Off-site PPA as a tool to protect against electricity price spikes: developing a framework for risk assessment and mitigation

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Abstract

This dissertation was developed in collaboration with E&C Consultants, an international energy procurement consultancy, to gain a deeper understanding of the impact of the energy crisis on Power Purchase Agreements (PPAs). Electricity price spikes occurred as early as 2021, initially driven by low gas storage levels, a post-pandemic economic rebound and then exacerbated by the Russian invasion of Ukraine. The situation had a range of consequences, from rising inflation, increasing energy poverty, food insecurity, and recession. PPAs are a well-known tool to protect energy consumers from price spikes, while at the same time contributing to sustainable technologies. PPAs are long-term bilateral contracts for the purchase and sale of electricity, usually generated from renewable sources. Volatility in the energy market in 2022 negatively affected the PPA market, causing a rise in prices by up to 10-15% only in the first quarter of 2022 and development of new trends. The primary goal of this Master's Thesis is to assess how the risk associated with PPAs has evolved between 2020 and 2023. It aims to examine whether, after the events in 2022, PPAs remain a robust solution that protects the off-taker from energy price spikes, ensures greater energy budget stability, and enables savings. To achieve this, the probability of PPA prices being higher than market prices is evaluated. Furthermore, this Thesis intends to gain a thorough understanding of each risk related to PPAs and the best strategies for mitigating it, in order to maximize the protection of the off-taker.

1. Introduction

In 2022, the global energy markets encountered an extraordinary surge in price levels, resulted from a sequence of events starting in 2021. Firstly, following the economic slowdown caused by the COVID-19 pandemic, the end of lockdown resulted in the rapid recovery of various industries and businesses. Secondly, major natural gas suppliers such as Gazprom reduced their volumes and did not refill their storage facilities in Europe to the levels seen in previous years. Thirdly, weather-related events, such as droughts and heat waves, had a major impact on the trends of the demand and electricity production. The already pronounced strain on the global supply chain and energy price dynamics experienced an escalation on February 24, 2022, when Russia invaded Ukraine. Since Russia is the world's largest exporter of fossil fuels, this event not only caused tremendous damage to the Ukrainian energy sector, but also impacted the entire global energy system. Russia has sought to use its position as an export leader to influence European countries, exposing consumers to higher energy bills and supply shortages. Europe, in turn, imposed sanctions on fuel imports as a tool of political pressure and a sign of support for Ukraine. These actions have cut off one of the main arteries of global energy trade, demonstrating the extreme vulnerability, fragility, and unsustainability of the energy system (World Energy Outlook 2022).

One of the well-recognized tools to protect clients from energy price spikes is through Power Purchase Agreements (PPAs). PPAs are long-term bilateral contracts for the purchase and sale of a certain amount of electricity, most commonly coming from renewable sources. Energy crisis impacted PPA market affecting its prices and the development of various trends. PPA prices in the first quarter of 2022 was reported to increase even by 10-15% (Zeigo and S&P Global Platts PPA Pricing Report, 2022)

This Master's Thesis was developed in collaboration with E&C Consultants and its major goal is to assess the changes in risk associated with Power Purchase Agreement contracts following the 2022 energy crisis. To comprehend this impact, it first introduces fundamental information about PPA contracts and their types. Subsequently, to better shield off-takers from uncertainties linked with these contracts, the main associated risks are presented alongside strategies for their mitigation. Next, a series of Monte Carlo simulations is conducted to evaluate how the risk of PPA prices exceeding the market price has evolved from 2020 to 2023. Two distinct markets, Germany and Spain, are selected for the simulations. Furthermore, a detailed analysis is performed to compare the benefits derived from such contracts during the reference period. The thesis also provides market analysis, offering insights into the actual number of transactions, disclosed volumes, and the most prevalent trends related to PPA contracts in 2022 and 2023.

2. PPA definition and typology

PPAs are long-term bilateral contracts for the purchase and sale of a certain amount of electricity, typically from renewable sources at an agreed tariff. PPAs are also an effective financial instrument, providing price stabilization, reducing price risk and allowing a budget planning. Of the many types of Power Purchase Agreements, the fundamental and best-known division is between on-site and off-site PPAs. On-site PPAs, are typically smaller projects, such as photovoltaic panels on rooftops or windmills, located on the off-taker's premise. In the case of off-site PPAs, the installation is located far from the consumer, which means that electricity must be transported through the distribution network. Off-site PPAs are usually larger projects, such as wind turbine fields with high power output and large amounts of energy, which must be balanced during periods of under- and overproduction. This dissertation focuses on off-site PPAs, due to their greater complexity (De Meulemeester, 2019; Kanellakopoulou M.).

Selecting the most suitable PPA for a particular company is crucial to avoid being tied into long-term contracts with a power price far above the market price. Power Purchase Agreement can be divided by several criteria:

a. Delivery point:
    i. PPA with a delivery at the exit point - the point where the consuming facility is connected to the grid, with the seller responsible for energy transport through the network.
    ii. PPA with a delivery at the entry point - the point where the generating facility is connected to the grid. Under the Point of Entry PPA contract, the seller is not responsible for transport through the distribution network, with energy settled in two ways as described in point 2.
b. Settlement Method:
    i. Physical (sleeving) PPA - an agreement that integrates the energy produced under the PPA with a conventional electricity supply contract by the supplier.

   ii. Financial PPA (swaps) - a contract where a third-party purchases energy at the point of entry at spot prices and then resells it at the point of exit at spot prices. One type of financial PPA is a Virtual Power Purchase Agreement (VPPA), also known as a Contract for Difference (CfD). Under the VPPA, the developer sells energy at variable market rates, calculating the deviation from the predetermined VPPA price. If the sum is positive, the developer compensates the buyer, and if negative, the buyer compensates the developer accordingly. VPPAs are highly beneficial for the buyer as they provide the opportunity to purchase Energy Attribute Certificates (EACs) confirming the renewable origin of electricity and can be used for carbon emission savings.

c. Delivery Profile:
   i. Pay-as-produced PPA - the energy off-taker is obliged to purchase the entirety or a pre-determined percentage (%) of the energy produced by the renewable installation, even if consumption is lower than the renewable energy production in a given hour.
   ii. Baseload PPA - the supplier commits to delivering a constant amount of energy every hour of the day for a specified period - a month or a year. The energy producer is responsible for balancing surpluses or shortfalls to ensure a consistent energy profile within the agreed time frame.
   iii. Pay-as-consumed PPA - the renewable energy producer adjusts energy production to a curve that reflects the customer's consumption pattern. Under this agreement, the risk is transferred to the supplier.

d. Balancing and residual energy - balancing energy refers to the mismatch between forecasted production and the actual production profile that must be sold or purchased from the grid. Residual energy pertains to the difference between forecasted production and the consumption profile. During the signing of a PPA contract, balancing services, and residual energy can be included in the PPA agreement or negotiated separately.

e. Pricing mechanism:
   i. Fixed price (one-shot or with an escalation) - one-shot fixed-price PPA means a predetermined fixed electricity price for the entire term of the contract. Conversely, under a with an escalation PPA, the energy price for a given year is predetermined and then increases each year by a pre-defined rate or an external reference point, for instance inflation rate.
   ii. PPA with SPOT price with discount.
   iii. PPA with a price cap / floor/ collar - price cap means the upper limit, and price floor means the lower limit of the price of electricity that the buyer is obligated to pay. The price collar includes both a price ceiling and a price floor.

f. Geographical scope:
   i. Cross-border PPA - contract for the purchase of electricity produced in a country other than the one where the customer is located.
   ii. PPA in the country - energy produced and consumer are in the same country (De Meulemeester, 2019; Kanellakopoulou M.).

Selecting the appropriate type of PPA from the aforementioned options is crucial for the success of this contract and is determined after a comprehensive understanding of all associated risks.

3. Risk of PPAs & Mitigation Strategies

Power Purchase Agreements have emerged as a popular solution, offering the prospect of price stabilization and the ability to reinforce sustainability commitments through the procurement of Energy Attribute Certificates (EACs), Despite their undeniable attractiveness, it is important to remember that PPAs are not without inherent risks, as elucidated in Chapter 3 below:

a) Price risk - is often defined as a PPA going "out-of-the-money," which means that a customer buys electricity at a higher price than the power from the grid. Clients can adopt certain strategies to address a price risk, including implementing alternative pricing mechanisms, such as collars or SPOT prices with indexation (Shea & Abott, 2020; De Meulemeester, 2019).
b) Shape risk / profile risk - arises from the unpredictability of the timing of renewable energy generation, while the total power output may align with expectations. Shape risk is completely born by the supplier in pay-as-consumed Power Purchase Agreements (Shea & Abott, 2020; De Meulemeester, 2019).
c) Volume risk - stems from the uncertainty associated with a power plant's ability to achieve the projected volume, estimated based on long-term meteorological data typically 20-30 years. One mitigation strategy is through a multi-technology PPA or multi-location PPA. By entering into such agreements, the client can reduce the amount of energy required for purchase, simultaneously minimizing market volatility exposure (Shea & Abott, 2020; De Meulemeester, 2019).
d) Cannibalization - refers to the scenario where renewable energy sources "cannibalize" their own profits. In times of abundance of renewable energy sources, there is a rapid surge in energy production from these technologies, leading to a decrease in the price at which they are sold (Kanellakopoulou & Trabesinger).
e) Operational risk - arises when renewable energy systems fail to meet predefined operational availability levels due to malfunctioning processes, personnel or equipment issues, or system problems. One strategy for mitigating operational risk is via the Proxy Generation VPPA, in which the size of the contract is determined by the amount of power the plant could deliver to the grid if it operated at maximum equipment capacity and in accordance with best operating practices (John, Taylor, & Davies, 2018; Tundermann, 2019; Shea & Abott, 2020).
f) Balancing risk - refers to the vulnerability to power system costs resulting from disparities between forecasted and actual renewable energy production. Mitigating balancing risks can involve strategies such as implementing a multi-technology PPA or engaging an external entity, like a utility, to consolidate assets into a resource pool for balancing risk management (Gabrielli, Aboutalebi, & Sansavini, 2022; Hedges & Duvoort).

g) Basis risk – is mainly related to VPPAs and arises from disparities in market prices at the power producer's location and the power consumer's location. Mitigating this risk involves securing supply contracts referencing established indices, like the Nordic Power Exchange price index (Nordpool). Additionally, cross-border VPPAs are executed in countries with highly correlated markets to minimize basis risk (Understand Basis Risk, n.d.; Collell, 2023).
h) Credit risk and counterparty risk - Credit risk refers to the uncertainty whether the buyer will meet their payment obligations on time or at all. Counterparty risk is the likelihood that one of the parties involved in the transaction will not fulfill their contractual obligations. Strategies to mitigate these risks include credit support, such as credit insurance, letters of credit (LoC), and parent company guarantees (PCG) (Trabesinger, 2020).
i) Non-market risks - arise from non-energy market events that can impact the outcomes of PPA contracts, such as regulatory changes, incentive adjustments, or fluctuations in various cost factors that can result in losses for PPA parties. A risk mitigation strategy may involve incorporating a clause in the agreement promoting good-faith renegotiation, stipulating that in the event of a significant change, both the energy off-taker and the project owner are obligated to convene a meeting and make a genuine attempt to discuss modifications (Shea & Abott, 2020; De Meulemeester, 2019).

Despite the numerous risks associated with PPAs, these agreements have offered numerous benefits, and their popularity did not wane in 2022, as described in Chapter 4.

4. PPA Market in 2022

A significant challenge for renewable project developers in 2022 was the raising LCOE (Levelized Cost of Electricity) and higher project costs driven by inflation. LCOE represents the expenses associated with a power generation facility over its lifetime, including both initial capital expenditures (CAPEX) and the present value of ongoing operating expenses (OPEX). Over the past two years, the investment costs of new photovoltaic power plants and onshore wind farms have increased by 15% to 25%. This shift has posed challenges for the development of renewable technologies and is reflected in the rising prices of PPAs. The growth in the investment costs can be attributed to several factors. Firstly, the cost of materials and components required for the construction of renewable assets has seen a significant rise. For example, materials for producing PV panels, such as steel, copper, aluminum, and polysilicon, increased by approximately 300% from 2020 to 2022. Secondly, the expenses associated with engineering, procurement, and construction (EPC) contracts for renewable assets have increased. Thirdly, the rise in interest rates has created greater difficulties in securing financing for renewable projects, with a 2% increase in interest rates in 2022 (Steinecke, Moncayo, Palumbo & Schilling, 2023.

Despite the most turbulent year in recent energy market history, the number and volume of PPAs remained relatively stable. According to Pexapark data, disclosed contract volumes declined by 21% from 10.7 GW in 2021 to 8.4 GW in 2022. However, the number of transactions increased by 4.5% from 154 in 2021 to 161 in 2022. Moreover, corporate PPAs accounted for the vast majority, comprising 80% of the total number of transactions and 83% of contracted volumes in 2022 (Pedretti & Kanellakopoulou).

The significant increase in the share of intermittent renewables in the grid mix, coupled with the sharp rise in spot, intraday and balancing electricity prices, has led to another important trend - the escalation of balancing costs. In the aftermath of the energy crisis, balancing costs exceeded 10 €/MWh in many markets. Sellers have often faced greater challenges when negotiating balancing agreements compared to conventional PPAs. Due to the same factors, the problem of cannibalization, mentioned in Chapter 3, has also increased, where the simultaneous production of renewable resources has resulted in lower prices for energy producers (De Meulemeester, 2019; Pedretti & Kanellakopoulou).

In addition, alternative price models such as partial fixed price, partial variable price, or inflation-linked PPA gained popularity in 2022. Such pricing mechanisms indicate that consumers have adopted a proactive strategy to counter market volatility and, by choosing more complex pricing mechanisms, want to protect themselves from large price spikes (Pedretti & Kanellakopoulou).

Another observable trend in the field of PPAs caused by the energy crisis is the significant escalation of counterparty risk and credit risk. Counterparty risk has emerged as a key contributor to the collapse of many PPAs in 2022, mainly attributed to challenges in reaching consensus on adequate credit support. Moreover, elevated market volatility has also increased the level of regulatory risk associated with new regulations designed to shield consumers from sudden price spikes. One example of such regulations is the EU-wide revenue cap of 180 €/MWh introduced by the European Commission in September 2022. This regulatory change has raised numerous concerns about its potential impact on Power Purchase Agreement revenues and investors' expected returns on investment (Pedretti & Kanellakopoulou).

Energy price spikes have also caused an increase in backwardation, a price phenomenon in which the futures price of a commodity is lower than the expected spot price at the time of delivery. For traders and investors, backwardation is a signal that the current price is too high, and the spot price is expected to eventually fall as the futures contract approaches expiration. The backwardation curve is very important for PPAs because it affects its duration and price. Significant backwardation has led to a price divergence between short- and long-term PPAs, resulting in significantly higher prices for the former. This phenomenon resulted in a high level of interest among power producers in choosing short-term hedges over the usually high-demanded long-term PPA (Pedretti & Kanellakopoulou). It is apparent that despite the volatile market landscape in 2022, PPA's popularity has not declined. Chapter 5 will examine how the risks associated with these contracts have changed over this period.

5. Risk assessment

Risk assessment of the off-site PPA project was conducted using Monte Carlo analysis, which is a multivariate modelling technique that uses multiple variables to predict possible outcomes. This statistical tool is used to generate probability distributions or to assess the risk of an investment or event. The Monte Carlo simulation tool uses historical price data for a specific market and, by performing a selected number of iterations, checks the probability of the Power Purchase Agreement price more expensive than market price. To analyze the impact of the energy crisis on PPA risk, three sets of simulations were run - in 2020, before the pandemic and then Russia's war with Ukraine, in 2022, when the impact of the energy crisis was more apparent, and in 2023, when energy prices gradually fell and relatively stabilized. For the risk assessment, two distinct markets have been selected: Germany and Spain. These countries differ in terms of the composition of their energy mix, dependence on Russian fossil resources, advances in renewable energy technologies and maturity of PPA markets. This choice was made to provide a comprehensive perspective on the impact of the energy crisis on the different European countries. Prior starting the Monte Carlo simulation, the following input data had to be defined:

1. Hourly power output from renewable installation for a year at the selected location - to obtain the first required set of inputs, it was assumed that the energy was produced by a photovoltaic (PV) installation. Subsequently, the European Commission's Geographical Information System was used, which is an interactive tool that collects hourly radiation and photovoltaic power production data from 2005 to 2020 for European countries. Using this tool, two locations - one in Germany and one in Spain - were selected by specifying the longitude and latitude, and then the hourly energy production from PV panels was collected for these specified sites for 2018-2020. A span of three years was selected for the examination since this duration would allow the creation of an average energy production profile for the region. The data was generated for the optimal conditions of PV modules, such as azimuth and tilt. In the next step, based on the E&C Consultants' expertise, it was assumed that the PV installation would produce 30 GWh per year. Then, the hourly production of the PV plant was calculated as a multiplication of hourly profile for a specific location and determined power output of 30 GWh. In addition, the PPAs considered in a simulation were baseload PPAs (Photovoltaic Geographical Information System).
2. Hourly energy consumption of a hypothetical client for one year - it was assumed that 50% of the customer's energy consumption would be met by energy generated by the PPA plant, resulting in a consumption of 60 GWh. This percentage was determined through internal discussions with E&C Consultants.
3. Energy market information for the selected country- historical energy prices were sourced from the European Energy Exchange (EEX), an energy trading platform for the German market in Europe, and OMIP, the entity in the Iberian energy market in Spain, known as "Operador del Mercado Ibérico de Energía - Polo Español, S.A.".
4. PPA price offered in Germany and Spain in 2020, 2022 and 2023 and balancing costs - PPA prices from the fourth quarter of 2020 and 2022, and the second quarter of 2023 were considered, using the LevelTen PPA Price Index. As mentioned, LevelTen considers the 10% most competitive bids in a given market to determine its index. Balancing costs were assumed based on the market research. Table 1 presents the

adopted PPA prices in Germany and Spain and balancing costs, which were the same in both countries (PPA Price Index Reports; Daily Balancing Cost Report ESO, 2023).

Table 1. Adopted PPA prices in Spain and Germany and balancing costs.

	Q4-20	Q4-22	Q2-23
PPA in Germany	49 €/MWh	90 €/MWh	75 €/MWh
PPA in Spain	34 €/MWh	46 €/MWh	46 €/MWh
Balancing cost	2.50 €/MWh	15 €/MWh	15 €/MWh

It is important to emphasize that in the simulation performed by the PPA tool, the profiles of photovoltaic production and customer energy consumption are constant and remain unchanged in each iteration. In contrast, the data set that varies in each iteration is the price profile. The price profile is generated in two stages. Firstly, the simulation uses one year of future calendar prices quotes to create an average future price and calculate its standard deviation. Depending on the selected market, the interactive tool creates an average price based on available futures traded products. For instance, the tool takes predicted futures prices from the day of the analysis for years 2024, 2025, 2026, namely Cal24, Cal25, Cal26 products. The tool then generates an hourly price profile for a period of one year, based on the historical SPOT prices and the previously obtained Gaussian future price distribution. This profile is generated for each iteration and finally, after a fixed number of iterations, the most probable profile and price is obtained. In the conducted analyses the main considerations are two key factors: customer savings from having a Power Purchase Agreement, and the risk associated with the PPA price being above the market price at a particular time. A review of these two factors for the period 2020-2023 can demonstrate the effectiveness of the PPA in protecting against energy price spikes. Based on the adopted assumptions, six simulations were conducted, each consisting of 500 iterations. The results are presented in Table 2.

Table 2. Results of the Monte Carlo simulation for Germany and Spain in 2020, 2022 and 2023.

	Analysis from 01/10/2020	Analysis from 01/10/2022	Analysis from 01/04/2023
Germany			
Revenue of having PPA	23.00 %	10.92%	15.19%
Risk of PPA ¨going out of the money¨	23.20%	33.40%	14.40%
Spain			
Revenue of having PPA	20.71%	10.53%	7.59%
Risk of PPA ¨going out of the money¨	21.00%	35.20%	34.20%

Looking at the results, PPA in both Germany and Spain within all the considered timeframe resulted in considerable cost savings compared to the conventional method of purchasing electricity from the grid. The greatest potential was in 2020 and this value significantly decrease in 2022 and 2023, mostly due to higher PPA price and balancing costs. Moreover, the extremely high and fluctuating energy prices affected the generated price profile. An intriguing situation emerged in 2023, when Germany experienced an increase in PPA savings, while Spain saw a decrease. This phenomenon may indicate the potential impact of the introduction of a price cap in Spain in 2022, which stabilized and reduced electricity prices in the country. These measures could result in the market price being closer to PPA priced, thus reducing the benefits of it. Nevertheless, PPAs continued to offer consumers a reasonable financial choice, even in the face of market fluctuations and uncertainty, as evidenced by the positive values obtained in the assessment (Gordon, 2022).

Risk of PPAs "going out of money" substantially increased in 2022 during the energy crisis. Notably, it rise more for Spain than for Germany. Such an increase for Spanish market could be caused by the introduction of a price cap, that lowered and stabilized energy prices, increasing the risk that a higher PPA price would surpass the market price. Looking at 2023, different trends for Germany and Spain emerge. In the case of the first selected country, risk significantly decreased and reached the lowest level of all simulations. The higher and more volatile market prices, coupled with a lower PPA price, provided a significant protective buffer, ensuring a favorable PPA price compared to the market price. On the other hand, the risk of PPAs becoming financially unviable in 2023 stayed relatively constant in Spain compared to the previous year, mostly due to constant PPA price and balancing costs, as well as the impacts of the previously mentioned price cap. Nonetheless, the maximum level of risk that the PPA price would exceed the market price was 35%, indicating relatively positive results.

6. Conclusion

After analyzing the results of the simulations, several conclusions emerge. Firstly, the challenging market situation in 2022 led to a decrease in generated savings from PPAs and an increase in associated risks, thus confirming the statement that the energy crisis had a negative impact on PPA-related risks. Secondly, even in this difficult energy landscape, the risk that the PPA prices would exceed market prices remained relatively low, accounting for about one-third of the scenarios. Furthermore, engaging in PPAs continued to yield significant cost savings compared to conventional grid power purchases. Furthermore, while evaluating the profitability of PPA, it is crucial to consider the situation when the savings from having a PPA in the first few years can offset higher prices in the future. Then, taking the entire PPA energy budget into account, it may be lower than buying energy from the grid for the entire period.

Very importantly, PPAs also contribute to the development of sustainable technologies and can bring significant savings to a company through the purchase of Energy Attribute Certificates and carbon tax reductions. Despite the challenges posed by rising PPA prices and the associated risks stemming from the energy crisis, this study has demonstrated that Power Purchase Agreements remain compelling instruments for ensuring stability and predictability in long-term energy costs. These agreements have proven their effectiveness in shielding against energy price fluctuations, facilitating price stabilization, enabling budget planning, and actively supporting the adoption of sustainable technologies.

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