UNIVERSIDAD PONTIFICIA COMILLAS

ESCUELA TÉCNICA SUPERIOR DE INGENIERÍA (ICAI)

OFFICIAL MASTER'S DEGREE IN THE ELECTRIC POWER INDUSTRY

Master's Thesis

Assessing the Viability and Risk Management of Photovoltaic Power Purchase Agreements

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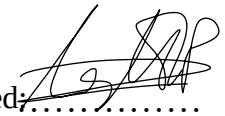
Signed:  Date: 27 / 06 / 2024

Authorization of the Master's Thesis CoordinatorDr. Luis Olmos Camacho

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Content

1. Introduction

By looking at the average price for the last years in the Iberian spot market, one could conclude that there must have been answers behind such a big price volatility. Not only has this been the case for the Iberian Peninsula, but for all Europe. As for Spain, the average annual prices from the electricity market were somehow stable until 2021. The average price registered from 2007 until 2020 is 46.09 €/MWh, being the maximum price of 145€/MWh and the minimum price of 0 €/MWh. However, in that exact year the average price was of 37.01 €/MWh.

The prior results might portray a slight volatility in prices that could be accepted. Nonetheless, prices skyrocketed in 2022, being the maximum price of an outstanding 700 €/MWh. The average price from 2021 until today has been 167.52 €/MWh. This can clearly be seen in Figure 1. Average spot prices in Spain. Own Elaboration based on data taken from OMIE

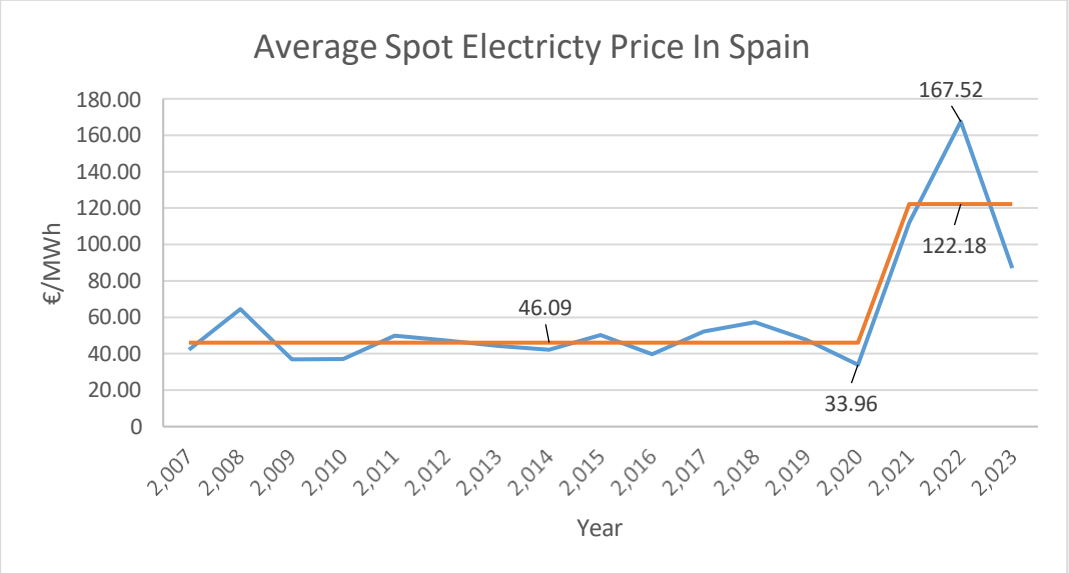


Figure 1. Average spot prices in Spain. Own Elaboration based on data taken from OMIE [1].

There are reasons to these prices. But nobody could anticipate them. In March 2020, the COVID-19 disease started spreading out. This led to governments forcing people to be locked down in their homes to prevent people from being infected. As a result, prices in 2020 went down at first. There was a big decrease in energy demand. The world stopped and industries all around the world had to reduce their operations. Low demand meant energy could be delivered with cheaper technologies and that was the case for a while.

The year 2020 registered the lowest average electricity price in the Spanish market in the last decade. From then on, prices have been going up.

COVID–wise, prices increased due to the hurdles the supply chain had to face to deliver gas, for instance. The pandemic provoked severe disruptions which led to a sudden increase in spot prices. Uncertainty helped those prices rise, making the market quite volatile.

Even though electricity prices went up due to the reasons priorly discussed, what made them escalate the most were the geopolitical conflict between Russia and Ukraine. In February 2022, a war broke out between those two countries. Russia attempted an invasion of Ukraine, and the resulting conflict has persisted to the present day. Russia is the second largest natural gas producer in the world. In 2021, they produced 24.78 bcm of natural gas. In that same year, it had supplied about a 40% of the natural gas in the European countries. In August 2022, that figure went down to the 17%. Despite Europe's significant efforts to cut down on natural gas consumption, the outcome did not entail a reduction in demand; instead, there was an increase in imports from other nations with higher natural gas prices. Other explanations regarding this high price volatility lay on an elevated demand due to changes in temperatures and high CO_2 emissions prices.

Europe found itself embedded in the same tendency. Prices escalated for the same reasons as mentioned before. Germany, France, and Italy, suffered the same trend, being the latter the one with the biggest impact. The highest average price registered during that period is held by Italy, when in August 22 they registered a mean of 543.48 €/MWh.

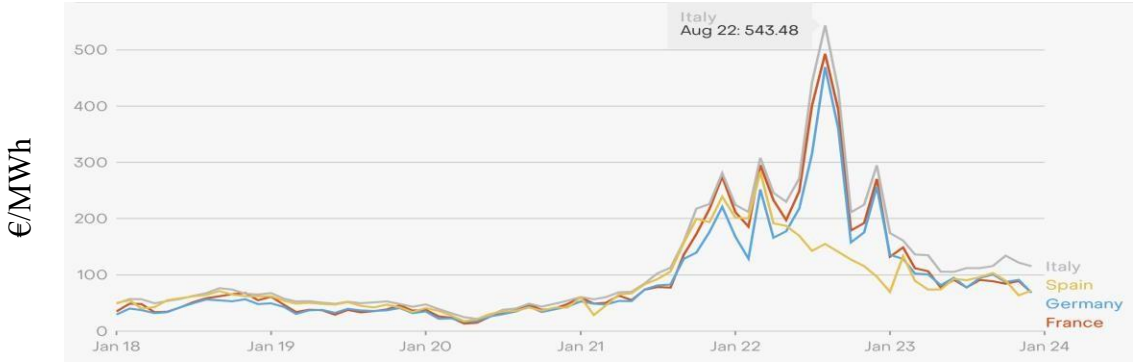


Figure 2. Average monthly spot prices in Europe's main electricity markets. Source Ember [2].

One could argue, according to the prior figure, that Spain did reasonably well when prices spiked. However, that happened due to the decision that the Spanish government took of

intervening the market by imposing a decree-law known as the Iberian Exception, in which they set a cap to gas prices. It has been proven that it was not the most efficient solution, but it helped keeping the prices down to certain limits.

All in all, by taking a look at the prices over the past years, it can be concluded that the electricity market is nothing but uncertain, as any other market. Not only Spain suffered from high prices, but all Europe. Ever since, risk mitigation tools have become more and more attractive. Companies want to hedge the risk and leave little margin for forecasting. This is where PPAs play an important role in the renewable sector, and this will be the topic I will be focusing on from now on. However, there are many ways to close a Power Purchase Agreement. Some, entail risk for the counterparty. Others, for the seller. There are some strategies that divide the risk between both parties too. Describing the risks and identifying their impact and how to mitigate them is crucial so as to not be affected by market movements.

1.1. Motivation

In an environment where prices continually escalate and deescalate, both consumers and companies find themselves vulnerable to financial strains. While consumers may well decide whether to opt for the free or for the regulated market, companies are exposed to market turbulences and have to look for alternatives to hedge risk.

Managing risks is one of many companies' main goals. From the buyer's point of view, closing deals that ensure they will not be exposed to sudden changes in electricity markets is essential. This can be done in many different ways but the main ones, in the present context, is to either close a future or to close a PPA. From the seller perspective, closing a PPA is also a way of ensuring stable revenues. But also, it is an accurate way of searching financial support from banks.

Even though the developer and the offtaker pursue opposite positions, the first one is hedging itself from low prices and the second one from high ones.

As seen in the prior chapter, the unpredictability of energy markets force companies to close hedging deals. There is where Power Purchase Agreements strategically emerge.

The focus of this thesis will be set in describing the viability and risk of closing different PPAs from the energy seller perspective.

What drives me to complete this thesis is helping a company such as X-Elio closing future deals analysing which structure of both, volume, and prices, fits best within their portfolio pipeline. In order to do this, there must be an exhaustive description of the different risks that may arise in a photovoltaic plant that the company may want to hedge.
By analysing the risks and knowing how to approach them, different strategies can be presented so as to decide which volume and price structure suits best for each project and market.

Other than closing fair deals that will help X-Elio project financing and hedging risks, the Net Zero objectives must not be forgotten. The path towards climate neutrality goes through renewable energy. Closing Power Purchase Agreements pushes the world closer to this goal since, for the first instance, the energy produced is completely clean and, for the second instance, counterparties aim at closing these contracts due to the Renewable Energy Certificates they provide.

Spain recently modified its Integrated National Plan of Energy and Climate, making it even more ambitious. The Iberian Peninsula pursues to generate the 81% of electricity from renewable sources by 2030. What is more, by that same year, 76 GW are expected to have been installed of photovoltaic plants, which is X-Elio's core business. To date, the Spanish National installed capacity goes up to 25.126 MW. This means that the current capacity must be multiplied by three times in order to reach the climate goals.

Power Purchase Agreements will get more and more popular in the recent years and having the know-how of these contracts is essential to make great deals that help companies build photovoltaic plants.

2. Objectives

1. Define the main power hedges.

The goal is to simply describe different hedges that are available in the market. Futures in the organized market and PPAs as an OTC transaction will be defined. This objective aims more at illustrating an overall view of what PPAs are, highlighting their main aspects and structures.

2. Describe and analyse risks affecting Power Purchase Agreements

As X-Elio's core business is the development of photovoltaic plants, risks will be linked to this renewable energy source. The sun does not move. However, there might be days in which there is not sun rays. This is obviously a huge risk because it affects photovoltaic plants production, thus affecting the revenues. Other risks include different volume profiles such as 'as produced' or 'baseload' profiles. There are risks attached to different price structures too like having a fixed price or a floor and a discount. All these risks will be explained.

3. Risk management of PPAs

Once risks have been studied, a model should be developed based on different PPAs structures and impact of the risks. Risks will have a probability assigned. Different portfolios will be created to analyse how risky they are and whether if it is worth it or not based on quantitative and qualitative assessment. The tool will include making stress tests that evaluate the resilience of the different combinations of structures according to the diverse portfolio. The goal is to understand how well a PPA behaves under several uncertainties. Forecasting offtaker's preferred structures will be done based on market sounding and historical data. Spot prices are given from internal analysis in the company.

Also, Value at Risk will be implemented in the different strategies taken into account. And a hedging portfolio will be created based on long-term PPAs, short-term hedges and trading strategies depending on the risks.

4. Conclusion

After in-depth analysis has been made, thorough conclusions will be drawn. The portfolio will be chosen decisions will have to be taken at a company level.

3. Table of Contents

4. Methodology and selected references

The methodology used will be based on research both, online and in-company to define the risks associated with an Independent Power Producer as X-Elio.
Firstly, in order to pursue the introduction, state of art and power hedges, a depth research based on papers and literature will be carried out. Some of the references chosen for that are the following (**the full bibliography will be shown in the final Master Thesis**):

[3]. Hollmén, Sara. Levihn, Fabian. & Martinsson, Gustav. (2022). "*When markets don't deliver: bilateral hedging by means of PPAs in managing intertemporal price risks in power generation investments*" Available: https://www.researchgate.net/publication/364770953_When_markets_don't_deliver_-_bilateral_hedging_by_means_of_PPAs_in_managing_intertemporal_price_risks_in_power_generation_investments

[4]. OmiClear (febrero, 2022). Circular A01/2014. "Definiciones y Disposiciones Generales". Available: circular_omiclear_a01-2014_definiciones_y_disposiciones_generales_1.feb.2022_es.pdf (omie.es)

[5]. Islam, Misbahul. & Chakraborti, Jayanta. (2015). "*Futures and forward contract as a route of hedging the risk".* Available: *https://www.researchgate.net/publication/288228197_Futures_and_forward_contract_as_a_route_of_hedging_the_risk*

[6]. Elwakil, Emad. & Hegab, Mohamed. (2018). "*Risk Management for Power Purchase Agreements".* Available: https://www.researchgate.net/publication/331958076_Risk_Management_for_Power_Purchase_Agreements

After having finished the general overview of the concepts that will be necessary to delve into the quantitative part of the thesis, the methodology followed will be based on excel and python models or tools to help analyse the data and define the optimal solution to the hedging portfolio.

Firstly, a risk matrix will be created based on the different risks of the diverse departments of the company. These entail engineering risks, site and permitting or market risks, among others. The tool will be used to analyse the impact and probability depending on the risk it is being dealt with. Here you can find how it will look like:

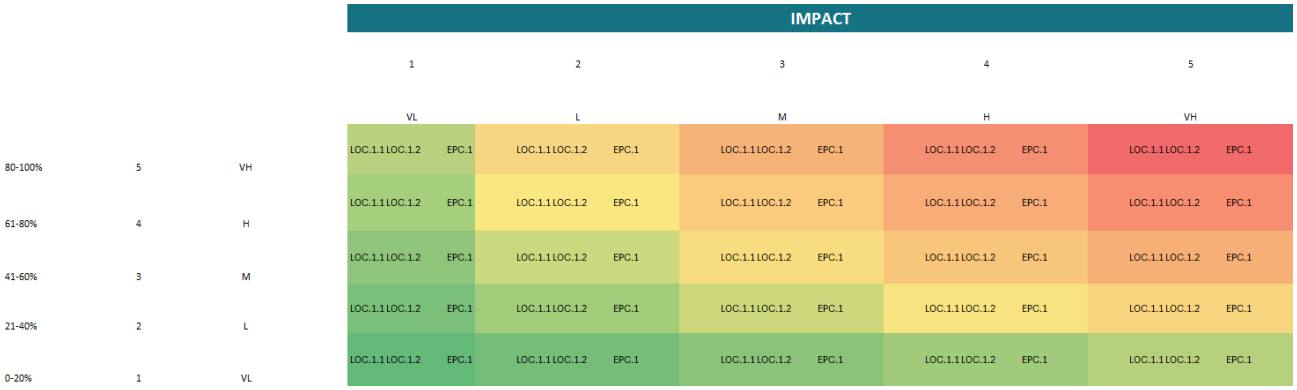
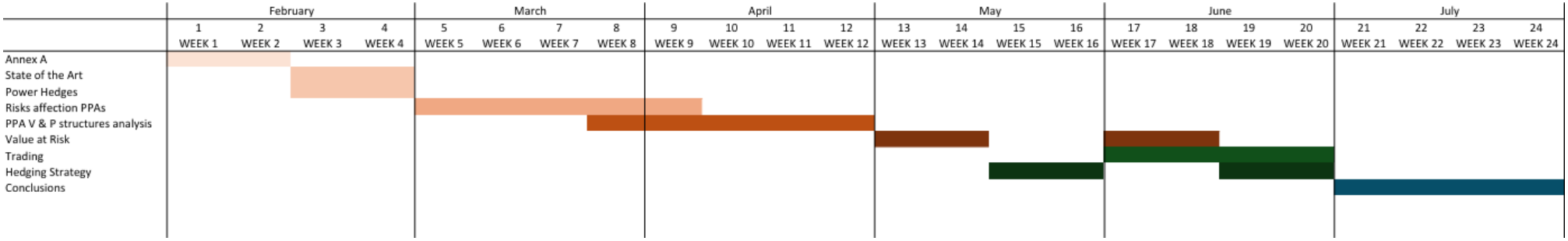


Figure 3. Risk Matrix. Own Elaboration.

The quantitative part in which the different PPA structures will be presented will be carried out with stress-test excel simulations, as well as python aid. The same will be done with the Profit and Loss books to see the realized and non-realized revenues and deal later with the Value at Risk. By getting the curves from the Markets department in X-Elio, the revenues can be obtained and optimized by creating different simulations depending on the PPA price and volume structures. This will be done in Excel and some visualizations may be carried out in python and Power BI.

In order to assess the risk, Value at Risk will have to be computed. The Value at Risk will be obtained from programming it in python. Both the historical and the Montecarlo VaR will be computed and compared. The inputs will be PPAs revenues, Forward Prices and Merchant profits. Tables and histograms will be portrayed so as to analyse what might be going on and extract the best out of the portfolio.

5. Work plan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Annex A
State of the Art
Power Hedges
Risks affection PPAs
PPA V & P structures analysis
Value at Risk
Trading
Hedging Strategy
Conclusions

Bibliography

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[2]. Ember. *European Power Price Tracker. Wholesale electricity prices in Europe.* Available: European power price tracker | Ember (ember-climate.org)

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