VALUATING WIND FARMS UNDER DEVELOPMENT

How to Value Offshore Wind Farms under Development Given Changes in Subsidies

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Executive Summary

During the last decade, global warming has become a substantial threat to the Earth. As a tool for reducing the carbon emissions, countries, firms, and consumers are shifting their focus towards the pollutant energy sector. Resultingly, renewable energy sources have received more attention, where the use of wind energy to produce electricity has been one of the most popular measures to counter the emission of carbon gasses. Previously, the Danish government has supported the sector using subsidies but are currently starting to reduce these. As the technology within the industry has been increasing, the costs of producing electricity from wind energy have been decreasing, which has caused a shift in policies regarding subsidies. As wind energy has become more popular, investors are realizing the value of the industry and thus, investments in the sector has significantly increased. The purpose of this study is to examine different valuation approaches in order to determine if these tools are useful in valuating Danish offshore wind farms without subsidies. The findings of the study are applied to the valuation of the Danish wind farm under development, Aflandshage. To capture the shifting market conditions, the project-specific risks, and the managerial flexibility related to wind farms development, a potential valuation model must incorporate these elements.

The thesis discusses traditional valuation models. As the original DCF model fails to incorporate the managerial flexibility and project-specific risks of the pre-operational period, it is therefore solely used to evaluate the operational stage of Aflandshage. However, the Expected Net Present Value succeeded in incorporating the stage-specific risks in the development stage, as it was possible to account for the probability of success of each stage. Conclusively, it was found that the Real Option Valuation bested the ENPV model in order to capture the full value of Aflandshage. However, both estimates reached the same conclusion, that Aflandshage is not a profitable investment. It was found that the removal of subsidies subtracted enough value to make the project non-profitable, as a higher price was found to be the lacking factor. While the costs and production have both reached a competitive level, the industry is found to be at breaking point between being self-sustainable without subsidies.

Contents

Introduction & Research Question

Since the early days of offshore wind farm development, and until recently, the industry has relied heavily on government subsidies, a critical factor in reaching the socio-economic goal of reducing carbon emissions with 30% by 2030[1] (Klimarådet, 2016). Besides pushing the political agenda, the subsidies were an indicator of the low expensive and inefficient technology within in the field, which drove productions costs up. Previously, the governmental guaranteed floor prices were a necessary component in presenting an attractive business case for investors.

The landscape has now changed drastically and financial decision makers within the industry are currently finding themselves at a crossroad, where production costs have reached a level where future offshore wind projects under *open door* offerings are unsubsidized (Danish Energy Agency, n.d. a). This change of policy has several implications for operators and investors, as the base scenario of future offshore wind farm earnings will be settled at the volatile spot price. This operational strategy is currently viewed as too perilous among operators, due to the money at risk in the pre-construction stage (AIP Management, Interview, May 6th, 2020). To solve this issue, Danish operators have speculated in adopting the same strategies as American power projects, who for several years have hedged against price risk through corporate power purchase agreements. This trend is slowly starting to emerge among Danish and European projects and both the Danish Energy Agency, PensionDanmark, and AIP Management expect these contracts to replace the stability of subsidies to some degree in the future. However, like any hedging instrument, these power contracts carry disadvantages as well. It is therefore currently a topic of discussion whether hedging of cash flows is profitably in the long run.

If wind farm developers and operators are exposed to both the volatility of electricity prices and project-specific risks, valuation modelling might have to change in the future, as the current market standard is the static Discounted Cash Flow model (interview, May 1st, 2020). Therefore, different methods of valuation could be more beneficial in order to incorporate the industry and project specific risk factors of the wind industry. Wind energy valuation is further complicated by local regulations and bureaucracy, and how the policy of subsidies is currently changing.

Investors having an efficient and accurate valuation model is crucial for the final investment decision. Wind energy investors used to depend on the final investment decision after the essential construction permits had been granted but as the number of market participants have increased along with the maturation of the market, the investment decision has gradually been pushed back due to competition (Interview, May 6th,

[1] 30% reduction relative to 2005 emissions (Klimaraadet, 2016)

2020). This thesis will examine how to valuate offshore wind projects from the early stages of idea and design planning until the end of the operational stage. Based on this, the research question becomes:

How should wind farms under development be valuated to support the final investment decision in an industry with decreasing subsidies?

<u>The following 5 questions has been established to support the research question</u>

1) How are the stages of wind farm development characterized?
2) Which risk factors affect the profitability within the industry?
3) Which valuation models are best suited for wind farm valuation giving the specific characteristics of the industry?
4) Case study - Aflandshage Wind Farm: How does the proposed valuation model apply to a Danish wind farm under development?
5) How will Corporate Power Purchase Agreements affect financial decision making in the future?

Methodology

The field of research is financial valuation of wind farms under development, which currently is an industry subject to significant change. This thesis will examine the implications of market changes by valuating a single case study of an upcoming wind power project, called Aflandshage, located south-west of Amager in Copenhagen and generalize the findings to the industry.

Case studies are defined by Flyvbjerg (2005) as “The detailed examination of a single example of a class of phenomena.” (Flyvbjerg, 2005, p. 464). By applying the existing valuation and strategic theory to a specific case, we have initially followed the deductive research approach, as the field of research dominates the applied method and selection of the specific case. As we seek to answer the problem of how to valuate a wind farm from pre-construction to decommissioning when taking new market conditions into account, the selection of Aflandshage Wind Farm (referred to as Aflandshage) has been decided based on elements from critical and paradigmatic case identification (Flyvbjerg, 2005). A critical case is defined as a case which has strategic significance in relation to a general question (Flyvbjerg, 2005, p. 474). If chosen correctly, this allows us to make the logical deduction that: if our findings apply to the Aflandshage wind farm, it should apply to (almost) every Danish wind farm constructed in the current environment. However, there is also an element of a paradigmatic case selection, as Aflandshage has been chosen as a showpiece of a prototype of current Danish wind projects under development (Flyvbjerg, 2005, p. 475). These considerations are made to increase the ability to generalize from the single case study, which is why the thesis also contains elements of the inductive research method.

Validity & Reliability

Validity is defined as the extent of which our data measures what it is attended to (Carmines & Zeller, 2011, p.3) and is an important assessment to make when obtaining data to answer the problem of the thesis. Our primary data is two semi-structured interviews with Senior Investment Managers, both also board members of a Danish wind farm operation, and one informal preliminary interview with an associate from the interest organization, Wind Denmark. The interviews serve the purpose of gaining industry specific information from practitioners, which is likely to increase the accuracy of the estimations from the financial and strategic analysis. By interviewing multiple market participants, it also benefits the process of identifying potential biases, which might exist within the industry.

The secondary data mainly consists of market reports from interest organizations and government branches, annual reports from enterprises within the industry and monthly stock returns. The overall assessment of the thesis' validity is high, but the reliability must still be assessed before reaching a satisfying research conclusion.

Reliability is the measurement of accuracy/precision of the data (Carmines & Zeller, 2011, p.3). The perfect theoretical reliability-scenario is when an infinite number of trials lead to a zero-variance outcome in the data results. However, in social studies and economics, this is an extreme anomality, which is why reliability assessments should rather consider the possibility of the data containing systematic biases. This represents a general problem within Corporate Finance, as financial models mostly require assumptions such as: no arbitrage, transparent markets and rational investors [2], which does not translate well from theory to practice, due to lack of agreement of single components in models, such as risk free rates, risk premiums and beta. While theoretical finance often employs an objective epistemology, practitioners are often shaped by subjective opinions based on conceived preunderstandings of an industry. To solve these inconsistencies, a modified objective epistemology is applied, where a critical approach and thorough analysis of the data can result in accurate conclusions. Regarding data sources, where the presence of systematic biases cannot be rejected, we have tried searching for alternative studies from multiple independent sources, to verify the data, whilst considering the verification-bias issue, before applying the input in our analysis.

The same idea is applied in order to counter the individual weaknesses attached to quantitative and qualitative methods. In consistency with Karpatschof (2015), we have applied a combination of the two to

[2] This ontology assumes a materialistic reality where objects exist regardless of the scientific approach

supplement each methods strength and weaknesses (Karpatschof, 2015, p. 459), as most of the thesis' quantitative estimations are backed up by qualitative data and vice versa.

In consistency with this framework, it is our opinion that the validity and reliability is acceptable, and thus the data is both accurate and reliable to answer the overall problem statement of this thesis.

Structure of the Thesis

This thesis is divided into 5 different parts and follows the structure illustrated in figure 1:

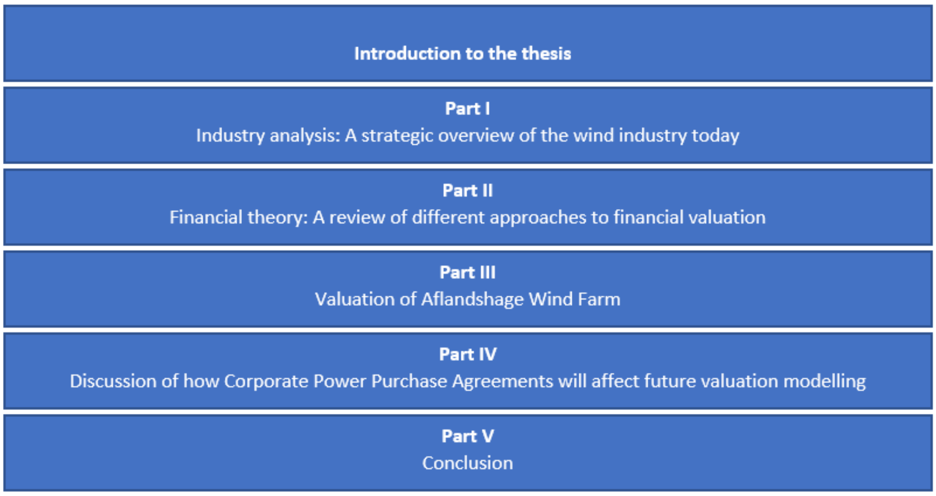

Figure 1. Own contribution.

Part I is a strategic industry analysis, which identifies key characteristics and value drivers of the wind sector today and in the future. Based on the findings in the strategic analysis, Part II contain a review and discussion of the available financial valuation theory, in order to establish which model captures the most precise estimate for wind farms under development.

Part III is the valuation of Aflandshage, a Danish wind farm project currently under development south of Copenhagen, which selection was explained in the previous section. The modelling and inputs are a combined result of our strategic findings in Part I and the financial elements from part II. Although the result of the valuation is a case study of estimating Aflandshage's stand-alone market value, the approach tries to expand its use to the general industry. As the wind industry currently is subject to disruptive changes, part IV discusses hedging strategies and how analysts should adjust the valuation approach giving our expectations to the sector, before summarizing our findings in part V.

Throughout the thesis, delimitations and assumptions have been necessary due to the scope of this project. The next section explains these and the considerations behind.

Delimitations and Assumptions

This section reviews the primary limitations made in the thesis. Minor or less significant assumptions made throughout the project will be described in the relevant sections instead.

Limitation of the Industry Analysis

As the industry of wind energy is a global industry which is regulated differently depending on country or region, the decision of valuating Aflandshage, means that the focus regarding laws and electricity markets is on Denmark. However, as the Danish wind industry is heavily influenced by neighboring countries due to the interconnectivity of the power grid and free market competition, regional factors affect the profitability and valuation of Danish wind farms. Therefore, relevant data and analysis will be used for other countries when found valuable.

Furthermore, wind turbines consist of complex technological issues and components, which is outside the scope of this thesis, as this knowledge requires an entirely different academic background. The preliminary stage of wind farm construction also contains complex wind simulations and geological studies, which the industry analysis only will describe briefly.

Limitation of the Case Study

While writing this thesis, it has unsuccessfully been attempted to contact relevant project managers at HOFOR A/S to request an interview about operations and strategies. Contact were made by e-mail 13th of March and supplied by phone calls during the week. However, due to the government lockdown, HOFOR A/S has not replied before May 12th, 2020 (see appendix 11). Therefore, estimating the income and costs of Aflandshage has been done by analyzing the structure of comparable Danish projects which, ceteris paribus, lowers the precision. However, this has not been assessed as a major issue, as the purpose of this thesis is to generalize the findings to the industry, rather than just describing the phenomenon of a single case.

Limitation of Valuation

This thesis only covers the four approaches Petersen, Plenborg & Kinserdal (2017) estimate as relevant for valuations. In consistency with other research on the topic, the Present Value, The Relative, The Asset-Based and Real Option Approach are assumed to contain all the necessary financial valuation theory in order to estimate the best suited valuation model of wind farms. When describing real option theory, the Black & Scholes Model and the Binomial Model is assumed to cover the necessary theory within the field, even though other methods and research exists.

When estimating the volatility of the revenue, the price of electricity and the capacity factor are assumed to be uncorrelated. It is recognized that in practice there might be some causal effects between the two variables, given some degree of correlation between the capacity factor and the supply curve.

Furthermore, it is also assumed that no autocorrelation between the historical data used in the Monte Carlo simulation exist, as data relating to the capacity factor of wind turbines is not publicly available on a daily, weekly, or monthly basis. This assumption has been made in order to allow the Monte Carlo simulation to also include capacity factor (on an annual basis) together with the volatility of spot prices of electricity, which is assessed at a more precise estimate. Under the assumption of no, a Durbin-Watson test has not been conducted.

The cut-off date for the valuation of Aflandshage has been established to December 31st, 2019.

Part I: The Industry Analysis

The industry analysis will mainly be based upon a supply chain analysis (Talluri, 2016), Porter's article, "How Competitive Forces Shape Strategy" (1979), a PESTEL analysis, and an analysis of the industry age (Grant, 2010).

1.1 Description of the Industry

This first section is intended to provide a basic understanding of the supply chain of the industry. When analyzing the industry, analysts should start by considering three important steps in the supply chain: the supply of fundamental technical components, the supply and construction of wind turbines, and the operation and management of the wind farms.

The first step consists of the supply of numerous small components, which the manufacturers of wind turbines require (Talluri, 2016; MegaVind, 2012). These components are often very specific, and the different suppliers generally operate independent from each other within their individual niches. Furthermore, the suppliers of components are often only supplying the wind turbine industry, as the demanded products are highly specific (MegaVind, 2012). As the suppliers often cannot sell their products to other industries, they rely heavily on the profitability of the wind industry, and thus are less likely to raise prices, as they are incentivized to keeping the industry profitable (Porter, 1979).

The second step consists of the manufacturers of wind turbines. This segment constructs the offshore wind farms after having received the necessary components from the first link of the supply chain. Currently, the major manufacturers in the industry of wind turbines are Goldwind Science & Technology, GE Renewable Energy, MHI Vestas, and Siemens Gamesa (Renewable Energy World, 2020). These companies construct the wind turbines and are responsible for the technological aspects, and thus, the efficiency of the wind farms. As will be discussed in detail in section 1.3, the technology is an essential characteristic of the wind turbine industry, as the profitability of the industry is directly linked to the efficiency and the costs of turbines. As a result of the many, larger manufacturers of wind turbines, the profitability of the second step of the supply chain is often critical, as the manufacturers compete on constructing the most efficient technology (Porter, 1979).

The third and final chain consists of operators of wind farms and electricity transmission, and are often the same companies as the owners, eg. Ørsted. The owners are also the companies who profit directly from the sales of electricity during the operational stage, whereas the companies operating within previous steps of the supply chain, primarily are involved in the development and construction stage of the wind farms.

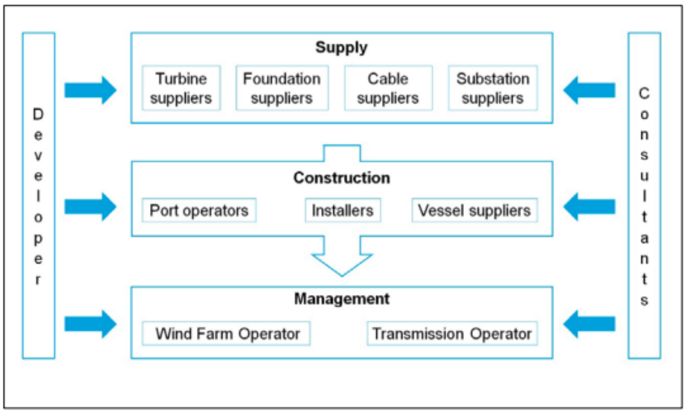

Figure 2: The Supply Chain. Source: Talluri, 2016

One of the essential elements of the industry is found in the last step of the supply chain, as consumers are not able to distinguish between the origin of their electricity. While consumer habits gradually are more driven by environmental concerns, they are not able to evaluate which source of energy their electricity consumption originates from. Eventually, this turns into an inconvenient paradox of energy distribution, as one of the main drivers behind the wind industry is the public's environmental concerns, and yet somehow the individual consumer has limited bargaining power (Porter, 1979).

Regarding environmental concerns, another important limitation to the industry is the geographical sites available for construction of wind farms. These limitations become essential, when firms must decide the location of a future wind farm, as the limitation is chosen externally by the government. This means developers cannot choose a location based on how profitable (regarding wind factors and power grid) the region might be but need to settle for sites available to them. As for public tender offers, the government decides on a specific geographical location of the future power plant but, to some extent, the same limitation is also present regarding projects constructed through the open-door procedure. Due to social acceptance and general infrastructural issues many geographical locations are unavailable as construction sites, leaving the developer with less strategic flexibility.

It is currently a political discussion whether wind farms should be constructed as onshore or offshore. There are several pros and cons for both, which are outlined in table 1:

Onshore	
Pros	Cons
Lower costs Simpler construction process Less loss of electricity during transmission	Neighbors Local authorities Restricted due to less space Government wants to close onshore
Offshore	
Pros	Cons
Potential for larger size Less problems with government Government supported Steadier wind speeds	Higher costs Complicated construction process Loss of electricity during transmission Impact on marine life

Table 1. Own contribution. Source: American Geoscience, 2019

The two main arguments for both is that wind farms are significantly cheaper to build than onshore, but offshore wind turbines are less damming towards to the local community. As for the difference between the size of the two markets in Europe, onshore wind had a capacity of 182,743 MW in 2019, while offshore wind only consisted of only 22,071 MW (WindEurope, 2019a). However, while Denmark still had more cumulative, onshore capacity than offshore capacity in 2019, the new installations of 2019 pointed towards a shift in focus. During 2019, 374 MW of offshore wind was built, while only 28 of onshore wind was built (WindEurope, 2019a). For the full list of all European countries, refer to Appendix 1. An important trend to notice from Appendix 1, is that most of the leading countries in the industry have built more offshore capacity than onshore capacity in 2019.

As these introductory remarks regarding the wind farm supply chain has been explained, the next section is a presentation of the different stages in the development process, which is an important element in the valuation of wind farms.

1.2 The Stages of Wind Farm Development

A wind farm is a long-term investment, usually expanding over three decades and contain several complex issues. Especially the pre-construction stage, which includes legal, geological, technical, and environmental studies, remains central to the final investment decision for the developer. The following section concerns the wind farm development process and is necessary in order to gain a basic understanding of characteristics and risks in the different stages.

The pre-operational period of wind farm development consists of several necessary licenses and studies, but can be divided into three individual stages, while the operational period is compiled into a single stage. The different stages are as follows:

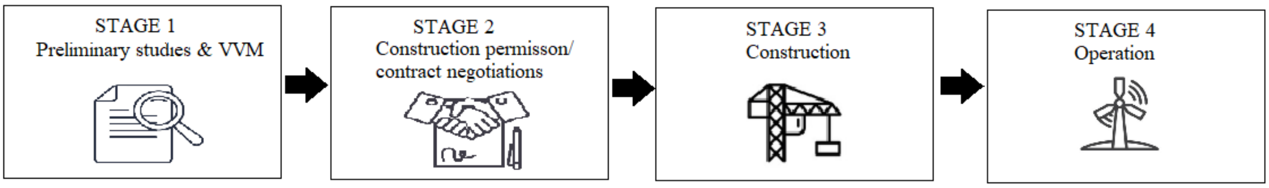

Figure 3: Wind farm development stages. Source: Own construction

1.2.1 Stage 1: Preliminary Studies & EIA

Applying for permission to perform preliminary studies is the first step any company must take in order to construct a wind farm, and the first of three permissions which is required from the Danish government. In Denmark, the developer must apply for a construction permission through the governmental branch called the Danish Energy Agency (Danish Energy Agency, nd.b). Companies can apply either through an *open door procedure,* where the company submits an application on its own initiative, or a *government tender offer* where DEA selects the most qualified bid from competing companies to win the contractual right to construct a wind farm in a politically determined area (Danish Energy Agency, n.d. b).

If the construction company gains permission to perform the preliminary studies in a given area, assuming there are no conflicts with district plans, local interests, and other government affairs etc., the developer must complete its studies within a year, as the permission expires (Danish Energy Agency, nd.c). The permissioned studies contain geological, noise, and wind studies which can have a significant effect on the profitability of the project due to potential compensations to the local community and the efficiency of production. All the administrative and legal costs realized by DEA related to handling the application is also placed upon the developer and is sunk if licenses are rejected.

The preliminary studies are also demanded by law to contain an EIA examination (Vurdering af virkning på miljøet/Environmental Impact Assessment), which is implemented in Danish law in the Promotion of Renewable Energy Act (The Renewable Energy Act, 2019). Any EIA examination must contain an assessment of the potential impact on the wellbeing of the general public, nature, and wildlife which the wind project might affect (Lov om miljøvurdering af planer og programmer og af konkrete projekter, 2018). If the consequences are too impactful on the local community, the project will either fail to gain a construction permission, or the magnitude of the economic compensations is likely to turn the project unprofitable. Generally, the necessary studies are costly and subject to a high degree of external uncertainty. Therefore, the likelihood of a project being finalized at this stage is low, considering the contingent events that needs to succeed. Between 60 and 80% of all projects are scrapped in the pre-construction stages (Noothout et al., 2016, p. 38).

1.2.2 Stage 2: Construction Permission & Contract Negotiations

If the company is granted permission to do preliminary studies, and the prospect turn out successful within a year, the developer can apply for the construction permission at the DEA. Meanwhile the constructing company starts negotiating with wind turbine producers and other suppliers (mentioned in step 1 in the supply chain description), while also reaching out to potential investors or creditors. It is recommended by the DEA to have cleared any potential issues regarding the preliminary stage before contacting investors, due to the lessor degree of uncertainty surrounding the projects, which renders a more attractive business case. When an offshore wind farm is constructed under the *open-door approach*, a minimum of 20% ownership of the farm must be offered to local citizens and interests. This regulation was implemented in 2009 to counter the threat of social acceptance issues, which Noothout et al. (2016) estimated to be a significant external threat to the construction of wind farms in Denmark. With the new regulative, economic compensation to neighbors was also raised and the period of public complaints were prolonged, to help gain social acceptance within the local community.

If the compensations are too high, financing falls through or contract negotiations with DEA and suppliers breaks down, the developer has the option not to exercise their right to construct the park. However, given the information available at this stage, and considering the sum of costs held already, the likelihood of construction will be higher than previous.

1.2.3 Stage 3: Construction

The construction stage is by far the costliest for any wind farm project and entering this stage therefore represents a point of no return for developer and investor. After the final investment decision is made, the costs and research related to the project have reached a level where the likelihood of never reaching the operational stage is very unlikely, given the value at risk. In the construction stage all components to the windmills must be bought, assembled, and connected to the grid. Not surprisingly offshore projects have significant higher construction costs than those onshore (Deloitte, 2016, p. 7), due to the higher degree of complexity of the engineering task (Standard & Poor, 2014, p. 264).

When the wind farm is completed the developer must apply for the third and final permission from the DEA. This license includes the permission to produce electricity and grants the developer the contractual right to exploit the wind power for up to 25 years (this license can be prolonged if needed) (Danish Energy Agency, n.d. c). The authorization will usually be approved if the developer has fulfilled its obligations in the construction permission contract. The construction stage usually stretches over a 2 to 5-year period, depending on the scale and complexity of the project (Deloitte, 2016, p. 5).

The construction stage needs cooperation between several companies, as the energy sector is quite specialized. The production of the wind turbines, which is a complex and technological process, is done by Vestas A/S (Denmark), Goldwind (China) or Siemens AG (Germany). The contractors, which oversee the design, planning and construction of the farm, is typically marine engineering enterprises like Van Oord BV (Netherlands) in cooperation with consulting companies like Rambøll A/S (Denmark). When construction is completed and the wind farm is fully operational, its cables must be connected to the power grid system in order to supply the final consumers with electricity. Prysmian S.p.a. (Italy) or NKT Holding A/S (Denmark) are examples of major power cable producers. Finally, the government owned company Energinet operates the general electricity transmission system in Denmark (Energinet, 2019).

1.2.4 Stage 4: Operation

When fully operational, a wind farm usually operates between 20 and 30 years and generates a high EBITDA-margin (60% - 90%) due to the low marginal production costs of energy (Deloitte, 2016, p. 5). The operational costs primarily involve electricity and fixed maintenance contracts throughout most of the expected park life. When the operational stage is over, the owners also must realize abandonment costs related to the disassembling of the wind turbines. The factors which affect the cash flows from the operational stage is described in depth in the PESTEL model in the next section.

1.2.5 Summarization

The previous section described the course of wind farm development and divided the process into 4 individual stages. 1) preliminary studies & EIA examinations 2) construction permission & contract negations 3) construction and 4) operation. Every stage has its own risks which can lead to projects being rejected. As the finalization of a wind farm is dependent on accumulative success through all stages, many wind projects never get constructed due to regulations.

As the foundations of wind development now has been described, the following chapter will examine the macroeconomic factors that affects the profitability within the wind energy sector.

1.3 PESTEL Analysis

A PESTEL analysis is typically included in the financial valuation, as it enables analysts to model the risk and implications that are present in an industry (Grant, 2010). Every aspect of the PESTEL analysis contributes with important elements to the valuation, as they all impact the final investment decision. Thus, every aspect will be analyzed. However, a minor modification of the original PESTEL analysis, is the combination of the political and legal aspects.

1.3.1 Political and Legal Factors

As for the political and legal aspect of the industry analysis, a main component is the subsidies that the government provides to the wind energy sector. Currently, it is a relevant discussion whether there should be given subsidies or not, but it has recently been decided that windfarms, which are connected to the power grid after February 20, 2018, will not receive the 3.33 cent/kWh that has previously been given (The Renewable Energy Act, §35a, pcs. 3). This will be further analyzed in the economical part of the PESTEL analysis.

A part of the governmental energy agreement of 2018 is to build three offshore wind farms, as it is estimated that offshore wind farms can compete on market conditions (The Climate Agreement, 2018). The plan is to build the largest windfarm to date during 2019/2020 and then two additional windfarms in 2021 and in 2023. Because of the assumptions that offshore wind energy will be able to sustain itself without financial interference from the government, the plan for onshore wind energy to be gradually phased out (Danish Ministry of Climate, Energy and Utilities, 2018) . Resultingly, the government will only allow the construction of offshore wind farms, as they deem these to be able to provide cheap and clean electricity without subsidies in the future, and with a lesser threat from social acceptance. Furthermore, the government aims to reduce the number of onshore windmills, and state they will not open for new projects if their target for reduction is not met. According to the Danish Climate Agreement (2018), Danish onshore wind farms are to be reduced in number from 4,300 today to 1,850 in 2030. From an investor's point of view, it means that the market of offshore windfarms is more attractive, as the current government polices become a significant factor in determining the profitability of the industry.

While this agreement is primarily favorable for the offshore wind industry, it brings minor concerns regarding local policies. In the agreement it is stated that local authority gets an increased distance from the shore from which they can object to projects. Prior to the Danish Climate Agreement (2018), the distance from the shore for which the local authority could object was 8 km, but has now been increased to 15 km. As will be discussed later in section 1.3.3, the effects of local objection have a considerable impact on the profitability of new wind farms.

1.3.1.1 Subsidies

As for subsidies, there are different rules dependent on how the projects are offered. If the project is offered through the open-door approach, new regulation states that the government will no longer subsidize these wind farms. Wind farms that got connected to the power grid before February 21st of 2018, would receive subsidies in the shape of 25 øre/kWh, although the total sum of the market price plus the subsidy could not exceed 58 øre/kWh. Consequently, if spot prices were high, this contract for difference (CfD) would require the operator to pay back the residual value to the government.

The supported productivity of the wind turbines was calculated as follows (Danish Energy Agency, nd.a):

$$Supported\ productivity = Efficiency\ (MW) * 6.600\ hours + rotor\ area\ (m2) * 5{,}6\frac{MWh}{m2}$$

While the subsidies no longer have relevance for future projects, it is a clear indication of two relevant factors for investors. First, the lower price of electricity impacts the investment decision, as no subsidies in addition to the spot price are granted. Consequently, the investors' required return on investment will increase, as the profitability of the project is exposed to a higher degree of uncertainty. The second part, which impacts financial decision making, is the derived effect of no governmental interference with a given market, as this is a clear indication of the industry's ability to self-sustain in the future. Resultingly, the self-sustainability of the market forces lowers the volatility of the market, as there is no longer uncertainty surrounding the subsidies from the government. While the volatility of the market may be lower due to the removal of subsidies, the revenue of wind farms is now more vulnerable to fluctuations in factors impacting the revenue.

Companies bidding on a project, through the tender-offer approach, aim to offer the lowest price which they require on the electricity in the operational phase. The offer will then be made of two factors: the actual price of electricity and the difference in the actual price of electricity and the winning bid. As an example, Vattenfall won the tender-offer of Kriegers Flak with a bid of 37.4 øre/kWh (Vattenfall, nd.). Even though the offer was record-breaking at the time, the fixed price is still above the expected future price of electricity, and thus, the government will have to subsidize the residual value. The expected distribution of market price and subsidies for Kriegers Flak, can be seen in figure 4:

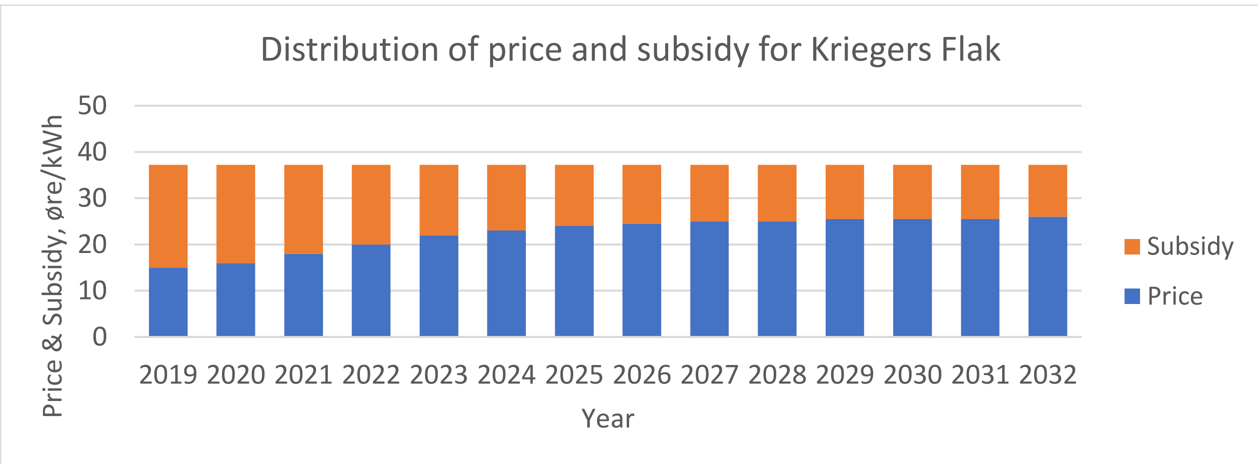

Figure 4. Source: Danish Ministry of Climate, Energy and Utilities, 2016

While Denmark is moving towards a renewable electricity market without subsidies, other countries in the region are not as likely to be heading down this path. If this is the case, Danish renewable energy producers are likely to an experience negative effect from the market liberalization process. This is due to the possibility of an artificial (lower) pricing of electricity in other European countries, driven by local subsidies. This would cause the regional electricity market to become unbalanced (Dansk Energi, 2019).

1.3.1.2 Political Drivers for Wind Energy

One of the most important political discussions concerning the modern wind industry is the determination of the carbon tax. While subsidies and the spot price of electricity are very relevant factors when determining the profitability of wind power, the carbon tax is just as important, as it impacts the competitive ability of the industry relative to substitute producers. If carbon emissions are raised, competition from energy driven by fossil fuel decreases, as they are subject to a higher tax payment than renewables are(Dansk Energi, 2019). Thus, if the government decides to increase taxes on carbon emissions, they explicitly raise the interest in the wind industry, as companies will shift towards green energy in the long run. In the short term however, the higher taxes would lead to higher marginal costs for power sources such as coal, oil, and gas, which, ceteris paribus, raises the price of electricity. Although, the inelastic household demand for electricity means most of the marginal tax effect would be paid by the consumer. The higher price of electricity would profit the wind industry in the short run, as production costs would not be as severely affected as other energy sources. However, the fluctuations in the tax on carbon over the previous years, raise significant concerns about the expectations of the tax. The carbon tax has had a severe impact on the coal industry, as the electricity production from coal has fallen from 341 TWh in 2013 to 160 TWh in 2017 (Dansk Energi, 2019).

The alliance known as “Powering Past Coal” aims to remove all production of electricity through coal, and so far, every Northwestern European country are determined to reach this goal by 2030. Furthermore, Denmark is currently considering moving this date to 2025 (Dansk Energi, 2019).

1.3.2 Economic Factors

Without subsidies, the income of a project is determined by two main factors: the total production of electricity and the price of electricity. As the price, and the market, for electricity play significant roles in determining the impacting market factors, an analysis will be conducted with the purpose of deriving relevant economical elements.

The Danish market for electricity is a combination of two different geographical markets: the market of Eastern Denmark and the market of Western Denmark. The markets are separated by Storebælt and has historically been independent of each other. As new sources of electricity with fluctuating production (eg. wind farms) have emerged, the need to combine the two became apparent, and thus, the connection was built in 2010. Besides Eastern and Western Denmark, the electricity grid is also connected to Sweden and Germany (see figure 6). Besides the different geographical separation, the markets are also divided into the wholesale and the retail market. The retail market is where the suppliers buy the electricity and sell it to the consumers, whereas the wholesale market is where the producers sell the electricity to the suppliers. The process of the electricity marketplace is shown in figure 5:

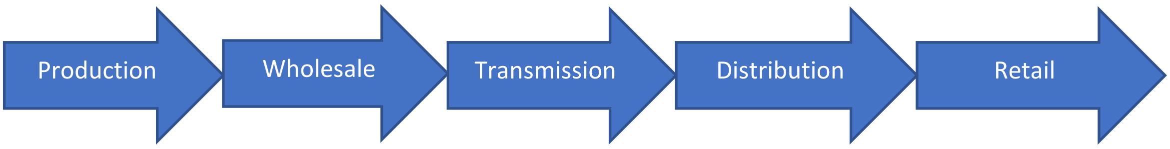

Figure 5. Own contribution. Source: Energinet, 2019

The wholesale market is overall divided into four phases, dependent on when you buy the electricity for the day of operation: the forward market, the day-ahead market, the intraday market, and the regulating power market.

1.3.2.1 The Forward Market

Years before the electricity is transmitted and up until the day before, it is traded in the forward market. Historically, the volatility of the day-ahead market is high, as the pricing varies widely across time and areas. To counter this, financial instruments are traded to hedge against large volatilities in the prices. No physical electricity is traded in this market, but the following instruments are:

- Futures
- Forwards
- Electricity Price Area Differentials (EPADs)
- Put and call options

The futures and forwards are used to hedge against volatility across time, while the EPADs are traded to hedge against geographical volatility, and are traded at NASDAQ OMW Commodities (Energinet, 2019). The concept of hedging against uncertainties in the industry will be discussed in part IV.

1.3.2.2 Day-Ahead market – The Spot Market

As soon as the forward market closes, the Day-Ahead market opens. The day-ahead market is a European cooperation, that connects all the electricity from Portugal to Finland (Energinet, 2019) and is the largest marketplace for electricity, covering 70% of the total traded electricity in the Nordic countries. The trading has been done through a Nominated Electricity Market Operator (NEMO), which, for the Nordic countries, is called Nord Pool Spot. Historically, Nord Pool Spot has been the only NEMO in the Nordic countries, but today there are several. The total grid connection of the connected countries can be seen in figure 6:

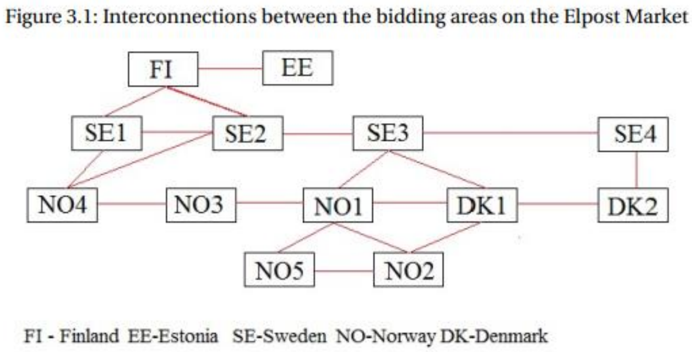

Figure 6. Source: Neamtu, 2016

The trading on the Day-Ahead market takes place the day before the electricity is transmitted and thus, it shows the expectations regarding consumption of electricity. The trading can be done on an hourly basis, where the suppliers send in their buy/sale offers for their demanded electricity during a given hour. When trade occurs, all the bids are matched, so a constant price is secured for every specific hour of the operating day.

While one of the general ideas of this system is to transfer lower price capacity to a higher price capacity zone (hereby creating a more efficient market), this is not always possible due to bottlenecks issues, which results in varying prices across different geographical zones.

1.3.2.3 Intraday Market – The Balancing Market

The Day-ahead market closes at 12:00 the day before transmission, after which the intra-day market emerges. The Intra-day market is, like the Day-Ahead market, a European cooperation of 14 countries. Currently, the Intraday market is significantly smaller than the Day-ahead market, but because imbalances are smoothed in the Intraday market, it is expected to grow as the amount of renewable energy production increases (Energinet, 2019). Because the amount of electricity production is relying on the daily wind factor, predicting the future pricing in the market is complex. Resultingly, the differences between expectations made in the Day-ahead market and the actual quantity of electricity generated will be larger, and thus a higher requirement of smoothing.

1.3.2.4 The Regulating Power Market

As production often differs from expectations, the prices found in the spot market often contain imbalances. To counter these imbalances, the regulating market is used. As imbalances are caused due to electricity producers not reaching their expected production (either caused by over or under production), the producers must pay a price to balance the market price. These costs are labeled balancing costs and can be found in table 2:

Regulating	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Average cost of balancing, øre / kWh	2.7	1.6	1.7	1.5	1.3	1.1	1	1	No data	No data
Rate of reimbursement for balancing costs, øre/kWh	No data	No data	2.3	2.3	2.3	2.3	1.8	1.3	0.9	0.9

Table 2. Own contribution. Source: Energistyrelsen, nd.

To support the future of the sector, the Danish government currently subsidize wind operators, to compensate them for the balancing. As of 2019, the subsidy is 0.9 øre/kWh (see table 2).

1.3.2.5 The Price of Electricity

As the profitability of wind turbines are linked to the prices of electricity, the economical aspect of the pricing will be central when making the final investment decision. As previously discussed, the price of electricity depends on demand and supply. However, the prices highly depend on the time of the day, as the demand is significantly lower during night. In times of high supply and low demand, the market pricing will decrease, and because there is no price floor, the equilibrium price turns negative on rare occasions. As seen in figure 7, the prices vary significantly during a week:

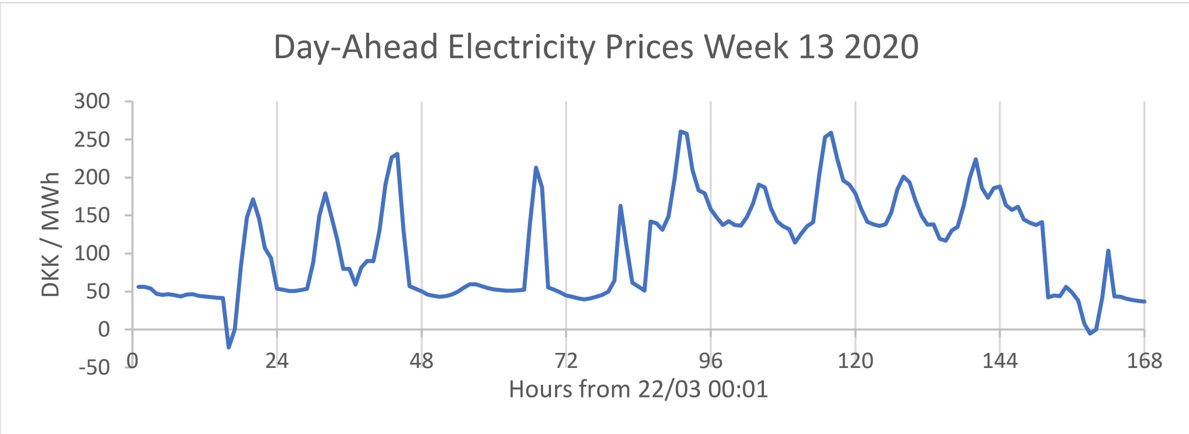

Figure 7. Own contribution. Source: Nord Pool Group, nd.a

Figure 7 shows the movement of the prices on the Day-Ahead market over the period of a week. Every vertical line in figure 7 shows the start of a new day at time 00:00, from which it can be seen how the price not only moves during a week, but even from hour to hour. As the price is determined by the demand and supply at the exact time of the trade, it means that the price of electricity should follow the demand, even when the price becomes negative. The negative prices are caused by over production, which result in supply only meeting demand at negative price levels. The negative prices exist to shut down the electricity production from dispatchable energy sources and, due to the low marginal costs of production from wind turbines, the electricity generated by wind farms is one of the last industries to stop its production. The supply curve for different power sources are found in figure 8:

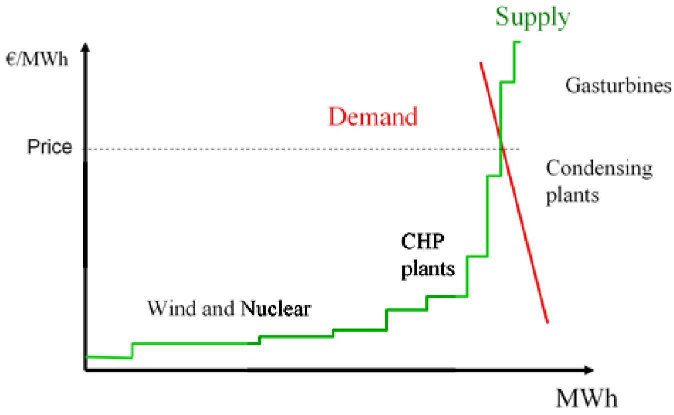

Figure 8. Source: Wind Energy The Facts, nd.

Resultingly, the electricity from wind turbines will become a larger part of the total consumption and thus further the profitability of the industry. While other commodities can be stored (eg. oil), this option is not yet profitable for wind energy, which means the industry of wind power is more exposed to fluctuations in demand and supply (exemplified in figure 7), resulting in spot prices with higher volatility than for most other commodities.

To estimate the profitability of the new generation of wind turbines it is important to understand the movement in future electricity prices. According to Dansk Energi (2019), the current price of electricity at 30 øre/kWh is not high enough to cover the costs of investments in new sources of electricity. Based on this, Dansk Energi (2019) establishes three different scenarios for the price:

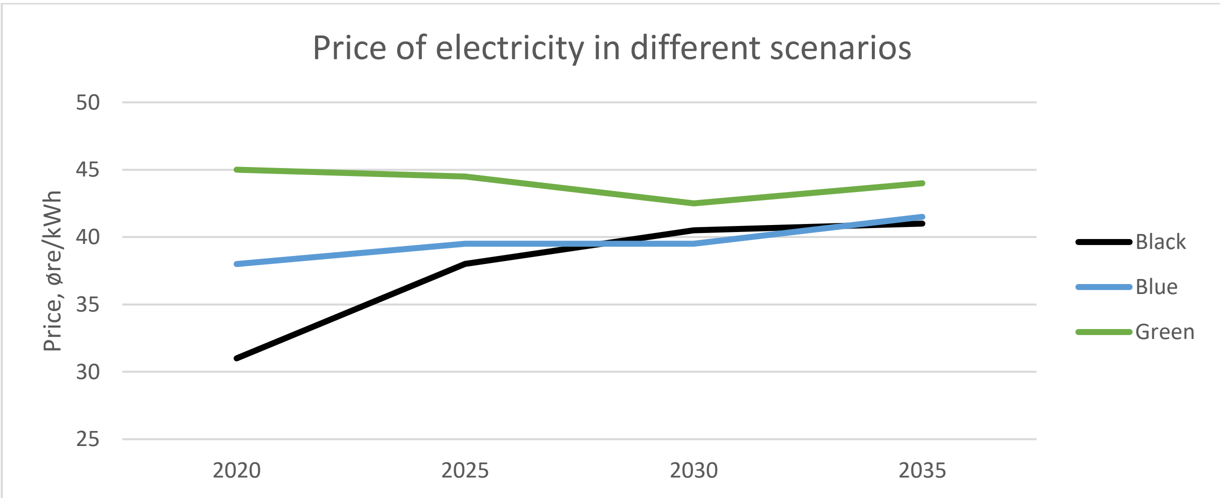

Figure 9. Own contribution. Source: Dansk Energi, 2019

The differences in the three scenarios are due to several factors which impact the price of electricity. As an example, in the black scenario, there are less green energy, and the price is more dependent on the future pricing of CO_2 premiums, whereas the fluctuations in the green scenario is more linked to subsidies, and assumes that the storage of electricity will become possible. The blue scenario assumes a moderate future, in which a smaller premium of carbon emission is present. However, as many different factors will impact the future of the price of electricity, it is difficult to estimate a precise price (Dansk Energi, 2019).

As previously mentioned, the future of the politics in Denmark and its neighboring countries might affect the price of electricity, if a discrepancy exists in the subsidies. A discrepancy will lower the prices to a synthetically low level, and thus negatively impact wind farms without subsidies.

As subsidies are diminishing gradually within the industry, this is currently forcing wind operators to look towards the private sector for cash flow stabilization. The next section will examine this transformation.

1.3.2.6 From Subsidies to Power Purchase Agreements

As subsidies are gradually removed, the wind operators have started to look towards the private sector to secure stable revenue streams through Corporate Power Purchase Agreements (CPPA).

The increasing demand for CPPA's has reduced investors' exposure towards the volatile electricity spot prices and reduced the need for government subsidies through Feed in Premiums, Feed in Tariffs or Contracts for Differences. The very first wind farms in Denmark were built in the late 1970's and were subsidized up to 40% of the projects initial costs, but by the 1990's the settlement was already reduced to zero, leaving the operators with a fixed price subsidy per MW sold instead (Danish Energy Agency, 2010, p. 8).

As the attention and interest in renewable energy sources grew through the 1990's and 2000', technological advancements lowered the projects development and capital expenditures, which gradually decreased the need for government stimulation. Danish wind farms constructed after February of 2018 will no longer receive a fixed subsidy (Danish Energy Agency, 2020c), as a mixture of technological advancements and corporate interest has made wind farms a more attractive investment case, with the ability to self-sustain (interview, May 6th , 2020).

Today the most common subsides to European or Danish tender offers are either through the feed in premium or the contract for difference (WindEurope, 2020, p. 41), which shares several similarities. Usually this type of agreement would be a two-sided contract which contains an upside cap hit, where the subsidy either gets cancelled or the supplier pays back the residual price (WindEurope, 2020, p. 41). There are multiple ways to structure the CfD settlements, but the general idea can be seen in figure 10:

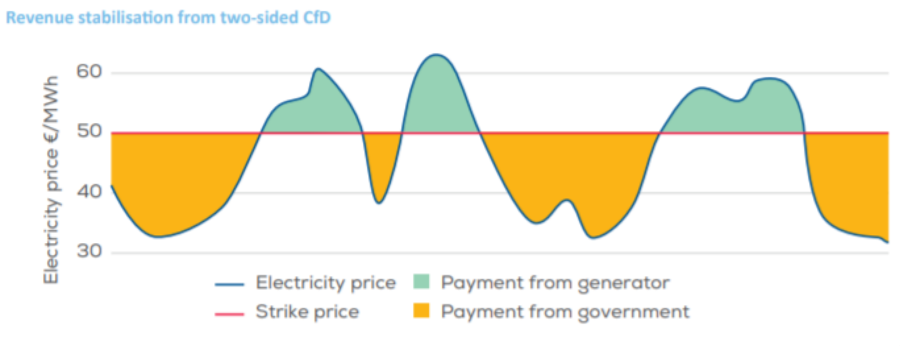

Figure 10. Government Contract for Difference (CfD). Source: WindEurope, 2020

In recent years, private investors have more frequently supported the renewable energy sector by negotiating price fixing contracts themselves. These are referred to as CPPA's and will be explained further in the following section.

1.3.2.7 CPPA: The Corporate Power Purchase Agreement

CPPA has been existing globally for the last 20 years, but only recently have Danish corporations started adopting these contracts in their operations. A power purchase agreement is a simple, long-term utility supply agreement between a specific power plant and an individual corporation. This differentiates from a company's normal energy consumption, which originates from the electricity grid system without supplier preferences. A CPPA is almost identical to the subsidized CfD, but solely involve two private companies, without government interference. Like the government subsidies, CPPA's can be structured in many profiles, but often contains the same characteristics of synthetic loans (currency or interest swaps etc.). In these cases, the corporation pays or receives the difference between the contract price and the current pricing in the market for a specific volume agreed in the contract. The corporation continues their relationship with their current electricity supplier but buys at the spot price. As the difference between the two separate payments cancel each other out, the corporation is left with a fixed price for the demanded electricity (Danish Energy Agency, 2019, p. 15). Therefore, the current pricing in the market determines whether the market value of the CPPA is positive or negatives for either party. As this type of agreement basically is a virtual promise, the corporations are granted a Guarantee of Origin (GoO) or Energy Attribute Certificate (EAC) as a prove of the origin of their electricity source (Danish Energy Agency, 2019).

Furthermore, there are also Physical/Traditional PPAs where a power plant makes the contract directly with a utility company to receive the generated electricity at a fixed price, and Direct PPAs where the power plant is constructed and connected on the buyer's property. Figure 11 summarizes the idea of a synthetic CPPA:

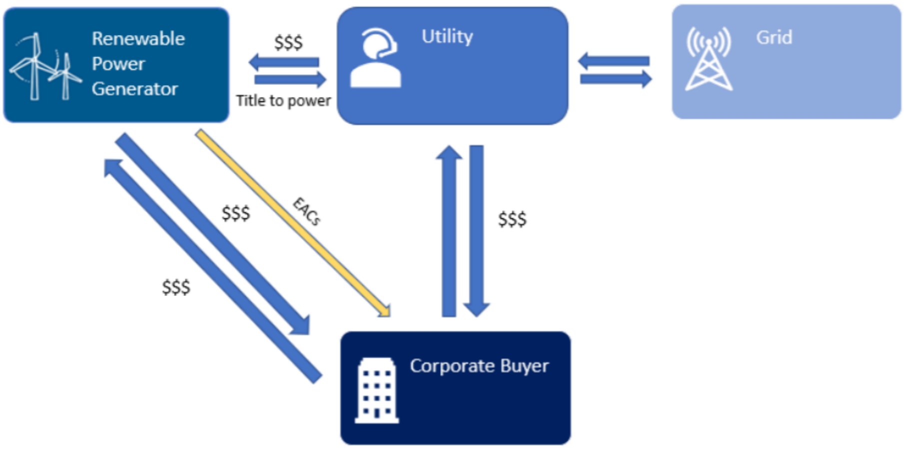

Figure 11. Synthetic CPPA. Source: Danish Energy Agency, 2019

As CPPAs are still a new phenomenon in Denmark, most of the generated electricity is still traded through the Nord Pool platform and distributed to the final consumers without a previously determined fixed price. By 2018 the only significant CPPA from Danish renewable energy sources was Novo Nordic A/S, who receives approximately 20% of the total MW capacity of the largest Danish offshore wind farm, Kriegers Flak, with the Swedish utility company, Vattenfall AB as the counterpart (Danish Energy Agency, 2019, p. 61).

However, WindEurope (2018) estimates that CPPAs will increase gradually (see figure 12), which will affect the valuation process of wind farm development, as cash flows would become less volatile. American corporations have already been using the agreements as part of branding and CSR strategies and the trend is likely to inspire Danish corporations to do the same (State of Green, 2019). This point of view is backed by AIP Management, which expects CPPAs to replace the stabilizing effect of the subsidies to some degree in the future (AIP Management, interview, May 6th ,2020).

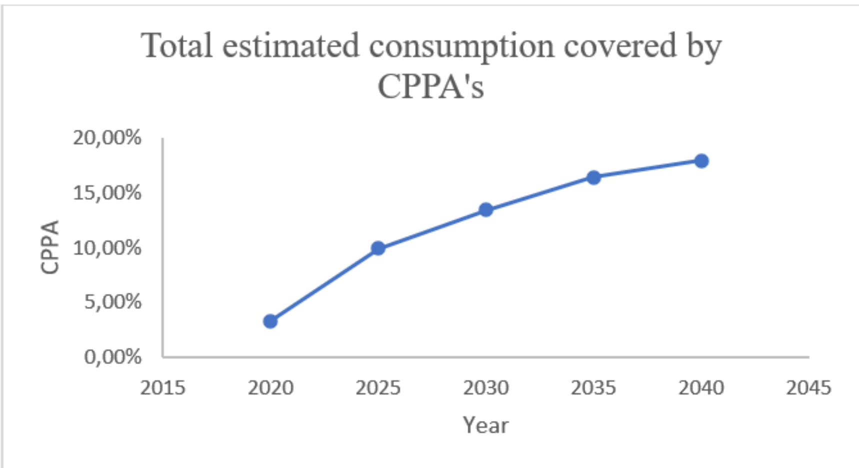

Figure 12. Own contribution. Source: Danish Energy Agency, 2019

This expectancy is also consistent with The Danish Energy Agency (2019), who finds a significant potential for CPPAs in the Danish utility market, given that Denmark has been an early adaptor and global pioneer within the renewable energy sector (Danish Energy Agency, 2019, p. 81).

Globally, corporations are gradually transitioning towards the use of sustainable and clean energy sources. The acceleration of this trend is partly supplier-driving, as wind farm operators search for alternative sources for cash flow hedging, due to diminishing subsidies, but also gives an indication towards the role corporate governance and strategy play in reaching the long-term goal for lower carbon emissions. It is therefore reasonable to expect that the cash flows from wind farm operations will change significantly within the life span of power plants built today.

1.3.3 Social Factors

The social aspect of the PESTEL analysis can help understand what complications and benefits potential wind farm developers and operators might face. In Denmark, one of the main complications of wind farm designing is the limited geographical areas available, where the presence of major turbines does not severely affect residents. This complication might have effects on the production of wind farms through delays or even cancellations, and thus increase the risks during development and construction. Furthermore, having wind farms close to residential areas decreases the value of the real estate, which might lead to developers having to compensate the owners even for unrealized losses. Again, this leads to increased production cost. The Renewable Energy Act (2019) states that if you own and operate a wind farm, you must cover an eventual loss of value on properties, if the loss is larger than 1% and is caused by the wind turbines. The negative value adjustment is primarily caused by wind farms being a source of visual pollution for residents along the shore, as one of the advantages of offshore wind turbines is that there are no complaints of noise pollution. It is also regulated through the Danish Promotion of Renewable Energy Act (2008), which states that 20% of a wind farm’s ownership must be offered to local interests. Therefore, the Danish wind projects often have several minority shareholders in the area around a power station, which helps promote local acceptance. As this significantly limits the threat of social acceptance, local ownership decreases the impact of what McKinsey (2017) defines as the *not-in-my-backyard* effect. The not-in-my-backyard effect is a concept which builds upon the resistance of residents when wind farms are built close to their homes, even though the residents might approve of wind farms in general (McKinsey, 2017). Choosing a construction site far from the shore also decreases this concept.

Generally, the complaints can cause some economical disadvantages for a wind farm developer but rarely significant enough to prevent the construction of a project. However, during the interview with PensionDanmark, it was found how the local community of an American wind farm prevented the construction of a project located near Cape Cod in Massachusetts after construction had started (Interview, May 1st, 2020). This specific case exemplifies the potential threat that neighborhood complaints and lawsuits represent to wind farm development.

1.3.4 Technological Factors

While technological factors do not relate directly to the owners of the wind farms, as they outsource this issue to companies earlier in the supply chain (Vestas, Siemens, Goldwind, etc.), technology still remains a key value driver for the industry profits. An analysis of the technological threats in the industry helps the valuation by giving indications of changes within the supply chain.

In general, the advancements in technology will have a positive effect on the capacity of windmills, as improvements lead to more efficient production. However, there are also significant technological challenges for wind energy, as many of the industry's issues remain unsolved. One of the major technological challenges of wind energy is that it is not currently profitable to store the electricity, and consequently there will be an unrealized production surplus in times of low usage rates (Locatelli, Invernizzi & Mancini, 2016). Resultingly, during these periods, the price of electricity might turn negative as discussed in section (1.3.2). Furthermore, Locatelli, Invernizzi & Mancini (2016) find that energy storage systems are still not economically viable without subsidies, and that there are limited means which can store energy amounts high enough to sustain large-scale wind farms. The highly volatile production of electricity also raises the problem of requiring backup electricity for when the wind farms are not producing enough electricity to sustain the power grid on its own. This problem is currently being solved by an implementation of a diversified energy grid, which contains input from multiple sources of electricity production. However, given a solution to the storage of electricity, it would enable the grid to store electricity generated in times of high supply and low demand, and use it when supply is low, and demand is high. Furthermore, this would enable the owners of wind farms to generate a more stable cash flow, that does not depend as much on the current capacity factor (Locatelli, Invernizzi & Mancini, 2016).

Another complication posed by the technology is the technological advancement of substitutes for wind energy. According to Kerr (2019), solar panels are currently improving significantly both in capacity and in decreasing costs of production. While solar energy only supplies the Danish power grid with 3% of the total electricity usage (as of 2019), it is estimated that advancements in the technology of solar panels will make them more competitive to wind farms, and thus it might create a threat for the industry of wind energy in the future. Currently, the cost of solar energy is dropping rapidly as seen from figure 13:

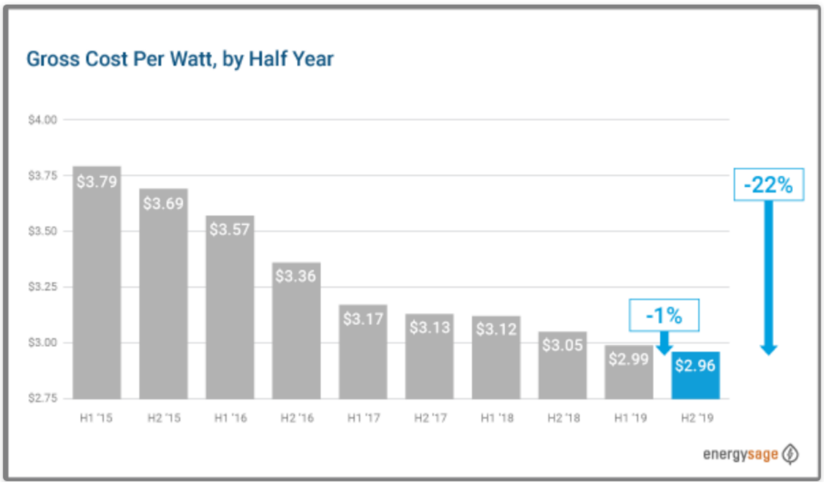

Figure 13: Source: Matasci, 2019

Besides solar energy, hydro energy also possesses a threat of substitution for wind turbines. According to the International Hydropower Association (2017), the energy supply of Norway consists of 95% energy from hydro plants, proving the potential of hydro energy. As such, both alternative power sources may show to outcompete wind energy, depending on how the technology advances. While different sources of electricity may fit better to some countries, the threat still exists due to the interconnectivity of the grid. Resultingly, Norway could extend their use of hydro energy and export their surplus electricity to other countries, given that such a strategy would be profitable.

However, even when accounting for the complications, the technology regarding wind energy still positively adds to the value of the industry. The significant improvements to the technology have helped developing larger and more efficient windmills, which means fewer turbines are able to supply the amount of electricity needed. Ørsted states that: "Today, each of the largest offshore wind turbines - with a wingspan of over 164 meters and a capacity of 8 MW - produce almost twice as much energy as the 11 small wind turbines of Vindeby – the world's first offshore wind farm, built in 1991 – combined." (Ørsted, nd.) This statement proves how substantial the improvements are, and while the complication of energy storage remains unsolved, there are currently being allocated massive financial resources to research on this topic (Dajani, 2019).

1.3.6 Ecological Factors

Global warming is currently a highly discussed topic globally, as it poses a significant threat to the climate. One of the main causes of global warming is carbon pollution, with one of the most significant sources of carbon emission being electricity production. More traditional sources of electricity have shown to cause a significantly higher level of carbon emission than newer, renewable sources of electricity. As countries and companies now are aware of the situation, they implement policies and taxes to counter the level of emissions (Nasa, nd.). Figure 14 shows how much carbon different sources of electricity emit:

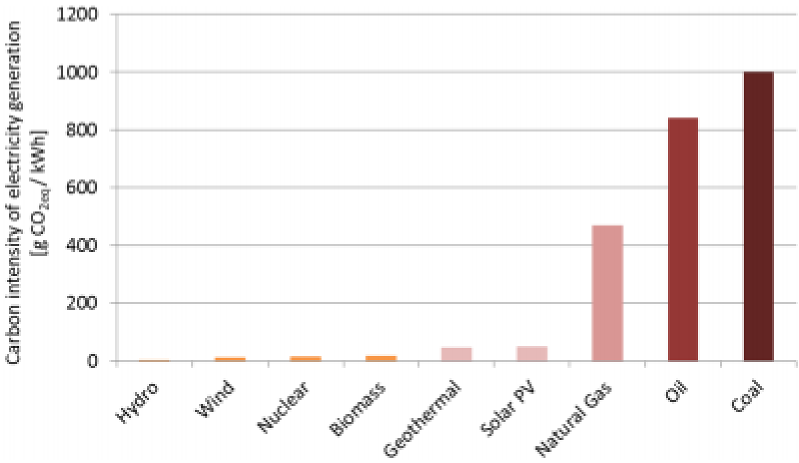

Figure 14. Source: Ajanonic & Haas, 2019

Renewable sources of electricity omit a significantly lower amount of carbon compared to traditional sources of electricity such as oil and coal. Besides electricity generated from hydro plants, wind is the best source of electricity regarding carbon emission.

The ecological aspect of the wind turbine industry is one of the essential industry drivers as it is a large element in public elections, as residents, in some countries, cast their ballot based upon the ecological policies of a politician or party (Kallestrup & Eller, 2019). Not only are ecological aspects a driving force for global governance, it is also impacting large industries and companies, as they aim to improve their public image through CSR strategies. The desire from both consumers, companies, and governments to promote green energy will be one of the main drivers for the industry, as governments will try to push policies to reach the socio-economic goal of less CO_2 emissions. Large Danish electricity suppliers, such as Ørsted, also promotes green energy, and are investing heavily into the evolution of the industry. Furthermore, Green Bonds, or Climate Bonds, have been in high demand on financial markets, where the issued debt is solely allocated to renewable energy projects, typically solar or wind energy. The increasing demand for green investments among private investors, currently represents a great funding opportunity for wind developers (WindEurope, 2019b).

Historically, wind energy has not been able to sustain itself without government subsidies, due to high costs of constructing wind farms compared to their production. However, many wind farms have still been built due to subsidies given by governments, to push renewable energy sources forwards. Thus, it has not only been economical aspects that have been the reason for building wind farms, it has also been based on ecological considerations. Furthermore, even if projects involving sources of renewable energy have not been directly profitable, many companies have still been willing to enter these projects. This is due to corporate social responsibilities, in which many companies have started sustainability goals (Parkhurst, 2017). Through corporate social responsibilities, the companies still profit due to improving their image to the public.

1.3.7 Conclusion on PESTEL

The PESTEL analysis identified potential threats or opportunities in each of its categories. The most significant political aspect was the finding that subsidies are being removed from the industry, as the government, through The Climate Agreement (2018), stated that the industry of wind farms would be able to sustain itself on market terms. The tax on carbon emission was also found to be a significant factor, as the tax rate has a significant effect on the profitability of the industry, as it decreases the competitiveness of substitute energy sources. During the economic analysis, the market for electricity was described, and several elements were identified to have an impact on the industry. The most significant of these is the presence of the European grid connection, which could potentially both benefits and harms the industry profits. Furthermore, the economic analysis found that Danish corporations slowly started to adopt CPPAs, which has the potential to replace the cash flow stability from the diminishing subsidies.

Social acceptance issues are one of the main reasons why the government decided focusing on offshore wind farms, as the potential of onshore wind farms in Denmark is limited due to lack of construction sites. The main conclusion of the technological aspect is that the technology is both benefiting and hurt the industry. The positive side of the technological was found to be in the advancements, which improved the efficiency of production in wind farms, and thus the profitability. However, it was also found that the technological advancements of substitute renewable energy sources might become a threat in the future. Finally, the ecological aspect discussed the drivers of the industry, and how corporate social responsibilities was helping to drive the industry forwards.

1.4 Industry Life Cycle

Built upon the foundation of the Product Life Cycle model, the Industry Life Cycle (ILC) provides a valuable analytical tool, as it enables executives to determine which strategies to apply given the characteristics of the current stage of the industry (Grant, 2010). As different determinants of firm survival changes over the life of an industry, it is essential for executives to understand which stage of the industry life cycle their business lie in. As an example, Peltoniemi (2014) finds that “innovation consistently increased the chances of survival only in the mature stage of the life cycle” (Peltoniemi, 2014, p. 237). The usage of the ILC model becomes significantly prominent when used to predict risks associated with the future of an industry. Using the characteristics of the different stages of the ILC, it is sometimes possible to give a prediction of which stage the industry is about to enter, and thus a prediction of which elements to be aware of in a given stage.

The purpose of this section is to estimate risks in the industry, where the ILC model will be used to determine central risk factors in the industry. While risks exist in every stage of the ILC, there are differences in the risks associated to each. Thus, it is highly relevant to determine which stage the industry of wind energy lies within (Grant, 2010).

The industry life cycle is divided into four different stages: introduction, growth, maturity, and decline (Grant, 2010, p. 271). As the introduction stage is defined as a stage of limited small sales market share, it is deemed non-relevant for the industry, given that 42% of the total Danish electricity generation is supplied by wind turbines. Thus, it will not be explored further, as the other stages will provide a more relevant and useful analysis. The three remaining stages are all likely to include some properties that are relevant for the industry of wind energy, and consequently, these will be explored further. The growth stage is, broadly described, the first stage where the industry opens op to the mass market and are the first stage of the ILC where the turbines no longer are viewed as novelty products (Grant, 2010, p. 271). While costs are high and quality is low in the introductory stage, the growth stage is also the first stage where dominant designs are emerges, resulting in lower production costs and higher quality. As the industry moves from introduction to growth, the improvement in technological factors are also increasing. After the growth stage, the industry moves towards maturity as it gets closer to market saturation. When market saturation is reached it will result in demand only stemming from current consumers, as the market's potential has been reached (Grant, 2010). As the industry demand starts to decline, the ILC moves towards its last phase, decline.

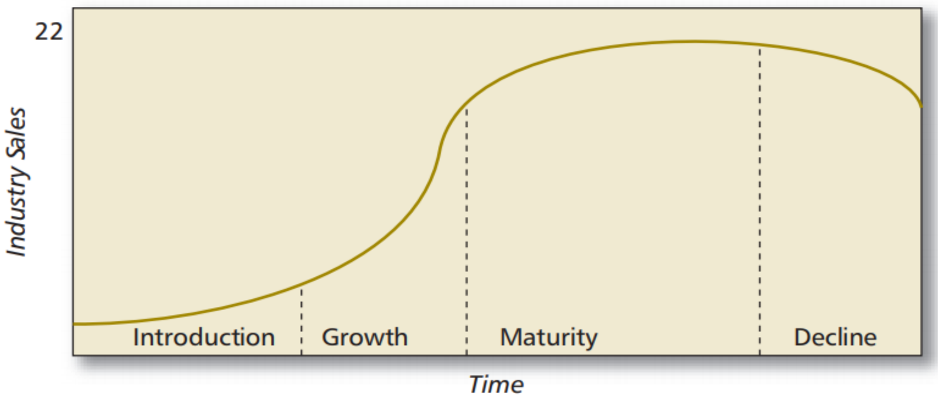

Figure 15. Source: Grant, 2010

To determine what stage the industry of wind power is currently at, the following factors will be analyzed: demand (market saturation), technology and products (existence of a dominant design) and competition (shakeout).

1.4.1 Market Saturation

Considering the demand when moving from growth to maturity, there will be a limited number of new consumers entering the market at the stage of maturity, and thus the increasing competition will result in firms competing on price and design for the same group of customers. This is known as market saturation, which is used to estimate when a market has reached its maximum potential for the number of new customers. An industry, operating in the growth stage, has not yet reached market saturation, as new customers are still discovering the industry. However, as the industry approaches maturity, the rate of new customers who enter the market are reduced which means that the industry is reaching the top of the curve (see figure 15).

Considering the industry of wind energy, the demand is a little different compared to other industries, as it is closely correlated to the general demand for electricity. Thus, the maximum demand which the wind industry may reach is determined by the maximum demand of electricity. However, to determine whether market saturation has been reached, the percentage of electricity provided by wind farms could be a determinant for the demand of wind energy. Thus, to determine the industry age according to the demand, it would be relevant to analyze the evolution of wind energy's percentage of the total electricity consumption. In figure 16, it can be seen how the evolution has looked for the previous 10 years:

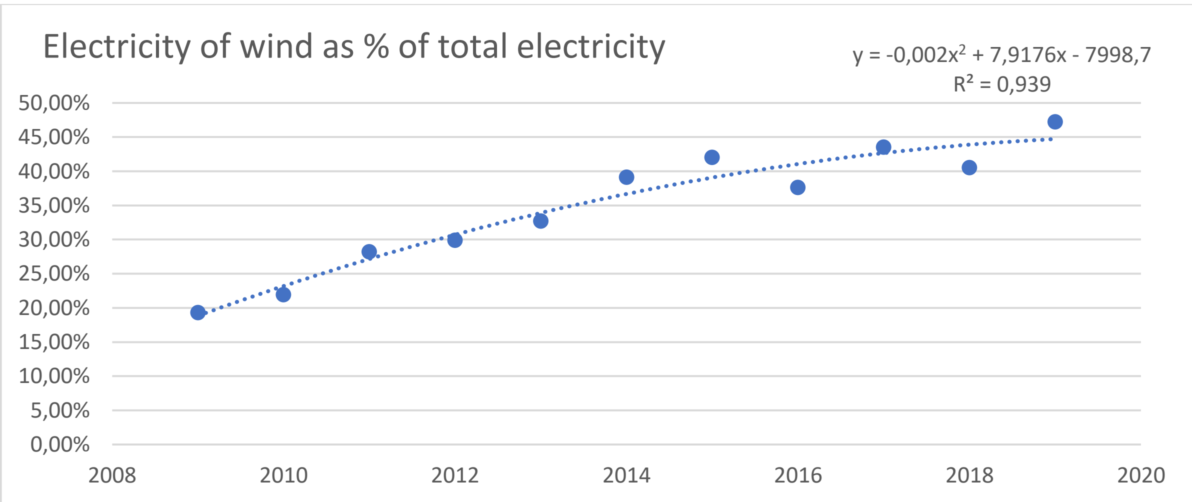

Figure 16. Own contribution. Source: WindDenmark, 2019

As it can be seen from figure 16, the percentage of total electricity generated by windmills is still rising, which would mean that market saturation is not yet met. It is, however, important to note that reaching the maximum of the industry life cycle curve is not equivalent to reaching a market where all electricity is generated from wind. Given the current technological challenges regarding wind power, having all electricity stem from wind turbines would be a highly unlikely scenario due to the complications of storing energy and controlling the wind. It would mean that in periods of low wind speeds, the electricity would not be able to keep up with the demand, and thus, the electricity grid requires other sources. However, as it is seen that the total share of electricity generated from wind power, is still growing on an annual basis, it is concluded that market saturation has not yet been reached. One important note, though, is that the trend of figure 16 appears to be polynomial with a R-squared value higher than that of a linear trend (0.939 for the polynomial and 0.899 for the linear). Following the theory of the industry life cycle, which also builds upon a polynomial figure, it could be concluded that the analysis of market saturation would point towards the industry being close to maturity. This statistical analysis is only done very briefly though, and a thorough analysis would require a larger sample size. It is, however, important to track the industry evolution for the coming years to determine whether the industry has reached the stage of maturity.

1.4.2 Competitiveness (Shakeout)

Determining the industry age by estimating the competitiveness of the industry can be difficult, as it is complex to estimate the threshold for competitiveness that defines when an industry has reached maturity. However, by analyzing the number of firms in the industry and their market shares, one might be able to estimate if a shakeout has happened. Shakeout is defined as a process that drastically reduce the number of firms in an industry and is often a sign of an industry reaching maturity (Grant, 2010). In the beginning of an industry cycle few suppliers are present, as firms have either yet to recognize the potential or has deemed the industry unprofitable at its current stage, due to low demand. After the initial phase, the industry starts growing and thus new firms enter as the industry grows gradually more profitable. Furthermore, there are often observed abnormal profits in an industry's growth stage, which attracts new firms to enter (Grant, 2010). After the period of growth, the industry enters maturity, where larger firms increasingly capture larger market shares, and the industry shifts towards fewer and bigger suppliers. To determine if a shakeout has happened in the industry of wind energy, both the manufacturers and the owners will be analyzed, to estimate their current market share. BloombergNEF (2020) states that almost 61 GW of both onshore and offshore wind turbines were commissioned globally in 2019, and that the market share of these 61 GW was divided as follows:

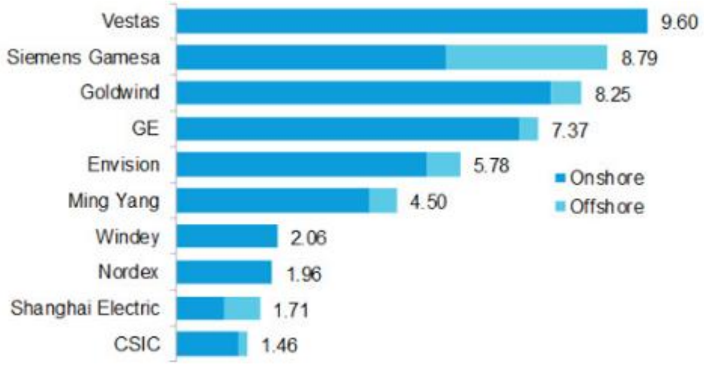

Figure 17. Source: BloombergNEF, 2020

As illustrated in figure 17, the largest manufacturer of wind turbines is Vestas, who supplied wind turbines with a total capacity of 9.6 GW or 15.7% of the total commissioned wind turbines in 2019. Both Siemens Gamesa and Goldwin are not far behind, and together these three companies make up 44% of the total commissioned wind turbines in 2019. Furthermore, the 10 largest firms make up 84.4% of the total market share, which would mean that a shakeout has recently happened, or is only due to happen in the far future. With few competitors having such a significant accumulated market share, it is difficult for smaller companies to compete due to the suppliers' economics of scale. 13D Research (2017) finds that economies of scale are happening as logistics and supply-chain cost savings can be observed for larger wind farms, which requires larger up-front investments, which smaller firms struggle to finance.

This is getting increasingly important as government tender offers are an important factor in wind farm development, and a main driver for winning public offerings is the ability to cut costs. As previously described, in tender offers, the best offer wins. As discussed in the technological aspect, there are not significant differences in wind turbines, which makes it difficult for smaller firms to differentiate their products. As one of the main drivers of lowering costs is the economics of scale, which is not applicable for smaller firms due to the large capital requirements of manufacturing wind turbines, they effectively cannot compete in tender offers, which consequently shifts the industry towards an oligopoly. These elements point towards an industry in the stage of maturity, as the growth stage is characterized by abnormal profits, resulting in a large surge of new firms entering the market. As it was found that a small number of firms shares most of the market, it would point towards maturity.

Analyzing the ownership of wind farms, the same picture is observed. When looking at the total installed capacity for Europe, there are a significant number of firms who own wind farms. For the accumulated capacity of wind firms in Europe, the five largest firms own 46% of all wind farms. It is also seen from figure 18 that firms categorized as "other owners" (firms who own less than 50 MW) have a market share of 30% which would indicate a stage of growth. However, if only wind farms installed in 2019 are observed, figure

18 shows how fewer firms take up a larger market share. Regarding the total installed capacity in 2019 the five largest firms own 58% and smaller firms categorized as “other owners” only own 5% of the total market share. This leads to the conclusion that the industry is moving towards maturity, as the capacity is starting to settle at the largest firms, and fewer smaller firms are investing in offshore wind farms. Furthermore, it might be an indicator of shakeout currently happening.

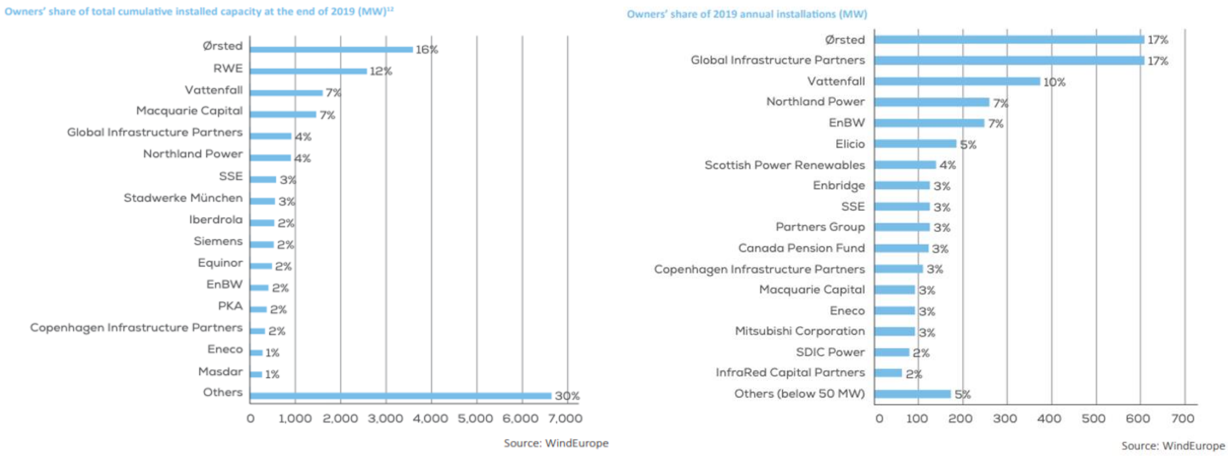

Figure 18. Source: WindEurope, 2019a

1.4.3 Dominant Design

Another factor to consider when estimating the industry age is the technological advancements, otherwise described as whether a dominant design has emerged or not. Determining whether a dominant design is present, is difficult since it is almost impossible to know whether a design can be improved further (Grant, 2010). However, while it is difficult to conclude on whether a dominant design has emerged, it was found in the technological analysis that the technology of wind turbines was found to be consistently improving. Every year, the costs of electricity generated from wind farms are reduced, which could lead to the conclusion that the technology of wind turbines is still developing, and thus there are no dominant design yet. Furthermore, the PESTEL analysis concluded that there were still several critical elements of the technological aspect of wind turbines which could be improved, furthering the conclusion that a dominant design has yet to emerge. In 2019, 11 offshore wind farms with a capacity of above 200 MW were built. Of these 11 wind farms, 7 used the turbine model Siemens SWT-7.0-154, 3 used the MHI Vestas V164, and 1 used the GE Haliade 150 (See Appendix 2 for an overview). While the fundamentals of the three models are quite similar (they are all approximately the same size and they all use three rotor blades), there is one major component of the wind turbines, which differ: the use of direct-drive technology. The direct-drive technology is, broadly speaking, a technology which eliminates the need for gearboxes on wind turbines. Currently, Vestas is the only one, of the top manufacturers of wind turbines, who do not use the direct-drive technology in their models, as Vestas state, that they are able to create more efficient turbines with their current design (Steitz, 2018). The main argument as to why the direct-drive technology is superior, is that it helps lower the cost of maintaining and operating wind farms. However, the direct-drive technology is also more expensive to construct initially, and thus, the decision rests in either lower constructing expenditures, or lower operating expenditures (Steitz, 2018). While the decision is important to owners and investors, as it determines in which stage the costs occur, it also shows that a dominant design may not be present in the industry. As the fundamental design was still deemed to be almost identical across manufacturers, it is finally concluded that the technological aspect of wind turbine industry indicates a transition between an industry age of growth and maturity.

1.4.4 Conclusion on Industry Life Cycle

Conclusively, the age of the industry is estimated to be in transition between growth and maturity, but slightly closer to maturity. The analysis of the market saturation used the percentage of total electricity generated by wind farms as a proxy for total market potential, which showed that there was still potential for extending the current market size. However, it also showed signs of not changing linearly, but instead starting to have a lower slope, which could resemble the curvature of the ILC model. The competitiveness of the industry also showed starting signs of maturity, as larger and fewer companies are starting to cover more of the total market share. While both the analysis of the market saturation and the competitiveness showed signs of maturity, the analysis of the dominant design showed signs of growth. As essential differences still exist in the technology of wind turbines, the industry has yet to settle on a dominant design. However, signs of maturity were still identified as wind turbines are using the same fundamental design across different manufacturers, indicating maturity.

In conclusion, the industry age is found to be in very late growth or very early maturity. In the next section, these findings will lead to the identification of project- and industry-specific risks.

1.5 Industry Specific Risks

As the market has yet to reach saturation, it will not be subject to the risk of firms having to compete for the same customers. However, an industry that has yet to reach market saturation are characterized as competing on technical improvements and increased efficiency (Grant, 2010). Resultingly, firms competing in the wind turbine industry will have to be able to stay ahead of competitors if they want to survive, because, even though market saturation is not met, firms will have to compete for the new customers. In the case of the wind turbine industry, this means that the firms must continue improving their technology, as it is one of the main drivers of lower prices in the industry. However, having to improve the technology comes with large costs as firms must invest heavily in R&D. As an example, Vestas states the importance of their investments into R&D: "The main priority when it comes to the allocation of capital is the required investments and research and development to realize Vestas' corporate strategy and its long-term vision of being Global Leader in Sustainable Energy Solutions." (Vestas, 2019, p. 15).

The two largest risk groups concerning the Danish market were found as the policies and regulations for the electricity market. These factors are also ranked higher by Noothout et al. (2016), who also provides the following spider graph for risks:

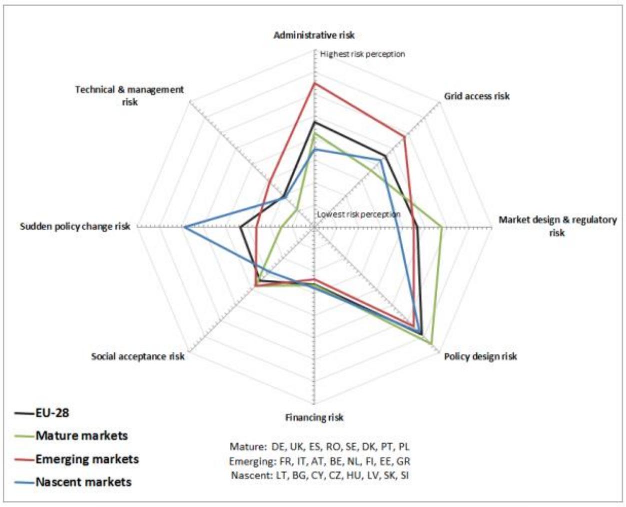

Figure 19. Source: Noothout et al., 2016

As it can be seen from figure 19, for mature markets, it is the risks associated to policy design and market design & regulatory factors that are ranked highest, while risks associated to grid access and technical & management rank the lowest. As the industry for wind generated electricity in Denmark is receiving fewer subsidies, and moving towards a higher degree of independency, new policies might be required to enable the market to develop. Firms need to be aware of the changing market, as it moves from growth into maturity, where subsidies and supportive policies are less likely to be.

1.6 Project Specific Risks

While the industry-specific risks were analyzed in the previous section, they do not cover all the threats which a wind farm might face. However, project-specific risks capture the threats associated to a specific wind farm. One of the central characteristics of the project-specific risks is that not all wind farms are likely to be impacted by these. More precisely, the project-specific risks are regarding problems, that may occur during the lifetime of the project, and are not affected by changes to the industry. During the development stage, the most significant risk in Denmark is social acceptance. While social acceptance was analyzed previously, it is important to be wary of site-specific social acceptance. Often social acceptance will not lead to the cancellation of a project, but it has happened on rare occasions according to PensionDanmark (Interview, May 1st, 2020). While there are risks associated to industry wide social acceptance, the site-specific social acceptance is regarding the neighbors of a specific power plant, and the problems/delays they can cause. Another risk to be wary of in the development stage issues concerning grid access (Noothout et al., 2016). Grid access risk is caused by the need to connect a wind farm to the power grid. While this is not typically a problem, different locations can pose significant barriers due to the distance between the wind farm and the nearest connection to the grid.

During the construction stage, the most significant risk is the technical problems (Noothout et al., 2016). Delays or compromises regarding the construction, can cause significant problems for the developers. As later shown, the largest costs of developing, constructing, and operating a wind farm, happen during the construction stage for offshore wind turbines. Resultingly, the risks in this stage are more significant due to the value at risk. During the operational stage, the largest risks are caused by market design[3], and thus, mostly influenced by changes to the industry. However, less significant project-specific risks are still present, where the most important is the risk of technical failures, which become more likely, the older the park gets. Owners of wind farms often negotiate service contracts during the operational phase to maintain the assets, and thus, the owners are not as affected by the operational risks in this stage (Noothout et al., 2016). The main risks in each stage can be found in figure 20:

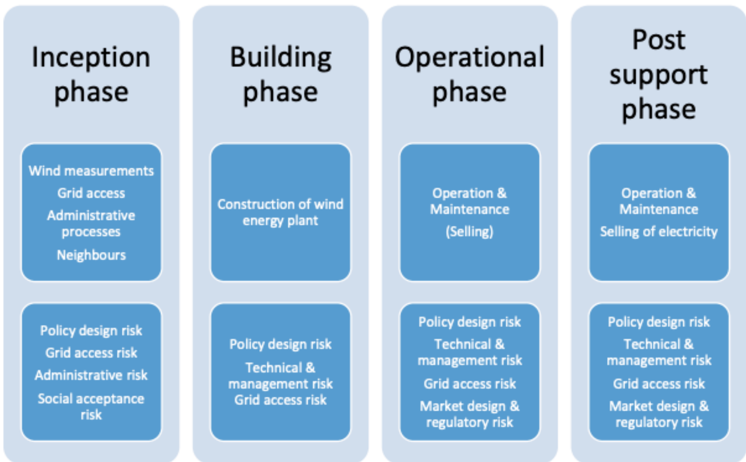

Figure 20. Source: Noothout et al., 2016

While the project-specific risks may pose a threat towards the owner and manufacturer of a wind farm, there is one factor which remains important: the wind farms will keep generating cash flows. As a result of this,

[3] "Market design & regulatory risks refer to the uncertainty regarding governmental energy strategy and power market deregulation and liberalization." (DiaCore, 2016, p. 22).

wind farms are less affected by times of crisis, as electricity is a necessity of our society, and thus one of last things to stop. While the fluctuations of the cash flows might be severe, the owners are still guaranteed cash flows even in troubling times. This is also stated by AIP Management, who finds that even though the current Corona crisis heavily impacts many industries, the society still needs electricity, and thus the wind farms are still producing (Interview, May 6th, 2020)

1.7 The Future of Electricity Generation

Regarding the industry moving towards maturity and becoming more self-sufficient, without the need of governmental interference, there are several factors to consider. Morten Dyrholm, Group Senior Vice President of Vestas, states that the dialogue with the government has changed drastically over the last few years, going from a discussion of the numerical size of the subsidies towards a discussion of how to make the industry self-regulated through market mechanisms. This will provide more flexibility to manufacturers of wind turbines and improving the integration of wind power in the Danish power grid (Andersen, 2019). The change in the discussion has primarily been based on the cost reduction for producers of renewable energy, which has enabled the industry to become self-sustainable. However, the reduction in subsidies for wind turbines also hurt the industry and, while some wind turbines can self-sustain, the reduction of subsidies still severely impacts the profitability of all wind turbines. This would result in a scenario, where the economic growth of the previous year is halted, due to developers not being able to use their profits to advance their wind turbines through R&D. Because of the slower development of the wind turbines, investors might be scared off, as the industry will face lower profits.

Figure 21 is a forecast of the total capacity of large energy sources, from 2010 to 2030. The forecast is based on the expectations from WindEurope (2019c), and the historic data found for the different energy sources. While the estimates of the forecast could be biased, the expectations highly depend on historic data, which clearly shows a change in the split of total capacity between the different energy sources.

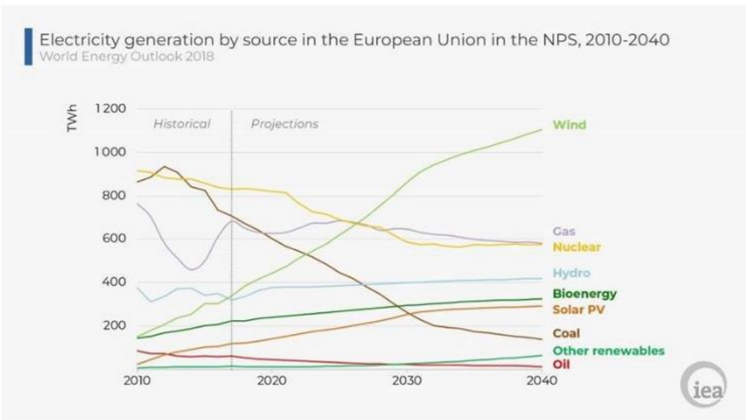

Figure 21. Source: WindEurope, 2019c

Figure 21 shows an expectation of wind energy becoming the largest source of energy by 2030, and significantly outcompeting other sources by 2040. However, this is the best-case scenario of the wind industry, and assumes that the risks outlined in the sections above, will not severely impact the profitability of the industry. Estimated from figure 21, the market expansion for most other power sources besides wind energy seems to have halted, which would lead to the conclusion that power sources such as gas and hydro had reached maturity on the ILC, while coal would be in the stage of decline. As each industry lies within different stages, there are also different risks associated to each, where the risks in the transition from growth to maturity are more severe (Grant, 2010)

1.8 Conclusion of Part I

The purpose of the industry analysis in this chapter is to identify essential factors which may impact a wind farm under development. The three major determinants of the revenue of a wind farm lies within the production, the price of electricity, and the subsidies. All three determinants are highly impacted by the industry in which the wind farm operates, and risks associated to the industry are likely to affect these. For the production, the technological aspect of the industry is important, as better technology leads to the better efficiency of the turbines and higher capacity factor. Furthermore, the ability to store electricity would benefit the production significantly, as the volatility of the production would be considerably lower, and the output of the wind farm more consistent. Technological advancements would also lead to cost reductions in shape of cheaper construction, which again would affect the valuation of the wind farm. However, even given significant technological advancements of wind turbines or other sources of electricity, it is highly unlikely that an already constructed wind farm would seize its production, and thus, the risk of the technological aspect are less apparent in the operational stage of the wind farm. Regarding the costs, the social aspect of the PESTEL analysis outlined significant elements that could impact the development and construction of the wind turbines, and thus lead to higher costs. The price of electricity is the determinant that is most likely to fluctuate given changes in the industry. This is primarily due to the regulative nature of the price of electricity, as it is highly impacted by changes in politics and regulations. Different political drivers were outlined, and it was found that drivers like the carbon tax would directly benefit the profitability of a wind farm. Furthermore, the artificially low prices driven by the differences in subsidies was only a risk that might affect the price in either direction. As for the subsidies given by the Danish government, it was found that the subsidies depended on the specific project, but it was also found that the Danish government was trying to remove subsidies from the industry, to let the industry be driven by market mechanisms. The future of the industry was found to be highly attractive, as it was yet to fully reach maturity, whereas competing industries had already reached maturity and even decline.

Part II: Valuation Theory & Models

The previous chapter analyzed the external factors affecting the industry of electricity generated through wind farms and found several factors of uncertainty, which ultimately could complicate the valuation process. Therefore, the general question raised by the industry analysis regarding the valuation of wind farms under development is: Which model(s) should theoretically generate the most precise estimate for the intrinsic value of a wind farm, given the degree of uncertainty surrounding the project? This chapter will try to answer the question by reviewing the available financial valuation theory. Valuation can be incredibly simple or complex depending on the circumstances surrounding a specific case, but there are generally four accepted categories of financial valuation approaches (Petersen, Plenborg & Kinserdal., 2017, p. 298):

1) The Present Value Approach
2) The Relative Valuation Approach
3) The Asset-Based Approach
4) The Contingent Claim Approach

The following chapter will consist of a brief discussion of the individual strengths and weaknesses of the four approaches and in which scenarios they should each be applied.

2.1 The Present Value Approach

Present value techniques, such as Economic Value Added (EVA) or Discounted Cash Flows (DCF) models, are the most applied methods for valuation. A survey by Petersen, Plenborg & Kinserdal (2017) finds that more than 95% of practitioners apply some variety of the present value approach when performing financial valuations (Petersen, Plenborg & Kinserdal, 2017, p. 299). All present value models are originally an offspring of the Dividend Discount Model, which determines the market value of a firm's equity by discounting future dividend payments to its shareholders.

$$\text{Market value of equity} = \sum_{T=1}^{\infty} \frac{\text{Dividend}}{(1+r_E)^t}$$

Where

R_E =Investor required return on equity

Equation 1: The Dividend Discount Model. Source: Petersen, Plenborg & Kinserdal (2017)

As dividend policies vary through economic cycles, countries, industries and companies, the free cash flow is mostly applied as the discounted revenue stream instead to get rid of potential noise in the calculation. The Dividend Discount Model's general mathematical method can still be applied when valuating projects.

By discounting the expected cash flow from the investment opportunity with the cost of capital required to finance the project, the expected net present value should be determined as so. The most common present value approach is the discounted cash flow model (DCF). Even though excess return approaches (EVA or RI) have become increasingly popular again in recent years, the DCF model is still the preferred valuation tool among practitioners (Petersen, Plenborg & Kinserdal, 2017, p. 304). The foundations and assumptions for the DCF model will therefore be laid out and explained next.

2.1.1 The Discounted Cash Flow Model (DCF)

The Discounted Cash Flow (DCF) model is the most widely recognized valuation model in practice, and the theory behind the model can be used to valuate several assets within in the financial field. The DCF model can be applied to pricing fixed income instruments, but also shares, projects or even entire companies, as the value of a company can be assumed to be the sum of its projects. (Myers, 1984, p. 134-135). The DCF model broadly consists of four input variables (Myers, 1984, s. 127):

1) The project's time horizon
2) The project's required investment
3) The projects generated cash flows
4) The projects specific discount rate

The model projects the net present value by discounting the generated cash flows to the investors (and creditors), over the course of the project's life, with the project's specific discount rate. In finance theory, it is generally accepted that a project should be accepted if the net present value generated by an investment opportunity is positive (greater than 0). The following section breaks down the components to the model.

$$\mathrm{NPV} = -\mathrm{CF}_0 + \frac{\mathrm{CF}_1}{1+\mathrm{r}} + \frac{\mathrm{CF}_2}{1+\mathrm{r}} + \cdots + \frac{\mathrm{CF}_\mathrm{T}}{1+\mathrm{r}^\mathrm{T}}$$

Equation 2: The Discounted Cash Flow Model. Source Brealey et al. (2014).

2.1.1.1 The Free Cash Flow

The free cash flow is defined as the cash flow from a project's operations deducted by the capital expenditures and represents the cash surplus remaining to shareholders and creditors after maintenance of its non-current assets (Petersen, Plenborg & Kinserdal, 2017, p. 88).

± **Operating Income (EBIT)**
± Adjust for items in EBIT with no cash flow effect
± Change in net working capital
± Corporate tax
= **Cash flow from operations**
± Investments in non-current assets net
= **Free Cash flow to the firm**

Equation 3. The Free Cash Flow to the firm. Source: Petersen, Plenborg & Kinserdal (2017)

For wind farms, the operating income (EBIT) is defined as the total electricity production (MW) times the spot price of electricity (or alternatively annual fixed cash flows from a power purchase agreement) deducted by development expenditures (DEVEX), capital expenditures (CAPEX), operating expenditures (OPEX) and abandonment expenditures (APEX). Since depreciations do not affect the cash flow from the project, the 15% annual depreciation rate (The Depreciation Act, §5c, pcs. 4) must be added to the operating cash flow and after adjusting for tax payments, the cash flow from operations is found. Often, wind farms will not have significant changes in net working capital affecting the free cash flow.

The expected cash flow from a wind farm typically looks like shown in figure 20 as illustrated by Megavind (2015). The cash flow profile is consistent with the description of the different stages to wind farm development in section 1.2, where year 1-3 is the development stage, year 4-5 is the construction stage and year 6 – 30 represents the operational stage.

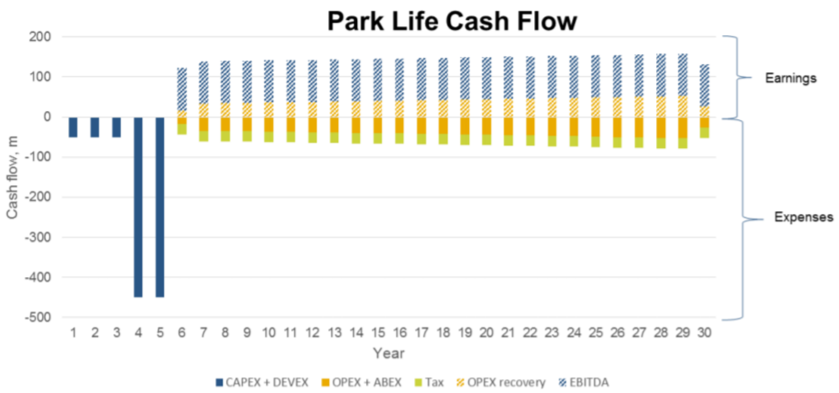

Figure 22: Expected Cash Flow from wind farms. Source: Megavind, 2015

2.1.1.2 The Project's Discount Rate

The discount rate is defined as the project's specific weighted average cost of capital and assumes that the project's residual claimers either are investors (shareholders) or creditors (bondholders). Therefore, the cost of capital does not initially factor the use of hybrid capital instruments into account, such as subordinated loans, convertible debt, or preference shares, when defining the project's capital structure.

The cost of raising equity is the shareholder demanded return on investment (r_E), and the cost of debt financing is the interest payments (r_D). Since interest payments are tax deductible, the final expression for the project's WACC is:

$$\mathrm{WACC} = \frac{\mathrm{E}}{\mathrm{V}} * \mathrm{r_E} + \frac{\mathrm{D}}{\mathrm{V}} * \mathrm{r_D} * (1 - \mathrm{t})$$

E/V = Part equity financing

R_e = Return on equity

D/V = Part debt financing

R_D = Cost of debt

t = The corporate tax rate

Equation 4: Weighted Average Cost of Capital. Source: (Petersen, Plenborg & Kinserdal (2017)

2.1.1.3 Financing

Like most other projects, the two most common financing methods for wind farm projects are through either sponsor equity or debt. The projects usually have a high financial leverage ratio, where the debt represents 70-80% of the total financing on average (WindEurope, 2019, p.11). In recent years, the stabilization of revenue streams through Feed-in Premiums (FIP), Feed-in Tariffs (FIT), CfDs (Contract for Differences) or CPPAs (Corporate Power Purchase Agreements) has lowered the operational risks for creditors and investors, which allows investors/operators to accept a higher degree of financial risk.

The debt is either issued as corporate bonds (see climate bonds in section 1.3.6) or as loans from banks or mortgage credit institutions. As a special rule, Danish wind turbines can also be registered under its own cadastral number, which allows the wind farm developer to apply for mortgages loans instead of ordinary bank loans with higher interest rates (Bekendtgørelse om realkreditinstitutters værdiansættelse og låneudmåling, 2017).

Equity is usually raised on capital markets as most of the major enterprises, in the industry of wind farms, are publicly listed. The capital is often raised by issuing shares in wind farms, and the recent increase in demand for stocks in renewable energy sources has provided project developers with strong liquidity opportunities. Since the equity investors does not have the same contractual and legal guarantees as the debtholders, equity-financing is the more expensive funding source. However, given the relative stable cash flows from most modern wind farms, due to subsidies and CPPA's, it allows for only 20-30% of the financing to come from equity sources, which lowers the project's cost of capital.

2.1.1.3.1 Debt Financing

The cost of debt is usually the cheapest source of financing for companies, primarily due to the corporate interest tax shield, but also the reduced risk for the debtholders, as they usually, through guarantees and collaterals, have the first claim to the project's assets in the case of bankruptcy. Even though the classical theory of capital structure by Miller & Modigliani (1958) recommends maximizing the present value of the interest tax shield, the trade-off theory explains that debt beyond a certain limit will increase potential bankruptcy cost and other expenses related to being under financial distress. The optimal amount of debt financing is found where the marginal cost of financial distress exceeds the marginal savings of the interest tax shield (Brealey, Myers & Allen). 2011, 455).

If the specific information about the project's debt is not available, the theoretically correct definition of the cost of debt is found by adding a specific credit premium to the risk-free interest rate. By applying this procedure, the cost of debt estimate is adjusted for the additional financial risk the individual project is exposed to, relative to a zero-risk investment. When taking corporate taxes into account, the cost of debt can be expressed as:

$$\mathrm{R_D} = (\mathrm{R_F} + \mathrm{R_S}) * (1 - \mathrm{t})$$

Where:
R_D = Cost of debt

R_F = Risk free interest rate

R_S = The projects specific risk premium

t = Corporate tax rate

Equation 5: The Cost of Debt. Source: (Petersen, Plenborg & Kinserdal (2017)

2.1.1.3.2 Equity Financing

As previously described, the investors of a project are exposed to a higher degree of risk when investing in a project or assets, resulting in a demand for a higher return rate than debtholders, ceteris paribus (Brealey et al., 2011, s. 221). The demanded return from an investor is usually calculated with the Capital Asset Pricing Model (CAPM), with the risk-free interest rate, the market rate of return and the assets specific beta-value, which illustrates the degree of risk and uncertainty related to investing in the project. r_E is defined as follows:

$$\mathrm{r_E} = \mathrm{r_f} + \beta * (\mathrm{r_m} - \mathrm{r_{f)}}$$

R_f = Risk-free interest rate

R_m - R_f= Market portfolio risk premium

β = Beta

Equation 6: Return of Equity. Source: (Petersen, Plenborg & Kinserdal (2017)

The underlying theory of Capital Asset Pricing Model assumes:

- Rational investors
- Free access to capital markets
- Transparency
- No taxes
- All investors can borrow at the risk-free interest rate
- All assets are traded

(Arnold & Lewis, 2019)

Equation 6 illustrates the linear equation called the Security Market Line which illustrates the relationship between risk and return, as investors are only willing to accept more risk if they are compensated by a higher return on equity. The SML also illustrates that by holding an uncorrelated portfolio of correctly priced assets, the diversification effect eliminates all unsystematic risk.

2.1.1.4 The Fisk-Free Interest Rate

In theory, the risk-free interest rate represents the return of an investment with no incurring risk, which can be interpreted as an investment with a zero percent chance of realizing a financial loss, while investors are not exposed to re-investment risk either. Theoretically, Petersen, Plenborg & Kinserdal (2017) recommends using a zero-beta portfolio as a proxy for the risk-free rate but, due to costs and practical issues in constructing this, end up applying the interest rate of zero-coupon government bonds (Petersen, Plenborg & Kinserdal, 2017, p. 346). Practitioners finds the optimal time to maturity is finding a bond, which spans over the same investment horizon as the project (Holm et al., 2005, p.4).

2.1.1.5 Market Return Risk Premium (MRP)

The market return risk premium defines the excess return gained from investing in the market portfolio/index and the current risk-free interest rate. By investing in any asset with some degree of financial risk, the investor will demand a premium (illustrated by the Security Market Line). The actual size of the risk premium can either be determined through an analysis of the historical spread (Ex-post) or through future forecasts (Ex-ante). Besides these two methods, there are generally 3 different assumptions about the market return risk premium, which is currently discussed within the financial field (Sørensen, 2017, p.40):

1. MRP should be determined from the investor's own subjective estimation.
2. MRP should increase over time because as a result of an increase in uncertainty.
3. MRP should be a constant rate and is estimated from the current pricing in the market.

Empirical research shows significant fluctuations in the MRP throughout time. Parum (2001) estimates that a historic average of 3% has been applied through most of the 20th century (1925 – 1997). PwC (2016) then estimated an average of 4,4% from 1998 – 2016 and Fernandez (2019) found an applied average of 6% from 2016 - 2019 among 132 Danish participants. This should speak against applying a fixed estimate for MRP, since the historical development shows an increase. However, there are different methods and sample sizes in the surveys, which decreases the comparability. The most recent and consistent historic survey is by Damodaran (2020a) who estimates the MRP in Denmark to 5.20% with the ex-post method, based on data from 1960 until today. However, today most discounted cash flow valuations apply a fixed WACC because of the simplicity. The participants from a survey by Holm et al. (2005) answered that they apply a variety of a combined ex ante and ex post method to calculate MRP (Holm et al., 2005, p.5). Regardless of the method applied, most practitioners estimate that a risk premium around 5% should be applied in valuations, which is considering the effect of potential economic cycles (Petersen, Plenborg & Kinserdal, 2017, p.363).

2.1.1.6 Beta

The value of beta is an indication of the amount of systematic risk investor is exposed to, by accepting an investment in the project/asset. The interpretation of a project's beta can be dissected into 4 intervals:

Beta	Interpretation
$\beta = 0$	Risk-free investment
$0 < \beta < 1$	Investment with less systematic risk than the market portfolio
$\beta = 1$	Investment with identical systematic risk as the market portfolio
$\beta > 1$	Investment with higher risk than the market portfolio.

(Petersen, Plenborg & Kinserdal, 2017, p. 346)

By observing the covariance of the historical returns between the market portfolio and the asset and relative to the variance of the market returns, beta can be found. For asset returns with a greater volatility, than the market portfolios, beta will be larger than 1. If the returns have identical volatility, beta is equal to 1 and finally assets with lower volatility in its returns than those of the market portfolio, beta will be less than 1 (Petersen, Plenborg & Kinserdal, 2017).

$$\beta_i = \frac{\sigma_{\mathrm{im}}}{\sigma_{\mathrm{m}}^2}$$

σ_{im} = Covariance between the returns of the asset and the market portfolio.

σ^2_m= Variance of market returns

Equation 7: Beta. Source: Brealey et al., 2011

Equation 7 is only applicable to securities, which are traded on financial markets. For unlisted assets, other approaches must be applied since the required data is not available.

As an alternative or a supplement to the estimate, beta can be found either from its peers or by analyzing fundamental factors.

2.1.1.6.1 Estimating Beta from Peer Group

Estimating beta from a projects/asset/company's peer group can be done by following 5 steps (Petersen, Plenborg & Kinserdal., 2017, p. 351):

1) Gather a peer group which consist of several comparable companies.
2) Estimate the beta (β_E) for each company in the peer group by using the Equation: $\beta_i = \frac{\sigma_{im}}{\sigma_m^2}$
3) Calculate the unlevered beta (β_A) for peers
4) Find the average unlevered beta for the peer group
5) Calculate beta of the project by levering the industry beta with the projects capital structure.

The 5-step model assumes that beta equity for a given project is a weighted sum of operational and financial risks. In theory, if the peer group is assumed to be chosen correctly and therefor has comparable operating risks, the beta assets should be identical to the target companies. Even though Sørensen (2017) finds that successful companies within the same industry generally have similar target capital structure, the financial risk varies between projects and companies, dependent on risk management. The components to the Beta assets Equation in step 3, can be determined as:

$$\beta_A = \frac{\beta_E + B_D * \frac{NIBL}{Equity}}{1 + \frac{NIBL}{Equity}}$$

Where:
β_D = Systematic risk from debt

NIBL = Net Interest-Bearing Liabilities.

Equity = Market value of equity

Equation 8: Beta Assets. Source: Petersen, Plenborg & Kinserdal (2017)

The project specific beta can now be estimated by levering the industry beta and hereby adjusting for a company's own financial risk by using the following Equation:

$$\beta_E = \beta_A + (\beta_A - \beta_D) * \frac{NIBL}{Equity}$$

Equation 9: Beta Equity. Source: Petersen, Plenborg & Kinserdal, 2017

This method also has its own limitations due to potential lack of available data or lack of comparable units. β_D is complicated to estimate in practice, which is why Koller, Goedhart & Wessels (2015) suggest either to assume that the systematic risk from a company's debt is equal to zero or to apply a fixed estimate of 0.3 (Koller, Goedhart & Wessels 2015. p. 301).

Even though companies or projects operates within the same industry, different organizational structures or business models might result in a violation of the assumption of identical unlevered betas (Petersen, Plenborg & Kinserdal., 2017). However, the variance should be limited, which is why the assumption is acceptable. Alternatively, analysts should estimate beta directly from the targets own fundamental factors, which is a qualitative approach to asset-risk assessment.

2.1.1.6.2 Estimating Beta from Fundamental Factors

Estimating beta from fundamental factors represents a more qualitative approach to the assessment of beta. This approach needs an in-depth analysis of the external, strategical, operational, and financial risks (Petersen, Plenborg & Kinserdal, 2017, s. 353). External, strategical and operational risks all affect the β_A-part of Equation 8, while the latter part $(\beta_A - \beta_D) * \frac{\text{NIBL}}{\text{Equity}}$ are a result of financial risk (financial gearing). due to Due the high degree of subjectivity in the method, the fundamental beta estimation can be an unprecise and biased estimator but serves well as a sanity check for quantitative beta estimations.

External risks are factors affecting the profitability of a project outside of the control of the management, which has previously been analyzed in the PESTEL and ILC models. The strategic risks are due to the competition within the industry, such as relative competitive advantages, supplier and customer relations and product pricing. To a certain degree, these factors are within the control of the management, depending on the magnitude of the business. Finally, there are operational risks which are almost completely within managements control, such as cost structure, production efficiency, IT systems, R&D, employees, and internal control systems (Petersen, Plenborg & Kinserdal, 2017, s. 354).

The financial risks measured through the financial gearing (NIBL/Equity) is determined by analyzing the characteristics of loans and capital structure. Interest payments, quality of debt, short- or long-term loans and the payment profile should all be identified, while also taking potential financial debt instruments, such as currency and interest swaps, into account (Petersen, Plenborg & Kinserdal, 2017, p. 359). All the factors identified in this section should be included in the total weighted systematic risk of the project. Arnold & Lewis (2009) has gathered the different parameters into the MASCOFLAPEC model (appendix 3), which is meant to gather qualitative data and convert into a quantitative estimate for beta.

2.1.1.7 Criticism of the Discounted Cash Flow Model

The Discounted Cash Flow model is a good valuation tool when pricing projects, assets, and companies, which deliver stable cash flows to its residual claimers (Myers, 1984, s.134-135). However, there is several underlying assumptions which potentially can mislead its users.

Even though the theoretical idea of discounting future cash flows seems correct, practitioners often find it difficult to budget the correct size of these (Myers, 1984, s. 133). This is especially applicable to the wind industry due to the volatile spot prices of electricity. However, the price of electricity is volatile, which makes projecting future cash flows more complex. Additionally, accounting for weather factors, the forecasting process is exposed to an even higher degree of ambiguity. However, if the investors have signed a fixed CPPA before construction, then the DCF valuation could be an accurate tool to value the operational stage of the wind farm, as cash flows would be predictable when there is no reliance on the spot price of electricity.

Another weakness to the DCF method is the degree of subjectivity in the WACC estimate. In the survey by Holm et al. (2005), the different methods behind estimating the different components in CAPM (beta, market risk premium, inflation rate, tax rate etc.) logically must lead to different pricing of the same asset, which violates the assumption of 'the law of one price. The CAPM assumptions listed in section 2.1.1.3.2 are generally unrealistic when transferred into a real life respective, but as Arnold & Lewis (2019) states: "It isn't perfect, but there isn't anything better". Analysts should consequently adjust the CAPM estimate to specific cases based on own judgement, which practitioners tempt to do according to Holm et al. (2005).

However, the most significant weakness to the present value approach might be the failure to adjust for projects which are dissected into different stages with different risks (section 1.2) and the exclusion of managerial flexibility (Triorgeris & Mason, 1987). Both issues will be assessed next.

2.1.1.7.1 An industry specific adjustment to the Discounted Cash Flow: The Expected Net Present Value

In order to incorporate project-specific risks of wind farms in the DCF model, The Expected Net Present Value (ENPV) offers a solution. The model allows to adjust for uncertainty in market conditions by calculating the NPV for likely scenarios and probability-weighting them. The value weighted sum of different outcomes is the expected net present value (Willigers & Hansen, 2008).

In consistency with the four stages from section 1.2, this approach can be transferred to wind farm valuation through the blueprint illustrated below:

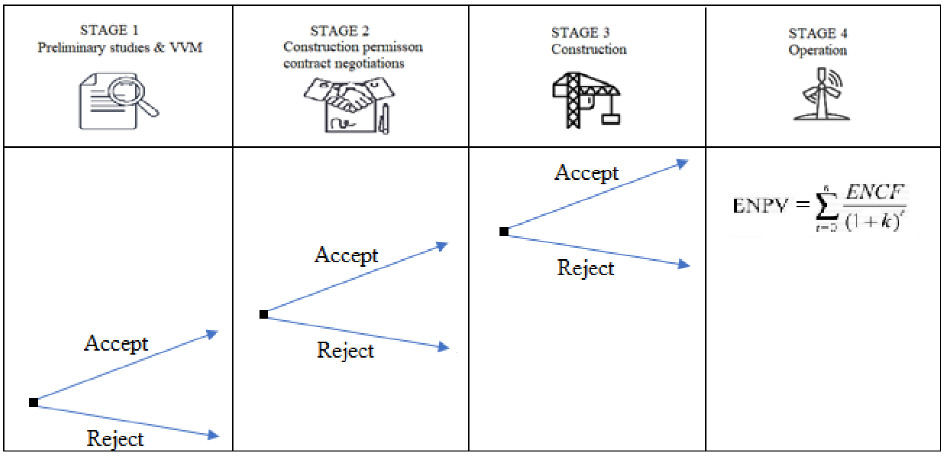

Figure 23. Own contribution. The Expected Net Present Value. Source: Willigers & Hansen, 2008

Figure 23 illustrates how valuation of a wind farms can be presented as a decision-tree analysis. In the first three stages of the development process, the project will either successfully gain permissions to move on to the next stage or is rejected. Given the different economic results in the two scenarios, the model adjusts this through the probabilities of each scenario when discounting the cash flows. As the theory behind the ENPV model is identical to the DCF model's, it will not be discussed any further. Evidently, most weaknesses of the DCF model also apply to the ENPV, as the model still assumes passive investor behavior and therefore do not incorporate managerial flexibility either. The model incorporates the project risks in the different stages of wind farm development, which is an advantage relative to the traditional DCF.

2.1.1.7.2 Managerial Flexibility

Managerial flexibility is both described by Myers (1984) and Trigeorgis & Mason (1987) and is defined as management's potential implementation of strategic actions after making an initial investment. By not adding the value of managerial or strategic flexibility to its estimate, the DCF model indirectly assumes that investor takes no further action after making the final investment decision. However, this is not always the case for the project operator, as they often deem it profitable (or less costly) to revise their decision and apply changes to the project while it is ongoing. By not taking this option into account, valuations will systematically be undervalued (Trigeorgis, & Mason, 1987, p. 47). Trigeorgis & Mason (1987) finds asymmetry and skewness in the distribution of the NPV estimations and, thus, suggest adding an extra component to the investment's decision criteria. Consistent with Trigeorgis, & Mason (1987) the expanded version of the original investment criteria should be as follows:

$$\text{Expanded NPV} = \text{Static NPV} + \text{NPV option}$$

Equation 10: The Expanded Net Present Value. Source: Trigeorgis, & Mason (1987)

The expanded equation builds upon the original investment criteria (accept is NPV > 0) and is consequently not an argument for rejecting the validity of the DCF models estimations. The new equation only represents an adjustment with its incorporation of managerial flexibility. Since Trigeorgis & Mason (1987) recommends using real option valuation (ROV), section 2.4 will examine the details of this concept. However, before ROV is explained, the following sections will lay out the foundations for the Relative and the Asset-Based valuation approach, which are the next models to evaluate.

2.2 The Relative Valuation Approach

Among practitioners, the relative valuation approach (multiples) is almost as popular as the present value method but rarely acts as the stand-alone valuation method, as multiples are best suited as a sanity check for present value approaches (Petersen, Plenborg & Kinserdal, 2017, p. 317). Multiples are very popularly applied because of the low degree of complexity. They are fast and easily applied compared to other valuation methods (Petersen, Plenborg & Kinserdal, 2017, p 2017, p. 298).

Like present value methods, some multiples estimate the enterprise value, while others directly calculate the value of the shareholder equity. Examples of multiples which estimates the enterprise value are: EV/Invested Capital, EV/NOPAT, EV/EBIT, EV/EBITDA, EV/Sales. To estimate the equity value directly, Price/Book Value or Price/Earnings can be applied (Petersen, Plenborg & Kinserdal, 2017, p, 2017, p. 298). Depending on the specific characteristics of an industry, some multiples are more relevant for the relative valuation approach than others. Within the wind industry, the individual projects are organized in small enterprises (A/S, P/S or ApS'), which potentially helps the sales process and reduce the owners legal exposure, but due to the Danish accounting regulations in The Financial Statement Act, the projects are allowed limited financial reporting standards (BDO, 2017)[4]. The lack of transparency makes it difficult to obtain or normalize key financial ratios like sales, NOPAT, and EBITDA, which is commonly applied in the relative valuation approach. Therefore, Deloitte (2016) applies the enterprise value over the total megawatt production from the wind farm (EV/MW) as the main multiple, when performing wind farm valuations (Deloitte, 2015, p. 7).

Multiples are applied by obtaining a peer group with comparable projects. However, it is not recommended to combine on-shore and off-shore projects in the peer group as cash flows and capacity factors varies. The EV/MW multiple is calculated individually for each project in the peer group by dividing the enterprise value with the total megawatt capacity of the project. Usually the analyst should apply an average or the

[4] As an example, small enterprises can just report "Gross profit" instead of sales and production costs (BDO, 2017).

median value of the peer group and multiply this factor with the project's own megawatt production to obtain the expected enterprise value. Equation 11 summarizes the multiple valuation approach:

$$\text{Enterprise value} = \frac{\text{EV (peer group)}}{\text{MW (peer group)}}\,\text{x estimated MW}$$

Equation 11: Multiple Valuation. Source: Own construction with inspiration from Petersen, Plenborg & Kinserdal (2017)

2.2.1 Criticism of the Relative Valuation Approach

There are several weaknesses to the multiple valuation method and, resultingly, the relative valuation approach is very rarely applied as the primary valuation tool. Instead multiple valuation normally serves the purpose of a sanity-check of the estimates of the DCF model.

Due to the simplicity of relative valuation, the model simplifies complex issues and disregards any historic or future aspects in its estimate. This issue can potentially be solved by using expected earnings instead of the current. While this method creates the same forecasting issues as Myers (1984) raised regarding uncertainty of budgeting future cash flows, Liu et al. (2002) still found this approach to be more accurate (Petersen, Plenborg & Kinserdal., 2017, p. 326),

As the relative valuation approach heavily relies on the comparability of the peer group, it is highly significant that these are truly comparable. This is relevant from a strategic, operational, and structural perspective, but also in terms of accounting policies. If a wind farm's financial statement reports are used to calculate the multiple, an analyst must make sure to account for potential differences in accounting policies on the balance sheet and non-recurring items from the income statement (Petersen, Plenborg & Kinserdal, 2017, p. 319). If the recognized items are not correctly adjusted for, the estimation will be subject to accounting noise. These necessary adjustments will eliminate the simplicity and quickness of using multiples, which originally is what the method is applauded for.

Like the present value approach, multiples do not integrate the value of managerial flexibility in its estimate and is not designed for projects with compounded stages, which makes the approach incompatible with the characteristics of wind farm development. Multiples can still be applied as a sanity check for the present value approach, but the relatively limited amount of accounting or market transaction data is problematic. In an interview PensionDanmark, it is explained that multiples are very rarely applied within the wind industry, as farms are incomparable due to technologic advancements, different policies, different subsidies etc. Practitioners often use the Levelized Cost of Energy model instead to compare wind farms (interview, May 1st, 2020).

2.2.2 An Industry Specific Relative Valuation Approach: The Levelized Cost of Energy Model

The "Levelized cost of energy" expression is an established concept used to compare the cost of energy from different sources, such as, oil, gas, wind, solar, etc. However, in May of 2015 a committee of wind energy organizations published a model specifically applied to the estimating the costs of offshore wind farms (Megavind, 2015).

In relation to finance theory, the LCOE model, does not produce any new knowledge, as most of the input variables are identical to a standard discounted cash flow models, but because that the LCOE model is tailored for a particular industry, practitioners might find inspiration in its specific cost structure of wind farms. The 5 main purposes of the models seek to:

- Develop a commonly accepted valuation model within the industry to estimate the cost of electricity from offshore wind farms.
- Become a general accepted tool for communication results within the industry.
- Present a method, which allows to compare the cost of offshore wind farms
- Produce a benchmark in the process of moving towards reducing LCOE in offshore wind
- Help identifying the main cost drivers and their potential for future LCOE reductions (Megavind, 2015, p. 2)

The LCOE Model's final output is a factor of the discounted cost of energy relative to the discounted future production, defined through the following expression, where the LCOE estimate represents the unit cost of one megawatt per hour of production:

$$\text{LCOE} = \frac{\text{Present value of cost}}{\text{Present value of production}}$$

Where:

Production = $\sum_{t=k}^{T} \frac{Electricity\ production_t}{(1+WACC_{real})^T}$

Cost = $\frac{DEVEX+CAPEX+OPEX+ABEX}{(1+WACC_{nominal})^T}$

Equation 12. Levelized Cost of Energy. Source: Megavind, 2015, p. 6

In the interview with PensionDanmark it is explained that the factor, which is calculated through Equation 12, is not a precise estimate for the NPV of a single farm, but gives a good indication of the technological performance relative to other energy sources (interview, May 1st, 2020). Thus, the LCOE model represents a relative valuation approach for the wind industry, as traditional multiples do not include a high degree of explanatory ability. This is primarily due to technological advancements over time and different subsidies which makes the profitability of different projects difficult to compare. Even the MW/EV multiple, which was suggested by Deloitte (2015), is not very applicable according to PensionDanmark, as transaction data often is not publicly available, which creates ambiguity to the market value estimation (interview, May 1st, 2020).

2.3 The Asset-Based Valuation Approach

The Asset-Based Valuation Approach is usually applied when valuating asset-heavy companies under liquidation or forced sale. The method is normally only applied when the expected realization value of the assets exceeds the expected value of future earnings (Petersen, Plenborg & Kinserdal, 2017, p. 329) Because of its general reliance on book values, the Asset-Based approach does not incorporate managerial flexibility in its estimation and is generally not suited for valuations of projects under development. This approach will therefore not be discussed any further.

2.4 The Contingent Claim Valuation Approach (Real Option Valuation)

The Contingent Valuation Approach (also referred to as Real Option Valuation) is the valuation method which incorporates the managerial right, but not the obligation, to implement operational strategies during a project's life span. This approach to valuation of projects contains several specific options which the management must consider before or after the final investment decision. While the Present Value Approach, as described in section 1.1, under certain circumstances can be an efficient valuation tool, the methodology of the approach does not allow for management to adjust the investment once the project has been accepted. Of the four different approaches described by Plenborg (2017), the contingent valuation approach is the only one that contains managerial flexibility, which allow decision makers to change and revise their original decision, as future events might impact the profitability. Real options hereby bridge the gap between corporate strategy and finance theory as recommended by Myers (1984):*" Strategic planning needs finance and should learn to apply finance theory correctly. However, finance theory must be extended in order to reconcile financial and strategic analysis"* (Myers, 1984, p.126). The following chapter will contain a discussion of when to apply real options, define the different types of options, and examine different models which might be applied to estimate the value of an option.

2.4.1 When to Apply Real Options

There is no decisive answer for when to apply real options, but it is important to establish that real options are not always the most efficient method to value projects. Simple or stable projects and fixed income instruments are very compatible with the present value approach, which commonly involves a less complicated method, thus making it easier to communicate the result (Myers, 1984, p. 130). However, the uncertainty within the renewable energy sector, regarding future electricity prices, fossil fuel prices, regulation, subsidies, and technological issues, makes real option valuation a more accurate approach (Venetsanos et al., 2002, p. 293-294). It is recommended to use ROV if at least one of the following assumptions are met (Mendez, Goyanes & Lamothe, 2005, p. 3):

1) The project is divided into a series of independent and successive stages, with the possibility of deciding, ahead of each stage, whether pursuing the investment is advisable or not.
2) The operator can abandon the project before its final construction
3) Project specific risks only appears after making the investing decision.
4) Changes in external market risks affects the value of the project during its lifespan

Furthermore, Copeland & Antikarov (2003) recommend the use of a ROV model when the NPV of a project is close to zero, due to the model's quite static decision criteria (accept if NPV > 0). If a project is not conclusively profitable or unprofitable, the ROV framework provides a better foundation for decision making.

As previously discussed, wind farm development is dissected into three stages, where the decision to continue development is a contingent decision based on success in the previous stage. Additionally, the profitability within the industry strongly relies on external factors such as electricity prices, wind speed, substitute energy sources and policy making, which is outside the control of operators. This adds to the degree of uncertainty within the industry, as the bargaining power from each operator is low (Porter, 1979). Since most European wind farms are still subsidized through government CfDs, FITs, or FIPs, profits have historically been low, but stable.

In theory, there is evidence to support applying real option valuation to wind farm projects under development, as most of these characteristics are compatible with the issues listed by Mendez, Goyanes & Lamothe (2005) and Copeland & Antikarov (2003). However, another issue is how to mathematically apply this valuation technique. Real option theory has several characteristics identical to those of financial option theory, which is why a brief presentation of call and put options will be necessary to understand the underlying theory behind the contingent valuation approach (Schulmerich, 2010, p.21).

2.4.2 Financial Options

Options are financial instruments which value is derived from the value of underlying securities. If an option is acquired, it grants the holder an opportunity to either buy or sell the underlying security, depending on whether the option is a call or put option.

Financial options are generally defined as a contractual right, but not an obligation to buy (call options) or sell (put option) an asset (S) at a fixed price (K) sometime in the future (Brealey et al., 2011 p. 513). Whether or not the option has any intrinsic value at maturity, is determined by the development in the price of the underlying asset. At the option's time of maturity, one of three scenarios will occur:

Scenario	*Call*	*Put*
1) The option is *in the money*	K < S	K > S
2) The option is *at the money*	K = S	K = S
3) The option is *out of the money*	K > S	K < S

Where:
S = Price of underlying asset

K = Exercise/strike price

If an option *is in the money*, this is interpreted as the option having intrinsic value and the right to buy or sell the underlying asset should be exercised, as the price is favorable relative to the current fair value of the security. If a call (put) option is in the money, the value of the underlying asset is greater (less) than the exercise price, giving the owner the right to buy (sell) an asset below (above) its market price. If the price of the underlying asset is equal to the exercise price at maturity, the option will be *at the money* and the owner of the option will be indifferent between exercising the right or not. The call (put) option is *out of the money* if the value of the underlying asset is less (greater) than the exercise price. Since options does not represent a contractual obligation to its owner, unlike futures, the worst-case scenario is that the options value is equal to zero at maturity and should not be exercised. Figure 23 illustrates the payoff profile of the options.

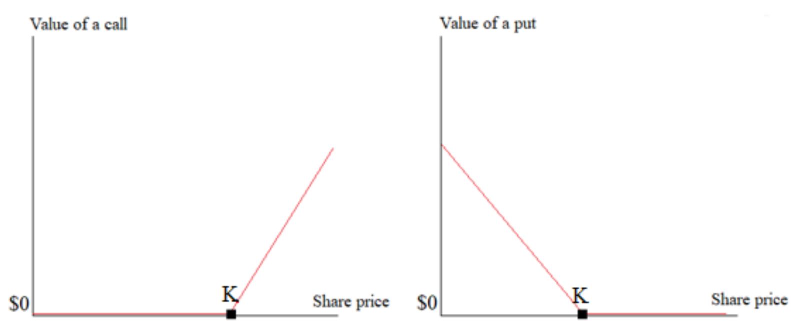

Figure 24: Payoffs from options. Own construction

The option's value at maturity can be summarized as shown in Equation 13.

$$\text{Call: MAX}[S - K; 0]$$

$$\text{Put: MAX}[K - S; 0]$$

Equation 13: Intrinsic value of options. Source: Brealey et al. (2014)

Regarding when to exercise an option, it is important to distinguish between European and American options. European options can only be exercised at maturity, when the option expires, while American options can be exercised any time until maturity (Brealey et al., 2014, p.513). Therefore, American options, ceteris paribus, will be more expensive due to the additional flexibility.

The five factors which affect the fair value of an option is the value of the underlying asset, the exercise price, the time to maturity, the volatility of the underlying asset and the risk-free interest rate (Brealey et al., 2014, p.27).

Table 3 illustrates how the different parameters are affecting the value of call and put options.

Movement in parameters	Call	Put
Value of underlying asset	+	÷
Exercise price	÷	+
Time to maturity	+	+
Volatility of underlying asset	+	+
Risk free interest rate	+	÷

Table 3: Movement in parameters. Source: Brealey et al., 2014

In order to perform a valuation of real options, the following variables must also be defined, independent of which model is used. The parameters, in theory, are identical to those of financial options pricing, but there are practical implications which makes the underlying factors differ.

2.4.3 Parameters in the Real Option Valuation

When pricing financial options, the 5 parameters in table 3 is obtained from publicly available data. However, in order to convert tangible projects and strategies into the theoretical framework of financial options, it is required to make coarse assumptions for reasons of practicality. In the next section, it is described how to convert the parameters from financial options to real option valuation.

2.4.3.1 Value of Underlying Assets (S)

For financial options, the underlying asset is usually a security, like a stock, preferably available on financial markets. For wind farms, however, it can be difficult to find a fitting security for this purpose. Therefore, it is recommended to use the Static NPV generated from a DCF valuation of the wind farms operational stage as a base case instead (Copeland & Antikarov, 2003, p. 44).

2.4.3.2 Exercise Price/Strike Price

In the theory of options, the exercise price is a fixed value defined in the contract, equal to the cost of exercising the contractual right to buy the underlying asset. For real options, the exercise price is equal to the costs of continuing/constructing the project. For wind farm development, the exercise price represents the costs related to making the initial investment or to continue to the next stage in the development process (Peters, 2016, p.4). Whether the project is profitable depends on the value of the underlying asset and the exercise price at the contract’s maturity. However, after the option is acquired, the value of the option will never fall below 0.

2.4.3.3 Time to Maturity and Number of Periods (n)
Like the exercise price, the time to maturity is fixed and defined in the contract for financial options. However, for real options it is not always possible to define the duration of each stage of development. The time to maturity for each real option in the compound model, is defined as the time period between the initial investment decision and the gateway into a new stage. The number of periods (n) depends on how many months or years the stages last and varies between operations. However, the total time to maturity for a real option is the accumulated sum of the duration of each stage.

2.4.3.4 Volatility (σ)
The volatility of options always depends on the standard deviation of the underlying asset (Peters, 2016, p. 5). As it is recommended to use a capital-based valuation model as the underlying asset, the volatility depends on the fluctuations in the estimates of the secondary valuation model. Therefore, historical variance, scenario analysis or Monte Carlo simulation is often necessary in order to examine the volatility of the value of the underlying asset (Peters, 2016, p. 14). As a proxy for the volatility in the DCF estimate, it is also a possibility to use the volatility of a twin asset, which has a strong explanatory ability for the development in the NPV of the underlying asset. As examined in Part I, the spot price of electricity is a relevant proxy for the volatility within the wind industry. However, the capacity factor is also a significant predictor of the wind farms revenue stream and must be included in the final volatility if possible.

The volatility of the asset is a critical value driver for real option valuation since the value of the option heavily relies on fluctuations in the underlying asset (Peters, 2016, p. 1). Higher volatility or uncertainty will add to the value of the option (see table 3), as the value of managerial flexibility increases. For real options, testing the volatility of the underlying asset is as important as testing the sensitivity in the estimated WACC in DCF models.

2.3.3.5 Risk-Free Interest Rate
The risk-free interest rate is previously described as the expected return of risk-free investment opportunity (see section 2.1) and thus, it will not be repeated in this section.

Real option valuation is based on the same framework as financial options, but often for tangible projects or corporate strategies rather than securities. If a business is investing in a project, management's ability to exercise strategies during the project's lifespan can be thought of as financial options. If the business is operating in a high-risk industry, where market conditions might look vastly different a year from now, it might be profitable to take precautions. The next section will exemplify a few real options and how they compare to financial options and the wind industry.

2.4.4 Different Types of Real Options

ROV is a heuristic valuation approach based on option theory. Therefore, there exists an almost endless variety of real options, as the individual calculations can be tailored after specific needs or characteristics. Depending on each project, some might be more sensible to apply than others, though, which is why only four different types of real options will be included and discussed, as only these are deemed useful for wind farms.

2.4.4.1 Option to Defer

An option to defer can be preferable when investors can postpone the final investment decision until more information is available. When development in market conditions, technological advancements, or policies, is plausible to change in the nearest future, management might prefer to push the final investment decision, until a point of clarification. This type of option is especially useful in industries dominated by high entry barriers and long-term investments, like the wind industry. As illustrated in section (1.2), financial investors prefer to push the investment decision until preliminary and contract negotiations is completed, which is identical to a deferred real option. A real option to defer an investment decision, shares the characteristics of an American call option, that are to be exercised if the projects' NPV of the exceeds the initial investment costs (Peters, 2016, p.5).

2.4.4.2 Option to Expand or Contract

In some cases, management might find it attractive to expand the scale of a project by adding extra capacity. However, if the profitability does not turn out as expected, management might want to exercise an option to reduce the scale of the investment. The real option to expand operations is equivalent to an American call option on adding extra capacity to the investment, where the exercise price is equal to the related expansion costs. For wind farms this opportunity will not always be available, depending on the permission and contract, which the constructor is bound by.

The option to reduce the scale of a project, has the characteristics of an American put option on the expected value lost from the limiting the capacity, with the exercise price being the future savings from the project (Peters, 2016, p.5).

2.4.4.3 Option to Abandon or Switch

In a scenario where market conditions turn out unfavorable for an investor, projects should not just be reduced in scale, but shut down completely. This decision allows companies to reduce the expected loss from a project, while having an opportunity to allocate its resources elsewhere. The option to abandon the project is relevant for wind farm development as pre-approvals might not be granted, EIA studies fail or changes in government subsidy policies make the project unprofitable. The real option to abandon a project is equal to an American put option.

A real option to switch between two projects is a little more complicated procedure because of the interdependence between the projects. The abandon and switch options are two American put options on the value of a project, with the exercise price being the cash generated from liquidating the assets (Peters, 2016, p.5).

2.4.4.4 Compound Option

Certain projects consist of multiple stages, where the decision to continue its construction or development entirely depends on whether the previous stage was successful. Previously, it has been illustrated how the wind farm development process is divided into 3 different stages before being operational, based on DEA's 3 required licenses. The wind farm will only be constructed if success is realized at the expiration date of every stage and otherwise abandoned completely. If the prospects of the preliminary studies or the EIA are negative, the developer is not likely to pursue a construction permission. Equivalently, the wind farm will not be constructed if permission is rejected or contract negotiations break down. Therefore, compound options are not one, but a series of European call options, which all need to be exercised at maturity for a project to reach its operational stage.

The compound option initially appears to be the most precise real option for wind farms under development, as this type of ROV contains the contingent investment decisions, which is consistent with section 1.2. If the economic prospect turns out negative, the project should be liquidated, which is why the abandonment option also indirectly should be applied in the valuation model.

As real option valuation is a heuristic approach, a variety of methods can be applied to price the value of the option. In the next section, the two most common models will be analyzed: The Black & Scholes Model and The Binomial Model by Cox, Ross, and Rubenstein. The section will also contain a review of the strength and weaknesses of the models and which of the two is the most applicable to valuation of offshore wind farms under development.

2.4.5 Pricing Real Options: The Black & Scholes Model

The Black-Scholes asset pricing model from 1973 is probably the most applied model, when it comes to valuating financial options. The model estimates the fair value of an option from the following parameters: price of the stock, exercise price, standard deviation, time to maturity and the risk-free interest rate (Brealey et al., 2014, p. 546).

$$\text{Value of call option} = \mathrm{S}\,\mathrm{N}(\mathrm{d}_1) - \mathrm{K}\,\mathrm{e}^{-\mathrm{r_f t}}\,\mathrm{N}(\mathrm{d}_2)$$

Where:

$d_1 = \frac{\ln\left(\frac{S}{K}\right)+\left(r_f+\frac{\sigma^2}{2}\right)t}{\sigma\sqrt{t}}$

$d_2 = d_1 - \sigma\sqrt{t}$

S = Value of underlying asset

N(d) = Cumulative normal probability density function

$K\,e^{-r_f t}$ = PV Exercise price of call

r_f = risk free interest rate

t = time to maturity

Equation 14: The Black & Scholes Model. Source: Brealey et al. (2014)

After estimating the price of a call option, the price of a put can be derived from what is known as the put-call parity. Under a no-arbitrage assumption the value of the put, with same time to maturity and exercise price, should balance the following equation:

$$C - P = S - K\,e^{-r_f t}$$

Where:

C = Value of call

P = Value of put

S = Value of underlying asset

$K\,e^{-r_f t}$= PV exercise price call

Equation 15: The Put-Call Parity. Source: Brealey et al. (2014)

The initial intention of the Black and Scholes model is pricing financial options, which are traded on capital markets with a relatively high degree of transparency and liquidity. Consequently, the assumption of no arbitrage and 'the law of one price' does not seem to be too controversial, when pricing most financial options. However, there are problems by transferring this philosophy to real-life projects, as two comparable projects are not necessary equally priced. For many asset-heavy investments, the traded value also might be significant under its theoretical fair value because of lack of liquidity in the market, which violates the model's assumption (Brealey et al., 2014, p. 576).

Furthermore, the Black & Scholes model is built on other assumptions, which is not compatible with real option valuation, as some real options often share the characteristics of American call/put options, whereas the Black and Scholes model is intended for European options. The distinction is important because of the mathematical implications of having the ability to exercise at any given time, in contrast to only exercising at maturity. This is a static assumption which, only in some cases, is compatible with real life managerial and strategic flexibility. As the compound option is identical to European put options, this is not an issue, but the

Black and Scholes model is not intended for projects constructed through multiple stages, which originally was why the compound option was advantageous for wind farms under development. For compound real options, it is recommended to use the Binominal Model by Cox, Ross & Rubenstein (1979) (Brealey et al, 2014, p. 532).

2.4.6 Pricing Real Options: The Binominal Model

In 1979, John Cox, Stephen Ross and Mark Rubenstein published an article, describing a method to price an option, with an underlying asset which follow a multiplicative binomial process through discrete time periods. The model has since developed into the most popular tool for valuating real options.

The binominal model simulates several possible outcomes in the value of an underlying asset and the hereby derived effect in the value of the option. As it is assumed that the underlying asset follows a binominal distribution, this implies that for every step forward in time, the value of the underlying asset will either increase or decrease. An increase in the number of steps in the binomial model equals an increase in total simulations, which should make the final estimate more accurate, as the variance of the model moves towards a normal distribution when the number of simulations increases (Brealey et al., 2014, p.540).

Whether the value of an option will move up or down is dependent on the volatility in the underlying asset, or in a twin-security, like electricity spot prices and the value of a wind farm. The Binomial Model has a strong reliance on the no-arbitrage assumption.

The key assumptions for the following option valuation are a multiplicative binominal process over discrete time and a fixed interest rate over the model's different stages. During the first time period, the stock price will either increase to: *u* at t=1 with *q* probability or fall to *d* at t=1 with the probability of 1-q.

To illustrate how to value the call option, assume that the option expires after only one period. As shown in section 2.4.2, the payoff profile of a call option has a limited downside, meaning the worst-case scenario will only make the option worthless. If the stock price is lower than the option's strike price, the option will not be exercised (because the option is out of the money), which equals a value of 0. If the stock is worth more than the strike price, the value of the option will be equal to the positive split between S and K (option is in the money) (Cox et al., 1979, p. 233).

$$\begin{tikzcd} & uS \quad \text{with probability } q \\ S \arrow[ur] \arrow[dr] & \\ & dS \quad \text{with probability } 1 - q \end{tikzcd} \qquad \begin{tikzcd} & C_{up} = \max\,[0;\, uS - K] \quad \text{with probability } q \\ C \arrow[ur] \arrow[dr] & \\ & C_{down} = \max\,[dS - K] \quad \text{with probability } 1 - q \end{tikzcd}$$

Equation 16: Development in S and C. Source Cox et al., 1979

Generally, there are two methods to value this call option, *The Replicating Portfolio Approach and The Risk Neutral Probability Approach.* The Replicating Portfolio Approach estimates the price of the option by creating a portfolio of risk-free bonds and stocks, which replicates the future cash flows from the option. Under the assumption of no arbitrage, the value of the option must be equal to the value of the replicated portfolio.

With the risk-neutral probability approach, a hedge portfolio is put together, consisting of positions in the stock and the call option, where the payoffs cancel each other out independently of the movement in the stock price. Since the hedging portfolio is risk free, its future cash flows at t = 1 can be discounted with the risk-free interest rate, and the value of the option today is found by subtracting the stock price today.

Theoretically, both methods should generate identical estimates, but Brealey et al. (2014) recommends using the Risk neutral probability approach due to its simplicity (Brealey et al., 2014, p. 538). When applying *The Risk Neutral Probability Approach* the following expressions must be defined:

$$p = \frac{e^{rf*\Delta t} - d}{u - d} \qquad q = 1 - p_u$$

$$u = e^{\sigma\sqrt{\Delta t}} \qquad d = e^{-\sigma\sqrt{\Delta t}} = \frac{1}{u}$$

Where:
p/q = Risk neutral probabilities

rf = Risk free interest rate

u = Up scenario

d = Down scenario

σ = Volatility

Δt = Time step per year

Equation 17: The Neutral Probabilities and u/d. Source Cox. et al. (1979)

By applying the expression for u and d, it is possible to track the movements in the underlying asset through multiple latent time steps. Figure 24 illustrates the movement through 2 periods. Because of the multiplicative assumption S_0 will always be equal to S_0 * u *d. This relation works all the way through the binomial tree, meaning the middle value in every even time step will be equal to S_0.

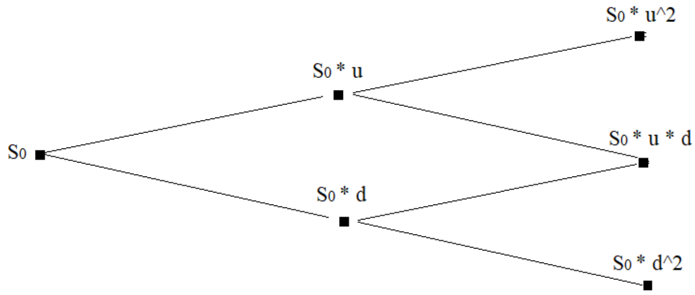

Figure 25: Movement in value of underlying assets through 2 periods. Source Cox et al., 1979

As Cox et al. (1979) previously showed, the value of the option depends on the price of the underlying asset at any given time. By applying Equation 16, then calculating the risk neutral probabilities and the up/down scenarios, the value of the real option can now be determined backwards through the binomial tree:

$$OV_o = \frac{[pOV_u + (1-p)OV_d]}{e^{r_f * \Delta t}}$$

Where:

OV_0 = PV of the option

OV_u = Value of option in up scenario

OV_d = Value of option in down scenario

p = Risk neutral probability

r_f = Risk-free interest rate

Δt = time steps

Equation 18: Value of an option. Source: Cox et al. (1979)

This summarizes the final 2-step binomial model by Cox, Ross & Rubenstein (1979):

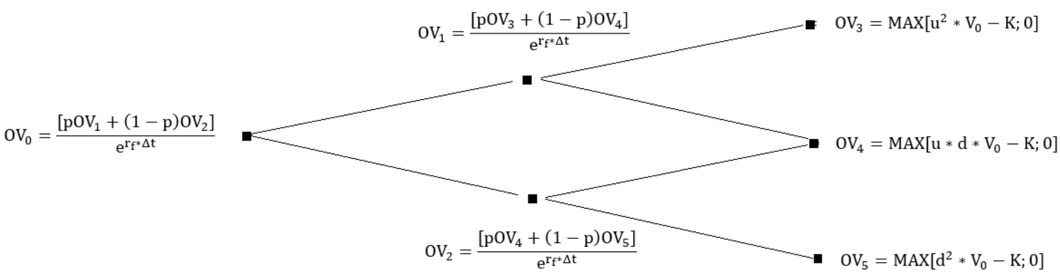

Figure 25: The Binomial Model. Source: Cox et al., 1979

When calculating the present value of the option, backwards induction must be applied, which means the starting point is the expiration date of the option. The option's value is then discounted backwards one period at a time until OV at t=0 is reached. If shorter time intervals are included in the model, the accuracy increases, since keeping the option's time to maturity the same, adding more time steps within the model generate less uncertainty about its estimate (Cox. et al., 1979, p. 247). Practitioners must balance the need for a more accurate estimate while not over-complicating the calculations and making the results too complex to communicate and illustrate.

2.4.7 Criticism of the contingent claim valuation approach

The most common criticism of real option valuation is the complex mathematics involved in the method, which makes the contingent claim approach difficult and time consuming to apply. Practitioners often prefer the present value approach and multiples because of simplicity, which is exemplified in the survey referenced by Petersen, Plenborg & Kinserdal. (2017), which shows only 5% of practitioners apply real option valuation. Holm et al. (2005) reaches a similar conclusion.

Brealey et al. (2014) describes that most financial managers view real options valuation as a "black box" method, due to its lack of recognition within the financial sector, resulting in the reluctance to apply them (Brealey et al., 2014, p. 578). PensionDenmark and AIP Management agrees with this point and states that ROV is difficult to communicate to non-financial investors (interview, May 1st, 2020).

It is also important to recall that real options are a heuristic approach originally based on the pricing of financial options. Therefore, critics argue that the underlying assumptions may not be transferable from one field to another, which leads to the use of unrealistic assumptions (Peters, 2016, p.10). There is no black and white blueprint on how and when to apply real options, which justify the skepticism among practitioners to a certain degree, but the use of coarse assumptions is not a new phenomenon in economics.

The no-arbitrage and liquidity assumptions, which was used to criticize the Black & Scholes model (1973) in section 2.4.5, apply to all real options no matter which method is used, but ultimately the same criticism could be put on most other valuation methods as well. Evidently, both the DCF and multiples have the same underlying assumptions of complete markets and the law of one price.

Real options are not a flawless approach to financial valuation, but its characteristics are a very compatible method to counter the issues of valuating projects in multiple stages with a volatile underlying asset. ROV also includes managerial flexibility which no other valuation approach properly allows.

2.5 Conclusion: Which valuation approach should be applied to wind farms under development?

This chapter has examined the strength and weaknesses by applying the four generally accepted valuation approaches. The combination of financial decision-making theory and the industry analysis of the wind industry lay down the framework for choosing the most accurate valuation method.

Through the 3 pre-operational stages, the compound real option is the most compatible method to incorporate the project-specific characteristics of wind farm development, because of its reliance on contingent investment decisions, where the development depends on success in the previous stage. The compound option is a string of European call options, which also indirectly contain the abandonment option, which is equal to buying a put option on the project, with the exercise price being the liquidation value at maturity.

While real options are preferable though stages 1-3, the operational phase (stage 4) has characteristics which allows to apply DCF valuation, as the need to incorporate managerial flexibility is less significant during the operational stage. The main factors of uncertainty are no longer licenses, contracts, and wind studies, but the spot price of electricity and the capacity factor, which must be estimated when budgeting the free cash flow. Besides this, the present value approach should be applicable at this stage, as most wind farms has stable operations for the next 25 years, through DEA's granted license[5].

Since there is an increasing trend among modern wind farms to negotiate CPPA's on significant percentages of the total MW capacity, this hedging strategy against the volatility of electricity prices, could eliminate some of the uncertainty of budgeting future cash flows. This is one of the main points of criticism from Myers (1984), and by reducing the extent of this issue, makes the DCF model more applicable. However, the static DCF estimate is only one part of the valuation, which also contains the value of the real option. CPPAs will initially be left out of the model, but instead discussed later in part IV.

Multiples do not generate an accurate estimate for wind farm development stages but can still be applied as a sanity-check to the DCF model's estimate, if the standards listed by Petersen, Plenborg & Kinserdal (2017) are met. However, due to the lack of market transaction data, most practitioners avoid the use of multiples, when valuating wind farms, and instead prefer the LCOE factor. The LCOE is an indicator of production efficiency across different sources of energy and is more relevant when comparing wind to substituting

[5] Operators still have the option to terminate the wind farm before the 25-year license expires, but the license can also be prolonged.

industries rather than internal projects. The Asset-Based Approach is not relevant when valuing wind farms under development, as these are usually applied when projects are being liquidated.

The best suited valuation model therefore contains a compound real option (with the underlying option to abandon) through stages 1-3 and a DCF valuation of the wind farms operating period (stage 4). This method should integrate managerial flexibility (Mason & Trigeorgis, 1987) and bridge the gap between corporate finance and strategy (Myers, 1984), while also incorporating industry specific characteristics. The ROV model should also incorporate the probability adjustments, which originates from the ENPV framework. By this inclusion, the project specific risks are quantified in the model.

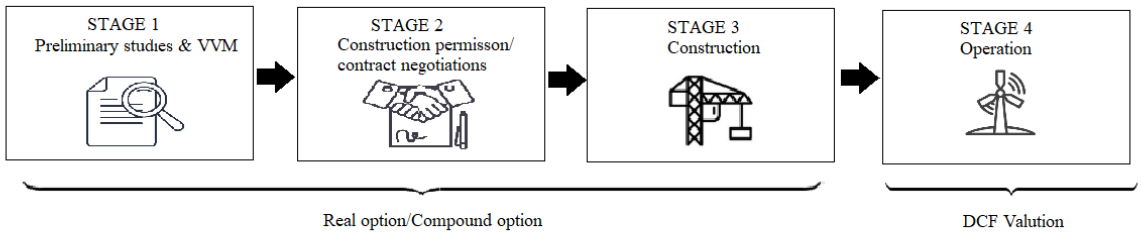

Figure 26: Valuation methods through the stages of wind farm development. Source: Own construction

As the model now has been established, the part III will apply this model to a current case study of a Danish wind farm under development. The introductory stage of part III will contain a brief description of the Aflandshage wind farm before applying the approach from figure 24.

Part III: Valuation of Aflandshage Wind Farm

The valuation of Aflandshage will be used as a case study on how to apply Real Options Valuation on a practical case. Due to the risks found in the industry analysis in part I, and the conclusion of the financial assessment in part II, the valuation of Aflandshage will be conducted using a Discounted Cash Flows model, an Expected Net Present Value model, and a Real Options Valuation model. The DCF model will only be conducted for the operational stage of the farm, as it fails to incorporate the project-specific risks of the first 2 stages. However, the ENPV model will be included in the first 2 stages as well. While the ENPV model includes every stage, it does not take changing market terms into account and thus, a ROV model is finally applied, to incorporate these parameters.

For the full calculation of the following section, we refer to the attached Excel file. Due to the scope of the calculations in the Monte Carlo simulation, only a cut-out is presented in the Appendices.

3.1 Description of Aflandshage Wind Farm

The 6th of March 2019, The Danish Energy Agency granted HOFOR A/S (Hofor) allowance to conduct preliminary examinations in the area known as Aflandshage (HOFOR A/S, 2019b). The purpose of the project is to construct a 250 MW wind farm with the intention of supporting 250,000 households with electricity. The area, for which the allowance was granted, is a 65 km^2 area southwest of Amager, where 44 km^2 is supposed be the area where the turbines are built, and the remaining area will then consist of the cables (Niras, 2019). A map of the expected location for Aflandshage can be found in Appendix 4. The grid connection will be transitioned through the established system at the 132 kW-station, Avedøreværket, to which the electricity from Aflandshage Wind Farm will be connected. As for the turbines used for the wind farm, it has not yet been decided which model and size that will be constructed. Hofor is allowed the construction of a wind farm with a total capacity of 250 MW, but distribution between size and the number of turbines, is yet to be determined. The model and supplier of the turbines is also yet to be decided.

As the project is currently in its early stages of development, Hofor still needs to conduct a public hearing, and reach an agreement with the local municipalities which the project concern (stage 2 of development). The project is located near the Swedish border, which means that hearings and agreements also need to include Swedish authorities.

Niras (2019) estimates the following timetable for Aflandshage, consistent with the stages described in 1.2:

DEVEX				CAPEX		OPEX / ABEX	
2019	2020	2021	2022	2023	2024	2025	2050
Environmental Impact Assesment Finished Ultimo 2020		Other allowances Finished Ultimo 2022		Construction Finished Ulti 2024		Operational Phase Finished Ultimo 2049	

Table 5. Own contribution. Source: Niras, 2019

As it was established in part II, real option valuation with the binominal model would be the primary approach to estimate the value of wind farms under development. However, the value of the underlying asset was determined as the static DCF value of the operational stage, which therefore is the first step in the valuation of Aflandshage.

3.2 Discounted Cash Flows model

As described in part II, the following parameters must be found to calculate the value of Aflandshage using a DCF model:

1. The Free Cash Flows
    - Income
    - Costs
2. The Weighted Average Cost of Capital
    - Beta
    - Risk-Free Rate
    - Market Risk Premium
    - Cost of Debt

The following section estimate these parameters, and finally use the DCF method to calculate the value of Aflandshages operational stage, which will be used as the underlying asset in the binominal model later in this chapter.

3.2.1 Estimating the Costs of Aflandshage

When evaluating any investment, it is necessary to estimate the costs that comes along with the project and the timing of these. Especially when valuating wind farms there are several factors that make the cost profile important and it is essential to understand the type of costs related to each stage of development. Generally, costs regarding wind farms are categorized into four categories: development costs (DEVEX), construction costs (CAPEX), operating costs (OPEX) and abandonment costs (ABEX) (Megavind, 2015, p.10). In figure 27 and 28, the costs are shown under the corresponding stage, and how they fall over the lifetime of a wind farm.

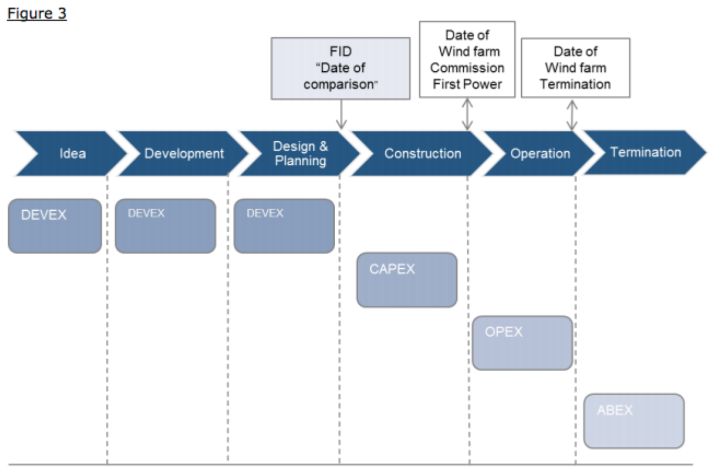

Figure 27. Source: Megavind ,2015

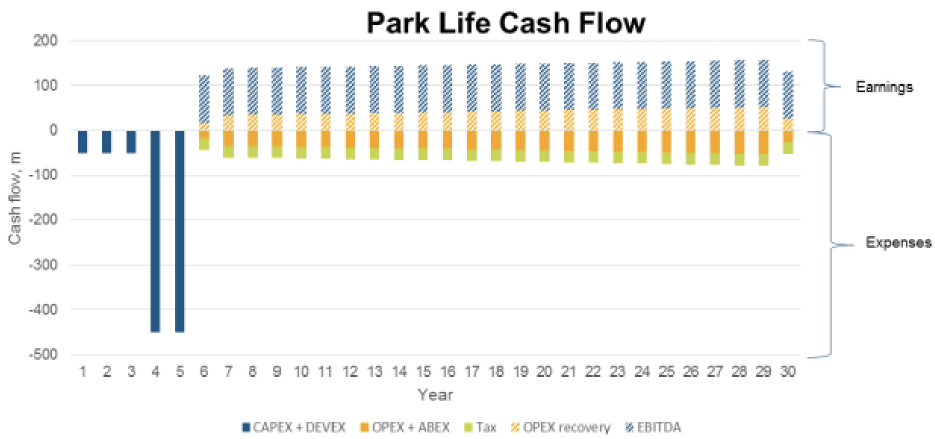

Figure 28. Source: Megavind, 2015

3.2.1.1 Development Expenditures

In the context of the industry of wind turbines, development costs are often associated with getting construction allowances in a specific area. As mentioned earlier (section 1.2), the construction of a wind farm through the open-door procedure requires certain environmental permissions. As Aflandshage is following this procedure, costs will be associated to the necessary preliminary permissions. These examinations are expensive but can also take up to several years to receive, and thus delay the construction of the wind farm. The development costs are mostly paid to firms that undertake the examinations for the wind turbines. However, DEVEX is not only regarding these examinations but are also costs related examine the profitability of different sites (wind studies etc.) and design planning. DEVEX is added to CAPEX to establish the total initial investment sum.

3.2.1.2 Capital Expenditures

Referencing figure 25, CAPEX are the costs that are associated to the construction stage of the wind farm development. The construction stage contains costs such as materials, transporting materials, salaries, machines for building the wind turbines, etc. As seen from figure 28, the blue lines (CAPEX + DEVEX) grow significantly in size as the farm enters year 4 and 5 of the process, which is because the wind farm is constructed in these years. Especially for offshore projects, CAPEX are significant (relative to those onshore), as costs of transporting materials and constructing the underwater foundations are high.

3.2.1.3 Operating Expenditures

While both CAPEX and DEVEX are expenditures which happen before the operational stage, OPEX is the costs that relates to operating and maintaining (O&M) the wind turbines. As seen from figure 28, OPEX are only relevant later in the process, and not part of the initial investment of the project. The purpose of the resources spent on O&M are to keep the wind turbines efficient throughout the park life. However, while there may be significant spikes in OPEX, as new software is launched or the turbines suffer unexpected damage, the owners of wind farms, pay a fixed fee for other companies to service the wind turbines. Resultingly, the OPEX of Aflandshage will be assumed to be covered by such a service agreement, and thus the OPEX, as seen from Hofor's point of view, will be constant throughout the lifetime of the wind farm.

3.2.1.4 Abandonment Expenditures

ABEX relates to the decommissioning of a wind farm and includes costs of taking down the turbines and clearing the area. In figure 28, APEX and OPEX are shown as one column, but due to how the costs structure is changing, the last year, there are no OPEX. This would mean that for year 30 in figure 28, all the project costs relate to the abandonment of the wind farm. However, due to the insubstantial cost of abandonment, and the given a minor scrap value, it is assumed that these two factors evens out, so that the ABEX are 0 when calculating the models.

3.2.1.5 Industry Numbers for Each Type of Cost

The easiest and most trustworthy method of estimating costs related to developing, constructing, and maintaining a wind farm would be to consult its operators. However, there are no publicly available information regarding Aflandshage, thus the estimates of the costs will be determined based on an analysis of similar wind projects. While this method provides more difficult and less concise, it has the upside of estimating costs derived from actual data for comparable project. Wind farms are often subject to significant external risks, which means the estimation of costs prior to the actual construction of the wind farm might be imprecise, as unforeseen circumstances could occur.

The following estimation of costs have been chosen based upon farms almost equal in size to Aflandshage and consist of turbines of similar capacity and technology. The data of table 6 has been determined based upon findings from Deloitte (2014) and Energinet (2018).

Park	CAPEX, EURm / MW	OPEX, EURm / MW / Year	FID	Turbine size	Total MW
Vattenfall, Horns Rev 3	2.46	0.077	2015	8.3	406.7
Vattenfall, Kriegers Flak	1.97	0.062	2017	8-10	600
Vattenfall, Near Shore	2.07	0.064	2017	6-10	350
Dong, Borssele 1+2	2.09	0.071	2018	8-10	700
Shell, Borssele 3+4	1.92	0.059	2020	8	700
Deloitte, Estimate	1,9 - 4,5	0,061 - 0,148	2014	-	-
Energistyrelsen, 2030 FID	1.64	0.0504	2030	-	-

Table 6: Own Contribution. Source: Energinet, 2018

While the data in table 6 has been found from similar farms, Deloitte (2014) has also estimated the costs of CAPEX and OPEX. Deloitte's (2014) estimate of CAPEX does not take the Learning Rate (LR) into account. Resultingly the report estimates costs representative for 2014, but are less precise given an FID of 2023, as productions costs has been lowered significantly.

The Learning Rate of the wind turbine industry is a determinant for how costs decrease, as technology and efficiency increase. The Learning Rate is presented as how many % the costs decrease when the total installed capacity has doubled. It is estimated that the LR from 2015 to 2030 is 13.8% for CAPEX and 14% for OPEX (Energinet, 2018). The Danish Energy Agency, which also conducted the analysis of table 6, has predicted the following changes for CAPEX and OPEX:

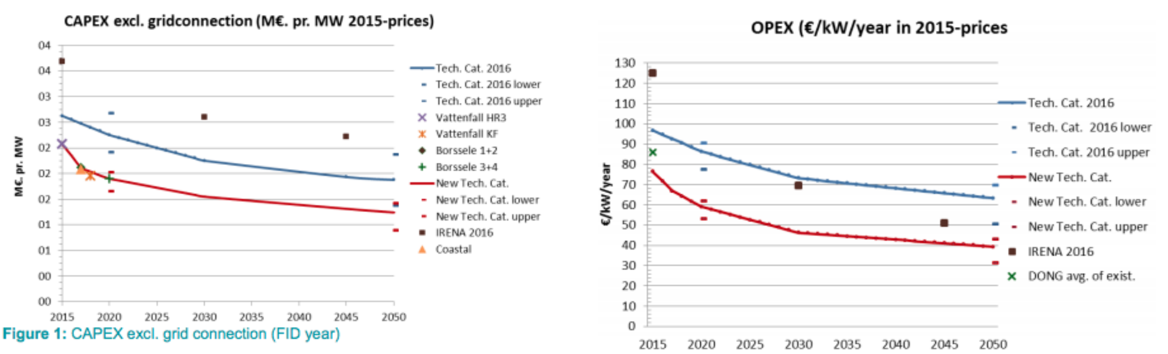

Figure 29. Source: Energinet, 2018

As observed in figure 29, the trendlines are rough estimates, and resultingly they appear linear over a period and then suddenly change to a lower slope. The blue and red curves in figure 29 are the expectations to the advancement in technology, where the new technology catalogue (red line) provides a cheaper estimate than the old technologic catalogue (blue line). Furthermore, Energinet (2018) estimates the following costs:

Investment costs excl. grid connection, M€/MW in 2015 prices	FID 2015	FID 2020	FID 2030	FID 2050
Current Technology Catalogue	2.9	2.6	2.2	1.9
New Technology Catalogue March 2017	2.46	1.92	1.64	1.4
IRENA (2016), Innovation Outlook: Offshore Wind for comparison	3.7		2.9	2.6 (2045)

Table 5: CAPEX excl. costs of grid connection.

Total* annual operating and maintenance costs, M€/MW/year in 2015 prices	FID 2015	FID 2017	FID 2020	FID 2030	FID 2050
Current Technology Catalogue	96.8		86.3	73.1	63.3
New Technology Catalogue March 2017	76.5	66.9	59.1	50.4	42.8
IRENA (2016), Innovation Outlook: Offshore Wind for comparison	125			69	51 (2025)

Table 6: OPEX.

Table 7. Source: Energinet, 2018

As seen from figure 27, the decrease in costs from 2020 to 2030 are roughly linear. By assuming linearity, and using the data provided in table 7, it has been possible to estimate CAPEX and OPEX for a wind farm with FID in 2023 using simple regression. The numbers from 2020 and 2030 would suggest an annual reduction in CAPEX by 0.028 EURm/MW and 0.00087 EURm/MW/year for OPEX. Based on this, the final estimation for a wind farm with an FID in 2023 can be found in table 8:

FID	CAPEX, EURm/MW	OPEX, EURm/MW/Year
2014	3.2000	0.1045
2015	2.4600	0.0770
2017	2.0200	0.0630
2018	2.0900	0.0710
2020	1.9200	0.0591
2023	**1.8360**	**0.0565**
2030	1.6400	0.0504

Table 8. Own Contribution. Source: Energinet, 2018

Using the data from The Danish Energy Agency and assuming a linear decrease in costs from 2020 to 2030, CAPEX will be **1.836 EURm / MW** and OPEX will be **0.0565 EURm / MW / Year,** given an FID of 2023**.**

Regarding DEVEX and ABEX, Stiesdal, Bindslev & Hansen (2017) estimate in 2025, the total costs from a wind park will be divided into 64% CAPEX, 32% OPEX, 3% DEVEX and 1% ABEX.

3.2.1.6 Total costs for Aflandshage

In section 3.1, it was stated that Aflandshage will have a capacity of 250 MW, but the size of the wind turbines will vary between 4 MW to 10 MW. It is assumed that the wind turbines will have a size of 8 MW, based on today's market standards for comparable projects. The FID for Aflandshage is 2023, as that is the year in which construction is expected to begin.

With a capacity of 250 MW, 2 years of construction, and 25 years of operations, the total CAPEX for Aflandshage will be 459.00 EURm and total OPEX will be 353.06 EURm. Assuming DEVEX equal to 3% and ABEX of 1% of the total costs, the costs will be as follows:

Type of Cost	EURm	% of total cost
Total CAPEX	-459.00	54%
Total OPEX	-353.06	42%
Total DEVEX	-25.38	3%
Total ABEX	-8.46	1%
Total Costs	845.92	100%

Table 9. Own contribution.

For use in Real Options Valuation later, the Development Expenditures are split into two periods. As stated in the outline, DEVEX spanned across 4 years and are split into two categories: The Environmental Impact Assessment and Other Allowances.

3.2.2 Estimating the Revenue Stream of Aflandshage

In the case of wind farms, three factors determine revenue: production, the price of electricity and subsidies. The only factor the owners has control of (to a certain degree) is the production, as it is mainly determined by the capacity of the farm. However, the owners are still subject to limitations of the allowance which they are granted. If the owners are subject to a limit of 250 MW production, it is not an option to build a wind farm with a higher capacity. While the production is determined internally, both the price of electricity and the subsidies are determined externally. As described in section 1.3.2, the price of electricity is given by the market. The subsidies are granted by the government and are thus affected by the current political environment. It is assumed throughout this section that Aflandshage is not a part of a CPPA, as the valuation is intended to assess whether the operations is profitable on market prices only. The concept of PPAs, and its influence on Aflandshage, will be discussed in part 4.

3.2.2.1 Production

The plan for Aflandshage, regardless of the exact number of wind turbines that will be built, is for the capacity to remain the same. This is achieved by adjusting the size and the numbers of the wind turbines and thus keeping the total capacity fixed at 250 MW. A wind park with a capacity of 250 MW will produce:

$$Full\ Production = 250\ MW * 365 \frac{days}{year} * 24 \frac{hours}{day} = 2{,}190{,}000 \frac{MWh}{year}$$

However, this is only if the turbines produce at maximum capacity, which is never the case. To make the production estimate more realistic, the number above must be multiplied with a capacity factor. The capacity factor is an expression of how much of the maximum capacity of wind turbines that are generated. While it incorporates geographical elements like the wind speed, it also incorporates downtime of the turbines. Downtime can typically occur when the wind speed is either too high or low, or when the turbines need to be shut off due to service and maintenance. In figure 30, it is seen how the turbines only generate electricity in a certain interval of wind speed of 8 – 55 miles per hours:

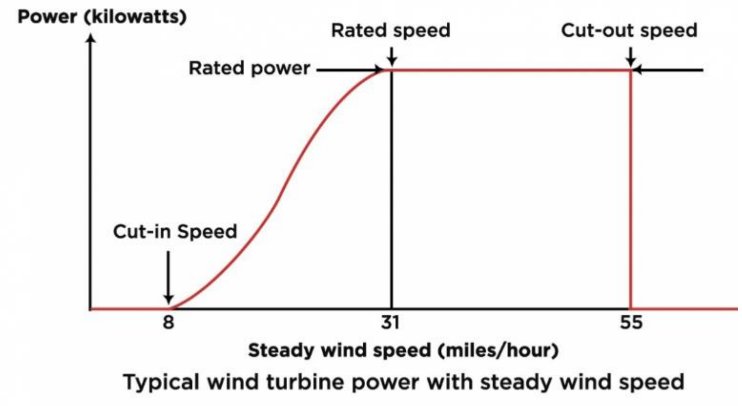

Figure 30. Source: Office of Energy Efficiency & Renewable Energy, 2017

The capacity factor captures all these elements and is the factor which must be multiplied by the maximum capacity. In table 10, estimated capacity factors for offshore wind turbines can be found:

Park	Age	Capacity Factor	Total Capacity, MW
Anholt	5.7	49%	399.6
Horns Rev 1	16.2	41.20%	160
Horns Rev 2	9.3	48%	209.3
Nysted 1	15.5	37.10%	165.6
Nysted 2	8.5	43.50%	207
Average		43.76%	
WindEurope		37%	
IEA		40%-50%	

Table 10. Own contribution. Sources: IEA, 2019

The average estimate of 43.76% is based upon actual capacity factors of the wind farms mentioned in table 10. The table only consists of Danish wind farms with a capacity of above 150 MW since these wind farms are more likely to be comparable to Aflandshage. Table 10 shows how the capacity factor has changed over the last years and displays a positive correlation between age and the capacity factor. While the average of 43.76% seem like a plausible estimate for the wind factor, WindEurope (2018) estimates an offshore capacity factor of only 37%. However, IEA (2019) finds that modern farms might have a capacity factor of up to 50%, but states this number only applies to the largest turbines available. While the capacity factor used in the calculation of the production has been determined by using wind projects of similar size, it cannot be rejected that the capacity factor also depends on other factors, which has not been accounted for.

Other, significant parameters when determining the capacity factor could be the wind speed on the site, the type of turbines, the pattern of how the wind turbines are placed, and the degree of maintenance. Based on the positive correlation between age and capacity factor, and the estimates of WindEurope (2018) and IEA (2019), a capacity factor of 50% has been chosen.

The actual production of Aflandshage will then be:

$$\text{Production} = \text{Capacity} * \text{Capacity Factor}$$

$$\text{Production} = 2{,}190{,}000{,}000 * \frac{\text{KWh}}{\text{year}} * 0{,}50 = 1{,}095{,}000 \text{ KWh}$$

Thus, the expected, average, annual production will be 1,095,000 kWh.

3.2.2.2 The Price of Electricity

The price of electricity generated by wind power is not the same as the spot price of electricity found on Nord Pool Spot, due to the need of backup from other power sources. As such, it is not possible to just use the spot price of electricity when calculating the revenue (Dansk Energi, 2019). Dansk Energi (2019) estimates the price of electricity generated by wind power will be 29 øre/KWh in 2023 and an average of 31 øre/KWh from 2020 to 2039. It is not relevant to estimate prices further than 2039, as the uncertainty will be too high for a useful estimate (Dansk Energi, 2019). In figure 31, the different estimates for the price of electricity from different power sources are shown:

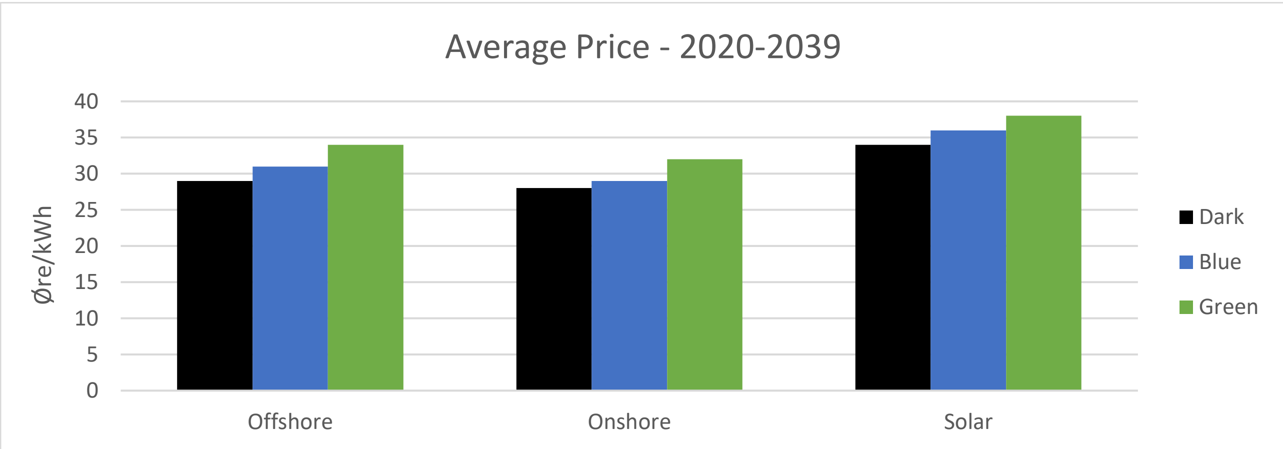

Figure 31. Own contribution. Source: Dansk Energi, 2019

The green scenario is if policies and renewable energy support rises and assumes a rapid evolution in the technology. The black scenario is if policies are made to counter renewable energy transition and shift the focus to eg. fossil fuels. The blue is an in-between-scenario and will be used as the estimate for the price, as it is a moderate estimate that does not assume significant changes to neither policies nor technology.

An estimated price of electricity generated by offshore wind power of 31 øre/KWh will be used, as it is found to be the best estimate for the operational stage of Aflandshage.

3.2.2.3 Subsidies

As discussed in section 1.3.1, there are no longer paid any subsidies for offshore projects offered through the open-door procedure. However, there are still balancing compensations granted from the government as shown in section 1.3.6. The current balancing compensation is 0.9 øre/kWh and will be added to the price. The grant only lasts for the first 20 years of the wind farm and will be removed entirely afterwards. Thus, the revenue for Aflandshage will be determined by the production, the price of electricity, and the balancing compensation.

3.2.2.4 Final Revenue and Costs

To summarize the section, a brief table is provided to give an overview of final income and costs. The following estimate are calculated on a basis of 250 MW maximum capacity and an operational stage of 25 years.

Type of Cost	EURm	% of total cost
Total CAPEX	-459.00	54%
Total OPEX	-353.06	42%
Total DEVEX	-25.38	3%
Total ABEX	-8.46	1%
Total Costs	845.92	100%
Total Revenue	1159.09	100%
Total Profit	313.17	27.02%

Table 11. Own contribution.

The numbers in table 11 are not discounting and therefore does not incorporate time value of money. It is simply meant as a quick measure to provide a brief overview at this stage. The estimates can also be expressed as figure 32, where the numbers are shown over total park life:

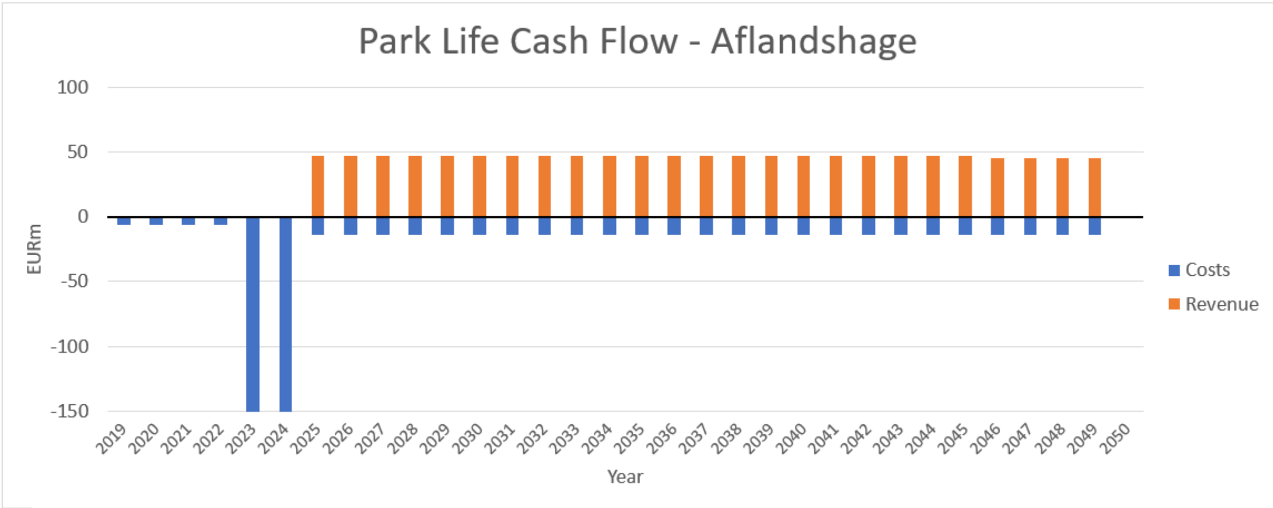

Figure 32. Own contribution.

3.2.2.5 Depreciations

As wind farms are assets with a long period of operations, their value and performance depreciate over time. Thus, the reducing balance principle can be used to depreciate the value of the wind farm over its life. Assets used for the production of either heat or electricity, with a capacity of over 1 MW, can, according to the Danish Depreciation Act §5C pt. 1 no. 4, be depreciated by a maximum of 15% of its depreciable value (The Danish Depreciation Act, 2016). The annual depreciations are hereby calculated from the initial value of the total Capital Expenditures, which were found to be 459.00 EURm.

3.2.2.6 Taxes

As Hofor Vind A/S is a Danish corporation, a tax rate of 22% is applied consistent with regulations in the Danish Corporate Tax Act's §2h, pcs. 3 (The Corporate Tax Act, 2016). The taxable income from Aflandshage's operational stage begins in 2025 and assuming no changes in the corporate tax rate, the current rate of 22% is applied.

DCF valuation often assumes that taxable income is always realized annually and is either deducted or added to the EBIT for simplicity reasons. In practice however, a deficit is deferred to later years and deducted the taxable income then cf. CTA. §12. The unrealized deferred tax asset hereafter occurs on the balance sheet for later use, due to the asset classification in the Financial Statement Act's §33 (The Financial Statement Act, 2019).

Aflandshage is expected to have a taxable income deficit through the first 6 years of operations (2025 – 2030), because of depreciations, which declines over time due to the degressive method cf. The Depreciation Act,

§5c, pcs. 4. These deficits will be utilized in the period from 2031 - 2039, as the deferred tax assets are reduced to 0. The year 2040 is therefore the first year that Aflandshages tax payments equals 22% of EBIT.

For a given year, the deferred tax asset is only 100% deductible, when the annual deficit is under 8.573 mio. DKK/1,12 mio[6]. EUR. Deficits greater than this limit is only 60% deductible each year. The remaining tax asset is deferred to later years. Appendix 4 contains the tax payments from the Aflandshage project in the DCF model.

However, the adjustment of deferring tax assets to later use is not applied to the pre-operational stages later in the real option valuation, due to simplicity. This assumption is made considering the large deficits in the construction stage would have a major effect on tax payments in the operational stage, which would distort the size of the free cash flows in the DCF valuation. It is determined that keeping the taxation separately across different models will increase the user value of both. In the ROV model a tax rate of 22% is therefore deducted every year a deficit is realized.

3.2.3 Free Cash Flows

Aflandshages free cash flows are determined with Equation 3, and table 12 provides an overview of part of the total calculated cash flows. Two of the assumptions for these calculations are that there are no changes in net working capital and no re-investment costs, as it is assumed that these are covered by OPEX. FCF are calculated as EBIT + Depreciations - Taxes, where the depreciations are added again due to no liquidity effect, but they still affect tax payments.

[6] An annual growth rate of 2,2% is added every year in The Personal Income Tax Act's §20 to follow the expected rate of inflation in the economy. However, due to prices in real term, this will not be applied in the model.

Year	2033	2034	2035
Capacity Factor	0.50	0.50	0.50
Production, kWh	1095000000.00	1095000000.00	1095000000.00
Price, cent/kWh	4.13	4.13	4.13
Balancing Compensation, cent/kWh	0.90	0.90	0.90
Costs, EURm	-14.12	-14.12	-14.12
Revenue, EURm	46.57	46.57	46.57
EBITDA, EURm	32.45	32.45	32.45
Depreciations	18.76	15.95	13.55
EBIT, EURm	13.69	16.50	18.90
Deferred taxes, start of year	-74.31	-65.27	-54.90
Possible activation, CTA §12	1.14	1.17	1.19
Activated tax assets	1.52	1.17	1.19
Deduction, 60%	7.53	9.20	10.62
Total tax deduction	9.05	10.37	11.82
Deferred taxes, end of year	-65.27	-54.90	-43.08
Deductable Income	4.64	6.13	7.08
Taxes	1.02	1.35	1.56
NOPAT	12.67	15.16	17.34
Cash Flows	2033	2034	2035
EBIT, EURm	13.69	16.50	18.90
Depreciations, EURm	18.76	15.95	13.55
Taxes, EURm	1.02	1.35	1.56
FCF, EURm	31.43	31.10	30.89

Table 12. Own contribution.

Finally, a discounting rate is needed to calculate the value of the Discounted Cash Flows, the next section will describe the considerations made regarding inflation.

3.2.3.1 Inflation

As the discounted cash flows of Aflandshage is modelled in real terms, the inflation rate has been omitted from the initial estimation of income and costs. Under normal market conditions Koller, Goedhart & Wessels (2015) is indifferent between the real or nominal prices, as they all other things equal yield identical value estimates (Koller, Goedhart & Wessels, 2015, p. 473).

Analysts must be aware that dependent on the price elasticity of demand, some industries struggle to raise prices at the same annual rate as the general rate of inflation in the economy, which over time destroys value creation. Thus, the valuation modelling should incorporate this dilutional effect in these cases (Koller, Goedhart & Wessels, 2015, p .486). However, the price elasticity of demand for electricity is inelastic, which is why the inflation concern from Koller, Goedhart & Wessels (2015) is not applicable to Aflandshage. Historically observations rather indicate the opposite (Finans, 2017).

In the time period after the liberalization of the Danish electricity market in 2003, prices of electricity outgrew the inflation rate in the period of 2009 – 2017 (Finans, 2017). However, adjusting to more mature market conditions today, the price of elasticity is assumed to follow the general inflation rate during Aflandshage's operational stage. The real term cash flows should consequently not generate a skewed valuation estimate, and accordingly, Aflandshages WACC and free cash flows is not adjusted for inflation.

3.2.4 Estimating the Weighted Average Cost of Capital

To calculate the value of Aflandshage Wind Farm using a DCF model, the weighted average cost of capital must be determined first. The calculation of the WACC includes several parameters, which all significantly impact the final value, as they all affect the WACC in either a positive or negative direction. The calculation for WACC is previously stated as:

$$\mathrm{WACC} = \frac{\mathrm{E}}{\mathrm{V}} * \mathrm{r_E} + \frac{\mathrm{D}}{\mathrm{V}} * \mathrm{r_D} * (1 - \mathrm{t})$$

In the calculations for r_E and r_D, there are several other parameters which was outlined in section 2.1. These parameters will be estimated in the following section, using the specific numbers for Aflandshage. First though, the project specific capital structure must be outlined.

3.2.4.1 Capital Structure for Aflandshage

The optimal method of estimating the capital structure, would be to get the estimate directly from HOFOR. However, as discussed in the delimitation, this has not been possible, and thus, other approaches must be considered, eg. estimating the capital structure based upon average capital structures of similar projects. WindEurope (2018) estimates that the average capital structure for wind farms is between 70-80% debt and 20-30% equity, while PensionDanmark (Interview, 1st of May, 2020) estimates that the average capital structure of projects associated to them are between 60% debt and 40% equity. A moderate estimate between these two sources are concluded to be close to the actual capital structure, and thus a capital structure of 65% debt and 35% equity is chosen in this analysis.

3.2.4.2 Estimating Beta for the Aflandshage wind farm

As described in section 2.1.1.6, a project's beta is usually determined by using one of three methods. Since the Aflandshage wind farm project is developed by Hofor Vind, which share capital is not publicly listed, Equation 7 is not applicable. However, it is still an option to estimate the industry beta by calculating beta equity of the wind sector and un-levering the industry mean. The method, which is suggested by Koller, Goedhart & Wessels (2015), Petersen, Plenborg & Kinserdal (2017) and Brealey et al. (2014), assumes that the industry beta is stable across all companies, as they are exposed to identical operating risks. Furthermore, this assumes that the beta asset of a company's projects is identical to the industry beta (Koller et al., 2015, p. 300). By making this assumption, observed differences in the beta of two companies with identical operations, must be due to differences in capital structure and hereby financial risks.

In the calculations, which is specified in Appendix 5 and 6, beta debt is assumed fixed at 0.3, which is consistent with Koller, Goedhart & Wessels (2015), Petersen, Plenborg & Kinserdal (2017) and Brealey et al. (2014). The assumption is derived from a study by Groh & Gottschalg (2011), which found that 'Baa' (Moodys) rated debt equals a beta debt value of 0.3 on average across the S&P 500 (Groh & Gottsschalg, 2011, p. 2019). As 7 of 8 companies in the peer group has a Baa credit rating, this assumption is deemed applicable.

To estimate beta of Aflandshage Wind Farm through the beta of the industry, the 5-step model described in section 2.1.1.6.1 will be used. As even quantitative beta estimations are subject to a significant degree of subjectivity in its assumptions, the estimates will be compared to a qualitative analysis of Aflandshages beta, based on internal, external macro, external industries, and financial factors as a sanity check.

3.2.4.2.1 Estimating Beta from the peer group

When applying the relative valuation approach, defining a projects peer group is exposed to subjective assumptions of comparability and even relevant companies might be omitted due to lack of available data. Hofor A/S is a utility company which primarily focuses on supplying the greater Copenhagen area with drinking water and energy from various sources. Wind energy is only a part of the Hofor Groups operations, and the wind entity has been organized in the subsidiary, Hofor Vind (Hofor, nd). The peer group has therefore been assembled based on the characteristics of Hofor Vind rather than the consolidated group.

When gathering the peer group, several companies have been omitted in this process due to significant revenue streams from oil and gas or other activities, which is considerably different to the renewable energy sector. The peer group consists of eight major European companies, which all have wind/renewable energy development and operation as one of its main business areas. All eight companies are publicly listed on European stock exchanges. The raw data has been retrieved from Investing's (2020) equity database.

Name	Country	Currency	Revenue in mio.	Interest bearing debt	Market value of equity	D/E Ratio	Beta Equity	Beta Assets
Ørsted		DKK	67828	49130	289370	0,17	0,55	0,47
innogy		EUR	35434	19433	24778	0,78	-0,14	-0,08
RWE		EUR	13125	5734	16783	0,34	1,12	0,84
e.on		EUR	41484	36937	21829	1,69	0,95	0,35
edp renewables		EUR	1824	3417	9159	0,37	0,64	0,46
IBERDROLA		EUR	36437	45076	58404	0,77	0,46	0,26
enel Green Power		EUR	7730	65821	61407	1,07	0,6	0,29
ENGIE		EUR	60058	54120	34120	1,59	0,85	0,33
Total Peer Group						0,60	0,74	0,61

Table 13: The peer group. Own contribution.

Since the peer group only consists of European enterprises with most of its operations located within EU, Koller, Goedhart & Wessels (2015) recommends using a regional index as a proxy for the true market index

(Koller, Goedhart & Wessels 2015, p. 298). The returns of local stock exchanges returns are often not well diversified, and thus not able to capture a precise beta estimate of a stock from a regional or global business (Koller et al., 2015, p. 298). Local market indexes also tempt to be heavily affected by single industries, which makes the beta estimate biased towards certain sectors rather than the general market index. To examine the stock returns of the peer group relative to the market returns, the value weighted MSCI Europe Index has been chosen. The index captures 438 mid- and large cap stocks across 15 developed European countries, which represents about 85% of the total market capitalization value in these countries (MSCI, 2020). Koller, Goedhart & Wessels (2015) suggest using monthly returns over a 5-year period when regressing a stock's returns against the market index, since more frequent intervals might lead to systematic biased estimates, due to lack of transactions in smaller markets.

By regressing every company's returns against the monthly MSCI Europe Index for 5 years, the average beta equity of the peer group is estimated to 0.74 (Appendix 6), which is less volatile than the returns of the market index, and thus exposed to less systematic risks. While the development process of wind farms is often bureaucratic and uncertain, the general renewable electric utility sector can be observed as a less volatile investment than the market index.

To un-lever the equity beta, and find the industry estimate, the average debt-to-equity ratio of the industry must be established. This ratio is derived from the net interest-bearing debt (NIBL) and the market capitalization value. NIBL and the market value of equity is defined as:

$$\text{NIBL} = \text{Financial liabilities} - \text{financial assets}$$
$$\text{Market value of equity} = \text{Number of outstanding shares} * \text{stock price}$$

To estimate the net interest-bearing debt (NIBL), the balance sheets for each of the companies have been reclassified into either operational (non-interest-bearing) or financial posts (interest-bearing) instead of the traditional non-current/current balance sheet presentation. The residual between the interest-bearing debt and the financial assets (cash, securities, current financial assets etc.) is the net interest-bearing debt (NIBL). The market value of equity is defined as the market capitalization value of the number of outstanding shares times the price of the stock on the balance sheet date. These are specified in appendix 6. By applying Equation 8, the unlevered beta average is estimated to 0.61, which is the unlevered estimate for Aflandshages beta (Koller, Goedhart & Wessels, 2015, p. 300).

$$\text{B}_\text{A} = \frac{0.74 + 0.3 * \frac{\text{NIBL}}{\text{Equity}}}{1 + \frac{\text{NIBL}}{\text{Equity}}} = \mathbf{0.61}$$

The industry beta is found to be consistent with Damodaran's (2020b) analysis of 22 European Green & Renewable companies which found an unlevered beta of 0.57. Koller, Goedhart & Wessels (2015) suggest that the unlevered beta of electric utility companies is in the range between 0.5 and 0.7 (Koller, Goedhart & Wessels 2015, p. 303). Furthermore, PensionDanmark applies a beta asset of 0,5 for equity financed wind farms, which is close to the 0.61 estimate (Interview, May 1st, 2020).

Koller, Goedhart & Wessels suggest applying Blume's smoothing adjustment to the raw estimate as betas are found to revert towards a mean of 1 over time. Since the windfarm investment is considered a long-term investment, the raw beta will be examined with the Equation applied by Bloomberg.com:

$$\text{Adjusted Beta} = \left(\frac{1}{3}\right) + \left(\frac{2}{3}\right) * \text{Raw Beta}_{\text{equity}} = 0.83$$

Equation 19: Beta Smoothing. Source: Koller, Goedhart & Wessels (2015)

Thus, the adjusted beta equity for the wind industry would be 0.83. However, before applying Blume's beta relation, the rolling beta trend for the peer group is analyzed, as industry risks change over time.

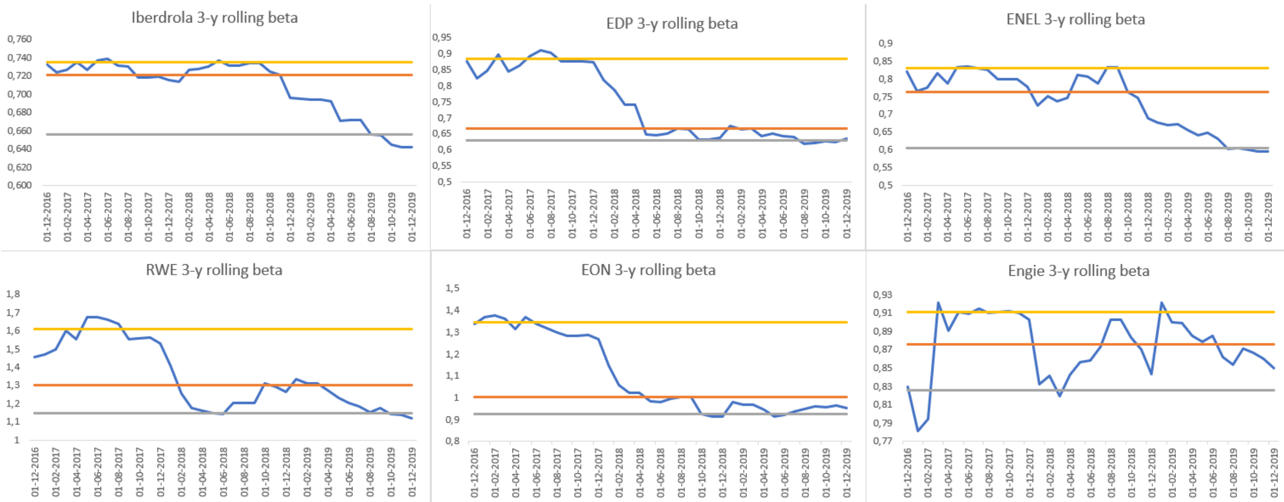

Figure 32: Rolling beta for peer group. Own contribution.

When observing the peer groups rolling beta over a 3-year period, an overall negative trendline is observed, and only RWE Group's beta seems to be moving towards 1. Therefore, the beta of Aflandshage should not be adjusted through Blume's beta relation (Equation 19), as the overall development initially seems to indicate the opposite scenario. Based on previous findings, the trend is consistent with the stable demand for electricity, which should be uncorrelated with the market index. The industry life cycle analysis also found the industry moving towards the maturity stage, which is consistent with the rolling beta trend. Thus, the industry beta for wind farm developers is estimated to an initial raw value of 0.61. When adjusting the industry beta with Aflandshage's capital structure, β_E is determined with Equation 9 to:

$$\beta_E = \beta_A + (\beta_A - \beta_D) * \frac{\text{NIBL}}{\text{Equity}}$$

$$\beta_E = 0.61 + (0.61 - 0.3) * \frac{0.65}{0.35} = \mathbf{1.18}$$

Regardless of which method is applied, estimating the beta is more 'art than science'. When regressing the returns, the average R-squared value is only 0.16 across the 8 companies with an average standard error of 0.06 (Appendix 5 and 6). Koller, Goedhart & Wessels (2015) suggest using two standard errors at the upper and lower boundaries in a confidence interval which realistically would allow the beta equity estimate to fluctuate between 0.62 and 0.86. These estimations are under the assumption that the peer group indeed is comparable, even though their business areas are somehow diversified. As a sanity-check the estimate is compared to a quantitative beta analysis from fundamental factors.

3.2.4.2.2 Estimating beta from fundamental factors

To make the estimate more substantial, and to support the findings from the peer group, a qualitative analysis of the Aflandshages beta value will be conducted. The analysis will take root in the findings of the industry analysis, and mainly focus on the risks identified in section 1. PwC (2010) states that 90% of the correspondents of their analysis used external sources to estimate beta values, and that these sources were supported by the common-sense method. The qualitative analysis of the beta will draw upon the method of the MASCOFLAPEC model (Fernandez, 2009).

Weight	MASCOFLAPEC Risk Category	Low 1	Average 2	Substantial 3	High 4	Very high 5	Weighted Risk
5%	Management		2				0.1
15%	Assets: Business / Industry / Products			3			0.45
5%	Strategy		2				0.1
10%	Country risk	1					0.1
10%	Operational leverage				4		0.4
10%	Financial leverage				4		0.4
10%	Liquidity of investment			3			0.3
10%	Access to sources of funds		2				0.2
10%	Partners	1					0.1
5%	Exposure to other risks	1					0.05
10%	Cash flow stability				4		0.4
100%	Beta						**1.3**

Table 14. Own contribution.

As seen from table 14, the final equity beta is estimated to be 1.3. The analysis of table 14 builds upon the analysis of the industry and of HOFOR. For this analysis, the factors which impact beta the most, are the industry, operational leverage, financial leverage, liquidity of investment and cash flow stability. The industry analysis identified several risks regarding both the PESTEL and the life stage analysis, which all impacts the value of Aflandshage. As the analysis significant risks associated to the current transition between growth and maturity and that elements such as politics and subsidies, all impacted the profitability of the industry, a risk factor of 3 is assigned to the qualitative beta equity. The risk assigned to operational leverage ranks high, as the majority Aflandshages cost are fixed (DEVEX and CAPEX), which means these costs are unavoidable and high regardless of the revenue stream after construction.

As Aflandshage capital structure was estimated to be 65% debt and 35% equity, a high-risk factor was assigned due to the higher chance of financial distress, resulting in the factor for financial leverage being 4. These factors also impact the beta equity, as they make the investment riskier, and thus, both the liquidity of the investment and the cash flow stability, are assigned a factor of 4. While the beta of 1.3 points towards the investment being riskier than the market, several factors also contribute to making the investment safer. Especially the partners and the sources of funding are safe, which was further underlined by AIP Management, who stated that it was easy to find stable investment partners. However, the risk factor of the access to funds are 2, because most of the investors were only willing to invest in the project after the construction stage, when most of the uncertainty was removed (Interview, May 6th, 2020).

The result from the fundamental beta analysis of 1.3 is in the range of the quantitative estimate found in section 3.2.4.2.1. While common sense analysis is an effective tool for comparison, the method is related to a high degree of subjectivity, and thus the estimate of 1.18 will be applied.

3.2.4.3 The Risk-Free Rate

Both Koller, Goedhart & Wessels (2015) and Petersen, Plenborg & Kinserdal (2017) suggest applying a 10-year government bond as a proxy for the risk-free interest rate. Since Aflandshage will be operated on Danish territory and developed by a Danish enterprise, the local government bond should also be chosen in order to match the currency of the project's cash flows. The choice of a local bond is to counter the inflation issue (Petersen, Plenborg & Kinserdal, 2017, p. 346)[7]. Preferably, an analyst wants to match the duration of the bond with the duration of the project[8], but due to a lack of liquidity in the 30-year government bond, Koller, Goedhart & Wessels (2015) suggest applying the 10-year bond as an alternative to avoid the pricing issue. Analysts can either apply a historical average or the current rate. Figure 33 illustrates the development in the p.a. interest rate for a 10-year Danish government bond over the last 20 years, which overall shows a significantly decreasing trend:

[7] Important factor in this issue when applying cash flows are in real terms
[8] This is also the theoretical base for AIP Management (Interview, May 6th, 2020)

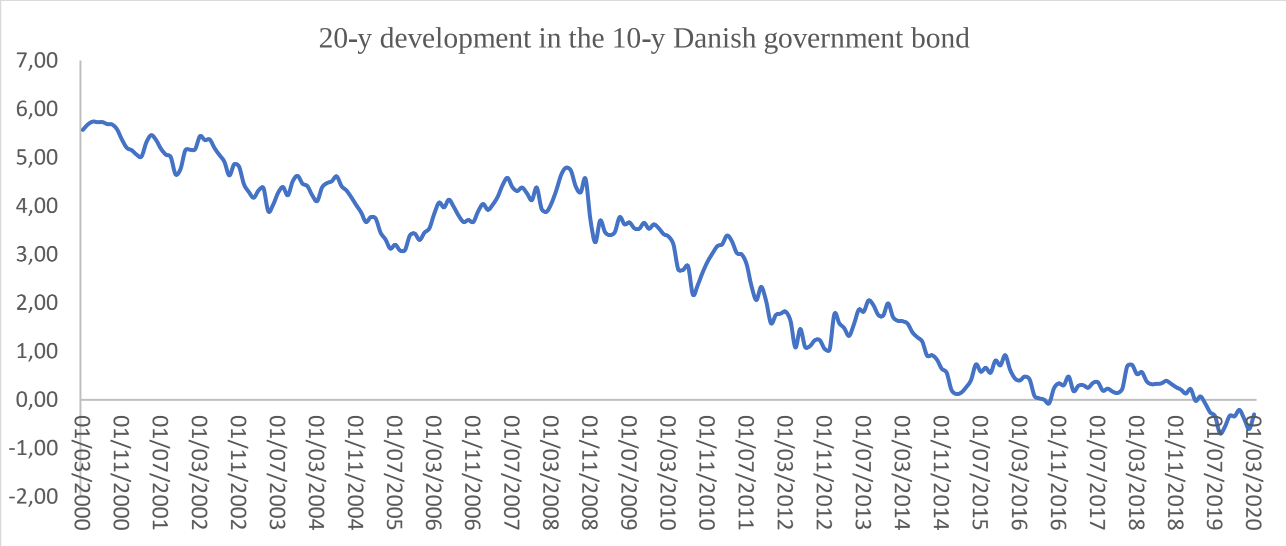

Figure 33. 20-year development in 10-year Danish government bonds interest rate. Source: Danmarks Statistik, 2020

The average interest rate of the bond over the last 20 years is 2.67% based on monthly data plots. This estimate is consistent with Petersen, Plenborg & Petersen (2017) who suggest that analysts in periods of low interest rates, analysts should consider applying a 20-year observation period instead of 10 (Petersen, Plenborg & Kinserdal, 2017, p. 366). However, the long historical time horizon is more relevant to valuations of companies, where the terminal period is a perpetuity.

The risk-free interest rate of the Aflandshage wind farm should rather represent the current interest rate, which is -0,30%. When asking PensionDanmark about the issue, they agree with applying a recent estimate for the risk-free interest rate, but due to an observation of lagged reactions to interest changes among investors, PensionDanmark still suggest applying a 3-year historical average. The 3-year average of a Danish government bond is 0.10%, which will be applied.

Considering the AAA rating (Moody's) of Danish treasury bonds, there will not be added a specific country premium to the risk-free interest rate estimate.

3.2.4.4 The Market Risk Premium

When valuating companies, the market risk premium should incorporate historical observations, as the valuation horizon is significantly different compared to projects with a fixed time frame. However, the risk premium for Aflandshage wind farm should reflect the current rating amongst market participants, as the investment case is valuated of today. The 2019 survey by Fernandez (2019) is the most relevant estimate, as previous analysis of the subject from Parum (2000), Holm et al., (2005) and PwC (2016) are historically relevant but outdated.

Fernandez (2019) follows the survey method in section 2.1.1.5 and the results are based on the answers of 135 participants. It is the latest answer of **6%** which is relevant.

However, it needs to be mentioned that applying **6%** as the risk premium is exposed to uncertainty, which ultimately leads back to the issues regarding the Capital Asset Pricing Model (CAPM) .The CAPM is a theoretical relation between risk and reward, and while the premise is sensible, the model does not provide a practical guideline for how to estimate its components. As the market risk premium, like beta, is more art than science, practitioners will inevitably find different conclusions and methodologies.

There are strengths and weaknesses to each method from section 2.1.1.5. Estimating the market risk premium from investors' own subjective approximations, does not necessarily involve theoretically correct methods and the variance of the survey-answers is potentially significant. The ex-post method strongly relies on the assumption, that past observations are the most precise variable to forecast future risk premiums, which is not necessarily a realistic assumption (PwC, 2016, p.5). Lastly, trying to forecast future rates are, like any forecasting process, surrounded by a significant degree of uncertainty in its assumptions. A quantitative forecasting model can be exposed to lack of explanatory power or omitted variable bias, while qualitative forecast might turn out inconclusive.

Based on the discussion and findings of this section, the most recent estimate of **6%** by Fernandez (2019) is still applied as a proxy for the market risk premium, as the survey is the most recent and therefore relevant estimation of Danish market participants expected risk premium. The spread of the answers is also small in Denmark, compared to most other countries in survey which support applying the mean.

3.2.4.5 The Cost of Debt

With the risk-free interest rate already determined, the project specific premium needs to be identified in order to calculate R_D with Equation 5:

$$R_D = (R_F + R_S) * (1 - t).$$

Since there is no public recording of Hofor Vind's credit rating, it is not possible to add a specific premium for the company through its PD-score[9]. Hofor Vind, a part of the Hofor A/S group, is owned by several Danish municipalities in the greater Copenhagen Area (Hofor, nd), evidently the credit rating must include the ownership structure, which significantly decreases the probability of default. Danish municipalities are primarily financed by KommuneKredit (AAA rated credit institution by both Moodys and S&P), which main purpose is providing cheap and stable funding for Danish government branches and municipalities

[9] Probability of Default (PD)

(KommuneKredit, 2019, p. 2). Aflandshage should therefore have better access to funding sources, than the latest financial report might indicate, if the key ratios where analyzed. Given the ownership structure of Hofor Vind and the general country risk, the probability of default is assessed to be very low. Thus, there will be added no specific premium above the current interest rates of Danish mortgages loans.

Hofor Vind A/S has financed its wind farm with mortgage-loans, as an individual windmill can be registered under an individual cadastral number. Ceteris paribus, this reduces the cost of debt for Hofor Vind, as financial expenses related to mortgages loans are lower than bank loans. To match the 10-year time horizon from the risk-free interest rate estimation, the characteristics of a 10-year mortgage loans is found as:

ISIN	RENTE	RENTELOFT	EFFEKTIV RENTE	UDLØB	TILBUDSKURS	AKTUEL KURS
LØBETID: 10 ÅR						
DK0009525164	-0,50%	-	-	okt. 2030	95,72	↑ 95,90

Table 15: Daily pricing of a 10-year bond. Source: Nykredit A/S, 2020

The effective interest rate of this bond is -0,32%,[10] and by adding a contribution margin/lending margin[11] for Danish mortgages loans of 1% the total cost of debt pre-tax for Hofors Aflandshage wind farm project is equal to 0.68%. After taxes, the cost of debt, including the risk-free interest rate, is:

$$\mathrm{R_D} = (-0.32\% + 1\%) * (1 - 22\%) = \mathbf{0.5304}\%$$

From a historical point of view, the cost of debt is currently exceptionally low (graph 33). Due to the current global COVID-19 pandemic, WindEurope (2020) finds it very unlikely that central banks will increase the interest rate in the short run, as higher interest rates usually are applied in times of high economic growth to counter inflation. As borrowing costs are low, it presents a good opportunity for long term investments in wind or other renewable energy sources (WindEurope, 2020, p. 44).

3.2.4.6 The Illiquidity Risk Premium

As Wind farm investments are long term investments, it is recommended by PensionDanmark to add an illiquidity risk premium to the WACC, to adjust for investors having to tie up capital for a long period of time (Willies Towers Watson, 2016, p. 3). In consistency with PensionDanmark, the Willies Towers Watson (WTW)

[10] Excels iteration methods is applied to goal seek the effective interest rate of the future payments.
[11] Bidragssats: A Danish margin for mortgage loans. The 1% is an estimate based on the margin for normal real estate loans. The rate is assumed to be a reasonable proxy for the wind farm contribution margin.

Illiquidity Risk Premium-model (IRP) will be applied. Firstly, WTW defines the concept of illiquidity as the opposite of liquidity, which is defined as:

1) The ability to trade in sufficient volume,
2) Without negatively impacting price
3) All with some level of confidence

(Willies Towers Watson, 2016, p. 3)

If the three accumulated conditions are not met, it is recommended to add a premium to the applied discount rate, as investors are exposed to a reduced degree of investment flexibility. The size of the premium depends on 1) investors' utility function 2) the level of illiquidity and 3) the volatility of the underlying asset (Willies Towers Watson, 2016, p. 3). Under the assumption of an average utility function, the IRP is determined with the following matrix:

Estimate of average required IRP		Asset cash flow volatility	
		Low	High
Level of illiquidity	Low	Lowest: 50-100 bps	Higher: 100-150 bps
	High	Higher: 100-150 bps	Highest: 150-250 bps +

Table 16: The IRP matrix. Source: Willies Towers Watson, 2016

The volatility of Aflandshage's cash flows has already been analyzed in the PESTEL and was established as high due to fluctuations in the price of electricity. This was a dominant reason for applying the real option valuation, as suggested by Mendez, Goyanes & Lamothe (2005). The level of illiquidity depends on which stage of development the wind farm currently is at. After gaining a construction permission, the degree of risk is significantly lower, as almost every wind farm is completed after construction begins, and thus easier to sell (interview, May 1st, 2020). AIP Managements estimates a sales process of up to 6 months for operational wind farms (Interview, May 6th, 2020). Aflandshage is still currently in the early stages of development and the level of illiquidity should still be valuated as medium-high. Assuming a medium-high level of illiquidity, but a high degree of volatility, the average required IRP is estimated to **2%**, in consistency with Pension Denmark, which apply an IRP in the interval of 0 – 2% (interview, May 1st, 2020).

3.2.4.7 Conclusion on Aflandshages Weighted Average Cost of Capital

As previously described, WACC was found using:

$$\mathrm{WACC} = \frac{\mathrm{E}}{\mathrm{V}} * \mathrm{r_E} + \frac{\mathrm{D}}{\mathrm{V}} * \mathrm{r_D} * (1 - \mathrm{t})$$

Using the numbers found in this section, and the conclusion of including an IRP, the final WACC for the project of Aflandshage can be found:

$$\mathrm{WACC} = \frac{\mathrm{E}}{\mathrm{V}} * \mathrm{r_E} + \frac{\mathrm{D}}{\mathrm{V}} * \mathrm{r_D} * (1 - \mathrm{t}) + \mathrm{IRP}$$

$$\mathrm{WACC} = 0.35 * 7.18\% + 0.65 * 0.36\% * (1 - 0.22) + 2\% = \mathbf{4.70}\%$$

Thus, a final WACC of 4.70%.

3.2.5 The Discounted Cash Flow Value

Using the WACC calculated in the section 3.2.4, and the FCF that was found in section 3.2.3, it is now possible to estimate the total DCF value. The model applied is:

$$\mathrm{DCF_0} = \sum_{n=i}^{i=1} \frac{\mathrm{PV_t}}{(1 + \mathrm{WACC})^{\mathrm{t}}} = \mathbf{347.28\ EURm}.$$

In Appendix 7, the total model can be found. Using this method, with all the estimates found in section 4, the DCF value of the operational stage of Aflandshage is 347.28 EURm.

3.3 Levelized Cost of Energy for Aflandshage

As described in Section 2.2.2, the Levelized Cost of Energy is a tool often used in practice to compare different sources of energy. While it provides an estimate of the how cost-efficient a power source is, it is not a valuation tool, but rather an alternative multiple analysis. As multiples are often used to comparing different companies in peer groups, the LCOE model will here be used to compare the cost efficiency of Aflandshage to other power sources. Figure 34 shows the LCOE of different power sources:

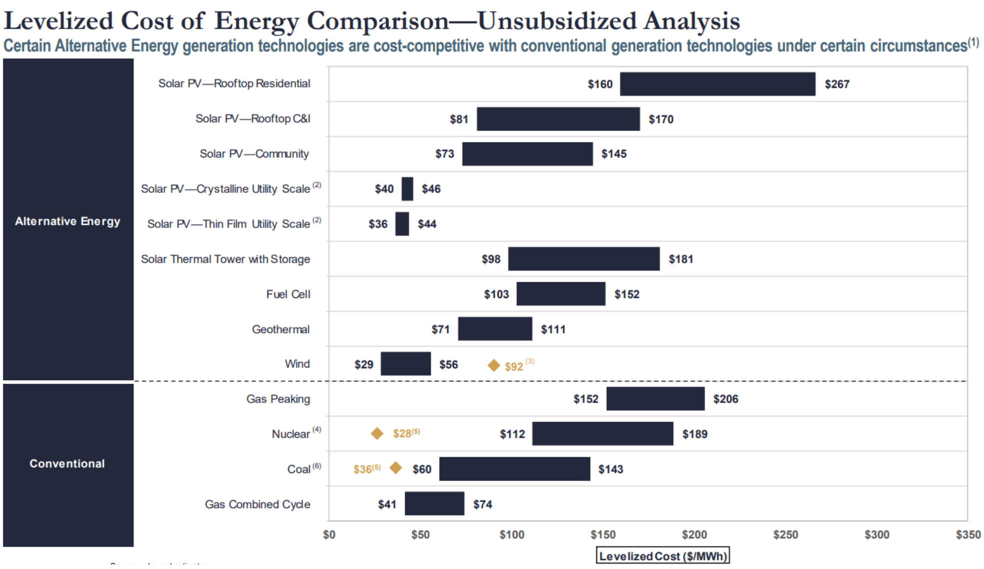

Figure 34. Source: Lazard, 2018

As seen from figure 34, the highest Levelized Cost is for Photo-Voltaic solar panels, installed on residential rooftops, while the lowest levelized cost is for wind. However, the yellow dot in figure 34 is the midpoint of the LCOE for offshore wind power, indicating that offshore wind is still more expensive than onshore wind. However, BloombergNEF (2019) finds that the LCOE of offshore has decreased significantly over the past years, whereas onshore wind has less of a reduction. To compare the LCOE of Aflandshage, Equation 12 is applied:

$$\mathrm{LCOE} = \frac{\text{Present value of cost}}{\text{Present value of production}} \rightarrow$$

$$\mathrm{LCOE}_{\mathrm{Aflandshage}} = \frac{474.58\mathrm{EURm}}{12{,}652{,}243.82\mathrm{MWh}} = 37.51\frac{\mathrm{EUR}}{\mathrm{MWh}} = 40.57\frac{\mathrm{USD}}{\mathrm{MWh}}$$

Compared to both the findings of figure 34 and BloombergNEF (2019), the LCOE of Aflandshage is significantly lower. Even compared to Danish offshore wind, the LCOE of Aflandshage is slightly lower, as the average LCOE among operating Danish offshore wind farms is 46 EUR/MWh (IEEFA, 2018).

3.4 Real Option Valuation

As previously discussed, there are several different types of options to choose from when valuing a wind farm. The two most important real options for a wind park were found to be the compound option and the option to abandon. Especially, the compound option is relevant for these types of projects, as it incorporates different stages of the development phase, which can be used to build a model in which it is possible to create multiple exercise points. As such, the compound option enables the valuation of a wind farm, to include the option to exercise at different stages. Furthermore, it is also possible to take the profitability of other stages into account as the option moves along. This means, that to move on to stage two, the first option must be exercised and so on. As different parameters, eg. the price of electricity change over time it is also possible to estimate when to exercise or not, given the path in the binomial grid. Thus, it grants the developers the right not to exercise in scenarios where the value of the option is 0, which happens when the costs related to continuing to the next stage is higher than the expected value of the farm.

The option to defer the project could have been relevant, but due to the characteristics of the Environmental Impact Assessment, this is not a possibility (as the assessment must be completed during a given time period). The permits from the DEA also has a fixed capacity limit, which is why the option to expand is not relevant either.

To estimate the value using a Real Option Model, the following parameters must be found:

- Time periods for the option
- The risk-free rate

- Exercise prices
- The probability of success in each stage
- The value of the underlying asset
- The volatility of the underlying asset

3.4.1 Time to Maturity for the Option

There are several distinct characteristics of the real option model regarding the time periods used for calculating the value of Aflandshage. First, there are several stages in where the project can be abandoned, and each stage is dependent on success in the previous stage. The four stages of costs have previously been described as, DEVEX, CAPEX, OPEX and ABEX, with the important feature that the revenue is only generated in the stage of OPEX. Regarding the real option model, it is important to distinguish each stage from one another, as it impacts the points time where exercising the compound option is possible. The stage of DEVEX will be split into two periods, as it is possible to stop the project after the initial assessments. Resultingly, the option will have three points from which it is possible to exercise; before the first period of DEVEX, between the first and second part of DEVEX, and before CAPEX. These points in time follows the structure of the 4 stages described in section 1.2. The total time periods for the option will be 4 years, or 8 semi-annual periods.

DEVEX				CAPEX		OPEX / ABEX	
2019	2020	2021	2022	2023	2024	2025	2050
Environmental Impact Assesment Finished Ultimo 2020		Other allowances Finished Ultimo 2022		Construction Finished Ulti 2024		Operational Phase Finished Ultimo 2049	

Table 17. Own contribution. Source: HOFOR A/S, 2019a

The reason for using semi-annually periods, is to bring more paths into the binomial model. More paths result in a more precise estimate, as more scenarios are simulated. However, adding more periods, also have a negative impact, as the model will become significantly more complex and unpresentable. Using semi-annually periods was deemed to give a precise answer, whilst not making the model overly complex.

3.4.2 The Probabilities of Success

The probability for success in each stage is used for calculating the ENPV and concerns the likelihood of the operator choosing to enter the next stage. This estimation is very complex, as many elements enter the equation, and as each wind farm is different, the probabilities vary widely between projects. However, Mendez, Goyanes & Lamothe (2009) has researched in the area and estimates the probability of entering the first stage of development to 72%, and 60% for entering into the next stage, and finally 40% chance of entering into the construction of the wind farm. The main difference between the project valuated by Mendez, Goyanes & Lamothe (2009) is that their case study is a farm located in Spain. This means that different risks are present when considering the probabilities of success in each stage. The main difference in risk difference across countries can be seen in table 18:

Table 2: Top-3 ranked risk categories per EU Member State

Member State	Rank 1	Rank 2	Rank 3
Austria	Grid access	Market & regulatory	Administrative
Belgium	Administrative	Grid access	Sudden policy change
Bulgaria	Policy design	Sudden policy change	Grid access
Croatia	-	-	-
Cyprus	Financing	Administrative	Policy design
Czech Republic	Sudden policy change	Policy design	Grid access
Denmark	Policy design	Social acceptance	Market & regulatory
Estonia	Administrative	Policy design	Technical & management
Finland	Administrative	Grid access	Policy design
France	Market & regulatory	Policy design	Social acceptance
Germany	Policy design	Technical & management	Administrative
Greece	Policy design	Financing	Social acceptance
Hungary	Policy design	Sudden policy change	Grid access
Ireland	-	-	-
Italy	Administrative	Policy design	Grid access
Latvia	Technical & management	Financing	Sudden policy change
Lithuania	Policy design	Social acceptance	Technical & management
Luxembourg	Policy design*	Administrative*	-
Malta	Administrative*	Policy design*	-
Netherlands	Policy design	Administrative	Social acceptance
Poland	Social acceptance	Policy design	Administrative
Portugal	Market & regulatory	Policy design	Financing
Romania	Policy design	Financing	Grid access
Slovakia	Grid access	Policy design	Sudden policy change
Slovenia	Administrative	Sudden policy change	Market & regulatory
Spain	Policy design	Sudden policy change	Market & regulatory
Sweden	Market & regulatory	Policy design	Social acceptance
UK	Administrative	Policy design	Grid access

* based on model results

Table 18. Source: Noothout et al., 2016

The most significant difference between Denmark and Spain is that social acceptance weighs higher in Denmark. Social acceptance is more likely to cause trouble soon in development, as the limit for neighbor complaints ends during the development phase. Resultingly, the estimated probabilities of success will be lower in the beginning for a Danish project. Furthermore, the Danish market is less likely to be impacted by sudden policy changes, which could impact the project at any given time in the development stage. Finally, the last conditional probability is assumed to be the same between Denmark and Spain, as they are both categorized as mature markets (Noothout et al., 2016). These considerations and arguments amount to the following probabilities of success:

Stage	Probability of succes	Conditional probability
Stage 1 - IEA	40.00%	40.00%
Stage 2 - Other Allowanc	60.00%	24.00%
Final Investment Decisior	72.00%	17.28%
Stage 3: Construction	100.00%	17.28%

Table 19. Own contribution. Source: Mendez, Goyanes & Lamothe, 2009; Noothout et al., 2016

It is assumed that when construction has begun, the project is not going to be cancelled, which is also emphasized by the interview with PensionDanmark (Interview, May 1st, 2020).

3.4.3 The Risk-Free Rate

The risk-free rate was discussed section 3.2.4.3 and estimated to be 0.1% p.a. This rate will be converted to the semi-annual rate during the following calculations.

3.4.4 Exercise Prices

The exercise prices for Real Option models are the costs that relate to entering the next stage of the project. As mentioned previously, there are specific costs related to each stage, and these costs make up the exercise price, as it is the price that must be paid to enter the next stage. Entering each stage is equal to exercising the option at the given time, but as there are only a certain likelihood of entering the next stage, the exercise price must be the probability adjusted costs. Using the probabilities found in the previous section and the costs estimated in section 3.2.1, the following probability adjusted costs are found:

ENPV	Accumulated Probability	Probability of Success	Cash Flows	Present Value	Probability Adjusted Present Value
Fase 1	1.00	0.40	-9.90	-9.90	-9.90
Fase 2	0.40	0.60	-9.90	-9.03	-3.61
FID	0.24	0.72	0.00	0.00	0.00
Fase 3	0.17	1.00	-358.02	-297.99	-51.49

Table 20. Own contribution.

The present value of the probability adjusted costs are calculated as the expected costs times the accumulated probability of the costs and discounted back using the Weighted Average Cost of Capital. These probabilities adjusted costs are used as the exercise prices, eg. a price of 9.90 EURm will be paid to enter the first stage of the option.

3.4.5 The Value of the Underlying Asset – The Expected Net Present Value

Typically, the value of the underlying asset would be a stock or a derivative but since the valuation is of a project, there is no direct definition of an underlying asset. It is assumed that it is impossible to find a project which perfectly mirrors the project of Aflandshage, due to the significant differences between wind farms. Furthermore, the underlying asset is often an asset which is traded on capital market, but since that is not possible to obtain for Aflandshage, the value of the DCF model is used as a proxy. However, the value found in the Discounted Cash Flow model is not taking the probabilities of success into account.

To account for the probability of the project not being finalized, the Expected Net Present Value for the operational stage is used as the value for the underlying asset. The probability adjusted value is found using the estimated probabilities of success previously calculated. The model and value will then be:

ENPV	Accumulated Probability	Probability of Success	Cash Flows	Present Value	Probability Adjusted Present Value
Fase 1	1.00	0.40	-9.90	-9.90	-9.90
Fase 2	0.40	0.60	-9.90	-9.03	-3.61
FID	0.24	0.72	0.00	0.00	0.00
Fase 3	0.17	1.00	-358.02	-297.99	-51.49
Disc. CF				344.06	49.48
ENPV					-15.52

Table 21. Own contribution.

Where the probability adjusted present value has been calculated as (Willigers & Hansen, 2008):

$$ENPV = \sum(p_{Stage} * PV_{Stage})$$

Where p_{stage} is the conditional probability of reaching a given state, and PV_{stage} is the present value of the FCFF in each stage. Furthermore, the costs of stage 1, 2 and 3 and the cash flows from operation have been discounted using the Weighted Average Cost of Capital.

As positive cash flows are not realized until construction is done, the value of the underlying asset is calculated as the final conditional probability times the DCF value of the operational phase. Based on the estimations in the ENPV model, the initial value of the underlying asset will be **49.48 EURm**. Note that the final value of the ENPV model has also been estimated to -**15.52 EURm.**

3.4.6 The Volatility of the Underlying Asset

As the conclusion of the industry analysis found significant risks and fluctuations regarding both price and production, the final volatility of the revenue must be found to incorporate these. While the project-specific risks mainly are regarding costs and the probabilities of success, the industry specific risks mainly concern the issue of price of electricity. This last issue will be addressed in the volatility estimation.

The volatility of the underlying asset is estimated using Monte Carlo simulation. However, since the cash flows of the wind farm are determined by capacity factor and the price of electricity, and both these fluctuate, the final volatility must incorporate the combination of the two. The applied method will consist of three stages: first, estimating the historic volatility of both the price and the capacity factor. Second, generate expected values of both using Monte Carlo simulation. Third, calculate the expected revenue given the values from the second step, and then estimate the total volatility of these results.

The aim of the Monte Carlo simulation is to determine numerical estimations of unknown parameters (Pease, 2018). While there exist many different approaches to Monte Carlo simulation, they all boil down to the generating of random numbers to derive expectations of future scenarios. It has been used extensively in corporate finance as a forecasting method in the stock market, as the stock market does not follow a simple model, but is highly complex and consist of many dimensions, which are impossible to account for (Pease, 2018).

As for estimating the final volatility of the underlying asset, the Logarithmic Cash Flow Returns Method is applied on the scenarios found in the Monte Carlo Simulation (Kodukula & Papudesu, 2006). This method estimates a volatility factor based on the cash flows calculated using the Monte Carlo simulation, and provides an annual volatility factor, which as the volatility in the real option modelling (Kodukula & Papudesu, 2006). The method is given by Equation 20:

$$\sigma = \sqrt{\frac{1}{n-1}\sum_{i=1}^{i=n}(x_i - \bar{X})^2}$$

Where n is the number of scenarios, x_i is a value of a given scenario and $\overline{X}$ is the mean of all the scenarios.

3.4.6.1 Estimating the Historic Volatilities

The historic volatility of the price of electricity is calculated upon the volatility of the daily prices of electricity over a period of 1 year. Data from 2019 is chosen, as that is the latest year for which data for the entire year can be found. The price used in figure 33, and for estimation of the volatility, is the average of the DK1 and DK2 prices. The data is visualized in figure 36:

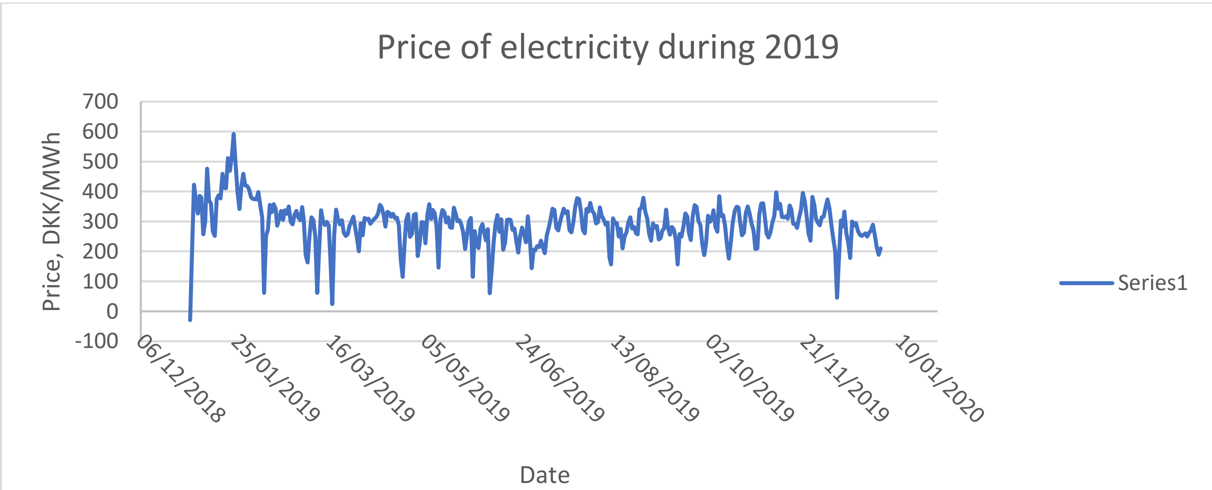

Figure 36. Own contribution. Source: Nord Pool Group, nd.b

The standard deviation of these prices is then calculated and estimated to be 0.0707. The historic volatility of the capacity factor is found in a study by WindEurope (2017) to be 0.023.

3.4.6.2 Monte Carlo Simulation

Besides the standard deviation of both, the estimation of expected values of the price and the capacity factor require the means. Both were previously discussed, and the price were found to average 31 øre/KWh, while the capacity factor was estimated to average 50%.

To perform the Monte Carlo simulation, the statistical distribution of both the price and the capacity is needed. The distribution for the capacity factor is plotted by WindEurope (2016), and looks as follows:

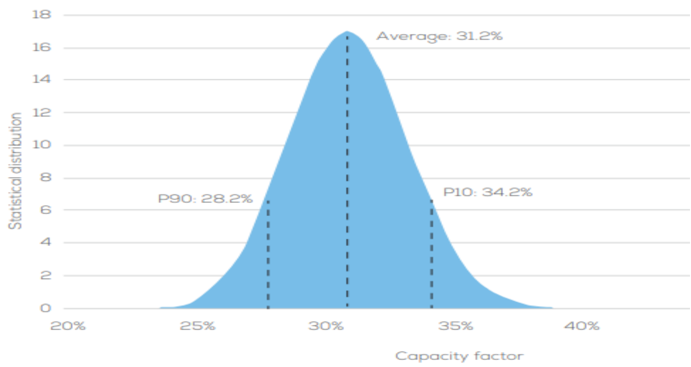

Figure 37. Statistical Distribution of the Capacity Factor for 1 year. Source: WindEurope, 2020

While figure 37 provides an estimate of the standard deviation and the statistical distribution of the capacity factor, its mean is lower than the mean for Aflandshage. This could be interpreted as the standard deviation and distribution found by WindEurope (2017) might be different to Aflandshages. However, it is assumed that figure 34 gives a fair estimate of both, and thus, it will be used for the calculation of the total volatility.

The distribution of the price of electricity is found by plotting all the prices in a histogram. The prices are found by Nord Pool Spot (2020) and are the same prices as provided in figure 38 (it is assumed that this distribution is the same as the price for electricity generated by wind farms):

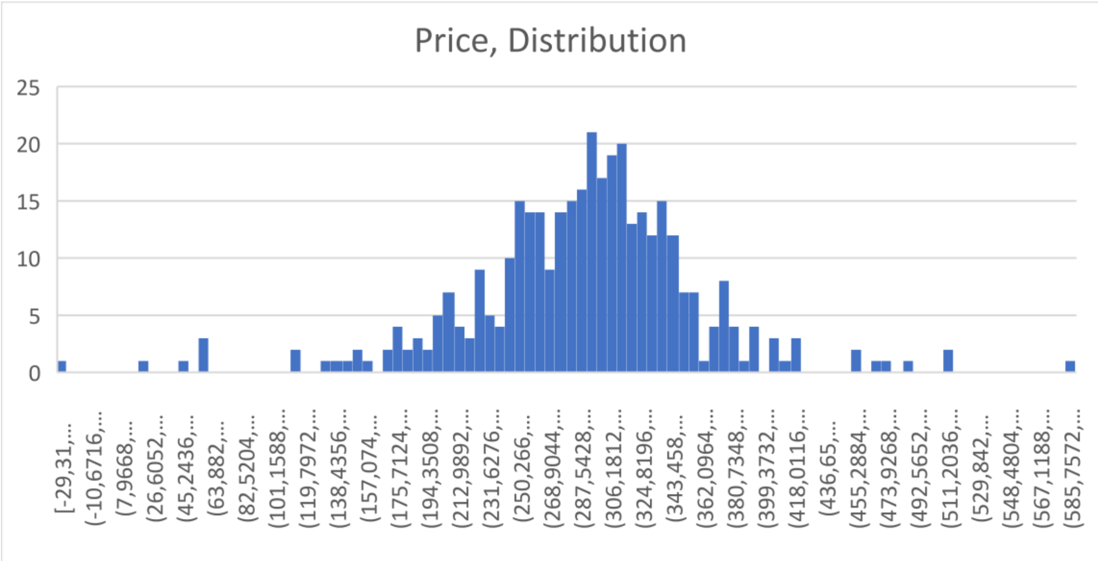

Figure 38. Statistical Distribution of the Spot Prices for 1 year. Own contribution. Source: Nord Pool Group, nd. b

Both histograms closely resemble the bell-shaped curve of the normal distribution. While there are clear deviations, it will be assumed that both datasets are normally distributed, which is used for the Monte Carlo simulation.

Using the assumption of the normal distribution, 10,000 scenarios are generated for both the price and the capacity factor with a mean of 0 and a standard deviation of 1. Using the 10,000 scenarios, it is possible to calculate the expected value of both the price and the capacity factor. Each scenario for the price and capacity factor is calculated by:

$$E(p_{electricity}) = \mu + X * \sigma$$
$$E(Capacity\ Factor) = \mu + X * \sigma$$

Where X is the value generated for each of the scenarios. Each value of X represents how much of an outlier the scenario is. The closer the value of X gets to 0, the closer the expectation of the price and the capacity factor gets to their means.

As an example, the first scenario provided values of -3.02 and -2.99, which would give the following estimates for the price and the capacity factor:

$$E(p_{electricity}) = \mu + X * \sigma = 31 + (-3.02) * 0.0707 = 10 \frac{øre}{KWh}$$
$$E(Capacity\ Factor) = \mu + X * \sigma = 0.50 + (-2.99) * 0.023 = 0.43$$

While this value is significantly lower than the average previously calculated, it is only one of 10,000 simulations. On average, the Monte Carlo estimate a price of 31.08 øre/KWh and a capacity factor of 49.94%.

One of the underlying assumptions of this estimate is that the capacity factor and the price is uncorrelated. The problem with this assumption is that the capacity factor and the price are marginally correlated, as a higher capacity factor equals a higher production, which would increase the supply of electricity. Resultingly, the price would fall, as more electricity is added to the grid. However, there are many different factors that determines if this correlation is true. As an example, the correlation would require that Aflandshage is able to transmit all its electricity through the grid, which might not always be possible due to limitations of the system. Conclusively, the assumption of uncorrelation is deemed to be acceptable.

3.4.6.3 The Expected Revenue and its volatility

The revenue of the wind farm is calculated as the capacity factor adjusted production times the price of electricity. This Equation is used given the scenarios found in the previous step, such that the first scenario would yield the following revenue:

$$Revenue = 2{,}190{,}000{,}000\ KWh * Capacity\ Factor * price_{electricity} \rightarrow$$

$$Revenue = 2{,}190{,}000{,}000\ KWh * 43\% * 10\frac{Øre}{KWh} = 9.84\ EURm$$

As the average revenue was previously calculated to be 38.02 EURm, it is once again clear that the first scenario is particularly low. The average revenue calculated by the Monte Carlo simulation is 38.62 EURm, and it seen how, as more scenarios are added, the simulation settles upon the average:

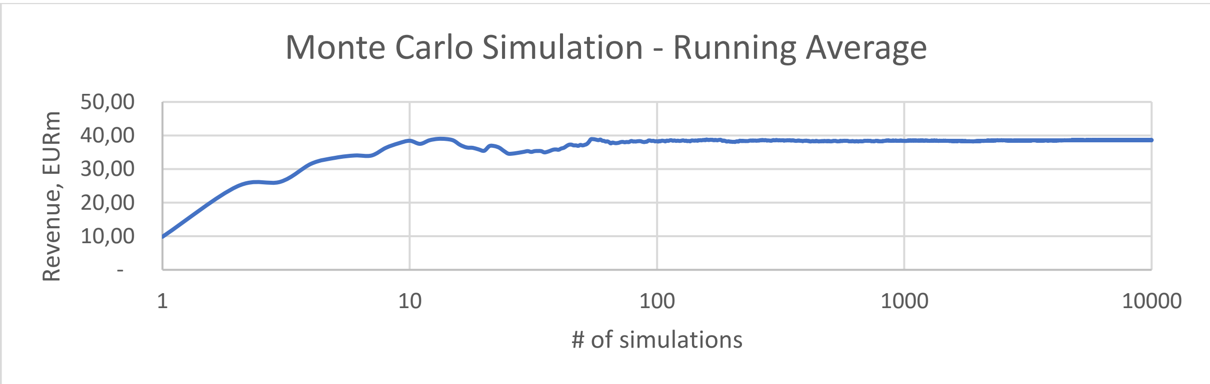

Figure 39. Own contribution

Figure 36 was calculated using a running average, and while presenting the data, it also provides the explanation as to why 10,000 scenarios were chosen. Figure 36 evens out around 38.62 EURm, and while adding more scenarios could provide a more precise estimate, the marginal effect of more scenarios was deemed to provide no significant value. The first 10 scenarios, and the according calculation amounted to:

Monte Carlo Vola Factor	Price	Vola Factor	Cap Factor	Production	Revenue	Log(rev)
- 3.02	0.10	-2.99	0.43	944,152,722.16	12.11	1.08
0.16	0.32	1.24	0.53	1,157,218,890.23	49.58	1.70
- 0.87	0.25	0.64	0.51	1,127,170,719.94	37.39	1.57
0.87	0.37	0.11	0.50	1,100,449,477.02	54.55	1.74
0.21	0.33	1.28	0.53	1,159,496,625.49	50.27	1.70
- 0.05	0.31	0.25	0.51	1,107,720,523.80	45.26	1.66
- 0.38	0.28	-0.14	0.50	1,088,067,383.82	41.03	1.61
1.26	0.40	0.87	0.52	1,138,598,335.79	60.58	1.78
0.93	0.38	-0.45	0.49	1,072,381,726.99	53.69	1.73
0.66	0.36	0.15	0.50	1,102,473,704.28	52.47	1.72

Table 22. Own contribution.

As the binomial model approximates a lognormal distribution, the lognormal volatility of the revenues is required. This volatility is estimated by log-transforming the 10,000 simulations of revenue, and then estimating the final volatility from these. The volatility is calculated using the Logarithmic Cash Flow Return Approach generates the final value of the volatility to be **11.03%.** (For the full calculation see Appendix 8 or the attached excel sheet)

3.4.7 Parameters of the Binomial Model

Using the results found in the sections, the essential parameters which calculates the value of the real option can be estimated. The parameters that are needed for the calculation are the up- and down factors and the risk-neutral probabilities.

3.4.7.1 The Up- and Down factors

As shown in section 2.4, these factors can be calculated as:

$$u = e^{\sigma\sqrt{\Delta t}}$$

$$d = e^{-\sigma\sqrt{\Delta t}} = \frac{1}{u}$$

Using the volatility of 11.03% and the periods of 0.5 years/period, the factors are estimated to:

$$u = e^{\sigma\sqrt{\Delta t}} = \exp\left(11.03\% * \sqrt{0.5}\right) = \mathbf{1.081}$$

$$d = e^{-\sigma\sqrt{\Delta t}} = \frac{1}{u} = \frac{1}{1.081} = \mathbf{0.925}$$

3.4.7.2 The Risk-Neutral probabilities

The risk-neutral probabilities were also previously discussed and is estimated by the following Equation:

$$p_{up} = \frac{e^{r_f * \Delta t} - d}{u - d}$$

$$p_{down} = 1 - p_{up}$$

Using the up- and down factors that were just estimated, the risk-neutral probabilities are:

$$p_{up} = \frac{e^{r_f * \Delta t} - d}{u - d} = \frac{\exp(0.1\% * 0{,}5) - 0.925}{1.081 - 0.925} = \mathbf{0.484}$$
$$p_{down} = 1 - p_{up} = 1 - 0.484 = \mathbf{0.516}$$

3.4.8 Constructing the Binomial Trees

The value of the wind farm as a real option depends on the changes in the underlying asset. As previously discussed, the value of the underlying asset for the real option models is the value of the Expected Net Present Value, that was based on the calculations from the DCF model. However, the findings regarding the cash flows in the DCF model pointed towards uncertainties in the price of electricity and the capacity factor of the wind park. Based on this, the Binomial Model will be built based upon three trees, as probable changes in the cash flows must be accounted for. As such, the first tree of the binomial model will consist of the changes in the cash flows. The second tree will depend on the findings of the first tree, such that the second three contains the value of the ENPV value, given the corresponding estimated average cash flow. The third tree is where the value of the option is calculated given the expected value in each corresponding node and the estimated exercise prices.

3.4.8.1 The First Binominal tree

The first node of the first tree is the average expected annual revenue, given an average price of 31 øre/KWh and a capacity factor of 50%. This results in an expected revenue of 45.26 EURm. The changes in the expected revenue depend on the Up and down-factors calculated previously, such that the second node of the tree will have 2 values: an up scenario and a down scenario, calculated as the initial value times the up- and down factors respectively:

$$Scenario_{UP} = 45.26\ EURm * 1.081 = 48.93\ EURm$$
$$Scenario_{DOWN} = 45.26\ EURm * 0.925 = 41.86\ EURm$$

Following the second node, the same method is applied throughout the first tree:

Changes in Revenue								
0	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**
45.26	48.93	52.90	57.19	61.83	66.85	72.27	78.13	84.47
	41.86	45.26	48.93	52.90	57.19	61.83	66.85	72.27
		38.72	41.86	45.26	48.93	52.90	57.19	61.83
			35.82	38.72	41.86	45.26	48.93	52.90
				33.13	35.82	38.72	41.86	45.26
					30.64	33.13	35.82	38.72
						28.35	30.64	33.13
							26.22	28.35
								24.25

Table 23. Own contribution.

3.4.8.2 The Second Binominal Tree

The second tree is built upon the first tree, so the value of the probability adjusted cash flows depends on the corresponding revenue found in table 23. From the new average revenue, the value is then calculated with every other parameter kept constant. The initial value of this tree will be the original value of the Expected Net Present Value of the operational stage, as the average revenue in the first node is equal to the original, average revenue. Node t=0.5 is then calculated as the probability adjusted DCF value given the corresponding value of the average revenue found in the first tree and then forwards discounted using the period-adjusted risk-free rate:

$$Scenario_{UP} = ENPV(Revenue = 48.93\ EURm) * (1 + 0.0055)^{0.5} = 55.46\ EURm$$
$$Scenario_{DOWN} = ENPV(Revenue = 41.86\ EURm) * (1 + 0.0055)^{0.5} = 45.40\ EURm$$

Again, the same method is applied throughout the second binominal tree:

Changes in Underlying Asset								
0	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**
49.48	54.54	59.97	65.68	71.95	78.56	85.72	93.42	101.68
	44.80	49.51	54.56	60.00	65.71	71.98	78.60	85.76
		40.44	44.83	49.53	54.59	60.03	65.74	72.02
			36.30	40.46	44.85	49.56	54.62	60.06
				32.45	36.32	40.49	44.87	49.58
					28.78	32.46	36.34	40.51
						25.12	28.79	32.48
							21.72	25.13
								24.30

Table 24. Own contribution.

3.4.8.3 The Third Tree

The calculations of the third tree are based upon the findings of both the first and second tree in addition to the risk-neutral probabilities found in the previous section. To construct the third tree, the calculations apply backwards induction as opposed to the two previous binominal trees. The first calculations are done by finding the corresponding value of the underlying asset minus the probability adjusted cost of entering the next stage and then checking whether this is above or below 0. In other words, it checks the value of the option, which is 0 given a negative value, as you would not exercise the option in a scenario where the value of the underlying asset is below the exercise price. The next three nodes are calculated using the risk-neutral probabilities. As it is possible to exercise between t=2 and t=2.5, the value of the option in this node must be calculated using the risk-neutral probabilities and the exercise price corresponding to that node. Then the next three nodes are gain calculated using the risk-neutral probabilities, leading back to the first node at t=0, where the risk-neutral probabilities and the exercise price are used again. In total, the third three and the value of the option will be:

Changes in the Value of the Option								
Stage 0	Stage 1				Stage 2			
2018 Ultimo	2019 Environmental Impact Assesment		2020 Environmental Impact Assesment		2021 Other allowances		2022 Other allowances	
0	0.5	1	1.5	2	2.5	3	3.5	4
0.00	4.19	7.10	11.47	17.06	27.18	34.30	41.95	50.18
	0.71	1.46	3.02	6.24	14.61	20.53	27.16	34.27
		0.00	0.00	0.00	5.42	9.07	14.34	20.53
			0.00	0.00	0.97	2.00	4.14	8.57
				0.00	0.00	0.00	0.00	0.00
					0.00	0.00	0.00	0.00
						0.00	0.00	0.00
							0.00	0.00
								0.00

Table 25. Own contribution.

To calculate each node of the third tree, different methods must be applied due to the characteristics of the compound option. Starting at the right side of the tree, the following method has been applied for t=4:

In node t=4, the following method is used for all scenarios:

$$OV_t = MAX(S_t - K; 0)$$
$$OV_4 = MAX(101.68 - 51.49; 0) = 50.18$$

Where S_t is the corresponding value calculated in the second tree.

After the right most node, Equation 18 has been applied for node t=0.5 to t=1.5 and from t=2.5 to t=3.5. The calculation is as follows for the t=0.5 node in the up scenario:

$$\mathrm{OV_t} = \frac{[\mathrm{pOV_u} + (1-\mathrm{p})\mathrm{OV_d}]}{\mathrm{e}^{\mathrm{r_f} * \Delta \mathrm{t}}}$$
$$OV_{0.5} = \frac{0.484 * 7.10 + 0.516 * 1.46}{\exp(0.05\%)} = 4.19$$

The same method is applied for all scenarios in the nodes previously mentioned. In node t=0 and t=2 the following method has been used:

$$OV_t = MAX\left(\frac{[\mathrm{pOV_u} + (1-\mathrm{p})\mathrm{OV_d}]}{\mathrm{e}^{\mathrm{r_f} * \Delta \mathrm{t}}} - K; 0\right)$$

$$OV_0 = MAX\left(\left(\frac{0.484 * 4.19 + 0.516 * 0.71}{\exp(0.05\%)}\right) - 9.90; 0\right) = 0$$

The calculation above is for node t=0. However, the same method has been applied in all scenarios of node t=2. As seen from the calculations, the estimate of the value found by the ROV model is negative and thus the value of the option becomes 0. However, in the next section the estimates of the model are being tested through a sensitivity analysis.

3.5 Sensitivity Analysis

Due to the many factor which impact both the DCF model and the ROV model, a sensitivity analysis will be conducted. The purpose of the analysis is not to only estimate the changes in the value given a change in the parameters, but also determine which factors are the most relevant. Three parameters of the DCF value as been chosen for the sensitivity analysis: the WACC, the revenue, and OPEX. These estimates have been chosen due uncertainty in their initial estimation, and because they are the factors with the highest impact on the value. Their impact on the DCF value will be tested in an interval of change from -20% to +20%:

Sensitivity Analysis	Change in					
% - Change	WACC (Absolute - Relative)		Revenue (Absolute - Relative)		OPEX (Absolute - Relative)	
-20%	394.64	14.70%	256.35	-25.49%	371.16	7.88%
-15%	381.15	10.78%	278.60	-19.03%	364.14	5.84%
-10%	368.25	7.03%	300.35	-12.71%	357.72	3.97%
-5%	355.89	3.44%	322.58	-6.24%	350.90	1.99%
Base Case	344.06	0.00%	344.06	0.00%	344.06	0.00%
+5%	332.72	-3.30%	365.46	6.22%	337.63	-1.87%
+10%	321.86	-6.45%	386.99	12.48%	330.39	-3.97%
+15%	311.44	-9.48%	408.22	18.65%	323.91	-5.86%
+20%	301.45	-12.39%	429.48	24.83%	316.95	-7.88%

Table 26. Own contribution.

The revenue and the operating expenditures were a rough estimate due to the limited data available of the Aflandshage project and the values might vary in practice, which emphasizes the value of conducting a sensitivity analysis. In table 26 and figure 40, it is seen how a 20% change in either direction impacts the value of the DCF model. Furthermore, from table 26, the relative change in the value can be seen, given changes in different factors, where the most impactful factor is found to be the revenue stream. Thus, a fall in the revenue of 10% would lead to a fall in the DCF value of 12.71%. Table 26 is consistent with the previous analysis, which stated that the price and capacity factor were some of the most impactful in the valuation.

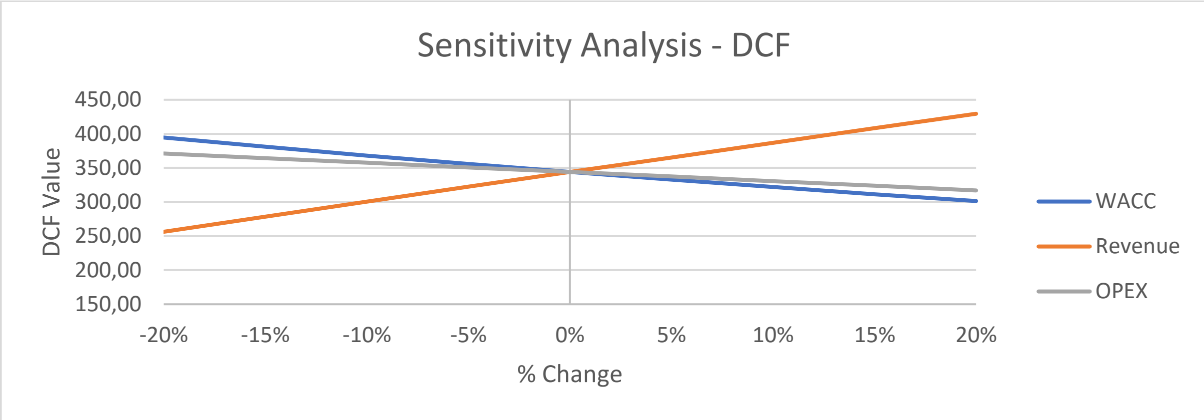

Figure 40. Own contribution.

The sensitivity analysis on the value of the ROV model are conducted with 5 different parameters: the volatility, beta, price, WACC and capacity factor. Additionally, a cross-factor sensitivity is also made on the price and capacity factors, which provides different scenarios in which both the price and the capacity factor changes. The sensitivity analysis of the 5 factors are found in table 27:

Scenario	Volatility	ROV Value	Beta	ROV Value	Price	ROV Value	WACC	ROV Value	Capacity Factor	ROV Value
Base Case	0.110	0	1.180	0	31.000		0.047	0	0.500	0
10%	0.121	0	1.062	0	34.100	0	0.042	0	0.550	0
20%	0.132	0	0.944	0	37.200	0	0.038	0	0.600	0
30%	0.143	0	0.826	0	40.300	4.408	0.033	0	0.650	4.791
Minimum for >0	0.300	171.99%	0.450	-61.86%	38.000	22.58%	0.032	-31.91%	0.610	22.00%

Scenario	CAPEX	ROV Value	OPEX	ROV Value
Base Case	-459	0	-353.06	0
10%	-413.1	0	-317.754	0
20%	-367.2	0	-282.448	0
30%	-321.3	0	-247.142	0
Minimum for >0	-310	-32.46%	-90	-74.51%

Table 27. Own contribution.

In addition to providing an overview of the impact on the value of the different factors, table 27 also provides an estimate of which value is required for a given factor to generate a positive value of the ROV model. While table 27 provides an analysis of a positive change in the volatility, the price, and the capacity factor, it also provides an analysis of a negative change in beta and WACC. This is done due to the initial negative value of the ROV model and thus, it would not give additional information to test the impact in a further negative direction. As seen from table 27, even a 30% change in volatility and beta do not make the value of Aflandshage positive. However, a 30% increase in the price or the capacity factor, would lead to a positive value. Furthermore, the last row of table 27 shows that a relative change of 171.99% in volatility is required to reach a positive value of Aflandshage, while only a 22.00% change is required in the capacity factor. This, again, is consistent with the previous findings of the capacity factor and price being the most impactful parameters of the value. Thus, the cross-sectional scenarios will include these two parameters:

Sensitivity	Price	+10%	+20%	+30%
Capacity Factor		55.00%	60.00%	65.00%
+10%	34.1	0.021	5.675	11.746
+20%	37.2	5.551	12.171	19.282
+30%	40.3	11.441	19.130	26.889

Table 28. Own contribution.

Table 28 shows that only a 10% different in both the capacity factor and the price would lead to a positive estimate of the value of Aflandshage.

Finally, the ENPV is calculated given the price of 38 øre/kWh. With a price of 37 øre/kWh, the ENPV is found to be -1.59 EURm, while the value of the ROV model is 0.53 EURm.

3.6 Summary of valuation

During this section, the value of Aflandshage was analyzed through four different valuation tools: The Discounted Cash Flows model, the Expected Net Present Value model, the Levelized Cost of Energy model and finally, the Real Option Valuation model. The purpose of the DCF model was to estimate the value of the operational stage, given a situation where the revenues only depended on the market price of electricity and the production of the wind farm. The DCF model did not include the development and construction stages as, part II found, the ROV model to be more precise during the pre-operational stages. The ENPV model was included primarily due to its usage as a proxy for the value of the underlying asset. However, the ENPV model is superior to the DCF model in the aspect of incorporating the project-specific risks. Through the ENPV model the probabilities of success was considered, which enabled the valuation of Aflandshage given its project-specific risks.

The LCOE model was used to compare Aflandshage to competing sources of energy. While the LCOE model provides a useful tool in comparing different project, as all relative approaches does, it fails to incorporate managerial flexibility. In part II, managerial flexibility was found to be a relevant factor in estimating the value of a wind farm, and thus it was concluded that the ROV model would provide a more precise estimate of the value. In table 29 the findings of part III can be found:

Model used	Estimated value
Discounted Cash Flows model	344.06 EURm
Expected Net Present Value model	49.48 EURm
Levelized Cost of Energy	37.51 EUR/MWh
Real Option Valuation model	0.00 EURm

Table 29. Own contribution.

Due to the characteristics of the DCF model and the LCOE model used in part III, it is not possible to make a final investment decision based upon these. However, both the ENPV model and the ROV model provides the necessary information to make a final investment decision. The findings of both models concluded that an investment decision should not be made, due to the negative value of the ENPV model and that the option in the ROV model should not be exercised. However, given a price of 38 øre/kWh, the value of the ROV is positive, while the ENPV was still negative at -1.59.

A sensitivity analysis was done to determine which factor that impacted the different models the most, and to determine which value of the different factors that would turn the final investment decision positive. It was found that factors impacting the revenue had the highest impact on both the DCF and ROV model, and that only minor changes could give a positive value of Aflandshage.

Part IV: Discussion - What Is the Optimal Strategy for Wind Farm Developers?

As described wind farm operators are exposed to a significant amount of volume and price risk, if operating on market conditions. The volume is affected by weather conditions (capacity factor), while the price is exposed to volatility in the spot prices. Consistent with previous findings, there is a high degree of uncertainty surrounding budgeting future earnings. The DCF and Binomial model from part III did not consider any cash flow hedging as a part of the valuation, as the intention was estimating the value of a wind farm operating on market terms.

Given the expected development in CPPAs in the Danish electricity market from now until 2040 (section 1.3.2), it is reasonable to expect that most wind farm operators will examine the potential upsides to hedging its revenue. According to WindEurope's (2017) estimations, only 6% of the income from wind farms will originate from government subsidies by 2030 relative to 75% in 2017 (WindEurope, 2017. p. 5). With this process of market liberalization, wind farm operators are likely to partly stabilize cash flows through financial markets or private contracts.

This section first contains a brief description of different financial derivatives applied within the industry and a discussion of which are the most advantageous to wind farms. Secondly, hedging from a debt- and equity holder perspective will be discussed, as incentives in these perspectives are different. Thirdly, the changes to the valuation process, if Aflandshage was to hedge its future cash flows, will be discussed.

4.1 Hedging Instruments Applied in the Wind Industry

Like most other utility commodities, options, futures, and forwards are used to hedge against unfavorable development in the revenue stream. However, most European countries have market problems due to the derivates not being frequently traded, resulting in an illiquidity and pricing issue (WindEurope, 2017, p. 33). Therefore, financial derivatives might not be a sustainable hedging solution in the long run, and it is consequently not surprising that CPPAs has trended recently. Section 1.3.2.7 contained the description of the Corporate Purchase Agreement, which has characteristics of a swap agreement and limits the exposure to price variability. However, the CPPA does not hedge against volume risk, which were unsolved until recently.

In 2016, the German insurance company Allianz introduced a hedging contract called the Proxy Revenue Swap (PRS) with an onshore wind farm in Texas. The PRS, which also is set up like a synthetic loan, hedges against both price and volume. In this type of contract the counterpart pays a fixed total annual rate, relative to the CPPA's fixed unit price and thus, the operator will not be exposed to low outputs due to bad weather conditions nor price fluctuations (Norton Rose Fulbright, 2017). This sort of contract all but limits the wind farm operator's exposure to any volatility, but consequently the investors' return on investment is relatively lower. For financial investors with a dominantly risk-averse profile, like AIP Management, this type of hedging could be relevant for future projects, while other investors might have different preferences. This will be discussed further next (Interview, May 6th, 2020).

4.2 Hedging from the Investor's Perspective

Before discussing the most value creating hedging strategies, the ownership structure of wind projects must be defined. The power producers still deposit most of the capital to a project, but financial investors, such as pension funds, infrastructure investors, or insurance companies, have recently showed increasing interest in renewable energy sources as long-term investments (WindEurope, 2018; Interview, May 6th, 2020). The distribution of the total European equity financing of wind farms in 2018 were 60% from operators and developers and 40% from financial investors (WindEurope, 2018, p.19). While investors outside the industry recently has shown an increasing interest in renewable energy sources, there still seems to be a lack of willingness to fund renewable energy projects in the early stages where liquidity is needed the most (WindEurope, 2018, p. 20; interview, May 6th, 2020). As the figure 41 illustrates, financial investors are more comfortable with entering the market at a later stage, where several external risks are eliminated or clarified, as licenses have been granted and studies turned out successful. Therefore, reducing the total risk of a project through hedges might attract investors in the pre-construction stage.

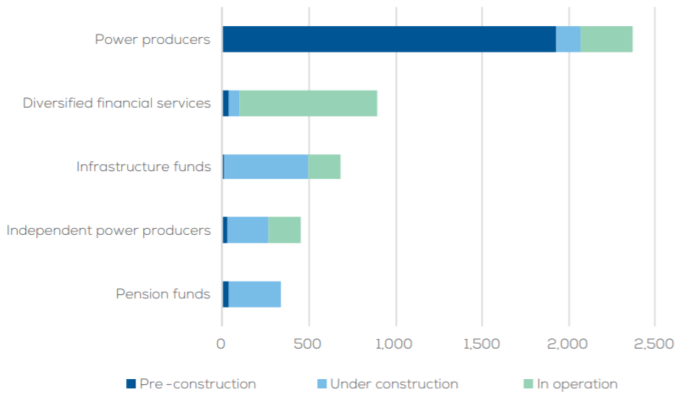

Figure 41. Market entry for different equity investors. Source: WindEurope, 2018

The structure of ownership is important as the risk preferences might be vastly different depending on the type of investor. Global or regional power producers might not prefer volume hedging strategies through costly financial options, futures, or forwards etc., as volume risk against weather conditions can be eliminated by operating a well-diversified portfolio of wind farms placed in different geographical locations. This does not apply to small local utility companies like Hofor, who currently operates only three smaller wind farms in Denmark with a limited total MW capacity.

Some financial investors, as opposed to AIP Management, may not prefer hedging at all, as they are attracted to the relatively high returns on their investment. The expected annual return on wind farm equity-investment is in the range of 7-8% without considering volume or price hedging, but only 3-4% with hedging (WindEurope, 2018, p 36). This finding is consistent with PensionDanmark, who estimates a return of 4-7% for offshore wind (Interview, May 1st, 2020). Therefore, an investment in a wind farm with a significant revenue stream from CPPAs or Proxy Revenue Swaps have similar characteristics with fixed income investments, which is less uncertain and easier to value.

However, major financial investors might prefer the high risk/high reward strategy without hedging, as they can balance their risk management through investments in other markets and securities. Financial hedging instruments, like forwards or futures, are, like any other insurance contracts, costly even if market development remains neutral as they carry an upfront cost. Brealey et al. (2014) summarizes this: "*Investors won't reward the firm for doing something that they can do perfectly well for themselves"* (Brealey et al., 2014, p. 684).

As discussed in this section, different owners might have different preferences of CPPA and PRS. Consequently, hedging strategies from an investor's perspective can neither be determined as profitable nor unprofitable. However, as wind farm project mostly are debt financed, the creditor-perspective must be assessed next.

4.3 Hedging from the Bondholder's Perspective

A project's creditors view risks very differently from shareholders, as their sole focus is the payback of debt. As wind farm projects are often high-leveraged operations, there is an increased risk of default if revenue streams are uncertain throughout the park life, even if the long run NPV is positive. Even if short run liquidity problems are solved without filing for bankruptcy, the downside of financial distress and violations of debt covenants can be costly for the owners. Due to the seasonality factor of wind speed, a windmill generates 30-45% more power in the winter months than in summer times, which makes the expected cash flows unevenly distributed throughout the year (WindEurope, 2017, p. 21). As the generated power cannot profitably be stored, wind farm operators might face cash flow issues during the summer months, as production is down, but interest and instalments on debt still must be honored.

The standard deviation of electricity spot prices was estimated in section 3.4.6 to 0.0707 and to 0.0230 for the capacity factor. It is not only the expected capacity factor which increases in winter times. The volatility also increases, which is illustrated in figure 42, where the light blue marker represents the interval in between the 10% and 90% percentile and the dark blue line representing the median factor.

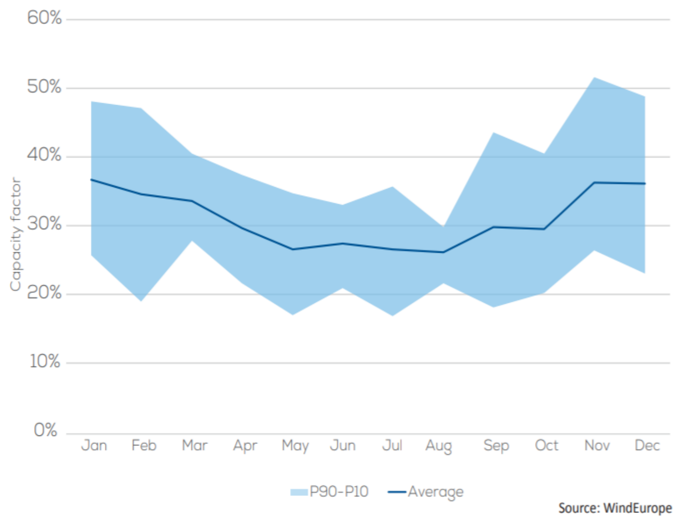

Figure 42. Annual capacity factor of wind. Source: WindEurope, 2017

By considering the potential cross effects from both the volume and price risk, the cash flows projection becomes complicated[12]. The CPPA, which is the most common instrument for operators, can only solve the issue of price, but the PRS fixes both risk factors completely. Hedging against external factors such as market pricing and weather conditions might not only have credit related advantages, but also increases the NPV of the investment (WindEurope, 2017, p. 34). Assuming the counterpart of the PRS to be a creditworthy associate, this eliminates the potential downsides to production, which increases the maximum debt capacity of a project by up to 10 percentages points (ceteris paribus) and consequently increases the total shareholder return[13] (WindEurope, 2017, p. 34). This is consistent with S&P' guide to credit ratings of power project financings, which defines Downside Analysis and liquidity as two of the key credit factors during the operational stage (Standard & Poor, 2014, p. 257).

Hedging has an upfront cost and limits the potential upside from an investment but increase the maximum debt capacity and lowers interest rates, which is why the effect is ambiguous. To discuss this further, it is now assumed that Aflandshage has signed a CPPA or a PRS hedging strategy instead of following the free market pricing.

4.4. Hedging Effect on Wind Farm Valuation

If Aflandshage wind farm is assumed to have eliminated its exposure to changes in electricity prices and volume, the volatility of the underlying asset (the static DCF value of the project) is equal to zero. Resultingly, the up and down scenarios in the binomial model will be identical across all time periods, which makes the

[12] As this thesis operates under a no correlation assumption between the two factors.

[13] Under the assumption of $R_e > R_D$, an increase in financial leverage will lower the WACC.

initial choice of real options worthless. Therefore, ROV should never be applied to a fully hedged projects without volatility.

A project with fixed cash flows is almost identical to fixed-income instruments and should instead be valuated with the present value approach (section 2.1), as the main criteria for DCF valuation is fulfilled. The issue of modelling the compounded stages of wind farm development is not eliminated through hedges, but the probability adjusted NPV can partly solve this issue then. Alternatively, Copenhagen Infrastructure Partners applies a rolling milestone valuation model, which gradually decreases the discount rate premium as the farm progresses through the stages (interview, May 1st, 2020).

However, applying the present value approach represents a circular issue, as DCF valuation omits the value of managerial flexibility. Triorgeris & Mason (1987) found that excluding this element leads to systematic undervaluation of projects. However, as the volatility decreases along with the stabilization of the revenue flow, the residual value (and importance) of managerial flexibility should diminish.

While real option valuation is useful under the current market conditions with decreasing subsidies, future development in CPPAs could replace this effect. This would diminish the residual value gained from ROV, and the current industry standard of DFC valuation might be the most efficient model again.

This discussion has however been based on the extreme scenario of 100% price and volume hedging. The valuation in part III where Aflandshage was assumed to have zero hedging represent the opposite extreme. In practice, the optimal solution would be likely be to fall in between to two poles. Without estimating a specific fixed percentage for cash flow hedging (as it depends on risk profile and financing), it is assessed to be profitable, to secure cash flows for debt payments to avoid the costs of financial distress.

Part V: Conclusion & Further Research

Currently, the industry of wind energy is highly relevant to analyze, due to the changes in governmental policies regarding subsidies. The industry is in an interesting situation where new wind farms are constructed without subsidies, as they are deemed to be able to compete on market terms. The removal of subsidies is driven by the lower costs of production, and thus the assumption that the investment now is profitable without subsidies. It is therefore relevant to examine whether this is actually the case. The purpose of this thesis was to examine how offshore wind farms under development should be valuated given the removal of subsidies, and to determine if wind farms are able to compete solely on market terms. The conclusion of this problem is found in this section.

5.1 Conclusion

As the main research question is defined as, how offshore wind farms should be valuated given a reduction in subsidies, several fields had to be researched in order to give an answer. It was found that the development and construction of wind farms had to undertake a complex, often bureaucratic, process containing several stages. As each stage was found to contain different risks, both regarding the specific project, but also the industry, the characteristics of these stages highly impacted the final investment decision. The stages were found to be development, construction, and operation. To progress beyond the stage of development, several allowances were required which resulted in the division of this stage into two steps. The first step was the initial evaluation of the wind farms and the Environmental Impact Assessment, where the second step was categorized as "Other allowances", which included final contract negotiations and construction permission. If a project progressed through the development stage, the construction of the farm would begin. While the stage of construction was found to be the most expensive, it was only very few projects which did not make it to the operational stage. The main element of the operational stage is the revenue, which is only generated during this stage. As the revenue is only generated in the operational stage, this is also the stage where fluctuations in price and capacity are most relevant, as these impact the revenue directly. At the end of the operational stage, which is typically lasts 20-30 years, the project is decommissioned.

To identify significant risks affecting a wind farm, an industry analysis was conducted. The purpose of the analysis is to find risk factors that could impact the valuation of wind farms and provide an understanding of fundamental factors which must be considered when investing in an offshore wind project. To identify the risks, the industry age is found, based on the findings of a PESTEL analysis. The PESTEL analysis finds that the changing political landscape is impacting the industry, as the removal of subsidies and policies of carbon taxes are both important elements of the profitability. During the economic analysis, the market for electricity is outlined, to give an understanding of how the price of electricity is determined. It is found that price fluctuations, is caused by the hourly changes in supply and demand. The concept of Power Purchase Agreements is also outlined, and the trend of companies leaning towards these as a substitute for subsidies has been discussed. It is concluded that the concept of PPAs were getting more attention as subsidies diminished, and it is found that the future of the industry is likely to include this concept to a higher degree. The highest impacting technological factors is found to be the advancements of competing power sources, and the reduction in cost of wind energy. It is estimated that the increase in wind energy in the power grid is partly due to the advancements in technology and the resulting reduction in costs. The ILC model is built upon the findings in the PESTEL analysis and included three determinants of industry age: market saturation, competitiveness, and dominant design. All three factors have been discussed based on the findings of the PESTEL analysis and, conclusively, it is found that the industry is close to maturity, or in the very beginning of that stage.

The four different valuation approaches that could be relevant for a wind farm under development is outlined in part 3. The discussion of the different models concluded that the DCF model was usable during the operational stage of the wind farm, due to its stable characteristics. While the DCF is the preferred tool among practitioners, it was found that a precise valuation of wind farms under development requires the incorporation of managerial flexibility. Due to this requirement, a Binomial Real Option Valuation model is concluded to be the most precise during the development stage of a wind farm. Furthermore, the Levelized Cost of Energy was concluded to be a good tool for comparing different power sources, as it provides a useful estimate of a multiple in the industry. Based on the theoretical discussion of the different models, and their use in the valuation of wind farms under development, it is concluded to use the binomial ROV model due to its precision, incorporation of managerial flexibility and project specific risks.

To test the chosen theoretical models in practice, Hofor's upcoming wind farm at Aflandshage is valuated. The DCF model values the operational stage of Aflandshage, the LCOE model finds the industry multiple, and the ENPV finds the value of the underlying asset used in the ROV model, which was finally used to incorporate the managerial flexibility. The conclusion from every model is the same: Aflandshage Wind Farm is not a profitable investment given no subsidies. However, the sensitivity analysis finds that the estimate of the value was most sensitive to changes in the price, and that a positive value of the ROV model only required a price change of 4.93 cent/kWh. Given this price, the ENPV is still negative, at a value of -1.59 EURm, proving how the use of the ROV model incorporates the value of managerial flexibility. The residual in the price of 4.93 cent/kWh is the value of the managerial flexibility, which is estimated to be 2.04 EURm.

In part II the subsidies of Kriegers Flak were identified, and it was found that this specific wind farm required a price of 37.4 øre/kWh (or 5 cent/kWh) to be profitable. However, as Aflandshage is a newer farm, it could be argued that it would require a lower price, which was found to be false in the sensitivity analysis of the ROV model. While the requirement of this price could lead to the conclusion that the estimates of the model is wrong, the problem can be limited by using the LCOE multiple. The LCOE multiple proves that the cost and production is at par with the reduction in the LCOE of wind energy, and even slightly lower than estimated. This leads to the conclusion, that the estimate of an electricity price of 4.13 cent/kWh might be wrong, as it is the only factor not considered in the LCOE calculations.

However, it could also be due to the timing of the project. As discussed in the industry analysis, the Danish government has recently decided to remove subsidies for wind farms under the open-door procedure, due to wind farms becoming cheaper and more efficient. While this might be the case, the industry currently stands at a breaking point, where the value of a wind farm, given the current technology, is close to 0. In conclusion, it is realistic that the value of an offshore wind farm under development and without receiving subsidies, could be valued to 0 due to the current state of the industry.

Part IV discusses the impact of hedging through power purchase agreements. The conclusion to this question is ambiguous as it can be narrowed down to investors individual risk profile. Some financial investors conclusively might want to pay the premium for stabilizing cash flows. This conclusion variates from the bondholder perspective as creditors prefer the guarantees hedging grants. As wind farm projects often are high-leverage investments, the bondholder perspective weighs highly, and some degree of volume/price hedge might be preferable to avoid financial distress.

Hedging however also changes the valuation approach to wind farms, as the higher degree of certain cash flows, increases the user value of the present value approach. If a significant amount of the revenue is generated through fixed power contracts, the ENPV or a milestone-based model should be applied, as ROV is not useful to projects with low or no volatility. Conclusively though, the use of the ROV model is found to be theoretically correct when valuing offshore wind farms under development in the current market, as it incorporates managerial flexibility and the project specific risks.

5.2 Further Research

As this thesis has been written in the winter and spring of 2020, it is only 2 years ago, subsidies were effectively removed from open door offerings. Therefore, the sample size and knowledge of actual Danish wind farms affected by this policy change is limited at this time, which also was our initial motivation for researching this topic. Regarding the sample size, only future projects (or lack of those) can illustrate the actual derived effect.

The examinations of this thesis found that operating in today's market, real option valuation has useful characteristics, which theoretically should be applied to financial valuation of wind farms. However, this conclusion is built on the assumption of a market where:

1) subsidies will represent an insignificant income sources already by the end of the decade and,
2) technological progressions will not allow most operators to accept full market exposure soon.

Given the expectations to power purchase agreement's entrance in the Danish market, these theoretical benefits might soon disappear. However, the maturing process of CPPAs could potentially be slowed down if advancements in construction technology evolves faster than projected. CPPAs might not settle like expected, if investors are more likely to accept the spot prices of electricity as their settlement price, due to lower capital expenditures. In this scenario real option valuation has a chance of settling in the industry as a validated valuation model.

This is not an unlikely scenario given the recent development in project costs. As an anecdotal example, when Anholt wind farm was completed in 2013, Dong Energy demanded a settlement price of 103 øre/kWh for the farm to be profitable[14] and Kriegers Flak, which is expected to be fully operational next year, only receives 37.4 øre/kWh. Even given the higher degree of supplier competition today, the development is still remarkable and probably have exceeded expectations from 10 years ago.

But as the wind industry still evolves fast and depends on many variables, forecasting the optimal valuation model in the future hardly seems realistic. This leaves the authors of this thesis to suggest readers to track the development intensely in the next decade, as the optimal valuation method might change soon again.

Furthermore, as owners become more vulnerable to the spot price of electricity and their production, it could be relevant to assess if a correlation between the price and production of wind turbines existed. If so, it could change the valuation method used in this thesis. The increasing amount of wind energy in the European grid will make this correlation more relevant, and it might even become the factor that stops the grid in becoming fully renewable. Furthermore, as wind energy is still becoming cheaper, and is likely to continue in the foreseeable future, it might lower the average spot price of electricity, due to wind farms requiring lower prices to cover their expenditures.

[14] This price was validated by Ernst & Young (interview, May 1st, 2020)

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