UNIVERSIDAD PONTIFICIA COMILLAS
ESCUELA TÉCNICA SUPERIOR DE INGENIERÍA (ICAI)
MASTER IN THE ELECTRIC POWER INDUSTRY

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OFFICIAL MASTER'S DEGREE IN THE ELECTRIC POWER INDUSTRY

Master's Thesis

Assessing the Viability and Risk Management of Photovoltaic Power Purchase Agreements

Author: Sergio Clemente Martín

Supervisor: Ángel Álvarez-Labrador

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Master’s Thesis Presentation Authorization

THE STUDENT:

Sergio Clemente Martin

Signed: Date: 27/06/ 2024

THE SUPERVISOR

Ángel Álvarez-Labrador Márquez de Prado

Signed: …………………… Date: 27 / 06 / 2024

Authorization of the Master’s Thesis Coordinator

Dr. Luis Olmos Camacho

Signed: …………………… Date: ……/ ……/ ……

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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*

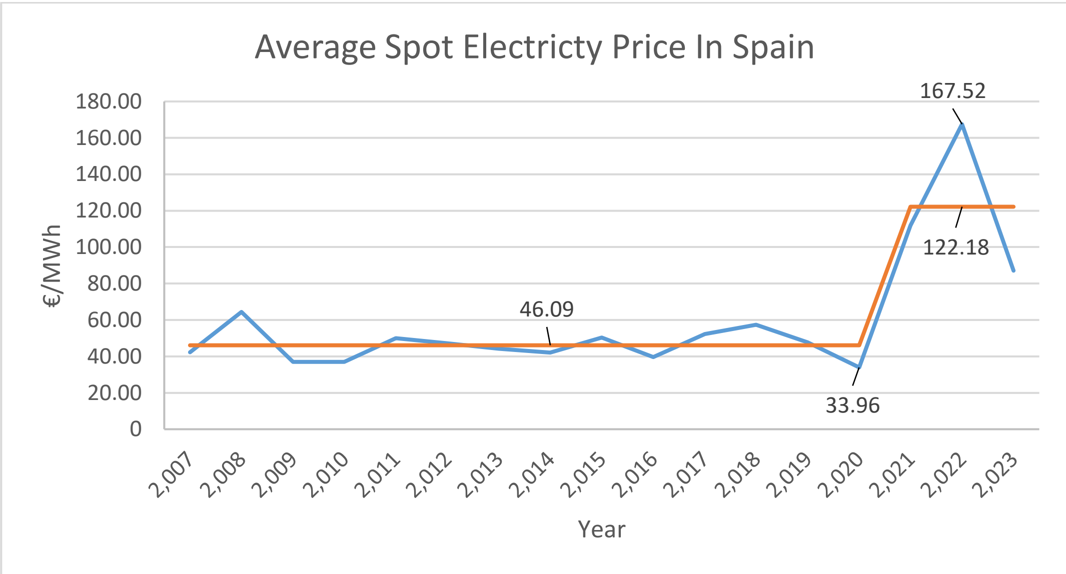

Figure 1. Average spot prices in Spain. Own Elaboration based on data taken from OMIE

This is due to the natural process of liberalization of the markets. A fer years ago, prices were limited up to 180 €/MWh. Now there is not such limit. But There are more 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.

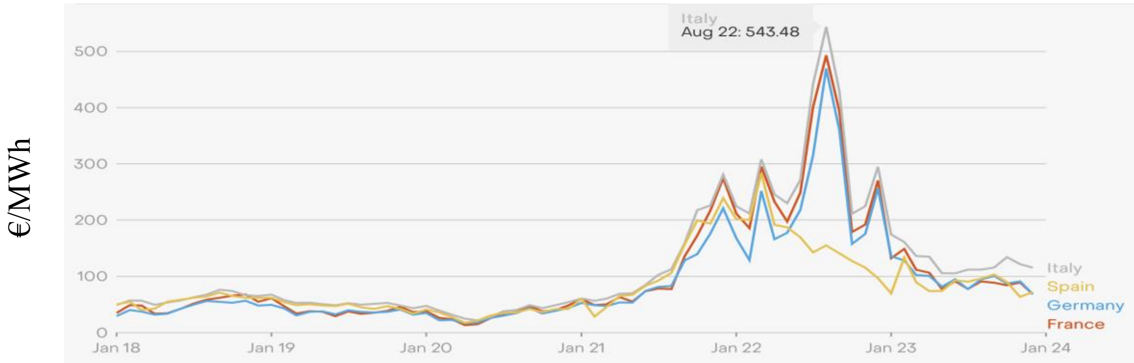

Figure 2. Average monthly spot prices in Europe's main electricity markets. Source Ember [1].

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 necessary. Companies want to hedge the risk and leave little margin for volatility impact. 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 structures of Power Purchase Agreement. Some, entail risk for the counterparty. Others, for the seller. There are some strategies that share 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.

In addition to price volatility, PPAs are a way to secure revenues to renewable energy producers. Countries all around the world are setting objectives of decarbonization and these include producing electricity with renewable energy. In order have stable revenues, PPAs are one of the best ways to allow investors to have assurance that their plants will be profitable.

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 market 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. Companies' main objective is to have a business plan in which their costs are known. Hence, knowing what they will be paying for electricity for a certain amount of time is what companies seek if they want to avoid risks. 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 and optimizing financial support from banks. Renewable energy plants are quite capital intensive. So in order to look for financing, one of the most used approaches is to opt for Project Finance. Banks or investors look for assurance in revenues that fit certain debt-service coverage ratio. As describe in the introduction, the electricity market is quite volatile and fixed revenue streams are seeked for. Hence, PPAs look like the optimal solution. However, there should be a balance between profitability and risk.

Even though the developer and the offtaker seem to pursue opposite positions, both look to hedge market risk by fixing their price, the first one is hedging itself from selling at low prices and the second one from buying at high ones.

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 that are usually associated.

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. An introduction to organized and Over the Counter markets, and their differences will be made. Also, their products will be presented.

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 price with a discount. All these risks will be explained. Nonetheless, there are not only market risks, but also other project development-related risks such as engineering, site and permitting or counterparty risks. These will be described, and a risk matrix will be portrayed to encapsulate these perils.

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 chosen will have to be taken at a company level.

3. Power Hedges

In the electricity sector, to hedge means to protect oneself of market risk. Markets are turbulent and constantly changing, thus, hedging oneself means making anticipated transactions that will give certainty over what the price will be in the future for a certain quantity needed. Sellers can provide a determined quantity that they want to sell (provided that they know the quantity) at a given price so that the revenues are fixed and known beforehand. The buyers get the benefit from closing a deal that gives the energy and quantity needed at a fair, unchanging price. In other words, power hedges are mitigation strategies that protect both, sellers, and consumers from markets fluctuations.

There are several techniques that energy companies use to hedge themselves. The most common one is the use of derivatives. Derivatives are financial instruments with a price settlement that depends on an underlying. Their future flows can be referred to different underlying, an interest rate, a Forex Exchange rate, a commodity price, stock prices or indexes or to other derivatives.
Derivatives can be traded in organized markets or in OTC markets. The main first generation of derivatives are futures, forwards, options, and swaps.

The most popular among them is signing a futures contract. This is an agreement to close a future purchase or sale at a predefined price and date. A forward is nothing else than a future but traded in the OTC market. Futures, being traded in organized markets have their advantages and disadvantages over forwards as it will be seen further on. PPAs, financially speaking, can be seen as forwards because the essence is the same.

Options give the owner (buyer) the right to buy (call option) or to sell (put option) certain asset at a predefined price and date. In order to have that right, a premium is to be paid by the buyer.

The last and least used derivative in the energy market is signing a swap. They are agreements to exchange different flows in the future, one receiving a fixed price and the other part receiving a floating price.

Even though there are many possibilities in which companies can prevent themselves from likely risk situations, futures and PPAs will be the ones discussed into further discussion since they are two most used, though opposed, options.

3.1. Organized Markets

Organized markets are known for being power exchanging entities that regulate the operations under the same standards for everybody. On some conditions, different agents are allowed to participate with no discrimination and playing within the same rules. In other words, organized markets, also known as wholesale electricity markets, are structured platforms where electricity is bought and sold. This is where power exchanges arise, that are nothing else than entities providing the possibility to trade on different modalities of organized markets. In the power industry, the organized markets are Futures, Day Ahead, Intraday and Balancing markets. Other derivates, such as options, can also be part of organized markets, even though these are less frequent.

According to Omiclear, this is what an organized market is: “a multilateral system that brings together or provides the possibility of bringing together the various buying and selling interests in wholesale energy products of multiple third parties to give rise to contracts, as defined in point (a) of No. 4 of Article 2 of Commission Implementing Regulation (EU) No. 1348/2014 of 17 December 2014” [2].
Understand the organized market as the OMIP, EEX profiles, etc. Clearinghouses where you contract with a central counterparty, not like in an OTC where you contract with an offtaker. It's important to note the differences in obligations and risks between the two, including cash flows, PnL, exposure, etc.
Having an organized trading platform offers numerous benefits to the market and its participants. It provides a reliable electricity price index and enhances transparency, which offers more opportunities and greater security for investors. This setup allows for

more efficient procurement or sale of electricity compared to traditional public procurement methods. It also minimizes counterparty risk and provides opportunities for risk mitigation. As an additional tool for managing trading risk, it helps create a price signal that enables operators to make economically sound decisions, such as buying or selling allowances, adjusting production, and selecting production methods. Additionally, it plays a crucial role in managing transmission system congestion. Moreover, trading activities become more efficient due to the standardized and regulated environment that supports these transactions [3].

As of now, there are seventeen organized marketplaces across Europe. Some countries, such as Spain, have their own Market Operator and Power Exchange (OMIE), whereas others have common Power Exchanges, such as France and Germany, that share EpexSpot. In the Spanish case, even though OMIE is not regulated, it is the only player in the country. However, that is only the case in the short-term markets. In futures markets, EEX, for instance, is another agent from which Spanish companies are allowed to trade with, adding more competition to the system. In the case of France, for instance, there are two Market Operators, which are EpexSpot and NordPool.

The European Union, in the energy packages, aimed at creating an internal European market that could provide flexibility and security of supply to its Member States. Hence, Nominated Electricity Market Operators emerged and adhered to act together managing day-ahead and intraday electricity markets.

The main principle and idea behind these markets is to provide energy agents with liquidity, competition, non-discrimination and security of settlement.
Even though liquidity is yet to be obtained, for instance, in the OMIP futures market, it is key in short-term markets. An example of this is that in the Spanish market, the energy traded including bilateral agreements is around 10 GWh higher than the energy traded in the day-ahead market. Given the fact that the average total energy traded is 30 GWh, around 67% of the energy is still traded in the day ahead, whereas the remaining 1/3 of the energy is traded by means of bilateral agreements.

Open markets are needed in order to make these markets work. Every agent acts under the same conditions so that the market is not distorted. In addition, bids are placed anonymously, prevailing the non-discriminatory treatment.

It is worth mentioning that besides organized markets, there are also organized schemes in the form of auctions, that given the fact that renewable energy is much needed, are taking a lot of importance in the sector. An auction may refer to any mechanism or set of rules for centralized exchanges. They are needed when markets either do not exist or they exist in an incorrect manner [4]. So far, the most well-known support mechanisms for renewables have been feed-in tariffs, which provided revenue irrespective of the market price. As of now, the current trend is heading towards Contract for Differences, CfDs. CfDs, are nothing else than PPAs held by governments in auctions. They provide a constant price called strike price, which is the one agreed (and bid) in the auctions.

However, CfDs are dependent from the market. If the spot market price is above the strike price, the generator will have to pay the consumers (government) the difference between the spot market price and the strike price, multiplied by the volume generated. If the spot market price is below the strike price, it will be the consumers who will have to pay the generator the difference between those two prices times the quantity. Hence the formula, seen from the generator's perspective is the following:

$$Revenue = Spot\ Price \cdot Q + Q \cdot (\text{Strike Price} - \text{Spot Price})$$

In which the first term of the formula is the actual physical activity of going to the market and the second term is the settlement of the CfD.

3.1.1. Futures

The present section will describe how futures contracts work. Futures are contracts ruled under organized markets.

As described before, futures contracts are agreements between two parties for the acquisition or sale of an underlying asset with a defined quantity and price in the future. In the case of study, the asset is electricity. These contracts are traded on a market. In the Iberian Peninsula, the Market Operator is called "OMIP", that together with the Clearing House "OMIClear" offer a trading platform for energy products. Not only do they offer futures being electricity and natural gas the underlying assets, but also other derivatives such as swaps, options and FTRs. Future contracts need to declare some specifications. Those are

- Quantity of the underlying asset
- Quality of the underlying asset
- The date and month of delivery of the underlying asset
- The units of price quotation & minimum change in price [5].

From the aforementioned, futures are usually traded physically. They can be seen as financial instruments, but under rare circumstances.

When a future is bought, the buyer takes a long position, aiming to hedge against price fluctuations, since the price is fixed at the agreed rate. From that moment until the effective date, the contract will be marked-to-market daily, resulting in cash flows based on the changes in market value. From the effective date until the expiry date, the settlement usually involves the physical delivery of the underlying asset or a cash settlement, as specified in the contract.

When you buy a futures contract, such as CAL 27 (which refers to a calendar year 2027 contract), you will not be making daily payments per se. Instead, the process involves daily mark-to-market adjustments. Each day, the value of the futures contract is re-evaluated based on the current market prices. If the value of the contract increases, your account will be credited with the gain. If the value decreases, your account will be debited with the loss. This is known as the mark-to-market process. To ensure you can cover potential losses, you need to maintain a margin account with a broker. If the market moves against your position and your account falls below the maintenance margin level, you will receive a margin call and need to deposit additional funds to bring the account back up to the initial margin level. From the contract's effective date to its expiry date, if you hold the contract until maturity, you will either receive the physical delivery of the underlying asset or a cash settlement, depending on the contract specifications.

In this mark to market process is where the main difference with a forward contract is. A forward contract does not have daily cash flows but what a period decided, literally, over the counter [6].

As for the products to be traded, in the power market, daily, weekly, monthly, quarterly or yearly products can be bought, meaning that the underlying asset will be acquired for that amount of time, starting on the moment that one buys it for.

The trading stage is a completely anonymous process in which two counterparties negotiate the exchange of the asset. In order to close the contract, both, the seller, and the buyer, need to provide a collateral (economical guarantee) to the clearing house. A clearing house is an independent entity associated with a futures exchange. It handles the settlement of trading accounts, the clearance of trades, the collection and management of margin funds, and oversees the delivery process and the reporting of trading information. It works as a protection for the counterparties.

The collateral is standardized. What this means is that the risk of not being paid in the event of default is reduced to zero. More precisely, while the probability is not strictly zero due to the potential for regulatory failure, such an occurrence is highly improbable. The guaranteed to be deposited is mathematically calculated so to be enough to cover the maximum loss in a one-day interval and it usually fluctuates between a 5% and a 10% of the total value of the contract. The collateral tends to be higher as the product is less liquid.

3.2. Over The Counter Markets

Over The Counter (OTC) markets are agreements between two or more independent parties where physical or financial instruments (power, bonds, swaps, options, etc.) are traded. As opposed to organized markets, contracts are tailored and made bespoke in every negotiation. For this purpose, parties agree on how the instruments will be settled and on all the conditions that might affect the tradeable good.

There is freedom of negotiation and products negotiated can be as imaginative as one may want. The flexibility is higher, as it is the risk. Agents operating in organized markets are hedge by the clearing house, which, in the event of default of the counterparty, will provide security to the party affected. However, that agent does not exist in bilateral contracts.

There are some advantages to signing these types of contracts. The first and most obvious is flexibility and customization. Another one is liquidity. As of now, futures markets are not very liquid. Signing a PPA, which can be seen as a future but traded Over The Counter, is much more liquid and can provide more opportunities than buying a future. A last point to bear in mind is the privacy that gives an agent to sign bilaterally a contract under Non-Disclosure Agreements (NDAs).

Nevertheless, these contracts expose agents to higher risks. Credit risk is the possibility that one party might default on the contract, jeopardizing the financial stability of the transaction. Market risk involves the inherent volatility of electricity prices and the lack of transparency, which can result in less effective price discovery. Regulatory risk is associated with potential changes in regulations that could impact OTC trading activities, creating uncertainty and compliance challenges. Additionally, operational risk encompasses the various risks related to the operational processes and systems involved in OTC trading, which can affect the smooth execution and settlement of trades.

The most notorious risk difference between organized and OTC markets may be the credit risk. While in the first one there is a whole entity that protects both counterparties from the risk of default, in the second one there is no such entity. Hence, both parties either agree on having a bank issuing a Letter of Credit (LC) or they ask for a Parent Company Guarantee (PCG).

A Letter of Credit is usually issued by a bank and acts as a commitment to make a payment when a criterion is met. Usually, that criteria is the event of default of the party that has been granted the LC. What banks get from this agreement is a fee provided buy the seller. A Parent Company Guarantee is, instead, a contract signed between a company and its client, which is usually a subsidiary of that same company. Therefore, there is an assurance that if the smaller company goes bankrupt, the parent will deal with the payment obligations [7], [8].

3.2.1. Power Purchase Agreements

A PPA (Power Purchase Agreement) is a long-term energy purchase or sales agreement between a renewable developer and a consumer in which the seller get guaranteed a price for the energy sold and the buyer knows at what price they will be buying the energy. It is an Over-The-Counter agreement and it does not necessarily need to be physical; it can also be financial (also known as virtual PPAs), in which there is no physical delivery of the energy. PPAs are known for being agreements in which what is exchanged is renewable energy.

In other words, the agreement essentially involves transferring the project and its environmental benefits (such as Guarantees of Origin). This commitment enables the renewable developers to make investment decisions considering profitability and risk, and/or to obtain the necessary financing to carry out the project. Besides, PPAs can be delivered onsite (Behind the Meter) or offsite, which means, that there is no direct connection between production and consumption.

PPAs are becoming more and more popular because of two main reasons. The first one is because the seller assures its revenues for a long term, which gives bankability and allowance for project financing. As renewable's industry is quite capital intensive, the form of financing is that of project finance, in which SPVs are created so to finance every asset independently from the others. In order to have banks finance these expensive projects, there must a sure revenue stream and this can be obtained, partially, with PPAs. The second one is because buyers' intention to sign PPAs is not only to assure their costs, which is important, but also to accomplish their decarbonization goals. Being PPAs agreements in which where the energy traded is renewable, buyers get green certificates, aligning with their climate change objectives.

PPAs' effervescence can be seen in the following graph, which is only referred to corporates:

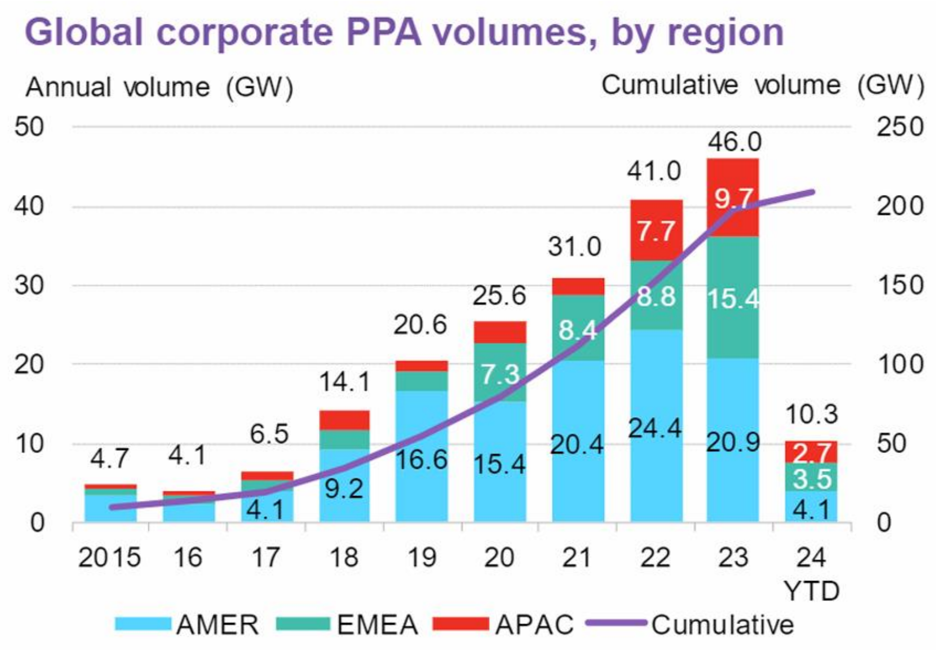

Figure 3. Global corporate PPA Volumes signed historically by region. Updated April 2024 [9].

As it can be seen, there is a huge fever for PPAs, as the corporate annual volume has increased tenfold in the last 8 years.

There are different types of PPAs. As explained before, they are contracts traded Over the Counter, thus, many structures can be taken into account. These will be further explained in the thesis. But now a brief introduction will be given.

PPAs can be divided into two main structures: volume and price structures. A volume structure is a way of setting with the counterparty a deal of what energy will be delivered. This can be either a fixed or a variable amount. The most common structure is the "As Produced" or "Pay as Produced". Which, in reality, means that there will only be a settlement when the power plant is producing. If the power plant is not producing, it essentially works as if no PPA existed. Another common structure is the fixed hourly profile structure. This is a contract in which the seller is committed to deliver (either physically or financially) a fixed shape of the production over a period of time. Inside of this category, the most common structures are the fixed solar profile (referred to PPAs signed with solar assets) in which a solar curve is committed, or the baseload structure, which aims at delivering a flat volume for the 24 hours of the day. This could be delivered in the case of a co-location of solar, wind and batteries, for instance.

Figure 4. PPA Volume structures [10].

The second main structure is the price structure. The most common one as of now is the fixed price structure, in which the seller receives a fixed price. This is also known as fixed for floating, in which the seller receives a fixed price, and the buyer receives a floating (variable) price according to the spot market price. Another common structure is the floor and market discount structure. In the latter, the seller gets, in the worst-case scenario, a fixed price of the aforementioned floor while when the market price is above the floor, it pays a discount to the offtaker. Other structures such as collars (floor and cap) or mixed structures are less common but equally valid.

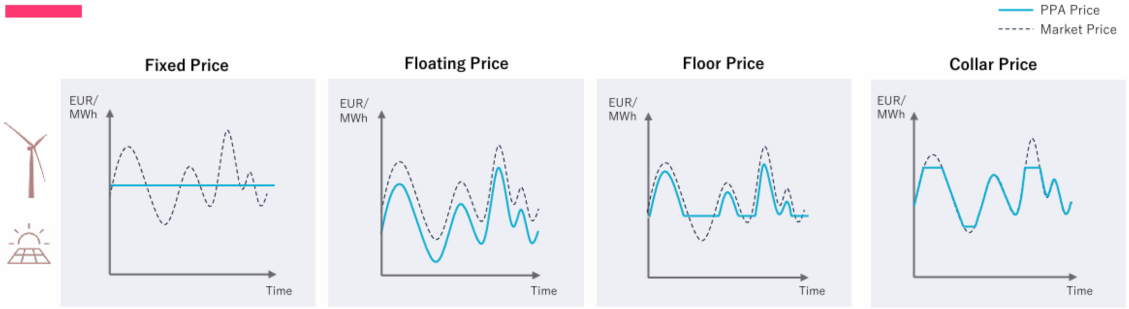

Figure 5. PPA Price structures [10].

4. Risk identification and assessment

From this chapter on, only Power Purchase Agreements will be dealt with. This fourth chapter will be about **identifying and assessing the risks that Power Purchase Agreements entail in a company like X-Elio**, which is a solar PV developer. The analysis will be based on PPAs signed in the **Spanish market**. X-Elio's value chain starts with the engineering of the project, followed by the site and permitting processes until it reaches a notice to proceed status, in which case an EPC is subcontracted. X-Elio owns a procurement and a construction team in-house even though the EPC is not done by the company itself. There is also an O&M team inside of the company, but the operation of the plants is subcontracted to BRPs too. Hence, to analyse what risks are entailed within PPAs, the different departments of the company will be analysed so as to identify what subjects can put at risk the signing of the PPA and their revenues.

X-Elio's strategy is to own mid-term the PV plants. Therefore, once they are constructed and running, the asset will be owned by the company for some time until its sold. This means that the revenue streams of the company come from three sides. The first and most obvious is from the electricity market. The energy that X-Elio produces with its solar assets is sold in the electricity market. The second revenue stream is fixing their revenues by means of PPAs. Therefore, depending on the strategy, energy revenues are split between PPAs and going to the market. Lastly, there is a clear revenue stream in selling the assets, in which the M&A team seeks for a return that matches X-Elio's expectations.

As to analyse X-Elio's risks when signing a PPA, this chapter will be segmented into different sections. These will cover the risks that each department entails and that the PPA team needs to bear in mind.

The strategy will be that of studying sub-risks inside of each team described previously. For instance, for the engineering team, there will be locational risks, land risks... and more. For every of those, some questions will be posed (so, inside of every sub-risk, there will be several hazards to be analysed), which ideally will have to be answered by the team involved in the peril. And depending on the answer, a risk percentage will be assigned to that threat. This refers to what extent the risk may affect the PPA or the project. A Route to Market (RtM) will be assigned to the risk depending on the percentage given previously and next steps will be defined.

After that, a probability will be set of the risk happening and the impact it may have on it, which will depend on the risk percentage previously assigned. The maximum of the risks' percentages assigned previously to the sub-risks will be called "blocker". In other words, if a sub-risk has, for instance, three questions, the biggest risk of those questions will be assigned to the impact. That percentage will be the one taken into account in the end when signing a PPA.

Finally, a risk matrix will be created for every sub-risk entailing a probability, going from Very High to Very Low and an impact, going from Very High to Very Low too.

An example of what a sub-risk inside of the engineering department would look like is seen below.

SUBRISKS	QUESTIONS	ANSWER	RISK	RTM	NEXT STEPS	PROBABILITY	IMPACT		BLOCKER	RISK MATRIX
LOCATION										
Interest Zone	How saturated is the market for solar PV developers in the location where the plant is to be installed	Not saturated	26-50%	Moderate Risk	Analysis and Mitigation studies	90%	No impact	50%		VL-VH
	How saturated is the capacity of the interconnection facility we are connecting to? (Is there enough interconnection capacity)	Not saturated	1-25%	Low Risk	Proceed with minimum caution	90%	No impact	25%	75%	VL-VH
	How stable is the regulatory environment in the specific zone where the PV plant is located?	Highly Unstable	51-75%	High Risk	Reevaluate and consider alternative projects	85%	↓ IRR	75%		M-VH

Figure 6. Sub-risk analysis table for the engineering team.

The risk matrix will look this way:

PROBABILITY			IMPACT 1 VL	IMPACT 2 L	IMPACT 3 M	IMPACT 4 H	IMPACT 5 VH
80-100%	5	VH	LOC.1.1 LOC.1.2 EPC.1	LOC.1.1 LOC.1.2 EPC.1	LOC.1.1 LOC.1.2 EPC.1	LOC.1.1 LOC.1.2 EPC.1	LOC.1.1 LOC.1.2 EPC.1
61-80%	4	H	LOC.1.1 LOC.1.2 EPC.1	LOC.1.1 LOC.1.2 EPC.1	LOC.1.1 LOC.1.2 EPC.1	LOC.1.1 LOC.1.2 EPC.1	LOC.1.1 LOC.1.2 EPC.1
41-60%	3	M	LOC.1.1 LOC.1.2 EPC.1	LOC.1.1 LOC.1.2 EPC.1	LOC.1.1 LOC.1.2 EPC.1	LOC.1.1 LOC.1.2 EPC.1	LOC.1.1 LOC.1.2 EPC.1
21-40%	2	L	LOC.1.1 LOC.1.2 EPC.1	LOC.1.1 LOC.1.2 EPC.1	LOC.1.1 LOC.1.2 EPC.1	LOC.1.1 LOC.1.2 EPC.1	LOC.1.1 LOC.1.2 EPC.1
0-20%	1	VL	LOC.1.1 LOC.1.2 EPC.1	LOC.1.1 LOC.1.2 EPC.1	LOC.1.1 LOC.1.2 EPC.1	LOC.1.1 LOC.1.2 EPC.1	LOC.1.1 LOC.1.2 EPC.1

Figure 7. Risk Matrix of the Engineering team.

The sub-risks will be analysed in each of the following sections. So will be the questions posed and the answers. The risks, RtM and Impact will now be described since they are common for every team.

1. Risk

As described previously, this section describes how badly can a peril affect the PPA signature of the project being discussed. It is directly related to the impact section, since the latter is obtained from the risk percentages. For every sub-risk, a risk percentage is assigned within a range. The ranges are the following:
0%, 1-25%, 26-50%, 51-75%, 76-99%, 100%
The lowest meaning that there is no hazard involved and the highest meaning that there is no way the project can move on with that risk being present.

2. Route to Market

This section is derived from the previous one. There are six routes to market, as there are six risk ranges. Here is the table that describes it:

Risk	*Route to Market*
0%	No Risk
1-25%	Low Risk
26-50%	Moderate Risk
51-75%	High Risk
76-99%	Very High Risk
100%	Loss of Project

Table 1. Risk and Route to Market association.

The strategy for every project will be based on this analysis. As shown before in the risk matrix, this table will be directly associated with a probability, so maybe there is a very high risk of something happening, but its probability is minimum so the company may decide not to take it into account.

What this RtM is aiming at is at providing the difficulty of moving on with a Power Purchase Agreement if there a risk. And it can be seen from both parties perspectives. Either from X-Elio's side, which may not want to proceed with an offtaker if there is a high risk or from the counterparty's side, who may stop the negotiations due to the perils.

3. Impact

Impacts are not directly dependent on the risk percentage set for a certain sub-risk. However, there should be a connection between them. The impacts considered are the following:

Impact	*Risk Matrix Identification*
No Impact	Very Low
↓ IRR	Medium
↑ IRR	Medium
↓↓ IRR	High
↑↑ IRR	High
Loss of Financing	High
↓↓↓ IRR	Very High
↑↑↑ IRR	Very High
Default	Very High

Table 2. Impact and risk matrix identification.

Even though there is not a direct link between, for instance, *0% risk* and *No Impact*, implicitly there should be some consistency between the two sections. However, one could consider that having a risk that goes from *1 to 25%* can also be associated with *No Impact*. And that is completely valid too.

It is X-Elio's decision to proceed with the project and PPA negotiations, but these impacts provide an overview of what could happen if the risk finally appears.
The remaining sections, as portrayed in Figure 6. Sub-risk analysis table for the engineering team. are: Questions, Answer, Next Steps, Probability and Blocker. However, these are not fixed and may change from sub-risk to sub-risk.

4.1. Engineering

As described before, X-Elio's company structure starts with the engineering team. In this chapter, the engineering team will not be analysed alone, but it will also include the Construction, Procurement and EPC departments.

Usually, the PPA team involved in signing long-term contracts has to be aware of every stage of the solar project. However, the commercialization of a project does not start until a moment in time in which many of the risks have been phased out. As a company, X-Elio starts looking for counterparties as soon as the *Declaración de Impacto Ambiental (DIA)* is obtained. Hence, it is evident that some of the following sub-risks will need to be seen as low risk to proceed with the PPA commercialization.

In the context of a Photovoltaic Independent Power Producer (IPP) developer, engineering risks associated with Power Purchase Agreements are critical factors that can significantly impact project success and financial stability. These risks encompass a range of technical challenges, including the reliability and performance of solar panels, the efficiency of energy conversion, and the integration of the photovoltaic system with existing grid infrastructure. Additionally, considerations such as site selection, weather variability, and potential technological obsolescence must be meticulously managed to ensure that the energy output meets the contractual obligations of the PPA. Understanding and mitigating these engineering risks is essential for optimizing project outcomes and securing long-term revenue streams.

Some sub-risks have been detected and will be thoroughly studied in this chapter.

4.1.1. Location

Location risk is a pivotal engineering concern for Photovoltaic IPP developers, as the geographical and environmental characteristics of a project site directly influence the efficiency and viability of solar energy production. A thorough assessment and strategic selection of the project location are crucial to mitigating risks and ensuring the long-term success of the PPA.

Several key factors will be analysed to ensure project success. These include Interest Zone risks, which pertain to market saturation and the regulatory environment that can impact project feasibility and profitability. Additionally, the balance between Generation and Demand is critical, as it involves evaluating whether the energy generated is sufficiently close to demand centres and identifying any restrictions on grid access. Lastly, the Opposition of local inhabitants is a significant consideration, as community resistance can lead to delays, increased costs, or project modifications.

1. Interest Zone

The questions posed regarding the interest zone are the following:

- How saturated is the market for solar PV developers in the location where the plant is to be installed?

This is a risk because curtailment for renewables is getting worse as more clean energy is being deployed. Our analysis, for instance, is that in the east side of the Iberian Peninsula there is no risk of curtailment, whereas in the west side of Spain, as of now there is a curtailment of around 5% that will decrease as the nuclear plant in Extremadura, Almazar, is closed by 2027 and as the demand increases with a hydrogen corridor.

- How saturated is the capacity of the interconnection facility the plant is connecting too?

Maybe, what happens is that there is not enough renewable competition, but the interconnection is saturated so that the PV plant will have to be technically curtailed. Before, it was about economic curtailment and, in this case, it is more of a technical restriction.

In PPAs, there must be clauses considering these curtailments. As for the technical one, it is not usually penalised, and it is included as **excused hours**, in which the PPA clauses do not apply. However, the economic one is not excused and if the plant is not producing it may not reach **minimum availability levels**, for which the seller will be penalised.

- How stable is the regulatory environment in the specific zone where the PV plant is located?

It is important to bear in mind that when installing a utility scale PV plant, it is not only about market regulation, which in the case of Spain, being a nodal market, might not necessarily be important to take into account when choosing the location, but what it is important is to know the councils and players that have to be dealt with in order to deploy the plant. If there are advanced negotiations of a PPA, a huge opposition might but the signature at risk.

2. Generation vs. Demand

The questions posed regarding generation versus demand are the following:

- Is generation close to demand? Is it a close area to industrial hubs or to consumption centres?

As mentioned above, when dispatching the plants the TSO must take into account security of supply. By being closer to generation, it is easier to be dispatched. Even though it is always easier to redispatch renewables because they are unpredictable, being close to generation gives them an advantage.

- Are there any restrictions on grid access or tariffs that could affect the economic viability of supplying electricity to nearby demand centres?

Restrictions on grid access can include limitations on the capacity of the transmission lines, regulatory barriers, or the availability of connection points to the grid. These restrictions can create bottlenecks that hinder the efficient distribution of electricity from the generation site to the demand centres. Additionally, tariffs imposed on grid usage can significantly impact the cost structure of delivering electricity. Higher tariffs may erode profit margins and reduce the overall economic attractiveness of the project.

3. Opposition

The question posed regarding generation versus demand is the following:

- Is it a location prone to high opposition of the inhabitants?

There is a risk of non-achieving the projects expectations due to neighbourhood complaints. It can affect the project by delaying it or even by its termination. Moreover, sustained opposition can escalate to legal challenges, protests, or campaigns against the project, potentially resulting in increased costs and extended timelines.

4.1.2. Land

It is essential to consider four critical sub-groups: topographical study, hydrological study, geological study, and land security. A topographical study evaluates the physical features of the land, such as elevation and slope, which can affect construction and efficiency. The hydrological study assesses water-related factors, including drainage and flood risk, to ensure the site is suitable and resilient to water-related issues. Geological studies are crucial for understanding soil composition and stability, impacting foundation design and long-term structural integrity. Lastly, securing the land involves legal and logistical processes to ensure ownership or long-term leases, mitigating risks of land disputes or access issues.

1. Topographical study

The question posed regarding generation versus demand is the following:

- Has the topographical study been conducted? If not, is there a plan to make one?

It is crucial for ensuring the feasibility, efficiency, and success of a construction project. It provides essential data for site suitability assessment, informs design and planning, and aids in accurate cost estimation. Additionally, it helps mitigate risks by identifying potential obstacles, ensures regulatory compliance, and considers environmental impacts

2. Hydrological study

- Has the hydrological study been conducted? If not, is there a plan to make one?

This study evaluates drainage patterns, flood risks, and water table levels, which are critical for site suitability and design. It helps prevent water-related issues such as erosion, foundation damage, and drainage problems.

3. Geological study

- Has the geological study been conducted? If not, is there a plan to make one?

It provides crucial information on soil stability, rock formations, and potential geological hazards such as landslides or sinkholes. It informs foundation design and construction methods, ensuring the structural integrity and safety of the project. Additionally, a geological study helps in estimating excavation costs and identifying suitable materials for construction.

Without all these permits, the project cannot proceed and therefore no PPA can be signed.

4.1.3. Equipment

As much as this section would have to be described inside of the procurement team, as said at the beginning, it has been included here so as to keep track of the main processes of the company. Therefore, only one sub-group will be considered (procurement).

This sub-group encompasses the selection, acquisition, and quality of essential equipment and materials. Ensuring procurement on time of high-quality is vital to maintaining the project schedule and avoiding delays. What is more, evaluating the reliability and compatibility of equipment reduces the risk of operational failures and maintenance issues.

The questions posed regarding procurement are the following:

- Have we worked with the current supplier?

Thus, an insight can be obtained of how well it works, if there have previously been any delays, if the materials are of enough quality…

- If we have not worked with them, do they have a good reputation?

As before, it is about getting to know the supplier and estimating whether the modules and other equipment will be on time and will be of good quality.

- Are there any potential supply chain disruptions or material shortages that could impact the timely delivery of equipment for the PV plant?

All these risks (location, land and procurement) are important when considering the **Commercial Operation Date** (COD). It is a crucial date when signing a PPA. There are three dates that are usually taken into account in the contracts. The first one is the **expected COD**, which is when the PV plant will be delivering the amount of energy that was agreed. The second is the **targeted COD**, which is a buffer between the expected and a reasonable delay agreed between both parties. From this second date on, delay damages usually apply. These damages are payments by MW of the plant and by days of delay. Therefore, if the targeted COD is reached, there will be daily payments of an amount times the MW of the plant. The third one is the **Longstop date** or termination date, from which the counterparty can terminate the contract. From this, it is evident that dates and delays are massively important.

4.1.4. Design

When analysing the design risk, the focus is put on the layout of the PV plants. It is of outmost importance to have a well-built design that fits in the land secured and that maximizes the energy output. As happened with curtailment, what is important usually in a PPA is to deliver a **minimum amount of energy**. Thus, if a PPA is signed with a volume that will be met and the layout or power of the plant change, it is a massive risk.
The questions are:

- Is it likely that the layout will be changed? Will it be for an increase or decrease of the power output?

4.1.5. EPC

Ensuring a competent EPC process is of utmost importance to adhere to project timelines, maintain budgetary constraints, and achieve the desired quality standards. Similar to the design risk, a well-executed EPC process ensures that the project is completed efficiently and meets the specifications required to fulfil the PPA commitments. Besides the minimum energy delivery clause as mentioned above, this can also lead to a **capacity shortfall**, in which the total capacity of the plant is lower than the one set in the contract. As it is subcontracted, the questions posed are whether it is going at the pace required and whether if it is complying with the regulatory requirements under the EPC agreement.

4.1.6. Delays

This section refers to the last paragraph of section 4.1.3. The company should always be aiming at delivering before the expected COD and, if that is not possible, tracking the process so as to deliver before the longstop date that may terminate the contract.

4.2. Site and Permitting

X-Elio does not usually start the commercialization of a project does not start until a moment in time in which the *Declaración de Impacto Ambiental (DIA)* is obtained. Therefore, fore the sake of simplicity, it will be assumed that the interconnection permit and access have been granted previously to the Environmental Impact Assessment (EIA) and therefore have no effect on the PPA.

4.2.1. Environmental Impact Assessment

The EIA is a permit that has to be conceded declaring that there is no environmental damage on constructing the solar project where it will be deployed. Depending on the voltage and where it is being installed, there are different administrative bodies responsible for processing the assessment.

For 400 kV projects or 220 kV located in more than one autonomous community, it is the General State administration who will proceed to accept the report. For 220 kV projects or lower, it will be the autonomous community [11].

Getting the EIA usually lasts for 15 to 24 months. The risk of signing a PPA prior to its obtaining is that if the EIA is proven negative, the whole project has to be cancelled and therefore no PPA applies. The **Development Security** deposit will have to be paid, which usually goes from 75,000 €/MW to 100,000 €/MW. There are some clauses that suggest project replacements, in the event that this situation (or the following ones) happen.

4.2.2. Autorización Administrativa de Construcción (AAC)

After being given the EIA, the next permit to be obtained is the AAC. This permit is the one that grants the developer with the right to begin construction. From this time on, there is more visibility on the timeline and a better approach to the expected COD can be given.

The risks that apply here are the same as in the prior point, and that any delay can get a project to enter into the delay damages phase until longstop date.

4.2.3. Autorización de Explotación (AE)

The AE allows the installations to be put into operation. This would actually mark the beginning of the PPA effective date.

For all these permits, there are regulatory risks, which can be mitigated by setting "change in law" clauses, that protects the PPA of possible regulatory changes that can disrupt its normal operation, or the achievement of the permits on time.

4.3. Operational

Operational risks are focused on how the plant will behave under misleads of events or unexpected situations. Additionally, it also covers mistakes due to error in forecasting. As such, they will so much be linked to revenues and delays.

4.3.1. Production Forecast

Whenever a PPA is closed, one of the main features the buyers ask for is the production forecast. What it is usually given is the P50, or, in other words, a production forecast that 50% of the times will be lower and 50% of the times will be higher. It is a good measure to get the expected revenues if the prices curves for the future are well calculated. Usually, the confidence level in the long-term weather forecast used is enough to not deviate much from the real production.

The main risks corseted in the production forecast are revenue calculations beforehand, which is actually one of the features sellers and buyers are aiming to know when signing a PPA. The other main risk is not delivering the minimum capacity that was agreed. Further detail will be provided on the risk when signing different volume structures and their relationship with the production forecast.

4.3.2. Equipment Damage

Another interesting point to take into consideration is the amount of time and the number of times that equipment is malfunctioning. In the event that a solar cell is not working there is not much problem. However, if it is a failure in a transformer, the problem gets bigger. As said in the previous point, there can be severe damages in terms of revenues because of not producing as much as expected. In the case of a physical PPA, energy would have to be bought in other markets, therefore, if bought higher than the cost of the BRP, it would mean losing money. In the event of a financial PPA, in the case of an "as produce" it will just mean no production so no PPA in place (besides having to achieve minimum availability clauses). In the event of a fixed profile, if the market price is above the PPA price, there will be a negative settlement. However, if the market price is below, there will be a positive settlement even though the plant might not be producing.

4.4. Counterparty & Credit risks

Counterparty and credit risks in the context of Power Purchase Agreements (PPAs) are crucial, as these risks involve the possibility of financial loss due to a counterparty's failure to meet the terms of the agreement. This typically concerns the off-taker's inability to purchase or pay for the power generated, often influenced by their financial stability or changes in market conditions. These risks are integral to the feasibility and profitability of PPAs, since any default can disrupt cash flows and overall financial planning. To mitigate these risks, it is essential to set appropriate credit limits, and possibly secure guarantees or insurance to protect against default and ensure the continuity of payments.

4.4.1. Counterparty Default

Counterparty default is the biggest risk there is for the buyer, since the counterparty cannot live up to its expectations and there is no chamber to support it. That is why, seller's sought for in X-Elio are investment grade ones with diversified revenue sources and that operate (if possible) in industries with stable demand.

As explained in point 3.2. what is done to prevent this from being a risk is to either issue a letter of credit (from both sides) or to have a Parent Company Guarantee that backs the agent up.

4.4.2. Seller Damages

There are several risk mitigation clauses that help prevent counterparty default. Delay Damages clauses are implemented to compensate for financial losses arising from delays in project completion, ensuring the developer adheres to the agreed timeline. They are calculated as the cost of opportunity of not reaching the Targeted COD and are to be paid from that date onwards. Capacity Shortfall Damages are stipulated to cover losses when the energy generation does not meet the contracted capacity, thereby protecting the off taker from under-delivery. Early Termination Fees are designed to secure compensation for the non-breaching party if the agreement is prematurely terminated, providing a disincentive against unjustified cancellations. Performance Guarantee Damages serve to enforce the quality and reliability of the energy supplied, with penalties for failing to meet specified performance standards. Lastly, a Development Security clause, often synonymous with performance guarantees, ensures that the developer has a financial stake in meeting the development milestones, safeguarding the project’s progression and completion. Each of these clauses plays a vital role in securing the investment and operational aspects of PPAs, ensuring that both parties have clear remedies and protections against various project risks.

4.5. Legal Risks

Legal risks in Power Purchase Agreements (PPAs) are predominantly associated with regulatory stability and compliance, which are vital for maintaining the viability and enforcement of the contract terms. These risks can arise from changes in energy regulations, environmental laws, or other legal frameworks that impact the operation and profitability of energy projects. For instance, sudden shifts in regulatory policies can lead to increased costs, operational constraints, or even the revocation of essential licenses.

Additionally, failure to comply with current laws can result in penalties, legal disputes, or damage to reputation.

4.6. Energy Management

This is the main part that may affect the PPA. This chapter will cover from price and volume structures to market volatility, curtailment and cannibalisation. PPA structures will be now analysed in further detail after what was seen in chapter 3.2.2.

4.6.1. PPA Volume Structure Risks

As explained previously, there are two main volume structures that are being signed in the market at the moment. The first and main one is the "*As Produced*" structure. The second one is the *"Fixed Profile"* structure.

4.6.1.1. As Produced

The risk in this structure is limited to the seller since what is earned is dependent on the volume produced in every moment. The settlement formula for a physical contract is the following:

$$Revenue = Strike\ Price \cdot Q_{PPA}$$

Where the strike price is the PPA price and Q is the quantity varying every moment. Therefore, if there is no quantity, there is no revenue. However, that would be the same effect as if the seller went merchant. Thus, the risk is limited to clauses of availability and to non-revenue issues, but it is not a matter of the PPA.

As for the financial contract, the formula is the following:

$$Revenue = Spot\ Price \cdot Q + Q_{PPA} \cdot (\text{Strike Price} - \text{Spot Price})$$

The first term refers to the revenues obtained from the plant going merchant with a 100% of the volume and the second term is the financial trade, in which the quantity is variable and dependent on the contract. It might be agreed to be an x% of the total volume of the plant. As it happened before, the risk is sealed since if there is no quantity sold, revenues go to zero as if there was no PPA.

The risk of the offtaker in that moment is the market price since, if it needs the energy, it will have to go full merchant without the hedge of the PPA. Therefore, if the spot market is lower than the PPA price, the counterparty will be losing money and if it is higher, it will be better off.

The conclusion is that the volume risk lies in between the offtaker and the producer.

4.6.1.2. Fixed Hourly Profile

By setting a fixed profile that will need to be delivered (either physically or financially) the risk increases exponentially, as so will the possible revenues (or decrease). In the physical contract, when setting a volume that has to be delivered, in the event that the plant is not producing for any reason (a transformer is damaged, there is no sun…) the energy will have to be purchased somewhere else. Risk will then depend on trading and on the prices for those days in which the PV cannot produced what was stablished in the profile. High prices will mean loss of money for the producer, but low prices will mean a good deal. The risk for the offtaker thus is completely limited to the payment of the PPA price times the profile agreed.

Regarding the virtual structure, according to the prior formula, Q_{PPA} is now fixed and therefore the financial term will always exist. High spot prices will mean a negative settlement for the producer and low spot prices will mean a positive one. So that term will be either positive or negative and will always be multiplied by the same volume. Therefore, the risk comes when there is no production (the physical part does not exist, or it is reduced) and prices are high since there will be a full negative settlement. On the other hand, if prices are low and there is no production, there will be “free money” as a positive settlement will be agreed even though the producer is not generating electricity.

4.6.2. PPA Price Structure Risks

As of now, two main price structures complement the volume structures. The first and most basic is the "*Fixed Price*" structure. The second one is the "*Floor and Market Discount*".

4.6.2.1. *Fixed Price Structure*

In this price structure the buyer agrees to pay a fixed price and the seller agrees to receive it. The physical PPA reduces every type of risk as costs and benefits are known beforehand. The offtaker know how much it will be paying for electricity for a long-term. The seller know how much it will be getting from selling the amount of electricity set in the volume structure.

As for the financial term, as in every CfD, the seller will pay the buyer the difference between a fixed, known, price when the spot market is higher than the PPA price and vice versa.

This arrangement provides a layer of financial predictability and security for both parties involved. However, it is important to consider the broader market implications of such agreements. While financial PPAs and physical PPAs stabilize cash flows, they also shift the focus to operational efficiency and market predictions. For instance, sellers are incentivized to maximize production efficiency to ensure they meet the contracted volumes, as their revenue is secured at a predetermined rate. Conversely, buyers, can better manage their budget and energy procurement strategies, mitigating the volatility of spot market prices. Nevertheless, this security comes at the cost of flexibility, as both parties lock in terms at the outset, potentially missing out on beneficial market shifts.

4.6.2.2. *Floor and Market Discount Price Structure*

This structure combines the fixed price when market values go lower than the floor and a discount on the market when the spot prices are higher than the floor.

Therefore, the PPA Price is defined as follows:

$$PPA\ Price = Maximum\ (Spot\ Price - Discount; Floor)$$

The discount can be either a percentage of the spot price or a nominal value in €/MWh. The risk is higher when it comes to be a percentage since it is dependent on market prices. If the curve skyrocket, the amount to pay will be higher than if the spot price is slightly above the floor price. In the other case, the payments are known beforehand.

The risk is in not capturing a high price due to a miscalculation of the floor. If the floor never applies and prices go quite close to the floor, the structure would be misused. However, if prices go down, the seller will always receive the floor, getting an upside that is a loss for the buyer. The risks for the buyer then are extreme prices. What the buyer pays if prices go up is the market price minus a discount. If prices go really high, they will still be paying high prices and having really costly electricity. On the other hand if prices go really down, they will still be paying the floor, not getting any advantage. Many times what the buyer is looking for with this structure is to get Guarantees of Origin regardless of the price.

4.6.3. Market Volatility

Although market volatility is implicit to the prior structures, it is worth mentioning. As seen before PPAs are a way of hedging the revenues but they still depend on market prices. Having the full portfolio (volume) hedged is a way of ignoring market volatility in the event of signing as produced physical PPAs, but it does not give any upside. Therefore, while sellers secure a steady revenue stream, they forfeit the opportunity to capitalize on low spot market prices. For buyers, while this structure shields them from price spikes, it similarly prevents them from benefiting from drops in market prices below the strike price. This trade-off highlights the essential balance between stability and opportunity in managing energy portfolios, where the decision to utilize PPAs as a hedge needs to be strategically aligned with broader market expectations and individual risk tolerance levels.

4.6.4. Curtailment

Curtailment in solar assets is currently a hot topic. The introduction of more renewable assets than the grid can support leads to two main issues. The first one to be addressed is economic curtailment. Economic curtailment is a company's own decision to stop producing due to non-beneficial revenue streams obtained from the market. As renewable capacity goes up, prices go down, therefore some plants may want to stop producing since they are not going to be obtaining any revenues. A PPA relieve this situation as producers may be willing to produce more often than usual since in the event of low prices they are hedged.

The second type of curtailment to be addressed should be technical curtailment. Technical curtailment is a decision from the TSO. The System Operator can decide to make a plant not produce in the event of risk of supply in the network. Usually, there are three factors that put the grid at risk. These are voltage levels, frequency and lines capacities. Renewables are usually the ones to be curtailed downwards in phase one of technical restrictions since there is over production. And this type of curtailment, if it is downwards (which is most of the time), it is not remunerated. This is a massive risk in the case of fixed shape PPAs because they have the urge to produce in the event of high prices. In the case of as produced PPAs, it is not such a relevant matter.

4.6.5. Cannibalization

Cannibalisation is so much related to the prior point. Cannibalization in power markets refers to the downward pressure on electricity prices resulting from the increased penetration of renewable energy sources, such as solar and wind power. This phenomenon occurs because the marginal cost of producing electricity from renewables is close to zero, leading to lower wholesale electricity prices during periods of high renewable generation.

Therefore, cannibalisation leads to revenue uncertainty. As more renewable energy sources enter the market, the increased supply during peak production times leads to lower electricity prices, which in turn reduces the revenue for renewable energy projects. This uncertainty in revenue can deter investment in new renewable projects.

High levels of renewable penetration, particularly from variable sources like wind and solar, can also challenge grid stability. The intermittent nature of these sources requires enhanced grid management and balancing capabilities to prevent blackouts and ensure a reliable power supply.

5. STRESS TEST ANALYSIS

The objective of the stress test is to compare different strategies and contracts to achieve the highest possible benefits at the lowest risk. In the case of X-Elio, as a developer of photovoltaic plants, there are several scenarios. On one hand, it can leave the plant to merchant, or, on the other, it can close a PPA that covers it from risks. The tests conducted start from a base case of production (P50) and prices. The goal is to set a route to market to a PV plant in X-Elio's portfolio. The name of the plant is Lucainena, and it is located in Almería. Therefore the production selected will be that of Lucainena. As for the price -Elio's future forecasts. These curves are in Euros/MWh in real terms as of 2024.

The analysis is based on the potential variations in prices and production throughout the year. The scenarios will involve a combination of different financial PPA prices along with daily price and volume stresses.

In the following chapter the strategies to be analysed will be those of a fixed price combined with an *as produced* structure as well as with a *fixed solar* profile. The floor and market discount price structure will be combined too with an *as produced* structure and with a *fixed solar* profile structure. The Revenues will be derived from the calculations made and it will be faced against merchant results.

5.1. Fixed Price Structure

For the consequent chapter, the profit and loss resulting from the PV asset going merchant will be compared to the revenues resulting from the PV asset either closing an *as produced* power purchase agreement or closing a *fixed shape* PPA.

5.1.1. Revenues Merchant Vs. Revenues *As Produced* at a fixed price

In this first scenario, the comparison will be made between the revenues that could be obtained from the plant if it were left purely to the spot market versus those that would be obtained if a fixed price *As Produced* PPA were closed.

In the base case shown below, we start with an estimate of prices and production. To obtain the benefits, which is the focus of the analysis, the calculation is the product of the hourly spot price and the estimated production.

As an initial analysis, applicable to all scenarios, the comparison will be made between the projected average price for the year 2024 and the projected captured solar prices (average price where solar production is zero), along with the captured prices weighted to the P50 of our plant.

$$Average\ Price = \frac{\sum_i P_i}{N} = 89.85 \frac{€}{MWh} \quad \forall\ i$$

Equation 1. Average price in 2024.

$$Captured\ Price = \frac{\sum_i P_i \cdot \rho_i}{\sum_i \rho_i} = 50.49 \frac{€}{MWh} \quad \forall\ i$$

Equation 2. Captured solar price in 2024.

Where:

P_i : Spot price

N = Number of annual hours

ρ = Production

i: Hour in the year

This first result gives us an initial intuition, without considering other parameters, of what a fair fixed PPA price for an *as produced* structure might be. What the captured price indicates is that the expected benefits if I do not sign a PPA (going to D-1) will be the same as if I sign an *as produced* PPA with the fixed price of the captured solar price.

$$Revenue\ Merchant\ = \sum_{i} P_i \cdot \rho_i = 3{,}836{,}600.83\ € \ \ \forall\ i$$

Equation 3. Revenues going merchant.

$$Revenue\ with\ the\ PPA\ = \sum_i (P_i \cdot \rho_i) + \ Q_f \cdot \ \rho_i \cdot (P_{PPA} - P_i) = 3{,}836{,}600.83\ € \ \ \forall\ i$$

Equation 4. Revenues with an as produced PPA being the fixed price the solar captured price.

Where:

Q_f : Financial quantity that is closed in the PPA.

P_{PPA} : Financial price (PPA price)

As a first conclusion, we find that by **closing a PPA price equal to the captured solar price**, we obtain **the same revenues as if we went directly to the market for any financial quantity** we set.

Below are the results of the first stress test conducted, which analyses the Revenues in response to variations in prices (horizontal) and production (vertical).

Revenues Merchant	3,836,660.83 €	80.00%	85.00%	90.00%	95.00%	100%	105.00%	110.00%	115.00%	120.00%
	80.00%	2,455,462.93 €	2,608,929.37 €	2,762,395.80 €	2,915,862.23 €	3,069,328.67 €	3,222,795.10 €	3,376,261.53 €	3,529,727.97 €	3,683,194.40 €
	85.00%	2,608,929.37 €	2,771,987.45 €	2,935,045.54 €	3,098,103.62 €	3,261,161.71 €	3,424,219.79 €	3,587,277.88 €	3,750,335.96 €	3,913,394.05 €
	90.00%	2,762,395.80 €	2,935,045.54 €	3,107,695.27 €	3,280,345.01 €	3,452,994.75 €	3,625,644.49 €	3,798,294.22 €	3,970,943.96 €	4,143,593.70 €
	95.00%	2,915,862.23 €	3,098,103.62 €	3,280,345.01 €	3,462,586.40 €	3,644,827.79 €	3,827,069.18 €	4,009,310.57 €	4,191,551.96 €	4,373,793.35 €
	100%	3,069,328.67 €	3,261,161.71 €	3,452,994.75 €	3,644,827.79 €	3,836,660.83 €	4,028,493.87 €	4,220,326.92 €	4,412,159.96 €	4,603,993.00 €
	105.00%	3,222,795.10 €	3,424,219.79 €	3,625,644.49 €	3,827,069.18 €	4,028,493.87 €	4,229,918.57 €	4,431,343.26 €	4,632,767.95 €	4,834,192.65 €
	110.00%	3,376,261.53 €	3,587,277.88 €	3,798,294.22 €	4,009,310.57 €	4,220,326.92 €	4,431,343.26 €	4,642,359.61 €	4,853,375.95 €	5,064,392.30 €
	115.00%	3,529,727.97 €	3,750,335.96 €	3,970,943.96 €	4,191,551.96 €	4,412,159.96 €	4,632,767.95 €	4,853,375.95 €	5,073,983.95 €	5,294,591.95 €
	120.00%	3,683,194.40 €	3,913,394.05 €	4,143,593.70 €	4,373,793.35 €	4,603,993.00 €	4,834,192.65 €	5,064,392.30 €	5,294,591.95 €	5,524,791.60 €

Figure 8. Revenues obtained going to the spot market under a stress test

The central value for production according to P50 and for a price level according to estimates is €3,836,660.83. When market prices rise, we can see from the horizontal row that profits increase. Similarly, if we move down the table, where production increases, profits also increase. This is a trivial conclusion since with an increase in market prices and higher production, the estimated profit increases. In the most favourable scenario, with production and price forecasts at 120%, gains are projected to be €5.54 million, representing a 44% increase. In the most unfavourable scenario, the gains are €2.45 million, representing a 36% decrease. **So going up in prices and volumes reflect a better impact than going down in the same variables**.

On the other hand, to see which impact is greater on profits, whether an increase (or decrease) in production or an increase (or decrease) in prices, we analyse the symmetry of the matrix. In this case, the matrix is symmetrical, so the impact is the same. This makes sense because profits are the product of market prices and production, so with an equal variation in prices and production, the impact is the same.

In the case of signing a PPA, in this initial approach, where the PPA price is the captured solar price, the volume at which we sign it does not matter. This analysis is done for a scenario where the volume is 80%, but the result would be the same if it were any other percentage.

	Revenues As Produced	3,836,660.83 €	80.00%	85.00%	90.00%	95.00%	100%	105.00%	110.00%	115.00%	120.00%
PRICES SCENARIO	100%	80%	2,946,555.52 €	2,977,248.81 €	3,007,942.09 €	3,038,635.38 €	3,069,328.67 €	3,100,021.95 €	3,130,715.24 €	3,161,408.53 €	3,192,101.81 €
PRODUCTION SCENARI	100%	85%	3,130,715.24 €	3,163,326.86 €	3,195,938.47 €	3,228,550.09 €	3,261,161.71 €	3,293,773.32 €	3,326,384.94 €	3,358,996.56 €	3,391,608.18 €
PPA PRICE	50.49	90%	3,314,874.96 €	3,349,404.91 €	3,383,934.85 €	3,418,464.80 €	3,452,994.75 €	3,487,524.70 €	3,522,054.64 €	3,556,584.59 €	3,591,114.54 €
FINANCIAL VOLUME	80%	95%	3,499,034.68 €	3,535,482.96 €	3,571,931.23 €	3,608,379.51 €	3,644,827.79 €	3,681,276.07 €	3,717,724.35 €	3,754,172.62 €	3,790,620.90 €
		100%	3,683,194.40 €	3,721,561.01 €	3,759,927.62 €	3,798,294.22 €	3,836,660.83 €	3,875,027.44 €	3,913,394.05 €	3,951,760.66 €	3,990,127.27 €
		105%	3,867,354.12 €	3,907,639.06 €	3,947,924.00 €	3,988,208.94 €	4,028,493.87 €	4,068,778.81 €	4,109,063.75 €	4,149,348.69 €	4,189,633.63 €
		110%	4,051,513.84 €	4,093,717.11 €	4,135,920.38 €	4,178,123.65 €	4,220,326.92 €	4,262,530.18 €	4,304,733.45 €	4,346,936.72 €	4,389,139.99 €
		115%	4,235,673.56 €	4,279,795.16 €	4,323,916.76 €	4,368,038.36 €	4,412,159.96 €	4,456,281.56 €	4,500,403.16 €	4,544,524.76 €	4,588,646.36 €
		120%	4,419,833.28 €	4,465,873.21 €	4,511,913.14 €	4,557,953.07 €	4,603,993.00 €	4,650,032.93 €	4,696,072.86 €	4,742,112.79 €	4,788,152.72 €

Figure 9. Revenues of an as produced, captured solar fixed price, under a stress test.

At first glance, it can be observed in the extreme values that signing a PPA cushions the impact of price variations. On one hand, in the most favourable scenario mentioned earlier, the profit is not as high as it would be if the plant were left purely to the merchant market. However, in the most unfavourable scenario, the revenues are higher than in the previous case, providing protection against sharp declines but not benefiting from significant increases. This can be better appreciated with the **spread** between the Revenues of the merchant strategy vs the Revenues of the *as produced* strategy (**Revenues PPA – Revenues Spot**).

	Spread		80.00%	85.00%	90.00%	95.00%	100%	105.00%	110.00%	115.00%	120.00%
PPA PRICE	50.49	80%	491,092.59 €	368,319.44 €	245,546.29 €	122,773.15 €	0.00 €	- 122,773.15 €	- 245,546.29 €	- 368,319.44 €	- 491,092.59 €
		85%	521,785.87 €	391,339.40 €	260,892.94 €	130,446.47 €	0.00 €	- 130,446.47 €	- 260,892.94 €	- 391,339.40 €	- 521,785.87 €
		90%	552,479.16 €	414,359.37 €	276,239.58 €	138,119.79 €	0.00 €	- 138,119.79 €	- 276,239.58 €	- 414,359.37 €	- 552,479.16 €
		95%	583,172.45 €	437,379.33 €	291,586.22 €	145,793.11 €	0.00 €	- 145,793.11 €	- 291,586.22 €	- 437,379.33 €	- 583,172.45 €
		100%	613,865.73 €	460,399.30 €	306,932.87 €	153,466.43 €	0.00 €	- 153,466.43 €	- 306,932.87 €	- 460,399.30 €	- 613,865.73 €
		105%	644,559.02 €	483,419.26 €	322,279.51 €	161,139.75 €	0.00 €	- 161,139.75 €	- 322,279.51 €	- 483,419.26 €	- 644,559.02 €
		110%	675,252.31 €	506,439.23 €	337,626.15 €	168,813.08 €	0.00 €	- 168,813.08 €	- 337,626.15 €	- 506,439.23 €	- 675,252.31 €
		115%	705,945.59 €	529,459.19 €	352,972.80 €	176,486.40 €	0.00 €	- 176,486.40 €	- 352,972.80 €	- 529,459.19 €	- 705,945.59 €
		120%	736,638.88 €	552,479.16 €	368,319.44 €	184,159.72 €	0.00 €	- 184,159.72 €	- 368,319.44 €	- 552,479.16 €	- 736,638.88 €

Figure 10. Revenues PPA as produced, fixed price - Revenues Spot under a stress test.

It is interesting to revisit the initial reasoning and see it reflected in the spread. Since the PPA price is the captured price, the spread for an unvarying market price (100%) is zero, resulting in the same revenues for all production levels. This is why the contracted percentage does not change the revenues, as mentioned in the previous paragraph. This applies to an unvarying PPA price but a spot price that varies proportionally.

On the other hand, we see the symmetry again. But in this case, if the forecasted price increases, the spread is negative, making it reasonable to opt for a merchant strategy. However, if the estimated price is expected to decrease, closing a PPA would be reasonable as the spread is positive.

If the PPA price changes downwards, it can be seen that revenues in all situations will decrease. This was to be expected. **The analysis to be drawn here is the percentage of prices at which a positive spread will be obtained compared to the merchant strategy**. While in the previous case, with a price decrease, the spread was positive, in this case, where the PPA price is below the captured price**, the spread will be negative except for the dumping effect of the PPA**. In other words, **the lower the PPA price, the less interest there is in signing it, as the spread with the market will be greater in favour of the market. And vice versa**. However, this situation can be reverted with interesting PPA prices and a decrease of the price curves. The advantage of the *as produced* strategy is that it poses no risk to the PPA and, in situations of falling prices, cushions the impact that the producer would face if operating solely in the daily market.

PRICES SCENARIO	100%
PRODUCTION SCENARI	100%
PPA PRICE	45.00
FINANCIAL VOLUME	80%

					PRICES				
Revenues As Produced 3,502,768.49 €	80.00%	85.00%	90.00%	95.00%	100%	105.00%	110.00%	115.00%	120.00%
80%	2,679,441.64 €	2,710,134.93 €	2,740,828.22 €	2,771,521.50 €	2,802,214.79 €	2,832,908.08 €	2,863,601.36 €	2,894,294.65 €	2,924,987.94 €
85%	2,846,906.75 €	2,879,518.36 €	2,912,129.98 €	2,944,741.60 €	2,977,353.22 €	3,009,964.83 €	3,042,576.45 €	3,075,188.07 €	3,107,799.68 €
90%	3,014,371.85 €	3,048,901.80 €	3,083,431.75 €	3,117,961.69 €	3,152,491.64 €	3,187,021.59 €	3,221,551.54 €	3,256,081.48 €	3,290,611.43 €
95%	3,181,836.95 €	3,218,285.23 €	3,254,733.51 €	3,291,181.79 €	3,327,630.06 €	3,364,078.34 €	3,400,526.62 €	3,436,974.90 €	3,473,423.18 €
100%	3,349,302.06 €	3,387,668.66 €	3,426,035.27 €	3,464,401.88 €	3,502,768.49 €	3,541,135.10 €	3,579,501.71 €	3,617,868.31 €	3,656,234.92 €
105%	3,516,767.16 €	3,557,052.10 €	3,597,337.04 €	3,637,621.98 €	3,677,906.91 €	3,718,191.85 €	3,758,476.79 €	3,798,761.73 €	3,839,046.67 €
110%	3,684,232.26 €	3,726,435.53 €	3,768,638.80 €	3,810,842.07 €	3,853,045.34 €	3,895,248.61 €	3,937,451.88 €	3,979,655.15 €	4,021,858.41 €
115%	3,851,697.36 €	3,895,818.96 €	3,939,940.56 €	3,984,062.16 €	4,028,183.76 €	4,072,305.36 €	4,116,426.96 €	4,160,548.56 €	4,204,670.16 €
120%	4,019,162.47 €	4,065,202.40 €	4,111,242.33 €	4,157,282.26 €	4,203,322.19 €	4,249,362.12 €	4,295,402.05 €	4,341,441.98 €	4,387,481.91 €

Spread (PPA PRICE 45.00)	80.00%	85.00%	90.00%	95.00%	100%	105.00%	110.00%	115.00%	120.00%
80%	223,978.71 €	101,205.57 €	- 21,567.58 €	- 144,340.73 €	- 267,113.87	- 389,887.02 €	- 512,660.17 €	- 635,433.31 €	- 758,206.46 €
85%	237,977.38 €	107,530.91 €	- 22,915.55 €	- 153,362.02 €	- 283,808.49	- 414,254.96 €	- 544,701.43 €	- 675,147.90 €	- 805,594.36 €
90%	251,976.05 €	113,856.26 €	- 24,263.53 €	- 162,383.32 €	- 300,503.11	- 438,622.90 €	- 576,742.69 €	- 714,862.48 €	- 852,982.27 €
95%	265,974.72 €	120,181.61 €	- 25,611.50 €	- 171,404.61 €	- 317,197.73	- 462,990.84 €	- 608,783.95 €	- 754,577.06 €	- 900,370.17 €
100%	279,973.39 €	126,506.96 €	- 26,959.48 €	- 180,425.91 €	- 333,892.34	- 487,358.78 €	- 640,825.21 €	- 794,291.64 €	- 947,758.08 €
105%	293,972.06 €	132,832.30 €	- 28,307.45 €	- 189,447.21 €	- 350,586.96	- 511,726.71 €	- 672,866.47 €	- 834,006.22 €	- 995,145.98 €
110%	307,970.73 €	139,157.65 €	- 29,655.42 €	- 198,468.50 €	- 367,281.58	- 536,094.65 €	- 704,907.73 €	- 873,720.81 €	- 1,042,533.88 €
115%	321,969.40 €	145,483.00 €	- 31,003.40 €	- 207,489.80 €	- 383,976.19	- 560,462.59 €	- 736,948.99 €	- 913,435.39 €	- 1,089,921.79 €
120%	335,968.07 €	151,808.35 €	- 32,351.37 €	- 216,511.09 €	- 400,670.81	- 584,830.53 €	- 768,990.25 €	- 953,149.97 €	- 1,137,309.69 €

Figure 11. Revenues of an as produced, low fixed price PPA, under a stress test and the spread with the spot market.

As it can be seen, the tendency for a 45€/MWh PPA is reverted as of 90% of change in prices. Of course there is a tendency to have lower revenues than if we went merchant, but what is interesting is that there are still positive spreads.

On the other hand, with a PPA price higher than the market captured price, the coverage will provide a positive spread even if spot prices rise. In the case of closing a PPA at €55/MWh, the spread will remain positive until the forecasted price increases by more than 5%.

	Revenues As Produced	4,110,643.23 €	80.00%	85.00%	90.00%	95.00%	100%	105.00%	110.00%	115.00%	120.00%
PRICES SCENARIO	100%	80%	3,165,741.44 €	3,196,434.72 €	3,227,128.01 €	3,257,821.30 €	3,288,514.58 €	3,319,207.87 €	3,349,901.16 €	3,380,594.44 €	3,411,287.73 €
PRODUCTION SCENARI	100%	85%	3,363,600.28 €	3,396,211.89 €	3,428,823.51 €	3,461,435.13 €	3,494,046.74 €	3,526,658.36 €	3,559,269.98 €	3,591,881.59 €	3,624,493.21 €
PPA PRICE	55.00	90%	3,561,459.12 €	3,595,989.06 €	3,630,519.01 €	3,665,048.96 €	3,699,578.91 €	3,734,108.85 €	3,768,638.80 €	3,803,168.75 €	3,837,698.70 €
FINANCIAL VOLUME	80%	95%	3,759,317.95 €	3,795,766.23 €	3,832,214.51 €	3,868,662.79 €	3,905,111.07 €	3,941,559.34 €	3,978,007.62 €	4,014,455.90 €	4,050,904.18 €
		100%	3,957,176.79 €	3,995,543.40 €	4,033,910.01 €	4,072,276.62 €	4,110,643.23 €	4,149,009.84 €	4,187,376.44 €	4,225,743.05 €	4,264,109.66 €
		105%	4,155,035.63 €	4,195,320.57 €	4,235,605.51 €	4,275,890.45 €	4,316,175.39 €	4,356,460.33 €	4,396,745.27 €	4,437,030.21 €	4,477,315.14 €
		110%	4,352,894.47 €	4,395,097.74 €	4,437,301.01 €	4,479,504.28 €	4,521,707.55 €	4,563,910.82 €	4,606,114.09 €	4,648,317.36 €	4,690,520.63 €
		115%	4,550,753.31 €	4,594,874.91 €	4,638,996.51 €	4,683,118.11 €	4,727,239.71 €	4,771,361.31 €	4,815,482.91 €	4,859,604.51 €	4,903,726.11 €
		120%	4,748,612.15 €	4,794,652.08 €	4,840,692.01 €	4,886,731.94 €	4,932,771.87 €	4,978,811.80 €	5,024,851.73 €	5,070,891.66 €	5,116,931.59 €

	Spread		80.00%	85.00%	90.00%	95.00%	100%	105.00%	110.00%	115.00%	120.00%
PPA PRICE	55.00	80%	710,278.50 €	587,505.36 €	464,732.21 €	341,959.06 €	219,185.92	96,412.77 €	- 26,360.38 €	- 149,133.52 €	- 271,906.67 €
		85%	754,670.91 €	624,224.44 €	493,777.97 €	363,331.50 €	232,885.04	102,438.57 €	- 28,007.90 €	- 158,454.37 €	- 288,900.84 €
		90%	799,063.32 €	660,943.53 €	522,823.74 €	384,703.95 €	246,584.16	108,464.37 €	- 29,655.42 €	- 167,775.21 €	- 305,895.00 €
		95%	843,455.72 €	697,662.61 €	551,869.50 €	406,076.39 €	260,283.28	114,490.16 €	- 31,302.95 €	- 177,096.06 €	- 322,889.17 €
		100%	887,848.13 €	734,381.70 €	580,915.26 €	427,448.83 €	273,982.40	120,515.96 €	- 32,950.47 €	- 186,416.90 €	- 339,883.34 €
		105%	932,240.54 €	771,100.78 €	609,961.03 €	448,821.27 €	287,681.52	126,541.76 €	- 34,597.99 €	- 195,737.75 €	- 356,877.50 €
		110%	976,632.94 €	807,819.86 €	639,006.79 €	470,193.71 €	301,380.64	132,567.56 €	- 36,245.52 €	- 205,058.59 €	- 373,871.67 €
		115%	1,021,025.35 €	844,538.95 €	668,052.55 €	491,566.15 €	315,079.75	138,593.36 €	- 37,893.04 €	- 214,379.44 €	- 390,865.84 €
		120%	1,065,417.75 €	881,258.03 €	697,098.31 €	512,938.59 €	328,778.87	144,619.15 €	- 39,540.57 €	- 223,700.29 €	- 407,860.01 €

Figure 12. Revenues of an as produced, high fixed price PPA, under a stress test and the spread with the spot market.

Once we have studied how income fluctuates with changes in the price of the PPA, we must analyse how the percentage volume contracted in the PPA affects it. **The conclusion reached is that the lower the price of the PPA, in the base case, the lower the percentage contracted in the PPA. As the price of the PPA increases, it is in our interest that the contracted percentage of the PPA is higher**. In an as produced case, it is not possible to speculate and contract more than the capacity of the plant.

What is interesting is to see the comparison in the same volume structure with different percentages.

The higher the spot price we think it will be, the lower the volume we will sign. Same analysis if we sign a lower price PPA but with lower spread in low percentages and higher spread in higher ones.

What seems important is that the threshold is not set at a 100% in terms of price. When the PPA Price is higher, high volumes will stand up to a 5% increase in prices rise. Therefore, high volumes with a high PPA Price fit together until the threshold between a

5 and a 10% increase. As for lower price PPAs, the limit (for this example) is between 90 and 95%, thus, aiming for a lower volume if prices are expected to go down.

5.1.2. Revenues Merchant Vs. Revenues *Fixed Solar Shape* at a fixed price

The higher the spot price, the less quantity I will want to have contracted; since in the fixed solar scenario the quantity is the P50, high prices are more detrimental. **The base case is more advantageous in fixed solar, as well as in situations of decreasing prices and decreasing volume.**

The first interesting analysis when signing a fixed solar is that, **for an invariable production scenario (100%, which in the end is the P50), the revenues obtained will always remain the same**. Thus, the estimation of the production is crucial. This is true given the fact that the fixed solar production to be signed aligns with the solar production of our solar plant.

This can be derived from the following formula:

$$R = P_{spot_i} \cdot \rho_i + \rho_{P50_i} * \left(P_{PPA} - P_{spot_i}\right) \ \forall \ i$$

Equation 5. Revenues for a fixed price, fixed solar profile PPA.

Where:

R: Revenues obtained from the physical operation and the financial contract, given a fixed PPA price and a fixed solar quantity, which is the P50 in this case.

P_{spot_i}: Spot price for every hour i.

ρ_i : Production of the contracted plant for every hour i.

ρ_{P50_i}: Fixed production agreed on the contract. In this particular case, it is the P50 (production with a 50% probability of the plant according to the PvSyst studies) for every hour i.

P_{PPA}: Fixed price as signed in the contract of the PPA.

So, if the production for every hour is the same as agreed on the contract, there are two terms in the equation that are the same, therefore cancelling each other. The final equation would be:

$R = \rho_{P50_i} * P_{PPA} \; \forall \, i$

Which does not depend on the spot price. Results are as follows:

PRICE VARIATION	***REVENUES AT A FIXED P50***
0%	3,836,660.83 €
20%	3,836,660.83 €
40%	3,836,660.83 €
60%	3,836,660.83 €
80%	3,836,660.83 €
100%	3,836,660.83 €
120.0%	3,836,660.83 €
140.0%	3,836,660.83 €
160.0%	3,836,660.83 €
180.0%	3,836,660.83 €
200.0%	3,836,660.83 €

Table 3. Revenues at a fixed shape, fixed price under a 100% price and volume scenario.

However, price variations may arise, and it does affect the revenues of the fixed solar PPA as seen in the following table:

		PRICES								
PnL Fixed Solar	3,836,660.83 €	80.00%	85.00%	90.00%	95.00%	100%	105.00%	110.00%	115.00%	120.00%
100%	80%	3,222,795.10	3,184,428.49	3,146,061.88	3,107,695.27	3,069,328.66	3,030,962.06	2,992,595.45	2,954,228.84	2,915,862.23
100%	85%	3,376,261.53	3,347,486.58	3,318,711.62	3,289,936.66	3,261,161.71	3,232,386.75	3,203,611.79	3,174,836.84	3,146,061.88
50.49	90%	3,529,727.96	3,510,544.66	3,491,361.36	3,472,178.05	3,452,994.75	3,433,811.44	3,414,628.14	3,395,444.84	3,376,261.53
P50	95%	3,683,194.40	3,673,602.75	3,664,011.09	3,654,419.44	3,644,827.79	3,635,236.14	3,625,644.49	3,616,052.83	3,606,461.18
	100%	3,836,660.83	3,836,660.83	3,836,660.83	3,836,660.83	3,836,660.83	3,836,660.83	3,836,660.83	3,836,660.83	3,836,660.83
	105%	3,990,127.26	3,999,718.92	4,009,310.57	4,018,902.22	4,028,493.87	4,038,085.53	4,047,677.18	4,057,268.83	4,066,860.48
	110%	4,143,593.70	4,162,777.00	4,181,960.31	4,201,143.61	4,220,326.91	4,239,510.22	4,258,693.52	4,277,876.83	4,297,060.13
	115%	4,297,060.13	4,325,835.09	4,354,610.04	4,383,385.00	4,412,159.96	4,440,934.91	4,469,709.87	4,498,484.82	4,527,259.78
	120%	4,450,526.56	4,488,893.17	4,527,259.78	4,565,626.39	4,603,993.00	4,642,359.61	4,680,726.21	4,719,092.82	4,757,459.43

Figure 13. Revenues of a fixed shape captured solar fixed price, under a stress test.

There revenues are not so evident as they were in the *as produced* structure. While for a constant and P50 production the revenues match the previously detailed formula, there is a different effect for scenarios in which production is lower than P50 and for scenarios in which production is higher than P50.

For scenarios in which the estimated production decreases, higher revenues will be obtained if the parameters followed by the price are the same. Therefore, a combination of high prices and low production is not as the combination of both, low prices, and low volumes. Since the volume to be financially delivered remains unchangeable, the second addend becomes bigger than the first, becoming more and more negative as prices rise. That is why, in the fixed solar structure there is not such a linear relationship if production goes down.

Nevertheless, **if production is forecasted to go up, the reasoning is much more straightforward as high prices mean higher revenues in the event of high production**. Since the volume to be financially delivered remains unchangeable, the first addend of the equation is bigger than the second, making the connection between prices and production directly proportional.

It can now be compared the fixed solar structure at a fixed price with the as produced structure at a fixed price too. For a PPA fixed price of 50.49 €/MWh, that is equivalent to the captured solar prices, the following spread is obtained.

50.49									
Spread FS - AP	80.00%	85.00%	90.00%	95.00%	100%	105.00%	110.00%	115.00%	120.00%
80%	276,239.68 €	207,179.78 €	138,119.89 €	69,059.99 €	0 €	- 69,059.80 €	- 138,119.69 €	- 207,179.59 €	- 276,239.48 €
85%	245,546.40 €	184,159.82 €	122,773.25 €	61,386.68 €	0 €	- 61,386.47 €	- 122,773.04 €	- 184,159.62 €	- 245,546.19 €
90%	214,853.12 €	161,139.86 €	107,426.61 €	53,713.36 €	0 €	- 53,713.14 €	- 107,426.39 €	- 161,139.65 €	- 214,852.90 €
95%	184,159.84 €	138,119.91 €	92,079.98 €	46,040.05 €	0 €	- 46,039.81 €	- 92,079.74 €	- 138,119.67 €	- 184,159.60 €
100%	153,466.55 €	115,099.95 €	76,733.34 €	38,366.73 €	0 €	- 38,366.49 €	- 76,733.10 €	- 115,099.70 €	- 153,466.31 €
105%	122,773.27 €	92,079.99 €	61,386.70 €	30,693.41 €	0 €	- 30,693.16 €	- 61,386.45 €	- 92,079.73 €	- 122,773.02 €
110%	92,079.99 €	69,060.03 €	46,040.06 €	23,020.10 €	0 €	- 23,019.83 €	- 46,039.80 €	- 69,059.76 €	- 92,079.73 €
115%	61,386.71 €	46,040.07 €	30,693.43 €	15,346.78 €	0 €	- 15,346.50 €	- 30,693.15 €	- 46,039.79 €	- 61,386.43 €
120%	30,693.43 €	23,020.11 €	15,346.79 €	7,673.47 €	0 €	- 7,673.18 €	- 15,346.50 €	- 23,019.82 €	- 30,693.14 €

Figure 14. Revenues PPA fixed shape fixed price - Revenues as produced fixed price under a stress test.

This spread is calculated as fixed solar revenues – as produced revenues. By observing the prior table, it can be seen that the spread is equal but opposite as prices go in contrary directions, thus creating a mirror. **For low prices scenarios, the preferred option would be to sign a *fixed solar* PPA. On the other hand, for high prices scenarios, the preferred option would be to sign an *as produced* PPA**. The latter results can be derived from equations 4 and 5.

As produced:

$$R = P_{spot_i} \cdot \rho_i + Q_f \cdot \rho_i \cdot (P_{PPA} - P_{spot_i}) \; \forall \, i$$

Fixed solar:

$$R = P_{spot_i} \cdot \rho_i + \rho_{P50_i} \cdot \left(P_{PPA} - P_{spot_i}\right) \; \forall \, i$$

By equalizing both equations:

$$P_{spot_i} \cdot \rho_i + Q_f \cdot \rho_i \cdot (P_{PPA} - P_{spot_i}) = P_{spot_i} \cdot \rho_i + \rho_{P50_i} \cdot \left(P_{PPA} - P_{spot_i}\right)$$

$$Q_f \cdot \rho_i \cdot (P_{PPA} - P_{spot_i}) = \rho_{P50_i} \cdot \left(P_{PPA} - P_{spot_i}\right)$$

$$Q_f \cdot \rho_i \cdot P_{PPA} - Q_f \cdot \rho_i \cdot P_{spot_i} = \rho_{P50_i} \cdot P_{PPA} - \rho_{P50_i} \cdot P_{spot_i}$$

Spot prices going down mean that the PPA price is higher than the average spot price, thus, making the PPA term bigger and positive in both sides of the equations. As Q_f is a percentage lower than a hundred, the fixed solar term will be bigger, creating a positive spread. However, if the production scenario eventually goes to really high levels (higher than 120%), it might happen that a combination of low prices and high production give a negative spread, meaning that an as produced option is preferred. In this case $Q_f \cdot \rho_i > \rho_{P50_i}$

Spot prices going up, however, mean that the average spot price is higher than the PPA price, thus making the second term bigger than the first one in both sides of the equations. As Q_f is a percentage lower than a hundred, the fixed solar term will be bigger, creating a negative spread. As it happened before, if the production scenario eventually goes to really high levels (higher than 120%), it might happen that a combination of low prices and high production give a positive spread, meaning that an as produced option is preferred. In this case $Q_f \cdot \rho_i > \rho_{P50_i}$

The volume percentage in which the spread is reverted is 125% (so a 25% up the base case scenario).

50.49									
Spread FS - AP	80.00%	85.00%	90.00%	95.00%	100%	105.00%	110.00%	115.00%	120.00%
80%	276,239.68 €	207,179.78 €	138,119.89 €	69,059.99 €	0 €	- 69,059.80 €	- 138,119.69 €	- 207,179.59 €	- 276,239.48 €
85%	245,546.40 €	184,159.82 €	122,773.25 €	61,386.68 €	0 €	- 61,386.47 €	- 122,773.04 €	- 184,159.62 €	- 245,546.19 €
90%	214,853.12 €	161,139.86 €	107,426.61 €	53,713.36 €	0 €	- 53,713.14 €	- 107,426.39 €	- 161,139.65 €	- 214,852.90 €
95%	184,159.84 €	138,119.91 €	92,079.98 €	46,040.05 €	0 €	- 46,039.81 €	- 92,079.74 €	- 138,119.67 €	- 184,159.60 €
100%	153,466.55 €	115,099.95 €	76,733.34 €	38,366.73 €	0 €	- 38,366.49 €	- 76,733.10 €	- 115,099.70 €	- 153,466.31 €
105%	122,773.27 €	92,079.99 €	61,386.70 €	30,693.41 €	0 €	- 30,693.16 €	- 61,386.45 €	- 92,079.73 €	- 122,773.02 €
110%	92,079.99 €	69,060.03 €	46,040.06 €	23,020.10 €	0 €	- 23,019.83 €	- 46,039.80 €	- 69,059.76 €	- 92,079.73 €
115%	61,386.71 €	46,040.07 €	30,693.43 €	15,346.78 €	0 €	- 15,346.50 €	- 30,693.15 €	- 46,039.79 €	- 61,386.43 €
120%	30,693.43 €	23,020.11 €	15,346.79 €	7,673.47 €	0 €	- 7,673.18 €	- 15,346.50 €	- 23,019.82 €	- 30,693.14 €
121%	24,554.78 €	18,416.12 €	12,277.46 €	6,138.80 €	0 €	- 6,138.51 €	- 12,277.17 €	- 18,415.82 €	- 24,554.48 €
122%	18,416.12 €	13,812.13 €	9,208.13 €	4,604.14 €	0 €	- 4,603.84 €	- 9,207.84 €	- 13,811.83 €	- 18,415.82 €
123%	12,277.46 €	9,208.14 €	6,138.81 €	3,069.48 €	0 €	- 3,069.18 €	- 6,138.51 €	- 9,207.84 €	- 12,277.17 €
124%	6,138.81 €	4,604.14 €	3,069.48 €	1,534.82 €	0 €	- 1,534.51 €	- 3,069.18 €	- 4,603.84 €	- 6,138.51 €
125%	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €
126%	- 6,138.50 €	- 4,603.84 €	- 3,069.18 €	- 1,534.51 €	0 €	1,534.82 €	3,069.48 €	4,604.15 €	6,138.81 €

Figure 15. Revenues PPA fixed shape fixed price - Revenues as produced fixed price under a stress test with volumes up to 126%.

The conclusions are the same with respect to merchant prices. As it could be seen in the *as produced* case, low prices meant that the PPA structure dumped the revenues, thus giving a positive spread. The same happens for the *fixed shape* structure. However**, the spread is more positive in the low prices scenario and more negative in the high prices scenario than the spread obtained in an *as produced* PPA**. The spread can be seen in the following figure, as compared to figure 10.

Spread FS - Merchant		80.00%	85.00%	90.00%	95.00%	100%	105.00%	110.00%	115.00%	120.00%
50.49	80%	767,332.17 €	575,499.12 €	383,666.08 €	191,833.04 €	- 0.00 €	- 191,833.04 €	- 383,666.08 €	- 575,499.13 €	- 767,332.17 €
	85%	767,332.17 €	575,499.12 €	383,666.08 €	191,833.04 €	- 0.00 €	- 191,833.04 €	- 383,666.08 €	- 575,499.13 €	- 767,332.17 €
	90%	767,332.17 €	575,499.12 €	383,666.08 €	191,833.04 €	- 0.00 €	- 191,833.04 €	- 383,666.08 €	- 575,499.13 €	- 767,332.17 €
	95%	767,332.17 €	575,499.12 €	383,666.08 €	191,833.04 €	- 0.00 €	- 191,833.04 €	- 383,666.08 €	- 575,499.13 €	- 767,332.17 €
	100%	767,332.17 €	575,499.12 €	383,666.08 €	191,833.04 €	- 0.00 €	- 191,833.04 €	- 383,666.08 €	- 575,499.13 €	- 767,332.17 €
	105%	767,332.17 €	575,499.12 €	383,666.08 €	191,833.04 €	- 0.00 €	- 191,833.04 €	- 383,666.08 €	- 575,499.13 €	- 767,332.17 €
	110%	767,332.17 €	575,499.12 €	383,666.08 €	191,833.04 €	- 0.00 €	- 191,833.04 €	- 383,666.08 €	- 575,499.13 €	- 767,332.17 €
	115%	767,332.17 €	575,499.12 €	383,666.08 €	191,833.04 €	- 0.00 €	- 191,833.04 €	- 383,666.08 €	- 575,499.13 €	- 767,332.17 €
	120%	767,332.17 €	575,499.12 €	383,666.08 €	191,833.04 €	- 0.00 €	- 191,833.04 €	- 383,666.08 €	- 575,499.13 €	- 767,332.17 €

Figure 16. Revenues PPA fixed shape fixed price minus Revenues Spot under a stress test.

From 125% in volume change on, the positive zone (left side of the table) would tend to be smaller up to a point in which it would become negative. The negative zone (right side of the table) would continue being negative but higher in absolute value.

Further analysis can be made in terms of PPA prices. As the financial volume in a fixed solar structure has to remain unchangeable, the only change to be made has to be price related. For PPA prices that differ from the captured solar price, the mirror effect does not longer exist. Signing at a high PPA price means that the financial side of the revenues equation will become positive more times than before, thus becoming less vulnerable to volumes variations. What is more, the spread will become more positive in the low prices scenario and less and less negative in the high prices scenario, up to a point in which the spread is always positive.

	PnL Fixed Solar	4,179,138.83 €	80.00%	85.00%	90.00%	95.00%	100%	105.00%	110.00%	115.00%	120.00%
PRICES SCENARIO	100%	80%	3,565,273.09	3,526,906.49	3,488,539.88	3,450,173.27	3,411,806.66	3,373,440.05	3,335,073.44	3,296,706.84	3,258,340.23
PRODUCTION SCENARIO	100%	85%	3,718,739.53	3,689,964.57	3,661,189.61	3,632,414.66	3,603,639.70	3,574,864.75	3,546,089.79	3,517,314.83	3,488,539.88
PPA PRICE	55.00	90%	3,872,205.96	3,853,022.66	3,833,839.35	3,814,656.05	3,795,472.74	3,776,289.44	3,757,106.14	3,737,922.83	3,718,739.53
FINANCIAL VOLUME	P50	95%	4,025,672.39	4,016,080.74	4,006,489.09	3,996,897.44	3,987,305.79	3,977,714.13	3,968,122.48	3,958,530.83	3,948,939.18
		100%	4,179,138.83	4,179,138.83	4,179,138.83	4,179,138.83	4,179,138.83	4,179,138.83	4,179,138.83	4,179,138.83	4,179,138.83
		105%	4,332,605.26	4,342,196.91	4,351,788.56	4,361,380.22	4,370,971.87	4,380,563.52	4,390,155.17	4,399,746.82	4,409,338.48
		110%	4,486,071.69	4,505,255.00	4,524,438.30	4,543,621.61	4,562,804.91	4,581,988.21	4,601,171.52	4,620,354.82	4,639,538.13
		115%	4,639,538.13	4,668,313.08	4,697,088.04	4,725,863.00	4,754,637.95	4,783,412.91	4,812,187.86	4,840,962.82	4,869,737.78
		120%	4,793,004.56	4,831,371.17	4,869,737.78	4,908,104.38	4,946,470.99	4,984,837.60	5,023,204.21	5,061,570.82	5,099,937.43

Figure 17. Revenues of a fixed solar profile, fixed price PPA.

	Spread FS - Merchant		80.00%	85.00%	90.00%	95.00%	100%	105.00%	110.00%	115.00%	120.00%
PPA PRICE	55.00	80%	1,109,810.16 €	917,977.12 €	726,144.08 €	534,311.04 €	342,477.99 €	150,644.95 €	- 41,188.09 €	- 233,021.13 €	- 424,854.17 €
		85%	1,109,810.16 €	917,977.12 €	726,144.08 €	534,311.04 €	342,477.99 €	150,644.95 €	- 41,188.09 €	- 233,021.13 €	- 424,854.17 €
		90%	1,109,810.16 €	917,977.12 €	726,144.08 €	534,311.04 €	342,477.99 €	150,644.95 €	- 41,188.09 €	- 233,021.13 €	- 424,854.17 €
		95%	1,109,810.16 €	917,977.12 €	726,144.08 €	534,311.04 €	342,477.99 €	150,644.95 €	- 41,188.09 €	- 233,021.13 €	- 424,854.17 €
		100%	1,109,810.16 €	917,977.12 €	726,144.08 €	534,311.04 €	342,477.99 €	150,644.95 €	- 41,188.09 €	- 233,021.13 €	- 424,854.17 €
		105%	1,109,810.16 €	917,977.12 €	726,144.08 €	534,311.04 €	342,477.99 €	150,644.95 €	- 41,188.09 €	- 233,021.13 €	- 424,854.17 €
		110%	1,109,810.16 €	917,977.12 €	726,144.08 €	534,311.04 €	342,477.99 €	150,644.95 €	- 41,188.09 €	- 233,021.13 €	- 424,854.17 €
		115%	1,109,810.16 €	917,977.12 €	726,144.08 €	534,311.04 €	342,477.99 €	150,644.95 €	- 41,188.09 €	- 233,021.13 €	- 424,854.17 €
		120%	1,109,810.16 €	917,977.12 €	726,144.08 €	534,311.04 €	342,477.99 €	150,644.95 €	- 41,188.09 €	- 233,021.13 €	- 424,854.17 €

Figure 18. Spread between the fixed solar shape and the merchant revenues.

Likewise, the opposite effect would be reflected if the PPA price was lower.

Up to here, the analysis was done with 1-year prices since, even though there would be fluctuations in the spread and revenues, the tendencies are the same. The essence in a fixed price is the same for a one, two, or ten-year PPA.

5.2. Floor and Market Discount Structure

The floor structure defers from the fixed price one. While the swap was purely a contract for differences in which the seller would have to pay to the buyer for spot prices higher than the PPA price and would receive money otherwise, the floor has a bit more to analyse and consider.

The PPA price with a floor structure follows the following formula:

$$PPA\ Price = Maximum\ (Spot\ Price - Discount; Floor)$$

Equation 6. Floor Price formula.

The settlement that was made in the fixed for floating structure was: PPA price – Spot price. However, in this case the offtaker will have to pay a fixed floor if the spot price – discount is below the floor and the seller will only have to pay a discount to the counterparty if that was not the case. The next figure portrays the spot prices (blue) compared to the revenues that would be obtained by the seller (orange) with the floor and market discount structure.

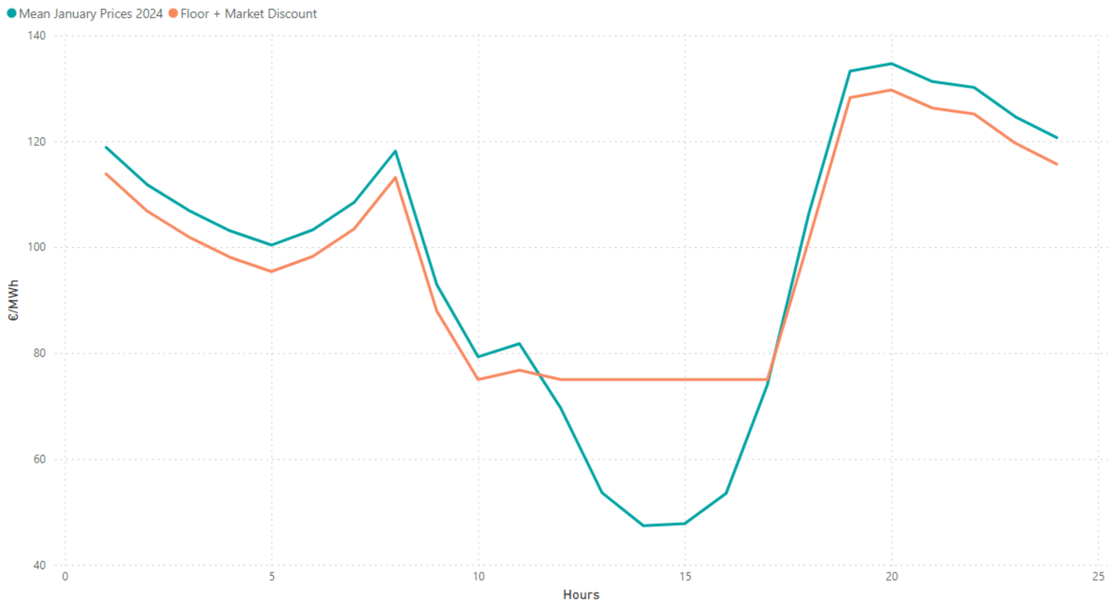

Figure 19. Floor structure graph compared to the market price.

The revenues, however, are calculated in the same way as they have been being calculated so far but changing the PPA price calculation to the one developed before.

$$Revenues = Physical\ leg + Financial\ leg = P_{spot_i} \cdot \rho_i + Q_f \cdot \rho_i \cdot (P_{PPA} - P_{spot_i})$$

When considering a floor and market discount structure, it is necessary to notice that the discount can either be offered as a percentage of the spot price or as a constant value in €/MWh.

It has to be considered that, in the event of a fixed solar profile, the payment if the floor is not being applied, is only the discount. Thus, reducing the risk for that structure.

5.2.1. Revenues *as produced with a Floor and Market Discount structure*

Now, the tendencies might vary with the term of the contract since the floor may or not be activated depending on the future prices. Thus, a long term, standard PPA contract analysis will be carried out. The length of the electricity prices data goes from 2024 until 2033. What is more, the strategy is analysed given an hourly floor, so the option applies for every hour.

Case 1: make the captured merchant price and the PPA captured prices be the same for no discounts.

If the floor is capped to zero, meaning that if spot prices minus the discount are negative the PPA Price is the floor, not the floor plus the negative price, the merchant captured price equals the contract price when the floor (and the discounts) is zero. This works as if it was a fixed price structure.

Again, as it happened with the fixed price, the volume contracted does not have an impact on the revenues when the captured price for the merchant revenues matches the captured price for the PPA. This means that, independently from the price structure, the revenues would be the same for any price signed that matches the captured merchant price throughout the whole life of the PPA as long as the scenario holds the 100% of the price hypothesis.

Case 2: Floor and discount combination to reach captured merchant prices. (Same captured price means same revenue)

Floor	25.00
Discount €	19.84
Captured PPA	43.24
Captured Merchant	43.24

Floor	25.00
Discount %	22%
Captured PPA	43.24
Captured Merchant	43.24

Floor	30.00
Discount €	30.54
Captured PPA	43.24
Captured Merchant	43.24

Floor	30.00
Discount %	28%
Captured PPA	43.24
Captured Merchant	43.24

Higher floor means that higher discounts can be made to the offtaker in order to get the same captured price as the one it would be obtained by going to the market. What is more, high floors mean that the counterparty will be willing to have a higher discount. Lower floors mean that the discount will eventually tend to zero, in which case the buyers will only be seeking for the guarantees of origin.

The tables above suggest that, given the prices seen in the market, this type of structure can give a better profitability, since no offtaker is going to look for a discount of 28%, but rather of 5 to 10%. Therefore, with lower discounts, the captured price for the PPA will be higher than the market one.

Analysis based on price and volume scenarios:

Let us take a first case in which the floor price is 30 €/MWh, and the discount is 5 €/MWh. The contracted volume in the as produced structure is 80% in this case. By carrying out a stress test varying price and production percentages, we obtain the following revenues:

	PnL As Produced	38,346,654.88	80.00%	85.00%	90.00%	95.00%	100%	105.00%	110.00%	115.00%	120.00%
Floor [€/MWh]	30	80.00%	25,832,871.65	27,027,333.34	28,233,443.86	29,451,809.00	30,677,323.91	31,909,685.88	33,149,221.51	34,397,257.85	35,650,910.70
Discount [€/MWh]	5	85.00%	27,447,426.13	28,716,541.68	29,998,034.10	31,292,547.06	32,594,656.65	33,904,041.25	35,221,047.85	36,547,086.47	37,879,092.62
		90.00%	29,061,980.61	30,405,750.01	31,762,624.34	33,133,285.12	34,511,989.39	35,898,396.61	37,292,874.20	38,696,915.09	40,107,274.54
		95.00%	30,676,535.09	32,094,958.34	33,527,214.58	34,974,023.19	36,429,322.14	37,892,751.98	39,364,700.54	40,846,743.70	42,335,456.46
		100%	32,291,089.56	33,784,166.68	35,291,804.82	36,814,761.25	38,346,654.88	39,887,107.35	41,436,526.88	42,996,572.32	44,563,638.38
		105.00%	33,905,644.04	35,473,375.01	37,056,395.06	38,655,499.31	40,263,987.63	41,881,462.72	43,508,353.23	45,146,400.93	46,791,820.30
		110.00%	35,520,198.52	37,162,583.35	38,820,985.30	40,496,237.37	42,181,320.37	43,875,818.08	45,580,179.57	47,296,229.55	49,020,002.21
		115.00%	37,134,753.00	38,851,791.68	40,585,575.54	42,336,975.43	44,098,653.12	45,870,173.45	47,652,005.92	49,446,058.17	51,248,184.13
		120.00%	38,749,307.48	40,541,000.01	42,350,165.78	44,177,713.50	46,015,985.86	47,864,528.82	49,723,832.26	51,595,886.78	53,476,366.05

Figure 20. Revenues of an as produced PPA with a 30 €/MWh floor and 5 €/MWh market discount structure.

As it could be expected, the lower the spot prices are, the lower the revenues. The same happens with the production; the lower, the lower the revenues. This is independent of the volume signed and of the floor signed.

What is remarkable is the spread between the floor and the merchant revenues. The pattern followed by the merchant revenues is the same as before. This is described in the following formula:

$$Merchant\ Revenues = Spot\ Price \cdot Production \cdot Scenario$$

Equation 7. Merchant revenues.

Therefore, optimistic scenarios would grant high revenues and pessimistic scenarios would deliver low revenues.

PnL Merchant	32,864,948.27	80.00%	85.00%	90.00%	95.00%	100%	105.00%	110.00%	115.00%	120.00%
	80.00%	21,033,566.89	22,348,164.82	23,662,762.76	24,977,360.69	26,291,958.62	27,606,556.55	28,921,154.48	30,235,752.41	31,550,350.34
	85.00%	22,348,164.82	23,744,925.13	25,141,685.43	26,538,445.73	27,935,206.03	29,331,966.33	30,728,726.63	32,125,486.93	33,522,247.24
	90.00%	23,662,762.76	25,141,685.43	26,620,608.10	28,099,530.77	29,578,453.44	31,057,376.12	32,536,298.79	34,015,221.46	35,494,144.13
	95.00%	24,977,360.69	26,538,445.73	28,099,530.77	29,660,615.81	31,221,700.86	32,782,785.90	34,343,870.94	35,904,955.99	37,466,041.03
	100%	26,291,958.62	27,935,206.03	29,578,453.44	31,221,700.86	32,864,948.27	34,508,195.68	36,151,443.10	37,794,690.51	39,437,937.93
	105.00%	27,606,556.55	29,331,966.33	31,057,376.12	32,782,785.90	34,508,195.68	36,233,605.47	37,959,015.25	39,684,425.04	41,409,834.82
	110.00%	28,921,154.48	30,728,726.63	32,536,298.79	34,343,870.94	36,151,443.10	37,959,015.25	39,766,587.41	41,574,159.56	43,381,731.72
	115.00%	30,235,752.41	32,125,486.93	34,015,221.46	35,904,955.99	37,794,690.51	39,684,425.04	41,574,159.56	43,463,894.09	45,353,628.61
	120.00%	31,550,350.34	33,522,247.24	35,494,144.13	37,466,041.03	39,437,937.93	41,409,834.82	43,381,731.72	45,353,628.61	47,325,525.51

Figure 21. Revenues for going merchant from 2024 to 2033.

At first sight, the tendency between going merchant and signing a floor PPA is the same. However, by subtracting the Revenues of the PPA with the Revenues of going merchant, the next results are obtained:

	Spread		80.00%	85.00%	90.00%	95.00%	100%	105.00%	110.00%	115.00%	120.00%
Floor [€/MWh]	30	80.00%	4,799,304.76	4,679,168.52	4,570,681.10	4,474,448.31	4,385,365.29	4,303,129.33	4,228,067.03	4,161,505.45	4,100,560.36
Discount [€/MWh]	5	85.00%	5,099,261.30	4,971,616.55	4,856,348.67	4,754,101.33	4,659,450.62	4,572,074.92	4,492,321.22	4,421,599.54	4,356,845.38
		90.00%	5,399,217.85	5,264,064.58	5,142,016.24	5,033,754.35	4,933,535.95	4,841,020.50	4,756,575.41	4,681,693.63	4,613,130.41
		95.00%	5,699,174.40	5,556,512.62	5,427,683.81	5,313,407.37	5,207,621.28	5,109,966.08	5,020,829.60	4,941,787.72	4,869,415.43
		100%	5,999,130.95	5,848,960.65	5,713,351.38	5,593,060.39	5,481,706.61	5,378,911.67	5,285,083.79	5,201,881.81	5,125,700.45
		105.00%	6,299,087.49	6,141,408.68	5,999,018.95	5,872,713.41	5,755,791.94	5,647,857.25	5,549,337.98	5,461,975.90	5,381,985.47
		110.00%	6,599,044.04	6,433,856.71	6,284,686.51	6,152,366.43	6,029,877.27	5,916,802.83	5,813,592.17	5,722,069.99	5,638,270.50
		115.00%	6,899,000.59	6,726,304.74	6,570,354.08	6,432,019.45	6,303,962.60	6,185,748.42	6,077,846.35	5,982,164.08	5,894,555.52
		120.00%	7,198,957.14	7,018,752.78	6,856,021.65	6,711,672.47	6,578,047.93	6,454,694.00	6,342,100.54	6,242,258.17	6,150,840.54

Figure 22. Revenues spread between the floor and market discount, as produced PPA and the spot market.

As it can be observed, the colours are reverted in the prior table when compared to the two tables above. **This means that the lower the spot prices but the higher the production, the most convenient it is to sign a PPA with a floor and market discount structure**. The reason behind this is that low prices assure that the cap is being activated more times, giving a higher difference with respect to the market. One more thing to add is that **it is always positive**, meaning that for that floor and discount, it will so much be convenient to sign it rather than going to the market.

When dealing with a percentual discount, the concept is exactly the same. Even though in absolute terms the discount changes as the spot prices change, the evaluation of the spread and fluctuations of revenues are the same as with a fixed discount.

Now that different prices and volume variations' conclusions have been derived, optimal prices combinations have to be seeked in order to get a solvent captured price that fits within the IRR and that feels competitive in the portfolio strategy.

As it was seen before, an equivalent ten year captured price of 43.24 €/MWh was obtained if the spot price scenario and the production scenario were believed to be true. Given the production of the plant and the spot prices, the merchant revenues obtained are of 32,864,948.27 €.

The captured price with the floor structure changes as follows:
Firstly, for a fixed monetary discount, where horizontally it is portrayed the variation of the floor price and vertically the discount made:

€/MWh	27	28	29	30	31	32	33
2	50.36	50.72	51.09	51.47	51.85	52.23	52.63
3	50.02	50.39	50.77	51.15	51.53	51.93	52.32
4	49.65	50.03	50.41	50.80	51.19	51.58	51.98
5	49.29	49.67	50.06	50.45	50.84	51.24	51.65
6	48.92	49.30	49.70	50.09	50.49	50.89	51.30
7	48.55	48.94	49.34	49.73	50.14	50.54	50.96
8	48.18	48.57	48.97	49.38	49.78	50.19	50.61
9	47.81	48.21	48.62	49.02	49.44	49.85	50.27

Figure 23. Captured prices for different floor and monetary discount prices.

The main diagonal is to be considered in the prior graph. As it was mentioned before, high floor prices indicate that the counterparty will ask for high discounts too. On the other hand, low discounts are aligned with low floor prices. Therefore, in the developer's side, the best possible situation (captured price of 52.63 €/MWh) is not so realistic.

By looking at the diagonal, it can be concluded that a euro increase in the floor price is almost equivalent to a euro increase in the discount. Then, the seller might as well think that a winner strategy can be offering an attractive (but low) discount with a low floor, which is the same as offering a higher floor, with a higher discount, but seems less competitive, even though technically the numbers are the same.

This analysis might as well be extrapolated for different scenarios. In reality, lower production scenarios and lower price scenarios give a lower captured price, but the relationship between discount and floor prices remains the same.

For the floor and market discount shown in the table above, the captured prices are higher than the market captured price. Thus, making sense to sign a PPA at any of those combinations. The question now is, until what scenario are these numbers valid?

The first assumption is that, if scenarios change, captured merchant prices change, but it will be assumed that the merchant captured price remains the same. **Since the P50 scenario does not affect the captured prices**, the one to be considered is the Spot prices scenario. For this case, **a spot price reduction of a 18% throughout the term of the PPA, will mean that for a 30 €/MWh floor with a discount of 5 €/MWh, the captured price would be the same as the merchant one for the base case**.

Now, let us take a look at the percentual discount. Horizontally it is portrayed the variation of the floor price and vertically the discount made:

€/MWh	27	28	29	30	31	32	33
2%	50.38	50.74	51.11	51.47	51.85	52.23	52.61
3%	50.06	50.41	50.78	51.15	51.52	51.91	52.29
4%	49.73	50.09	50.45	50.82	51.20	51.58	51.97
5%	49.40	49.76	50.13	50.50	50.88	51.27	51.66
6%	49.07	49.43	49.80	50.18	50.56	50.95	51.34
7%	48.74	49.11	49.48	49.86	50.24	50.63	51.02
8%	48.42	48.78	49.16	49.53	49.92	50.31	50.70
9%	48.09	48.46	48.83	49.21	49.60	49.99	50.39

Figure 24. Captured prices for different floor and percentual discount prices.

The trend is the exact same as before, but there are slight changes in the captured prices. The top right corner gives a small disadvantage to this strategy, whereas the bottom left corner is more beneficial.

Seeing these numbers, it seems like the floor and market discount strategy is way better than the fixed price strategy. The issue here is that banks see more of a problem in the floor rather than in the fixed price. As it is seen as an option, prices may stabilize around that number, giving lower revenues to the plant.

5.2.2. Revenues *fixed shape with a Floor and Market Discount structure*

For this case, revenues will be equivalent to those in equation five and the PPA price will be the one shown in equation 6.

As the revenues from going merchant have been portrayed in the prior section, the Revenues from the fixed shape structure will be directly shown below:

	PnL Fixed Shape	32,291,089.56	80.00%	85.00%	90.00%	95.00%	100%	105.00%	110.00%	115.00%	120.00%
Floor [€/MWh]	30	80.00%	27,032,697.84	28,197,125.47	29,376,114.13	30,570,421.08	31,773,665.23	32,985,468.21	34,206,238.27	35,437,634.22	36,676,050.79
Discount [€/MWh]	5	85.00%	28,347,295.77	29,593,885.77	30,855,036.80	32,131,506.12	33,416,912.64	34,710,878.00	36,013,810.42	37,327,368.74	38,647,947.69
		90.00%	29,661,893.70	30,990,646.07	32,333,959.48	33,692,591.16	35,060,160.06	36,436,287.78	37,821,382.57	39,217,103.27	40,619,844.58
		95.00%	30,976,491.63	32,387,406.38	33,812,882.15	35,253,676.20	36,703,407.47	38,161,697.57	39,628,954.73	41,106,837.79	42,591,741.48
		100%	32,291,089.56	33,784,166.68	35,291,804.82	36,814,761.25	38,346,654.88	39,887,107.35	41,436,526.88	42,996,572.32	44,563,638.38
		105.00%	33,605,687.49	35,180,926.98	36,770,727.49	38,375,846.29	39,989,902.30	41,612,517.13	43,244,099.04	44,886,306.84	46,535,535.27
		110.00%	34,920,285.42	36,577,687.28	38,249,650.16	39,936,931.33	41,633,149.71	43,337,926.92	45,051,671.19	46,776,041.37	48,507,432.17
		115.00%	36,234,883.36	37,974,447.58	39,728,572.84	41,498,016.38	43,276,397.12	45,063,336.70	46,859,243.35	48,665,775.90	50,479,329.07
		120.00%	37,549,481.29	39,371,207.88	41,207,495.51	43,059,101.42	44,919,644.54	46,788,746.49	48,666,815.50	50,555,510.42	52,451,225.96

Figure 25. Revenues with a fixed shape, floor and market discount PPA structure.

As a first analysis, what can be seen is that for a 100% volume scenario, revenues change along the prices axes. This did not happen in the fixed shape fixed price structure. The reason behind this is that the PPA price keeps changing with the discount as prices change. Therefore, it cannot be kept constant. However, as it happened in the fixed shape fixed price structure, maximum revenues are lower for the floor and market discount, but minimum revenues are higher. Therefore, it is a convenient strategy if there is a belief of low prices and low volumes forecast.

By taking a look at the spread with the merchant revenues, subtracting PPA revenues minus merchant revenues, what was obtained was the following:

	Spread		80.00%	85.00%	90.00%	95.00%	100%	105.00%	110.00%	115.00%	120.00%
Floor [€/MWh]	30	80.00%	5,999,130.95	5,848,960.65	5,713,351.38	5,593,060.39	5,481,706.61	5,378,911.67	5,285,083.79	5,201,881.81	5,125,700.45
Discount [€/MWh]	5	85.00%	5,999,130.95	5,848,960.65	5,713,351.38	5,593,060.39	5,481,706.61	5,378,911.67	5,285,083.79	5,201,881.81	5,125,700.45
		90.00%	5,999,130.95	5,848,960.65	5,713,351.38	5,593,060.39	5,481,706.61	5,378,911.67	5,285,083.79	5,201,881.81	5,125,700.45
		95.00%	5,999,130.95	5,848,960.65	5,713,351.38	5,593,060.39	5,481,706.61	5,378,911.67	5,285,083.79	5,201,881.81	5,125,700.45
		100%	5,999,130.95	5,848,960.65	5,713,351.38	5,593,060.39	5,481,706.61	5,378,911.67	5,285,083.79	5,201,881.81	5,125,700.45
		105.00%	5,999,130.95	5,848,960.65	5,713,351.38	5,593,060.39	5,481,706.61	5,378,911.67	5,285,083.79	5,201,881.81	5,125,700.45
		110.00%	5,999,130.95	5,848,960.65	5,713,351.38	5,593,060.39	5,481,706.61	5,378,911.67	5,285,083.79	5,201,881.81	5,125,700.45
		115.00%	5,999,130.95	5,848,960.65	5,713,351.38	5,593,060.39	5,481,706.61	5,378,911.67	5,285,083.79	5,201,881.81	5,125,700.45
		120.00%	5,999,130.95	5,848,960.65	5,713,351.38	5,593,060.39	5,481,706.61	5,378,911.67	5,285,083.79	5,201,881.81	5,125,700.45

Figure 26. Spread between the fixed solar shape, floor PPA and the market revenues.

Regarding this PPA prices, there are always higher revenues in the event of signing a PPA. However, as it happened before, the spread compared to that in the *as produced* case is higher for lower volumes whilst is lower for higher volumes. Something that should be noted in this case is that the spread is constant along the same price. This tendency is the same as commented previously in the case of the fixed price. Analysing it with equations:

$$Spread = P_{spot_i} \cdot \rho_i + \ \rho_{P50_i} \cdot \left(P_{PPA} - P_{spot_i}\right) - \ P_{spot_i} \cdot \rho_i = \ \rho_{P50_i} \cdot \left(P_{PPA} - P_{spot_i}\right)$$

Equation 8. Spread between fixed shape PPA revenues and merchant revenues.

Thus, it is only affected by a term that is constant.

Captured prices remain the same as before. By definition, as seen in equation 2, capture prices are independent of volumes, therefore not being affected by the volume structure of the PPA.

6. Value at Risk

In order to identify and quantify the risk in the portfolio of PV assets, a VaR analysis will be carried out. In this case, spot, and PPA strategies will be evaluated to take a decision on what route to market to follow.

"Value at risk is a statistic that quantifies the extent of possible financial losses within a firm, portfolio, or position over a specific time frame" [12]. In this sense, it will be used to measure the biggest amount of money that can be lost with one of the strategies previously mentioned with a certain level of confidence. For example, if you are looking for the 95% VaR, you would sort the portfolio values from worst to best and select the value below which 5% of the outcomes fall. This value represents the maximum expected loss with a 95% confidence level.

There are different methods to calculate it. In the present thesis, only two of those will be portrayed. The first one that will be used is the historical method. By using this method, historical values are gathered and ordered from lower to higher. Thus, depending on the confidence level chosen, the VaR will be placed higher or lower in that rank. It is a method based on the past to forecast future outcomes so, even though it is the easiest, it is also the least accurate. Its equation is the following:

$$VaR = V_m \cdot \frac{V_i}{V_{i-1}}$$

Equation 9. Historical Value at Risk [12].

Another possible method to calculate the VaR is running Monte Carlo simulations. This technique involves running a large number of simulations to model the behaviour of asset prices based on probabilistic functions. By iterating thousands, or even millions, of times, Monte Carlo simulations generate a distribution of possible portfolio outcomes.

The process begins with defining the underlying assumptions, such as the statistical properties of the assets' returns (mean, variance, and correlations) and any relevant market conditions. Using these inputs, the Monte Carlo method generates random price paths for the assets in the portfolio. Each path represents a possible future state of the portfolio. After simulating many paths, the results are aggregated to create a distribution of potential portfolio values at the end of the holding period [13].

In order to assess risk, certain steps have been followed to run the simulations. At first, the historical data series are obtained. In this case, historical forward values are obtained from 2014 to 2024 from eex. These will be valid for a first assessment based on forwards. These values are for a calendar year in 2025 (product lasting only a year). Secondly, a statistical distribution for the historical data has been modelled. Prices have been modelled as lognormal, since it is their trend throughout history. This is common in the stock market, but not so much in the electricity market. However, % returns have been modelled as normal, which is useful when measuring forwards and, in this case, the difference between daily average spot prices. That being obtained, the P&L can be modelled, and the Value at Risk can be calculated.

6.1. VaR for Futures

With the data set from eex, a VaR from a futures' portfolio can be depicted.

A future's portfolio will be created. The price at which will be bought is that of **45 €/MWh** and the volume will be equivalent to Lucainena's production, as it is the PV plant to be analysed. Its yearly production is **76,940.5 MWh**, therefore, based on that volume, and the price, the lognormal returns are calculated. The equation used is the following:

$$\%\ LorNormal\ Returns = \frac{Cal25_i - Cal25_{i-1}}{Cal25_{i-1}} \cdot 100$$

Equation 10. Lognormal returns as a percentage.

$$LogNormal\ Returns\ € = Volume \cdot Price \cdot \frac{LogNormal\ Returns\ [\%]}{100}$$

Equation 11. Lognormal returns in Euros.

And the results at a **99% confidence level** for the historical simulation:

Historical				
Variable	Units	Mean	Standard Deviation	VaR
LogNormal Return	€	540.1	90,275.68	-202,065.49
LogNormal Return	%	0.02	2.61	-5.84

Table 4. Historical returns for a futures' portfolio.

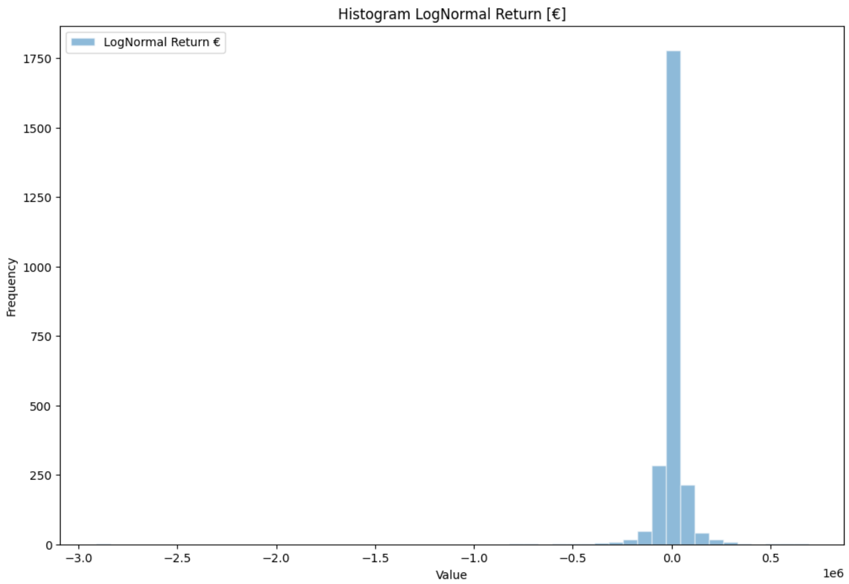

Figure 27. Histogram of the returns under a futures portfolio.

As seen in the figure and in the table above, the maximum expected loss at a 99% confidence level is -202,065.49 €, which is quite high, but it is just around a 6% of a variation from forwards prices in consecutive days. The revenues of going merchant in the worst-case scenario are 2,455,462.93 €, which make the loss an 8% of the minimum merchant revenue. It is a high value but the difference in the merchant case between a 100% scenario and an 80% scenario is that of a 64%, which suggests that buying a forward Cal25 at that price and for that volume is a good choice.

The results for the Monte Carlo simulation, at the same confidence level and for 10,000 scenarios (selected from 7 different runs):

Monte Carlo		
Variable	VaR €	VaR %
LogNormal Return	-208,671.70	-6.00
	-210,337.89	-5.94
	-210,961.91	-6.19
	-204,449.33	-6.16
	-215,001.45	-6.07
	-209,008.46	-6.20
	-206,358.84	-6.08

Table 5. Returns for the futures portfolio under a Monte Carlo simulation.

With an average of 209,255.65 € and -6.09%, values in the Monte Carlo simulation are pretty similar to the historical method. Therefore, it can be concluded that a maximum of -210,9961.91€ might be lost at a 99% confidence level.

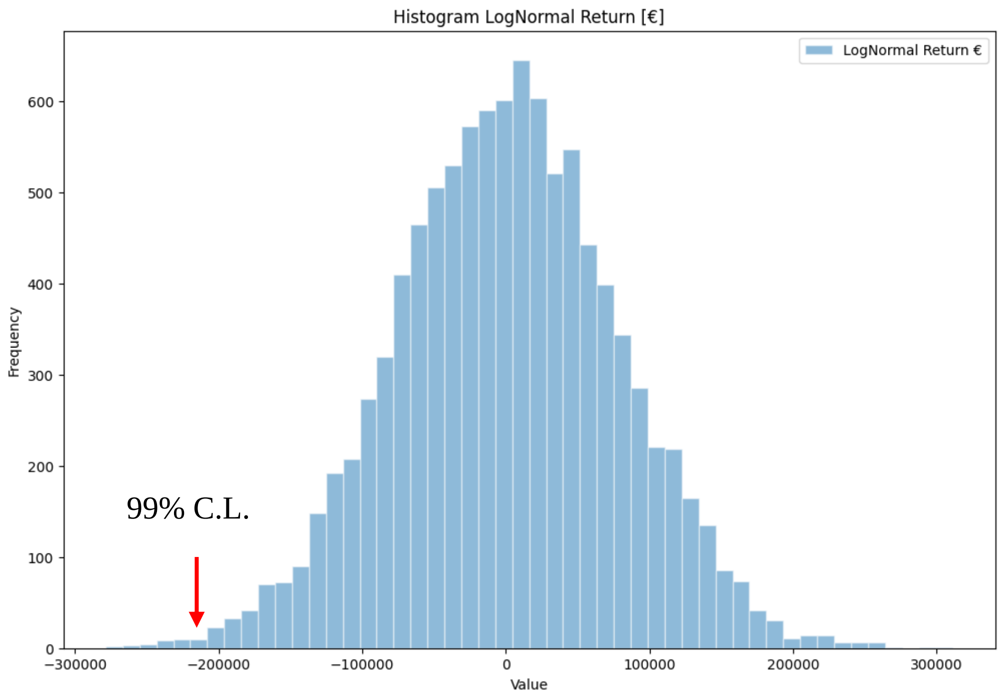

Figure 28. Histogram of the returns under a futures portfolio with a Monte Carlo simulation.

6.2. VaR As Produced

As of now, X-Elio's 2024-2033 curves will be used as the input data to analyse the value at risk of signing the PPAs describe in section 5.

The same process as before is followed. Instead of dealing with Cal25 forward prices for the last ten years, what is done is to reproduce the same equations with average daily prices from the curves previously described. Historical and Monte Carlo simulations will be run.

In the Monte Carlo simulations, we use a normal distribution to model revenue because it reflects the aggregated effect of numerous independent factors influencing revenue, such as market demand fluctuations, seasonal effects, and random external influences.
Historical revenue data has been analysed and found to fit a lognormal distribution. But for the sake of simplicity a normal distribution has been used.
The normal distribution's properties facilitate straightforward simulation and analysis, allowing for efficient computation of a wide range of scenarios.

6.2.1. Fixed Price

A fixed price of 45 €/MWh has been chosen for the following analysis. It is what was seen before as rational and what is currently being monitored at the market (even lower prices, but it would not make sense to go much below that price as the captured solar prices stand at 50 €/MWh in 2024 and 43€/MWh for the 10-year average). Therefore, these are the inputs:

Variables	*Values*
Contracted Volume	80 %
PPA Price	45 €/MWh
GOs Price	2 €/MWh

Table 6. Variables for the fixed price, as produced PPA.

Notice that the GOs price is the price at which green certificates have been estimated to be issued and therefore its negative value is the limit price at which the PV asset will produce electricity.

Given those values:

Variables	*Values*
Captured Spot Price	43.8 €/MWh
Captured PPA Price	44.76 €/MWh

Table 7. Captured spot and PPA fixed price as produced prices.

The revenues are:

Variables	*Values*
Revenue Spot	33,816,303.66
Revenue PPA	34,559,307.49
Delta PPA – Spot	743,003.83

Table 8. Revenues of the spot and fixed price, as produced PPA.

Notice that the revenues from the spot are slightly higher (from point 5) as the PV asset does not produce below minus GOs price.

By comparing the Value at Risk of going merchant for 10 years with respect to signing the PPA, these are the results:

1. Historical VaR

		Historical		
Variable	Units	Mean	Standard Deviation	VaR
Revenues Spot	€	385.71	339.48	2.81
Revenues PPA	€	394.19	167.83	76.64

Table 9. Revenues of the spot and fixed price, as produced PPA under a historical VaR simulation.

And seen in a histogram:

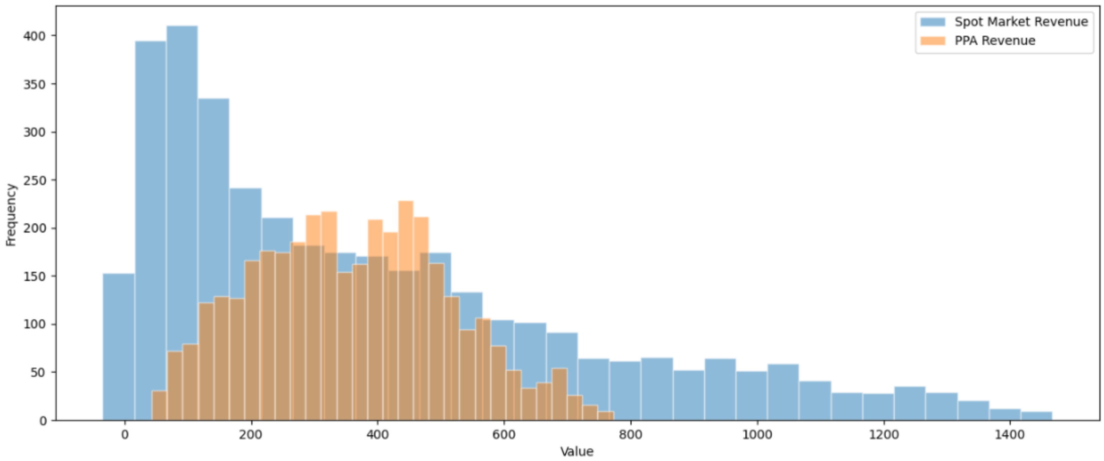

Figure 29. Histogram of the market revenues and the as produced fixed price PPA revenues.

For both, the average earnings for a day are around 350-400 € this makes sense since capture prices are low, and the production of this 38 MW plant is not extreme. However, what can be observed from the distribution is that the PPA dumbs the revenues and stacks them over the centre, which means that the standard deviation is much lower. This is what is exactly expected from a PPA. Therefore, the minimum amount of money obtained in a day at a confidence level of 99 is much higher with a PPA than going merchant.

2. Monte Carlo

VaR Spot Market €	*VaR PPA €*
-417.22	-1.89
-413.59	-4.91
-407.46	6.72
-374.01	6.26
-416.32	-7.33
-416.74	-8.26
-402.3	1.54

Table 10. Monte Carlo simulation of the VaR in the Spot market and the as produced, fixed price PPA.

For seven simulations, the average VaR in the spot market is -406.8 € and with a PPA -1.12 €. Again, the PPA dumps the losses down to a minimum. These results do not match exactly with the historical values, which can be because of the number of simulations given a large standard deviation. Either way they can be a good result to be compared with other PPA structures.

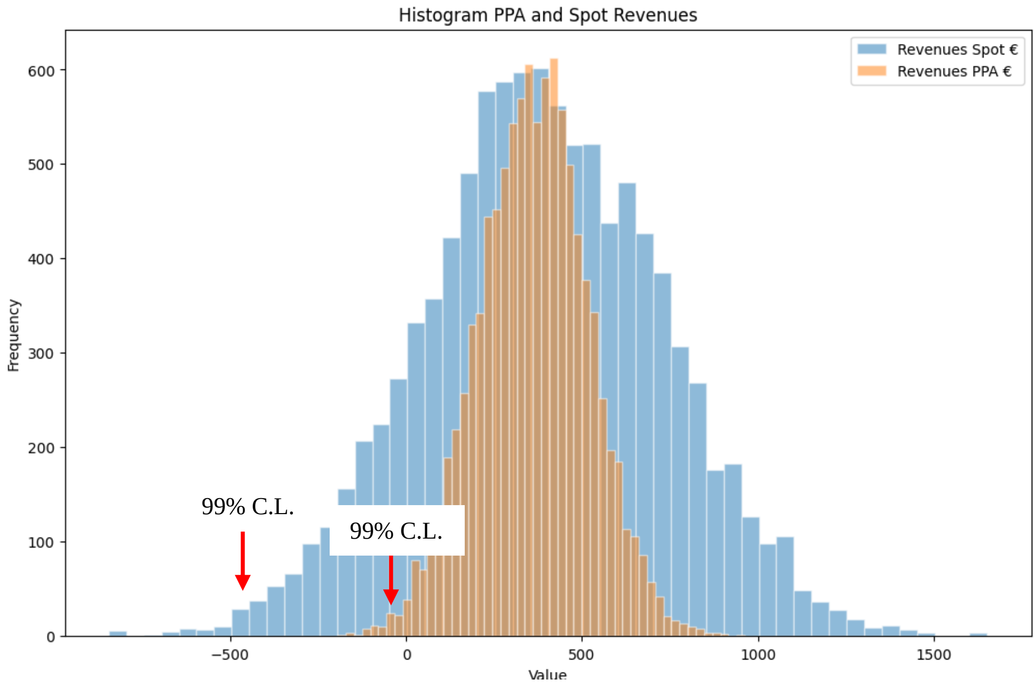

Figure 30. Histogram of the Spot and a as produced, fixed price PPA revenues under a Monte Carlo simulation.

6.2.2. Floor and Market Discount

A floor price of 30 €/MWh and a discount of 5 €/MWh have been chosen for the following analysis. It is what was seen before as rational and what is currently being monitored at the market (even lower prices, but it would not make sense to go much below that price as the captured solar prices stand at 50 €/MWh in 2024 and 43€/MWh for the 10-year average). Therefore, these are the inputs:

Variables	*Values*
Contracted Volume	80 %
Floor Price	30 €/MWh

Discount	5 €/MWh
GOs Price	2 €/MWh

Table 11. Variables for the floor and market discount, as produced PPA.

Given those values:

Variables	*Values*
Captured Spot Price	43.8 €/MWh
Captured PPA Price	50.59 €/MWh
Discount	-12.6%

Table 12. Captured prices for the spot market and the floor and market discount, as produced PPA.

The captured PPA price is much higher than the spot and fixed price PPA prices. This was seen in section 5. It would make more sense to opt for a lower floor price instead, but markets are moving around those numbers.

The revenues obtained are:

Variables	*Values*
Revenue Spot	33,816,303.66
Revenue PPA	39,066,614.45
Delta PPA – Spot	5,250,310.79

Table 13. Revenues in the spot market and with a floor and market discount, as produced PPA.

By comparing the Value at Risk of going merchant for 10 years with respect to signing the PPA, these are the results:

1. Historical VaR

		Historical		
Variable	Units	Mean	Standard Deviation	VaR
Revenues Spot	€	385.71	339.48	2.81
Revenues PPA	€	445.6	279.00	60.76

Table 14. Historical VaR for the floor and market discount as produced PPA.

As the mean grows in the revenues of the PPA, the standard deviation grows as well, meaning that the revenues are bigger, but also the dispersion we might expect from a PPA. This is not an excellent strategy since what we would like to get is assurance. However, the VaR is lower than before, meaning that what can be lost at maximum is lower. So even though the deviation is bigger, as the mean is moved towards the right, the VaR is lower.

And seen in a histogram:

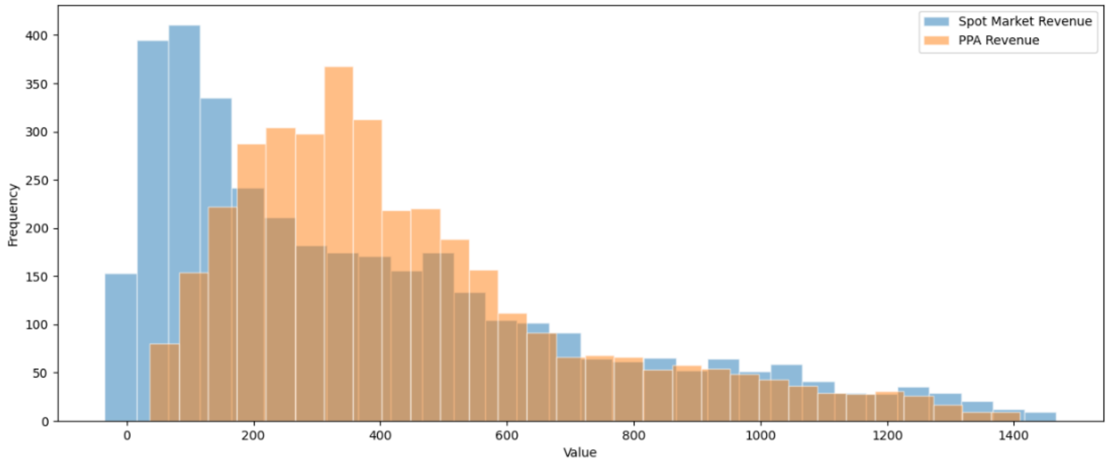

Figure 31. Histogram of the spot and floor and market discount as produced PPA.

For both, the average earnings for a day are around 385-450 € being higher those of the PPA. However, what can be observed from the distribution is that the PPA dumbs the revenues, but not as much as before, being the tails wide in both cases. This might be seen as a great risk, but since the tail is on the right, this is good.

2. Monte Carlo

VaR Spot Market €	*VaR PPA €*
-422.81	-211.89
-399.81	-216.77
-424.32	-213.65
-403.94	-209.1
-405.3	-185.37
-400.98	-215.47
-406.6	-196.52

Table 15. Monte Carlo simulation for the floor and market discount as produced PPA:

For seven simulations, the average VaR in the spot market is -409.11 €, quite similar to the VaR obtained before (ideally if there were infinite runs it would be the same number). With the PPA the average VaR obtained is -206.97 €. This is quite a shock (but reasonable, since the strategy is to follow the curve with a discount) because it is a great number, closer to the merchant one and really far away from the small figure obtained in the as produced PPA. Again, the PPA dumps the losses down but not as much as before. **The standard deviation has a huge effect on these results and therefore this strategy will be discarded as the optimal for the PPA. As much as the captured price is way bigger, there is a huge risk of getting negative revenues and unexpected ones. When following the price curves, there is a greater risk. In order to predict with a better stability, this option will be discarded.**

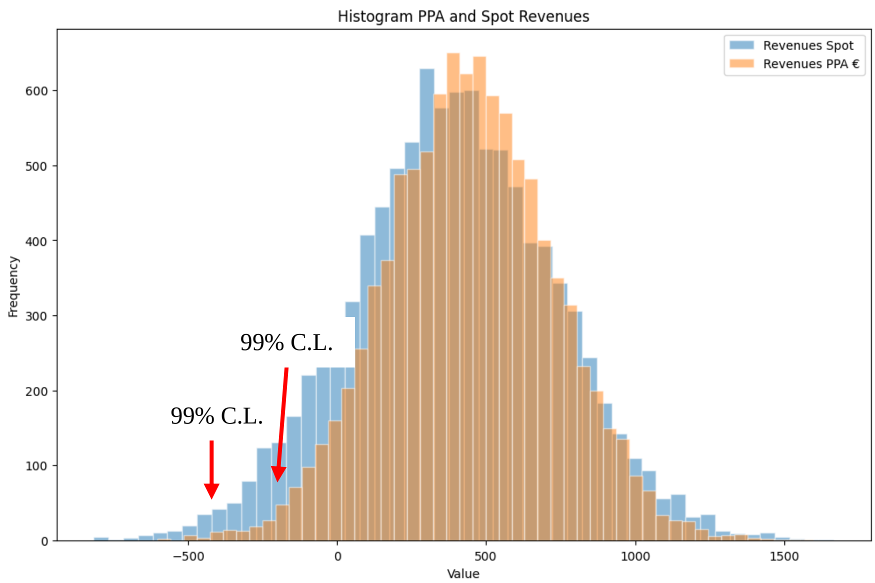

Figure 32. Histogram of the spot and floor and market discount as produced PPA revenues under a Monte Carlo simulation.

6.3. VaR Fixed Shape

The results that were dealt with in the *as produced* PPA, will be now handled when switching to a fixed shape PPA.

A historical VaR is computed with a confidence level of 99%. Revenues are obtained for fixed shape PPAs and set in order to see the maximum amount of money that can be lost within a day.

6.3.1. Fixed Price

A fixed price of 45 €/MWh has been chosen for the following analysis. It is what was seen before as rational and what makes sense comparing to. The results obtained are the following:

Variables	*Values*
Contracted Volume	80 %
PPA Price	45 €/MWh
GOs Price	2 €/MWh

Table 16. Fixed shape, fixed price PPA variables.

Given those values:

Variables	*Values*
Captured Spot Price	43.8 €/MWh
Captured PPA Price	44.76 €/MWh

Table 17. Captured prices for the spot market and fixed shape, fixed price PPA.

These values are the same as for the *as produced* case since no variation in the curves are being considered. Introducing variability to spot prices or to volume would make these values change. These values are not stressed since the captured PPA price is divided by the volume and therefore making a small difference.

Variables	*Values*
Revenue Spot	33,816,303.66
Revenue PPA	34,559,307.49
Delta PPA – Spot	743,003.83

Table 18. Revenues of the Spot market and the fixed shape, fixed price PPA.

These is exactly the same as we would expect since an as produced and a fixed shape PPA are the same as long as the P50 is respected. Therefore, al the results will be the same but for the Monte Carlo simulations, which will necessarily give similar results too.

Therefore, let's stress both volume curves and see their differences:

Stress - volume (%)	*VaR As Produced*	*Var Fixed Shape*
140	107.29	92.4
120	91.96	84.38
100	76.74	76.74
80	61.31	66.56
60	45.98	30.98

Table 19. Historical VaR comparison between an as produced and a fixed solar shape, fixed price PPA.

For high volume production, the VaR is higher for the as produced case, meaning that it would be recommended to opt for this option. For low volume production, the Value at Risk is slightly better for the 80% but gets quickly worse in the next simulation. **If we went lower, VaR in a fixed shape would decline quickly whereas the as produced case would remain more constant. This would also depend on whether prices remained the same or they went up. In the case of going up, it would be a favourable situation for the fixed shape.**

For the Monte Carlo simulation, for the sake of simplicity, only one value would be registered:

Stress - volume (%)	*VaR As Produced*	*Var Fixed Shape*
140	-3.54	-107.19
120	4.56	-29.92
100	-5.1	10.82
80	3.48	5.71
60	2.4	-54.38

Table 20. Monte Carlo VaR comparison between an as produced and a fixed solar shape, fixed price PPA

After running many simulations, what has been observed is that fixed shape values are much more extreme than as produced ones. This makes the PPA much more volatile and less attractive.

6.3.2. Floor and Market Discount

The same floor price of 30 €/MWh and a discount of 5 €/MWh have been chosen for the following analysis as it would not make sense to compare other PPA prices. As it happened before, if there are no variations of volume the results would be the same of the as produced case. What it is important now then is to stress the volumes to see what VaR are obtained.

Stress - volume (%)	*VaR As Produced*	*Var Fixed Shape*
140	85.06	77.34
120	72.91	69.04
100	60.76	60.76
80	48.60	55.27
60	36.45	49.19

Table 21. Historical VaR for an As Produced and a Fixed Shape, floor and market discount comparison.

So the tendency is the same as before, but for low volume cases, which seems to be better damped with the fixed shape structure.

For the Monte Carlo simulation:

Values in the fixed shape are huge because of the great standard deviation there is with the floor structure.

Stress - volume (%)	*VaR As Produced*	*Var Fixed Shape*
140	-306.74	-339.66
120	-250.94	-282.30
100	-211.59	-207.23
80	-156.65	-120.75
60	-134.02	-67.54

Table 22. Monte Carlo VaR for an As Produced and a Fixed Shape, floor and market discount comparison.

7. Conclusions

As a way of conclusion, there is no optimal way of signing a PPA. However, there are ways of reducing the risk. These ways five lower profitabilities but better bankability, since banks will be looking for low risk high revenue.

First and foremost, market forecasts are inaccurate, and price curves are difficult to predict. Based on X-Elio's scenarios, going merchant can get the solar plant analyzed close to 4 million euros in 2024. In the worst-case scenario, there would be a decrease in revenues of a 36%, whereas in the best-case scenario, an increase of 44% in revenues can be expected.

When signing an as produced, fixed price PPA, if the price at which the contract is signed is the captured solar expected price (for a solar asset), the contracted volume does not matter. Therefore, for a fixed 100% scenario, the PPA and merchant revenues are the same. That being said, for different prices scenarios, the higher it is the market prices expectations, the least convenient it is to sign a PPA and vice-versa. What should be noted is that in the lowest-case scenario for that type of PPA, the revenues of signing a PPA are always higher than the revenues of going merchant. However, in the best-case scenario, merchant revenues are way better. This means that PPAs dump the losses in low-prices scenarios.

For a fixed price – fixed shape PPA, for an invariable production scenario, the revenues obtained will always remain the same. It is always best to have high volumes and prices scenarios. The most detrimental case is to have really high prices with really low volumes.

Therefore, for low prices scenarios, the dumping is better for a fixed solar shape, whereas for high prices scenarios the preferred option would be to sing an as produced PPA.

Regarding floor and market discount structures, if it is an as produced structure, the lower the spot prices but the higher the production, the most convenient it is to sign a PPA with a floor and market discount structure.

High floors and high discounts are equally competitive as low floors and low discounts. It happens the same for the fixed shape – floor and market discount PPA. The spread is best when the spot price is low.

Risk-wise, going merchant gives a really high standard deviation that is worth considering. When signing a fixed price, as produced PPA at 45 €/MWh, the least one could earn at a 99% confidence level with a PPA is 76.74 € in an hour. The least one could earn going to the market is 2.81, so there is a huge advantage in the PPA. The Monte Carlo simulation gives much more extreme scenarios in which one could even lose 417€ at a certain hour.

Floor and market discount with an as produced structure offer a higher standard deviation and a lower VaR. This means that the structure is worse. This can also be reflected in the Monte Carlo simulation, where the PPA revenues and the Spot market revenues get closer because of the standard deviation.

Fixed shape VaR are more volatile and lower, which makes that option less attractive.

Therefore, the preferred option would be to go for an as produced, fixed price PPA.

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