it operates) can agree a PPA with another agent, who can sell to a marketer or a consumer with access to the market when the day of the supply arrives, paying the difference between the market price and the price agreed in the PPA to the holder of that contract. If the market price is higher than the price agreed in the PPA, this agent will obtain a profit in the operation by pocketing the difference, while, if the market price is lower, he will be forced to sell that PPA at a lower price than the negotiated, incurring losses[21].

Network diversions and regulation

It can occur that deviations in the network that have been foreseen because of some sort of conditions such as atmospheric factors that make renewable production impossible, variations in demand, technical restrictions or incidents in the network. There is a market in which electricity generation units (increase in power) or pumping units (decrease in power) can intervene in quantities between 1 and 300 megawatts to go up or down. After the system operator calls a diversion session and publishes a series of requirements to be met, the maximum response time to make offers is 30 minutes from the moment of publication of the requirements.

The price paid for this diverted energy is the marginal resulting from this specific diversion market, and must be paid by sellers or buyers of electricity who have not complied with what has been agreed on the daily or intraday market. It is assumed that the scheduling horizon for these offers is until the next intraday session, since at that time the market offers should cover the system requirements.

In addition to the diversion market, there is another regulation market called the Tertiary Regulation Market. Generators and pumping units capable of increasing or decreasing their power quickly (less than 15 minutes) take part in this market. Here we can find combined cycle plants that are operational but not at full power, since those plants have the virtue of being able to increase or decrease power in a short time because of their architecture, giving flexibility to the system. The system operator (REE) establishes the total reserve necessary for each generation unit of the system so that in case of unforeseen events they can be used quickly, and the production units can modify their sale offers continuously. The **primary regulation** (response in less than 30 seconds) and **secondary** regulation (response in less than 5 minutes) have a similar operation, but it is automated, and it is not necessary to contact the production or pump unit.

Electricity power in the society:

Today, electricity is a staple good in all homes, as well as being one of the main productive inputs of practically all industries. According to the 2017 CES report[22], electricity accounts for a quarter of total energy consumption (only behind petroleum derivatives, which account for half of energy consumption), in addition to suppose the 2% of GDP and employ directly around 80,000 people in 2016. The electricity sector is constantly changing, and in recent years they have been

[21] https://www.opengy.com/ppa-modalidades/
[22] Informe del sector eléctrico en España CES 2017. Page 16

focusing their efforts towards a decarbonization of the system by investing in renewable sources of electricity.

Main source of energy

The electricity generation park is made up of the following generation sources:

1- Thermal Combined Cycles (Gas or oil)
2- Wind energy
3- Hydraulic energy
4- Coal thermal
5- Nuclear Thermal
6- Solar thermal and photovoltaic
7- Cogeneration

The basic principles of operation of thermal power plants have much in common, although the power generation process is very different. In other words, in the case of combined cycle, coal or nuclear power plants, the process consists of heating the water in a primary generation circuit (secondary in the case of combined cycle power plants) to move turbines connected to an electric generator.

Moreover, combined cycle power plants have a particularity, which is that the residual heat from the combustion of gas or oil used to generate the movement of a main turbine (Brayton cycle) is used to evaporate water from a circuit, generating steam at high pressure and moving another turbine (Rankine cycle) which also generates electricity (hence its name, since they combine the energy of a thermal transfer cycle with the energy from combustion)[23].

Renewable energy sources, on the other hand, have the advantage of not needing any fuel to operate, and therefore they do not emit polluting gases into the atmosphere. However, those sources are not so stable when it comes to maintaining a certain power over a long period of time, since they depend on the forces of nature to generate electrical energy (photovoltaic energy cannot be generated at night, or wind energy with no wind).

Finally, nuclear power plants have the advantage of not emitting polluting gases into the atmosphere, in addition to producing electricity consistently for long periods of time with a very high generation power. However, managing nuclear waste can be a serious problem in the long-term, not to mention that the consequences of an accident that exposes radioactive material to the atmosphere would be an environmental disaster of catastrophic proportions.

Since 2010, the government began with a plan to close coal-fired power plants, which has become notorious this past year with the enclosure of another 7 power plants based on this

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[23] How a gas turbine works. Gas power generation General Electric: https://www.youtube.com/watch?time_continue=2&v=zcWkEKNvqCA&feature=emb_title

technology[24]. This plan is justified given the low competitiveness of this technology, the increase in the cost of the emission rights of the EU ETS system (Emission Trading System) and the decrease in the price of liquefied natural gas in the last year[25].

As we have explained before, the Iberian electricity market is interconnected with France and Morocco, which leads to the export and import of electricity. The European Union recommends that the interconnection capacity should be at least equal to 10% of the installed power, but the Iberian market only has a transfer capacity for 5% of its installed power due to the difficulties that arise in our geography. To try to improve this percentage, there are some projects such as:

1- Arkale 22Kv phase shifter: It consists of a phase shifter transformer in Arkale (In operation since 2017) that increases the connection capacity with France.

2- Gulf of Bizkaia Project: An increase in capacity of the exchange network between Spain and France of 5000MW is estimated (expected for 2025).

3- Central Pyrenees Project: It is a project in study phase to increase the capacity of the interconnection between Spain and France (the start-up date has not yet been estimated).

4- Spanish-Portuguese border project: It is a project to increase the connection capacity with Portugal by around 3500MV. (The commissioning date has not yet been estimated.)

REE publishes the balance of electricity exchanges across borders monthly. For example, in the following illustration we have the balance of the electricity trading between Spain and the countries connected for July 2020:

Illustration 5: Balance of electricity power exchange between borders (July 2020)

Source: Red Eléctrica de España: https://www.ree.es/es/datos/intercambios

[24] https://elpais.com/sociedad/2020-06-28/espana-desconecta-siete-termicas-y-arranca-el-proceso-para-enterrar-el-carbon.html
[25] https://es.investing.com/commodities/natural-gas-streaming-chart

Every day we can see what proportion of the electricity demanded each hour comes from each of the sources mentioned above. For example, if we take the data randomly for electricity demand of the last year, at 2:00 p.m. (noon) and 4:00 a.m. (dawn), we can see that the electricity demand comes from:

Table 3: Electricity demand by seasons (2019-2020)

Electricity demand in the different seasons of the year (Noon: 2:00 p.m., Early morning: 4:00 a.m.)										
Source	**Season of year**									
	Summer		**Fall**		**Winter**		**Spring**		**All the year**	
	14:00	**4:00**	**14:00**	**4:00**	**14:00**	**4:00**	**14:00**	**4:00**	**14:00**	**4:00**
Wind power	12,48	19,40	21,48	27,37	20,94	31,42	14,55	24,97	17,36	25,79
Hydraulics	6,93	3,08	9,53	6,73	14,29	7,43	12,47	11,97	10,80	7,30
Solar photovoltaic	10,91	0,08	10,07	0,07	12,95	0,06	19,34	0,13	13,32	0,08
Solar thermal	5,09	1,40	2,17	0,02	2,05	0,01	4,37	0,72	3,42	0,54
Renewable thermal	1,32	1,84	1,33	1,81	1,46	2,05	1,84	2,51	1,49	2,05
Nuclear	20,82	29,36	17,52	24,56	21,19	29,73	18,88	25,62	19,60	27,31
Coal	2,22	2,60	2,43	2,85	3,20	3,70	1,83	2,42	2,42	2,89
Combined cycle	27,10	26,91	21,65	19,75	10,43	10,06	11,48	14,42	17,66	17,78
Cogeneration and waste	10,84	14,75	11,34	15,40	10,84	14,47	11,26	15,19	11,07	14,95
International exchanges	2,30	0,61	2,49	1,45	2,66	1,08	4,00	2,04	2,86	1,30
Balearic link	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Source: Own elaboration based on data from REE (Electricity demand per hour)[26]

If we add up all the energy that comes from renewable sources (Wind, solar photovoltaic and thermal, hydraulic and renewable thermal), we obtain that 36,76% of the energy that has been consumed at two in the afternoon comes from the source mentioned. This changes if we make the same calculation for four in the morning, with the consumption of renewable sources being 25,78%. This is obvious, since at this time of the morning we cannot use the energy generated by the sun, so most of the electricity that covers this drop in demand comes from nuclear, combined cycle and cogeneration plants, although in some cases wind energy also helps to cover those hours.

Virtually, in the case of nuclear power plants, it is not a matter of producing more electricity in the early morning than at noon (about 7,000MWh in both cases), but as the total demand for electricity decreases, and the amount of power they produce remains constant, the proportion of this source of energy on the grid increases. This occurs because stopping a nuclear power plant has a very high cost, in addition to the fact that in some cases it can even be dangerous

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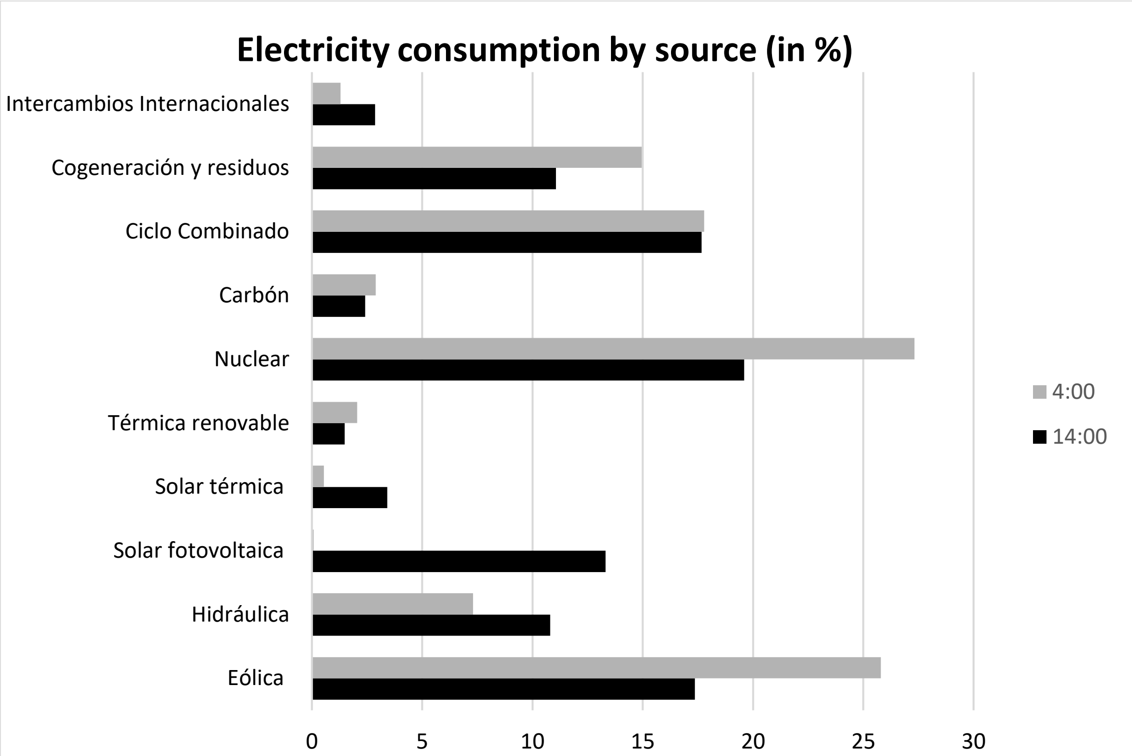
[26] To obtain the values in the table, the data from the REE web page of 10 random days for each season of the year at four in the morning and two in the afternoon have been taken and the average contribution of each one has been calculated from the sources. The values for the whole year are the averages of each source in the 4 seasons of the year.

due to the high temperatures reached in the reactor core and the parasitic effects such as xenon poisoning[27].

If we observe the next graphic, we can see the difference between the power added by every generation source at midnight and afternoon, being significantly higher for the nuclear power plants and wind power cases:

Graphic 2:Electricity consumption by sources (2019-2020 average)



Source: Own elaboration based on REE data (electricity demand by hours)

Household consumption

The residential sector accounts for 19% of the country's total energy consumption, and within the total energy consumption of residential homes, on average, 41% is for electricity. There are certain electrical appliances at home that, although they have a high consumption of power, when are used in short periods of time at certain hours of the day do not involve a very high consumption. However, household appliances that are connected all day such as refrigerators, freezers and air conditioning systems (on hot days) are those that account for most of the daily electricity consumption at home.

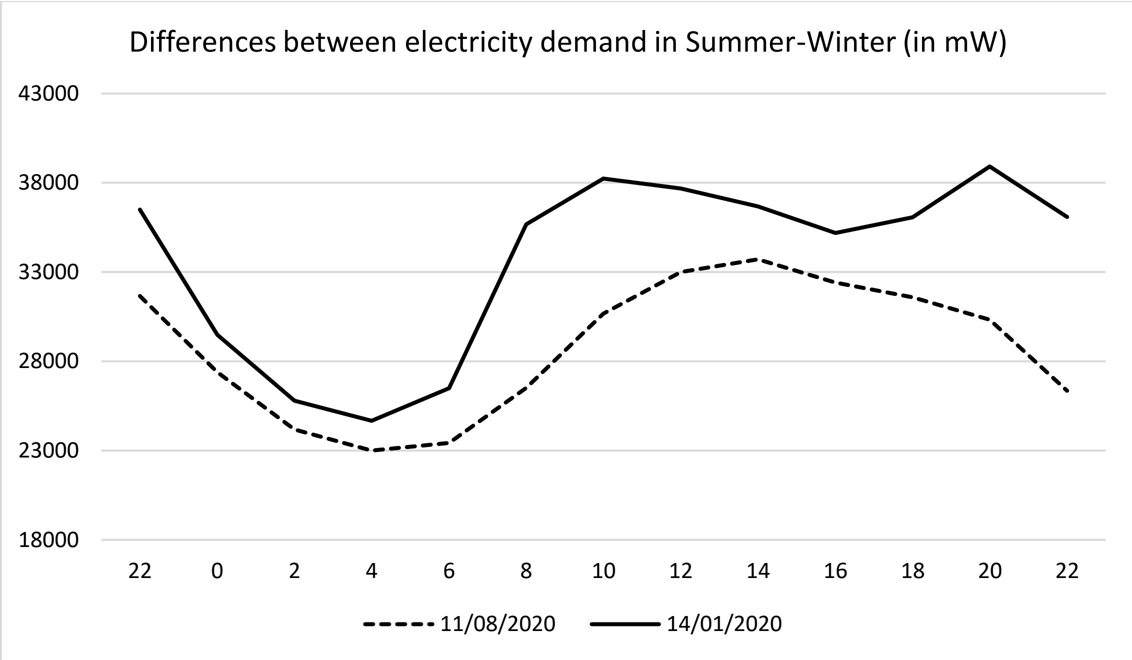
As we have seen previously, the demand for electricity varies throughout the day. Therefore, it is logical if we think that the electricity that is sold in periods of high demand will be more

[27] Xenon poisoning occurs when a large amount of the xenon 135 isotope stacks in the core of the reactor due to a progressive deacceleration of the fission reaction, mainly caused by the activation of the control rods. This isotope has the ability to absorb neutrons (moderator) that uranium releases when there is in a fission reaction process, which makes more difficult to restart the fission reaction chain.

expensive than the one sold in the hours of the day when electricity demand is low. Furthermore, other factors such as the hours of sun per day, the average temperature, the rains in certain territories, the winds or the technical restrictions of the network can also alter the price of the electricity we end up paying.

In the next graphic we can see the difference in the real demand of electricity between summer and winter, being higher in the months of winter:

Graphic 3: Electricity demand curves by hourly sections (01/14/2020 and 08/11/2020)



Source: Electricity demand of the Iberian system (REE)

In 2014, the Last Resort Rate (TUR) system was eliminated (as well as the CESUR auctions that set the prices of these rates) to implement a consumption accounting system through programmable meters. All consumers with installation powers of less than 10kW can benefit from this rate if they wish, which has a fixed component established by the Ministry of Industry (Tolls), as well as a component that varies depending on electricity consumption and the market price of electricity. There are 3 rate options in order to meet the needs of small consumers:

1- **Default rate (Toll 2.0A)**[28]**:** The ideal one for a consumer who requires a homogeneous use of electricity throughout the day.

2- **Efficiency 2 periods (Valley rate, Toll 2.0DHA):** (or time discrimination): Ideal for consumers who have a greater need between 23 p.m. and 12 a.m. (next day) hours of the day. The kWh prices in this time slot are considerably lower.

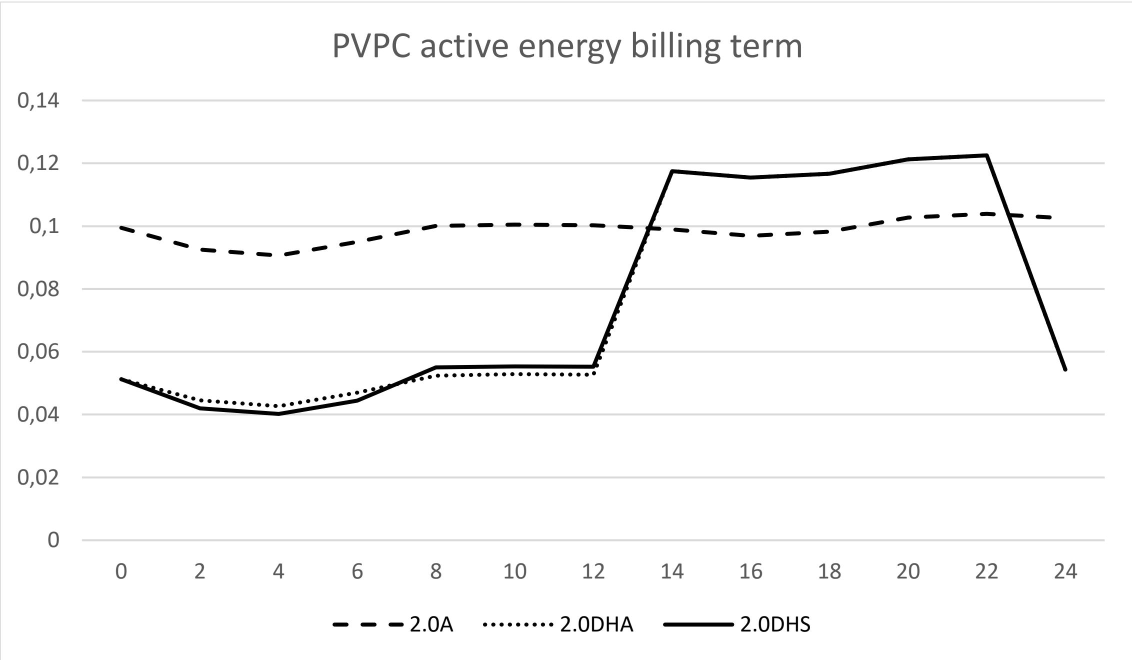
[28] There is also an option for consumers who require a power between 10kW and 15kW. In this case, the rates are 2.1A, 2.1DHA and 2.1DHS, and for consumers above 15kW of power the only rate they can contract is 3.0A, without time discrimination. Above 3.0A would be the high voltage connections.

3- **Electric vehicle rate (Super-valley rate, 2.0DHS toll):** (similar to the previous one, but with a greater price difference): Ideal for consumers who make intensive use of electrical appliances between 11 p.m. and 12 a.m. of the day.

Each consumer is free to contract with his corresponding marketer the type of rate that is more convenient for him. For example, if a consumer has an electric vehicle that he will charge during the early morning hours, and during hours of high electricity demand he is away from home, most likely he will contract a super-valley rate to benefit from the cheapest price per kWh possible during those night loads.

Here we have a graphic comparison between the rates available for average home consumers and how the price of the kWh changes between hours:

Graphic 4: comparison of the total price per kWh in euros with the different access tolls



Source: Red Eléctrica de España

Since 2013, buildings must have an energy certification in order to be rented or sold as a measure to encourage energy savings and efficiency, being able to compare the most efficient buildings and giving them added value. Moreover, most modern appliances carry a similar label that determines how efficient they are, comparing them with other similar appliances sold in the European market.

Electricity bill:

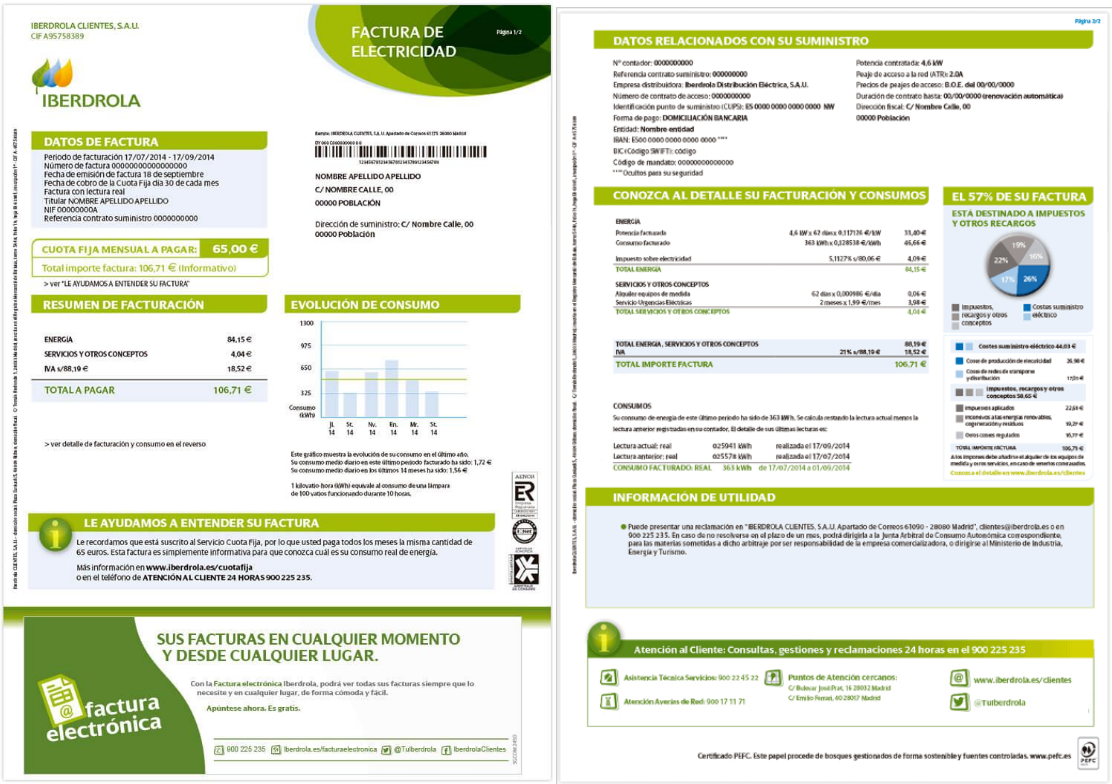
In addition to the components derived from weather conditions, the availability of the transmission network, and variations in the price of kW / h due to market fluctuations, there are other important components in our electricity bill. In this section we will see a breakdown of a current home bill to see what items the end consumer ends up paying for, as well as other content of interest (we take an Iberdrola company bill as an example):

1- Top corner: Name of the Iberdrola Group marketing company that issues the invoice (Iberdrola Clientes), billing period (07/17 / 2014-17 / 09/2020), issued invoice number, issue date and date collection[29]. In this case, the marketer has a billing modality in which customers pay a predetermined fee each month, and if at the end of the year they have consumed less than the total fees paid, they are reimbursed the money. If on the contrary they have consumed more, they are charged for the difference. In this case, the total amount to be paid is for informational purposes only.

2- In the middle left area, we can see a summary of our consumption in 3 concepts: Energy, Services and other concepts and VAT, although on the back of the invoice we can find more detailed information about this. On the right you can see our consumption in the last months in terms of kWh and the consumption that corresponds to each hour of the day if the client has contracted a time discrimination service, and on the far right the different certifications (ISO, Adhesion to the consumer arbitration system, PEFC…).

3- On the back of the invoice, in the upper left side there are identifying data such as the meter number, the supply contract number (CUPS number or Universal Supply Point Code), the distribution company, the supply contract number. access to the network etc., in addition to the customer's bank details. On the right side, the contracted power, the access toll (ATR), the reference to the article of the BOE that regulates the prices of access tolls, the date of completion of the contract and the client's fiscal address.

Ilustration 6: Example of an electricity bill of a consumer of Iberdrola Comercialización



Source: Iberdrola's official webpage. Understand your bill

[29] https://www.iberdrola.es/informacion/facturas/factura-luz

In the center you can see a breakdown of consumption and the concepts for which the customer is charged:

Billed power: It is a fixed amount that is calculated by multiplying the contracted power in kW by the number of billing days and by the average price per kWh.

That is to say,

$$\boldsymbol{PF = kW * D * \overline{P_{kWh}}} \text{ where,}$$

$$\begin{gathered}\boldsymbol{PF = Billed\ power\ in\ Euros} \\ \boldsymbol{kW = Contracted\ power\ in\ Kilowatts} \\ \boldsymbol{D = Time\ in\ days\ with\ this\ power\ contracted} \\ \boldsymbol{\overline{P_{kWh}} = Price\ of\ the\ seller\ for\ \frac{kW}{h}\ during\ D\ in\ Euros}\end{gathered}$$

Therefore, if a consumer has a contracted power of 2.3kW during a billing period of 63 days in which the price of the kWh has been 0.123329,

$$\boldsymbol{2,3 * 63 * 0,123329€ = 17,8703721€ \approx 17,87€}$$

Billed energy: It is the variable part that depends on the consumption made throughout the billing period. Consumers who are covered by the PVPC and who have a smart meter will be billed for the consumption they have made every hour at the price that corresponds to their rate (Punta, Valle or Supervalle). Therefore, the consumption of these households is measured as follows:

$$\boldsymbol{EF = \sum_{t=1}^{T} kW_t * PkWh_t \quad t = 1, 2, \ldots T}$$

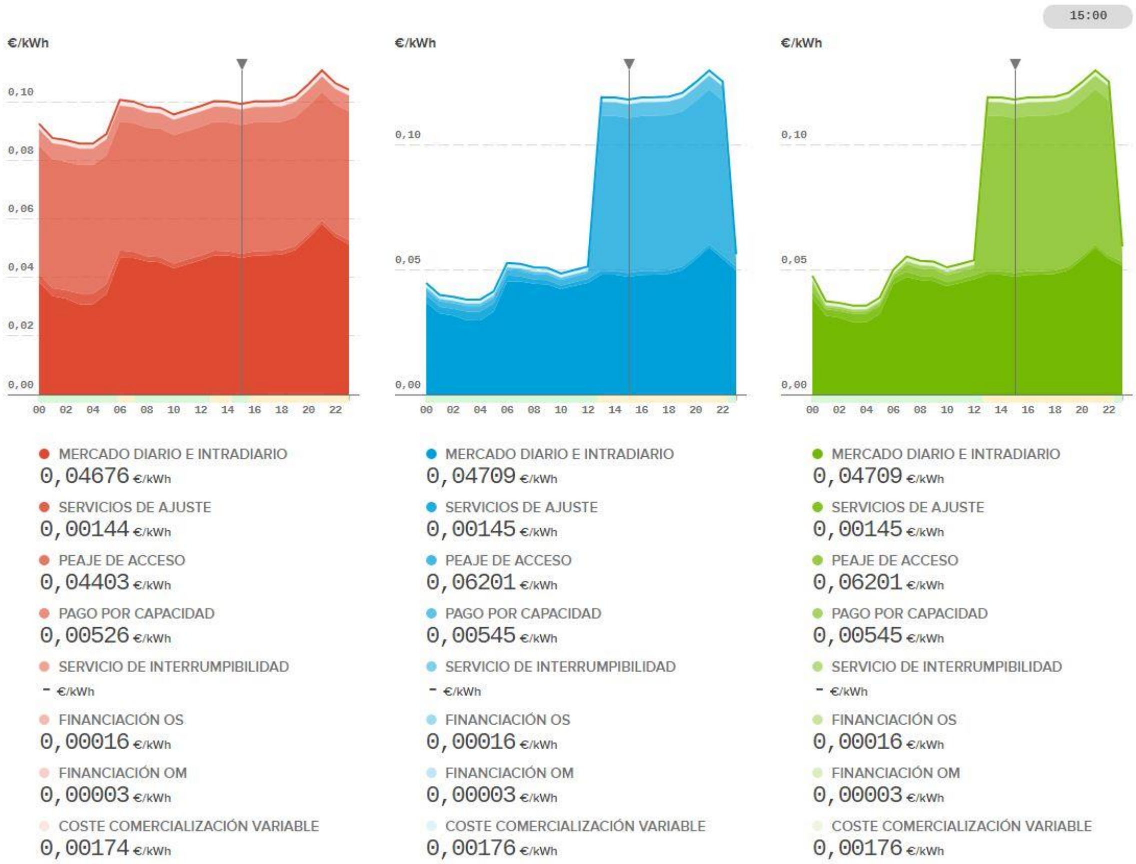
Where,

$$\begin{gathered}\boldsymbol{EF = Billed\ energy\ during\ the\ whole\ billing\ period} \\ \boldsymbol{t = Hour\ inside\ billing\ period} \\ \boldsymbol{kW_t = Consume\ in\ kW\ for\ t\ hour} \\ \boldsymbol{PkWh_t = Price\ of\ kW\ in\ t\ hour}\end{gathered}$$

Therefore, if a consumer has a tariff with hourly discrimination, the price of kW in the early morning hours will be lower than in the daytime hours, in addition to the differences in prices for each hour that are published on the REE website. This kWh includes the price at which the kWh is traded on the daily and intraday market, those derived from the adjustment market, the corresponding access toll, the payment for capacity, a financing fee from the market operator and the variable marketing cost for each marketer.

In the next illustration we can see the difference in the prices of the electricity and the components involved in every toll option available for little consumers:

Illustration 7: Components in the kWh PVPC for the 3 types of access tolls



Source: Sistema de Información del Operador del Sistema (eSIOS) https://www.esios.ree.es/es/pvpc

Consumers who do not have a smart meter can choose to use the **LUMIOS**[30] calculator that REE makes available to everyone on its website. In this way they can have approximate information on the consumption they have made during a billing period.

Consumption is measured by the marketer both electronically in case of having a smart meter, and physically by subtracting the value indicated by the meter that was marked last month. If an operator of the retailer has not have access to the meter, the electricity consumption is estimated based on the customer's historical consumption data, and they are notified on the invoice that the reading shown is based on an estimation.

Tax on electricity: This tax was established by law 38/1992 on special taxes within the framework of the manufacturing tax. However, as of the publication of Law 28/2014 of November 27, this tax is considered outside the manufacturing tax with the heading "special tax on electricity", taxing the supply of energy for consumption. The marketers are the ones in charge of collecting this tax and they inform us of it on the electricity bill. The taxable base of this tax is the amount corresponding to the sum of the billed Power and billed energy. The tax calculation is carried out as follows:

$$(\boldsymbol{PF} + \boldsymbol{EF}) * \mathbf{1,05113} * \mathbf{0,04864}$$

30 https://www.esios.ree.es/es/lumios?rate=rate1&start_date=23-08-2020T21:28&end_date=24-08-2020T21:28

This is done to avoid the subsequent application of VAT to the amount of the electricity tax. Therefore, if we have a consumer with a billed power **(PF)** of € 17.87 and a billed energy **(EF)** of € 34.27:

$$(\mathbf{17,87€} + \mathbf{34,27€}) * \mathbf{1,05113} * \mathbf{0,04864} = \mathbf{2,6657598€} \approx \mathbf{2,67€}$$

Services and other concepts: In addition to what consumers pay in terms of the electricity they consume and the power they have contracted, the marketer also charges a monthly fee for emergency services and for the rental of measurement equipment (meters). However, if a consumer wants to avoid the rental costs, they can choose to purchase their own meter. Finally, a 21% VAT is applied to the total amount, including the amount of electricity tax that we have previously calculated.

Source of the electricity and its price: Does the source of the electricity influence the final price?

As mentioned previously in this job, when the electricity supply curve is drawn up in the daily and intraday market, electricity providers begin to offer MW at different marginal prices depending on the generation technology they use. In this way, the first MW that enters the grid comes from generation sources that have a lower opportunity cost or in some cases even zero. For example, if an operating wind power plant chooses not to produce electricity during a time of day when the wind is blowing with great force, it is giving up the opportunity to put that electricity on the market without obtaining any benefit in return.

For this reason, all MW from renewable sources are offered at zero marginal price. The same occurs with the power that comes from nuclear power plants, but in the case of nuclear power plants, it is because shutting down a nuclear power plant has a high economic cost in addition to posing a risk to the integrity of the plant itself in some cases. Therefore, the price of MWh is determined by the other technologies that operate in the electricity grid and will be higher or lower depending on the power they contribute to the grid.

The plants that tend to be the most decisive in establishing the coupling price are those that use combined cycle technology to produce electricity. This means that the price of gas and oil also influences the matching price of the intraday market, by increasing intermediate costs in power generation plants with this technology. The lack of rain, wind or sun also has a direct effect on the marginal price, since the amount of power obtained from renewable sources is less.

In the following model, data about prices and electricity production by source have been taken from the intraday market, and although determining factors such as the price of gas and oil are not taken into account, it can be seen in broad terms how the contribution of different energy sources affects at the marginal price of matching:

So, the model used is as follows:

$$Pmg_i = \beta_0 + \beta_1 W_i + \beta_2 H_i + \beta_3 SF_i + \beta_4 ST_i + \beta_5 TR_i + \beta_6 N_i + \beta_7 C_i + \beta_8 CC_i + \beta_9 CG_i + \beta_{10} IT_i + \beta_{11} BL_i$$

And we can see the Gretl MCO estimation results in the next table:

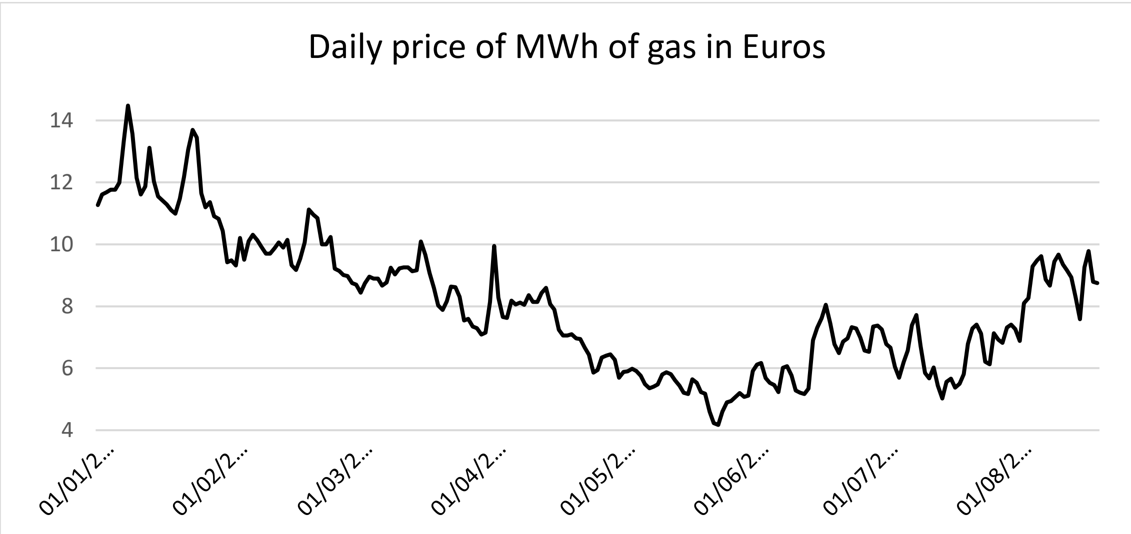
Table 4: OLS (Gretl)[31] estimation of the marginal price of electricity for one hour

	Coeficiente	Desv. Típica	Estadistico t	Valor P
Constante	222,943	111,705	1,996	0,0771
Eólica	-0,000705845	0,00107185	0,6585	0,5267
Hidráulica	0,000501721	0,001761	0,2849	0,7822
Solar Fotovoltáica	-0,000911272	0,00094754	−0,9617	0,3613
Solar Térmica	-0,00600116	0,00396996	−1,512	0,1649
Térmica Renovable	0,0533632	0,0420508	1,269	0,2363
Nuclear	-0,0308824	0,0142073	−2,174	0,0578
Carbón	0,109598	0,0298628	3,670	0,0052
Ciclo Combinado	0,00181109	0,00162024	1,118	0,2926
Cogeneración y residuos	-0,00145376	0,00306772	−0,4739	0,6469
Intercambios internacionales	-0,00146039	0,00148817	−0,9813	0,3521
Enlace Balear	0,0976504	0,0837576	1,166	0,2736

Source: Own elaboration from data of demand by hourly sections and intraday price of the REE

The part of the demand that remains uncovered when renewable and nuclear generation sources do not generate enough energy and that is finally covered by combined cycle and cogeneration plants, is called a **thermal gap.** As the price of MWh is set marginally, often in this section of the aggregate supply is where the final price of the intraday market is determined due to the unpredictability of the weather.

Graphic 5: Daily MWh[32] price of natural gas



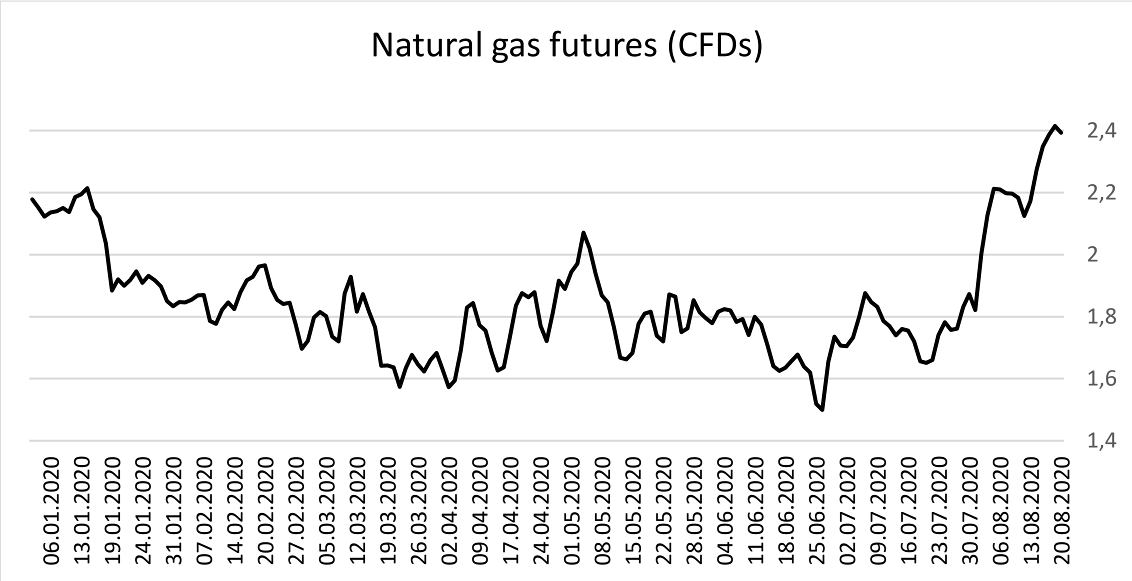
Source: MIBGAS, Iberian market of gas

[31] To prepare the table, the REE data on electricity demand and production in 10-minute time slots have been taken and averages have been made for each hour between four in the afternoon and ten at night, in addition to the price for each hour for August 18, 19 and 20, 2020. These averages are used as regressors in the OLS model, and although it only has 21 observations and does not observe relevant variables such as rainfall, temperatures in certain territories, wind or hours of sunshine, you can guess which sources of electricity are those that make the price of MWh more expensive.

[32] Although natural gas is measured in m^3, consumers are charged a price equivalent to the kWh produced by a cubic meter of gas. In the case of the daily gas market, the magnitude used is MWh.

During this year 2020, gas futures prices have remained stable at considerably low prices, making the energy from combined cycle gas plants not make the price of electricity too expensive. However, in the last month the price of gas CFDs[33] has made a small rebound as we can see in the following graphic:

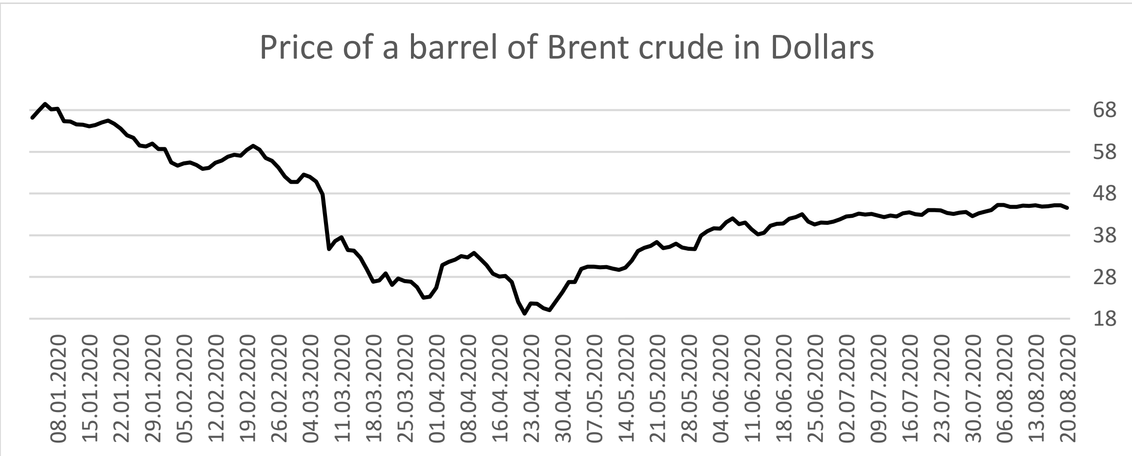
Graphic 6: Value of contracts for differences between January 1 and August 20, 2020



Source: Natural Gas Futures, Investing.com

Oil has continued in a downward trend similar to the natural gas, probably due to the low demand for oil derivatives as a result of the lockdowns caused by the COVID-19 pandemic. That trend is clearly seen in the following graph:

Graphic 7: Brent crude oil barrel futures price in dollars

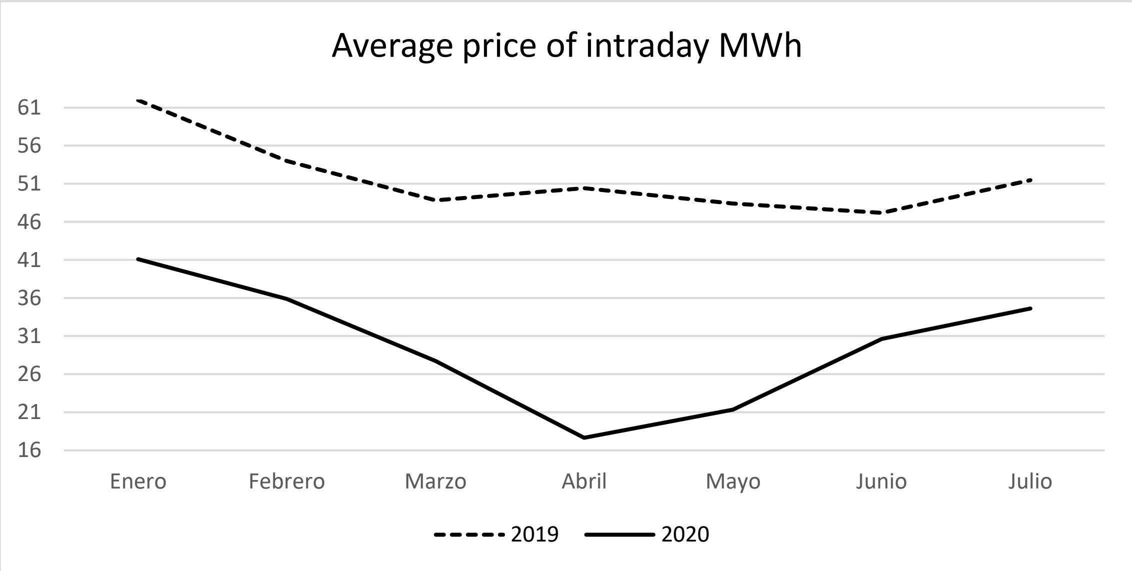


Source: Oil Futures, Investing.com https://es.investing.com/commodities/brent-oil-historical-data

[33] Contracts for Differences or CFDs are bilateral agreements between a buyer and a seller in which the seller agrees to pay the buyer the difference between the value of an underlying asset (gas in this case) between the time of purchase and the time of sale.

These phenomena have caused to have an average price in the intraday market that is considerably lower than last year for the same dates, since if intermediate production goods are cheaper in the power plants that fill the thermal gap left by renewable energies (mostly gas and oil), the marginal price resulting from the matching of the supply and demand for the intraday market will be lower.

Graphic 8: Comparison of the intraday average price between the year 2019 and the year 2020



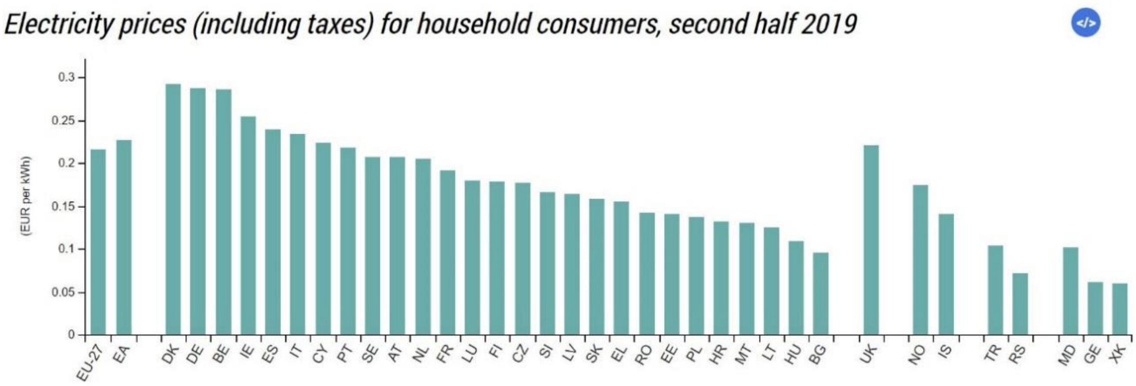
Source: OMIE

We can therefore say that electricity prices do depend on the portion of energy that is being provided from each of the sources. If the proportion of energy that comes from nuclear power plants is lower than usual (something uncommon, but that could happen at times when maintenance or changes of fuel cells are being carried out), if there is little wind in the regions with a higher population of wind farms, or little rainfall that does not allow the filling of reservoirs for the use in hydroelectric generation, the marginal price of electricity will rise. The same will happen if the price of gas and oil rises, not to mention the CO_2 emission rights that are traded in the EU ETS, which has been one of the determining factors for the closure of coal plants as we have mentioned before in this work.

On the other hand, if the nuclear power plants are at full capacity, if there are gusts of wind that allow the correct operation of the wind power plants, and the weather is sunny during daylight hours, it is very likely that the marginal price in the daily market is low, and logically something similar happens when the price of natural gas and oil falls, in both cases assuming that we are facing an equal demand for electricity.

Those factors mean that the price of electricity we pay in Spain is above the European average, and according to Eurostat data we are in the fifth place in terms of price per kilowatt hour in Europe.

Graphic 9: Price of kWh by EU countries



Source: Eurostat https://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_price_statistics

Conclusion:

Taking into account the methodology used for this work, such as the exposition of the historical context, description of the different agents involved in the generation, transport, distribution and commercialization, explanation of the operation of the electricity market in its different aspects, data display, graphs, tables and illustrations, this text might be able to fulfill the objective set at the beginning of the study: Help the reader to learn about the Spanish electrical system in a way that is understandable to someone not initiated in engineering matters.

As I mentioned in the Introduction, electricity is a staple good in today's society and in many occasions, we do not fully understand why they are variations in the price of our electricity bill, as well as the different concepts for those we pay or if there is any external factor that influences our consumption.

In some sections, when we talk about energy and its commercialization, we are referring to an ephemeral good whose generation in many cases cannot be precisely predicted since, as in the case of renewable sources that are subject to factors such as atmospheric phenomena. In addition, we are talking about a good whose storage is practically unviable in large quantities, so it must be consumed immediately and hence the importance of the electricity market and its different aspects of daily, intraday and term.

It was impossible to explain the Spanish electricity sector without including a brief review of the industry historical background, especially since the mid-20th century, when projects were carried out under the direct supervision of the government. Because, although the Spanish electricity sector dates back many years, this period is essential to understand the shortcomings that the sector suffered during the 1980s, ending with its liberalization and later the tariff deficits and the irruption of the renewable generation technologies.

This work could not be concluded without reserving space for renewable energies or other sources of electricity that may be controversial, such as nuclear; or how changes in oil and natural gas prices influence the final electricity cost. Not because most of the electricity comes from sources that use these resources, but rather because the market was being configured in such a way that the price is set marginally, the kilowatts of these generation sources are decisive to establish the coupling price. This means that, although we have a large proportion of energy from renewable sources, we continue to pay a high price, and that is the main reason because the private consumers paid in 2019 a price per kilowatt hour that is among the 5 most expensive in Europe.

Regarding the bibliography and documentary sources, it is worth highlighting the amount of information that can be found using institutional sources, such as the web archive of the Official State Gazette, the different specialized pages of the sector both in engineering and market issues and marketing or the extensive amount of data offered by *Red Eléctrica de España*.

I understand that it is a complex market and difficult to expose in a simple and understandable way for a consumer who is not familiar with the fields of engineering or economics, but this complexity has a reason for being, and that in the end supply the population with a good such as electricity is not an easy task, since technical factors such as the availability of the network or the power limitations of the substations make they influence. Furthermore, the peninsular geography limits the interconnection options with the rest of European countries, which affects to the flexibility of electricity trade with our neighbours negatively.

To conclude, I would like to emphasize that in recent months we have enjoyed electricity prices considerably cheaper than usual, but it is very likely that at the moment when the price of natural gas or oil begins to rise, electricity does too. The only way we have to avoid these fluctuations would be filling the thermal gap with energy from renewable sources or from a stable source such as nuclear. However, the prejudices of the population towards this source of energy make it difficult to develop a nuclear park capable of compensating the energy from thermal power plants, so the best alternative may be to try to increase the generation capacity from renewable sources and try to improve the energy efficiency of homes.

Annex:

Table 5: Proportion of electricity over total demand by generation sources

	Día	Eólica		Hidráulica		Solar fotovoltaica		Solar Térmica		Térmica renovable		Nuclear		Carbón		Ciclo Combinado		Cogeneración y res.		Inter. internacionales		Enlace balear		Potencia total en MW	
		Mediodia	Madrugada	Mediodia	Madrugada	Mediodia	Madrugada	Mediodia	Madrugada	Mediodia	Madrugada	Mediodia	Madrugada	Mediodia	Madrugada	Mediodia	Madrugada	Mediodia	Madrugada	Mediodia	Madrugada	Mediodía	Madrugada	Mediodía	Madrugada
Valores en verano	21/06/2019	8,08	16,07	11,19	5,93	10,15	0,08	6,55	2,15	1,34	1,73	21,53	29,52	2,25	2,04	26,01	25,69	11,62	15,31	1,28	1,48	0	0	32796	23393
	30/06/2019	11,24	15,63	9,92	5,42	10,78	0,07	5,95	2	1,46	1,95	22,53	30,29	2,23	2,47	22,85	25,08	11,34	15,17	1,7	1,92	0	0	30159	22879
	09/07/2019	10,56	20,27	8,51	1,04	9,35	0,08	5,61	1,85	1,32	1,82	19,96	28,3	2,88	3,45	28,4	26,7	10,09	14,59	3,32	1,9	0	0	34699	24444
	19/07/2019	8,17	13,55	9,62	3,63	10,67	0,06	5,46	2,49	1,21	1,85	18,23	27,32	2,49	3,3	29,65	33,19	10,15	14,61	4,35	0	0	0	37641	25087
	28/07/2019	7,04	23,94	5,23	1,25	13,86	0,06	7,05	0,61	1,45	1,77	24,12	29,05	2,33	2,49	26,93	26,47	11,99	14,36	0	0	0	0	27490	21712
	07/08/2019	8,9	15,08	7,3	2,47	7,98	0,08	2,12	2,5	1,28	1,79	19,23	27,56	2,58	3,01	34,69	33,67	10,05	13,84	5,87	0	0	0	35587	24375
	16/08/2019	4,76	10,24	4,66	3,99	13,94	0,09	6,31	2,27	1,37	1,97	21,01	31,08	1,44	2,29	30,16	32,03	10,73	15,29	5,62	0,75	0	0	32517	22201
	26/08/2019	12,03	21,97	8,33	4,08	8,86	0,09	2,02	0,07	1,26	1,81	19,79	29,73	0,9	1,07	35,71	27,18	10,27	14	0,83	0	0	0	34816	22478
	10/09/2019	40,13	38,72	0	0	11,17	0,1	5,13	0,03	1,27	1,72	20,73	28,77	2,88	3,61	8,09	12,77	10,6	14,28	0	0	0	0	31619	23760
	23/09/2019	13,85	18,53	4,53	2,95	12,38	0,05	4,71	0	1,26	1,95	21,03	31,95	2,18	2,3	28,5	26,27	11,56	16	0	0	0	0	31493	20467
Valores en otoño	23/09/2019	13,85	18,53	4,53	2,96	12,38	0,05	4,71	0	1,26	1,94	21,03	31,95	2,18	2,3	28,5	26,27	11,56	16	0	0	0	0	31493	20467
	01/10/2019	19,4	15,69	3,54	1,75	12,73	0,08	4,44	0,2	1,26	1,83	20,77	30,63	2,29	3,29	23,7	25,94	10,38	15,19	1,49	5,4	0	0	32921	22426
	10/10/2019	9,1	18,66	4,16	1,05	11,83	0,05	4,83	0,04	1,36	1,85	18,5	26,4	2,87	3,75	32,49	30,22	11,52	15,89	3,34	2,09	0	0	31856	22464
	19/10/2019	23,57	25,64	4,12	2,17	9,31	0,08	0,59	0	1,48	1,96	21,18	28,07	1,75	2,35	22,79	21,34	12,51	16,98	2,7	1,41	0	0	27945	21255
	28/10/2019	6,97	14,21	7,67	2,07	8,64	0,04	1,73	0	1,34	2,03	19,36	29,33	3,67	5,44	27,88	23,68	12,38	17,57	10,36	5,63	0	0	31163	20569
	06/11/2019	24,79	37,18	10,38	7,61	10,13	0,15	1,38	0	1,28	1,7	14,52	19,72	2,53	1,73	24,56	18,2	10,43	13,71	0	0	0	0	31269	22367
	15/11/2019	28,21	38,23	10,6	8,94	7,6	0,08	1,11	0	1,26	1,67	12,48	16,48	3	3,96	24,58	15,74	11,16	14,9	0	0	0	0	34188	23432
	24/11/2019	33,56	43,29	14,03	3,82	9,31	0,1	1,03	0	1,46	1,79	16,36	21	1,75	1,91	10,33	13,04	12,17	15,05	0	0	0	0	28060	21041
	05/12/2019	18,9	27,84	17,96	15,73	7,26	0,05	1,52	0	1,26	1,5	14,69	19,59	4,23	3,78	17,98	16,45	11,5	15,06	4,7	0	0	0	34051	23348
	22/12/2019	36,47	34,41	18,29	21,15	11,53	0,03	0,34	0	1,34	1,85	16,3	22,38	0	0	3,69	6,57	9,74	13,61	2,3	0	0	0	26740	19468
Valores en invierno	23/12/2019	27,11	35,83	23,41	16,45	13,12	0,03	0,76	0	1,23	1,75	18,2	23,12	0,89	0,54	4,56	7,54	10,72	14,01	0	0,73	0	0	29530	19176
	02/01/2020	9,65	10,08	23,92	14,1	9,57	0,08	1,35	0,03	1,1	1,81	21,11	37,4	2,02	2,19	20,6	19,98	10,68	14,33	0	0	0	0	33401	18726
	12/01/2020	5,42	15,11	13,55	11,27	16,21	0,16	3,24	0,05	1,5	2,14	23,09	32,17	4,76	6,64	15,94	15,28	10,92	15,49	5,37	1,69	0	0	30586	22048
	22/01/2020	15,2	33,31	20,52	5,28	5,97	0,13	0,06	0	1,22	1,99	18,81	27,92	3,36	4,08	20,3	13,63	10,04	13,66	4,52	0	0	0	37528	24538
	01/02/2020	35,97	45,68	4,1	0	11,52	0,03	0,68	0	1,67	1,94	23,53	29,76	3,14	3,34	6,84	4,73	11,58	14,52	0,97	0	0	0	29169	22635
	10/02/2020	28,82	40,75	6,53	0	15,41	0,05	3,47	0	1,44	1,87	21,69	30,07	5,22	5,43	6,03	7,89	10,97	13,94	0,42	0	0	0	32508	21900
	20/02/2020	6,96	21,73	13,78	8,33	16,96	0,09	4,57	0	1,69	2,12	21,72	30,11	3,84	5,32	16,03	12,17	11,21	15	3,24	5,13	0	0	32515	23504
	02/03/2020	46,92	50,95	6,64	4,19	13,37	0,01	0,6	0	1,4	2,02	18	22,17	2,05	2,41	1,37	5,52	9,65	12,73	0	0	0	0	32793	21405
	10/03/2020	14,35	36,69	16,15	6,5	16,61	0,01	5,22	0	1,64	2,22	22,05	30,34	3,66	3,72	5,85	5,88	10,97	14,64	3,5	0	0	0	31996	22932
	20/03/2020	19	24,05	14,26	8,21	10,77	0,01	0,5	0	1,71	2,63	23,72	34,19	3,1	3,28	6,78	8,02	11,63	16,35	8,53	3,26	0	0	29733	20676
Valores en primavera	21/03/2020	10,43	23,81	18,74	6,95	9,94	0	0,16	0	1,73	2,27	24,75	34,48	2,27	3,2	9,52	9,9	11,66	16,67	10,8	2,72	0	0	28557	20545
	30/03/2020	32,28	43,1	9,48	0	12,25	0,19	0,11	0,13	1,75	2,12	23,29	28,24	1,49	2,81	8,12	11,32	10,71	12,09	0,52	0	0	0	28538	18480
	09/04/2020	14,91	19,1	12,64	8,18	14,83	0,15	0,09	0	1,91	2,6	22,52	31,64	2,46	3,37	14,13	18,98	11,32	15,98	5,19	0	0	0	25428	17464
	19/04/2020	8,26	8,41	15,03	19,05	18,06	0,07	4,97	0	1,84	2,56	23,47	33,34	1,71	2,43	8,61	14,74	11,2	16,1	6,85	3,3	0	0	25043	17616
	29/04/2020	34,7	42,57	3,97	16,09	23,44	0,16	6,56	0	1,45	2,29	13,13	17,3	0,88	1,15	5,55	6,51	10,32	13,93	0	0	0	0	27954	19709
	08/05/2020	12,68	31,36	14,32	14,69	21,87	0,06	6,34	0	1,95	2,65	15,59	21,79	1,56	2,16	5,8	10,88	11,39	15,43	8,5	0,98	0	0	27694	19861
	17/05/2020	11,78	32,74	13,05	12,2	23,76	0,17	5,54	0,27	2,23	2,73	17,77	22,2	0,74	0,92	9,49	13,79	11,91	14,98	3,73	0	0	0	24365	17736
	29/05/2020	5,61	14,06	16,34	20,85	23	0,3	6,45	2	1,67	2,67	13,28	19,54	1,84	2,08	17,19	17,6	10,76	15,49	3,86	5,41	0	0	30367	20707
	10/06/2020	9,04	23,51	13,57	11,36	21,28	0,09	5,78	2,19	1,89	2,64	16,8	23,73	3,76	3,92	16,65	17,12	11,23	15,16	0	0,28	0	0	29914	21326
	20/06/2020	5,81	11,05	7,57	10,35	24,98	0,09	7,67	2,64	1,94	2,61	18,15	23,89	1,58	2,12	19,69	23,4	12,07	16,11	0,54	7,74	0	0	27960	21075

Table 6: Average of the power generated per hour and source

Día	Hora	Eólica	Hidráulica	Solar fotovoltaica	Solar Térmica	Térmica renovable	Nuclear	Carbón	Ciclo Combinado	Cogeneración y res.	Inter. internacionales	Enlace balear	Precio Marg. MWh (€)
18/08/2020	AVG 16	4294,00	2960,50	5161,33	1682,50	553,50	6961,00	312,50	7514,17	3482,17	-2183,83	-304,00	35,99
	AVG 17	4251,17	3299,83	4616,17	1936,33	549,83	6959,67	308,33	7817,00	3480,33	-2542,17	-304,00	37,60
	AVG 18	4242,17	3908,17	3575,17	1753,67	548,17	6961,00	308,17	8104,17	3446,67	-2393,00	-304,00	39,59
	AVG 19	4159,83	4178,67	2139,00	1702,17	550,50	6965,67	286,00	8326,17	3446,83	-1572,17	-304,00	39,66
	AVG 20	4119,00	4398,83	545,17	1205,67	554,33	6966,67	255,67	8863,50	2870,50	-335,50	-304,00	41,09
	AVG 21	4062,50	5548,17	19,17	764,17	554,17	6966,33	254,67	9876,67	3486,83	-181,33	-304,00	42,78
	AVG 22	4106,67	4933,50	5,00	652,17	543,17	6970,83	255,17	9588,00	3480,33	-154,67	-285,50	44,58
19/08/2020	AVG 16	10048,17	960,17	6613,00	2089,67	547,33	6945,00	355,67	4284,67	3296,83	-2690,50	-304,00	28,29
	AVG 17	10230,33	891,17	6001,50	2083,50	518,50	6942,50	355,83	4659,50	3328,83	-2677,33	-304,00	27,52
	AVG 18	10315,67	2004,33	4912,33	2066,83	515,50	6947,00	310,83	4670,33	3347,17	-3112,17	-303,83	27,03
	AVG 19	10201,17	2352,83	2936,33	1951,50	516,83	6946,67	308,33	5468,67	3374,83	-2572,33	-304,00	26,52
	AVG 20	9575,50	3277,50	682,17	1288,00	532,00	6948,50	271,33	6366,33	3461,50	-1510,00	-304,00	30,02
	AVG 21	8912,00	4116,83	45,83	751,83	530,00	6784,67	254,67	6810,83	3488,00	39,50	-304,00	38,33
	AVG 22	7997,00	4160,83	33,83	619,67	529,00	6954,50	307,00	6422,33	3507,33	262,83	-285,67	41,92
20/08/2020	AVG 16	11090,67	760,00	6349,17	1980,67	543,17	6935,83	313,83	5020,00	3391,67	-3935,17	-304,00	27,66
	AVG 17	11872,67	353,33	5551,33	1984,50	544,83	6934,17	308,33	5149,50	3403,17	-3890,67	-304,00	27,26
	AVG 18	12570,50	475,33	4371,50	1995,33	544,17	6936,33	307,83	5100,33	3440,00	-3867,33	-304,00	27,72
	AVG 19	12270,67	1626,83	2527,17	1859,17	549,00	6939,33	307,50	5763,00	3444,50	-3738,00	-304,00	31,55
	AVG 20	11159,17	2873,83	546,83	1190,33	516,00	6938,67	308,00	6527,00	3456,50	-2428,83	-304,00	36,10
	AVG 21	10176,50	3794,17	23,50	712,17	516,00	6942,17	308,17	7164,67	3999,50	-961,33	-304,00	40,71
	AVG 22	9611,83	3692,67	16,17	595,17	548,17	6947,83	295,67	7002,50	3497,00	-1248,67	-274,00	43,82

Table 7: Power generated per hour and source (18/08/2020)

Día	Hora	Eólica	Hidráulica	Solar fotovoltaica	Solar Térmica	Térmica renovable	Nuclear	Carbón	Ciclo Combinado	Cogeneración y res.	Inter. internacionales	Enlace balear	Precio Marg. MWh (€)
18/08/2020	16:00	4275	2791	5580	1539	551	6967	308	7227	3483	-1783	-304	
	16:10	4243	2977	5451	1563	554	6963	308	7308	3482	-2095	-304	
	16:20	4301	2993	5112	1653	554	6952	309	7472	3482	-2137	-304	
	16:30	4341	3118	4950	1717	554	6967	307	7702	3482	-2363	-304	
	16:40	4306	3002	4943	1765	554	6963	323	7712	3482	-2360	-304	
	16:50	4298	2882	4932	1858	554	6954	320	7664	3482	-2365	-304	
	AVG 16	4294	2960,5	5161,333333	1682,5	553,5	6961	312,5	7514,166667	3482,166667	-2183,833333	-304	35,99
	17:00	4306	2955	4880	1936	554	6962	313	7696	3482	-2355	-304	
	17:10	4340	3338	4727	1958	549	6962	308	7673	3480	-2684	-304	
	17:20	4194	3306	4762	1942	549	6955	308	7810	3480	-2577	-304	
	17:30	4186	3360	4559	1929	549	6959	308	7830	3480	-2569	-304	
	17:40	4201	3367	4528	1927	549	6958	308	7866	3480	-2500	-304	
	17:50	4280	3473	4241	1926	549	6962	305	8027	3480	-2568	-304	
	AVG 17	4251,166667	3299,833333	4616,166667	1936,333333	549,8333333	6959,666667	308,3333333	7817	3480,333333	-2542,166667	-304	37,6
	18:00	4284	3583	3929	1859	549	6954	309	8064	3470	-2530	-304	
	18:10	4262	3665	3708	1795	548	6964	309	7997	3442	-2312	-304	
	18:20	4216	3691	3691	1755	548	6959	308	7986	3442	-2178	-304	
	18:30	4214	4060	3542	1724	548	6962	308	8092	3442	-2399	-304	
	18:40	4249	4161	3442	1695	548	6963	307	8179	3442	-2391	-304	
	18:50	4228	4289	3139	1694	548	6964	308	8307	3442	-2548	-304	
	AVG 18	4242,166667	3908,166667	3575,166667	1753,666667	548,1666667	6961	308,1666667	8104,166667	3446,666667	-2393	-304	39,59
	19:00	4203	4048	2952	1724	548	6968	288	8056	3466	-1938	-304	
	19:10	4181	4072	2720	1722	551	6970	288	8038	3443	-1576	-304	
	19:20	4136	4104	2244	1754	551	6965	288	8174	3443	-1655	-304	
	19:30	4110	4333	1944	1738	551	6962	289	8428	3443	-1556	-304	
	19:40	4126	4235	1629	1699	551	6965	290	8585	3443	-1464	-304	
	19:50	4203	4280	1345	1576	551	6964	273	8676	3443	-1244	-304	
	AVG 19	4159,833333	4178,666667	2139	1702,166667	550,5	6965,666667	286	8326,166667	3446,833333	-1572,166667	-304	39,66
	20:00	4217	4435	1075	1469	551	6972	255	8426	3461	-898	-304	
	20:10	4191	4031	836	1354	555	6967	256	8551	3467	-265	-304	
	20:20	4182	4208	601	1247	555	6962	256	8868	3467	-345	-304	
	20:30	4082	4281	417	1150	555	6966	256	8922	3467	-268	-304	
	20:40	4039	4516	234	1062	555	6965	255	9147	3467	-131	-304	
	20:50	4003	4922	108	952	555	6968	256	9267	-106	-106	-304	
	AVG 20	4119	4398,833333	545,1666667	1205,666667	554,3333333	6966,666667	255,6666667	8863,5	2870,5	-335,5	-304	41,09
	21:00	4030	5089	45	879	555	6967	255	9590	3486	-301	-304	
	21:10	4053	5018	22	841	554	6968	255	9812	3487	-50	-304	
	21:20	4059	5663	17	782	554	6961	254	9934	3487	-38	-304	
	21:30	4046	5748	14	729	554	6967	255	10061	3487	-133	-304	
	21:40	4078	5981	11	685	554	6969	255	9934	3487	-238	-304	
	21:50	4109	5790	6	669	554	6966	254	9929	3487	-328	-304	
	AVG 21	4062,5	5548,166667	19,16666667	764,1666667	554,1666667	6966,333333	254,6666667	9876,666667	3486,833333	-181,3333333	-304	42,78
	22:00	4072	5466	5	663	554	6972	256	9908	3487	-180	-294	
	22:10	4074	5416	5	659	541	6973	254	9878	3479	-204	-284	
	22:20	4089	5012	5	653	541	6969	255	9700	3479	-128	-284	
	22:30	4112	4793	5	650	541	6970	255	9686	3479	-218	-283	
	22:40	4130	4421	5	646	541	6971	256	9332	3479	-120	-284	
	22:50	4163	4493	5	642	541	6970	255	9024	3479	-78	-284	
	AVG 22	4106,666667	4933,5	5	652,1666667	543,1666667	6970,833333	255,1666667	9588	3480,333333	-154,6666667	-285,5	44,58

Table 8: Power generated per hour and source (19/08/2020)

Día	Hora	Eólica	Hidráulica	Solar fotovoltaica	Solar Térmica	Térmica renovable	Nuclear	Carbón	Ciclo Combinado	Cogeneración y res.	Inter. internacionales	Enlace balear	Precio Marg. MWh (€)
19/08/2020	16:00	9893	855	6769	2094	554	6951	355	4132	3321	-2637	-304	
	16:10	9906	945	6724	2091	546	6944	356	4358	3292	-2736	-304	
	16:20	10023	1007	6662	2089	546	6947	356	4335	3292	-2752	-304	
	16:30	10093	978	6568	2088	546	6944	356	4234	3292	-2615	-304	
	16:40	10130	1025	6523	2088	546	6941	355	4300	3292	-2613	-304	
	16:50	10244	951	6432	2088	546	6943	356	4349	3292	-2790	-304	
	AVG 16	10048,16667	960,1666667	6613	2089,666667	547,3333333	6945	355,6666667	4284,666667	3296,833333	-2690,5	-304	28,29
	17:00	10247	797	6323	2085	546	6941	357	4301	3283	-2569	-304	
	17:10	10179	749	6204	2086	513	6944	356	4493	3338	-2602	-304	
	17:20	10220	899	6080	2087	513	6938	355	4753	3338	-2786	-304	
	17:30	10259	978	5948	2082	513	6939	354	4783	3338	-2759	-304	
	17:40	10198	910	5800	2083	513	6949	356	4723	3338	-2479	-304	
	17:50	10279	1014	5654	2078	513	6944	357	4904	3338	-2869	-304	
	AVG 17	10230,33333	891,1666667	6001,5	2083,5	518,5	6942,5	355,8333333	4659,5	3328,833333	-2677,333333	-304	27,52
	18:00	10322	1368	5469	2077	513	6947	326	4694	3338	-3071	-303	
	18:10	10263	1942	5274	2076	516	6947	309	4432	3349	-3111	-304	
	18:20	10214	2141	5071	2070	516	6954	308	4580	3349	-3050	-304	
	18:30	10296	2164	4827	2068	516	6948	306	4698	3349	-3100	-304	
	18:40	10365	2257	4559	2054	516	6943	307	4796	3349	-3164	-304	
	18:50	10434	2154	4274	2056	516	6943	309	4822	3349	-3177	-304	
	AVG 18	10315,66667	2004,333333	4912,333333	2066,833333	515,5	6947	310,8333333	4670,333333	3347,166667	-3112,166667	-303,8333333	27,03
	19:00	10336	2166	3942	2048	516	6943	309	4961	3354	-2724	-304	
	19:10	10278	2068	3581	2031	517	6946	308	5229	3379	-2506	-304	
	19:20	10197	2137	3180	2004	517	6948	308	5341	3379	-2610	-304	
	19:30	10174	2294	2751	1959	517	6951	307	5636	3379	-2322	-304	
	19:40	10159	2474	2301	1886	517	6945	308	5756	3379	-2649	-304	
	19:50	10063	2978	1863	1781	517	6947	310	5889	3379	-2623	-304	
	AVG 19	10201,16667	2352,833333	2936,333333	1951,5	516,8333333	6946,666667	308,3333333	5468,666667	3374,833333	-2572,333333	-304	26,52
	20:00	9877	2941	1449	1632	517	6954	309	6085	3379	-2120	-304	
	20:10	9781	2760	1068	1472	535	6946	285	6120	3478	-1285	-304	
	20:20	9640	3167	737	1333	535	6943	260	6249	3478	-1568	-304	
	20:30	9481	3490	456	1196	535	6945	259	6337	3478	-1549	-304	
	20:40	9371	3605	261	1094	535	6950	259	6489	3478	-1231	-304	
	20:50	9303	3702	122	1001	535	6953	256	6918	3478	-1307	-304	
	AVG 20	9575,5	3277,5	682,1666667	1288	532	6948,5	271,3333333	6366,333333	3461,5	-1510	-304	30,02
	21:00	9185	3767	63	899	535	6954	255	7023	3478	-971	-304	
	21:10	9130	3671	47	829	529	6953	255	6750	3490	61	-304	
	21:20	9032	4105	43	767	529	6949	255	6750	3490	183	-304	
	21:30	8884	4272	41	704	529	6947	254	6695	3490	446	-304	
	21:40	8687	4418	39	668	529	5951	254	6789	3490	257	-304	
	21:50	8554	4468	42	644	529	6954	255	6858	3490	261	-304	
	AVG 21	8912	4116,833333	45,83333333	751,8333333	530	6784,666667	254,6666667	6810,833333	3488	39,5	-304	38,33
	22:00	8322	4460	39	628	529	6953	285	6681	3494	328	-294	
	22:10	8195	4292	39	626	529	6957	289	6836	3510	47	-284	
	22:20	8015	4701	35	623	529	6957	294	6404	3510	459	-284	
	22:30	7979	3951	31	619	529	6958	296	6273	3510	246	-284	
	22:40	7826	3875	30	612	529	6949	334	6249	3510	198	-284	
	22:50	7645	3686	29	610	529	6953	344	6091	3510	299	-284	
	AVG 22	7997	4160,833333	33,83333333	619,6666667	529	6954,5	307	6422,333333	3507,333333	262,8333333	-285,6666667	41,92

Table 9: Power generated per hour and source (20/08/2020)

Día	Hora	Eólica	Hidráulica	Solar fotovoltaica	Solar Térmica	Térmica renovable	Nuclear	Carbón	Ciclo Combinado	Cogeneración y res.	Inter. internacionales	Enlace balear	Precio Marg. MWh (€)
	16:00	10761	949	6567	2049	539	6939	345	4603	3380	-3825	-304	
	16:10	10773	833	6392	2039	544	6932	309	5245	3394	-3897	-304	
	16:20	10998	783	6405	1990	544	6938	307	5232	3394	-4000	-304	
	16:30	11305	683	6387	1938	544	6935	307	5002	3394	-4075	-304	
	16:40	11314	678	6214	1902	544	6936	307	5160	3394	-3796	-304	
	16:50	11393	634	6130	1966	544	6935	308	4878	3394	-4018	-304	
	AVG 16	11090,66667	760	6349,166667	1980,666667	543,1666667	6935,833333	313,8333333	5020	3391,666667	-3935,166667	-304	27,66
	17:00	11559	572	5953	2023	544	6933	309	4973	3394	-3938	-304	
	17:10	11625	472	5870	2002	545	6934	307	5184	3405	-3761	-304	
	17:20	11784	291	5594	1969	545	6935	308	5299	3405	-4010	-304	
	17:30	11896	233	5368	1950	545	6933	308	5091	3405	-3813	-304	
	17:40	12138	224	5260	1974	545	6932	309	4993	3405	-3728	-304	
	17:50	12234	328	5263	1989	545	6938	309	5357	3405	-4094	-304	
	AVG 17	11872,66667	353,3333333	5551,333333	1984,5	544,8333333	6934,166667	308,3333333	5149,5	3403,166667	-3890,666667	-304	27,26
	18:00	12414	264	4969	2003	545	6933	309	5162	3405	-3945	-304	
	18:10	12666	287	4768	2014	544	6938	308	4933	3447	-3981	-304	
	18:20	12673	393	4476	2005	544	6936	309	5195	3447	-3949	-304	
	18:30	12605	543	4295	1990	544	6933	308	4943	3447	-3876	-304	
	18:40	12606	650	4005	1987	544	6941	307	4946	3447	-3714	-304	
	18:50	12459	715	3716	1973	544	6937	306	5423	3447	-3739	-304	
	AVG 18	12570,5	475,3333333	4371,5	1995,333333	544,1666667	6936,333333	307,8333333	5100,333333	3440	-3867,333333	-304	27,72
	19:00	12370	1102	3408	1951	544	6938	309	5650	3447	-3798	-304	
	19:10	12341	1349	3121	1922	550	6941	307	5362	3444	-3728	-304	
	19:20	12357	1479	2757	1920	550	6940	306	5444	3444	-3701	-304	
20/08/2020	19:30	12311	1710	2348	1879	550	6939	308	5601	3444	-3705	-304	
	19:40	12178	1991	1953	1799	550	6939	307	6039	3444	-3617	-304	
	19:50	12067	2130	1576	1684	550	6939	308	6482	3444	-3879	-304	
	AVG 19	12270,66667	1626,833333	2527,166667	1859,166667	549	6939,333333	307,5	5763	3444,5	-3738	-304	31,55
	20:00	11660	2344	1193	1523	551	6935	307	6420	3444	-3166	-304	
	20:10	11455	2648	889	1377	509	6940	308	6073	3459	-2522	-304	
	20:20	11314	2908	580	1245	509	6937	310	6138	3459	-2538	-304	
	20:30	11099	3023	351	1100	509	6938	308	6575	3459	-2169	-304	
	20:40	10781	3077	193	987	509	6939	308	6881	3459	-1992	-304	
	20:50	10646	3243	75	910	509	6943	307	7075	3459	-2186	-304	
	AVG 20	11159,16667	2873,833333	546,8333333	1190,333333	516	6938,666667	308	6527	3456,5	-2428,833333	-304	36,1
	21:00	10517	3510	40	848	510	6940	309	6988	3472	-1448	-304	
	21:10	10325	3557	22	794	510	6943	309	6796	3505	-999	-304	
	21:20	10248	3718	20	732	519	6943	307	7210	3505	-800	-304	
	21:30	10107	4065	20	670	519	6941	307	7410	3505	-937	-304	
	21:40	9989	3885	20	625	519	6942	308	7264	6505	-760	-304	
	21:50	9873	4030	19	604	519	6944	309	7320	3505	-824	-304	
	AVG 21	10176,5	3794,166667	23,5	712,1666667	516	6942,166667	308,1666667	7164,666667	3999,5	-961,3333333	-304	40,71
	22:00	9743	3991	19	600	519	6949	307	7211	3507	-901	-304	
	22:10	9689	3920	16	594	554	6947	308	7552	3495	-1515	-208	
	22:20	9693	3835	16	596	554	6946	307	7119	3495	-1410	-283	
	22:30	9580	3674	16	594	554	6949	309	6922	3495	-1275	-283	
	22:40	9506	3480	16	593	554	6948	282	6715	3495	-1191	-283	
	22:50	9460	3256	14	594	554	6948	261	6496	3495	-1200	-283	
	AVG 22	9611,833333	3692,666667	16,16666667	595,1666667	548,1666667	6947,833333	295,6666667	7002,5	3497	-1248,666667	-274	43,82

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