MÁSTER EN INGENIERÍA EN TECNOLOGÍAS INDUSTRIALES

TRABAJO FIN DE MÁSTER

A Decision-Making Tool for Investment, Procurement and Operation for Retailers in Electricity Markets

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Declaro, bajo mi responsabilidad, que el Proyecto presentado con el título

A decision-making tool for Investment, Procurement and Operation for Retailers in Electricity Markets

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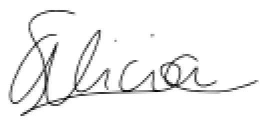

José Pablo Chaves

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Contents

Figures

Tables

Acronyms

EACs	Energy Attribute certificates
EU	European Union
FEC	Final Energy Consumption
GO	Guarantees of Origin
HICP	Inflation rate
ICT	Information and communication technologies
ISA	Integrated Supply Aggregator
ITC	Investment Tax Credits
KWh	Kilowatt hour
LGC	Large-scale Generation certificates
LNG	Liquefied Natural Gas
MWh	Megawatt hour
NEMO	Nominated Electricity Market Operators
PEC	Primary energy Consumption
PPA	Power Purchase Agreement
PPS	Purchasing Power standard
PV	Photovoltaic
PVPC	Voluntary Price for Small Electricity consumer
RECs	Renewable Energy Certificates
SDG	Sustainable Development Goals
SMEs	Small and Medium Enterprises
SPV	Special Purpose Vehicle
TPO	Third-Party ownership
TWh	Terawatt hour
US	United States

Resumen

La forma de consumir y producir energía está cambiando debido al aumento de los precios, la inestabilidad política y las emisiones de CO2. A la mayoría de las empresas se les cobran grandes cantidades de dinero debido a las emisiones de CO2 cuando producen energía con carbón o gas. La Unión Europea anima a las empresas a producir una cantidad mínima de emisiones de CO2, además, cualquier exceso que supere el límite impuesto por la UE se cobrará, con el fin de promover la generación de energía renovable.

Se están desarrollando múltiples herramientas para llevar a cabo algoritmos que apoyen la generación, comercialización y distribución de energía de forma optimizada en términos operativos y de costes.

La mayoría de las metodologías se centra en horizontes a más corto plazo, sin involucrar agentes del largo plazo. Sin embargo, es de total relevancia teniendo en cuenta los contratos PPAs que se firman a un año, o instalaciones de autoconsumo que funcionan hasta 20 años. Al final, llevar a cabo un modelo de optimización para los próximos 20 años no tendría sentido porque perdería precisión, sin embargo, si puede ser representativo si se lleva a cabo en un horizonte de 3-5 años [1].

Los modelos que se llevan a cabo deben considerar, llevando a cabo el mayor detalle posible, la demanda de energía, los precios fijos y la generación renovable. El principal problema a la hora de predecir la generación de energía renovable proviene de los niveles de autoconsumo.

A la hora de estimar los precios para los consumidores se pueden considerar dos formas de modelización. Por un lado, como se ha mencionado, fijando un precio por MWh, a través de los contratos PPAs, o considerando la volatilidad de los precios de la energía debido al mercado diario e intradiario. Para obtener una predicción de la volatilidad de los precios es necesario tomar como referencia datos históricos y las variaciones diarias [2] [3].

En este informe, se describe y resuelve la optimización de un modelo desde dos puntos de vista distintos, optimizar por un lado la función de costes para una comercializadora, y proporcionarle ahorros al cliente final a través de soluciones de autoconsumo financiadas.

El principal objetivo del trabajo es la adaptación y uso de una herramienta de optimización para el desarrollo de la toma de decisiones de una comercializadora, en sus estimaciones sobre el

aprovisionamiento de energía, en el corto y largo plazo. La herramienta se ha desarrollado en GAMS, como modelo de optimización estocástico, y su validación se basará en casos de estudio utilizando datos reales del mercado eléctrico español.

En el sector energético, existen muchas leyes reguladoras que en ciertos casos limitan el crecimiento económico y expansión de las comercializadoras como proveedoras de electricidad, lo que hace más beneficioso el proyecto, tratando de aumentar el beneficio de estas empresas, sacando un mayor provecho a los mercados eléctricos.

El proyecto refleja una simulación basada en datos futuros de la electricidad, según las predicciones de OMIP, comparando los precios de contratos PPA en el largo plazo y los precios del mercado diario de energía, con el fin de minimizar costes y maximizar los beneficios obtenidos para la comercializadora. Como resultado del análisis, se demostrarán los beneficios de contratar PPAs, en comparación con los precios del mercado SPOT, en términos de costes globales.

Adicionalmente, para optimizar no solo los costes de suministro eléctrico de las comercializadoras, sino también de los consumidores finales, el proyecto describe alternativas para financiar instalaciones de autoconsumo. De esta forma, se fomentará el uso de energías renovables, el cliente final podrá obtener ahorro en su factura de la luz, y la comercializadora conseguirá fidelizar un cliente durante todo el plazo de financiación que acuerde, mientras le continúa suministrando electricidad.

Como resultado de la adaptación y optimización del modelo, en función de los precios futuros de la electricidad, las comercializadoras tendrían los siguientes costes, según distintas capacidades de PPAs (GWh) adquiridas del mercado. Como se puede observar en la tabla a continuación, el coste total que asumiría la comercializadora se reduciría a medida que se contrate más PPA.

Para cubrir una demanda total de 21.339,67GWh, la comercializadora tendrá tres opciones a la hora de contratar energía a través de PPA. O bien comprar 500 GWh, o 1.000 GWh, o bien 5.000 GWh, en función de la cantidad contratada, el precio total a pagar será menor, cubriendo el resto de la energía demandada a través del mercado SPOT.

Escenarios	Escenario 1	Escenario 2	Escenario 3
Potencia PPA contratada (GWh)	500	1,000	5,000
Precio total estimado (‘000€)	**2,684,805.40**	**2,430,935.60**	**399,977.30**

Table 1: Resumen de los resultados obtenidos

Abstract

The way of consuming and producing energy is changing due to higher prices, political instabilities, and CO2 emissions. Most of the companies are charged big amounts of money due to CO2 emissions when producing energy with fuel, coal, or gas. As the European Union encourages companies to produce a minimum amount of CO2 emissions. Any excess that is above of the limit imposed by the EU will be charged, in order to promote the renewable energy generation.

Multiple efforts have been made to develop supported algorithms focused on generators, traders and distributors in order to optimize their way of operating and reduce their costs. A smaller number of studies aimed to evaluate the perspective of consumers, retail suppliers or retailers.

The problem is with electricity procurement by retailer or consumer, given the long-tail and unpredictability of electricity prices. In addition, most of methodologies are focused on shorter-term horizons, not considering the possibility of agents for longer term. This concept of the longer period is of total relevance as self-consumption installations are usually taking high performance for around 20 years. Making predictions 20 years from now, would not make sense as models would lose accuracy, but focusing on 3-5 years of contract periods can make models find the balance between accuracy and longer prediction [1].

Every model should be as detailed as possible, avoiding simplifications, in energy demand, pricing and renewable generation. The main problem when predicting renewable energy generation comes from the levels of self-consumption, which are not that easy to be predicted

When estimating pricing for consumers two ways of modelling can be considered. From one hand, , by fixing a price per MWh, (PPA contracts) or considering the volatility of the energy prices due to the market. To obtain a prediction of the volatility of the prices it is needed to take as reference the historical data and daily changes [2] [3].

The problem is described and solved according to two different points of view, to optimize the costs function from an retailer perspective and to achieve savings for the end customer of the retailer.

Whereas retailer, the project refers to a new type of energy service provider which can increase or moderate the electricity consumption of a group of consumers according to total electricity demand on the grid. A retailer can also operate on behalf of a group of consumers producing their own electricity by selling the excess electricity they produce.

Promoting competition across the energy market finds that, consumers should be free to engage with the independent retailer and supplier of their choice, without facing contractual obstacles from either type of company.

The main objective of this work is the adaptation and use of an optimization tool to optimise investment, procurement, and operation decisions of an retailer in electricity markets, capable of coupling the short and long-term horizons. The tool was developed in GAMS, as a stochastic optimization model and its validation will be based on case studies using real data from the Spanish electricity market.

In the energy sector there are many regulatory laws that in certain cases limit economic growth and its expansion, what makes the project and the study more beneficial trying to increase the profit to the maximum getting more out of the electricity markets.

The project reflects a simulation based on future data, predicted by the OMIP, of the electricity prices from the spot market compared to the PPAs prices in order to minimise the costs and maximise the benefits obtained to the retailer. As a result, the output from the analysis elaborated will demonstrate the benefits of contracting as much PPAs as possible, compared to electricity from the spot market in terms of overall costs for the retailer.

By the time, to optimise not only the costs of supplying electricity for the retailers, but the costs assumed by the end customers, the project also will be focused on self-consumption installations for customers, that could be provided by retailers. As the market is growing notoriously in Spain, and several ways of financing are emerging, the optimization of the project can be adjusted by different ways of financing the report includes different financing ways that can be provided by any retailer to its end-customers. The ways for financing self-consumption installations described, allow the retailer to keep the clients for longer term, by the time they continue supplying electricity.

The project is committed not only with costs optimisation for electricity consumption, but also for self-consumption, in order to promote renewable energy. Different financing alternatives are explained through the document, to accelerate its expansion and growth.

There will be also a focused-on uncertainties and volatility of the electricity markets, related to climatological changes and prices, so that they become near-constant variables for the model.

As a result of the adaptation and optimisation of the model, based on future electricity prices, the retailers would have the following costs, based on certain capacity bought from the spot market and the remaining amount from PPAs. According to three different scenarios, with different PPAs values, the overall expected cost will reduce as more PPA energy is contracted.

To cover a total demand of 21,339.67 GWh, the retailer will have three options when contracting energy through PPAs. Either buy 500 GWh, or 1,000 GWh, or 5,000 GWh, depending on the amount contracted, the total price to be paid will be lower, covering the rest of the energy demanded through the SPOT market.

Cases	Case 1	Case 2	Case 3
Max 1-year contracted (MWh)	500	1,000	5,000
Expected total cost (‘000€)	**2,684,805.40**	**2,430,935.60**	**399,977.30**

Table 2: Output summary for the overall costs of electricity supplied.

The table demonstrates how the PPAs help optimising the costs compared to the spot electricity market prices.

1. Introduction

Solar energy consumption is experiencing high demand and is leading an energy transition among households and small business, reducing reliance on carbon-based fuel energy suppliers [4].

Solar energy outperforms other renewable energy sources as Solar Photovoltaic (PV) is an energy source that does not have fuel cost associated to its generation. Wind, for instance, doesn't have either. In addition, PV is the easiest renewable energy technology to implement for self-consumption [3].

In the EU, solar PV energy generation increased from 25TWh in installed capacity in 2010, to 160TWh in 2021 [5]. Solar PV and onshore wind represented the biggest investment focus among all renewable generation sources globally. In addition, Western Europe remains one of the largest areas of investment for renewable energy. Self-consumption is in high demand because it allows lower energy prices, reducing monthly electricity instalments [5].

Electricity markets are recognised as high volatility markets, with strong increases in prices and in energy demand. Some changes in electricity prices come from gas and coal participation in the electricity mix-generation. The mix-generation is also strongly connected to climate changes as they include renewable energy, what involves more uncertainty on prices and generates more volatility when predicting the energy that is going to be produced.

In order to reduce volatility of prices, there are PPA (Power Purchase Agreements) contracts which fix the price per MWh.

Power Purchase agreement is generally the primary contract between a public sector purchaser "offtaker" and a privately-owned power producer.

Therefore, the structure and risk allocation regime under the PPA is central to the private sector to raise finance for the project, recover its capital costs and earn a return on equity.

Related to the sale of capacity and energy, the PPA may require the project company both to make available to the purchaser an agreed level of capacity at the power plant and deliver the energy generated in accordance with its provisions [5] [6] [7].

In addition, pricing regime in the PPA could have two components:

- A capacity charge: which is payable by the offtaker in consideration of the power plant operator making generation capacity, which sold to the offtaker whether its offtakes electricity from the power plant. This component is typically designed to provide a revenue for the project and is the primary channel through which each project proponent would recover its fixed costs (including its capital investments, financing costs and a return on equity).
- Output charge**:** this is usually referenced to the volume of electricity delivered and is intended to cover the project company's variable costs.

  Private project proponents and lenders will require the PPA to run for a long term to guarantee investment recovery. PPA contracts will commonly last between 10-25 years, where the promoter of the agreement will oversee operational costs and maintenance for power plants [8].

1.1. Objectives

The primary aims of this project encompass several key objectives. Firstly, analysing the market trends in terms of energy sources across multiple jurisdictions, to evaluate how the renewable energy is expanding and how relatively new sources as self-consumption is arising.

Secondly, to describe how the PVPC regulation impacts on a positive way the end consumers, to offer them a regulated and transparent pricing structure, with options that reflect the current market prices for electricity.

Thirdly, to analyse the economic impact in terms of costs of the electricity that a retailer company provides to its end customers. The economic impact is assessed by measuring the amount of energy that is contracted through PPA contracts and the amount of energy that is contracted through the spot market, to supply the entire demand annually.

Finally, the description of a tool to provide financing for solar self-consumption products in the long term for the end customers. At the end, when consumers contract a long-term financing product, up to 220 years, they will end up paying a lower monthly instalment, achieving savings on their electricity since day one, and the retailers will have higher probabilities of maintain their customers for longer periods.

1.2. Motivation

The project is developed to estimate the costs for an retailer within the top 5 companies in Spain in terms of market share, to optimise its function of costs when supplying electricity to its customers, according to market prices, both from the spot electricity market and long-term PPAs contracts.

Whereas retailer, the project refers to a new type of energy service provider which can increase or moderate the electricity consumption of a group of consumers according to total electricity demand on the grid.

As mentioned, the project will optimise investment and procurement from different retailers' points of view. Additionally, the project will provide different financial tools for retailers to provide solar self-consumption solutions for the long term. Providing these solutions, by the time they supply electricity, will allow each retailer to engage its customers for longer terms.

Promoting competition across the energy market finds that, consumers should be free to engage with the independent retailer and supplier of their choice, without facing contractual obstacles from either type of company.

In the energy sector there are many regulations that in certain cases limit economic growth and its expansion, this what makes the project and the study more beneficial trying to increase the profit to the maximum getting more out of the electricity markets.

In addition, the project as part of consumer retailers will be focused on self-consumption installations for customers, as the market is growing notoriously in Spain, and several ways of financing are emerging, where the optimization of the project can be adjusted.

This project is also committed to the economic optimization of a clean and green energy, describing optimization financing solutions for self-consumption installations. that will accelerate the growth of renewable energies.

The project also looks for dealing the uncertainties and volatility of the electricity markets, related to climatological changes and prices, so that they become near-constant variables for the model.

1.3. Definitions

1.3.1. PPA

Power Purchase agreement is generally the primary contract between a public sector purchaser "offtaker" and a privately-owned power producer, including a capacity charge and output charge components, as stated in the introduction section.

More than 35 countries across the world have PPAs contracts, being Europe and North America the ones with the biggest contracts between a company and an independent power producer [7]. In Europe, the Nordic Countries most companies use PPA contracts to reduce their costs of IT companies as they have large data centres with high energy consumption costs. Countries such as Argentina, Brazil and Chile have signed PPA contracts to buffer the volatility of prices in the retail sector. Australia and India are promoting PPA contracts due to several reasons as electricity prices are scaling, giving back the energy to the grid is setting several constraints as well as reliability concerns have promoted SMEs and Corporates towards PPAs.

1.3.2. EACs

Energy attribute certificates (EAC), these certificates guarantee the origin of the energy, where companies buy certificates to demonstrate they consume/produce renewable energy. Some certificates are guarantees of origin (GOs) and renewable energy certificates (RECs).

A market of EAC is created where companies can track their renewable energy production and allow consumers making credible claims of the energy they consume. Each certificate guarantees the use of a specific quantity of renewable energy. Most of customers can choose the origin of the energy they will consume, so to have the certainty of the precedence of the energy, companies need to have these EAC certificates.

EAC can be acquired separately from any physical purchase of energy or can be acquired together when the energy is bought. Prices for EAC and variants vary depending on supply and demand, as well as depending on the country and location. For example, in the United States prices were around USD 0.5 per MWh in the voluntary market. However, in India, Solar EAC increased considerably as companies were demanding these certificates, so prices reached maximum of USD 23 per MWh. For long - term purchases in Japan EAC had prices between USD 27 and USD 46 MWh [7].

Some countries have their own specific systems for EAC, differing the systems from the EU.

In Australia, green certificates are known as large-scale generation certificates (LGCs). The Australian government supports the renewable energy transfer in large scale, as well as the small-scale technology. These certificates guarantee compliance with Australia´s renewable energy target. More than 500 generators are involved within these certificates to promote renewable energy consumption [7].

Japan maintains two different certificate systems for SMEs and Corporates, where there are called Green Energy Certificates and GHC emissions reduction, and both availabilities are limited and can be purchased directly from generators or brokers.

In Mexico, Green Certificates are built for the compliance of corporate and industrials clients with national requirements.

1.3.3. Emission allowances

Emission allowance refers to the tradeable instrument that allows any company, SMEs or Corporate to emit a certain unit of pollution when producing energy. The European Union stablishes a minimum amount of pollution allowed for retailers to emit free of charge. When retailers or companies exceed the limit set by the EU they are mandated to purchase allowances from the government or other participants. By this scheme, a market of emission allowances is created between all retailer's companies.

Those who emit less CO2 pollution than the limits stablished by the EU, can sell to other retailers the difference between what they have emitted and what they were allowed to. In the same manner, retailers who emit more than expected, need to pay for the difference, buying emission allowances to those companies who sell them to the market. As it is a liberalised market, prices of emission allowances vary according to supply and demand.

By limiting the total amount of emissions, the EU tries to promote the use of renewable energies. Over the past years, renewable energies had higher prices than in 2021-2022 [9], so emission allowances had lower prices. As the price of renewable energies decreases, the price of emission allowances increases, as there are more possibilities to avoid exceeding the CO2 emissions.

1.4. SDG commitment

Sustainable Development Goals (SDG) are an initiative promoted by the United Nations to give continuity to the development agenda after the Millennium Development Goals.

The SDG are the blueprint for a sustainable future for all. They interrelate with each other and incorporate the global challenges we face every day, such as poverty, inequality, climate, environmental degradation, prosperity, peace and justice. In order to leave no one behind, it is important to manage to meet each of these goals by 2030.

The project is mainly related with the following SDG, as promotes renewable energy, considering a clean ang green energy. In addition, as it will optimise several models, more people will have the opportunity to have access to these renewable energies, contributing to climate change, inclusion, and sustainable consumption and energy production.

- 7, "Ensuring access to affordable, reliable, sustainable and modern energy for all". The 7th ODS principle, aims to ensure universal access to affordable, reliable and modern energy services for the population. To promote sustainability by increasing the share of the renewables in the global energy mix, and to enhance international cooperation to facilitate access to clean energy, promoting investment in renewable energy and its infrastructure.
- 8, "Promoting sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all". Where the 8th SDG principle aims to eradicate forced labour, human trafficking, and all forms of moder slavery, including facilities to enhance labour productivity through education, training and access to technology, fostering innovation and economic growth.
- 9, "Developing resilient infrastructures, promoting inclusive and sustainable industrialization, and foster innovation". The 9th SDG aims to encourage the growth of renewable industries, resource-efficient creating decent job opportunities. In addition, upgrading infrastructure, such as transportation energy, water and sanitation systems together with information and communication technologies (ITC) to provide sustainable services for the population.
- 12," Ensuring sustainable consumption and production patterns". The 12th SDG recognises the importance of shifting the production and consumption towards sustainable patterns

to address environmental challenges, starting from education and increasing public awareness.

- 13, “Taking actions to combat climate change and its effects”. Where the main objectives of the 13^{th} SDG principles, are to reduce the carbon emissions to limit global warming, improving the ability of countries and cities to adapt to the adverse impacts of climate change.

According to the five SDG principles described, the project aims to give an overview of the how the renewables energies have been growing across different countries, to make any reader aware of the current situation to make population be updated on how the energy industries evolves. In addition, to provide affordable electricity and limit the prices, the PVPC and the latest regulatory changes are explained in detail. Finally, the model developed aims to explain how to optimise the costs of the electricity from a retailer point of view, together with solar self-consumption solutions to promote clean energy with different financing alternatives so that more consumers can afford it and can consume renewable energy [21].

2. Energy market and Industry overview

Renewable energies are becoming an attractive energy source to population and investors, as there have been an increasing trend on demand from consumers and investing from companies around the world who are actively investing in self-consumption of renewable energies. These positive trends would accelerate the energy transformation and will help achieving the Paris Agreement´s objective, of keeping the global average temperature under the exceed of 2ºC.

Since 2018 all companies across Europe and North America started signing PPAs contracts as a way of acquiring energy from renewable sources, as well as green procurement programmes and EACs. In general terms, 35 countries across the world sign PPAs contracts and more than 75 countries sign utility green procurement programmes and declare to have EACs [7]

The investments in renewable energy have reached up to USD 280 billion over the last years, being 90% of the total investments done by the private sector. Companies are pushed to invest in renewables as they look for economic, social and environmental benefits, what translates into cost savings, long-term price stability and security of supply [6].

There are different factors involved when evaluating if a company is into the renewable energy sector and can be considered as sustainable, as i) the level of maturity of climate and energy management, ii) the cost-competitiveness of renewables, and iii) the availability of options that enables companies to source renewable electricity.

In Europe, more than 50% of the companies actively procuring renewable energy, in Asia more than 47%, 45% of companies in north America and almost 30% in Oceania. Ordered in a descending way, from the largest consumers and producers’ companies of renewable energy, to the one that less, within the most relevant countries, are: United states, Japan, United Kingdom, Sweden, Germany, France, Switzerland, South Africa, India and Spain. Most of the companies reporting renewable energies and signing PPA contracts become from developed countries, where among emerging economies, South Africa and India are the countries with the largest number of companies being active in the renewable sector [7] [10].

2.1. Electricity market overview

The European Union is currently facing a high increase in electricity prices. The European commission is developing measures to support and mitigate the impact and help Europe’s development, willing to strength resilience against future shocks. Geopolitical tensions caused by the invasion of Russia on Ukraine in February 2022 reinforced the uncertainty of the European gas supply what increased volatility on energy prices on the electricity market.

The gas imports from Russia continued falling. Russia had a pipeline of supply only of 28% of the total EU gas imports in Q1-22, and 34% of them came in form of Liquefied Natural Gas (LNG). The total gas imports made from the EU increased only 10%, whereas LNG imports were 72%. Regarding costs estimated, the EU spent €78 billion on gas imports the first quarter of 2022, where €27 billion were related to Russian imports. By the end of the first quarter in 2022, the European average gas storage filling rate was 26%, 4 bps lower than the gas storage levels in 2021. This led to an increase of prices, where the European capital cities had an increase of 84% in the energy prices by May 2022 [10].

In 2022 in Europe, gas prices have increased more than four times compared to 2021, what has result in an increase of wholesale prices of more than three times in several markets. The highest increases on wholesale prices have been registered in Spain and Portugal, with an increase of more than 411%, and Greece with an increase of 343%, and France with an increase of 336% [10].

Despite the fact carbon allowances registered a new peak in February, reaching up to €96/tCO2, it felt in March to €80-€85/tCO2 due to the increase in renewable energies, where the renewables manage to reach 39% in the first quarter of 2022, fossil fuels were 37% [10].

Renewable energies are growing faster than fossil fuels and energy demand. The capacity for the renewable energies has increased allowing a 10% growth in 2022 compared to 2021. While nuclear energies decreased 3%, coal generation raised up to 7%. In global terms, China and US are balanced by growth in Europe, as gas power has experienced a decrease of 2.6% in Europe, North America, and Middle East offsets the decline in Europe [11].

2.2. Electricity demand:

The pandemic caused an impact on energy consumption in the European Union. In 2020, the primary energy consumption, considering all energy users, and final energy consumption considering all end users, experienced a historical drop. The European final energy consumption (FEC) felt by 8% between 2019 and 2020. This drop may be caused by the Covid-19 pandemic measures adopted, as it is the largest energy drop in the energy consumption recent history. The transport sector was the most affected due to mobility restrictions, industrial activity was the second most affected in 2020, where the FEC declined by 3.5%. On the other hand, energy consumption in households remained stable, however energy consumption in commercial and public buildings dropped by 5.6% [12] [13].

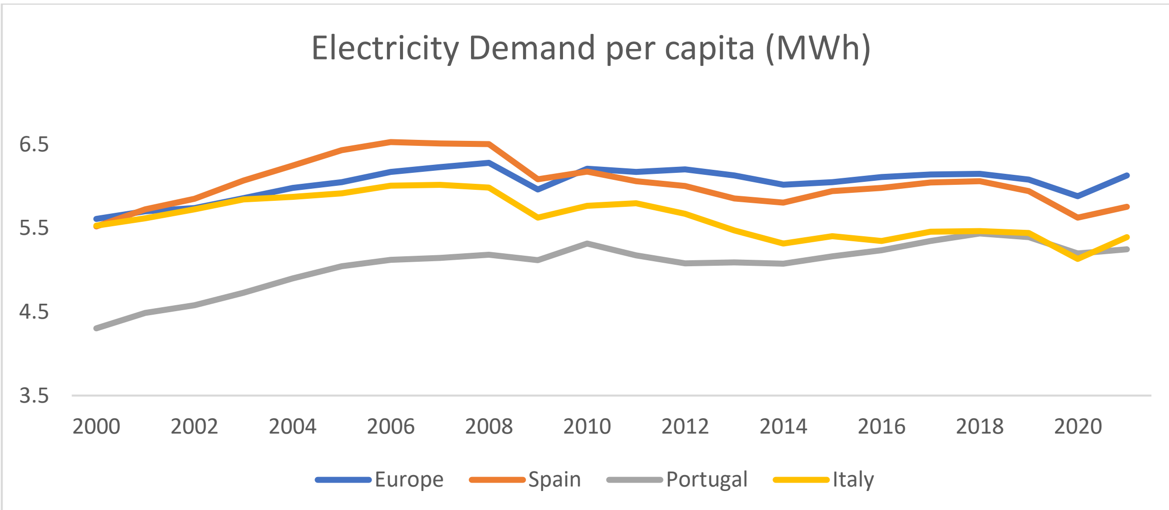

Figure 1: Electricity demand per capita (MWh) [12]

Primary energy consumption (PEC) had an even stronger decrease. Between 2019 and 2020, PEC decreased by 8.6%, five times more than the previous year as shown in Figure 1. The decreased left the lowest level of PEC since 1990. The largest drop was of 18% for solid fossil fuels. In 2020, the sectors that experienced the largest decreased were liquid, nuclear and gas. The replacement of fossil fuels by renewables energies in electricity generation also caused a reduction in PEC.

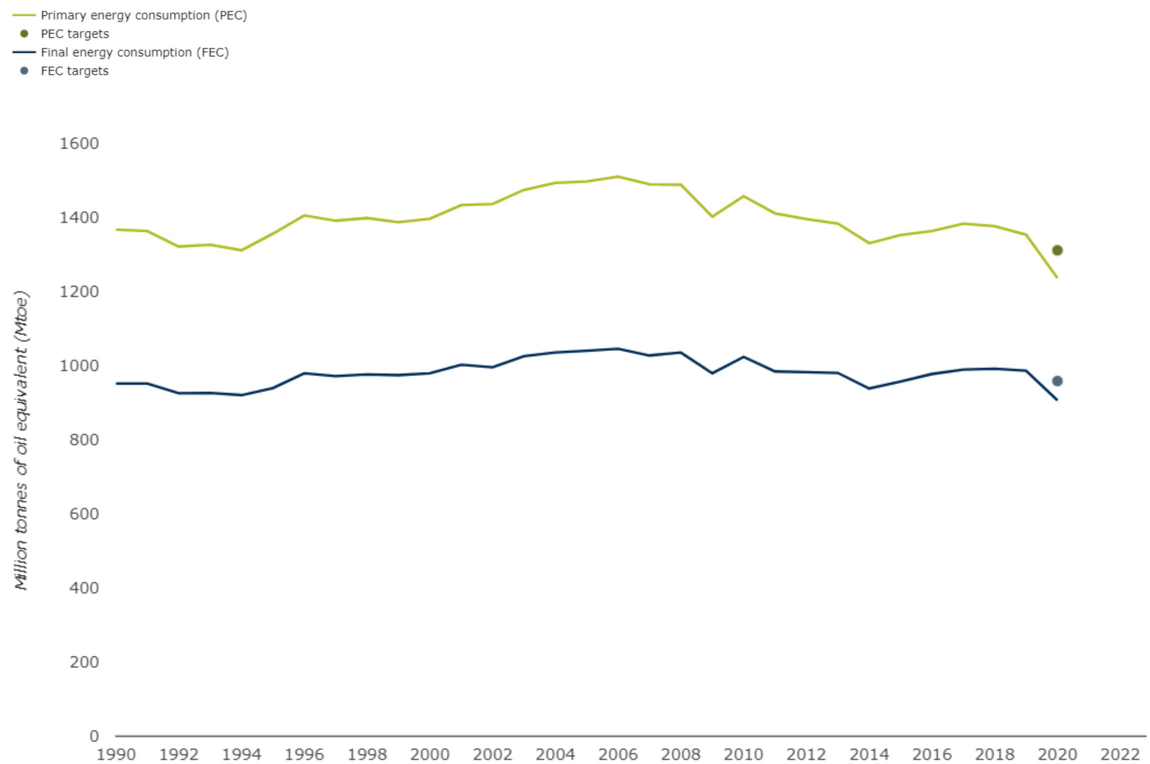

Figure 2. Primary and final energy consumption [12]

According to the data described, the European Union met its energy efficiency target reduction of a 20% compared to 2007 projections for 2020. PEC in 2020 was estimated to be 5.7% and FEC 5.4% [12].

After the drop in 2020 caused by the pandemic, a growth of 6% was experienced in 2021. For 2022, the global electricity demand is expected to grow by 2.4%, following the same trend of growth from 2015 to 2019. Before of the Russian invasion of Ukraine, the electricity demand was expected to reach up to 3% of growth, but the high energy prices and uncertainties have negatively impacted the demand outlook. In addition, several sanitary measures applied in China have varied the industrial production and have increased tensions between different supply chains. The industry consumes about 40% of world total energy demand, and 20% is demanded by commercial services. However, India has been an exception as the electricity demand has beat records in 2022 due to unusually hot temperatures [12] [13].

As a regional development, the global worldwide demand has had a considerable increase since 2019. The graphic shown below also represents the forecast and expectations done before the Russian invasion to Ukraine, and the updated forecast done in June 2022, once the impact and results have started to be seen. As mentioned, the updated forecast remains below the previous trend as the energy demand will not increase as much as expected.

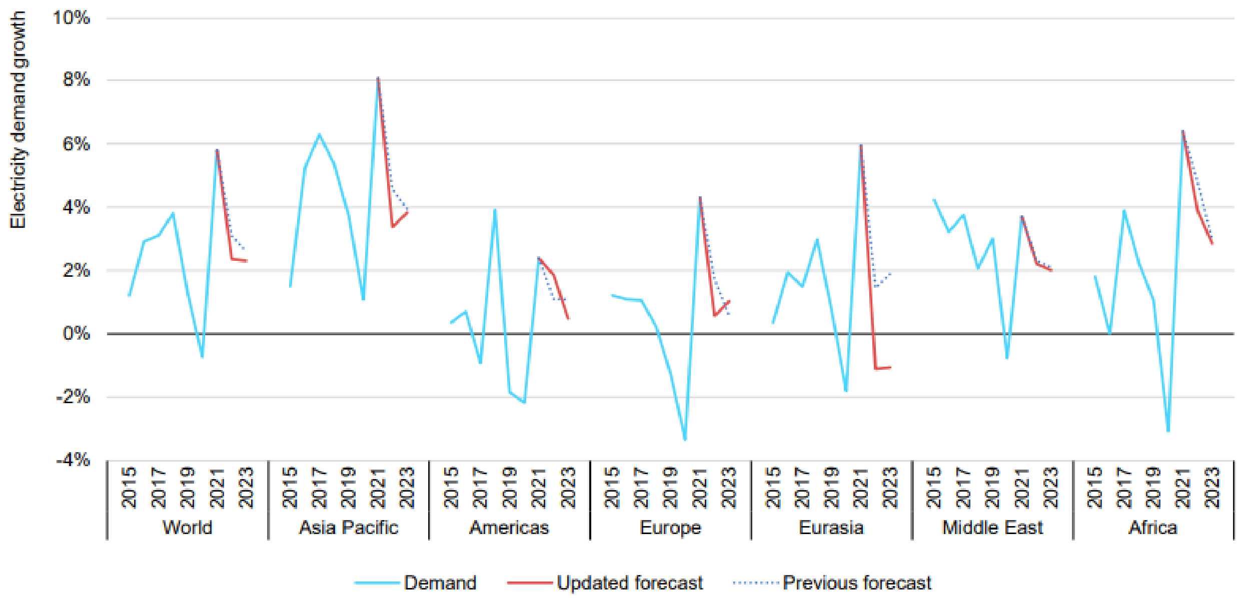

Figure 3: Electricity demand growth [12]

On the other hand, electricity demand in Europe will be more affected than America, as energy prices have been particularly high. The demand has also been decreased due to milder temperatures in the first quarter of 2022 compared to 2021. In some countries such as France or Scandinavian countries, the demand decreased by more than 5% year on year, in Ukraine, monthly electricity demand has decreased more than 30% due to the war against Russia [14].

2.3. Electricity supply:

Renewable energies are expected to grow faster than demand and avoid fossil fuel-based generation. At the end of 2022 and beginning of 2023, renewable energies have faced the fastest-growing source electricity supply. As nuclear generation supply has been decreased by 3%, due to lower capacity availability and European restrictions, low-carbon generation emission grows up to 7%, exceeding the demand.

By the end of 2023, renewable energy supply have grown by 8% exceeding the electricity demand.

The evolution of global electricity supply from 2018 to 2023 is shown below in the Figure 4:

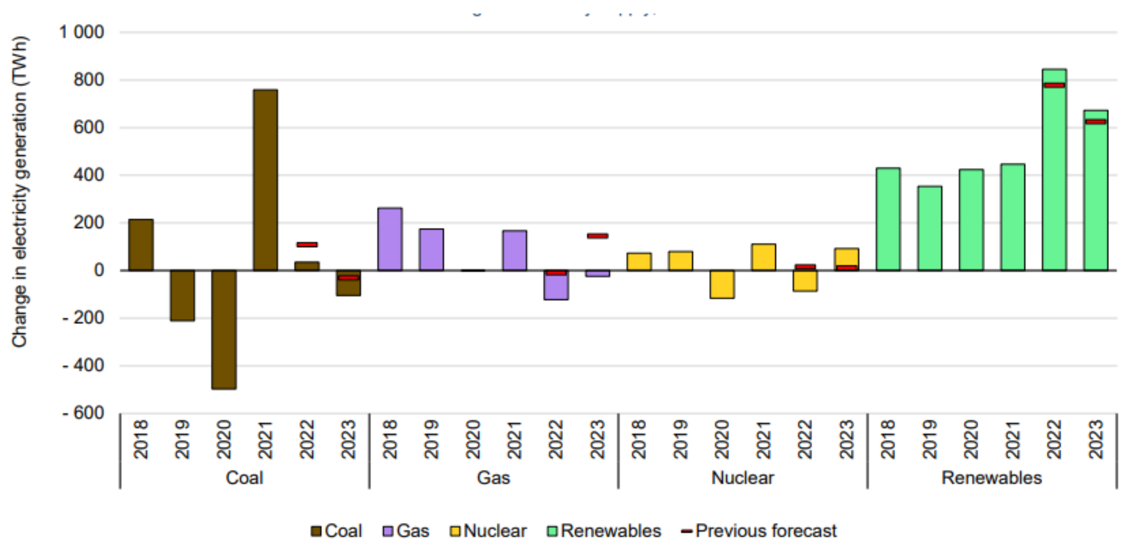

Figure 4: Electricity generation (TWh) [14]

Regarding regional developments, in the Asia Pacific region, renewable energies are expected to grow more than 13% in 2023, exceeding the demand, due to countries as India, China and Japan, nuclear generation is expected to continue growing [14].

On the other hand, in the American region, renewable energies will continue growing, mainly in the United States, exceeding an increase of 11% in 2022 and 6% in 2023.[14].

In Europe, prices are directly affected by the increase in fossil fuel prices and supply shortages. Nuclear generation has declined significatively, up to 12% by the end of 2022. During 2023, renewable energies have reached a growth of 7%, exceeding demand, with stable generation of nuclear generation. These factors have been affected by the price for gas and measures taken to reduce the dependency from Russia [14] [15].

2.4. Electricity Prices:

Electricity prices have been increasing all-over Europe [15] since 2021 due to lower gas storage levels and the increase of CO2 prices. The primary factors for the variation of the increase of the electricity prices are:

1. Fuel Costs: The prices of fossil fuels, such as natural gas and coal, can significantly impact electricity prices. Fluctuations in global fuel markets and changes in supply and demand for these resources can influence electricity generation costs.
2. Renewable Energy Integration: While renewable energy sources like wind and solar are beneficial for sustainability, their intermittent nature can impact electricity prices. When renewable generation decreases due to weather conditions, conventional power plants may need to be utilized, which can be costlier.
3. Carbon Pricing and Emissions Regulations**:** Spain, like many other countries, has implemented policies to reduce greenhouse gas emissions. Carbon pricing mechanisms and emissions regulations can add costs to fossil fuel-based electricity generation, ultimately influencing prices.
4. Infrastructure and Network Costs: Maintaining and expanding the electricity transmission and distribution network incurs costs that can be passed on to consumers. Investments in grid infrastructure, including smart grid technologies, can lead to increased electricity prices.
5. Market Dynamics and Competition: The structure and competitiveness of the electricity market can affect prices. If there is limited competition among suppliers, it may result in higher prices. Market reforms and promoting competition can help mitigate this issue.
6. Taxes, Levies, and Subsidies: Government taxes, levies, and subsidies aimed at supporting renewable energy development or promoting energy efficiency can impact electricity prices. These additional costs are often passed on to consumers.
7. Exchange Rates and Energy Imports: Spain relies on energy imports to meet its demand, and fluctuations in exchange rates can influence the prices of imported energy. Exchange rate fluctuations can directly impact the cost of electricity generation and subsequently affect consumer prices.

Electricity prices for household consumers have increased on average for the Euro area 23% from 2017 to the end of 2021. Household consumers are defined as the ones consuming annually between 2,500 KWh and 5,000 kWh [15]. The highest electricity prices have been in the second half of 2021 in Denmark with 0.34 Euro/kWh, and Germany with 0.32 Euro/kWh. The lowest electricity prices have been in Hungary and Bulgaria with 0.10 Euro/KWh [15].

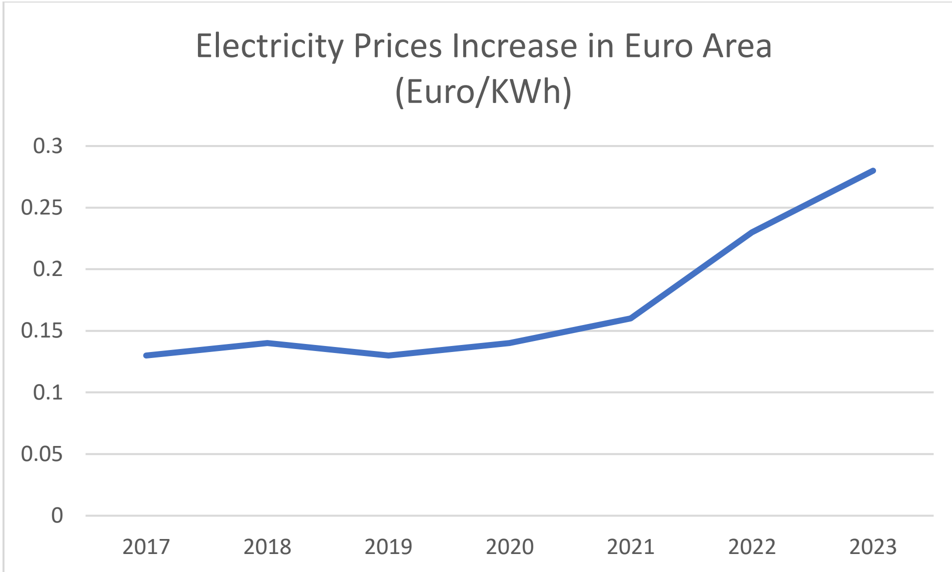

Figure 5: Electricity prices in Europe [15]

Electricity prices for household consumers have maintained an increasing trend since 2008 in the Euro area. The price without taxes, where the energy, supply and network increased faster than the inflation rate (HICP) until 2013, when the price was €0.134 per KWh. From 2014 to 2019 seemed to be stable, but the prices started to increase again by the beginning of 2020, experiencing the highest increase in the second half of 2021. Additionally, the weight of the taxes has increased by 4.8 percentage points over the last 13 years, from 31% in 2008 until 36% in 2021.

For prices adjusted according to inflation and including taxes, the total price for household consumers by the end of 2021 was €0.195 per KWh, almost 20% higher than the prices in 2008 of €0.16 per KWh [15]Comparing electricity prices excluding taxes, would have approximately similar levels as the prices in 2008, due to lack of inflation.

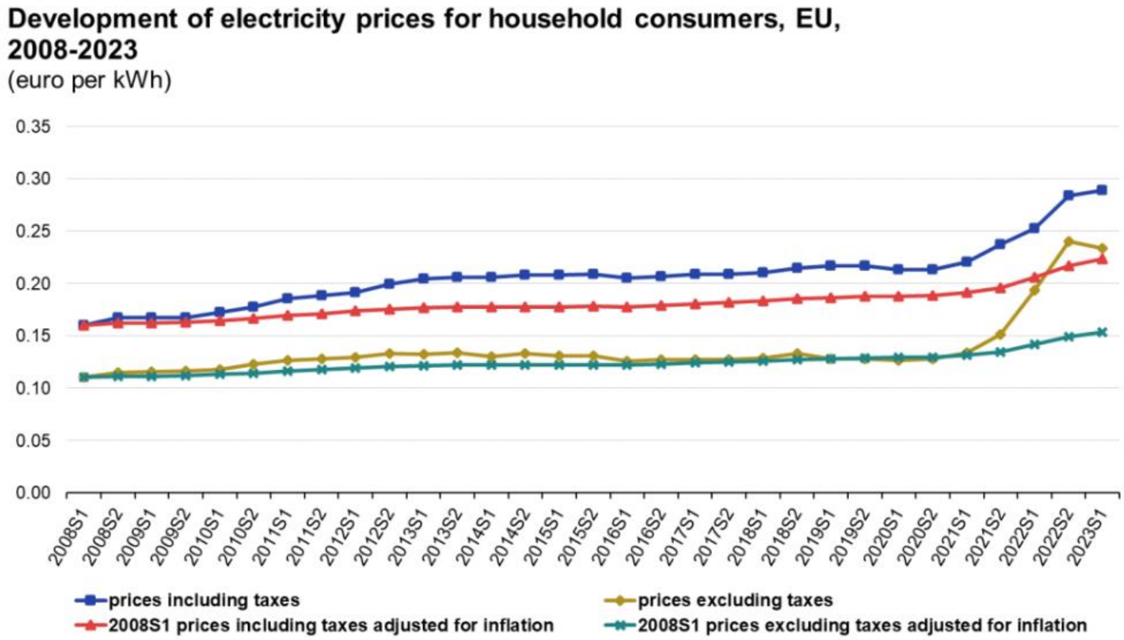

Figure 6: Development of electricity prices for households consumers [7]

The geographic distribution of the prices for household consumers is shown in the graphic below in Purchasing Power standard (PPS) per 100 KWh. The highest prices based on purchasing power standard have been both in Romania (31.0) and in Spain (30.0). The lowest values for the electricity prices have been observed n Netherlands (12.5) and Finland (14.5) [12].

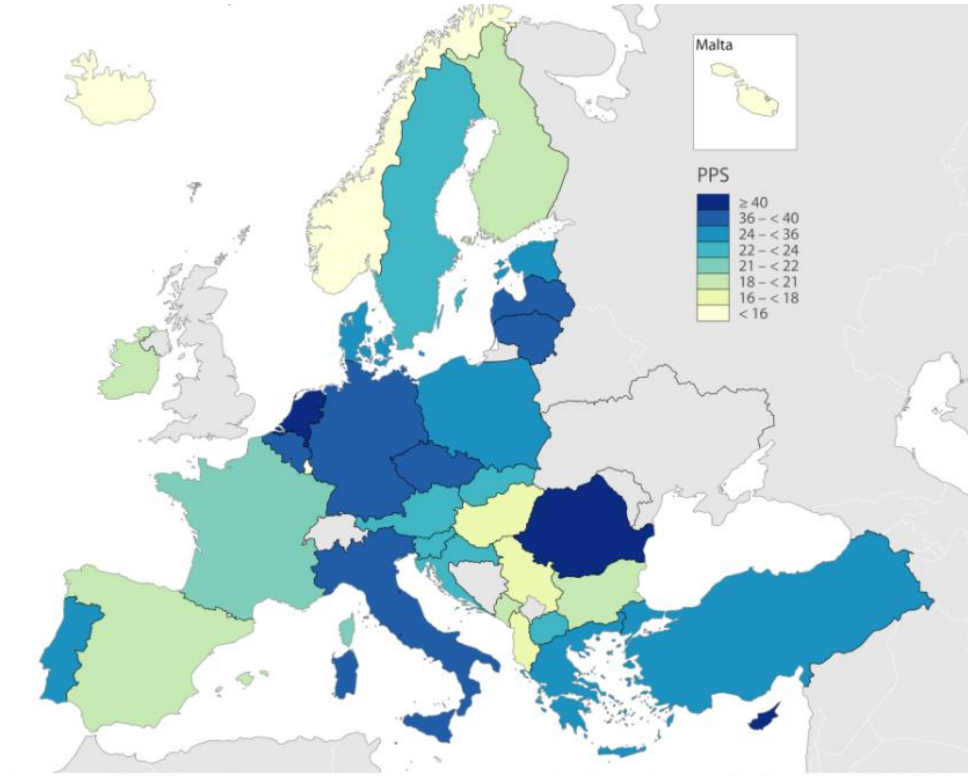

Figure 7: Purchasing Power Standards in Europe [14]

2.5. Carbon emissions:

The strong tendency on carbon generation makes that the emissions keep increasing. However, it was expected at the beginning of the year that the emissions kept stable during 2022 until 2023, a small decrease of 500 bps has been noticed, after experience the maximum historic of 13Gt of CO2 emissions in 2021. This decrease is due to two factors, i) the electricity demand has been lower than expected and ii) the renewables energies have increased their production.

Only in Europe it is expected to see an increase of 300 bps by the end of the year, although the increase on renewables as the use of carbon has increased, to avoid the gas consumption and to compensate the drop in the nuclear generation. The Americas are the largest contributors to avoid and to reduce the emissions, as they are replacing the fossil fuels with renewable energies. [14].

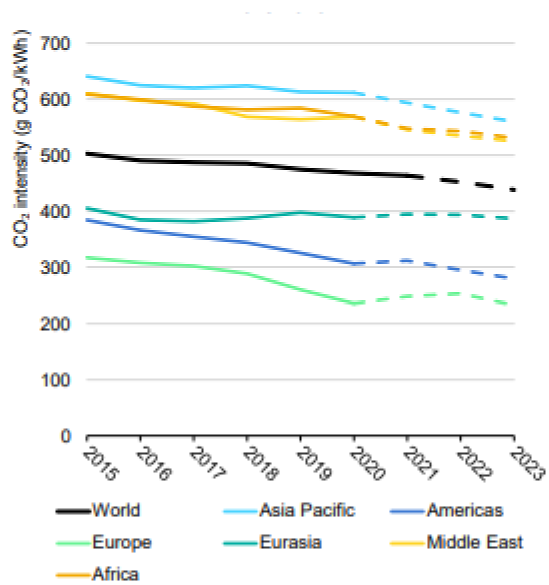

Figure 8: CO2 intensity per continent [14]

2.6. Pathways to the energy independence:

There are several measures classified by 4 different groups, in order to reduce the dependency on fossil fuels, particularly imports from Russia. Firstly, based on using energy supply alternatives; secondly, implementing austerity measures to reduce the energy consumption, as stablishing standards for moderating heating and cooling; thirdly, applying measures to keep the same levels of energy but optimising their use, as for example, improving the insulation of buildings; and lastly, increasing the use of domestic energy sources, as self-consumption generation. The measures described to combine and reduce the climate change, as increasing the energy independence, will reduce the dependence on fossil fuels in the short term, keeping the changes and having a positive impact in the long term.

2.7. Daily market, an intraday auction market and a continuous intraday market

Daily market: The daily market, also known as the Single Day-Ahead Coupling (SDAC), as an integral part of the electricity production market, aims to carry out electricity transactions by submitting offers for the sale and acquisition of electricity by market agents for the next twenty-four hours. This market, coupled with Europe since 2014, is one of the crucial pieces to achieve the objective of the European Internal Energy Market.

Every day of the year around mid day, the electricity prices and energies are determined throughout Europe for the following twenty-four hours. The price and volume of energy at a specific hour are established through the intersection of supply and demand, following the agreed-upon model approved by all European markets.

Buyers and sellers located in Spain or Portugal will submit their offers to the daily market through OMIE, which is the designated Nominated Electricity Market Operators (NEMO) in those countries. Their buy and sell offers are accepted based on their economic merit order and the available interconnection capacity between price areas. If the interconnection capacity between two areas is sufficient to allow the electricity flow resulting from the negotiation in a particular hour of the day, the electricity price for that hour will be the same in both areas. However, if the interconnection is fully utilized during that hour, the price-setting algorithm will result in a different price in each area. This mechanism described for electricity price formation is called market coupling [11].

The results of the daily market, based on free contracting between buyers and sellers, represent the most efficient solution from an economic standpoint. However, given the characteristics of electricity, it is also necessary for it to be physically viable. Therefore, once these results are obtained, they are sent to the System Operator for validation from a technical feasibility perspective. This process is called management of system technical constraints and ensures that the market results are technically feasible in the transmission network. As a result, the results of the daily market may undergo slight variations because of the analysis of technical constraints performed by the System Operator, resulting in a viable daily program.

Price limits for offers and notification and price thresholds:

The maximum and minimum price limits for the daily market in the MIBEL zone (Spain and Portugal) are established as follows:

- Maximum offer price limit: +4,000 EUR/MWh.
- Minimum offer price limit: -500 EUR/MWh.

Price notification thresholds for the daily market are established as follows in the MIBEL zone (Spain and Portugal):

- Maximum price notification threshold for the daily market: +200 EUR/MWh.

- Minimum price notification threshold for the daily market: -20 EUR/MWh.

These thresholds are established to monitor and manage electricity prices in real-time or on a daily basis within the energy market. The thresholds are to achieve limits aiming to achieve certain objectives as follows:

1. Price Volatility Management: Electricity prices can experience significant fluctuations throughout the day due to changes in demand and supply factors. Price notification thresholds are set to alert market participants, such as electricity suppliers, traders, or grid operators, when prices deviate beyond certain predefined levels.
2. Renewable Energy Integration: With the increasing integration of renewable energy sources like wind and solar, electricity generation becomes more dependent on weather conditions. Price notification thresholds can help grid operators and utilities anticipate periods of high or low renewable energy output.
3. Demand Response Initiatives: Price notification thresholds can encourage consumer participation in demand response programs. By alerting consumers about peak pricing periods or high electricity prices, they can adjust their electricity usage during expensive times, which helps stabilize the grid and reduce overall energy costs.
4. Market Efficiency and Transparency: Setting and adhering to price notification thresholds enhance market transparency. When electricity prices approach or exceed these levels, market participants gain insights into market conditions and are better equipped to react accordingly.
5. Preventing Market Manipulation: Price notification thresholds can serve as a mechanism to detect potential market manipulation or abnormal price movements. Authorities and regulatory bodies can monitor market behaviour closely.

The price thresholds defined by market operators for conducting a Second Auction are as follows:

The harmonized price thresholds at the European level that initiate the process of this Second Auction and are applicable in the Spanish and Portuguese zone are as follows [11]:

- Positive threshold: +2,400 EUR/MWh.
- Negative threshold: -150 EUR/MWh.

Intraday market:

Intraday markets are an important tool for market participants to adjust their resulting daily market program according to their real-time needs by submitting offers to sell and acquire energy.

Currently, intraday markets are structured into six auction sessions within the MIBEL area and a continuous cross-border European market. These sessions take place after the system operator has made the necessary adjustments to ensure the viability of the resulting program following the daily market.

Similar to the daily market, once these markets have been conducted, the results are sent to the system operators to enable them to schedule their balancing processes.
Harmonized maximum and minimum offer price limits are established for the intraday auction market and continuous intraday market.

The following initial values are set as the maximum and minimum price limits for the intraday markets in the MIBEL zone (Spain and Portugal) [11]:

- Maximum offer price limit: +9,999 EUR/MWh.
- Minimum offer price limit: -9,999 EUR/MWh.

Price notification thresholds for the intraday auction market are established as follows in the MIBEL zone (Spain and Portugal) [11]:

- Maximum price notification threshold for the intraday auction market: +200 EUR/MWh.
- Minimum price notification threshold for the intraday auction market: -20 EUR/MWh.

Price notification thresholds for the continuous intraday market are established as follows in the MIBEL zone (Spain and Portugal) [11]:

- Maximum price notification threshold for the continuous intraday market: +1,500 EUR/MWh.
- Minimum price notification threshold for the continuous intraday market: -150 EUR/MWh.

3. Improvement of the configuration of the European electricity market for small consumers

The prices of energy increased significantly throughout 2021 and 2022. This was due to reductions in gas supply, especially following the start of Russia's war against Ukraine and the use of energy as a weapon, as well as internal scarcity of hydroelectric and nuclear energy. The price increases were also attributed to the rising energy demand as the global economy rebounded from the COVID-19 pandemic [17]. These price increases quickly impacted households, industries, and businesses across the EU, prompting immediate measures from governments to mitigate them.

At the European level, the EU swiftly provided a set of energy price instruments, with measures aimed particularly at vulnerable consumers (such as income support, tax deductions, and gas-saving and storage measures). The REPower EU plan was introduced, to promote the generation and consumption of sustainability energies, to diversify the sources of energy and reduce the carbon and fossil dependencies [17].

A temporary state aid regime was established with measures to cushion the impact of high prices, along with a robust gas storage regime, effective gas and electricity demand reduction measures, faster authorization processes for renewable energy and grid infrastructure, and price limitation schemes to prevent excessive profits in gas and electricity markets.

These short-term measures helped member states address the immediate consequences of the energy crisis. However, the crisis also revealed the vulnerability of consumers and industries and our lack of resilience against energy price increases. Businesses and citizens considered the impact of fossil fuel energy production on electricity prices excessive. Furthermore, the capacity of member states to cushion short-term prices with long-term contracts appeared inadequate. Therefore, the President of the European Commission announced the need for a fundamental reform of the electricity market framework in the 2022 State of the Union address. In early 2023, a proposal to amend the wholesale energy market was published by the European Commission [17].

While the EU's internal energy market generates significant benefits and growth across Europe, the recent energy crisis highlighted how the short-term focus of the energy market framework can divert attention from broader and longer-term goals. The reflection of short-term prices in consumers' bills led to price disruptions, with energy bills for many consumers tripling or quadrupling, even as the costs of wind and solar energy decreased. The sudden exposure to volatile and high prices caused some energy providers to go bankrupt, and many energy-intensive industries were forced to shut down.

Therefore, the proposed measures aim to create a buffer between short-term markets and electricity bills paid by consumers, particularly by incentivizing long-term contracting. The functioning of short-term markets will be improved to better integrate renewable energies, while flexibility will be strengthened. The proposal also aims to empower and protect consumers. The recent price volatility has also highlighted the lack of flexibility in the electricity grid, with prices often influenced by gas-generated power and a general shortage of low-carbon flexible supplies, demand response, and energy storage. As more wind and solar energy are integrated into the system, low-carbon flexible technologies will be needed to balance variable supply with variable demand [17].

In addition to the present proposal, the Commission is formulating recommendations to progress innovation, technologies, and storage capabilities. In broader terms, the sensitivity of electricity prices to fossil fuel prices underscores the need to accelerate the deployment of renewable energies, along with system flexibility, to replace fossil fuels. REPower EU also provides this boost to renewable energies, economic growth, and the creation of quality jobs. It is based on the momentum of the European Green Deal to enhance European competitiveness through innovation and the transition to a zero-net-emissions economy, aligning closely with the Commission's Industrial Green Deal Plan.

A fundamental reform is needed to facilitate necessary investments amidst recent price volatility, uncoordinated regulatory interventions, and access barriers caused by grid infrastructure and regulations. The proposal addresses the concerns of consumers, industry, and investors regarding exposure to short-term volatile prices caused by high fossil fuel prices. The proposal will optimize the configuration of the electricity market by complementing short-term markets with a more prominent role for longer-term instruments, allowing consumers to benefit from fixed-price contracts and facilitating investments in clean technologies. Ultimately, this will reduce the need to generate energy from fossil fuels and lead to a decrease in consumer prices during future fossil fuel crises, thanks to the low operating costs of renewable and low-carbon energy.

The proposal suggests measures to protect consumers from this volatility, empowering them with greater choices of contracts and direct access to renewable and low-carbon energy. To improve investment conditions for companies, especially those seeking decarbonization pathways, measures are proposed to counter short-term price spikes through power purchase agreements and more prudent obligations for energy suppliers. The proposal also aims to improve the integration of variable renewable energy and low-carbon energy into the short-term market. This includes measures to promote demand response and storage, among other non-fossil flexibility options.

The proposal further enhances and clarifies promoter access to longer-term contracts, supported by both the government (such as contracts for differences) and private sector (such as power purchase agreements). This aims to provide secure and stable income to renewable and low-carbon energy promoters, reduce risk and capital costs, while avoiding excessive profits during periods of high prices.

While the current market configuration has provided an efficient and increasingly integrated market for decades, the energy crisis has revealed several deficiencies related to: i) insufficient instruments to protect consumers, including businesses, from high short-term prices; ii) excessive influence of fossil fuel prices on electricity prices and the inability to better reflect low-cost renewable and low-carbon energy in electricity bills; iii) the impact of extreme price volatility and regulatory interventions on investment; iv) the lack of non-fossil flexibility (such as storage or demand response) to reduce dependence on gas-fired generation; v) limited diversity of supplier contract types; vi) difficulties in accessing renewable energy directly through energy sharing; and vii) the need for robust energy market monitoring to better guard against market abuse [17].

To protect small consumers from price volatility, the proposal will establish the right to both fixed and dynamic price contracts, multiple contracts, and improved and clearer information about contracts. Consumers will be offered a variety of contracts that better suit their circumstances. In this way, consumers, including small businesses, can secure safe and long-term prices to mitigate the impact of sudden price disruptions, and/or choose dynamic pricing contracts with suppliers if they want to take advantage of price variability to use electricity when it is cheaper (e.g., for charging electric vehicles or using heat pumps). This combination of dynamic and fixed prices maintains market incentives for consumers to adjust their electricity demand while also providing security for those who wish to invest in renewable energy sources (e.g., rooftop solar panels) and cost stability.

In addition to the existing protection framework for vulnerable consumers and those in energy poverty, the proposal will also provide access to regulated retail prices for domestic consumers and SMEs in times of crisis and stabilize the supply industry by requiring suppliers to better protect themselves from price hikes through increased use of forward contracts with producers (locking in future prices) and by requiring Member States to establish a supplier of last resort regime.

The proposal empowers consumers by creating the right to directly share renewable energy without the need to form energy communities. Increased energy by sharing the surplus from the energy produced, can enhance the use of low-cost renewable energy and provide greater access to direct use of renewable energy for consumers who may otherwise lack such access.

To increase the stability and predictability of energy costs, thus contributing to the competitiveness of the EU economy, which faces excessively volatile prices, the proposal aims to improve access to more stable long-term contracts and markets. PPAs can provide protection against price volatility, but they are currently generally available only to large energy consumers in very few Member States. One obstacle to the growth of this market is the credit risk that consumers may not always be able to purchase electricity throughout the entire period. To address this situation, Member States must ensure that companies facing barriers to entry in the PPA market and not in financial difficulties have access to instruments to reduce the financial risks associated with buyer default under PPAs, such as market-based price guarantee systems. To further promote market growth for these agreements, renewable and low-carbon energy project developers participating in a public support tender should be allowed to reserve a portion of generation for sale through a PPA. In addition, Member States should strive to apply evaluation criteria in some of these tenders to incentivize customers facing barriers to entry to access the PPA market. Finally, the obligation for suppliers to adequately protect themselves can also drive demand for PPAs, which are a way to lock in future prices. Some forms of public support guarantee the energy producer a minimum price from the government but still allow the producer to fully charge market prices even when they are very high. With the recent increase in prices, much publicly funded (cheap) energy has been sold at these high market prices. To curb this situation and stabilize prices, investment support should be structured in a two-way manner, setting a minimum price but also a maximum price so that revenues exceeding the upper limit are returned. The proposal will apply to new investments in electricity generation, including investments in new electricity generation facilities as well as investments for repowering, expansion, or life extension of existing electricity generation facilities. Furthermore, the proposal will require that this money subsequently be channelled to assist all electricity consumers in proportion to their consumption in order to mitigate the impact of price increases. Another means to protect against price volatility is to use long-term contracts that lock in future prices, also named as forward contracts. This market shows limited liquidity in many Member States but could be enhanced across the EU, allowing a greater number of suppliers or consumers to protect themselves against excessively volatile prices over longer periods of time. The proposal will create regional benchmark prices through a centre to increase price transparency and require network operators to allow transmission rights for more than one year so that if a forward contract is between parties across regions or borders, they can ensure the transportation of electricity. Finally, to ensure that markets behave competitively, and prices are set transparently, regulators' capacity to monitor the integrity and transparency of the energy market will be strengthened. The third objective is to boost investment in renewable energy to triple its deployment in line with the goals of the European Green Deal.

This will be achieved in part by improving long-term contract markets. Power purchase agreements and contract-for-difference not only provide consumers with stable prices but also provide reliable income for renewable energy suppliers. This reduces their financial risk and significantly reduces their cost of capital, creating a virtuous circle where stable income reduces costs and drives demand for renewable energy. Renewable energy is also a better investment when its ability to produce electricity is not limited by technical constraints of the system. The more flexible the system (power generation that can be quickly ramped up or down, storage that can absorb or supply electricity to the system, or responsive consumers that can increase or decrease their electricity demand), the more stable prices can be and the more renewable energy the system can integrate.

As an added value of the European Union, the EU's action to address the shortcomings of the current electricity market configuration brings added value, as it is more efficient and effective than actions taken by individual Member States, thus avoiding a fragmented approach. The proposed measures to address the identified deficiencies will be more ambitious and cost-effective if driven by a common legal and policy framework. Additionally, action at the Member State level would only be possible within the limitations of the existing EU framework for electricity market configuration, established in the Electricity Regulation and the Electricity Directive, as well as the RITME Regulation, and would not be able to achieve the necessary changes in that framework. Therefore, the objectives of this initiative cannot be achieved solely by the Member States themselves, and this is where EU-level action adds value.

To conclude this section, the European Commission has been implementing different measures and schemes to limit the excessive prices of the electricity and prevent the excessive profits in gas and electricity markets.

The proposed measures aim to create a buffer between short-term markets and electricity bills paid by consumers, particularly by incentivizing long-term contracting, to empower and protect consumers.

4. Methodology to calculate prices for small electricity consumers, PVPC:

Volunteer price for the small consumer or Precio Voluntario para el Pequeño Consumidor (PVPC), voluntary price for the individual or small electricity consumer, is the methodology which establish voluntary prices for electricity consumers and the legal regime for contracting, configured as a dynamic price that internalises the volatility of the wholesale market price signal.

The Spanish electricity market has recently undergone a significant change in the way it calculates prices for small electricity consumers. This change, known as the PVPC, was implemented in January 2019 and is the result of a new regulation by the Spanish government.

The PVPC is a new pricing system for small electricity consumers and replaces the previous system known as "tarifas de último recurso" (TUR). Under the TUR system, prices were based on the market price of electricity and determined by the government. The PVPC system is different in that it is based on a voluntary price set by the electricity suppliers. This price is determined by the cost of production, the cost of transmission and the cost of distribution. In addition to the new pricing system, the PVPC also includes a number of other measures to ensure that small electricity consumers are not disadvantaged by the new pricing system. These include [16]:

- A cap on the price of electricity that suppliers can charge small consumers:

  The cap on the price of electricity that suppliers can charge small consumers is designed to protect them from high prices. It is a maximum amount that suppliers can charge for each unit of electricity that they sell to small consumers. This cap is based on the average cost of electricity across the country and is adjusted each year to reflect changes in the cost of electricity. The cap is set by the energy regulator and is usually based on the most recent data available on the cost of electricity. This cap is designed to ensure that small consumers are not unfairly charged higher prices than larger customers. The cap is usually set at the level of the average cost of electricity in the country but can be adjusted to reflect changes in the cost of electricity. For example, if the cost of electricity rises, the cap may be adjusted upwards to ensure that small consumers are not paying more than what others are paying. In addition to the cap on the price of electricity, suppliers may also be required to offer discounts to small consumers. These discounts may be based on the amount of electricity used or may be available to customers who are on a specific tariff. The discounts are designed to ensure that small consumers are not paying more than what others are paying for the same amount of electricity.

- A system of discounts for small consumers based on their level of consumption:

  In Spain, small consumers are offered discounts based on their level of consumption. The discounts range from 0% to 15%, depending on how much energy the consumer uses. The discounts are calculated based on the consumer's average energy consumption over a period of 12 months. The more energy the consumer uses, the higher the discount they will receive. Consumers who use up to 500 kWh are eligible for a 0% discount. Consumers who use between 501 and 1000 kWh will receive a 5% discount. Consumers who use between 1001 and 2000 kWh will receive a 10% discount and those who use more than 2000 kWh will receive a 15% discount. In addition to the discounts, consumers are also eligible for certain subsidies. These subsidies are aimed at helping consumers reduce their energy consumption and make energy more affordable [16].

- A system of incentives for suppliers to offer competitive prices:

  The Spanish electricity market is a regulated market and is divided into two parts: the free market and the regulated market. In the free market, electricity suppliers compete to offer the best prices to consumers. They can offer lower prices, better customer service and incentives such as discounts for purchasing in bulk. On the other hand, the regulated market is managed by the government and prices are set by the government. The government also sets incentives for electricity suppliers to offer competitive prices. These incentives include subsidies, tax breaks and other financial incentives. The goal of these incentives is to ensure that electricity consumers have access to competitive prices [16].

Current increase in electricity prices and its associated volatility observed since the second half of 2021, has caused some regulatory changes based both in the wholesale and retail sector, to adapt the ambitious target for the integration of renewables to the realities of the electricity sector. The aim is to allow end-consumers to capture benefits of renewable energy of electricity production, to consume sustainable and affordable energy sources. It might be highlighted that the consumers who have been the most affected by the increase of the energy prices are the ones with supply contracts indexed to the wholesale electricity market, as the final price of the electricity is passed by the electricity traders, reflecting the evolution of the marginalist matching prices in those markets.

On March 28th, 2021, it is modified the Decree 216/2014 to implement a methodology for the calculation of voluntary prices for the small electricity consumer and its legal contracting system, configured as a dynamic price that fully internalises the volatility of the wholesale market price signal. The Decree was created in 2014, becoming the regulated price the most competitive electricity supply offer on the market. However, this competitiveness has been achieved at the expense of high exposure to agents to the day-ahead market, undermining the incentives to procure through forward hedging instruments, which has proved to be a weakness in the context of the bullish rally of electricity prices mentioned.

The regulatory change mentioned together with other regulatory Decrees have encouraged the trading of electricity in the day-ahead and intraday markets, exposing agents to the vagaries of short-term markets and considerably reducing the liquidity of forward markets.

In addition to the measures to promote supply-side forward contracting introduced in Royal Decree-Law 6/2022, adopting urgent measures in the framework of the National Plan of response to the economic and social consequences of the war in Ukraine.

The article defines the maximum price that an individual could pay for the electricity consumed. Initially, the determination of the costs stated that the energy prices was configured as a weighted average of the daily market prices, which caused the high inflation in prices. Therefore, this Decree introduces a price signal for forward products, configuring it as a basket of products, including a distribution of weights between the monthly, quarterly, and annual products. However, at the same time, the shorter-term products allow benchmark marketers to match in a more accurately way their energy portfolio to the current supply needs.

Particularly, it is proposed that for the forward price signal, the split between the products should be such that the monthly product accounts for 10% of the total, the quarterly product for the 36% and the annual product is 54%. By this way, there is an incentive both from the offer and demand sides.

Finally, and associated with the formula, energy costs have been set up under a scheme that allows the oscillations of the daily market prices to keep intact, without undermining the indexation of the forwarded products, which will promote more efficient consumption behaviour between consumers.

Regarding the indexation of the PVPC, the current update of the Decree will introduce modifications in the weights of the products, introducing prices from the auctions, in the event that this provides participation of the reference marketers.

Additionally, the Supreme Court has handed down several rules declaring the inapplicability of the previous financing system for the social bonus. Due to the urgency in defining a financial mechanism for the social bonus, the Royal Decree-Law 6/2022 of 29th of March, modified the law 24/2013 covering the updated scheme of financing. The law specifies that the financing costs for the social bond will be assumed by the parties included in the electricity sector, including the production, transport, distribution, and commercialisation of electricity. The reference marketers are required to contribute in the social bonus, what is also covered by the PVPC. Apart from individuals and small consumers, SMEs will be allowed to beneficiate from the PVPC regulation, with a maximum power of 10 kW.

On the other hand, the Royal Decree 738/2015 of 31st of July, regulates the activity of electricity production and the procedure for the dispatch of electricity systems for the non-peninsular territories, with the aim of adapting the remuneration scheme received by installations with additional facilities in the non-peninsular territories.

Regarding the modifications and updated on the Royal Decree 216/2014 of 28th of March, which stablish the calculation methodology for the volunteer prices for the smaller consumer of electricity:

- Individuals or SMEs will be allowed to access to the PVPC as long as they are under a voltage lower than 1 kV and power contracted lower than 10 kW in each of the existing periods. Each reference marketer would do the accreditation of the conditions for each SMEs at the beginning of the contract.
- Voluntary prices for individuals will be calculated incorporating the following concepts:
    - The costs of production of electricity will be determined within the prices of the daily market during the period which the invoice issuance relates.

- The invoice will be issued by the reference marketer, based on real invoices according to the applicable regulations. In the case of individuals with remote measurement equipment and management capabilities, billing will be based on the hourly consumption values made available and sent by the supplier. However, for those cases without telematic reading, billing will be applying the actual reading per period available to the marketers, calculated in accordance with the provisions of this Royal Decree.

- The invoice of the PVPC for individuals will be composed of the sum of four different factors, including, power terms, invoicing of the active energy, invoicing for financing the social bond, and if corresponds, the reactive energy.

- The costs of the energy production are set according to different costs per hour, as per the following formula [16]:

$$\text{CPh} = Pmh + Ta + SAh + OCh$$

Where:

h: hour per tariff period to be considered in the calculation of the PVPC prices, within the facturation between two invoices.

Pmh: average hourly price obtained from the results of the daily and intraday market in the hour “h” of the period “p” in accordance with the provisions of article 10 of the Royal Decree.

SAh: value of the cost of the system adjustment services associated with the supply in hour “h” of tariff period “p”. The SAph shall be calculated in accordance with the provisions of article 11 of the Royal Decree.

OCh: Other costs associated to the electricity supply, including the amounts corresponding to the payment of marketers, the capacity of te mechanisms as well as the interruptible services.

Ta: adjustment term, calculated as follows:

$$\text{Ta} = (A - 1) * Pmah + B * Ft$$

Pmha: arithmetic average price of the daily hourly curve obtained from the results of the daily and intraday market.

Ft: average price of the values of the features of the basket price, including products of annual, quarterly, and monthly baseload.

A: daily and intraday market weighting factor, expressed as a percentage of 45%.

B: forward market weighting coefficient, expressed as a percentage of 55%.

- The terms for the costs of production, including Pmh, Ft, Sah, and other associated costs as OCh, will be published by each operator on its web site before 20:15h ahead of the supply for each of the following 24 hours.
- Regarding the costs for the future prices, it will be estimated according to the following formula represented below [16]:

$$\text{Ft} = An * Pfannual + (bn,t * Pfquarterly) + (Cn,m * Pf\ monthly,m)$$

$Pfannual$: average price of the annual futures prices with settlement in year "n", expressed in €/MWh. It is calculated as the arithmetic average of the reference quotes published by the OMIE, three months prior to the start of the settlement.

$Pfquarterly$: average price of the quarterly future prices with settlement in quarter "t" expressed in €/MWh. It is calculated as the arithmetic average of the reference quotes published by the OMIE in every quarter, 15 days prior to the start of the settlement.

$Pf\ monthly,m$: average price of the monthly future prices with settlement in month "m", expressed in €/MWh. It is calculated as the arithmetic average of the reference quotes published by the OMIE in every month, 5 days prior to the start of the settlement.

An: weighted average coefficient of the future annual prices at year "n". It will take the value 0.54.

bn,t: weighted average coefficient of the future quarterly prices at quarter "t" of the year "n". It will take the value 0.36.

Cn, m: weighted average coefficient of the future monthly prices at month “m” of the year “n”. It will take the value 0.1.

Additionally, under the same Law there is a first additional provision, which modifies the term of the production costs of the voluntary prices for the small consumer.

The structure for the production costs of the energy, CPh, could be modified through the Order of the Minister for Ecological Transition and Demographic Challenge, subject to the agreement of the Government´s Delegate Commission for Economic affairs to incorporate the following aspects [16]:

- A reference to the price resulting from the auctions of the infra-marginal, manageable, and non-emitting energy, if these auctions provide for the participation of the reference marketers, in accordance with the provisions of article 3.9 of Royal Decree Law 17/2021, of urgent measures to mitigate the impact of the increase of natural gas prices on the retail and electricity markets.
- In accordance with the described above, modifying the values of the weighting coefficients of the daily, intraday market and forward market, to incorporate the reference to the price resulting from the auctions of infra-marginal, manageable, and non-emitting energy.
- To modify te values, an, bn,t and cn,m, in order to modify the distribution of weights between the different forward products that make up the basket of products, in accordance with the provisions of the article 10.bis of Royal Decree 216/2014 of March.

As an additional provision, it defines the necessity and proportionality of the voluntary retail prices, for that, the National Commission of markets and competition, will develop an annual report providing detailed picture of the structure of the retail market, including the level of competition in all retail sectors and in particular the household sector.

As a first transitional provision, weighting coefficients defined in Article 9 of Royal Decree 216/2014, will be adopting the following values for 2023 and 2024 [16]:

Coefficient	Year	Value
A	2023	0.75
B	2023	0.25
A	2024	0.6
B	2024	0.4

Table 3: Values for the first transitional provision

As a second transitional provision, for SMEs subject to the voluntary price for the small consumer, who do not maintain the right to PVPC. This limitation of the PVPC application only for individuals and small business will be effective until 31st December 2023.

The Spanish government has recently approved a new PVPC reform for the electricity prices in Spain for small consumers, which will be in place the following year. 2024, for the future electricity prices. With this reform, of the PVPC, a partial disconnection from spot markets is carried out by incorporating references from futures markets, which will provide more stability to consumers' final bills. This inclusion of futures will be gradual: they will represent 25% in 2024, 40% in 2025, and 55% in 2026 [22]. To conclude with this section, the proposed PVPC changes mentioned, reinforce the idea of having long-term markets in the price formation of consumers, ensuring a lower volatility of the prices.

5. Description of the model used: Electricity portfolio optimisation for retailers

5.1. Objectives and development

The main reason to implement an optimisation model for retailers is the raise of the electricity prices. The model will optimise the electricity portfolio of an Integrated Supply Retailer (ISA), considering the available procurement options, coupling the short and long-term horizons, from the end-consumer perspective. Most decision support algorithms studied and developed have focused on generators, traders and distributors portfolio optimization. A smaller number of studies aimed to evaluate the perspective of consumers, retail suppliers or retailers [1].

The optimization model used in this work has consider uncertainties, where deterministic models may not fully capture the inherent variability or uncertainty, (this model has been developed in the IIT and is being used here for case studies purposes).

It will enable a probabilistic approach to modelling, allowing for a more comprehensive understanding of the system's behaviors and better decision-making under uncertainty. The model will follow the following:

1. Define the system: it will start by clearly defining the key variables, parameters and relationships involved.

- Decision Variables:

• v_c1yr: volume of one-year contracts procured by the retailer, in MWh/month.

• V_spot,$_{s,t}$: volume of spot market contracts procured by the retailer, in MWh/month, at month t, in scenario s.

- Parameters:

• Spot_price,$_{s,t}$: prices of one-year contracts for each scenario.

• Stochastic prices: monthly average of the electricity prices for each scenario.

• Monthly load: electricity demand for each scenario in MWh.

• Scenario probability: probability assigned to each scenario.

• I_rate: {0.1%}: interest rate, as a percentage per month.

• Ave: {0.01}: parameter that weighs the level of risk-aversion in the objective function.

• Max_c1yr: {100}: maximum level of one-year coverage, fixed for all periods, in MWh/month (=average monthly load).

2. Define the objective function: function to be optimized maximizing the variables within the parameters defined:

$$disc\_cost_{s,m,t} = \frac{cost_{s,m,t}}{(1 + irate)^t}$$

$$cost_{s,m,t} = \sum_{s,m} v_{s,m,t} \times p_{s,m,t} \qquad \forall\, t \in \{1,2,3, \dots 12\}$$

1) This model has been developed in the IIT and is being used here for case studies purposes.

To be able to account for a risk parameter in the objective function, it is calculated the volatility of the spot price vol_spot,s for each scenario s, as follows:

$$vol\_spot_s = \sigma\_spot_s \times \sqrt{T}$$

$$\sigma\_spot_s = \sqrt{\frac{\sum_t (spot\_price_{s,t} - av\_spot_s)^2}{N}}$$

3. Constraints: the model will also consider two constraints that have to be met when optimizing the objective function in order to minimise the costs:

   The sum of contracted volumes must be equal the load:

$$\sum_m v_{s,m,t} = v\_c1yr + v\_spot_{s,t} = load_t \qquad \forall\, s \in \{1,2,3,4,5,6\},\ t \in \{1,2,3, \ldots 12\}$$

   It has been stablished a limit on the one-year contract volume, given by the average monthly load (max_$c1yr$):

$$0 \leq v\_c1yr \leq \max\_c1yr$$

4. Scenarios: it has been assigned different probability distributions to different scenarios. Each scenario considers different PPAs periods, and different spot prices from different periods of time to show fluctuation within the prices.

5. Output: the model will finally show the optimised variables, indicating the volume contracted for PPAs considering its restriction, and the volume of MW contracted for the spot electricity, with its final optimised cost. In all the cases the total amount of energy contracted, considering PPAs and spot energy, will satisfy the demand required by the end customers.

5.2. Data provided for the model

In order to analyse the optimisation model described, electricity prices levels and energy demands have been considered to run the model. The parameters will be fixed during the whole case study scenario, while the variables will be stressed to reach out the expected result.

The model will optimise the costs for an retailer, and how much electricity should contract from the spot market compared to PPAs, according to its demand forecast, and future electricity prices [18], for four different scenarios, from 2023 to 2026. As the data for electricity prices is based on estimations done by the OMIE, the model assigns higher probability to the scenario with the recent data than the scenario with the data for 2026.

- Parameters [18]:

  1-year contract price: electricity prices for the PPAs contracts for different periods of time, from 2023 to 2026, being fixed prices during the complete year.

1y PPAs prices per MWh (€/MWh)	2023	2024	2025	2026
	56.4	68.52	58.54	55.00

Table 4: PPAs input prices for 1 year

  The future electricity prices from 2023 to 2026, defined in the model during 12 periods [18]. As it can be seen in the table below, the future electricity prices are less accurate as time passes, where the is information disaggregated for future electricity prices on a monthly basis for 2023, but quarterly or even yearly for the following years.

Periods	year / month	2023	2024	2025	2026
per-1	January	143.00	122.70	88.86	62.00
per-2	February	119.25	113.26	88.86	62.00
per-3	March	107.30	113.00	88.86	62.00
per-4	April	104.20	80.47	88.86	62.00
per-5	May	103.00	80.47	88.86	62.00
per-6	June	91.00	80.47	88.86	62.00
per-7	July	101.00	91.51	59.18	62.00
per-8	August	92.00	91.51	59.18	62.00
per-9	September	91.00	91.51	59.18	62.00
per-10	October	98.96	100.77	59.18	62.00
per-11	November	117.00	100.77	59.18	62.00
per-12	December	123.19	100.77	59.18	62.00

Table 5: Prices per month from 2023 to 2026 (€/MWh)

  To visualise the parameters, the figure below shows the trend of the future electricity prices, for each of the periods considered in the model, from 2023 to 2026.

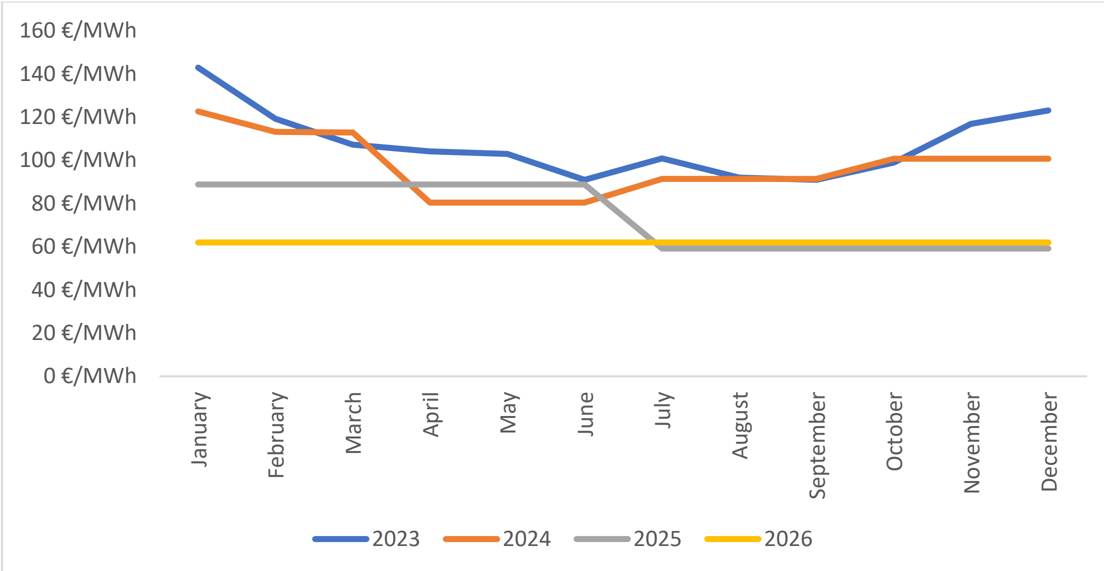

Figure 9: future electricity prices from 2023 to 2026 in Spain

Monthly load: to simulate the monthly load in MWh that an retailer in Spain would have to provide to its end customers, it has been estimated that the retailer has a market share of c.10%, to simulate a relevant energy consumption on the market. As of the last quarter of 2022, the first aggregator in Spain had a market share of c.46% in terms of electricity sold and number of clients, both as last resource and fixed electricity prices, the second biggest had a market share of c. 20%, the third a market share of 14% and the fourth largest retailer had 11% [19].

The monthly load in the model has been estimated as the average of the future electricity demand for the following 3 years, for end consumers, times the market share of the 10%.

Months	Final demand considered (GWh)
January	2,138.92
February	1,893.32
March	1,950.16
April	1,824.39
May	1,855.00
June	2,052.19
July	2,105.96
August	1,975.19
September	1,851.71
October	1,828.18

November	1,864.65
December	1,892.53

Table 6: Final electricity demand considered (GWh)

On the other hand, the electricity demand in Spain during 2021 and 2022 has remained with higher stability compared to the electricity prices, keeping a decreasing trend as shown in the Figure 10.

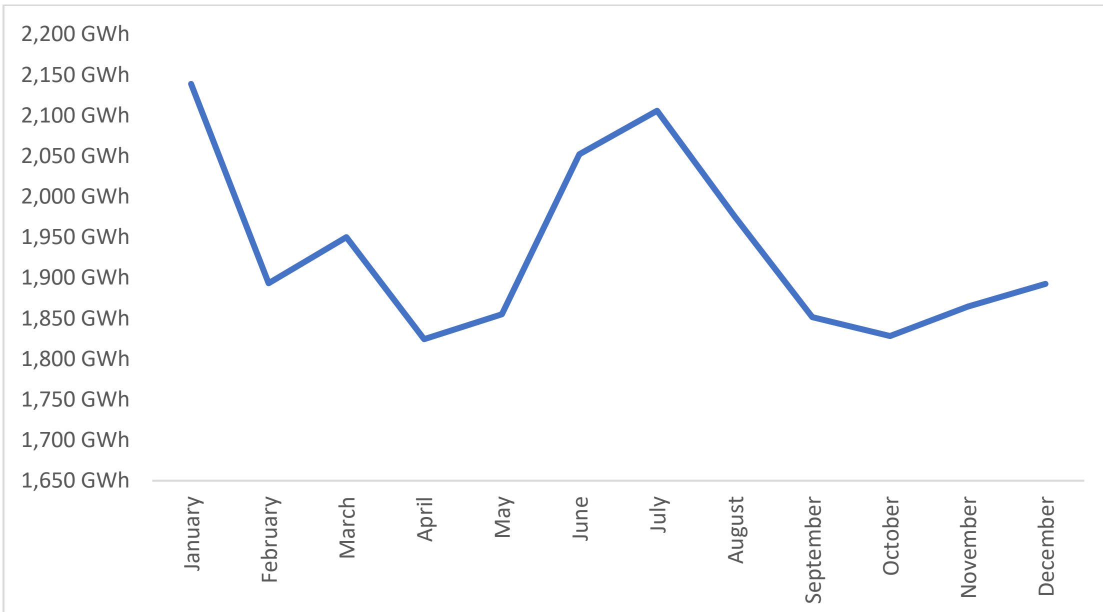

Table 7: Demand considered for the Case study as input (GWh)

- Scenario probability**:** as each of the scenarios considers future electricity prices, to estimate the function costs for an retailer, in order to make more accurate decisions and estimations, the probability assigned to the data of 2023 is slightly higher compared to the data for 2026, as it can be shown in the table below:

Scenario	Year	Probability assigned (p.u)
1	2023	0.50
2	2024	0.40
3	2025	0.30
4	2026	0.20

Table 8: Probabilities assigned in the model for each scenario

- Constraints: as described at the beginning of the case study. as first constraint is that all the monthly load must be supplied, so the energy contracted both from the spot market or for 1-year contract must be equal to the demand in GWh.

  On the other hand, the second constraint is the maximum amount of 1year contract level that can be contracted, which will directly affect the output, in terms of final costs and energy supplied on each period.

  Three different scenarios have been run to compare how this constraint affect the result considering all the variables and parameters.

6. Output analysis

6.1. Results from the base case scenario

As it can be shown on the table 6 below, all the 1-year power contracted for the PPA will be maximised as the prices remain lower on average for all of the periods compared to the spot prices. Based on the PPA amount, the retailer would have to contract the remaining electricity from the spot market to supply the whole monthly load. As it can be seen, as the PPA amount increases the volume contracted from the SPOT market decreases. In addition, the overall cost resulting from the optimization model reduces, as the PPA amount contracted increases. In the third scenario, it has been overestimated the amount of PPA contracted, covering the whole monthly load, which result in a non-cost from the SPOT market, but only due to the cost of the PPAs.The tables below represent the output values for the electricity from the spot market for each of the 12 periods per year, for each different probability scenario. Each of the tables, represent different scenarios where different power levels of PPA are contracted, where i) in the first case, the PPA covers 500 GWh of the entire demand, the second case covers 1,000 GWh with PPA, and third one would cover 5,000 GWh.

The tables summarize for each period, under the different probabilities' scenarios, which would be the power contracted from the SPOT market, to cover the full electricity demand, considering the available PPA. Not in every scenario the PPA levels will be maximised, as it will depend on the costs of each electricity source (PPA price vs SPOT market price) to optimise the overall function costs.

Total cost ('000 €)	**2,684,805.4**
PPA contracted (GWh)	Case 1: 500
SPOT market (GWh):	
scen-1.per-1	1,639
scen-1.per-2	1,393
scen-1.per-3	1,459
scen-1.per-4	1,324
scen-1.per-5	1,355
scen-1.per-6	1,552
scen-1.per-7	1,606
scen-1.per-8	1,475
scen-1.per-9	1,352
scen-1.per-10	1,328
scen-1.per-11	1,365
scen-1.per-12	1,393
scen-2.per-1	1,639
scen-2.per-2	1,393
scen-2.per-3	1,459
scen-2.per-4	1,324
scen-2.per-5	1,355
scen-2.per-6	1,552
scen-2.per-7	1,606
scen-2.per-8	1,475
scen-2.per-9	1,352
scen-2.per-10	1,328
scen-2.per-11	1,365
scen-2.per-12	1,393
scen-3.per-1	1,639
scen-3.per-2	1,393
scen-3.per-3	1,459
scen-3.per-4	1,324
scen-3.per-5	1,355
scen-3.per-6	1,552
scen-3.per-7	1,606
scen-3.per-8	1,475
scen-3.per-9	1,352
scen-3.per-10	1,328
scen-3.per-11	1,365

scen-3.per-12	1,393
scen-4.per-1	1,639
scen-4.per-2	1,393
scen-4.per-3	1,459
scen-4.per-4	1,324
scen-4.per-5	1,355
scen-4.per-6	1,552
scen-4.per-7	1,606
scen-4.per-8	1,475
scen-4.per-9	1,352
scen-4.per-10	1,328
scen-4.per-11	1,365
scen-4.per-12	1,393

Table 9: Output of the SPOT prices per scenario – Case 1

The second example shows, compared to the first one, how the electricity contracted from the SPOT market decreases, as in this case, the power level from the PPA is maximised, and in every case, the overall electricity demand is covered.

Total cost (€)	**2,430,935.6**
PPA contracted (GWh)	Case 2: 1,000
SPOT market (GWh):	
scen-1.per-1	1,139
scen-1.per-2	893
scen-1.per-3	959
scen-1.per-4	824
scen-1.per-5	855
scen-1.per-6	1,052
scen-1.per-7	1,106
scen-1.per-8	975
scen-1.per-9	852
scen-1.per-10	828
scen-1.per-11	865
scen-1.per-12	893
scen-2.per-1	1,139
scen-2.per-2	893
scen-2.per-3	959
scen-2.per-4	824
scen-2.per-5	855
scen-2.per-6	1,052
scen-2.per-7	1,106
scen-2.per-8	975
scen-2.per-9	852

scen-2.per-10	828
scen-2.per-11	865
scen-2.per-12	893
scen-3.per-1	1,139
scen-3.per-2	893
scen-3.per-3	959
scen-3.per-4	824
scen-3.per-5	855
scen-3.per-6	1,052
scen-3.per-7	1,106
scen-3.per-8	975
scen-3.per-9	852
scen-3.per-10	828
scen-3.per-11	865
scen-3.per-12	893
scen-4.per-1	1,139
scen-4.per-2	893
scen-4.per-3	959
scen-4.per-4	824
scen-4.per-5	855
scen-4.per-6	1,052
scen-4.per-7	1,106
scen-4.per-8	975
scen-4.per-9	852
scen-4.per-10	828
scen-4.per-11	865
scen-4.per-12	893

Table 10: Output of the SPOT prices per scenario – Case 2

The third example shows how the PPA levels have been over estimated, and so, there is an excess of PPA contracted as. In this case, the values are negative, not only because there is no need to contract any electricity from the SPOT market, as the PPA covers the entire demand, but also because the surplus of PPA is sold back by the retailer.

Total cost ('000 €)	**399,977.3**
PPA contracted (GWh)	Case 3: 5,000
SPOT market (GWh):	
scen-1.per-1	-2,861
scen-1.per-2	-3,107
scen-1.per-3	-3,041
scen-1.per-4	-3,176
scen-1.per-5	-3,145
scen-1.per-6	-2,948

scen-1.per-7	-2,894
scen-1.per-8	-3,025
scen-1.per-9	-3,148
scen-1.per-10	-3,172
scen-1.per-11	-3,135
scen-1.per-12	-3,107
scen-2.per-1	-2,861
scen-2.per-2	-3,107
scen-2.per-3	-3,041
scen-2.per-4	-3,176
scen-2.per-5	-3,145
scen-2.per-6	-2,948
scen-2.per-7	-2,894
scen-2.per-8	-3,025
scen-2.per-9	-3,148
scen-2.per-10	-3,172
scen-2.per-11	-3,135
scen-2.per-12	-3,107
scen-3.per-1	-2,861
scen-3.per-2	-3,107
scen-3.per-3	-3,041
scen-3.per-4	-3,176
scen-3.per-5	-3,145
scen-3.per-6	-2,948
scen-3.per-7	-2,894
scen-3.per-8	-3,025
scen-3.per-9	-3,148
scen-3.per-10	-3,172
scen-3.per-11	-3,135
scen-3.per-12	-3,107
scen-4.per-1	-2,861
scen-4.per-2	-3,107
scen-4.per-3	-3,041
scen-4.per-4	-3,176
scen-4.per-5	-3,145
scen-4.per-6	-2,948
scen-4.per-7	-2,894
scen-4.per-8	-3,025
scen-4.per-9	-3,148
scen-4.per-10	-3,172
scen-4.per-11	-3,135
scen-4.per-12	-3,107

Table 11: Output of the SPOT prices per scenario – Case 3

6.2. Analysis and conclusions from the base case scenario

Analysing the overall costs for the retailer based on three different cases of PPAs in GWh contracted, it can be seen that the costs reduce considerably. As a result, based on future prices from the OMIE, both for the SPOT market and for PPAs contracts, as much PPA is contracted less are the costs assumed by the retailers to supply electricity to its end customers.

PPAs guarantee certain economic stability, as the prices from the SPOT market can fluctuate, but the PPAs ensure the same price during the whole year. Although SPOT electricity prices are expected to decrease by 2025, as it has been seen over the recent years, unexpected events can occur (i.e. the war in Ukraine, or the Covid-19 pandemic) which may increase the electricity prices from the SPOT market considerably. In addition, apart from providing a higher stability, the overall costs are reduced, as it can be seen in the table 7 below. Where, when there is a PPA volume contracted of 500 GWh the total price is 10.44% higher than the second case where there are 1,000 GWh contracted.

Case1 –GWh PPA contracted	Average cost (€/MWh)	Expected total cost (´000 €)
500 GWh	115.5	**2,684,805.40**

Table 12: Output result from the model analysis – Case 1

Case2 –GWh PPA contracted	Average cost (€/MWh)	Expected total cost (´000 €)
1,000 GWh	104.6	**2,430,935.6**

Table 13: Output result from the model analysis – Case 2

Case3 –GWh PPA contracted	Average cost (€/MWh)	Expected total cost (´000 €)
5,000 GWh	17.21	**399,977.3**

Table 14: Output result from the model analysis – Case 3

7. Additional tools for the optimization of the electricity prices: self-consumption solutions

In order to provide energy efficiency solutions to the end customers, retailers can offer photovoltaic installations for self-consumption, so the end users will reduce their monthly expenses on their electricity bills. In addition, if retailers provide the option of financing the PV installations, during for example, 10 – 20 years, they will be able to maintain customers for longer periods of time by the time they keep selling them electricity [7].

When providing financing alternatives up to 20 years, the consumers can achieve savings since day one on their electricity bill, as the instalment they will pay for the panels will be lower, and also, they will get a reduction on their electricity bill due to the use of the panels.

Across Europe, the demand for self-consumption is increasing, from both individual clients and SMEs or Corporates, and many of these installations is being financed during long periods of time. The main rationale for the financing, is that the end customer will achieve savings on their electricity bill since day one, as long as the financing period is longer, as the monthly instalment for the PV gets reduced.

Many SMEs and Corporates are developing the option of installing PV plants to consume renewable energy produced by its own PV plants. These installations are set both on-site or off-site the companies. When companies install PV plants, they usually become responsible for the maintenance and installation costs, as well as the whole process of the life´s cycle, assuming the associated risks.

Some models allow financing PV plants, involving third parties, who limit the associated risks and assume the initial costs of the panels, these contracts can be reached through PPA contracts or even leases or rentals.

Most common projects are those located on-site, but in some cases the renewable energy for self-consumption proceeds from external plants, where consumers have to pay also for transmission costs. These kinds of markets are allowed only on countries where have liberalised electricity markets. Self-consumption installations are used to reduce costs as users would consume their own energy produced.

Additionally, companies who are off the grid have become self-consumption dependant, to ensure their energy supply. When companies are isolated from the grid of suffer lack of energy stability due to large distances, PV plants and energy storage devices are the best option to guarantee energy consumption.

7.1. Alternatives for financing self-consumption installations:

Financing self-consumption installations is an opportunity for retailers to keep their end-customers larger periods of time, and to reach financing reducing the risks, and maintain the liquidity levels of the company, there are several ways to provide it.

The type of financing provided by retailers will depend on the type of the end-customer, as it will vary from SMEs/Corporates or individuals, depending on the size of the installation, and the product offered. There can be different products offered for self-consumption installations, according to the end-customer needs:

- Renting or Leasing:

  The PV installation will be rent by the customer during the contract period, while the panels will be owned by the company. When the contract is finished and the PV installation is amortised, the customer can choose whether to keep the installation or not. Additionally, fees are usually higher than leasing fees as it usually includes maintenance and insurance costs. To execute a leasing contract it is needed a financial institution, such an Special Purchase Vehicle (SPV), and particulars will own the panels at the end of the contract. During the contract, panels are owned by the retailer, who also incurred the maintenance or insurance costs [1].

- PPAs:

  Consumers will pay the retailers according to the amount of the energy they have produced, with a fixed price per KWh. Additionally, PPA contracts could include a minimum production guarantee to compensate the retailer if the production keeps below a certain threshold.

- Solar Loans:

  Retailers could offer solar loans as a way of financing solar panels for its homeowners. Unlike leases, rentings and PPAs contracts, the client will own the panel since the beginning of the loan. Solar loans usually last less periods as 18 months, where the client will partly pay for the loan received plus an additional interest rate applied.

As a way of summarizing the mentioned above, the following table indicates the main features between the financing alternatives:

	Ownership	**Duration**
Renting/Leases	Retailer	10 years
PPAs	Retailer	15 – 20 years
Solar Loans	Customer	18 months

Table 15: Comparison of self-consumption products offered by retailers [2]

The retailer will remain the property of the assets for both leasing/renting and PPAs contracts, unlike solar loans. These arrangements are known as Third-Party Ownership (TPO), which allow the retailer monetizing investment tax credits (ITC), as well as accelerating depreciation associated with the PV installation.

Last trends seen over 2022 in the market suggest a shift from TPO contracts to solar loans. In 2021, Wood Mackenzie estimated that 60% of PV plants would be financed by solar loans by the end of 2022, and for 2023 would experience an increase up to 70%.

Under all contractual forms, the retailer would be benefited from long-term payment contracts, which results in cash flows streams being also appropriate for securitisation when aggregated in a sufficiently diversified pool. In addition, TPO has allowed retailers financing PV installations with Tax Equity investors, looking for monetizing ITC and accelerated depreciation.

Retailers could benefit from Tax Equity as remains a primary source of financing for leases and PPA contracts. On the back of Tax Equity structures, market participants have become very familiar with this way of financing structure, which leads to warehouse facilities and solar ABS:

- Warehouse Financing: structure that allows the retailer originating new self-consumption contracts and at the same time deconsolidating them from its balance sheet, transferring the risks of default to third party investors. This solution allows any retailer increasing its portfolio without reducing the liquidity levels of the Company. In addition, the structure can be easily developed as there is no need to have many different third parties involved.

Warehouse financing is carried out for many emerging solar companies with little volume and track record but high growth expectations.

Warehouse financing will allow winning track-record allowing reaching better financial terms in the near future. Additionally, to execute a warehouse financing it is not needed rating as the structure is to develop and collect data.

Warehouse financing allows the company growing and originating solar PPA contracts and the balance sheet, keeping the ownership of the portfolio.

The company sells the proceeds coming from PPA contracts to an SPV, on a revolving basis with the possibility to increase the issuance until the maximum permitted by the fund.

- Solar ABS Securitisation: financing structure similar to the Warehouse financing structure but is developed when the retailer has a portfolio of contracts originated of c.€200m, which is transferred directly to the investor. In the Warehouse financing structure, the contracts are transferred as soon as they get originated, however, in the Solar ABS transaction structure, the whole portfolio is financed at once. The overall costs increase as there are more third parties involved, but the pricing for the financing is lower.

  In terms of ABS securitisation, it is collateralized by the solar contracts, and the retailer once they are originated sells the proceeds to transferring entities and third parties. In addition, the retailer would issue different classes of notes. Credit enhancement of the notes issued can consist of i) overcollateralization, ii) yield supplement overcollateralization amount, iii) subordination, in case of Class A and Class B notes, and iv) amounts on deposit in a reserve account.

  For Solar ABS Securitisation is better to execute with PPA contracts because it guarantees fixed cash flows and reduces the volatility of the renewable energy prices.

  Additionally, solar ABS Securitisations have the following advantages:

  - Lower credit risks than loans financing as the financial structure is divided in tranches.
  - Longer financial terms and lower capital cost.
  - PPAs securitisation reduce energy price volatility.

- Assets are removed from the balance sheet reducing credit risks, as they are transferred to an SPV.
- The retailer allows getting more liquidity.

Regarding Tax Equity structures, there are three common structures, as Partnership Flip, Lease Pass-Through and Sale-Leaseback:

- Partnership Flip:

  The structure evolves a tax equity investor and the retailer, where the cash flows from the underlying portfolio vary over time. The investor would receive for at least the first five years, most of the cash flows, and the ITC and depreciation benefits. When the tax benefits have been monetized, the ownership changes to the retailer who starts receiving the cash flows.

- Lease Pass-Through:

  The TPO would lease the PV installation to the Tax Equity Investor, which subleases the system to the homeowner. In this Tax Equity structure, the TPO provider can pass through the ITC benefits to the investor, which provides the upfront capital, and during the first years received both the ITC benefits and the cash flows from the customer.

- Sale-Leaseback:

  This structure allows the retailer selling the PV installation entirety to the Tax Equity Investor and then leasing back the aggregated portfolio. The investor would be able to monetize the tax benefits associated to the structure, since keeps the ownership of the solar installation. Finally, the retailer would then lease the PV installation to the homeowner.

7.2. Case studies and financing Experience

In order to support the benefits of financing solar installations by retailers to their end customers, there are provided different case studies executed in the US, as there are not public transactions in Europe yet. The transactions show how the financing conditions can be optimised, to retailers can provide a greater number of PV installations financed and increase its market share.

Solar ABS transactions have been successfully closed in the US since 2013, offering different sizes, tenors and ratings. In the US, there are two main types of solar ABS, securitised by lease/PPAs or securitized by solar loans. Solar loans have become the largest source of financing for residential PV installations, accounting for 74% of volumes in 2021 [2].

From January 2021 to April 2022 the total collateral balance of Solar Loans reaches a total volume of €65.69bn. where the weighted average WAC is c.4%. in the US.

More than 55 transactions have been executed in the US market from 2013 to December 2021, keeping the trend within the market as follows:

- Transaction sizes in the range between $[50-550]million.
- Overcollateralization of the part of the portfolio with the lowest risk being c.34%.
- Ratings in the range between BBB and AA.
- Securitized contracts have mostly been a mix of solar leases and PPAs (57% of the market).

Additionally, some of the most relevant transactions have occurred in the US, executed by two different retailer companies as, Sunrun and Loanpal.

- Sunrun Securitisation of residential solar: Sunrun executed a Solar ABS securitisation of leases and PPAs for residential solar assets, in September 2021, where the company achieved a weighted average capital cost below any prior transaction they had executed [20].
- Loanpal solar loan 2021: Loanpal launched its current solar loan origination platform where it originated loans to mostly prime credit quality homeowners for the purpose of purchasing home improvements, including solar panel systems and batteries.

To conclude, both Loanpal and Sunrun, who are part of the biggest retailers in the US market, have been providing solar panels to their customers, being financed through solar loans. These companies then, have securitised as a way of financing these loans, to gain more liquidity, reduce the risks, and acquire more financial stability to originate and provide more solar loans. Within this scope, these companies, have had their customers, not only paying for the solar loans on a monthly basis, but also for the electricity they were consuming, what allowed them to retain for longer terms the end customers at optimised costs.

8. Conclusions

To conclude, it has been discussed how the electricity market in Europe is changing, designing a new reform in Europe to accelerate the energy consumption from renewable sources, to reduce the dependency from the gas, making consumers less dependent on the volatility of the fuel prices and potential market manipulation, making in addition an industry more competitive and cleaner. This point of reaching the energy efficiency for the end consumers has been analysed from an retailer perspective, who at the end, has to optimise its costs and keep increasing their market share. In order to optimise the costs of an retailer when buying the electricity to supply to its customers, a real case study has been implemented, for a Spanish retailer.

On the other hand, the main reason for the PVPC regulatory changes is to reduce the price volatility to the end customers. But in addition, and as a result, the use of renewable electricity is also promoted, to stablish the electricity market to avoid over demand, and to reduce the electricity dependency from fossils or fuel, by promoting the integration of new energy sources as the self-consumption sources through solar panels.

As described on the Case study, the PPAs contracts are more beneficial in terms of costs compared to the electricity prices from the SPOT market, considering the future prices in Spain on the daily market from 2023 to 2026. Although the trend of the electricity prices is expected to decrease, compared to the previous two years, the model demonstrates the efficiency of contracting as much PPAs energy possible. In addition, other potential advantage of the PPAs contracts is eliminating the dependency on the volatility of the electricity prices of the SPOT market. To promote the energy efficiency the European Union is being adjusting and promoting new initiatives, but also regulation has changed in terms of the PVPC to protect the end consumers and promote the energy transition.

To support the energy transition and reduce the dependency of the electricity market, retailers are offering to its end users self-consumption solutions, with the possibility of financing during long periods to achieve savings on the electricity since day one. As it has been seen in the US market, there are many different alternatives to finance these installations, optimising costs and ensuring that customers will be consuming electricity within the same retailer for longer periods of time, as by the time they finance and pay for the self-consumption installation the consume electricity supplied by the same retailer.

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