Benefit of a Direct Trade Power Purchase Agreement with a Wind Farm

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Abstract

In the Netherlands more wind farms are constructed and energy is contracted in long-term Power Purchase Agreements (PPA) to guarantee a steady revenue stream for the wind farm owners. However, until now only large corporates closed PPA contracts to obtain the Renewable Energy Credits (RECs) from a wind farm and claim to be renewable. A new type of PPA is designed that has a direct link between the corporate and wind farm and transfers both power and the RECs. This direct trade PPA is analysed by applying an economic theory, the property rights theory, on the energy sector and by modelling the financial consequences. The result is a framework with the transactions, the risk allocation and the economic incentives of the actors involved. It shows more incentives to invest in renewable energy, moreover the corporate takes more volume risk on the energy production in order to obtain benefit which can be reduced by contracting a service provider. Furthermore, the financial model shows a significant financial benefit for a direct trade PPA compared to a traditional contract and shows a positive effect on the match between supply and demand. Moreover, the match and benefit can be increased by 25% by adding solar capacity in combination with wind energy. The next step is to further investigate this direct trade PPA and to promote this PPA type to corporates that want to invest in renewables and use this as a preferred contract type.

Keywords: Power Purchase Agreement, Wind Farm, Direct Trade, Service Provider, Property Rights Theory

1. Introduction

An increase in the share of renewable energy is necessary now as the deadline closes in for the climate goals. Last year (2018) the climate top in Katowich discussed again all the measures countries need to take to reach the goals of the Paris Climate Agreement and keep the temperature rise under the two degrees Celsius [1, 2]. The energy sector is an important sector since it contributes for a large part to the emissions and a change is needed to fully supply the electricity and heat demand with renewables. In the Netherlands the goals for the energy transition demand a reduction of CO2 emission with 80 to 95%, according to the Energieagenda 2050 [3]. Moreover the amount of renewable energy needs to be increased by 1 GW per year for offshore wind to meet the goal of 16% renewable energy in 2023.

To reach these goals, many countries build large wind parks in the sea or on land. These projects were in the beginning often subsidised, but recently more projects try to build the parks without subsidy [4]. This will force offshore wind operators to be inventive in the financing of their projects, influenced by the energy markets which will become more decentralised with declining energy prices for wind [5].

A solution is the use of Power Purchase Agreements (PPA) to contract the energy of a wind farm for a long period. These contracts specify the volume and price for the energy of the wind farm. PPAs are already widely used in the energy market in the US and they are more and more used in the EU and Asia [6]. The main reason parties are joining PPA contracts is to hedge their electricity prices for a longer period, and they want to become more sustainable by increasing the share of renewable energy in their energy contracts [5]. The incentive for developers and utilities to use PPAs, is the security the contract offers with a guaranteed off-take of their power, so both volume and price are guaranteed. The result is a stable income from the energy they sell in the PPA contract by which they can attract investors and cover their capital costs.

In a standard PPA the wind farm sells its power in a PPA to a large corporate who in turn sells all this energy to a utility. This is called 'sleeving', the corporate uses the utility to balance all the generated power and buys only the power from the utility that it needs. The difference with a regular energy contract is that the corporate owns the green certificates of the wind farm and can say that their energy demand is sustainable.

A new PPA structure is now investigated in this paper that does not sleeve the power through an utility. The corporate uses directly the power that is generated from the wind farm and sells only the surplus power to the utility or service provider (SP). A problem that rises with this structure is the uncertain production of the wind farm and the administrative responsibility for the corporate to the TSO. A balancing service is required to supply power as the wind supply is not sufficient, sell the surplus power and do the forecast of the wind and program responsibility with the TSO.

The problem is, firstly, the intransparency of the service costs, customers cannot make the comparison between the costs for using the services of a retailer and the costs for doing these

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tasks themselves. The price for matching the supply and demand should be made more transparent with a specification of the cost components. Secondly, a framework lacks that describes the relations between the parties in a direct trade PPA agreement. The responsibilities, the power flows and the financial flows are not clearly allocated. Thirdly, there is no data of the advantages of a direct PPA agreement. Is this construction feasible in the current electricity market? This thesis aims to provide insights in the economic and financial effects of a direct PPA on the energy sector.

2. Method

Two methods are used in this research, the property rights (PR) theory and a modelling approach. First, a literature review is done into the PPA contracts and the functioning of the energy market in the Netherlands (section 3). This is done by using the Scopus search engine complemented by searches with Google Scholar and by using forward and backward snowballing. Keywords used are "PPA energy", "direct energy trade", "property rights energy sector", "value proposition retailer". Results were sorted on number of citations, relevance and year to manipulate the order of the search results and select all the relevant papers. Papers were selected if they described the types of PPA contracts, case studies on PPA contracts, the role of a retailer now & in the future and the functioning of the energy markets. Second, a modelling study is done using the software tools Excel, Python and R-studio. Furthermore, in section 4 the property rights theory is applied to the energy sector to gain insight in the transactions and how they are decomposed. It gives an integrated view on complex transactions and the incentives of the actors and the economic efficiency of the market. In section 5 the financial results are presented using a quantitative model. Finally, in section 6 and section 7 the results are discussed and a conclusion is drawn.

3. Literature Study

In the literature there are two main PPA types: the sleeved PPA and the virtual PPA. The implementation of these PPAs in several countries in the world is analysed by Dingenen and Reid [7]. In a sleeved PPA the energy is traded in a PPA with a corporate or consumer, the energy is than sold to the utility and only the required energy is bought back from the utility. All the energy of the wind farm is sleeved through the utility to provide balancing and is than supplied to the consumer. The consumer does not carry the risk of the production volume. The other PPA, the virtual PPA, differs from the sleeved PPA because the wind park has a PPA agreement with the utility and not directly with the corporate. The utility buys the power, balances it with the grid and supplies the corporate with power. A special characteristic of this PPA is that the corporate has a separate contract with the wind farm. In this contract they agree on a fixed strike price, the corporate pays always the same price and the wind farm and the consumer settle the differences.

In the literature most PPA projects are closed by very large corporates who can consume the full production of a wind turbine or wind farm. There demand is that large that the wind power is only a small part of their demand and has less influence on their security of supply. Examples of these companies in the Netherlands are Google, Dutch Railways (NS), Philips, AkzoNobel and DSM. However, there are only so many companies like Google or Walmart that can buy hundred of megawatts at a time [8]. The developers of wind project need to be innovative and search for solutions to close deals with smaller buyers. At the MIT university a first large aggregated solar power PPA project was developed in the end of 2016. This aggregated PPA needs four components: a utility as a natural aggregator, a developer of the wind or solar farm, an investor that can carry the risks and split the production in parts and customers that contract parts of the production. By aggregating their demand they capture benefits that they could not negotiate solely, and this large solar farm would not have been developed [9].

In the current projects found in the literature, only the benefits of price hedging and the revenues of green certificates from wind power are considered. Both in the sleeved and virtual PPA only the price and the renewable energy credits (RECs) are traded and the energy is sold to the customer through a utility as is analysed by [10, 11, 12, 13]. However, a new PPA is designed which focuses on the match between supply and demand and the direct link between production time and RECs.

In order to balance the supply and demand the SP must trade in the energy markets. The characteristics of electricity demand the system to have at each point in time a total production equal to total consumption. This is done by a balance management system that ensures the security of supply through the continuous, real-time balancing of power demand and supply, in order to stabilise the system frequency [14]. The system balance is maintained by the Balance Responsible Parties (BRPs) and the Balancing Service Providers (BSPs). The BRPs inform the grid operator on the planned electricity production, consumption and transport needs. Every generator and consumer is obliged to have a contract with a BRP. If there is a mismatch between the program of the BRP and the real-time production and demand than the electricity is traded on the energy markets: the day-ahead market, the intraday market or the imbalance market. These markets have different bidding times ranging from one day ahead to 15 minutes ahead. The most efficient option is to trade as much energy on the day-ahead market and prevent trading on the imbalance market since the prices on this market are more volatile and can even go negative. The SP in the case of a direct PPA is also a BRP and manages the trading.

4. Property Rights Framework

In the property rights theory the concept transaction costs and the concept property rights are the point of focus. It gives multiple definitions of these concepts in the literature. In general Libecap [15] defines transactions costs as *"the cost for bargaining, information, measurement, supervision, enforcement and political action"*. So it is about the costs that are made independent of the costs of the good that is transferred. In the property rights theory transaction costs are defined as the cost for establishing and maintaining property rights [16] and if

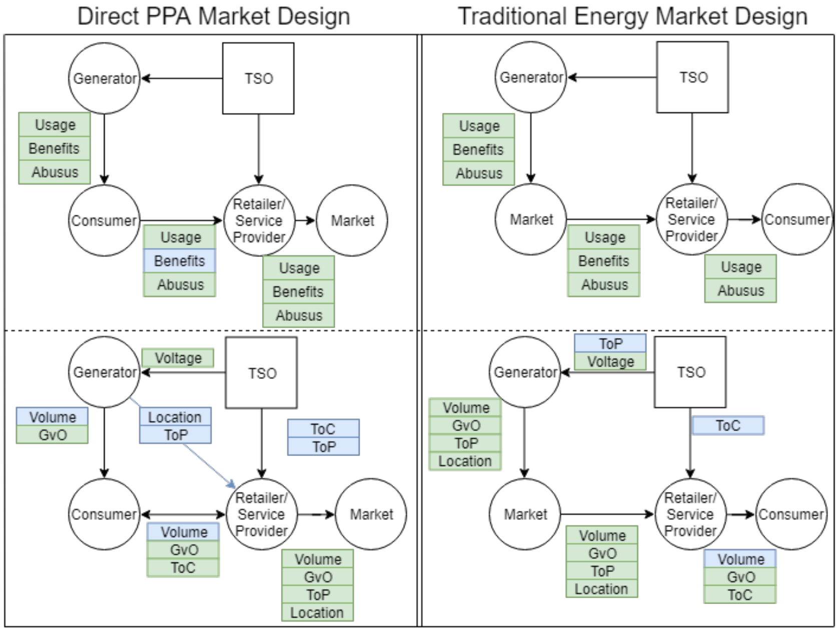

Figure 1: Comparison of market designs of a traditional and direct PPA contract: on the first level the property right concepts and on the lower level the specification of energy properties transferred in the transaction

Electricity Properties	
Time of Production (ToP)	Volume
Renewable Energy Credit (REC)	Voltage
Transport Right	Speed
Time of Use (ToU)	Location
Current Owner	

Table 1: Properties of electricity: these properties are important in the energy sector and determine the costs and ownership of energy

these property rights are formed, adjusted or weakened it goes hand in hand with transaction costs [17]. The term property rights can be seen as a bundle or a portion of rights to use a resource that is owned. Basically it is about the ownership of a resource. This ownership can be divided in the right to use an asset (usus), the right to benefit from an asset (fructus), the right to change its form and substance (abusus) and the right to transfer one or more of these rights to others (transfer) [18]. If someone has all these rights, he has the full bundle of property rights and has complete ownership.

If this theory is applied to the energy sector, there are more properties than just the ownership bundle. Electricity has its own unique characteristics that can be identified in a transactions. These properties are listed in Figure 1. The transactions in the energy sector are shown in Figure 1. In this analysis both the ownership rights as well as the energy properties are identified in the transactions. This analysis gives insight in the energy sector and the allocation of revenues, costs and benefits. Moreover, the incentives and risk can be identified using this insight and framework.

The ownership of the transport infrastructure is allocated to the TSO/DSO and they trade the right to use to the other parties. They can only use the grid and not transform or abuse the grid by causing large imbalances. The ownership of energy is traded on the market and regulated by the market rules. For example not all actors have the right to transfer because they are not a BRP. The difference in a direct PPA is that the consumer has a direct link with the wind farm and gets the right to benefit (fructus). This right can be used to sell power to the service provider and get revenue from that. This revenue stream is an important aspect that contributes to the increased benefit in a direct PPA.

The most important energy properties that stand out are the volume, the time of production (ToP) and the time of consumption (ToC). In a direct PPA the consumer buys a energy volume and the REC from the wind farm, in contrast to the traditional market where the consumer buys it from the retailer. The retailer has a separate link with the generator to obtain the location and ToP to submit the program to the TSO, in the regular market this happens directly between the TSO and the generator.

The risk allocation differs between these two contract. As said, the transfer of the volume happens in another position in the chain. The consumer has a larger volume risk when it buys energy from the generator because there is not a market in-between that balances the production. The consumer is dependent on the wind availability that determines the production. This increased risk is partly delegated to the SP, this allocation of risk is important in this new construction. An advantage of this allocation is that the consumer has a more transparent view on where the energy is from and has an incentive to use power when there is sufficient wind. In the traditional system this incentive lacks since the power is always delivered against a fixed tariff. The consumer has now a financial incentive, since the better the match between demand and supply the lower the costs are for the SP. At the side of the retailer and SP, the incentive is changed from maximising the supply of energy to consumers, into maximising the match between supply and demand. The SP is focused on the match and not on the sales of energy units. The costs for this service are determined by the time and volume of consumption, the time and volume of the energy production and the risk that the SP has for trading the surplus & shortages on the market. These cost components will be analysed in the next section in the financial model.

5. Results

The results of the model are presented in Table 2. Here the total energy costs and balancing costs of the direct PPA, the traditional contract and the two experiments with a Battery Energy Storage System (BESS) and solar capacity are shown. It can be seen that the direct PPA has a benefit compared to the traditional contract of almost 4000 euros. This result is in line with the hypothesis that there is a financial benefit by cutting out the traditional retailer and close a direct PPA with a wind farm. The service costs of the traditional contract include a fee of around 20% on top of the energy costs, this is the profit margin of the retailer. The costs of the service provider consist of the costs for trading on the apx market and on the imbalance market. This ratio is 80/20, so 80% percent of the surplus and shortage is traded on the apx and 20% on the imbalance market. The benefit of the service provider consists of the risk factor, this factor compensates for the risk the SP has for trading on the energy markets. The imbalance market is very unpredictable and can result in extra costs, for example if power is sold when there is a surplus on the market or when power is bought during shortage. So there is a risk factor of 30 percent assumed on top of the service costs. The total trade in the direct PPA is around 3.5 MWh and includes the shortages and the surplus. In almost 50 percent of the time the wind production is a match with the demand.

In the right two columns of the table the results of the experiments are shown. Both experiments show lower total costs than the direct PPA, there is a saving of respectively 4k and 3k. However, the comparison is not completely fair because the costs of the BESS are not included in this total costs. Currently, the battery costs are still very high. In this experiment the battery has 41 cycles which result in a total costs for one year of almost 33k.

The effect of the BESS on the service cost is however positive, especially the cost reduction on the imbalance trading costs of 3.2k. Moreover, the match of supply and demand also improves as can be seen at the total energy trade of 3.3 MWh. The combination of solar and wind production in the second experiment shows a positive impact on the service costs and on the traded energy. Even though, the savings on the service costs are reduced due to the high apx costs. The amount of energy traded is a measure for the match between supply and demand, which has improved significantly by the added solar production. According to these results the solar production does have a positive effect on the match.

	Total Traditional	Total Direct PPA	Total S1: BESS	Total: S2: PV+Wind
Cost Consumer	€183,598	€179,635	€175,671	€176,505
Costs energy/PPA	€146,976	€146,976	€146,976	€145,360
Costs Service	€36,622	€32,658	€28,694	€31,144
Cost Service Provider	€179,635	€25,122	€22,073	€23,957
Costs energy/APX	€32,658	€8,630	€8,766	€10,690
Costs service/Imbalance	€146,976	€16,491	€13,307	€13,267
Benefit Service Provider	€183,598	€7,537	€6,622	€7,187
Risk factor		€7,537	€6,622	€7,187
Benefit Wind farm	€146,976	€146,976	€146,976	€145,360
Trade [kWh]	0	3,559,311	3,298,161	2,916,571
Production [kWh]	0	3,559,311	3,298,161	2,916,571
Battery Cycles				41
Battery Costs				€32,912

Table 2: Financial benefit of the direct trade PPA and the experiments with a BESS and a combination of solar & wind. All three model runs show a positive result on the total energy costs and the service costs, compared to the traditional PPA.

6. Discussion

The property rights analysis and the financial results show that the direct PPA has benefits over an traditional energy contract. The direct PPA is an attractive solution for corporates and consumer to contract renewable energy. The results give a clear view on how the risks and ownership is allocated in the energy sector and it gives new insight in the costs for balancing energy on the energy markets. The new PPA structure is a very innovative solution in the energy sector. It will be a solution for the wind parks that are developed and looking for investors and buyers of the energy. The PPA drives the increase in investments in renewables in the Netherlands by this contract form. The direct PPA can aggregate smaller companies to fully take-off the production of a wind park. Moreover, it is a new step in the right direction to a further unbundled energy sector in which customers can decide where they get their energy from and what services they need from a retailer or service provider.

The results can be explained from an economic and financial perspective. The property rights theory shows that the incentives of the consumer are more focused on investing in more renewables. This direct link with the wind farm ensures the increase of green energy in the Netherlands instead of a certificate on grey energy in traditional contracts and sleeved PPAs. In this direct link the consumer does carry more risks as they have a high volume risk and less predictable prices. They rely more on the volatile production of the wind than the they do with a sleeved PPA or traditional contract with the service of the retailer. The increased risk is compensated by the right to benefit the consumer has in the direct PPA construction. The advantage of buying the power directly and be responsible for this production is that the consumer can also get revenue from this power, in contrast to the traditional contract where the consumer only pays for the energy it uses. The benefit is however decreased as the consumer covers the volume risk by contracting the service provider to manage this risk. The consumer has control in what way they want or can carry the risk and how large their benefit is.

The financial perspective shows that there is small saving on the total energy costs. This is mainly the result of a large role for the retailer that is cut-out from the supply chain. The margin of the retailer is about 10-20% which include also the costs to cover their risks and administration activities. Still, this margin is a large share of the energy price the consumer pays. The consumer in the new situation pays the same for the energy in the PPA, but without the additional margin of the retailer on this energy. The consumer still relies on a service provider, but the costs in this contract are much lower and the total margin that is paid to the SP is also lower. The difference between the all-in energy price and the price for the PPA is shared between the consumer and SP and that results in a financial benefit.

Furthermore, the results also show the effect of a BESS. The bottom line of the experiment with the BESS is that the business case for this technology is currently not positive. The energy prices are not high enough to really obtain benefit from storing energy in cheap moments and use energy from the battery in expensive moments. Moreover, the prices of the battery are still high and do have a negative effect on the business case. The battery for private use is at this moment not interesting. The battery can be used in the grid if it offers services to the TSO which can generate revenue, e.g. the Automatic Frequency Response Reserve (aFRR) of the Frequency Control Reserve (FCR) market where the battery can be used to quickly respond to imbalances.

The results in this research are promising, although there are limitations and opportunities for further research. First, the modelling period in this model and the data used is based on the year 2017 and this gives a limited view on the the energy costs of multiple years. Despite, the analysis of the cost components and the comparison of both contract structures is still valid if only one year is modelled. Additionally, the energy market is very hard to predict, so modelling studies of the future energy costs are also very uncertain. The energy costs of both contract types depend on the same market prices so the difference would be in the same range if more periods are simulated. A second discussion point, is about the assumptions done in the model. These assumptions are validated but still could have an impact on the results, for example the assumption on the risk factor of the service provider and the profit margin of the retailer. This model choice may be different in the reality since retailers trade most of their energy in long-term markets in bilateral contracts. These contracts are not transparent and public available so it is difficult to validate this. On the other hand the prices of the long-term market are not that far from the apx prices.

7. Conclusion

To conclude, a direct trade PPA does have financial benefit compared to a traditional contract and it gives incentives to contribute to more investments in renewable energy, moreover this contract gives more options to improve the the match between supply and demand. The energy is directly traceable to the wind farm where it is produced, in contrast to traditional contracts with grey energy from the long-term market. Moreover, the service provider has the incentive to maximise the match between supply and demand and reduce the imbalances on the grid. This incentive is weaker in the current energy market where the retailer has an incentive to maximise the supply of energy to its consumers. Also, this research shows options to improve the match by using battery storage or additional solar capacity. This match can be improved up to 25% for a combination of solar and wind capacity. The battery, on the other hand, shows a less promising result to reduce the surplus and shortages.

The next step is to further investigate this direct trade PPA with other model periods and more demand profiles of corporates. Still, the results of this research are promising and this PPA type may be promoted to corporates that want to invest in renewables. Additionally, as this new contract structure is further implemented, a research can be done into the opportunities to make this contract type available for smaller consumers (households).

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