MSC IN ECONOMICS AND BUSINESS ADMINISTRATION
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MASTER´S THESIS

INVESTING IN UNSUBSIDIZED OFFSHORE WIND FARMS: THE PENSION FUND´S PERSPECTIVE

Authors:
Gjergji Gjeta - 125164
Lorenzo Versari - 124989

Supervisor:
Andreas Zarp-Karsholt

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DEPARTMENT OF FINANCE
COPENHAGEN BUSINESS SCHOOL

Abstract

With relevance to the targets governments have set in terms of increased renewable energy capacity, our research primarily focuses on the future of the offshore wind industry and the role of pension funds. These institutional investors hold the biggest share of the global wealth and have until now played an important role in the development of the industry. As costs are falling and support schemes for offshore wind projects are being decreased accordingly, debates arise over the further need for government subsidies to be in place at all. A full exposure to merchant risk would entail significantly higher levels of risk that might not be bearable by pension funds due to their high risk aversion. This thesis aims to contribute to this research gap by assessing the attractivity for pension funds of a potential unsubsidized offshore wind project. More specifically, we evaluate the investment case of a 1,000 MW offshore wind farm starting construction in 2020 in the United Kingdom, without the support of government subsidies and hence fully exposed to merchant risk.

In the first part of the thesis a financial analysis of the project as a standalone is performed. IRR and APV of the project are estimated at different prices scenarios through Monte Carlo simulations. The results revealed a promising investment case with a generally positive Adjusted Present Value, except in the low-prices scenario where the Internal Rate of Return was 6.1% on average, slightly below the cost of capital required for the project.

The analysis continued with the assessment of three portfolios representing the different investment strategies pension funds pursue. Leveraging on Modern Portfolio Theory, the investment case was integrated in each of the portfolios. In order to assess the maximum exposure to the project that the different schemes can accept, the portfolios were optimized at an adequate risk level representative of Pension Fund’s risk appetite. The results of the analysis confirmed that the investment presents an attractive return profile compared to the other available asset classes. However, due to its high volatility, Pension Funds would generally not be willing to allocate a significant weight of their total portfolio to the unsubsidized offshore wind project.

Targeted initiatives designed to reduce the project’s volatility might increase the attractivity of the investment for Pension Funds. Further research in that regard is therefore recommended.

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1. Introduction

The scope of this chapter is to elaborate on the background, relevance and target of the thesis. This includes a clear delimitation of the problem statement and the relative research question.

1.1. Background

The energy industry is undergoing a relentless transformation with the potential of dramatically changing the way electricity is being produced. As it happens, investments in renewable energy are arousing more and more interest as economies around the world turn their agenda towards the pursuance of environmentally friendly and low-carbon initiatives.

Among these new energy sources, wind power, both onshore and offshore, is estimated to become the main source of clean energy generation in the future, capable of satisfying 35% of global needs by 2050, with solar photovoltaic being its closest competitor (IRENA, 2019a).

There is little doubt that these trends found their fuel in the ever-increasing attention on Environmental, Social and Governance (ESG) performances from both private and public corporations across the globe. Raising concerns with regards to pollution and climate change shifted the popular favor to sources of energy that would help mitigate carbon emission as well as improve air quality standards (IRENA, 2019b). At the same time, it is believed that these new energy sources would bring strategic and socio-economic benefits as well. More specifically, reports show positive effects on employment as well as energy security where countries heavily dependent on fossil fuels would be able to diversify their energy sources therefore decreasing their exposure to power shortages (IRENA, 2019a).
Finally, a main rationale behind the recent development of the clean energy industry is related to the increased competitiveness of the sector with regards to costs (IRENA, 2019a). In particular, under current regulations, reports from Cornwall Insight show that offshore wind in the UK is expected to outcompete onshore installations potentially becoming the cheapest source of clean power (Edwards, 2019). As it happens, the combined attention on ESG performances, the

significant incentive programs promoted by many European countries and the gradual technological innovation lead to a progressive interest by investors (O'Dea, 2018).
Discussion with regards to the identity and requirements of investors is a key factor for the further development of the industry. Projections shows that investments in clean energy projects still require significant injections of capital to meet the 2025-2030 goals (IEA, 2019b). For that purpose, research has been directed towards the identification of optimal providers of capital. Some results suggested that this role could be taken by big institutional investors such as pension funds (Della Croce, Kaminker, & Stewart, 2011). As a matter of fact, pension funds were among the first investors to step into these direct investments and to fill the financing gap of renewable energies (Reuters, 2012). This gap was created as a consequence of the inherent high risk these energy investments carried, that acted as a deterrent for banks (Reuters, 2012).
To further prove the point, according to the All-Party Parliamentary Group (APPG) on Alternative Investment Management (2019)[1], pension funds should consider increasing their exposure to alternative investments as response to current global trends. While the long-term horizons and the possibility to reap an "illiquidity premium" make these investments inherently appealing to the strategy of pension schemes, the attractiveness is further exacerbated by the currently low interest rates within the fixed income securities market (APPG, 2019). Due to these considerations, the role of pension funds and their investment strategy will constitute a key element of this thesis.

Recent developments in Europe, and in the UK in particular, opened debates on new energy investments becoming independent from governmental support (Evans, 2018). A number of projects have been awarded contracts at prices at or below the average expected wholesale electricity price on the open market (Evans, 2019). However, there are still uncertainties whether the industry is ready for such a move. As a matter of fact, the transformation will subject the industry to a higher level of risk ultimately straining its sources of capital as investors would require higher returns. At the same time, it is argued that increasing renewable capacity would ultimately put a pressure on electricity prices and therefore undermining the profits of generators exposed to the risk of the market (Musker, 2018). Economic and political turmoil then could pose an additional challenge increasing the uncertainties these subsidy-free investments would be subject to, fundamentally opening a gap in the research.

[1] From this moment forward the "All-Party Parliamentary Group on Alternative Investment Management" will be referenced as "APPG".

1.2.Problem Statement

The scope of the thesis is therefore to address the aforementioned gap by investigating from an institutional investor perspective the financial and strategic feasibility of clean energy investments subject to the regulations and hazards of the free market. This research aims to estimate the impact of merchant risk in an investment decision and then assess the compatibility of these investments with the existing pension funds' portfolios and investment strategies. Using modern portfolio theory, our purpose is to quantitatively measure the attractivity of unsubsidized wind projects for pensions funds. More specifically, the research aims to assess how much of their wealth these institutional investors would be willing to allocate to these investments given the higher risks derived from the full exposure to the wholesale market. The research will focus on the offshore wind sector as it was deemed the most relevant under current developments. In addition to that, the UK will be the geographic focal point of the analysis due to the highest growth potential that the market presents within the global landscape (BVG Associates, 2019a). Furthermore, recent outcomes saw the English government dramatically decreasing assistance to clean energy projects (Merrick, 2018). Paired with the increased uncertainty brought by the changing political landscape, this analysis could as well become relevant to institutional investors interested in diversifying their portfolios.

Provided the background and objective of the thesis, the study outlines the following research question:

1- *How does the investment case of a subsidy-free offshore windfarm starting construction in 2020 in the United Kingdom look like, and would this be an attractive investment for pension funds given their investment strategy?*

The answer to the research question will first focus on the results of different evaluation techniques widely used in financial theory, as well as risk management tools applied to a benchmark wind park. Prior to the analysis, the authors stress the need to thoroughly comprehend the market for renewable energies as well as the offshore wind segment. Understanding the trends and factors influencing the production, consumption and pricing of power is critical to the assessment of the case study. This awareness becomes then fundamental for the analysis and appraisal of different scenarios.

As an immediate follow up, the target group of the study will be analyzed. This translates into discerning the schemes and investment strategies of different UK pension funds. In particular, the authors believe that understanding pension funds’ exposure to different asset classes and their relative returns and volatilities is a key requirement for successful investment decision making.

2. Methodology

This chapter will provide the reader with an understanding of the process upon which the research was laid out. First, this section presents an outline of the structure of the study which will be followed by a further clarification of the thesis' research approach. The chapter will then be concluded with a detailed examination of the limitations of the research.

2.1. Research Structure

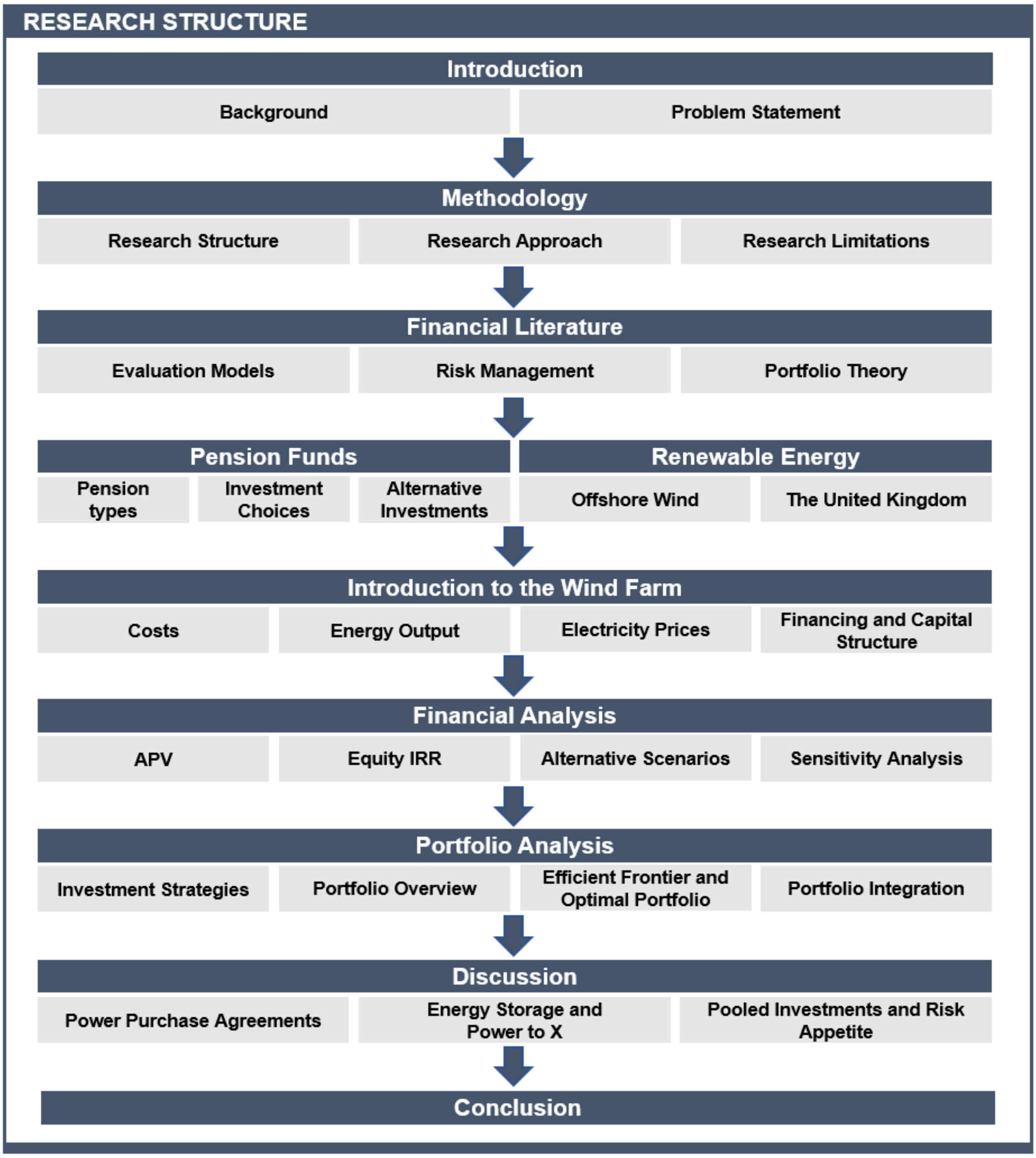

Figure 2.1 Source: Own depiction

Figure 2.1 presents the overall structure outlined in this study. After having established the methodology, the first part of the thesis will strive to build an appropriate theoretical framework upon which the analysis of the practical case study should refer to. Chapter 3 will be dedicated to the description of the academic literature encompassing financial evaluation techniques, risk management models and portfolio theory. Chapter 4 will then offer an understanding of different pension fund schemes and strategies. In addition to that, the section will review the potential benefits of alternative investments for the portfolio of these institutional investors. Ultimately, the first part of the thesis will be concluded in chapter 5 with an overview of the developments and trends affecting the renewable energy market. Both historic figures and future projections for the industry will be presented.

The second part of the thesis will see the application of the theoretical framework chosen for the assessment of the UK offshore wind project. For that purpose, chapter 6 will provide an introduction to the case study model. In particular, the assumptions behind project costs, energy production, electricity prices and capital structure will be defined. Chapter 7 and 8 will then constitute the core of the analysis. Here, the model and the assumptions will be tested in order to extract the results required to address the problem statement. Finally, the remaining chapter will critically evaluate the findings of the research in order to set the ground for the following considerations and recommendations.

2.2. Research Approach

The approach selected for this study will be inspired by robust, holistic frameworks extensively described in the academic literature. More specifically, the authors will apply models and techniques suited for combining several variables towards the appraisal of an investment for a sensible decision making (Tziralis, Kirytopoulos, Rentizelas, & Tatsiopoulos, 2009).
As it is in the nature of the topic discussed, the analysis and discussion of the data will mainly rely on the assessment of the quantitative data analysis. Nevertheless, the full potential of the research will be achieved through a combination of both quantitative and qualitative research.

2.2.1. Case Study

The focus of the thesis will be the case study of an offshore wind farm located in the UK and constituted by 100 turbines with 10 MW of capacity each, for a total plant capacity of 1 GW. The project will be analyzed from the perspective of a pension fund jointly investing with the developer of the offshore installation. Entrance of the financial investors will coincide with the first year of construction in the year 2020 succeeding the final investment decision (FID) in 2019. The project is supposed to undergo a construction period of 2 years. Operations are then expected to immediately follow the completion of the installation (BVG Associates, 2019b).

As it constitutes the purpose of this research, the wind farm will operate under the assumption that no subsidies are applied to fix the power price. Therefore, the investment will be fully exposed to the merchant risk.

The case study will be constructed following determinate assumptions with regards to costs, power production, prices and financing structure suggested by reports and outlooks collected by the authors.

Taking into account the inherent complexity of precisely forecasting future conditions, we overcome this limit by proposing and testing different probable futures (Ratcliffe, 2000). The analysis includes therefore the appraisal of three different wholesale electricity prices forecasts. Benefits of this method will be reaped in terms of better decision making as the different outcomes will require careful revaluation of the investment strategy (Mietzner & Reger, 2005). The approach will be further complemented with the application of a sensitivity analysis.

2.2.2. Portfolio Analysis

Having first analyzed the financial performance of the unsubsidized project from a standalone perspective, the paper will then assess through Markovitz's portfolio theory the fit of the investment case into three diverse compositions of pension funds' investment portfolios. Those portfolios are assumed to be representative of the different investment strategies pension funds pursue. The goal is to evaluate the effects of an additional investment class represented by the unsubsidized offshore wind project and quantitatively determine the attractivity of the latter for the chosen institutional investors' portfolios. The analysis will reveal how much capital pension funds would be willing to allocate to the project, given their risk appetite and investment strategy. The outcome of this analysis will be of key importance not only from an investor point of view, but also for policy makers who have to match the goals and targets they have set for future capacity additions with the investment's attractiveness for large providers of capital.

2.2.3. Data Collection

The following research has been carried out without the sponsorship of a specific organization. Due to this, all the data collected is derived from publicly available sources with the exception of a few interviews with industry experts. These were made with the purposes of delimiting the procedures, data and tools that would be most appropriate for the research. As it stands, most of the data collected for the purpose of the study derives from secondary sources.

2.2.4. Data Processing and Evaluation Tools

The tools and techniques applied to the study were extracted from a few of the main courses of the FSM study line, namely corporate finance, financial markets & instruments and risk management. This arises from the necessity to build our work on robust frameworks that would ultimately increase the value of the proposed study. Evaluation of the offshore wind farm will see the application of present value approaches such as the adjusted present value model and the calculation of the project internal rate of return. On a further note financial statements were modelled following a project finance approach under the assumptions that debt holders are repaid solely from the cash obtained from the project and not from the balance sheet of the company. The rationale behind this is twofold. First, it will allow the study to evaluate the investment as a standalone project that is detached from the balance sheet of a specific company. Secondly, the offshore wind industry has seen a notable surge of investments under the dynamics of a special purpose vehicle (SPV) where both funding and revenues are detached from the liabilities of the owners (Mora, Spelling, van der Weijde, & Pavageau, 2019).

In order to take into consideration the exposure to market risk and the inherent volatility of electricity prices, the profile of the investment will be delimited through the application of a large number of iterations according to the Monte Carlo method (Tziralis et al., 2009). The calculations will be executed through the excel add-in ModelRisk (Vose Software, 2020).

The study will also require leveraging on the framework of modern portfolio theory. This includes the techniques required to estimate the efficient frontier and the optimal portfolio.
Ultimately, the tradeoff between risk and return will be reflected in each stage of the thesis. It will be applied in the calculation of the cost of capital for the case study through the capital asset pricing model and also in the Portfolio analysis as it stands at the very foundation of modern portfolio theory.

2.3. Research Limitations

It is widely accepted in the academia for a study to have limitations. As a matter of fact, it is even encouraged as a way to identify gaps and direct future research for the development of the collective knowledge (Brutus, Aguinis, & Wassmer, 2013). As it is true for all existing research, this study presents limitations that should be considered when evaluating its findings and recommendations.

A first limitation is related to the thesis' scope. From a broader perspective, the study aimed to determine the compatibility of alternative investments to the strategies and portfolios of pension funds. This would suggest the need to properly examine a wide range of different investment categories encompassing known and innovative technologies. However, the amount of resources and commitment necessary would be incompatible with the requirements and range of this thesis. For this purpose, as it was previously delimited in the research questions, the analysis will be limited to the segment this study deemed most relevant, namely the offshore wind sector.
The scope of the paper is also limited with regards to an additional factor. More specifically, the study uniquely aims to provide a quantitative assessment of the exposure to merchant risk. The research hence does not include other types of risks (e.g. technology risks, supply chain risk). The rationale behind this limitation is twofold. First, precise data with regards to the distribution of other risks was not easily accessible. Secondly, the authors believed the risk analysis should be focalized on the financial discipline in line with the expertise maturated during the master program. As a result, the analysis of the volatility of the investment will be only be measured against the volatility of the market. Further research should then try to expand the model toward the analysis of different types of alternative investments as well as exploring the combined effects of additional risk sources.

A further limitation is related to the data collection. For the purpose of the study, the paper will analyze a benchmarked offshore wind farm with construction start in 2020. The estimates of the site characteristics as well as the costs incurred are therefore rounded averages of what could be expected from offshore wind installations built before 2025. The choice was driven by the necessity to focus the study on projects that could be subject to the new regulation and characteristics of the electricity market. As it happens, offshore wind farms' attributes are extremely technology and site specific. Small variations with regards to the inputs of both dimensions greatly affect the distribution of costs and therefore the outlook of an investment (BVG Associates, 2019b).
While the sensitivity analysis proposed should help addressing this variability, the authors believe that a final investment decision by the institutional investors should take into considerations adjustments of the inputs in order to better reflect the investment opportunity at hand. In addition to that, it should be stressed that the validity of the data presented by the research is somewhat short term. As a matter of fact, the industry is developing extremely quickly making existing technologies as well as investment evaluations obsolete in a short span of time. At the same time, current developments in the global scenario created significant uncertainties that are not yet reflected in the data collected. Therefore, the analysis proposed by the study will provide a pre-Covid-19 outlook.

A final consideration has to be made with regards to the validity and relevance of the findings. In particular, the results of the portfolio integration chapter will be the outcome of a theorical exercise that does not fully account for the complexity of the real world. For the portfolio analysis the authors have used a fixed volatility level of 6% to represent the risk appetite of the average pension fund. This assumption is a clear limitation of this thesis as it assumes that all pension funds have the same risk aversion equal to 6% volatility. pension funds are distinct in type, size and hence subject to different internal and external regulations that might influence their risk preferences. The results therefore do not have a universal relevance to all pension funds but can only be applicable to those that have similar portfolios to the ones described in this research, under the assumptions made. To conclude, the findings provide a general guidance to assess the attractivity of the presented investment, acknowledging that outcomes could vary at the individual pension fund level, where additional considerations must be made. The research limitations extend further as the model relies on both industry and personal assumptions with regards to evaluation models, costs, prices and deal structure. These will be introduced and fully detailed later in the study.

3. Financial Literature

The purpose of this chapter is to provide a delimitation of the theoretical frameworks applied in the study. The evaluation techniques employed in the financial model will be first introduced, followed by the risk management approach selected for the research, that is the Monte Carlo Simulation. The chapter will then be concluded with an outline of the theory behind the portfolio analysis.

3.1. Evaluation Models

According to Damodaran (2007), valuation lies at the very core of the financial disciplines essentially constituting their “heart”. Essence of evaluation models is to extract and ultimately define the “true value” of a firm or investment (Petersen, Plenborg, & Kinserdal, 2017). As it happens, meaningful decision making could only be provided after defining this value as well as its drivers (Damodaran, 2007). Both research and practice have been prolific on the subject and as a result, multiple approaches for the determination of an investment’s value exist. It becomes critical then to determine the merits and limits of these methods in order to find the framework that best fits the study at hand. Petersen et al. (2017) classify these models into four distinct categories. A first approach is described by present value models where the analysis of future cash flows becomes the reference for the firm/asset evaluation. A second approach propose estimating the target value by referencing to specific financial metrics of “comparable” companies. Alternatively, the authors suggest methods based on the estimate of the market or book value of a firm’s existing assets. The last category describes contingent claim valuation models where assets are evaluated based on real option theory.

The first step in determining the best fit for the case is understanding the nature of the investment. As previously mentioned in the methodology section, the analysis of the wind farm takes a project finance approach. More specifically, the renewable project will be developed under the structure of an SPV, a legal entity completely detached from the organizational structure of the equity contributors (Mora et al., 2019). Under this configuration, accrued liabilities for the project do not hold claims on the owner’s balance sheets and are defined as non-recourse (Esty, 2004). It can be deducted that potential cash flows are effectively the only source for repayment of debt and contributions to equity holders (Mora et al., 2019).

Because of the key role that cash flow constitute within a project, the authors believe present value approaches to be the most relevant for the case.

3.1.1. Net Present Value

The traditional corporate finance approach to the assessment of an asset relies on the discounted cash flow evaluation. According to this technique, the intrinsic value of an investment is related to the future expectations of cash flows which are discounted at appropriate risk adjusted rates (Damodaran, 2007).

In turn, these models are differentiated according to the cash flow proxy being analyzed (Torrez, Al-Jafari, & Juma'h, 2006). An analysis of the value for the equity holders is usually provided through the dividend discount model. However, within the field of project finance, we operate under the assumption that all left over cash flows generated by the project are distributed to the owners of the special purpose vehicle. As a result of this consideration, the dividend discount model can be generalized with the Free Cash Flow to Equity analysis (FCFE).

Equity NPV

$$Equity\ NPV = I_0 + \sum_{t=1}^{n} \frac{FCFE_t}{(1+R_e)^t} + \frac{FCFE_{n+1}}{R_e - g} * \frac{1}{(1+R_e)^n}$$

$NPV = net\ present\ value$
$FCFE = free\ cash\ flow\ to\ equity\ holders$
$R_e = levered\ cost\ of\ equity$
$g = cash\ flows\ growth\ rate$
$t = time\ period$
$I_0 = starting\ investment$
$n = periods\ number\ in\ the\ forecast\ term$

Formula 3.1 Source: Own depiction based on Petersen et al. (2017)

The formula displayed above provides the excess return value for the equity holders of the asset where future cash flows to equity are tested against the magnitude of the initial investment. These cash flows are distinguished between the ones accrued in the forecasting period (first term) from the ones predicted in the terminal period (second term), which are expected to grow at a constant rate "g". Cash flows are then discounted at the relevant cost of equity capital.

An alternative method is to directly calculate the value of the project (Damodaran, 2007). More specifically, the approach considers the entire array of free cash flows to the firm extracted under the assumption of a fully unlevered capital structure. Debt effects are the factored into the calculation by discounting these cash flows at the after tax weighted average cost of capital. The process can be described with Formula 3.2 presented below.

Project NPV

$$Project\ NPV = I_0 + \sum_{t=1}^{n} \frac{FCFF_t}{(1+WACC)^t} + \frac{FCFF_{N+1}}{WACC-g} * \frac{1}{(1+WACC)^n}$$

$NPV = net\ present\ value$
$FCFF = free\ cash\ flow\ to\ the\ firm$
$WACC = weighted\ average\ cost\ of\ capital$
$g = cash\ flows\ growth\ rate$
$t = time\ period$
$I_0 = starting\ investment$
$n = periods\ number\ in\ the\ forecast\ term$

Formula 3.2 Source: Own depiction based on Petersen et al. (2017)

On a similar note to the previous equation, the cash flows are tested against the value of the initial investment required. Benefits of the second approach is the possibility to extract the cash flows on a pre-debt basis (Damodaran, 2007).

3.1.2. Cost of Equity

The introduction to the evaluation methods sparks the need for further analysis. In particular, the model requires an understanding of the relevant cost of capital computed in the calculations. This section starts by presenting the steps required to identify the appropriate equity rate of return.
According to the literature, different approaches exist with regards to the estimation of the relevant cost of equity. Eventually, all these models aim to establish a relation between the risk of the investment and the resulting required return (Kolouchová & Novák, 2010).
A first approach is identified by the dividend discount model commonly represented by Gordon´s Wealth Growth Model (Nhleko & Musingwini, 2016). As stated by the theory, the investors´ required rate of return is ultimately defined by the dividends payouts and the price of the underlying stock (Nhleko & Musingwini, 2016). It should be immediately noted that the approach is indeed incompatible with project and/or companies that do not present a perpetual stream of dividends and has therefore limited applications in practice.
An additional approach is described by the capital asset pricing model (CAPM) proposed by Sharpe (1964) and Lintner (1965). Under this methodology, the cost of equity for an investment is

estimated from historical data under the assumption that these will correctly indicate future performances (Nhleko & Musingwini, 2016).

Overall, researchers have not reached a consensus with regards to the "best" approach when estimating the cost of equity (Pratt, 2008). Indeed, flaws within the models can be identified in all the methodologies proposed. Nevertheless, the CAPM is the most commonly used approach by practitioners (Graham & Harvey, 2001). Accordingly, the CAPM is the technique employed by this study.

The capital asset pricing model essentially describes a linear relationship between the expected return from the investment and its inherent risk (Širůček & Křen, 2015). This is best described in the Formula 3.3 shown below.

Required return on Equity

$$R_e = R_f + \beta(R_M - R_f)$$

$R_e = required\ return\ on\ equity$
$R_f = risk\ free$
$R_M = market\ return$
$\beta = project\ beta$

Formula 3.3 Source: Own depiction based on Bodie, Kane, & Marcus (2014)

As the formula shows, the cost of equity is obtained by adding to the risk-free rate the market premium adjusted by the risk of the investment identified by the Beta factor. It should be noted that under the capital asset pricing model, investors are only compensated for being exposed to the systematic risk of the market under the assumption that the specific unsystematic risk can be fully eliminated through diversification (D'arcy & Dyer, 1997).

3.1.2.1. Risk free and Risk premium

The risk-free rate is usually defined as the rate of return an investor could safely expect to realize without incurring in any risk (Petersen et al., 2017). Under the current practice, government bonds are typically considered as a proxy of risk-free investments (Petersen et al., 2017). For the analysis of long-lived projects, there is a debate on whether a 10-year or 30-year bond would closely resemble the most appropriate risk-free rate for the analysis. For the purpose of this study, the authors rely on the argument provided by Damodaran (2008) stating that a 10-year government security of a mature market is the best fit for project evaluation. To keep consistency with the analysis of wind farm located in the United Kingdom, the risk-free rate will be extracted from the 10-year UK government bond.

The excess return of the stock market portfolio over the risk free is defined as Equity risk premium (Fama & French, 2002). The metric is critical for the application of the CAPM model and, as it happens, multiple approaches for its estimate exist. The risk premium could be derived from historical data on stock returns, as well as by analyzing the current equity prices for an estimate of future premium expectations (Schröder, 2007). A third approach where the metric is estimated by surveying investor expectations is also proposed in the literature (Fernandez, 2009). For the scope of the evaluation, the authors believe that an implied estimate of the equity risk premium constitutes the best fit. The rationale derives from the higher "predictive power" of this approach and it relies on the efficiency of the target market (Damodaran, 2017).

3.1.2.2. Beta

According to the CAPM formula explained above, the Beta provides an estimate of the systematic risk undertaken by the investors when they make an investment (Levy, 1984). The metric symbolizes the co-dependence and sensitivity of the investment's returns with the movements of the market (Rossi, 2016).
Provided that a beta value of 1 is identified with the market risk itself, coefficients higher than 1 are representative of investments that are more volatile than the market (Levy, 1984). The opposite holds for values lower than 1. Unsurprisingly, the risk-free asset presents a Beta factor equal to zero (Rossi, 2016).

The Beta value can be estimated in several ways. The results of a survey conducted on 2,500 professors by Fernandez (2016) ultimately proved that there doesn't seem to be a homogeneous way to calculate this metric. On way is to extract the Beta from historical data through a statistical regression where the asset/investment returns are tested against a comprehensive market index (Damodaran, 1999). Again, the methodology based on a backward-looking approach could be claimed defective with regards to its actual predictive power. Nevertheless, it is widely employed by practitioners (Damodaran, 1999).

Provided that the aforementioned approach will be the one selected by the study, its direct applicability will not be possible. Renewable energy projects are not publicly listed on exchanges. Therefore, a statistical regression will not be possible.

The alternative approach will be based on an analysis of comparable companies (Petersen et al., 2017). More specifically, this study will calculate the Betas of selected listed companies operating in the offshore wind industry and consider the average of these values as the project's beta.

Finally, it should be noted that the CAPM technique requires the levered beta of the project. That is a measure of the covariance with the market returns that takes into account the adjusted after-tax risk of leverage. Under this consideration, Beta coefficients obtained from the proposed analysis need first to be unlevered according to the debt structure of each company. The obtained results will then be averaged out. As a final step, the gained equity beta will be adjusted for the financial leverage of the project. The procedure is described in the Formula 3.4 presented below.

Levered and Unlevered Beta

$$\beta_L = \beta_U * \left(1 + (1 - T)\frac{Debt}{Equity}\right)$$

$\beta_L = beta\ levered$
$\beta_U = beta\ unlevered$
$T = tax\ rate$

Formula 3.4 Source: Own depiction based on Bodie et al. (2014)

3.1.3. Weighted Average Cost of Capital

Having established the levered cost of equity, it is possible to then calculate the weighted average cost of capital. Formula 3.5 depicted below takes into consideration all funding sources with regards to the proportions of the capital each contributed. The cost of debt required by the formula is extracted from the interest rates required by loan providers.

WACC

$$WACC = \frac{Debt}{Debt + Equity} * R_d * (1 - T) + \frac{Equity}{Debt + Equity} * R_e$$

$WACC = weighted\ average\ cost\ of\ capital$
$R_e = levered\ cost\ of\ equity$
$R_d = cost\ of\ debt$
$\mathrm{T} = tax\ rate$

Formula 3.5 Source: Own depiction based on Brealey, Myers, & Allen, (2011)

3.1.4. Adjusted Present Value

The frameworks described above are extensively applied in both financial theory and practice. However, the authors believe that some flaws in the approach could significantly affect the evaluations proposed in this research. In particular, a few considerations should be made with regards to the levered cost of capital estimated with the CAPM model and the WACC. The authors believe that their static natures do not adjust to the characteristics of the project finance model analyzed in this paper. More specifically, the leverage structure of the investment is extremely variable. Debt levels are at the peak in the first years when loans are undertaken and then gradually decrease to zero as the tenure date is reached. As a result, a calculation of the levered cost of equity and resulting WACC might not provide the best estimate of the project's cost of capital. Therefore, this thesis deems valuable an evaluation approach based on the Adjusted Present Value method.

The model was first introduced by Myers (1974). The model can be essentially described according to the equation below. The formula already accounts for no terminal period as the analysis focuses only on cash flows accrued during the operating life of the project.

APV

$$APV = I_0 + \sum_{t=1}^{n} \frac{FCFF_t}{(1+R_e)^t} + \frac{TS_t}{(1+R_d)^t}$$

$APV = adjusted\ present\ value$
$FCFF = free\ cash\ flow\ to\ the\ firm$
$\mathrm{TS} = tax\ shield$
$R_e = unlevered\ cost\ of\ equity$
$R_d = cost\ of\ debt$
$\mathrm{t} = time\ period$
$\mathrm{I}_0 = starting\ investment$
$n = periods\ number$

Formula 3.6 Source: Own depiction based on Brealey et al. (2011)

The value of the investment is therefore described as the combined effect of a debt free, unlevered cash flow (first term) and the present value of the debt effects (second term), measured through the tax shields payments (Fernandez, 2005; Myers, 1974). The model provides a clear advantage in the evaluation of a project with variable leverage ratio. While the WACC approach assumes a static capital structure through a fixed discount rate, the APV accounts for the effects of debt only when those are accrued. The effects are then added to the base evaluation of the unlevered company (Damodaran, 2007). It should be noted that even this method is not impeccable. There have been debates over the years with regards to the appropriate discount rate for the present value of the tax shields (Fernandez, 2005). Some researchers argue that tax shields should be discounted at the unlevered cost of equity (Harris & Pringle, 1985; Kaplan & Ruback, 1995). This paper follows the original approach of discounting tax shields at the relevant cost of debt (Luerhman, 1997; Myers, 1974).

3.1.4.1. Tax Shields

The previous paragraph introduced the necessity to calculate the tax shield in order to apply the adjusted present value method. The simplified approach to the calculation identifies the estimate as the multiplication of the interest expenses for a given year with the current corporate tax rate. However, this study believes that that procedure requires a further elaboration. More precisely, under specific situations, the firm/project is not capable to fully enjoy the benefits of tax shield (Velez-Pareja, 2016).

Tax Shield			
$EBIT_{adj} \geq FE$ $TS = T * FE$	$0 < EBIT_{adj} < FE$ $TS = T * EBIT_{adj}$	$EBIT < 0$ $TS = 0$	$EBIT_{adj} = EBIT + other\ net\ income$ $FE = financial\ expenses$ $T = tax\ rate$

Formula 3.7 Source: Own depiction based on Vélez-Pareja (2016)

The Formula 3.7 describes three different scenarios leading to different calculations of the tax shield. The first scenario describes the textbook approach to the calculation. Indeed, when the adjusted EBIT is positive and higher than the financial expenses, the tax shield is fully earned. However, it is possible that while operating profits are positive, they might be lower than financial expenses. Under this setup, the tax shield is calculated by multiplying the adjusted EBIT by the tax rate. It should be noted that in this scenario no taxes are ultimately paid by the firm/asset. However, it would be incorrect to assume that tax shields are not earned in this situation(Velez-Pareja, 2016). Finally, when the operating income is negative, no tax shield is realized.

The described equations provide a suitable approach to the calculation of the tax shield. Nevertheless, this approach is bound to certain assumptions that rarely hold in practice. Some of these are effectively breached when the payments of taxes are advanced or delayed with respect to their accrual (Velez-Pareja, 2016). As a matter of fact, the financial model built for this thesis allows for the carry forward of net operating losses. In order to account for this possibility, the tax shield was calculated as the difference in tax payments between the actual levered project and the unlevered counterpart. The methodology is accurate only under the consideration that no interest income is applicable to the case study (Velez-Pareja, 2016).

3.1.5. Internal Rate of Return

As this study aims to assess the investment's financial performance, a valid proxy for the investment's annual expected return needs to be identified. This research believes that the Internal Rate of Return approach suggested by Boulding (1935) would best fit the purpose. Calculation of the metric is presented by Formula 3.8 below. The IRR is presented as the rate that would make the NPV equal to 0.

IRR

$$NPV = \sum_{t=0}^{n} \frac{CF_t}{1 + IRR} = 0$$

$NPV = net\ present\ value$
$CF = cash\ flow$
$IRR = internal\ rate\ of\ return$
$t = time\ period$
$n = periods\ number$

Formula 3.8 Source: Own depiction based on Brealey et al. (2011)

The methodology of the IRR has been extensively discussed over the years with plenty of researchers and academics intensely criticizing its shortcomings. It has been proved indeed that the IRR has several limitations and does not correspond to the actual rate of return of a project (Crean, 2005; Volkman, 1997). In particular, it has been described how under specific conditions the IRR might present multiple or no solution at all. The method might as well present flaws in ranking mutually exclusive projects and in considering the scale of the investment (Brown, 2006). It is at the same time widely accepted that irregularities and imprecisions are common to all evaluation approaches. Researchers tried over the years to propose alternative metrics to the IRR (Solomon, 1956). However, none of these has proved to possess fewer flaws (Volkman, 1997). The purpose of the thesis is not to provide a revolutionary and impeccable method of evaluation. It is instead to provide estimates in line with the best practices applied in the academia and in the industry. As a matter of fact, the approach of assuming the IRR as the return on the investment has been taken by different researchers (e.g. Muñoz, Sánchez de la Nieta, Contreras, & Bernal-Agustín, 2009).

Therefore, this research endorses the IRR approach as a proxy for analyzing the profitability of the investment. At the same time, limitations are stated for a better understanding of what the results of the analysis might entail.

3.1.6. Volatility of Returns

Having identified the proxy for the investment return, the research requires now an assessment of the project's risk, namely the volatility of the returns.

A widely used approach for the volatility estimation is the "Logarithmic Cash Flow Return Approach" (Lewis & Spurlock, 2004). According to this methodology, the returns could be calculated from either the historical or the future project's cash flows as described by the Formula 3.9 displayed below.

Logaritmic Cash Flow Return

$$R_i = Ln\left(\frac{CF_t}{CF_{t-1}}\right)$$

$R_i = return\ on\ logaritmic\ cash\ flows$
$CF = cash\ flow$
$t = time\ period$

Formula 3.9 Source: Own depiction based on Lewis and Spurlock (2004)

While the computational procedure is quite straightforward, considerations should be made with regards to the nature of the cash flows. If the data series contains a negative figure, an inaccurate volatility estimate would be generated as the logarithm of a negative number cannot be returned (Lewis & Spurlock, 2004). An alternative method is the "Normal Cash Flow Return" approach.

Normal Cash Flow Return and Volatility

$$R_i = \frac{CF_t}{CF_{t-1}} - 1$$

$$\sigma = \sqrt[2]{\frac{1}{n-1}\sum_{i=1}^{n}(R_i - \bar{R})^2}$$

$R_i = normal\ return\ on\ cash\ flows$
$CF = cash\ flow$
$t = time\ period$
$\sigma = cash\ flows\ volatility$
$\bar{R} = mean\ cash\ flows\ return$
$n = number\ of\ cash\ flows$

Formula 3.10 Source: Own depiction based on Lewis and Spurlock (2004)

This technique accounts for the possibility of having negative cash flows, which is plausible when it comes to real investment evaluations (Lewis & Spurlock, 2004). The Formula 3.10 above presents the equations for the normal distributed return calculation and the cash flows series' volatility.

3.2.Risk Management

The first part of the research question proposed by this thesis introduces the need to assess the effects of merchant risk exposure. As a result, the evaluation models individuated in the previous section need to be complemented with frameworks and tools capable of capturing this risk factor. These tools are extracted from the discipline of risk management.

Within the field of renewable energy, the focus of risk management practices lies in the appraisal of factors that ultimately affect the cash flows of the project (Arnold & Yildiz, 2015).
As stated in the delimitation section, this study will predominantly analyze the risks that are related to the revenue-side of an offshore wind investment. These are represented by the uncertainty in the future wholesale electricity prices, to which investors are going to be exposed in a scenario with no guaranteed fixed prices coming from subsidy schemes.

The proposed method for the assessment of this risk is the Monte Carlo simulation, which will be employed for the evaluation of the equity internal rate of return (IRR), the adjusted present value (APV) and the overall volatility of the cash flows.

3.2.1. Monte Carlo Simulation

The Monte Carlo Simulation is a widely used statistical technique in the field of risk management and decision making (Rezaie, Amalnik, Gereie, Ostadi, & Shakhseniaee, 2007). The model dates back to the 1940s when it was first presented to the public (Metropolis & Ulam, 1949). Ever since, the popularity of the model increased exponentially and paired with other computational software, Monte Carlo has been progressively called to address the complexity of the real world (Eckhardt, 1987). Kelliher and Mahoney (2000) apply Monte Carlo in order to improve "long term investment decisions" within the real estate market. Buchner (2017) applies the model as part of a framework for risk assessment in private equity investments. Shaffie and Jaaman (2016) proposed the application of the technique towards the enhancement of capital budgeting decisions. Even within

the power industry, engineering and investment decisions have been addressed through Monte Carlo simulations.
The rationale behind the extensive application of the method lies behind the capability of Monte Carlo to picture several scenarios where numerous variations of the inputs are computed according to their inherent uncertainty (Brealey et al., 2011). As a matter of fact, the model succeeds in overcoming the weaknesses of single-point estimate models such as sensitivity analysis or the traditional capital budgeting models that are limited to the portrayal of single scenarios (Spinney & Watkins, 1996). The use of the formal probabilistic approach is considered an advantage, as not only the possible outcomes can be simulated, but also their likelihood. At the same time, the drawbacks of the method include the computational burden (Katz, 2002). Figure 3.1 below details the stages required for the correct application of the model.

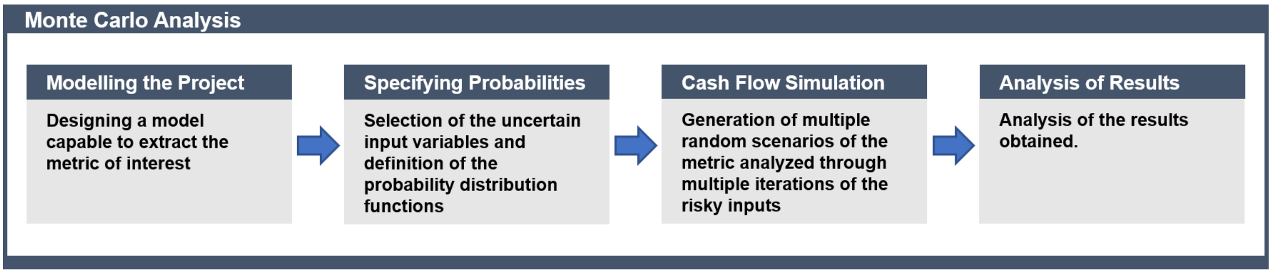

Figure 3.1 Source: Own depiction based on Brealey et al. (2011)

In the context of a financial analysis, the Monte Carlo simulation procedure starts with the construction of the reference project cash flow sheet which should include all relevant relationships between the input variables (Katz, 2002). The next step is to identify critical variables/parameters that have an impact on the economic performance of the project. The selection of these inputs requires the determination of each variable's distribution function (Brealey et al., 2011). Finally, the Monte Carlo simulation generates multiple scenarios where each selected input randomly fluctuates according to its probability distribution.

Critical to the accurate application of the Monte Carlo simulation is the uncorrelation of the input variables. The extraction of random samples from variables that do exhibit a correlation with one other would ultimately result in a flawed analysis (Arnold & Yildiz, 2015). For the purpose of this research, the electricity wholesale prices for the UK market have been selected as the input variable of the risk analysis. As no other inputs are subject to analysis, the correlation concern can be considered addressed.

The difficulty in the implementation of the Monte Carlo approach is the determination of the inputs' distribution function. It is important that the variables in the analysis resemble expected values and hence reflect the future rather than the past. The layout of the input variables should be based therefore on forecasts, expert analysis or when these are not available, historical data is utilized with the assumption that the expected future values have the same distribution and probability function as the past values.

In the application case presented within this paper, a derivation procedure was applied for the input´s probability distribution function. In particular, the expected future wholesale price volatility was assumed to reflect its historical value.

Monte Carlo simulations are conducted in this paper to account for merchant risk in the financial analysis of a wind farm investment. Based on the given assumptions, the analysis is performed for a 25-years period. The outcome of the model will be a graphic representation of the most relevant financial metrics (i.e. APV, IRR).

An Excel add-in software called ModelRisk was used for the computations.

3.3. Portfolio Theory

The complete answer to the research question established by the study requires an appraisal of pension funds' portfolios. The proposed analysis leverages on the frameworks proposed by Markowitz (1952), the leading figure in modern portfolio theory. In his publication he identified risk and return as the sole determinants of investment decisions. The mean-variance theory proposed by Markowitz (1952) allows investors to maximize their expected return on the portfolio at any chosen level of risk.

The ground-breaking approach proposed by this theory was the focus on the correlation of the expected returns and their combined effect, rather than just analyzing each asset individually (Elton & Gruber, 1997). The mean-variance approach ultimately allows for a less risky portfolio composition compared to alternative approaches that disregard the returns' interdependencies (Elton & Gruber, 1997).

3.3.1. Stages of Portfolio Analysis

Under the assumptions of modern portfolio theory, rational investors either seek to maximize the returns at a given level of risk, or alternatively to minimize the risk for a predetermined expected return (Omisore, Yusuf, & Christopher, 2012). According to the theory proposed by Markowitz (1952), provided a pool of alternative securities, the portfolios that maximize the returns at any risk level lie on what is defined as the efficient frontier.

The identification of these optimal compositions of assets essentially requires addressing the trade-off between portfolio return and volatility. These two measures are estimated according to the equations presented in Formula 3.11 below.

Portfolio Return and Volatility

$$E(R_P) = \sum_{i=1}^{n} w_i E(R_i)$$

$$\sigma_P = \sqrt[2]{\sum_{i=1}^{n} \sum_{j=1}^{n} w_i w_j Cov(R_i, R_j)}$$

$E(R_P) = expected\ return\ on\ portfolio$

$E(R_i) = expected\ return\ on\ asset\ i$

$w_i = asset\ i\ weight\ in\ portfolio$

$\sigma_P = portfolio\ volatility$

$Cov(R_i, R_j) = Covariance\ between\ asset\ i\ and\ j$

Formula 3.11 Source: Own depiction based on Bodie et al. (2014)

The total portfolio return is calculated as the sum-product of each asset's return by its weight in the portfolio. The portfolio volatility instead is measured by taking into account the portfolio weights, the single assets' variances and the covariance of each asset with all the others. An alternative way to calculate the volatility is to use matrix mathematics (Bodie et al., 2014).

While the efficient frontier could be drawn by maximizing the portfolio return at each level of risk, a quicker way is through the calculation of two Portfolios only: the minimum variance portfolio and the tangent portfolio which is characterized by the optimal risk-return profile. The efficient frontier can then be found as a combination of the two, putting different weights on each to identify the single data points of the efficient frontier (Omisore et al., 2012). As stated above, each Portfolio lying on the Efficient Frontier presents the maximum possible return for a given level of risk.

This relation between the incremental excess return over risk was first described by Sharpe (1964) and is represented by the equation below.

Portfolio Sharpe Ratio

$$S_P = \frac{E(R_P) - R_f}{\sigma_P}$$

$S_P = portfolio\ sharp\ ratio$
$E(R_P) = expected\ return\ on\ portfolio$
$R_F = risk\ free$
$\sigma_P = portfolio\ volatility$

Formula 3.12 Source: Own depiction based on Bodie et al., (2014)

It should be noted that modern portfolio theory allows for an additional investment in a riskless asset. Higher Sharpe ratios are available through a combination of the tangent Portfolio and the risk-free security (Bodie et al., 2014). The introduction of the risk-free asset expands the possibility to reach returns beyond the "limits" imposed by the efficient frontier of risky assets. Investors can in this way obtain any risk-return combination individuated by the capital allocation line (CAL).

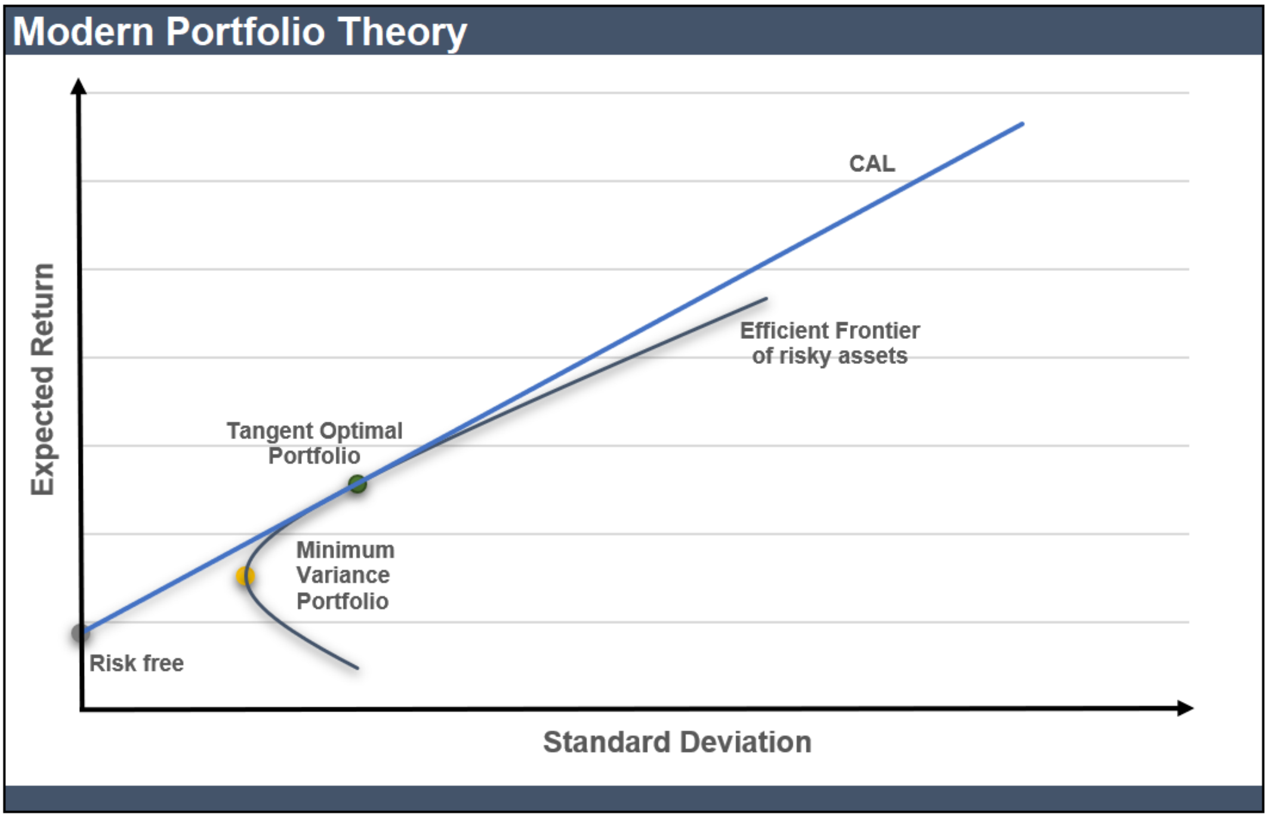

Figure 3.2 Source: Own depiction based on Bodie et al. (2014)

As can be seen in the graph presented in Figure 3.2 above, the CAL constitutes a straight line originating from the risk-free assets and tangent to the efficient frontier. Under the perfect market assumptions, investors can freely move on this line by overinvesting or shorting in the Tangent

Portfolio at the risk-free rate (Bodie et al., 2014). This research however will disregard the CAL and only consider risky portfolios with maximized Sharpe ratios lying on the Efficient Frontier.

3.3.2. Theory Limitations

While this study's approach significantly leverages on the modern portfolio theory proposed by Markovitz (1952), the authors recognize that the practical applications require additional considerations and limitations that cannot be fully grasped by theory (Elton & Gruber, 1997). It is therefore recognized that the theoretic model leverages on significant assumptions. In particular, markets are assumed to be efficient and at the same time to be excluding transaction costs or taxes (Mangram, 2013; Markowitz, 1952). Similarly, investors are assumed to possess complete information, be consistently rational and always exhibiting utility maximizing behaviors (Mangram, 2013; Markowitz, 1952). In practice we find that this is rarely the case. For example, the assumption that investors do not possess credit limit and can freely buy or short at the risk-free rate is strongly contested in this study (Omisore et al., 2012).

The pension fund portfolio analysis in chapter 8 will provide a clearer representation of the limitations recognized by this study and how these were factored within the calculations.

4. Pension Funds

The purpose of this chapter is to provide an analysis of UK pension schemes and their investment objectives. The chapter will also include an assessment of alternative investments that could represent appealing instruments for pension funds' investment strategies.

4.1. General Overview

A benchmarked 60/40 portfolio consisting of 60% global equities and the remaining 40% invested in fixed income securities returned 19.3% in 2019. At the same time, the average global pension fund portfolio return was 15,2%. The key consideration from those figures is that pension funds are shifting away from what used to be the "normal" investment portfolio (Segal, 2020). Recent trends suggest that these institutional investors are increasing their exposure to alternative investments. Allocations to those assets (e.g. infrastructure, private equity) have increased to 23% compared to the approximate 6% share of two decades ago (Segal, 2020).
While this more diversified asset allocation was effectively outclassed in 2019 due to a bull market, the transformation is not expected to revert back to the traditional portfolio version (Segal, 2020). As a matter of fact, increased allocation to infrastructure, private equity and real estate projects constitute a countermeasure to the current outlook of decreasing interest rates as well as increasing life expectancy (APPG, 2019).

According to Schich, Antolin, & Yermo (2011), pension funds could actually enact different strategies to address the funding pressure generated by the increased liabilities and the decreased fixed income instruments' appeal. A first option lies in the increase of the assets' duration to allow for a better harmonization between assets and liabilities. An alternative could then also be represented by systematically addressing pension policies, more specifically by requesting increased contributions as well as lowering the amount distributed to beneficiaries. The fourth one, which is also the one that is covered in this research, concerns a review of the investment strategies by looking into alternative sources of return to public equities and bonds. (Schich et al., 2011).

While the year 2019 provided an argument for a classical 60/40 portfolio, research from Aberdeen Standard Investments (ASI) (2019) states that the strategy would not be efficient. Figures over the last two decades suggested an average annual return of just over 7% for a conventional 60/40 combination. Most notably, for UK pension funds which are the focus of this research, returns are expected to fluctuate around an annual mean of 3% (ASI, 2019). The decrease in compounded benefits from the lower expected returns could heavily affect the capability of UK pension funds to meet their liabilities. As a result, the attention should be strongly directed to alternative ventures (ASI, 2019).

Given our focus on the United Kingdom, the next part of the paper will focus on the description of the country's pension types and investment strategies that the typical pension fund pursues.

4.2. Pension Types

The basis of the current pension arrangements in the United Kingdom date back to over a century ago when the Old-Age Pension Act was introduced in 1908 (Thurley, 2008). These provisions overruled the outdated regulatory practices established by the Poor Law of the 19th century which did not effectively cover retirement arrangements (Thurley, 2008). The purpose behind the edict was to provide financial income to those residents that were no longer able to be part of the workforce (APPG, 2019).

Over the years, provisions addressing citizens leaving the active workforce have been revised and complemented (i.e. National Insurance Act of 1946). Private companies also began to take the role of pension providers with regards to their retiring employees (APPG, 2019).
The early stages of pension provisions were characterized by defined benefits (DB) schemes. Under those arrangements, after their retirement pensioners were granted a fixed stream of income in exchange of defined salary contributions during their active work life (APPG, 2019). It should be noted that DB schemes allow for a mismatch between the contributions of the worker and the benefits received during the retirement life. In some instances, the guaranteed fixed pension could translate into retired workers receiving more than what they effectively contributed. Pension funds actively addressed this gap by reinvesting contributions and relying on the support of new members joining the workforce (APPG, 2019).

Over the years, demographic changes in the developed countries resulted in a significant pressure on the mechanics of defined benefit schemes. Phenomena such as an increased life expectancy and a shrinking workforce increased pension funds' liabilities (Cocco & Lopes, 2011). As can be evinced from the Figure 4.1 below, the UK has experienced a solid increase in the segment of population at the age of 65 and above, effectively constituting over 18% of today's population.

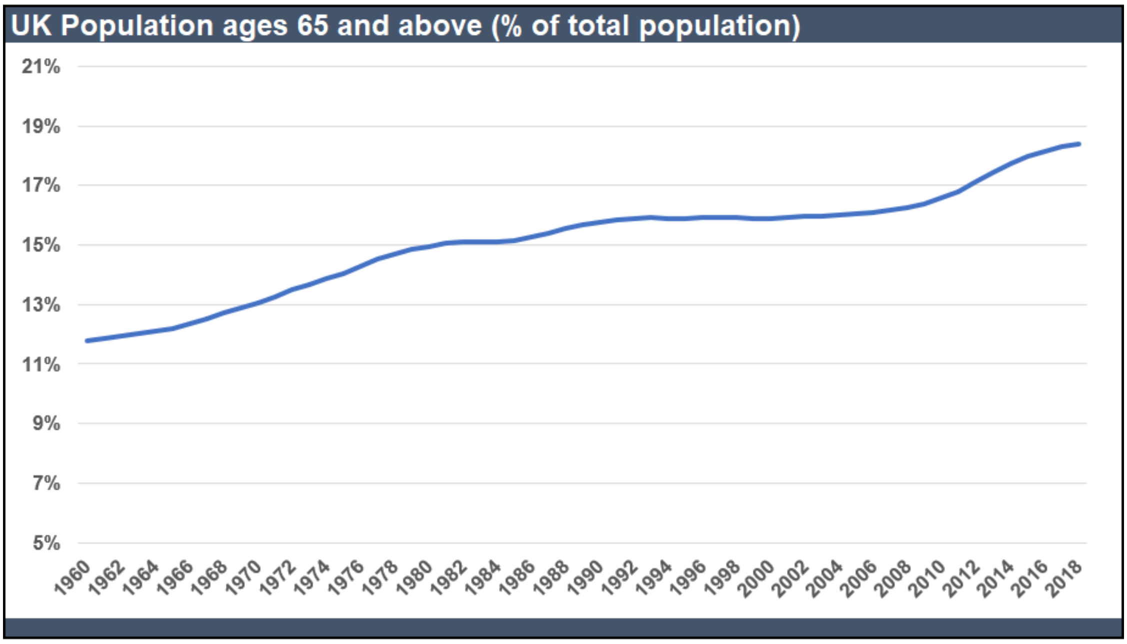

Figure 4.1 Source: Own depiction based on APPG (2019) and The World Bank (2019)

The situation has been further exacerbated by the low rates of return that have characterized the market in recent years, making it more difficult for pension funds to cover the funding gap with the returns over their investments (APPG, 2019).

As a reaction to this problem, the so-called "defined contribution" (DC) plans have increased in popularity (Choi, 2015). Under a defined contribution scheme retired workers do not receive a predetermined amount, rather their final benefits amount to their direct contributions as well as the capital gains accrued as a result of the pension fund investments (Choi, 2015). This ultimately resulted in a shifting of the risks (APPG, 2019). According to The Pensions Regulator (TPR) (2020), in the United Kingdom, DC schemes currently dominate the private sector while DB plans are still widely employed in the public segment. The surge in defined contribution plans can also be attributed to the regulatory edicts on automatic enrollment (AE). Unless specifically requested by the worker, the policy provides for the automatic enrollment of the individual in its company's pension scheme (APPG, 2019).

4.3. Investment Choices

Defined benefit and defined contribution schemes stand at the opposite end of pension investment strategies with hybrid combinations in between (EFAMA, 2008). As it happens, the differences between the two arrangements are not uniquely represented by the income amount provided to the retired workers. They are actually characterized by different goals and a different exposure to risks that ultimately result in distinct investment strategies (APPG, 2019).

4.3.1. Defined Benefit Schemes

According to the provisions established by DB schemes, eligible citizens enjoy a pre-determined income after retirement (APPG, 2019). As a result, the main objective of DB pension schemes is to honor this obligation when it becomes due. Differently from other investors who assess risks in terms of expected returns, defined benefit schemes measure risks according to their capability of repaying their beneficiaries (APPG, 2019).

The traditional approach to meet these requirements relied on a combination of bond and global equities (APPG, 2019). Only recently, DB pension funds have started to increase their exposure to alternative investments. Under the benefits of fixed long-term investment horizons, these funds pursued absolute return strategies by investing in illiquid markets and real assets (APPG, 2019). The rationale behind the strategy is the possibility to reap both diversification and illiquidity premium benefits (Dimson & Hanke, 2004).

4.3.2. Defined Contribution Schemes

Differently from defined benefit plans, the scope of DC schemes is to optimize the final retirement pension against workers´ contributions during their working life. This process of optimization is achieved by allowing contributors to personally select different fund options according to their appetite for superior returns and correlated risks (APPG, 2019). The possibility for beneficiaries to actively decide how to allocate the contributed capital, demonstrates how the introduction of DC plans initiated a transition in which individuals are increasingly accountable for their retirement savings as well as the risks incurred (Choi, 2015). Despite the possibility of customization, current figures suggest that the default plan (the one new members are automatically enrolled in) is the one chosen by almost all individuals (APPG, 2019).

Another profound distinction between DB and DC is that defined contribution plans are heavily constrained by both regulatory policies and operational practices. As a matter of fact, DC funds must provide a justification for the selected investments that are not traded on regulated markets. In case those get approved, they still must be limited to a small fraction of the investment's total capital, which is set by the individual fund (APPG, 2019). In addition to that, DC schemes are also constrained with regards to the annual administrative charges they can levy on contributors. According to a report from the Department for Work & Pensions (DWP) (2016), the amount is effectively restricted to 0,75% of the total individual's contributions. Lastly, operational practices require DC schemes to be able to offer a "daily liquidity" (The Investment Association, 2018). Combined, these factors translate into defined contribution schemes investing in low-cost liquid investments. (APPG, 2019).
A detailed composition of the typical UK DC scheme portfolio in 2018 is portrayed below.

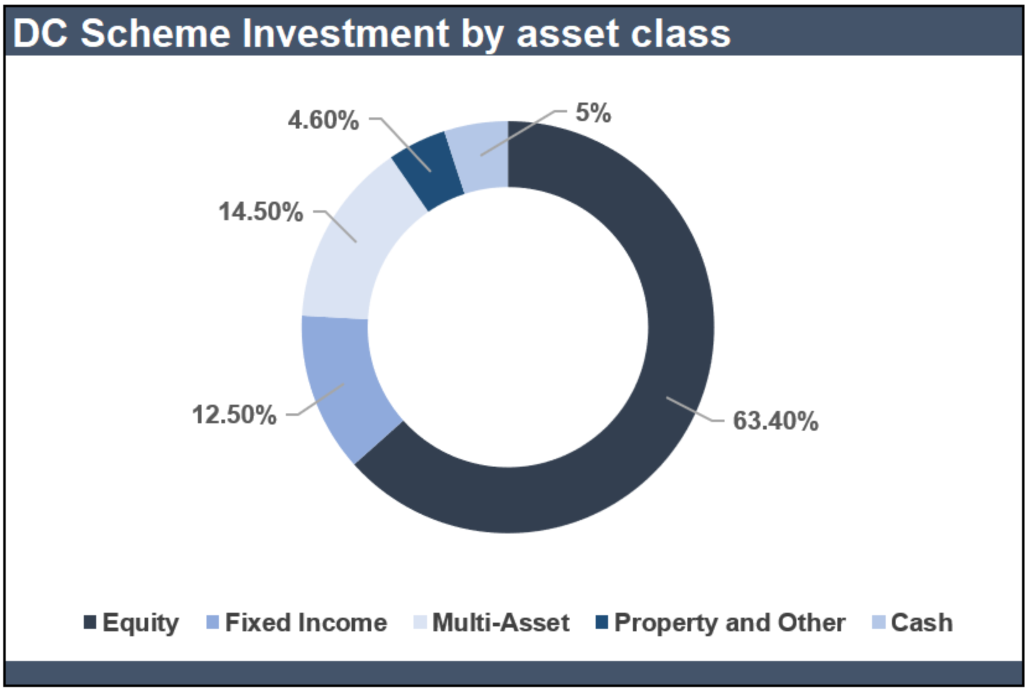

Figure 4.2 Source: Own depiction based on APPG (2019)

As could be expected, the pursuit of low cost and liquid investments is reflected in a portfolio composition of mostly equities and bonds through passive strategies. The closer the contributors get to retirement age, the more allocation is given to lower risk fixed income instruments (APPG, 2019). Illiquid investments then account for less than 5% of the total portfolio weight.

As stated before in the chapter, bonds and equities will not offer the same rate of return they have been offering in the past. This consideration poses a major challenge to pension funds as they will see their investment returns shrink. Increasing the allocation to alternative investments could represent a solution to this problematic (APPG, 2019).

4.4. Alternative Investments

Alternative investment is a definition that is commonly used in the asset management industry for those investments that have the characteristics of being private, illiquid and hence presenting different features compared to the traditional stock investments, fixed-income securities, cash or cash equivalents. Alternative investments can be divided into several categories, the most common being private equity, hedge funds and real assets. (World Economic Forum, 2015).

Private equity refers to direct equity investments in which managers called general partners (GP's) raise capital from limited partners (LP's) with which they create funds constituted by several companies that they purchase entirely, or in significant majority stakes. GP's then implement strategic, operational and financial engineering with the aim of creating more efficient companies and sell them at a higher price for a profit (APPG, 2019).
The reason why private equity managers buy-out entire companies is to reap the benefits from an total elimination of the principal agent problem where managers and owners have conflicting interests (Jensen, 1986). They believe that the target companies are misusing their free cash-flows, therefore they use leverage to improve their performance and increase the companies' valuation (Jensen, 1986). Private equity managers take advantage of their full ownership to effectively implement improvements to the company. The effects of their reforms require time to generate results, generally 4 to 7 years, after which GP's resell the company with the intention of generating high rate of returns both for their LP's, and for themselves, given that their compensation is composed by a fixed percentage plus a carried interest (BVCA, 2020).

The hedge fund investment category refers to pooled funds that invest in both traditional and alternative investments (APPG, 2019). However, differently from traditional investment strategies who try to outperform a given benchmark, hedge funds seek to generate positive alphas for their investors in the form of absolute returns. In other words, they attempt to deliver positive absolute returns to their investors regardless of the fluctuations of the financial markets (APPG, 2019). Managers who employ absolute return strategies make use of leverage, short selling and derivatives in order to deliver on their claims. Ultimately, investments in hedge funds are considered illiquid as they require the invested capital to be locked in the fund for at least a year (APPG, 2019).

Another form of alternative investments is real assets. In this category, managers invest in physical assets employing specific investment strategies (APPG, 2019). The most common targeted assets are generally classified as residential/commercial real estate, infrastructure, and commodities. The investments in this category have the characteristics of being long-term and illiquid, as they take time both to generate profits and to be liquidated (APPG, 2019). In this sense they have similar traits to private equity, which also required time for the capital to be freed and returned to the investor. A peculiar characteristic of real assets that investors appreciate, is that they generally provide returns that are weakly correlated to the equity and bond market, as the underlying assets are able to generate revenues that are not directly linked those of the wider financial markets. (APPG, 2019).

Despite the differences between the specific categories introduced above, there are some typical traits that characterize alternative investment managers. Their investment strategies can be described in a dual manner: either targeting untraditional asset classes or revenue streams that are not linked to the general market, or targeting traditional assets using unconventional techniques such as leverage and short selling (APPG, 2019). Another common trait is that they establish limited-liability partnerships or corporations that require the capital invested to be locked in for a defined period of time, and hence poses some liquidity constraints to the investors. Ultimately, as they are characterized by a high degree of specialization and make use of sophisticated investment strategies, they generally charge higher fees than passive index strategies (APPG, 2019).

4.4.1. Potential Benefits of Alternative Investments

As several research papers and articles have shown (Liang, 1999), alternative investments have the potential of bringing many benefits to a classical portfolio composed mainly of stocks and bonds. By including alternative investments in their portfolios, Pension Funds could enhance their expected rates of return, obtain additional illiquidity premiums and further increase diversification in their portfolios. All these benefits can represent a solution to the above-mentioned problems UK pension schemes are facing, that are longer life expectancy and lower expected rates of return (APPG, 2019).

4.4.1.1. Superior Performance

Alternative investment managers have often promised in the past to be able to deliver superior rates of return compared to a general market index: this concept is known in finance as "Jensen's alpha" or simply "alpha" (Jensen, 1968). There has been evidence of some alternative investment managers that have indeed been able to beat the market and offer superior returns to their investors (Liang, 1999). While some have delivered on their claim, others have failed to do so. Therefore, the ability to outperform the market is not a characteristic of all investment managers, but theory reveals that if properly chosen, some managers are better than others in delivering superior return. The difficult challenge becomes then being able to attract and invest capital in those managers that have proved to be able to deliver superior rates of return compared to the market (ASI, 2019). Provided that defined contribution pension schemes aim to maximize the beneficiary's pension investment, as a logical consequence, they should consider allocating capital to those alternative investment managers who are able to outperform the market (APPG, 2019). Instead of allocating to any investment manager that promised outperformance, pension funds would have to execute a thorough due diligence process in order need to identify the best performing managers and ensure that the promised outperformance would persist, rather than being just a mere product of luck. Allocating funds to those managers who are repeatedly able to deliver outperformance would then have a tangible effect on the rates of return, and consecutively on the beneficiaries' pension outcome (APPG, 2019).

4.4.1.2. Illiquidity Premium

As we discussed above, alternative investments are in some cases able to deliver superior rates of return. Illiquidity premium, or the excess return investors demand for locking-up capital over a period of time, is one way to increase the total portfolio rate of return. More precisely, illiquidity premium is a consequence of investing capital over a long period of time in assets that are not tradable on a regulated market (APPG, 2019). There is evidence from research of the existence of illiquidity premium (Amihud, Hameed, Kang, & Zhang, 2015). Given the structure of their liabilities, Pension Funds have generally long investment time horizons, and for that reason they are well positioned to take the advantage of a longer-term illiquid investment. This has started to become a reality for many DB pension schemes around the world. Several Canadian pension funds for example are now investing in infrastructure and are enjoying the benefits of illiquid assets in their portfolios. (APPG, 2019).

Allocating capital to illiquid investments could have positive impacts on pension funds' portfolios, nevertheless expected time horizon and illiquidity of the investment need to be carefully considered in the context of the scheme’s objectives and member profile.

4.4.1.3. Diversification

Over the past decade, the equity markets have generally been on the rise. This trend started right after the 2008 global financial crisis, supported by the program of quantitative easing employed by several central banks, which led to key interest rates falling to record lows (APPG, 2019). According to many economists, low interest rates combined with strong economic growth in many countries and especially in the USA, are the two key contributors to the record high valuations we see in today’s financial markets (APPG, 2019; Imbert, Sheetz, & Gibbs, 2018).

However, there is a general belief among practitioners that the current financial cycle may be coming to an end and the fear of a recession is materializing. Interest rates have recently started rising and quantitative easing programs are being tightened (APPG, 2019). This upward tendency in the interest rates may be challenged by the spread of the coronavirus Covid-19, which is currently representing a huge sanitary and economic threat to several countries around the world and whose effects are not yet foreseeable. United Kingdom’s decision to abandon the European Union in 2019 has unambiguously led to additional market uncertainty (APPG, 2019). Established that the financial markets are being subject to major forces of uncertainty, UK's pension funds need to build as much resilience as possible to risk, especially due to the fact that following a simple passive index strategy does not provide any protection from the current developments in the global economy. In this context of high risks, diversification is an obvious answer for mitigation, as it allows to lower the risks without additional costs. In the current status quo (and this is especially true for DC schemes) most of the diversification in UK Pension Fund's Portfolios is obtained through bonds. However, research has brought evidence that in some circumstances bonds and equities can have a significant degree of correlation with one another (Fan & Mitchell, 2017). Analysts are predicting that this phenomenon will be greater in the future, further exacerbated by the decline in expected returns from both asset classes (APPG, 2019). On a final note, literature has demonstrated that bonds generate a relatively small diversification to a portfolio primarily composed of equities, unless the position is increased making use of leverage (Asness, Frazzini, & Pedersen, 2012). All these reasons combined point in the direction of alternative investments, which can play a role in providing benefits to pension funds' portfolios (APPG, 2019).

5. Renewable Energy

Having touched upon the concept of alternative investments in the previous chapter, this study will now investigate the renewable energy category. The focus will be on the primary scope of the research, that is offshore wind. The global outlook will be first discussed in terms of markets, players and future developments. The lens will then shift on the geographic area of interest, the United Kingdom.

5.1. General Overview

The term renewable energy classifies those sources of energy that cannot be depleted but are instead naturally replenished (Ellabban, Abu-Rub, & Blaabjerg, 2014). Sources such as wind, solar, wave, hydro and biomass are utilized to produce clean electricity as an alternative to the combustion of fossil fuels. These technologies have been known for years but interest and investments have recently increased due to European and global targets for carbon emission reductions (IRENA, 2019b). To achieve the ambitious goals that were set in the Paris Climate Agreement, several countries put up in place commercial incentives such as feed-in tariffs and contracts for difference with the aim of fostering investments in the renewable space, promote competition among producers and decrease the Levelized Cost of Electricity (LCOE). Governments, industry, financing institutions and project developers have worked to drive down costs and improve performances (Amin, 2015). These efforts have had an enormous success and achieved cost reductions along the entire value chain. The effect of it is the injection of increasing amounts of capital in the renewable industry, which is expected to grow at a considerable pace in the foreseeable future. Projections exhibit renewable net capacity additions towering over other energy sources as displayed in Figure 5.1.

Solar and wind power have emerged as the most affordable power sources for many locations and markets, with cost reductions and increased capital injections set to continue into the next decade. As a matter of fact, onshore wind and solar photovoltaic could outcompete in costs coal-based power plants (IRENA, 2019c). Offshore wind, while not being at the same level yet, is expected to outclass all the other technologies and potentially become the cheapest source of energy in the future (Edwards, 2019).

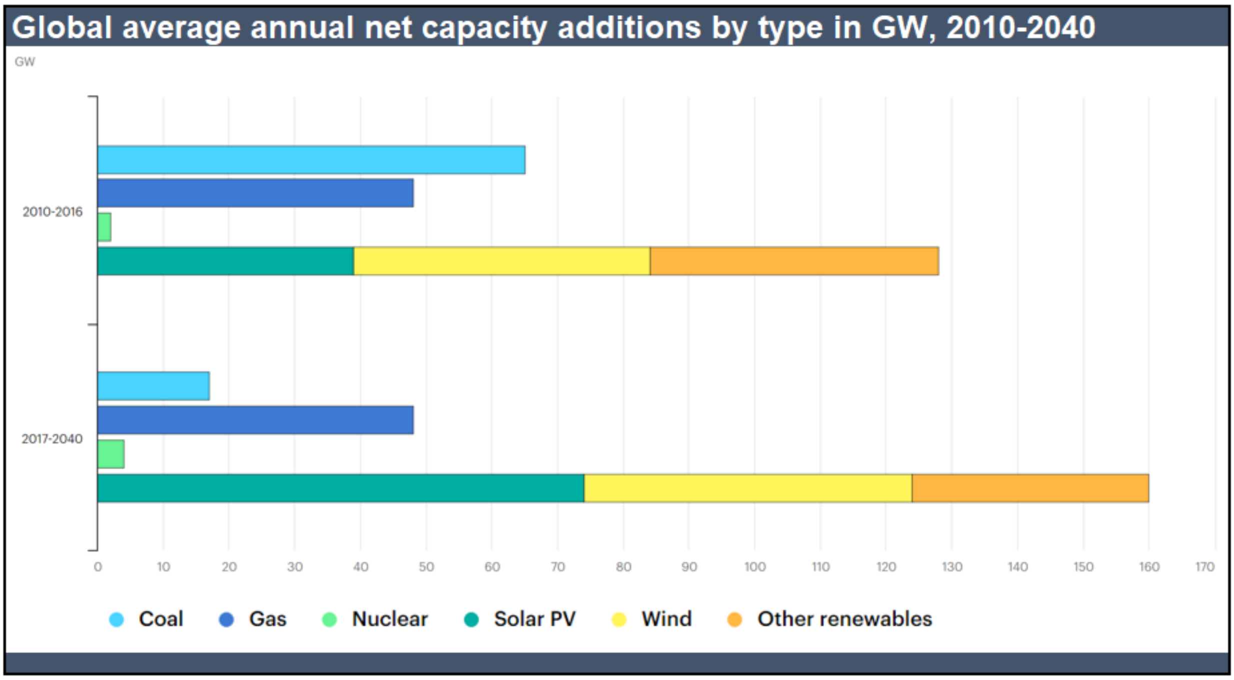

Figure 5.1 Source: IEA (2017)

5.2. Offshore Wind

The current outlook exhibits offshore wind capacity being way below the levels of its onshore counterpart. Nevertheless, the industry is expected to grow exponentially in the near future, effectively reaching the threshold of USD 1 trillion of business value (IEA, 2019a). The main driver behind the surge of offshore wind is the increasing size of wind turbines resulting in superior performances derived from higher capacity factors at lower overall costs. These improvements were reflected in a yearly market growth of approximately 30% for the period 2010-2018 (IEA, 2019a).

Intensive policy support has been critical to the development of the industry. Financial and regulatory initiatives in 17 different countries made the construction of 5,500 turbines possible across all offshore wind parks (IEA, 2019c).

Most of this growth was fostered within European borders. More specifically in the North Sea which could be effectively considered the cradle of offshore wind. The abundancy of wind resources and the characteristic of the seabed made it the perfect environment for the testing and development of this technology. Figures for the period between 2010 and 2018 presented capacity additions of approximately 17 GW. This resulted in 80% of the global volume being enclosed within European borders. (IEA, 2019c). According to current scenario, the European offshore wind development is not expected to slow. On the contrary, capacity is expected to increase four-fold by 2030 (IEA, 2019a).

While Europe still maintains the supremacy in terms of offshore wind capacity, new players are starting to close the gap. As it stands, China has initiated a revision of its energy policies. As part of the 13th Five-Year Plan endorsed by the Chinese government, the republic launched significant investments in offshore wind installations aiming for 5 GW of effective total capacity by 2020. (IEA, 2019c) As a matter of fact, China accomplished the highest capacity addition than any other country in 2018 with 1.6 GW. While still at its early stages, the technology is also starting to penetrate the United States of America, potentially opening significant opportunities (IEA, 2019c).

Overall, the technology is expected to increasingly spread to untouched markets. Projects could be soon realized in Australia, Chinese Taipei, India, Japan, Korea, New Zealand, Turkey and Viet Nam (IEA, 2019c). According to the U.S. Department of Energy (DOE) (2018) The most recent data presents 150 new offshore installations in the pipeline, of which two-thirds are expected to be completed by 2021.

5.2.1. Market Size and Key Players

The previously described growth in the offshore wind industry is supported by ever increasing capital injections from investors. Figures from the European area show offshore wind investments accounting for 25% of total renewable capacity funding. This capital is distributed along the extensive value chain that encompasses each offshore wind project ranging from its development to the final decommissioning (IEA, 2019b).

5.2.1.1. Developers and Owners

Offshore wind can be considered as a highly capital-intensive technology to be deployed. Large upfront investments are required to face the engineering and logistic challenges of setting up the installation at sea (Morthorst & Kitzing, 2016). As a result, the development of offshore wind farm is effectively restricted to large players capable of meeting the engineering and funding requirements (ORE Catapult, 2018).

As of 2018, European companies led the global market with regards to the development and ownership of offshore wind farms. Ørsted stays at the top of the ranking with an equity market share of 12.86% (IEA, 2019a). It should be noted that the figure would be higher if not for Ørsted's strategy of divesting 50% of the equity shares before the operations' start (e.g. Ørsted, 2014, 2017). With 10.44% market share, the second player is the German company RWE as a result of the acquisition of the German utilities E.ON and Innogy (IEA, 2019a). As already mentioned in the previous section, Chinese companies occupy a significant position in the offshore landscape with the power utility China Longyuan seizing the third place with a global equity market share of 5.34% (IEA, 2019a).

5.2.1.2. Manufacturers

The offshore wind turbine manufacturers' landscape is then considerably concentrated according to the available data from 2018 (IEA, 2019a). On a similar note to project developers, leading turbine manufacturers are represented by European companies. In particular, the Spanish company Siemens Gamesa along with the Danish firm MHI Vestas Offshore Wind account for 71% of the market share for the year 2018, with a combined sold capacity of 17,763 MW for the period ranging from 1995 to 2018 (IEA, 2019a). Chinese companies occupy the remaining three spots in the top 5 offshore wind turbine manufacturers, as displayed in figure 5.2.

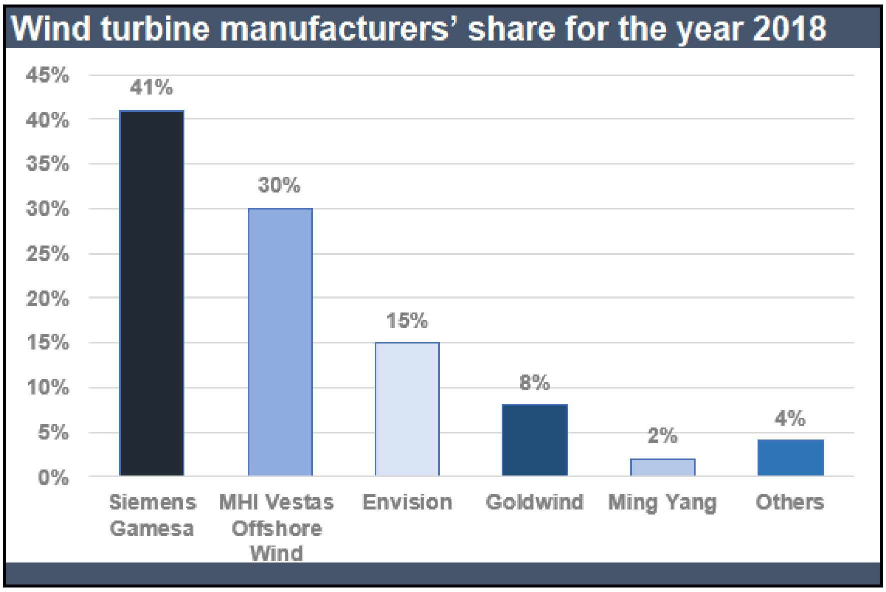

Figure 5.2 Source: Own depiction based on IEA (2019a)

It should be noted that the offshore wind industry comprises several other players operating on an intermediary level between manufacturers and operators. Figures for the period 2010-2018 estimate around USD 5 billion spent each year between construction and operations for wind farms in both Europe and China (IEA, 2019a).

5.2.2. Technologies

The year 1991 marked the inauguration of the first offshore wind farm, installed off the coast of Denmark. Since then the technology has made impressive advancements as most of the developers and turbines manufactures' focus has been directed towards output improvements (IRENA, 2019a). As a matter of fact, the relative superior offshore wind's output compared to other renewable-based power plants is what makes the industry attractive. Offshore wind's capacity factor significantly exceeded on average the capacity factor of its direct competitors, namely solar photovoltaic and onshore wind for the year 2018. The data showed a respective average of 33% compared to respectively 14% and 25% (IEA, 2019a).
Significant upgrades are expected in the future with capacity factors of wind farms operating at optimal conditions going beyond the 50% threshold (IEA, 2019a). In reality, advancements in this regard are expected from all renewable's technologies. However, the development pace of offshore wind is estimated to be unmatched under the current outlook. As it stands, the technology is expected to even outperform conventional sources of electricity. An average capacity of 45% for new European installations would be effectively higher than the average capacity coefficient of coal-fired power plants (IEA, 2019a). Paired with the current progress in power storage solutions which would fundamentally address the main drawback of renewable sources, offshore wind could potentially disrupt the conventional energy supply system (IEA, 2019a).

5.2.2.1. Turbine Size

The quest for increased output was first approached by addressing the size of the turbine itself, which doubled over the period ranging from 2010 to 2016, ultimately reaching heights over 200 meters (IEA, 2019c). This also translated in the exponential increase in the swept area, that is, the area captured by the blades which increased by 250% over the six-years period (IEA, 2019c). The industry is also quickly introducing further innovations. 10 MW turbines are expected to be operating as of 2020 (BVG Associates, 2019b), aiming for 15 to 20 MW rated turbines by the year 2030 (IEA, 2019c). The major increase in size involves dealing with significant engineering and logistic challenges that effectively translate into higher capital expenditures per turbine. However, at the same time, the possibility of decreasing the number of turbines given a constant nominal capacity of the power plant could lead to benefits in terms of lower operation and maintenance costs that could translate in an increased competitiveness of the wind park (IEA, 2019c).

5.2.2.2. Location

A second approach to the pursuit of superior performances is related to locational solutions. Over the years, offshore wind plants have been constructed farther from the shore. The rationale behind this was the pursuit of superior wind resources that would lead to an increased output (IRENA, 2019a). As it happens, there are limitations to what can be achieved through an increase in size. It is argued that there is a breakeven point at which a marginal increase in size would bring a negative trade-off between increased performance over costs. For this reason, projects are being pushed farther from the shore where the higher quality of wind resources would favor the trade-off (IEA, 2019c). The 2018 figures show the majority of the commissioned project being located at approximately 50 kilometers off the coast (IEA, 2019c). This comes with the exception of a few large UK projects in the Dogger Bank area, which is located around 130 kilometers off the coast of Yorkshire. Despite the distance, the location offers singular conditions as the water depth ranges between 20 to 35 meters allowing for the more traditional and low cost monopile foundations (Harvey, 2015).

As a matter of fact, the hunt for more abundant wind resources farther from the costs has been challenged by the technical and financial hardships of dealing with the relative increased in water depth (IEA, 2019a). Monopile foundations, the cheapest and most common technology for current projects cannot be employed at depth exceeding 50-60 meters. At these water depths, the costs incurred significantly outweigh the benefits (IEA, 2019a).

To address this limitation, alternative technologies are being explored. Most notably, significant investments are directed towards the development of floating offshore wind (IEA, 2019a). The market opportunity is enormous given that it would unlock vast and potentially uncontested areas with higher wind speeds. The technology could leverage on the proven effectiveness of floating alternatives for gas and oil installations, although modifications in design that would suit the characteristics and the structural requirements of a wind farm are required (IEA, 2019a). As could be expected from a considerably less mature industry, floating offshore wind projects built up to date are considerably smaller than the fixed-bottom counterpart. Examples can be found in the 2 MW Floatgen project in France, the 3 MW Hibiki wind park in Japan and the 30 MW Hywind installation in Scotland (IEA, 2019a). Nevertheless, growth is also expected within this sector. The year 2020 should mark the construction end date for the largest floating installation so far, namely the 200 MW wind farm off the coast of the Canary Islands build by the Norwegian multinational Equinor (IEA, 2019a).

The further development of the technology will be critical for the expansion of the offshore wind industry. However, given the early technological stages and the inherent high costs, the technology is still heavily dependent on subsidies (IEA, 2019a). Hence, it will not be relevant for the scope of this study.

5.2.3. Costs and Pricing Trends

In the introduction to this chapter this study mentioned the increased cost competitiveness of the offshore wind sector. Within the industry, that estimate is provided through the appraisal of the Levelized Cost of Electricity (LCOE), which takes into consideration both the costs and production of the analyzed energy source (WindEurope & BVG Associates, 2017). The calculation of the metric is provided in the Formula 5.1 below.

LCOE

$$LCOE = \frac{\sum_{t=1}^{n} \frac{I_t + M_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{AEP_t}{(1+r)^t}}$$

$LCOE = levelised\ cost\ of\ energy$
$I_t = investment\ expenditures\ in\ period\ t$
$M_t = operations\ and\ maintenance\ expenditures\ in\ period\ t$
$AEP_t = annual\ energy\ production\ in\ period\ t$
$r = relevant\ discount\ rate$
$n = number\ of\ years\ of\ project\ lifetime$

Formula 5.1 Source: Own depiction based on WindEurope & BVG Associates (2017)

By taking into account both investment and operating costs over the annual production of the power plant, the measure effectively provides the marginal costs of electricity over the production of one unit of power (Ioannou, Angus, & Brennan, 2017).

Historically, conventional sources of power such as gas-based and coal-fired plants exhibited considerably lower LCOE values compared to renewables. Because of this reason, the development of clean energy sources has relied on financial support from the government, who significantly overpaid for the power produced resulting in higher costs for the final consumers. The situation has changed over the years as the LCOE's for both solar and wind have decreased significantly (IRENA, 2019a). Figure 5.3 presents the global LCOE level for offshore wind measured in 2018 real prices. It should be stressed that the calculation of the levelized cost of energy does not take into consideration tax nor inflation (WindEurope & BVG Associates, 2017).

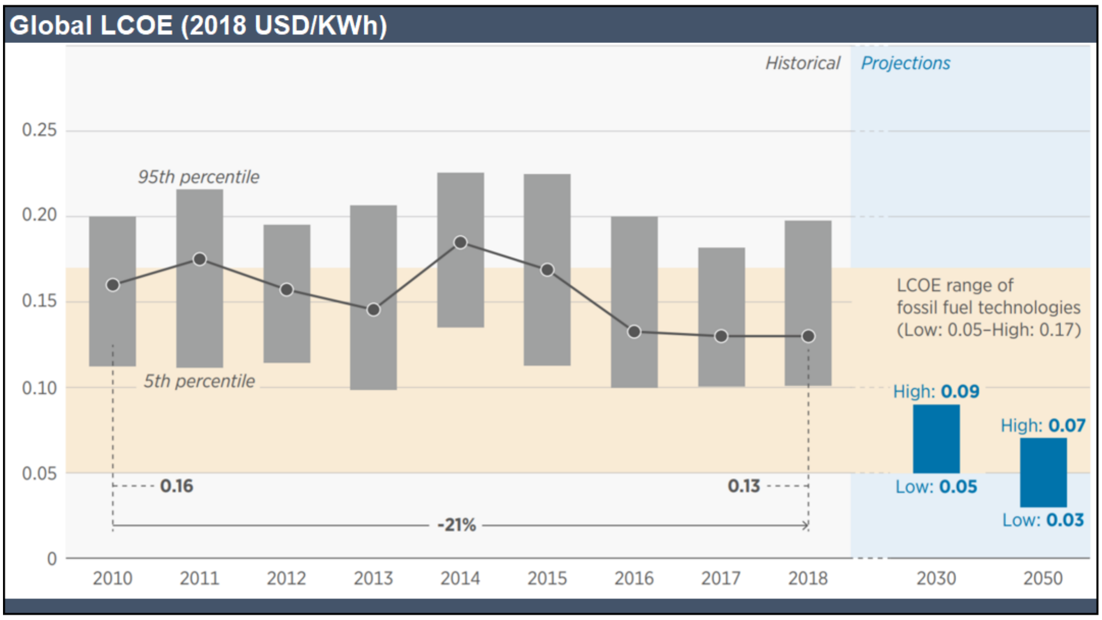

Figure 5.3 Source: IRENA (2019a)

While some time is required for the industry to outcompete fossil fuels on a global scale, in some regions the turning point is extremely close. In the UK for example the first power plants with lower LCOE's than fossil fuels are expected in 2021 (Mathis, 2019).

According to some research (DOE, 2018) , the key driver in the lowering of costs is the competition created in the industry through auction schemes. The main contribution to the LCOE reductions have then been fostered by technology innovations in both manufacturing and supply chain (IRENA, 2019a).

5.2.4. Global Outlook

As already mentioned in the previous sections, during the early stages of the technology, both the financial and regulatory governments' support played a crucial role in the development of the industry. As a matter of fact, while financial support could be gradually hindered as result of the increased competitiveness, regulatory intervention will still play a fundamental part in the future expansion of the industry (IRENA, 2019a). As a matter of fact, provided the current policy outlook, the global offshore wind market is estimated to grow by 13% each year for an effective fifteen-fold increase in capacity by 2040 (IEA, 2019c). Reports by IEA (2019c) even suggest that policies could be turned towards a more aggressive support to renewables for an accelerated decarbonization. This could lead to a total offshore capacity of 560 GW by the end of the next two decades translating in annual capacity addictions between 30 and 40 GW. Figure 5.4 presents the effects of policy support over the progress of the offshore wind industry.

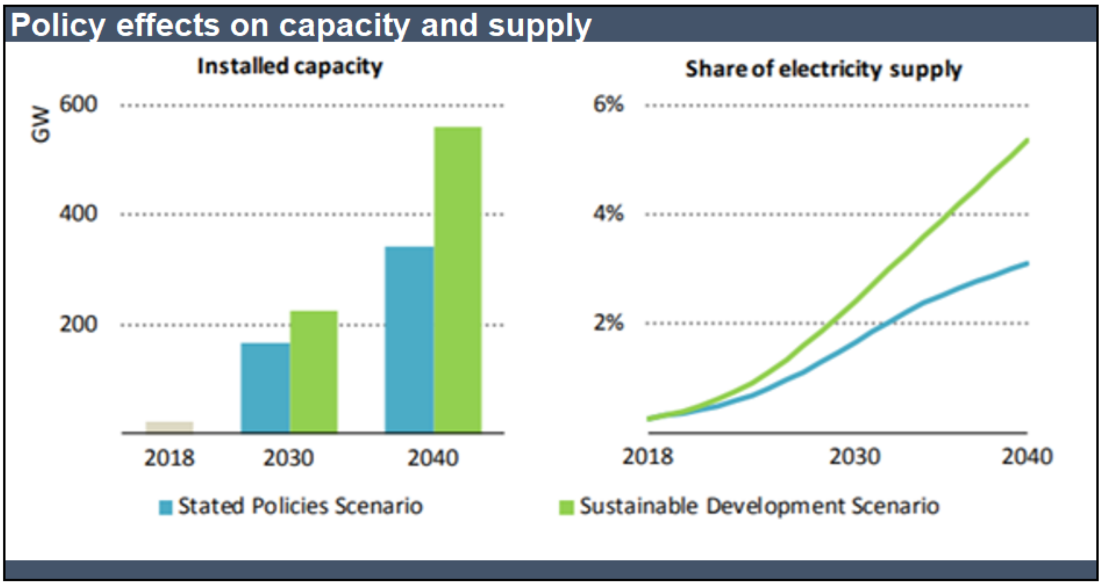

Figure 5.4 Source: IEA (2019c)

According to the state policies scenario, offshore wind is expected to cover 3% of the global electricity supply by 2040. The road to this achievement effectively requires USD 840 billion of investments (IEA, 2019c).

5.3. The United Kingdom

The United Kingdom represents an important market for renewable energy and the country's capacity generation is increasing at a very fast pace. According to estimates of the UK Department for Business, Energy & Industrial Strategy (BEIS) (2020), in 2019 renewable energy represented 36.9% of the total country's annual electricity generation. Just a decade ago non-renewable sources constituted approximately 80% of the generation. Now they are gradually declining. Coal-fired power plants only captured 1% of market share in the latest count and are expected to be completely banned by 2025 (Ambrose, 2019).

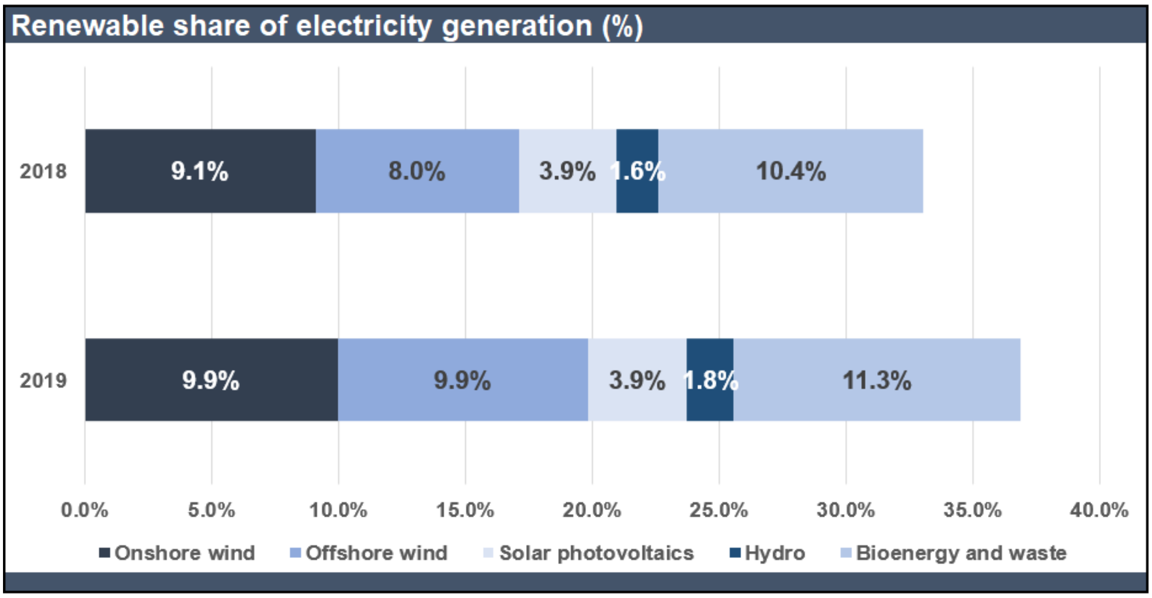

Figure 5.5 Source: Own depiction based on BEIS (2020)

Figure 5.5 presents the generation mix of renewable energy sources for the years 2018 and 2019. As shown, wind power is the strongest contributor to renewable energy generation with a share of 20% between onshore and offshore. Worth mentioning, In the third and fourth quarter of 2019 offshore accounted for more than onshore capacity suggesting the technology could take the lead among other sources (BEIS, 2020). The UK represents the biggest market for offshore wind globally, expected to triple in size and to generate more than a third of UK's electricity by 2030. Prices for offshore farms are now so low, that the government contemplates to remove subsidies from the next generation of projects (Rowe, 2020). Among other things, this research aims to verify this statement by assessing the exposure to merchant risk and how the investment decision will be impacted by it.

6. Introduction to the Wind Farm

The scope of this chapter is to provide a clear delimitation of the assumptions and inputs at the base of the proposed financial model. After a brief overview of the project, the section will review the costs incurred during the lifetime of the windfarm. The authors will then introduce factors affecting wind power production and electricity prices. The section will then continue by presenting the capital structure assumed by the model as well as the role of debt within the analysis. A comprehensive overview of the model assumptions will then conclude the chapter.

6.1. General Overview

OVERVIEW		
Wind Farm Type		Offshore
Country		United Kingdom
Currency		GBP
Financial Investment Decision		2019
Construction Start Date		2020
Operation Start Date		2022
Investment Lifetime	Years	27
Operation Lifetime	Years	25
PROJECT ASSUMPTIONS		
Plant Capacity	MW	1000
Turbine Capacity	MW	10
# of Turbines	#	100
Water Depth at Site	m	30
Average Annual Wind Speed	m/s	10
Distance to Shore	km	60
Net annual average electricy production	MWh/year	4,471,000

Table 6.1 Source: Own depiction based on BVG Associates (2019b)

Table 6.1 outlines the main characteristics of the site and technology assumed for the analyzed wind investment. It should be noted that the model does not reflect a specific project but should be instead considered as a general representation of an upcoming offshore wind farm. A consistent portion of the data was collected from a BVG Associates' report outlining the main site and technology characteristics that could be expected from offshore installations built before 2025

(BVG Associates, 2019b). The report is composed of figures and insights provided by leading manufacturers and operators within the field of renewable wind energy.
As detailed in Table 6.1, the analysis will focus on an offshore wind farm to be built in the UK. The currency reference will be the British pound, therefore the need to address currency exchange risk is eliminated.

The project presents an expected lifetime of 27 years before the eventual decommissioning. This includes 2 years of construction which are supposed to start at the beginning of 2020. When construction is concluded, the wind farm will operate and generate electricity for a period of 25 years. The total capacity of the installation is 1 GW, comprised of 100 turbines of 10 MW capacity each. The wind park is installed at an average of 60 km from the coast, at approximately 30 m of depth and subject to average wind speeds of 10 m/s. The net annual electricity production is 4,471,000 MWh for each year.

6.2. Costs

In order to provide a valuable assessment of the project, it is crucial to properly understand the identity and magnitude of the expenditures as well as the timing in which they are incurred. As already mentioned in the project limitations, the figures assumed for this model should be considered as an average of the expenses incurred for a project with the characteristics described in the previous chapter.
The costs incurred in the realization of an offshore wind farm can then be aggregated in four main categories: namely financing costs, investment costs, operating costs and decommissioning costs (BVG Associates, 2019b).

6.2.1. Financing Costs

Financing costs are those costs associated with obtaining and employing the funds required to start the project. These include the cost of equity and any interest/fees incurred when requesting a loan from a financial institution. When assessing the levelized costs of energy of offshore installations, it is estimated that the cost of capital accounts for up to half of the total value of the project (IEA, 2019c). As it happens, assessing the financing costs of the investment ultimately leads to an evaluation of how risky the project is perceived by the lenders of capital. More specifically, factors that increase the risk of the project such us untested technologies and unfavorable market conditions fundamentally increase the cost of capital. On the other side, learning economies and increasing maturity of the industry would lead to a lower cost of capital due to the lessening of the risks (IRENA, 2019a). A more detailed description of the cost of capital will be provided in the section related to the capital structure.

6.2.2. Capital Expenditures

The investment expenses (or Capex) of a wind farm encompass those costs incurred to acquire, build and maintain the physical assets of the installation. These expenditures generally incurred before the commercial operation date can be further categorized in *development*, *turbine and equipment*, *plant balance* and lastly *installation and commissioning*.

Development costs are usually the first capital expense in the life cycle of an offshore windfarm and are required to address environmental, design and legal concerns (BVG Associates, 2019a). As a matter of fact, extensive wind resource surveys as well as hydrological and geological studies are required to assess the energy production potential as well as the costs associated with specific soil, depth and wave conditions (Deloitte, 2014). In addition to that, several surveys are required to address the disruptive impact that the windfarm construction and operation could represent with regards to wildlife such as marine mammals and seabirds (Sturman, 2018). Strictly correlated with the results of these studies are the project and process design costs, aimed at establishing the optimal layout of the wind park and its components (IRENA, 2019a). Development costs also include expenses incurred to obtain legal permits and agreements to build the windfarm as well as the associated labor costs (BVG Associates, 2019a).

Turbine and equipment costs represents the largest portion of the capital expenditures (BVG Associates, 2019b). These include the manufacturing and assembling of the wind turbine components such as the rotor, the nacelle and the tower as well as the fraction of commissioning and installation required from the supplier of the wind turbine (BVG Associates, 2019a). Despite representing the larger fraction of the CAPEX, it was also one of the segments that experienced consistent cost reductions as a result of supply chain improvements with regards to larger volumes and increased component standardization (BVG Associates, 2019b).

Plant balance costs include all the equipment and component expenditures except for the wind turbine (BVG Associates, 2019a). According to the case data, the largest partition of these costs is represented by the turbine foundations. There are currently several alternative turbine foundation technologies divided between fixed and floating structures. Fixed structures, monopiles in particular, are the most sought out option due to the relative lower cost compared to the other alternatives (IEA, 2019c). However, their application is not always possible. As it happens, turbine foundations are particularly sensitive to factors such as water depth. The deeper the seabed, the tougher the engineering challenge which ultimately leads to higher costs. As a matter of fact, deeper waters usually require more expensive technologies such as jacket foundations (IEA, 2019c). According to the site and project assumptions we can assume monopiles to be the foundations considered in the financial model.
Plant balance costs also include the offshore and onshore substations as well as the entire array and export cables system required to connect the power produced offshore to the onshore grid connection (BVG Associates, 2019a). These usually involve trade-offs with regards to transmission efficiency and costs. More specifically, high-voltage alternating current (HVAC) transmission is cheaper but associated to higher efficiency losses due to "reactive resistance" (IRENA, 2019a). On the other side, high-voltage direct current (HVDC) transmission overcomes reactive power flow issues but is then associated to more expensive converter stations (BVG Associates, 2019a). While both options become more expensive the further from the shore the installation is built, HVDC transmission becomes competitive once the cables connection spans between 80-150 kilometers (IRENA, 2019a). Given the project's distance from shore assumption of 60 km, we assume HVAC transmission to be the one designed for the project.

Installation and commissioning costs involve those activities and ultimately the expenditures incurred for the transport and subsequent installation of equipment and components on both land and sea, as well as insurance and project management expenses (BVG Associates, 2019a). On a similar note to the precedent capital investments, site characteristics heavily affect the magnitude of these costs. Deeper waters and specific seabed features might require more expensive solutions (i.e. rock drilling), affecting the cost competitiveness of the project (BVG Associates, 2019a).

Within the financial model, these costs will be captured in the balance sheet. According to the case data, installation and commissioning costs amount to GBP 2,370,000,000. It should be noted that the UK operates under the so called OFTO model. Under this regime, the transmission assets of a wind farm are either constructed and maintained by an Offshore Transmission Owner (OFTO) or they are financed and build by the wind farm developers and then transferred through an auction sale to the OFTO, which in turn maintains and operates them (Ofgem, 2014). As every wind project has followed the latter option so far (Ofgem, 2019b), the same procedure will be assumed for this case study.

The transaction is heavily regulated. The Office of Gas and Electricity Market (Ofgem) defines the final transfer value of the assets (FTV) and several OFTO's go through a competitive tender process bidding on their cost of capital. The OFTO with the lowest required cost of capital wins the auction (Deloitte, 2019). Creating competition is the main rational behind the model, as the pressure drives down construction and operations costs, to the benefit of the final consumers (KPMG, 2012).

Estimating the FTV is a complex process and involves several evaluations. As a precise value was not provided, this study provided an estimate in accordance with case data, industry reports and most importantly experts' opinions (McWhirther, 2020). The estimated value amounted to GBP 729,000,000 and included the development, materials and installation costs of both the offshore and onshore substations and export cables. It should be noted that the estimate provides a conservative measure compared to the average CAPEX for a 1,000 MW installation reported by DNV GL (see Appendix 1).

For the purpose of the thesis we assume that the FTV complies with the estimate of the developers and as a result no loss or gain is realized from the sale. Based on industry experts interviews (McWhirther, 2020), the neutrality of the transaction has been factored in our model by subtracting the FTV to the total CAPEX.

As a model assumption, the final balance of the CAPEX will be equally divided over the first two years of construction. Under the premise of 95% tax depreciable value, capital expenditures will be subject to a straight-line depreciation over the 25 years of operating life, in line with procedures used by Bloomberg New Energy Finance (BNEF) (2020). This paper wants to stress that the assumption takes a conservative approach, as in practice wind farm projects could enjoy higher levels of tax relief through capital allowances. The authors believe that additional knowledge on tax regulations and a further sophistication of the model could ultimately provide an upside value to the evaluation. Finally, this model takes the assumption that being fixed in contractual terms, no inflation should be factored on these expenditures.

6.2.3. Operational Expenditures

Operating expenditures are those costs sustained during the operating lifetime of the wind farm and include all the activities required for the regular operation of the offshore installation’s assets (BVG Associates, 2019a). The real value for the annual OPEX was estimated to be GBP 76,000,000 (BVG Associates, 2019b). According to experts of the industry (McWhirther, 2020), this figure is compatible with the operating costs of current 1,000 MW wind farm projects. This estimate includes operations, maintenance and service costs as well as other related charges expected during the lifetime of the project.

It is important to state that, as a result of the OFTO transaction, the generator has to pay fees for the provision and maintenance of the transmission assets, namely the Transmission Network Use of System (TNUoS) charges (Ofgem, 2020a). These have to be added to the Balancing Services Use of System (BSUoS) fees that cover the daily operational expenditures with regards to balancing the transmission system (National Grid, 2015). Both are estimated by and paid to the National Grid which acts as the owner of the transmission network for England and Wales as well as the Electricity System Operator (ESO) for the entire kingdom, consistently matching the supply and demand balance for electricity (National Grid, 2019). In addition to that, the wind installation is billed for the lease of the seabed.

These costs will be gathered in the operating expenses in the income statement and will be subjected to an annual inflation rate of 2% according to the target consumer price index set by the Bank of England (2019).

6.2.4. Decommissioning Costs

Decommissioning expenditures (DECEX) are related to those expenses sustained for the removal and dismantling of the offshore installation. These include the disposal of the structure, the equipment along with the labor, machinery and logistic expenses required to perform such feat (BVG Associates, 2019a). Currently, given the average project life of 25/30 years, no offshore installation has ever been completely dismantled as the first ones are not expected before early 2030s (IRENA, 2019a). Because of this, while estimates of decommissioning expenditures could be provided, there is a persistent uncertainty regarding both value and timing of costs. As a matter of fact, after the end life of a wind farm project several possibilities are likely to occur. The plant could be entirely dismantled if the technology becomes obsolescent. Alternatively, an extension of the land lease and subsequent repowering of the assets could lead to a prolonged operating life (Deloitte, 2014). In other words, replacing wind park assets with updated and more efficient versions (IRENA, 2019a), could lead to further cash flows streams that would require additional analysis.

For the reasons explained above, decommissioning costs have been excluded from the financial analysis

6.3. Energy Output

Having already familiarized with the costs incurred for the construction and operation of a wind farm, this study introduces now the first critical factor influencing the revenues of the project, namely the annual energy production (AEP) of the offshore installation (Hevia-Koch & Klinge Jacobsen, 2019).

6.3.1. Factors Influencing Power Production

The net average capacity factor, that is, the ratio between power produced and the nominal installed capacity over a period of time (The Crown Estate, 2019), is affected by several elements, the most notable being the wind resources present at site (IEA, 2019c). The search for higher wind speeds is pushing offshore installations farther from the shore as the trade-off between costs for production becomes more convenient. The relationship between the wind speed and the gross energy output is usually described by the turbine power curve. Figure 6.1 pictures the power curve of a typical V164-10MW turbine manufactured by MHI Vestas Offshore Wind.

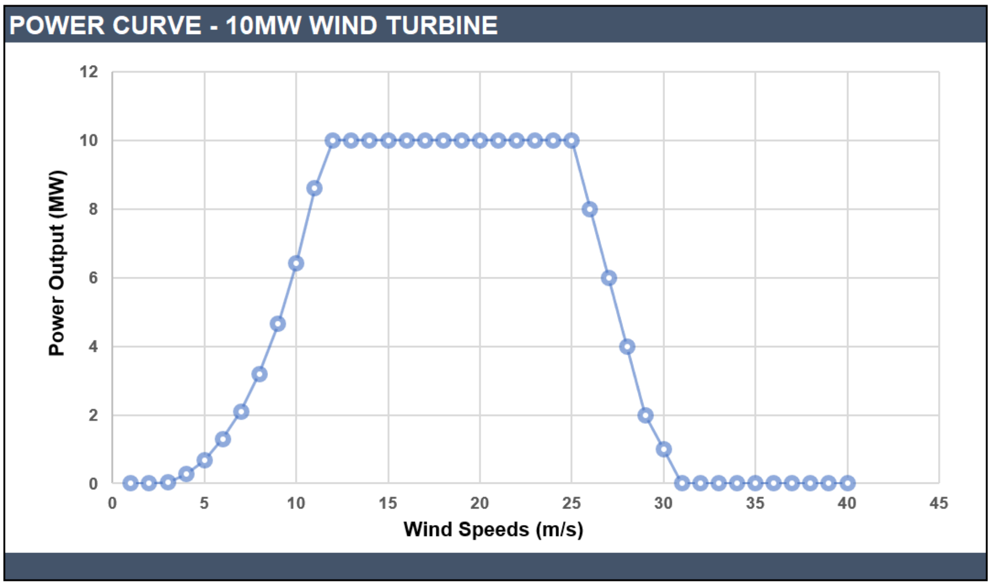

Figure 6.1 Source: Own depiction based on YOUWINd (2020)

As described by the graph, the gross output reaches its full capacity when the wind speed average is around 12 m/s. Wind speeds are generally variable and affected by seasonality, particularly in the UK where on average higher velocities are observed during winter time (IEA, 2019c). It should be noted however that excessive wind speeds are associated with decreasing and ultimately zero power output as turbines are turned off to avoid the damaging of the components. Despite this extreme case, higher wind speeds are generally looked favorably upon. For this reason, a careful planning of the installation layout is required and sought after in order to minimize the wake effect of the offshore installation (IRENA, 2019a). This effect is associated with an increased wind turbulence that causes a reduction in the wind speed for the turbines positioned downstream (González-Longatt, Wall, & Terzija, 2012). In order to reduce the wake effect, manufactures are pushing to design taller turbines as higher altitudes are associated with higher wind speeds and lower turbulence (The Crown Estate, 2019).

At the same time, it is possible that despite favorable wind conditions, the power generated by the installation could be reduced or cut off altogether in what is defined as "curtailment" of wind energy (Fine, D'Costa, & Kumaraswamy, 2017). Several motives could be the rationales for a decrease in the power generation. Potential negative externalities on wildlife habitats that could require downtime during specific times of the day is one of the possible reasons (Rogers, 2020). Similarly, excessive energy supply on the market as well as issues derived from a transmission system that is not capable to adapt to the full power load generated, could both lead to the restriction of the operations (Fine et al., 2017). Ultimately, towards the end of the operating cycle, wind farm components necessitate maintenance interventions that require a temporary shut-down of the turbine (Deloitte, 2014). Estimating turbine downtime becomes then critical for a more precise assessment of power production.

The data collected for the case study takes into account the effects mentioned above, including additional factors and inefficiencies that would cause power losses. As a result of these considerations, the data estimates a constant net average annual electricity generation of 4,471,000 MW/h (BVG Associates, 2019b).

6.4. Electricity Prices

In order to provide and answer to the proposed research question, the thesis needs to test how the exposure to merchant risk affects the proposed offshore wind investment case. As no subsidies or tariffs will be considered for the reference case, power prices will be the second and main determinant of the project revenues. Therefore, a thorough understanding of the power markets is a prerequisite for the subsequent project evaluation.

6.4.1. UK Power Market

The electricity transfer from producers to the consumers is composed of transactions that interest two different markets, namely the wholesale market and the retail market.

The wholesale market acts as a place of trade between generators of electricity and suppliers (ELEXON, 2019a). Suppliers then sell the acquired energy to the final consumers, at adjusted prices, in the retail market (Ofgem, 2020d). Like most of the other advanced economies, the UK power market is essentially deregulated, allowing for competition among energy suppliers which results in a downward pressure on prices (Ofgem, 2020d). Supervision of both markets is then provided by the Office of Gas and Electricity Market, which essentially acts as silent regulator ensuring price, customer and environmental fairness and protection (Ofgem, 2018).

As the thesis aims to analyze the investment case of an offshore wind farm, the study will focus only on the dynamics of the UK wholesale market.

6.4.1.1. Wholesale Market

Electricity is a peculiar commodity. As a matter of fact, the inherent characteristics of electricity and the technologies currently available do not allow for a cost-effective storage of power (ELEXON, 2019a). As a result, supply and demand for electricity require constant balancing (Ofgem, 2020e).

While the Electricity System Operator (ESO) oversees the final balance between supply and demand, the main balancing push is provided by the intense trading activity within the wholesale market (Ofgem, 2020e). This trading activity is rather dynamic and does not present a simple unilateral flow where the electricity goes directly from generators to suppliers and ultimately to the end consumer. As an example, generators might be required to buy power when the amount they produce does not cover the contracts they entered into (ELEXON, 2019b). At the same time, suppliers might be required to sell amounts in excess after the demand from the final consumers has been met. Third parties can also participate in the trading activities, speculating on the prices in order to extract profits from price imbalances (ELEXON, 2019b).

In general, trading activities can take place either on regulated power exchanges where participants trade multilaterally between each other, or through bilateral trading also defined as over the counter (OTC), where the parties involved determine the quantity and prices of the transaction without a third-party interference (Ofgem, 2020e). Transactions on both the power exchanges and OTC can trade contracts with different time horizons. More specifically, electricity can be traded intraday, day-ahead, or alternatively in the futures market with delivery dates ranging from months, seasons or one year ahead of the transaction date (Deloitte, 2019). Ultimately, power could flow and be traded across national borders through interconnectors. Under current regulations, the UK has an active cross-border trading with Ireland, the Netherlands and France (Ofgem, 2020b). However, it should be noted that from January 1st, 2021, all the trade arrangements could be affected by the outcome of FTA negotiations between the UK and the European Union (BEIS, 2019a).

6.4.1.2. Wholesale Prices

As a consequence of the deregulation of the power market and the introduction of competitive forces, wholesale electricity prices in the UK have been significantly affected (Worthington &

Higgs, 2011). Electricity prices are fully exposed to the trends and shocks from both demand and supply. It could be expected that a significant increase in power generation, all else held equal, would lead to excessive supply and in turn a decrease of the price level. Similarly, a decrease in the generation due to decommissioning or disposal of outdated power plants would increase prices down the line. Understanding the dynamics between these two forces becomes then critical to the forecast of merchant prices.

Overall, the behavior of spot electricity prices can be described by a framework that identifies three distinct patterns (Blanco, Choi, & Soronow, 2001). First, on a similar note to wind speeds, the theory describes how prices essentially follow a seasonal pattern as the fluctuations in the price level comply with the change in weather (Blanco et al., 2001). Secondly, prices are assumed to move around a long-term average determined by both production costs and power demand, with a behavior defined as "mean-reversion" (Blanco et al., 2001). Empirical observations provide confirmation of the mean reversion behavior of electricity prices and demonstrate a strong correlation with gas prices. Figure 6.2 below depicts monthly averages for wholesale electricity and gas prices in the UK on a day-ahead basis.

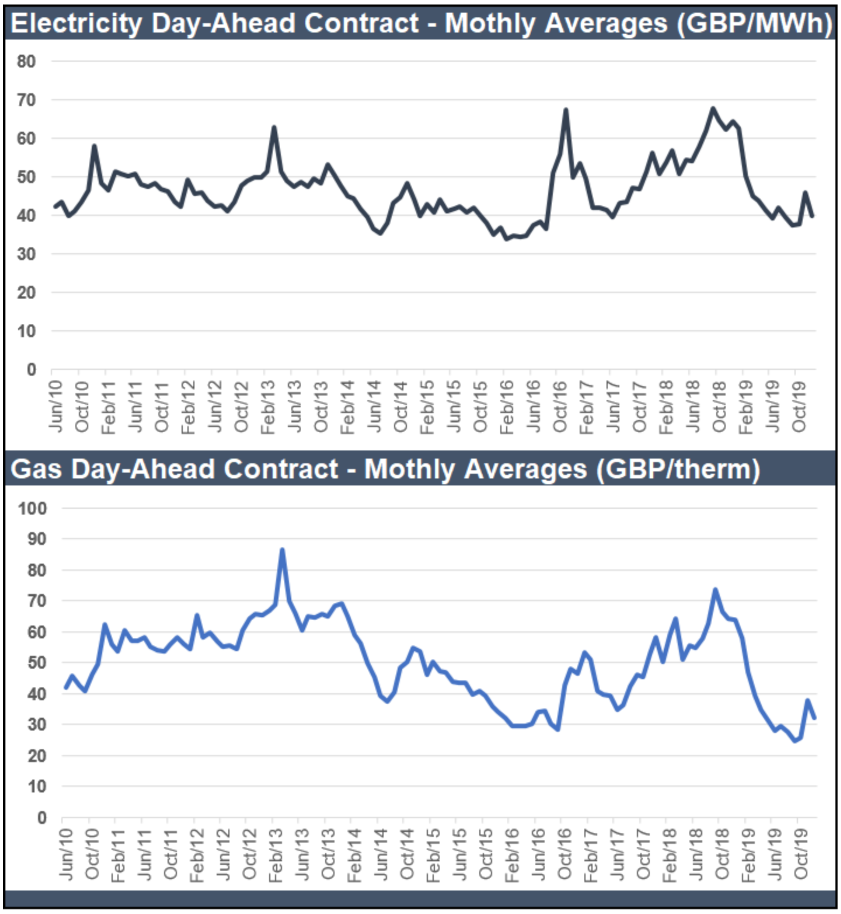

Figure 6.2 Source: Own depiction based on Ofgem (2019a, 2020c)

As can be discerned from the data, electricity prices follow the trend of gas prices with correlation values of 0.90 up to April 2019 (Ofgem, 2019c). Given the key role that gas and other fossil fuel played in the UK electricity generation mix (Ofgem, 2019c), their prices provided the average production costs that electricity prices tended to follow in the long-term.

Finally, Blanco et al. (2001) identify positive and negative price level "spikes" as a result of sudden imbalances in the market.

6.4.2. Price Scenarios

The analysis of the investment's return and profitability will be based on three different price scenarios. Data was collected from a report published in 2018 by the Department for Business, Energy and Industrial Strategy and subsequently revised in 2019 (BEIS, 2019b). Annex M of the projections display forecasts of wholesale baseload prices up until 2035 for different future states of the world (BEIS, 2019b).

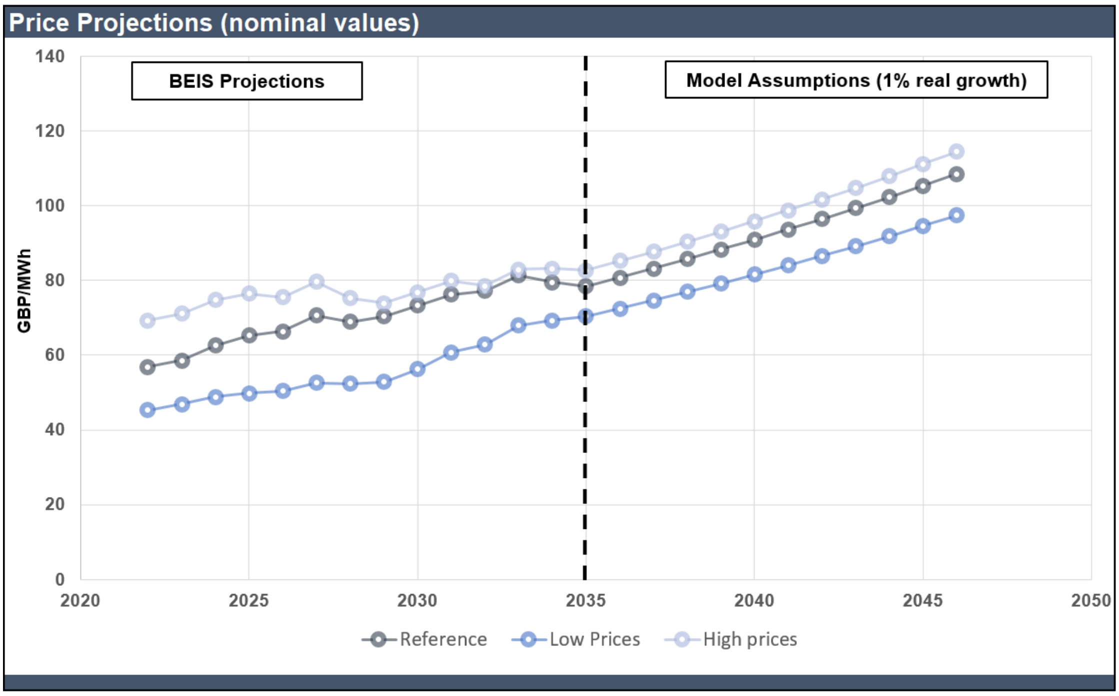

Figure 6.3 Source: Own depiction based on BEIS (2019b) and expert estimate (McWhirther, 2020)

For the purpose of this research, the authors selected 3 scenarios. More specifically we opted for a *reference* scenario which displays central estimates on future economic growth and fossil fuel prices according to current policy enactment; a *low* scenario that provides price estimates in case of low fossil fuel prices and ultimately a *high* scenario that, holding everything else constant, assumes high fossil fuel prices in the future (BEIS, 2019b). Figure 6.3 above provides a graphic representation of the nominal prices implemented in the calculations.

BEIS projections only cover the years up to 2035, for the remaining 11 years of the operating life of the wind farm we assumed a 1% growth in real prices based on expert's best practices (McWhirther, 2020). It should be noted that the prices provided by the report are 2018 real prices. These were adjusted for the actual inflation of 2019 and for the subsequent expected annual inflation of 2% targeted by the Bank of England (2019). Appendix 2 and 3 provide a more detailed representation of the data points.

6.4.3. Price Cannibalization

Blanco et al. (2001) stated that long term electricity prices follow an average of the production costs determined by power supply and demand. From a short-term perspective, electricity prices are set according to the most expensive source of energy employed in order to meet the required demand, in what is defined as the merit order effect (Pöyry, 2010). According to this principle, sources characterized by lower marginal costs of production are employed until full capacity is reached. If demand has not been met, more expensive sources are engaged, and prices rise accordingly (Pöyry, 2010). While wind energy is capital intensive, its marginal cost is almost zero as it does not require fuel. As a result, it is generally "consumed" first (Pöyry, 2010).

Figure 6.4 below describes the mechanics behind the merit-order effect. As explained before, an increase in the supply derived from higher wind outputs, could potentially lead to a significant decrease in clearing prices depending on the initial demand level. The magnitude of this effect is exacerbated by the inelastic nature of electricity demand (Roldan-Fernandez, Burgos-Payan, Riquelme-Santos, & Trigo-Garcia, 2016).

This effect sparks some considerations with regards to the prices captured by wind installations and accordingly the inputs of our analysis. As it happens, the revenues from wind projects are dependent on the profile of the total electricity generated (Jones & Rothenberg, 2019). Provided that most of the revenue is generated during high production periods, according to the merit-order effect, higher renewable energy generation is associated with lower prices. As a result, the actual sale prices wind generators receive should be adjusted downwards compared to the average wholesale prices. This phenomenon could be defined as a price cannibalization (López Prol, Steininger, & Zilberman, 2020).

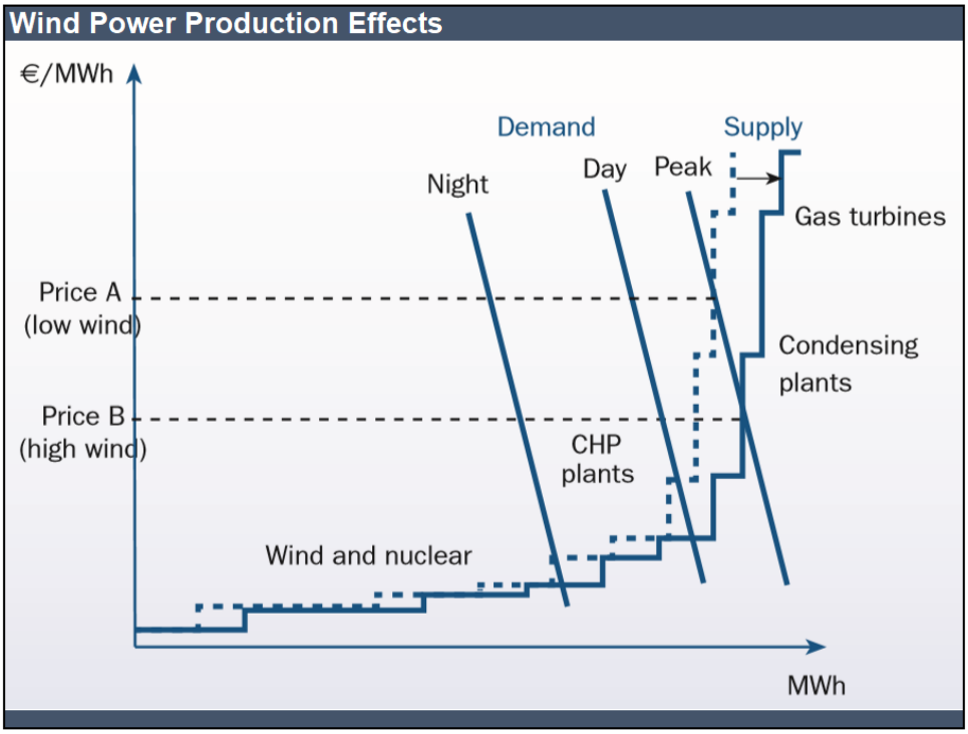

Figure 6.4 Source: Pöyry (2010)

BEIS and Aurora displayed an average cannibalization rate of 10% over the estimated UK wholesale baseload prices (Aurora Energy Research, 2017).

However, as the renewable capacity increases, it's hardly likely that the effect would remain constant (López Prol et al., 2020). Estimates of industry experts reveal that the 10% rate in 2020 would reach 20% by 2040 (McWhirther, 2020). Under the assumption of a constant growth rate, this translates into an effective annual growth rate of 3.53% for the cannibalization effect. These estimates were applied to the financial analysis proposed by the study. It should be noted however that the situation might be different over the years. Under one scenario a fast-increasing renewable capacity might further exacerbate the effect. In a different state of the world, future strategies could foresee this phenomenon and be adjusted accordingly, ultimately minimizing the impact on revenues. Our recommendation is that due to its fundamental importance for any renewable energy investment case, this effect should be closely monitored.

6.4.4. Price Volatility

The consequences of the deregulation of the power market can be observed in the inherent volatility of electricity prices (Blanco et al., 2001). As part of this thesis aims to assess the effects of merchant risk exposure to the profitability of the selected investment case, the price volatility estimate becomes a critical input for the risk analysis of the investment. The estimation of future price volatility is generally based on two distinct approaches (Darsinos & Satchell, 2007). The first one is the backward-looking approach, which assumes that historical data is a good reference for the future and therefore uses the historical volatility value. The second method is based on the assumption that the past is not representative of the future and estimates an implied volatility from instruments such as derivatives and options (Mayhew, 1995). As a matter of fact, early stage literature openly supported the implied method over the historical one (Mayhew, 1995). However, the tendency of derivatives to reflect inflation effects rather than expected prices (Deloitte, 2014) constitutes a significant drawback.

Similar to the discussion on the equity risk premium and beta, we find that there is not a "best" alternative between historical and implied method, as both arguments bring forth merits and flaws. In this case, due to the absence of future options within the same range of the project's life, the calculation of the price volatility will be based on a historical approach. Annual electricity baseload price data from year 2009 to 2019 was used for the calculation. Literature presents contrasting opinions on the period length. A few studies find that more extensive samples are associated with an increased bias (Butler & Schachter, 1986), while others state that shorter samples might overestimate the volatility (Beckers, 1981). We can conclude that there is not a general rule on the length of the sample.

Table 6.2 presents the calculation of the annual volatility from the data series. Formulas 3.8 and 3.9 were applied for the respective calculations of the logarithmic return and volatility. The figures for annual wholesale prices were collected from data published by BEIS (2019b) and Ofgem (2019a). As presented, the calculations provided an annual volatility value of 16.70%.

Historical Wholesale Price Volatility

$$\bar{R} = 0.09\%$$

$$\sigma = \sqrt[2]{\frac{1}{n-1}\sum_{i=1}^{n}(R_i - \bar{R})^2} = 16.70\%$$

$$Avg\ Price = 47.9$$

Years	Prices (GBP/MWh)	Log Return
2009	42.76	
2010	47.50	10.51%
2011	53.39	11.69%
2012	49.65	-7.26%
2013	54.59	9.47%
2014	44.63	-20.13%
2015	42.18	-5.67%
2016	40.31	-4.54%
2017	50.54	22.62%
2018	58.56	14.73%
2019	43.14	-30.56%

Table 6.2 Source: Own calculation

6.5. Financing and Capital Structure

In the introduction to this paper, the authors stressed the importance to identify proper capital providers capable of satisfying the funding requirements of the growing industry. Based on the current outlook, wind-farm projects have rapidly been able to secure funding, as they were compliant with investors requirements (WindEurope, 2019).

The capital required for an offshore wind-farm investment comes in the form of both equity and debt. The importance of accurate assumptions on the capital structure was already highlighted in this research, as it has a significant impact on the levelized cost of energy of offshore installations (IEA, 2019c).

6.5.1. Debt

Funding through a project finance approach has become more common in the offshore wind industry as an increasing number of projects have been initiated through a standalone company (Green Giraffe, 2019). Under this structure, both profits and liabilities are accrued directly to the project company and are separated from the balance sheet of the owners (Esty, 2004).

Under this mechanism, lenders must gauge the investment solely on the project's cash flows and have a claim only on the project's assets in case of default (Green Giraffe, 2019).

Thanks to subsidy support schemes, debt providers have started to get comfortable with the dynamics of non-recourse debt. As a matter of fact, in the year 2018, non-recourse funding for wind farms in Europe amounted to EUR 26.9 bn (WindEurope, 2019).
Overall, the good sentiment towards wind projects led to increasing leverage structures with debt levels estimated around 70%-80% of the total value (WindEurope, 2019). The appetite towards these ventures, along with the decreasing interest rates, resulted in extremely cheap debt financing with interest rates lower than 3% (Green Giraffe, 2019).

The analysis proposed by this study proposes an investment not backed by subsidies and hence fully exposed to merchant risk. Because of this, adjustments to industry averages are required. In particular, the study finds a 70% debt ratio to be unrealistic. The model has therefore been adjusted to a 50% debt ratio, as a result of interviews with an industry expert (McWhirther, 2020). On a similar approach, the nominal cost of debt was estimated to be 100bps over a comparable subsidized project (McWhirther, 2020). Under the assumption that a subsidized project could raise debt at 3% (BNEF, 2020; Green Giraffe, 2019), the model assumed a nominal cost of debt of 4%.

Wind projects can generally raise first a debt for construction, and afterwards refinance with a new loan to repay the old one under more favorable terms and generally longer maturities (WindEurope, 2019). Under the lack of empirical evidence from previous unsubsidized projects and the rationale of higher risk, the study assumed no refinancing options.
Consequently, debt will be raised with the purpose of financing construction. Under a conservative approach, the model assumed equity first financing. Given the 50% gearing and the equal Capex distribution between equity and debt, the latter will be raised in the last year of construction and accordingly no interest during construction (IDC) will accrue.

Debt transactions are strongly regulated by financial contracts in which lenders determine specific covenants over the size and repayment of principal (Mora et al., 2019). These restrictions are ordinarily related to a minimum debt service coverage ratio or the maintenance of a reserve account, ultimately resulting in the sculpting of annual installments to meet the requirements (Deloitte, 2014). The model proposed by this study does not factor covenants as these are specific to the project subject to the contract. Repayment has then been assumed to follow annuity payments with debt tenor of 15 years (BNEF, 2020).

6.5.2. Equity

The research operates on the assumption that the financial investor (pension Fund) enters the deal at the start of the first year of construction, therefore sharing the specific risk with the project developer. The deal has been assumed to be a 50:50 ownership between the developer and the investor. The authors have chosen this particular structure as it has proved roots in today´s investment scenario. Examples are the divestment of 50% of ownership of the German wind farm Gode Wind 2 and the UK offshore installation Walney Extension to a consortium of pension funds (Ørsted, 2014, 2017).
Consequently, the institutional investor is expected to contribute with half of the total CAPEX including 50% of the development costs already accrued to the project. According to the leverage structure proposed, the pension fund will then benefit from any surplus after debt service in equal measure with the wind farm developer.

6.5.2.1. Equity cost of capital

In the financial literature in chapter 3, the study provided the rationale behind the APV approach proposed by the model. The calculation of the metric requires an estimate of the unlevered cost of equity for the investment. By leveraging on the theory proposed in the literature chapter, this study proceeds with collecting and estimating the three inputs for the CAPM calculation.

The value of the market risk premium was collected from a dataset of Damodaran (2020). The estimate of 5.39% reflects expectations of the future equity risk premium, that is an implied measure. As already stated in the limitations, current developments in the global markets could cause an upside adjustment of the risk premium.

An estimate for the risk-free was then extracted from the 10-year UK bond yields historical data. Current rates are at an all-time low with values fluctuating around 0.30% (Bloomberg, 2020). Given the assumption that the investment reached a financial investment decision in 2019, this study finds inappropriate to employ the current values of the risk-free. Therefore, the figure was estimated by calculating the daily average for the year 2019 (see Appendix 4). The computations resulted in an average risk-free rate of 0.88%. The value was then nominalized according to an expected inflation rate of 2% resulting in a nominal risk-free rate of 2.90%, according to the formula shown below.

Nominal risk-free

$$nominal\ rate\ of\ return = (1 + real\ rate\ of\ return) * (1 + inflation\ rate) - 1$$

$$2.90\% = (1 + 0.88\%) * (1 + 2\%) - 1$$

Formula 6.1 Source: Own calculation based on Bodie et al. (2014)

Lastly, the appraisal of the project's unlevered beta was conducted by analyzing the profile of comparable companies. As expected, no companies that can be considered pure-plays were found. The reason for it is that all companies who operate in the offshore wind industry are active across several geographies and possess broader portfolios including other energy production technologies. The authors selected therefore five public firms that have large market shares in the offshore wind industry and can hence be considered as an expression of the overall offshore wind industry's risk (see Appendix 5-9). The major developers and manufacturers were therefore included. In particular, the study focused on: Ørsted, RWE, Vestas Wind Systems, Siemens Gamesa Renewable Energy and EDP Renováveis.

Peer Group Comparison

Company	Levered Beta	Average Debt/Equity	Corporate Tax Rate	Unlevered Beta
Ørsted A/S	0.39	0.67	22%	0.26
RWE AG	0.81	0.80	30%	0.52
Vestas Wind Systems A/S	0.61	0.17	22%	0.54
Siemens Gamesa Renewable Energy S.A.	0.65	0.10	25%	0.60
EDP Renováveis S.A.	0.52	0.50	25%	0.38
			Average	**0.46**

Table 6.3 Source: Own calculation

The betas were calculated through a regression between each company's returns with the returns of the market index, expressed by the MSCI World Index ETF. Five years of daily stock prices were used for the calculation, as this corresponds to a standard procedure in financial literature. After calculating the levered betas, those were unlevered according to Formula 3.4 using each company's average debt-to-equity ratio and country specific corporate tax rate. The gearing ratio was initially collected from Thomson ONE (2020) for a period of 5 years, consistent with the regression data. However, the less recent years presented abnormal values that we decided to not include in the debt-to-equity average, as they are the outcome of extraordinary events and hence not an expression of business as usual. Ultimately, the average was taken from the last 3 years of operation (see Appendix 5-9). Corporate tax values were then collected from KPMG (2020). As a result of all these calculations, the average unlevered beta found was 0.46.

Having individuated all the inputs for the CAPM equation presented in Formula 3.3, the study estimated an unlevered cost of equity of 5.37% as shown below.

Unlevered cost of equity

$$R_e = R_f + \beta(R_M - R_f)$$

$$5.37\% = 2.90\% + 0.46 * 5.39\%$$

$R_e = unlevered\ cost\ of\ equity$
$R_f = risk\ free$
$R_M = Market\ return$
$\beta = Project\ Beta$

Formula 6.2 Source: Own calculation based on Bodie et al. (2014)

On a similar approach to the one offered in the previous section, the authors deemed necessary to adjust the resulting figure. As it stands, an unlevered cost of equity of 5.37% reflects the risks associated to a subsidized renewable energy project. A full merchant risk exposure would therefore require an upside adjustment to risk expectations. As a result of an interview with professionals of the industry, the study corrected the estimate of the unlevered cost of equity to 8% (McWhirther, 2020). As previously indicated, the valuation of the investment does not require the calculation of the levered cost of capital.

6.6. Model Overview

Table 6.4 aggregates the main assumptions and the data collected for the study. The model incorporates a corporate tax rate of 19% as well as the possibility to carry forward net operating losses for tax deductibility purposes. These have been adjusted according to the limit imposed by UK tax regulations. More specifically, according to the HM Revenue & Customs (HMRC) (2018) operating losses can be carried forward with no expiration, but are ultimately limited to GBP 5,000,000 plus 50% of the excess negative profits realized.
From the overview it can then be deducted that the Capex does not result in interests either paid or capitalized during the construction period. As mentioned in section 6.2 of this chapter, the net plant

balance was depreciated according to the proposed method by Bloomberg (2020), until a final value of 5% was left.

FINANCIAL MODEL - REFERENCE CASE

General Assumptions		**Financing Structure**	
Construction start date	2020	Funding type	Equity First
Operation start date	2022	Gearing ratio	50%
Operation life (years)	25	Debt tenor (year	15
Market Assumptions		Cost of debt	4%
Inflation rate	2%	Repayment	Annuity
Corporate tax rate	19%	Senior debt	100%
Depreciation rate	4%	Junior debt	0%
Tax Depreciation (% Capex)	95%		
Cannibalization rate	10%		
Cannibalization growth rate	3.53%		

Year	2020	2021	2022	2023	2024	2035	2036	2037	2045	2046
Net annual electricity production			4,471,000	4,471,000	4,471,000	4,471,000	4,471,000	4,471,000	4,471,000	4,471,000
Nominal Merchant prices			56.89	58.58	62.57	78.40	80.77	83.21	105.57	108.76
Effective Cannibalization rate	10.00%	10.35%	10.72%	11.10%	11.49%	16.82%	17.41%	18.03%	23.78%	24.62%
Nominal Captured prices			**50.80**	**52.08**	**55.39**	**65.21**	**66.70**	**68.21**	**80.46**	**81.98**
Inflation index	102.00%	104.04%	106.12%	108.24%	110.41%	137.28%	140.02%	142.82%	167.34%	170.69%

Year	2020	2021	2022	2023	2024	2035	2036	2037	2045	2046
Fixed OPEX			(80,651,808)	(82,264,844)	(83,910,141)	(104,331,714)	(106,418,348)	(108,546,715)	(127,179,777)	(129,723,372)
CAPEX	(820,500,000)	(820,500,000)								
Depreciation Expense			(62,358,000)	(62,358,000)	(62,358,000)	(62,358,000)	(62,358,000)	(62,358,000)	(62,358,000)	(62,358,000)
Accumulated Depreciation			(62,358,000)	(124,716,000)	(187,074,000)	(873,012,000)	(935,370,000)	(997,728,000)	(1,496,592,000)	(1,558,950,000)
Net Plant Balance	820,500,000	1,641,000,000	1,578,642,000	1,516,284,000	1,453,926,000	767,988,000	705,630,000	643,272,000	144,408,000	82,050,000
Equity funded	**820,500,000**	**-**								
Debt funded	**-**	**820,500,000**								
Interests capitalized	-	-								
Interests paid	-	-								

Table 6.4 Source: Own calculation

A more detailed representation of the table and the financial model built for this thesis could be observed in Appendix 10. The material was provided in an Excel spreadsheet format.

7. Financial Analysis

In this chapter we will provide an evaluation of the profitability of the offshore wind investment under merchant risk exposure. The data and the assumptions presented in the previous chapters will be used, through a Monte Carlo approach, to produce distributions of key financial metrics such as Adjusted Present Value and Internal Rate of Return. This section will then propose a sensitivity analysis to assess the relative impact that the inputs have on the selected metrics. The calculations shown will be based on the static reference scenario. A detailed overview of the calculations for all the proposed scenario including the results of the Monte Carlo simulations could be found in Appendix 10 which was provided in an Excel spreadsheet format.

7.1. APV

The evaluation of the feasibility of the entire project is approached through the calculation of the adjusted present value. This methodology was proposed as a consequence of the variable leverage structure of the investment where the debt issued in the second year of construction is effectively repaid throughout 15 years of operations.

The APV calculation separately addresses the present value of the project assuming that is solely financed by equity, and the present value of the net effects of debt. The first step starts from the investigation of the free cash flows to the firm. That is, the cash flows available for distribution to all parties holding a claim to the project.

FREE CASH FLOW Year	2020	2021	2022	2023	2024	2035	2036	2037	2045	2046
Revenues			227,112,843	232,853,259	247,635,044	291,573,497	298,237,331	304,959,928	359,732,010	366,517,552
Nominal Fixed Opex			(80,651,808)	(82,264,844)	(83,910,141)	(104,331,714)	(106,418,348)	(108,546,715)	(127,179,777)	(129,723,372)
EBITDA			**146,461,035**	**150,588,415**	**163,724,903**	**187,241,783**	**191,818,984**	**196,413,213**	**232,552,233**	**236,794,180**
Depreciation			(62,358,000)	(62,358,000)	(62,358,000)	(62,358,000)	(62,358,000)	(62,358,000)	(62,358,000)	(62,358,000)
EBIT before NOL			**84,103,035**	**88,230,415**	**101,366,903**	**124,883,783**	**129,460,984**	**134,055,213**	**170,194,233**	**174,436,180**
NOL Initial Balance										
Tax Losses										
Net Operating Losses										
NOL Ending Balance										
Adjusted EBIT			**84,103,035**	**88,230,415**	**101,366,903**	**124,883,783**	**129,460,984**	**134,055,213**	**170,194,233**	**174,436,180**
Tax Rate			19%	19%	19%	19%	19%	19%	19%	19%
Tax on Adjusted EBIT			(15,979,577)	(16,763,779)	(19,259,712)	(23,727,919)	(24,597,587)	(25,470,490)	(32,336,904)	(33,142,874)
NOPAT			**68,123,458**	**71,466,636**	**82,107,192**	**101,155,864**	**104,863,397**	**108,584,723**	**137,857,329**	**141,293,306**
Depreciation			62,358,000	62,358,000	62,358,000	62,358,000	62,358,000	62,358,000	62,358,000	62,358,000
Change in NWC										
Change in CAPEX	(820,500,000)	(820,500,000)								
FCFF	**(820,500,000)**	**(820,500,000)**	**130,481,458**	**133,824,636**	**144,465,192**	**163,513,864**	**167,221,397**	**170,942,723**	**200,215,329**	**203,651,306**

Table 7.1 Source: Own calculation

Table 7.1 shows the procedure with which the FCFF of the project have been calculated. Firstly, both operating costs and depreciation expenses have been deducted from the project's revenue in order to estimate the EBIT. Under the assumption of an unlevered investment, taxes are calculated directly from the operating income. It should be noted that the model accounted for the carry forward of operating losses, hence taxes are calculated on the adjusted EBIT. While this static case does not include losses, the mechanism is called to action during the iterations produced by Monte Carlo. Taxes are then subtracted from the EBIT to find the net operating profit after taxes (NOPAT). Finally, FCFF are obtained by adding back non-cash expenses such as depreciation and by subtracting the change in net working capital and Capex. Within this model, no working capital has been factored as the balance sheet includes neither current assets, nor current liabilities (Petersen et al., 2017).

The next step in the calculation of the APV relates to the estimation of the net debt effects. This model accounted for debt benefits through the calculation of a tax shield. Following the theory proposed in chapter 3, the calculation of the tax shield has been proposed as the difference in tax payments. This specific methodology allows to take into consideration the effect of the carry forward of operating losses under the consideration that no interest income is applicable (Velez-Pareja, 2016).

PROFIT AND LOSS STATEMENT											
	Year	2020	2021	2022	2023	2024	2035	2036	2037	2045	2046
Revenues				227,112,843	232,853,259	247,635,044	291,573,497	298,237,331	304,959,928	359,732,010	366,517,552
Nominal Fixed Opex				(80,651,808)	(82,264,844)	(83,910,141)	(104,331,714)	(106,418,348)	(108,546,715)	(127,179,777)	(129,723,372)
EBITDA				**146,461,035**	**150,588,415**	**163,724,903**	**187,241,783**	**191,818,984**	**196,413,213**	**232,552,233**	**236,794,180**
Depreciation				(62,358,000)	(62,358,000)	(62,358,000)	(62,358,000)	(62,358,000)	(62,358,000)	(62,358,000)	(62,358,000)
EBIT				**84,103,035**	**88,230,415**	**101,366,903**	**124,883,783**	**129,460,984**	**134,055,213**	**170,194,233**	**174,436,180**
Interest Expenses				(32,820,000)	(31,180,933)	(29,476,303)	(5,567,500)	(2,838,334)			
EBT before NOL				**51,283,035**	**57,049,482**	**71,890,600**	**119,316,283**	**126,622,650**	**134,055,213**	**170,194,233**	**174,436,180**
NOL Initial Balance											
Plus Tax Losses											
Less Net Operating Losses											
NOL Closing Balance											
Adjusted EBT				**51,283,035**	**57,049,482**	**71,890,600**	**119,316,283**	**126,622,650**	**134,055,213**	**170,194,233**	**174,436,180**
Tax Rate				19%	19%	19%	19%	19%	19%	19%	19%
Tax (on Adjusted EBT)				(9,743,777)	(10,839,402)	(13,659,214)	(22,670,094)	(24,058,304)	(25,470,490)	(32,336,904)	(33,142,874)
Net Income				**41,539,258**	**46,210,080**	**58,231,386**	**96,646,189**	**102,564,347**	**108,584,723**	**137,857,329**	**141,293,306**

Table 7.2 Source: Own calculation

Table 7.2 above presents the profit & loss statement for the project. In particular, the analysis identifies the tax calculation under the comprehensive assumption of the project being levered. It is now possible to finalize the calculation of the APV by adding the present value of the FCFF discounted at the unlevered cost of equity, and the present value of the tax shield discounted at the cost of debt. Estimate of the present values were obtained through the Excel function XNPV to account for the end of the year timing of cash flows. Table 7.3 displays an exhibit of the calculations. As expected, tax shield values only accrue during the tenor of the debt.

ADJUSTED PRESENT VALUE	Year	2020	2021	2022	2023	2024	2035	2036	2037	2045	2046
Interest Rate		4%	4%	4%	4%	4%	4%	4%	4%	4%	4%
Remaining Years				15	14	13	2	1			
Initial Balance				820,500,000	779,523,327	736,907,587	139,187,512	70,958,339			
Debt Drawdown			820,500,000								
Debt Service				(73,796,673)	(73,796,673)	(73,796,673)	(73,796,673)	(73,796,673)			
Interest Payment				32,820,000	31,180,933	29,476,303	5,567,500	2,838,334			
Repayment of Principal				(40,976,673)	(42,615,740)	(44,320,369)	(68,229,172)	(70,958,339)			
Closing Balance			820,500,000	779,523,327	736,907,587	692,587,218	70,958,339	0			
Tax shield				**6,235,800**	**5,924,377**	**5,600,498**	**1,057,825**	**539,283**			
FCFF		**(820,500,000)**	**(820,500,000)**	**130,481,458**	**133,824,636**	**144,465,192**	**163,513,864**	**167,221,397**	**170,942,723**	**200,215,329**	**203,651,306**
Cost of Equity (unlevered)	8%										
Cost of Debt	4%										
PV FCFF	1,314,152										
PV Tax shield	41,920,720										
APV	**43,234,873**										

Table 7.3 Source: Own calculation

The APV value proposed in the table does not properly describe the value of the investment. As a matter of fact, the value of GBP 43,234,873 is a static value and does not reflect an investment exposed to fluctuating electricity prices. Therefore, the analysis makes use of Monte Carlo simulations in order to take that variability into consideration.

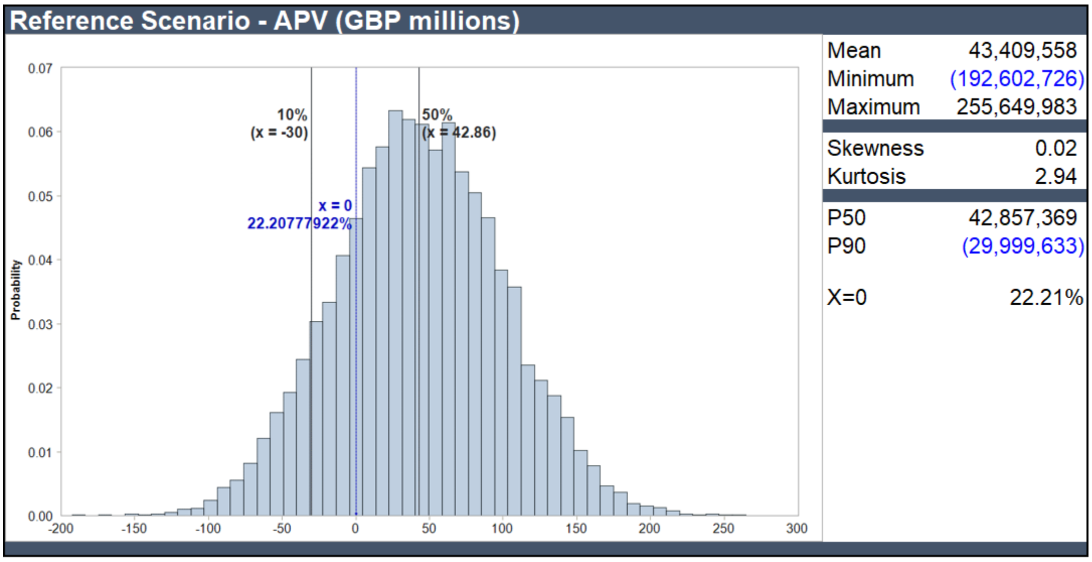

Figure 7.1 Source: Own depiction using ModelRisk (Vose Software, 2020)

Figure 7.1 displays the results of the APV's distribution after 10,000 Monte Carlo iterations. The reference case scenario reveals that there is a 50% probability (P50) that the adjusted present value will be above or below GBP 43,409,558. Furthermore, the P90 stands at around GBP -30 million, meaning that in 90% of the cases the APV will be above that value. In 77.79% of the cases, the APV returns a positive value in the reference scenario.

7.2. Equity IRR

Another key output of this analysis can be identified in the Equity Internal Rate of Return. The calculation of the Equity IRR is based on the free cash flows to equity holders. This consideration can be made under the assumption that the free cash flows to the equity holders (FCFE) are fully distributed as dividends.

EQUITY IRR	Year	2020	2021	2022	2023	2024	2035	2036	2037	2045	2046
EBITDA				146,461,035	150,588,415	163,724,903	187,241,783	191,818,984	196,413,213	232,552,233	236,794,180
Taxes Paid				(9,743,777)	(10,839,402)	(13,659,214)	(22,670,094)	(24,058,304)	(25,470,490)	(32,336,904)	(33,142,874)
CFADS				**136,717,258**	**139,749,013**	**150,065,689**	**164,571,689**	**167,760,680**	**170,942,723**	**200,215,329**	**203,651,306**
Interest on Senior Debt				(32,820,000)	(31,180,933)	(29,476,303)	(5,567,500)	(2,838,334)			
Senior Debt Repayment				(40,976,673)	(42,615,740)	(44,320,369)	(68,229,172)	(70,958,339)			
Cash after Debt Service				**62,920,585**	**65,952,340**	**76,269,016**	**90,775,017**	**93,964,007**	**170,942,723**	**200,215,329**	**203,651,306**
Debt Default											
Repayment of Default											
Cash available to shareholders				**62,920,585**	**65,952,340**	**76,269,016**	**90,775,017**	**93,964,007**	**170,942,723**	**200,215,329**	**203,651,306**
Equity funded Capex		(820,500,000)									
FCFE		**(820,500,000)**	**-**	**62,920,585**	**65,952,340**	**76,269,016**	**90,775,017**	**93,964,007**	**170,942,723**	**200,215,329**	**203,651,306**
FCFE - Cumulative		(820,500,000)	(820,500,000)	(757,579,415)	(691,627,074)	(615,358,058)	401,103,151	495,067,158	666,009,881	2,166,535,700	2,370,187,006
Payback Period	11										
Equity IRR	**10.03%**										

Table 7.4 Source: Own calculation

The table above describes the calculation of the Equity IRR. The FCFE have been estimated through a waterfall approach where each party holding claims in the project's proceeds has been satisfied in order. More specifically, equity holders are entitled to cash flows after the taxes are paid and the debt is serviced. Again, to account for the end of the year timing of cash flows, the IRR was obtained by applying the Excel function XIRR.

Following the same approach as with the APV, uncertainty regarding the electricity prices is introduced in the IRR calculation. The results are visible in Figure 7.2 and they describe an Internal Rate of Return distribution around a mean value of 10.04%. The P50 metrics showcases a value of 10.03%, while the conservative P90 presents a return on the equity investment of at least 9.30%.

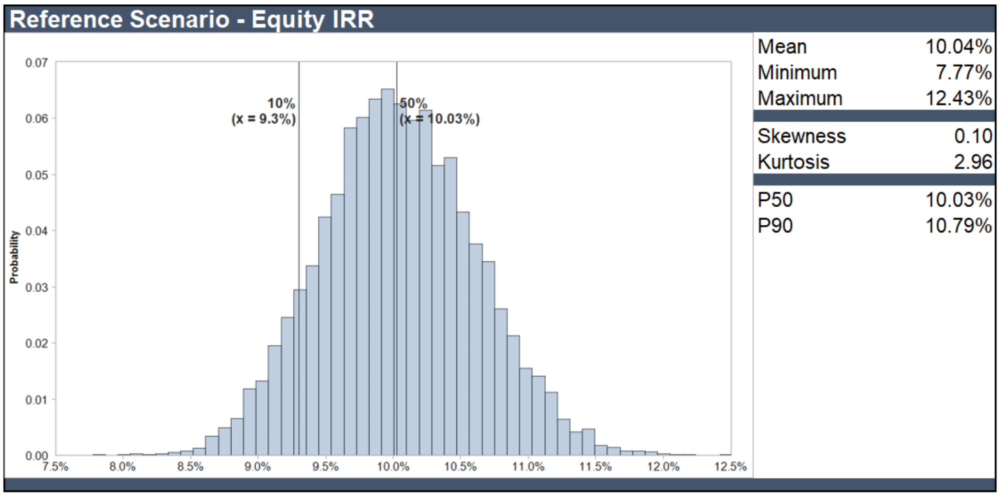

Figure 7.2 Source: Own depiction using ModelRisk (Vose Software, 2020)

7.3. Alternative Scenarios

The calculations provided above are based on the base case projection of future wholesale electricity prices. Following the same methodology, the study now provides figures for the low price and high price scenarios.

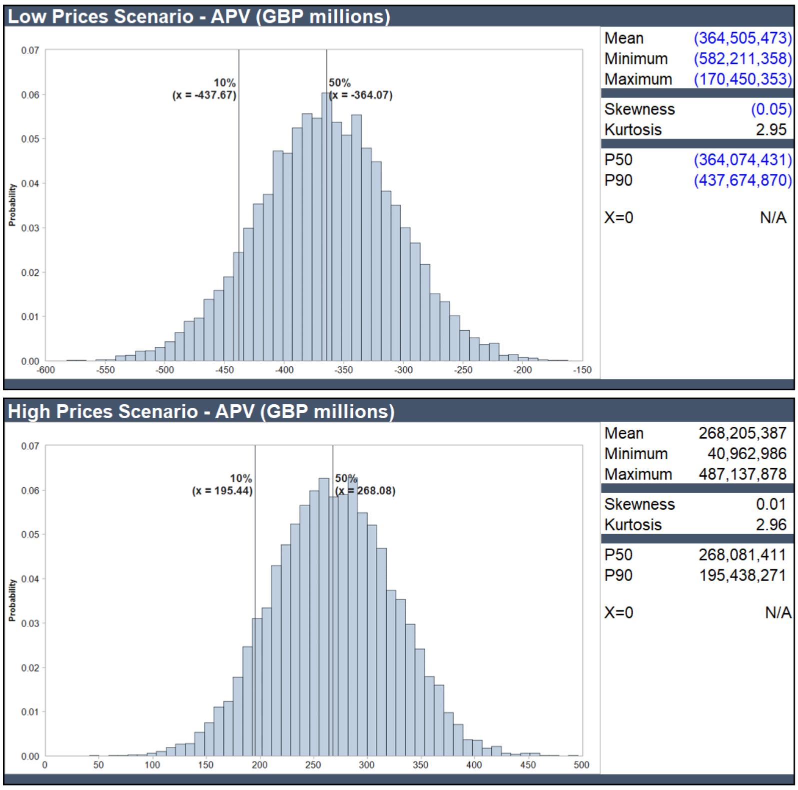

Figure 7.3 Source: Own depiction using ModelRisk (Vose Software, 2020)

Figure 7.3 presents the distribution of the adjusted present value for the two alternative scenarios. With regards to the high prices scenario, the outlook of the investment is encouraging as both P50 and P90 results showcase positive Adjusted Present Values. As a matter of fact, even the minimum value recorded by the simulation would support the investment decision. On the other hand, the low prices scenario analysis details a completely different stance. The scenario returns negative values for the entire distribution of the adjusted present value effectively discouraging any investment decision.

The study now provides the internal rate of return distributions for the equity holders. The results are displayed in Figure 7.4 and reflect the dynamics described by the APV distributions.

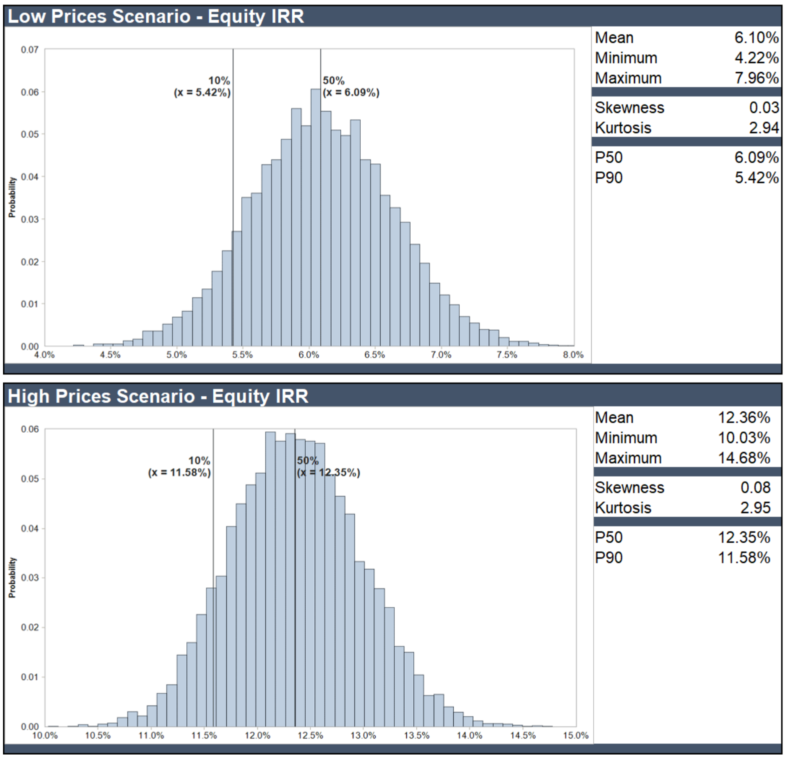

Figure 7.4 Source: Own depiction using ModelRisk (Vose Software, 2020)

More specifically, the high prices scenario reinforces the positive outlook presenting a P50 of 12.35% and a P90 of 11.58%. The evaluation of the low prices scenario showcases instead values that are lower than the unleveraged cost of capital, with a P50 of 6.09% and a P90 of 5.42%.

7.4. Sensitivity Analysis

The previous evaluations provided a clear overview of the unsubsidized offshore wind investment, both from the perspective of the overall project and from the angle of the equity holders. According to the established methodology, the focal point of the study lied on the uncertainty of the market for electricity. Indeed, this has been considered as the main influence for the appraisal of unsubsidized renewable projects.

Nevertheless, effective decision-making needs also to take into consideration developments in other areas that could ultimately affect the outcome. This concern has been taken into account with the sensitivity analysis depicted in Figure 7.5 below. The data table related to the tornado plot depicted could then be found in Appendix 11.

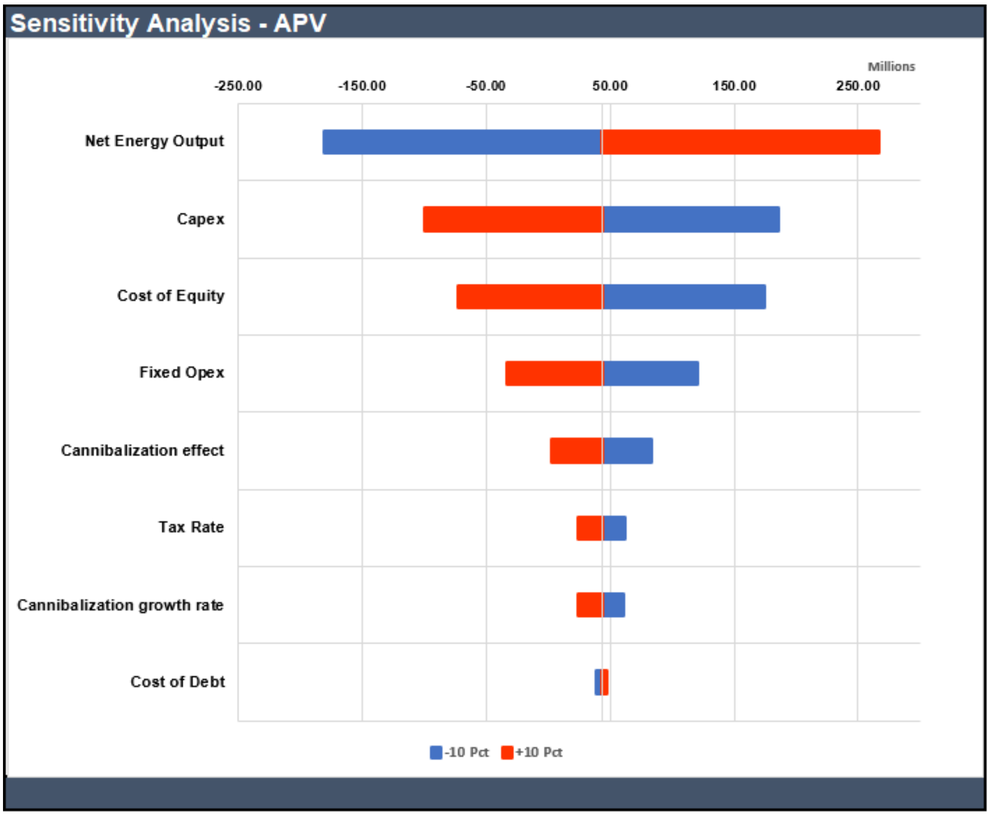

Figure 7.5 Source: Own depiction

For the purpose of the analysis, the project´s adjusted present value has been tested for a 10% variability of the selected inputs.

Unsurprisingly, the adjusted present value has been found extremely sensible to the net output of energy produced by the wind farm as a positive 10% change in production corresponded to an additional 447,100 MW/h of yearly production for the studied wind farm. The proven impact that energy production has on the profitability of the investment further reinforces the pursuit of the industry for increased performance and superior capacity factors.

Changes in Capex constitute the second factor with regards to impact. The results are in line with the consideration of offshore wind being a capital-intensive industry. On a similar note to the energy production, the high influence of capital costs on the value of the investment is behind the drive for technology and supply chain improvements.

The analysis then identified the discount rate as the next main determinant of the output. This is not a surprising result as the relevance of financing costs in the evaluation of investments has been extensively proved in practice (IEA, 2019c).

Overall, the analysis provides an interesting perspective on how certain inputs would ultimately affect the output. However, the method presents significant limitations. More specifically, the variability in the output is considered against the variability of each input while holding everything else constant. This hardly happens in the real world. In particular, the merit order effect suggests that an increase in energy output could potentially lead to an increased severity of the cannibalization effect. While the sensitivity analysis projected a relatively low impact of a 10% increase in the initial cannibalization rate, concerns should be raised whether the proposed increase in output would be reflected with an exponentially increase in the cannibalization effect. As a result of this consideration, the study reiterates the necessity of further investigation. In particular, additional research is required to explore the interdependencies between technological, political and economic uncertainties that affect the industry.

8. Portfolio Analysis

This chapter attempts to present a theoretical and quantitative assessment of the attractiveness of the unsubsidized offshore wind project from a portfolio perspective. Firstly, three diverse portfolio compositions of typical pension funds will be presented. Markovitz's portfolio theory will then be employed to evaluate the effects of an additional asset class represented by the offshore wind project. The aim of this analysis is to reveal how attractive the unsubsidized UK project is for pension funds, and how much capital would they be willing to allocate to it, given their risk appetite and investment strategy.

8.1. Investment Strategies

Nowadays, pursuing an enlightened strategic asset allocation is critical to achieve superior investment returns. According to a report from Aberdeen Standard Investments (ASI) (2019), a tactical selection of assets can effectively improve performances.

The first perk of strategic asset allocation can be identified within the structural process that requires careful and constant evaluation of the investment classes, in particular with regards to the risk premium (ASI, 2019). As it happens, the metric is highly volatile as it is significantly affected by future expectations. An outlook deemed positive by investors results in a decreased risk premium as more wealth is distributed. Returns are then lowered accordingly. The opposite is then true when investors hold more pessimistic expectations. The overall decreased risk willingness inflates risk premia and thus the expected returns (ASI, 2019). Ultimately, value is extracted by recognizing this mechanism and by allocating wealth to assets exhibiting the best price/risk premia trade off (ASI, 2019).
Benefits from strategic allocation are then indirectly extracted from the attention on expected future returns. The discipline relies on the understanding that historical values cannot be expected to reliably represent the future. As a results trends and changes in the global economic and regional landscapes needs to be carefully considered (ASI, 2019).
Lastly, key to the practice of strategic asset allocation is diversification. As already outlined in the financial literature in chapter 3, the combination of uncorrelated assets within a portfolio allows for an improved risk/return trade off (Elton & Gruber, 1997). This has been currently put to heavy

strain as the decreasing interest rates severely affected the marginal benefits from a bond allocation strategy. As a result, new asset classes need to be discovered to supplement the decreased appeal of traditional diversification approaches (APPG, 2019). The key to the search is the analysis of correlation coefficients. More specifically, assets uncorrelated with the fluctuations of the equity market are required in order to provide benefits (ASI, 2019).

Historically, the correlation appraisal practices of investors have been found flawed. During the financial crisis of 2008, several unconventional investments made to hedge market fluctuations ultimately displayed a significant sensibility to the movements of the equity markets. Therefore, investors are now looking to alternative investments that could satisfy the diversification requirement (ASI, 2019).

8.2. Portfolio Overview

The study will now analyze three potential pension funds' portfolios that have different approaches to asset allocation and diversification. The first is a classic portfolio composed mainly of equities and bonds. The paper will later introduce a more modern portfolio that moves slightly beyond the traditional mix of pure equities and bonds. Finally, a third portfolio which presents a more ambitious approach to diversification and has a significantly increased risk-return profile will be presented.

The procedure for creating and optimizing the different benchmarked portfolios was the following:

1. The asset class selection for each portfolio, their respective expected returns and volatilities were taken from ASI (2019). These are based on a ten-year horizon standard forecast.

2. The authors then selected an ETF on the market that would best represent each asset class and extracted from an online source the correlation matrix based on the last 5 years daily historical returns. A shorter range was preferred because correlations between assets tend to change over time and a period of 5 year would in this case best reflect the most recent correlation measures for the chosen securities. Table 8.1 presents the correlation matrix of all the assets classes. A more detailed representation of the selected ETF and the relative correlation coefficients is displayed in Appendix 12.

All Asset Classes Correlation Matrix												
	Global Equ	Global Equ	Global DM	Global IG E	Global Higl	EM Debt (L	Senior Sec	ABS - Mez	Insurance	Global Cor	Infrastructi	Wind Energy
Global Equities	1	0.55	-0.08	-0.16	0.33	0.22	0.52	-0.21	0.75	0.64	0.79	0.74
Global Equities Low Volatility	0.55	1	0.05	-0.05	0.23	0.14	0.22	-0.07	0.41	0.41	0.47	0.48
Global DM Govt Bonds	-0.08	0.05	1	0.63	0.05	0.21	-0.02	0.52	-0.16	0.15	0.10	0.04
Global IG Bonds	-0.16	-0.05	0.63	1	0.08	0.22	-0.05	0.76	-0.30	0.16	0.10	0.02
Global High Yield Bonds	0.33	0.23	0.05	0.08	1	0.17	0.20	0.01	0.16	0.22	0.40	0.40
EM Debt	0.22	0.14	0.21	0.22	0.17	1	0.15	0.20	0.06	0.23	0.30	0.25
Senior Secured Loans	0.52	0.22	-0.02	-0.05	0.20	0.15	1	-0.12	0.39	0.35	0.45	0.40
ABS - Mezzanine	-0.21	-0.07	0.52	0.76	0.01	0.20	-0.12	1	-0.34	0.10	0.01	-0.08
Insurance Linked Securities	0.75	0.41	-0.16	-0.30	0.16	0.06	0.39	-0.34	1	0.46	0.52	0.50
Global Commercial Property	0.64	0.41	0.15	0.16	0.22	0.23	0.35	0.10	0.46	1	0.70	0.55
Infrastructure Social	0.79	0.47	0.10	0.10	0.40	0.30	0.45	0.01	0.52	0.70	1	0.74
Wind Energy	0.74	0.48	0.04	0.02	0.40	0.25	0.40	-0.08	0.50	0.55	0.74	1

Table 8.1 Source: Own depiction based on Portfolio Visualizer (2020)

3. Starting from the correlation matrix, a covariance matrix was created for each portfolio (see Appendix 13) in order to calculate the total portfolio variance according to Formula 3.11. Given that there is no security on the market that can be considered representative of the unsubsidized offshore wind project, this paper then assumed that the correlation between the latter and the other asset classes can be calculated using an ETF constituted by stocks of several companies in the offshore wind industry. For that purpose, First Trust Global Wind Energy ETF was selected (First Trust, 2020). This is a proxy, given that the ETF is a diversified product across regions and composed of several companies that have different risk-return profiles. However, this study found it to be an appropriate product to be used for the correlation of the offshore wind industry returns with the other asset classes.

4. The final procedure was to optimize the portfolio weights in order to reach the best possible risk return trade-off, which is done through the maximization of the portfolio's Sharpe ratio. The procedure was executed with Excel Solver disregarding short positions. In order to have comparable results across the 3 different portfolios, volatility was set at a fixed level of 6% as an optimization constraint, which is a conservative number, in line with the risk averse profile of the typical pension fund.

8.2.1. Traditional Balanced Portfolio

Table 8.2 presents the optimal (max. Sharpe Ratio) Traditional Balanced portfolio, which is made up of a combination of global equities, government bonds and corporate bonds.

	Traditional Balanced			
	Weight (%)	Expected Return (%)	Volatility (%)	Sharpe Ratio
Global Equities	33.4	4.4	16.0	0.22
Global DM Govt Bonds	31.7	1.3	3.9	0.11
Global IG Bonds	34.9	1.8	7.8	0.12
TOT	100.0			
Portfolio Total Return (%)		2.5		
Portfolio Volatility (%)		6.0		
Portfolio Sharpe Ratio		0.3		

Table 8.2 Source: Own calculation

It should be noted that equity returns are expected to be lower than their long-term average. The rationale behind the reduced value can be extracted from sub-optimal growth expectations as well as from "cyclically stretched profit margins and valuations" (ASI, 2019).

Government bonds, as already anticipated, also exhibit a significantly lower return compared to their historic averages. More specifically, the estimates for the next decade present a 2% annual decrease compared to past performances (ASI, 2019). Investment grade (IG) corporate bonds are also slightly affected by the low interest rates. However, the expected returns for this asset class are assumed to be comparable with past performances (ASI, 2019).

8.2.2. Modern Balanced Portfolio

	Modern Balanced			
	Weight (%)	Expected Return (%)	Volatility (%)	Sharpe Ratio
Global Equities	25.9	4.4	16.0	0.22
Global DM Govt Bonds	18.1	1.3	3.9	0.11
Global IG Bonds	31.0	1.8	7.8	0.12
Global High Yield Bonds*	15.0	3.9	9.1	0.33
Global Commercial Property*	10.0	5.5	9.9	0.47
TOT	100.0			
Portfolio Total Return (%)		3.1		
Portfolio Volatility (%)		6.0		
Portfolio Sharpe Ratio		0.4	*Maximum weights for illiquidity constraints	

Table 8.3 Source: Own calculation)

Table 8.3 displays the Modern Balanced portfolio. The portfolio composition is structurally not too different from the more traditional approach, but it introduces an increased attention to asset class diversification. High yield bonds are added to the portfolio as well as investments in commercial real estate.

According to the Aberdeen report (2019), high yield bonds offer a higher expected rate of return against a small increase in the volatility and hence represent a good addition for portfolios who seek increased asset class diversification and better returns over the long run.
With regards to commercial real estate, benefits are extracted in terms of diversification and inflation protection. The estimate of the expected return on commercial properties takes into consideration both rent income and capital gains from a change in the market price of the assets. (ASI, 2019).

8.2.3. Diversified Growth Portfolio

	Diversified Growth			
	Weight (%)	Expected Return (%)	Volatility (%)	Sharpe Ratio
Global Equities Low Volatility	16.9	4.4	13.7	0.26
Global High Yield Bonds	4.3	3.9	9.1	0.33
EM Debt (Local)	23.7	4.1	9.4	0.34
Senior Secured Loans*	10.0	4.6	7.1	0.52
ABS - Mezzanine*	15.0	6.7	10.2	0.57
Insurance Linked Securities*	5.0	5.2	7.6	0.57
Global Commercial Property*	10.0	5.5	9.9	0.47
Infrastructure Social*	15.0	6.0	10.6	0.48
TOT	100.0			
Portfolio Total Return (%)		5.1		
Portfolio Volatility (%)		6.0		
Portfolio Sharpe Ratio		0.7	*Maximum weights for illiquidity costraints	

Table 8.4 Source: Own calculation

Table 8.4 presents the last of the benchmarked portfolio, namely the Diversified Growth portfolio. The combination aims to meet the needs of moderately risk-averse, growth investors. It should be first noted that government and investment grade corporate bonds are excluded altogether as a result of the inherent low returns (ASI, 2019). The allocation is also severely restricted in the amount of asset dedicated to global equities allowing for broader diversification. Diversification benefits are then exacerbated by the relative low correlations between the additional asset classes (ASI, 2019). This results in a final portfolio that could be reasonably expected to outperform traditional compositions under the current economic outlook, as it provides a higher expected rate of return over the same portfolio volatility of 6% (ASI, 2019).
While performing the portfolio optimization, the weights of the more illiquid asset classes were constrained to maximum amounts of the total weight, in order to reflect the liquidity needs of pension funds and also avoid unrealistic results where the theorical optimal portfolio would have

been composed solely of one asset class and disregarded the others. These constraints are assumptions extracted from the 2019 Aberdeen Standard Investments report and might be different from fund to fund.

Under a diversified growth allocation, the portfolio is composed of alternative credit instruments, emerging markets securities and real assets (ASI, 2019). Alternative credit instruments are comprised by both senior corporate loans and asset-backed securities (ABS) at a mezzanine level. These asset classes are generally described by floating rates which effectively hedge the risk of upswings in the interest rates. As could be expected from the lower seniority, ABS enjoy higher returns as a result of lower liquidity and higher risks (ASI, 2019).
It should be then noted that the exclusion of government bonds was limited to the debt instruments issued by developed countries. As a matter of fact, fixed income instruments issued by emerging economies could be considered appealing to investors. The latest performances displayed solid figures, as regulated inflation and attractive growth translated to an approximate 6% annual return (ASI, 2019).
Lastly, a quarter of the portfolio weight was allocated to real assets. These represent both real estate and infrastructure investments which as stated in the previous sections, offer benefits in terms of lower equity correlation and superior returns (ASI, 2019).

As of today, the majority of pension investments are focused on assets that are traded on public markets (ASI, 2019). However, superior returns could be achieved by allocating wealth to private assets. Research shows that losing liquidity benefits in favor of longer investment horizons translates into a return premium ranging from 2% to 4% (ASI, 2019). The increased interest for private markets in recent years means that this premium is now at the lower end of the range, but, given the low expected returns elsewhere, it is still worthwhile. Nevertheless, access to superior returns is significantly dependent on the investment managers skills as private illiquid markets still allow for significant spreads between the best and worst performing players (ASI, 2019). Careful manager selection is then critical to the success of an investment strategy. As a general rule for investors that can bear illiquidity risk, a more aggressive diversification strategy may deliver higher returns with lower risk (ASI, 2019).

This being said, a visual representation of the benefits of diversification will be now provided. Next, the paper will proceed with the inclusion of the offshore wind project to all 3 portfolios. The goal is to quantify its optimal allocation in each of the benchmarked compositions, measure the impact on the overall risk and profitability and in this way assess the attractivity of this “new asset class” for pension funds.

8.3. Efficient Frontier and Optimal Portfolio

Before proceeding with the portfolio integration of the offshore wind project, a graphical demonstration of the benefits of diversification will be provided. Diversification is a concept that is widely agreed on in financial literature but also a topic of discussion between investment managers when it comes to the creation of the optimal portfolio.
This paper’s approach to showing the effects of diversification is to compare the Efficiency Frontiers of each of the 3 starting portfolios and assess how a differentiation in the asset classes allows to reach better results at the portfolio level.

Following a theoretical approach, the Efficiency Frontier can be found as a combination of the Minimum Variance portfolio and the Tangency portfolio, which is the one that provides the best risk-return trade-off and has therefore the maximum Sharpe Ratio. In this analysis, given the constraints that have been put to the maximum weights for some illiquid asset classes in the Modern and Growth portfolios, the optimal compositions at a 6% volatility will not correspond to the optimal risk-reward portfolios for that level of risk. The optimal portfolios presented in this thesis will therefore not lie exactly on the efficiency frontier. This is an expected outcome given that the theoretical approach takes in consideration only two variables, return and volatility. In the real world, the approach to portfolio construction is more complicated than that, and necessarily needs to consider other variables, such as liquidity for example.

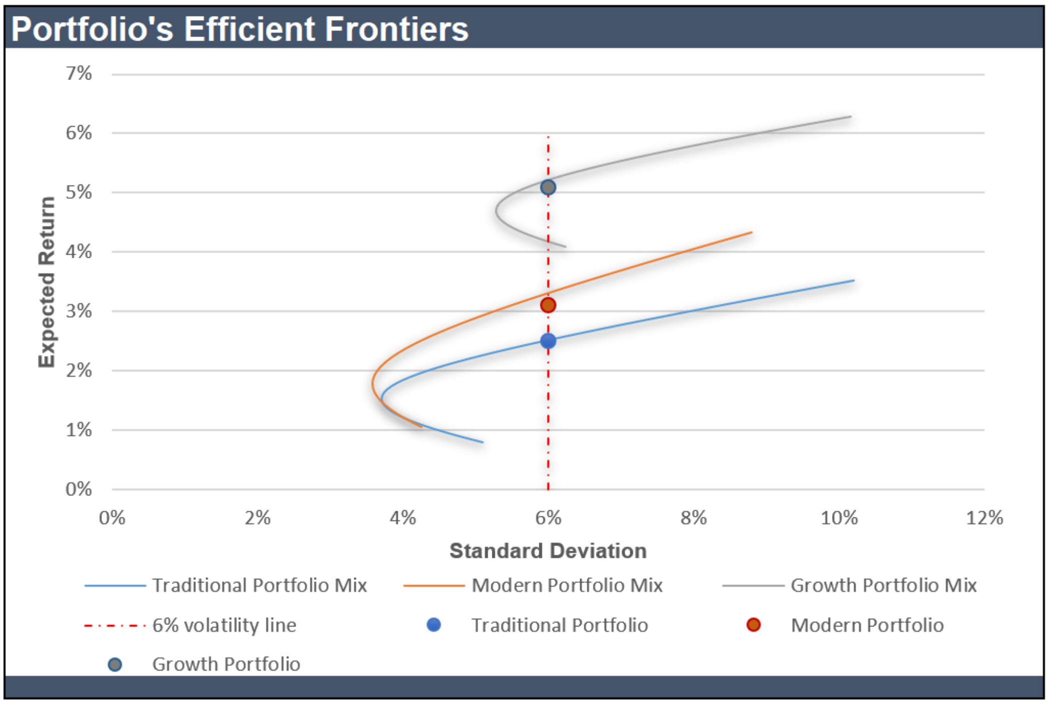

Figure 8.1 Source: Own depiction (data points in Appendix 14)

As can be seen in Figure 8.1, the Traditional Balanced portfolio lies at the bottom of the graph. With only three asset classes of equities and bonds available, this portfolio offers a limited expected return for the level of risk that pension funds are willing to take.

A slight improvement comes with the addition of two new asset classes in the Modern Balanced portfolio, in which we start seeing the first effects of diversification. The same expected returns of the Traditional portfolio are available at a significant lower level of risk. Another way to express the same concept is that at a comparable level of risk, the Modern portfolio offers higher rewards. We can immediately note how at 6% standard deviation, the expected return is higher than in the previous portfolio. With more asset classes available in the portfolio mix, and hence an even a more sophisticated approach to diversification, the Growth portfolio offers the best reward-to-risk opportunities. This portfolio is generally riskier than the other two as the minim variance Portfolio lies further to the right of the graph compared to the others. However, for comparable risk levels at and above the minimum standard deviation threshold, the Growth portfolio offers significantly higher returns.

As it can be observed from the Efficiency Frontiers' graph, having in the portfolio mix additional asset classes that are not perfectly correlated to the equity market, allows for further diversification and better risk-reward trade-offs. As it is not perfectly correlated to the market, we can expect this to be true also for the additional asset class represented by the offshore wind project. The expectations are that when the project will be integrated to the 3 different portfolios, the Traditional Balanced portfolio will have the most benefits, as it is the least diversified. Contrariwise, the Growth portfolio will have the least.

In the next section the portfolio optimization including the offshore wind investment will be performed. The analysis will reveal what benefits an additional investment in Offshore wind can bring to the 3 identified portfolios, but most importantly, assessing how much exposure to it would they be willing to accept given their risk appetite will ultimately determine the attractivity of the unsubsidized project to pension funds.

8.4. Portfolio Integration

The paper will now simulate the effects of "adding" an investment in the unsubsidized offshore wind project to the portfolios we have previously introduced. The goal of this chapter is to determine how much exposure to this investment pension funds can accept given their risk appetite and their investment strategy. The pre-requisite of this analysis is the creation of a new asset class with the characteristics of the investment. For simplicity reasons the thesis will refer to this asset class as "Offshore Wind".

Integrating Offshore Wind to the pension funds' portfolios and performing a mean-variance analysis requires three variables to be defined:

- expected return
- volatility (or standard deviation) of the returns
- covariance with the other asset classes

Starting from the first one, given that the analysis is based on a real project and not a security, this research has considered the Equity Internal Rate of Return (IRR) as the expected rate of return of the project. This assumption presents some limitations that were thoroughly introduced in the dedicated chapter. However, it is widely used in business practice and also in several theoretical research. For these reasons, the authors found it to be the best approximation considering the nature of the investment under analysis. The Equity IRR distribution of the project was obtained from the Financial Analysis using Monte Carlo simulations. For computational purposes and a clearer visualization of the results, the analysis of each price scenario was performed separately considering the average IRR value of the distribution as the expected rate of return on the project.

Regarding the volatility of the returns, two considerations must be made.
The first one concerns the cash-flows used for the calculation. Given that this thesis is looking at the project from an equity investor's perspective, the correct procedure would be to calculate the volatility of the returns using the cash flows available to the equity holders. However, following this approach would provide a biased result. The reason is that the proposed financial structure considers the debt to be repaid in 15 years of operations, resulting in the cash flows to the equity holders being significantly increased after that date. This jump, due to the financial structure and not to the risk of the cash-flows per se, alters the value of the volatility and hence provides an incorrect measure of the riskiness of these cash-flows. In order to avoid this problem, the research assumed that the risk of the cash-flows to the equity holders is the same as the risk of the cash-flows to the project, hence the FCF's were used to calculate the volatility of the returns.

The second consideration is a consequence of the first one. Given that Free Cash Flows can assume negative values, the "Normal Cash Flow Return" approach had to be used to calculate the returns and their volatility. As explained in the financial literature this is an alternative method to the "Logarithmic Cash Flow Return" and assumes a normal distribution of the Cash-flow returns. For the purpose of the calculation, in order to take out the effects of inflation and obtain comparable figures, cash-flows were deflated before calculating the returns. Similarly to the approach used with the IRR, the study employed Monte Carlo to simulate the cash-flows from which the returns were calculated. What is obtained is a range of values that describes the distribution of the cash-flow return's volatility. The results are displayed in Figure 8.2 below.

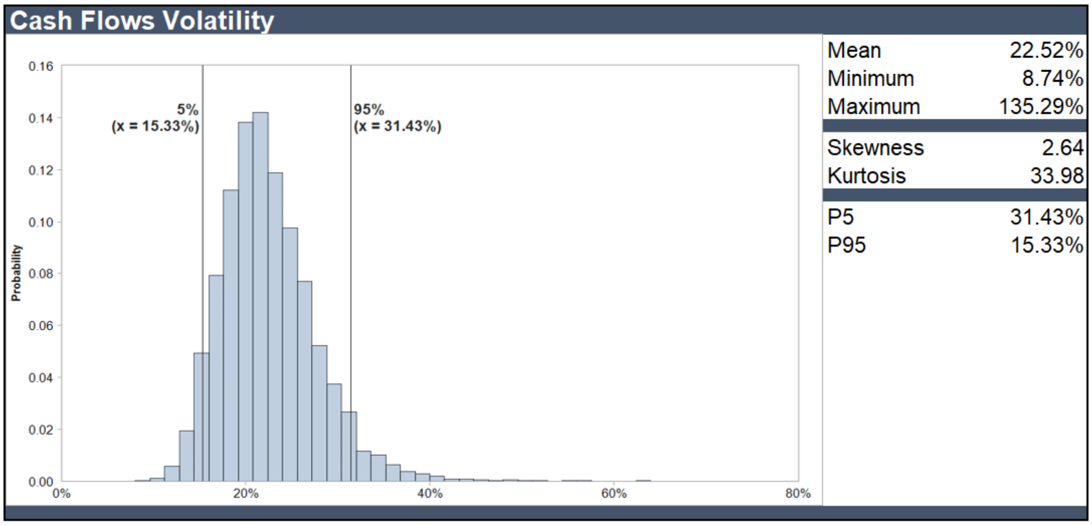

Figure 8.2 Source: Own depiction based on ModelRisk (Vose Software, 2020)

This time instead of picking the average value for each scenario, the authors decided to consider the whole volatility distribution from the 5th percentile to the 95th. The reason for it is dual. The first one is that volatility has a similar distribution across scenarios. Secondly, keeping volatility as a varying input in our analysis allows us to better describe how the portfolio allocations change at different project volatility levels. This type of analysis provides a more thorough understanding of pension funds' volatility acceptance and describes the potential allocations to the investment at varying risk levels. The results provide in this way a direct relationship between target levels of project risk and pension fund's willingness to invest (or attractivity).

Last but not least, correlation with the other asset classes needed to be addressed. The most correct approach in statistics would be to perform a regression analysis of an unsubsidized offshore wind project's historical returns with the returns of the other asset classes. Since no security that is representative of offshore wind under merchant risk exposure is available, we decided to use as a proxy a traded ETF comprising stocks of several companies operating in the Offshore Wind industry. The covariance of this instrument's historical returns was then calculated against the other asset classes historical returns for a period of 5 years.

Having created the additional asset class "Offshore Wind", it was then possible to incorporate it in the 3 portfolios and perform an optimization at 6% volatility level. This level of risk was chosen as an assumption for pension funds' risk aversion. The analysis presented in the next paragraph will reveal how the asset allocations in the optimal portfolio change at different volatility levels of the

Offshore Wind Project and in different expected return scenarios. What will be determined in this way is the maximum weight each portfolio can allocate to Offshore wind at a given level of project volatility. Furthermore, estimates of the benefits for each portfolio in terms of increased return will be presented. As a result of this analysis, the authors will be able to provide an answer to the second part of the research question, which intends to quantify the attractiveness of unsubsidized Offshore Wind projects to pension funds, from a portfolio perspective.

8.4.1. Traditional Balanced Portfolio

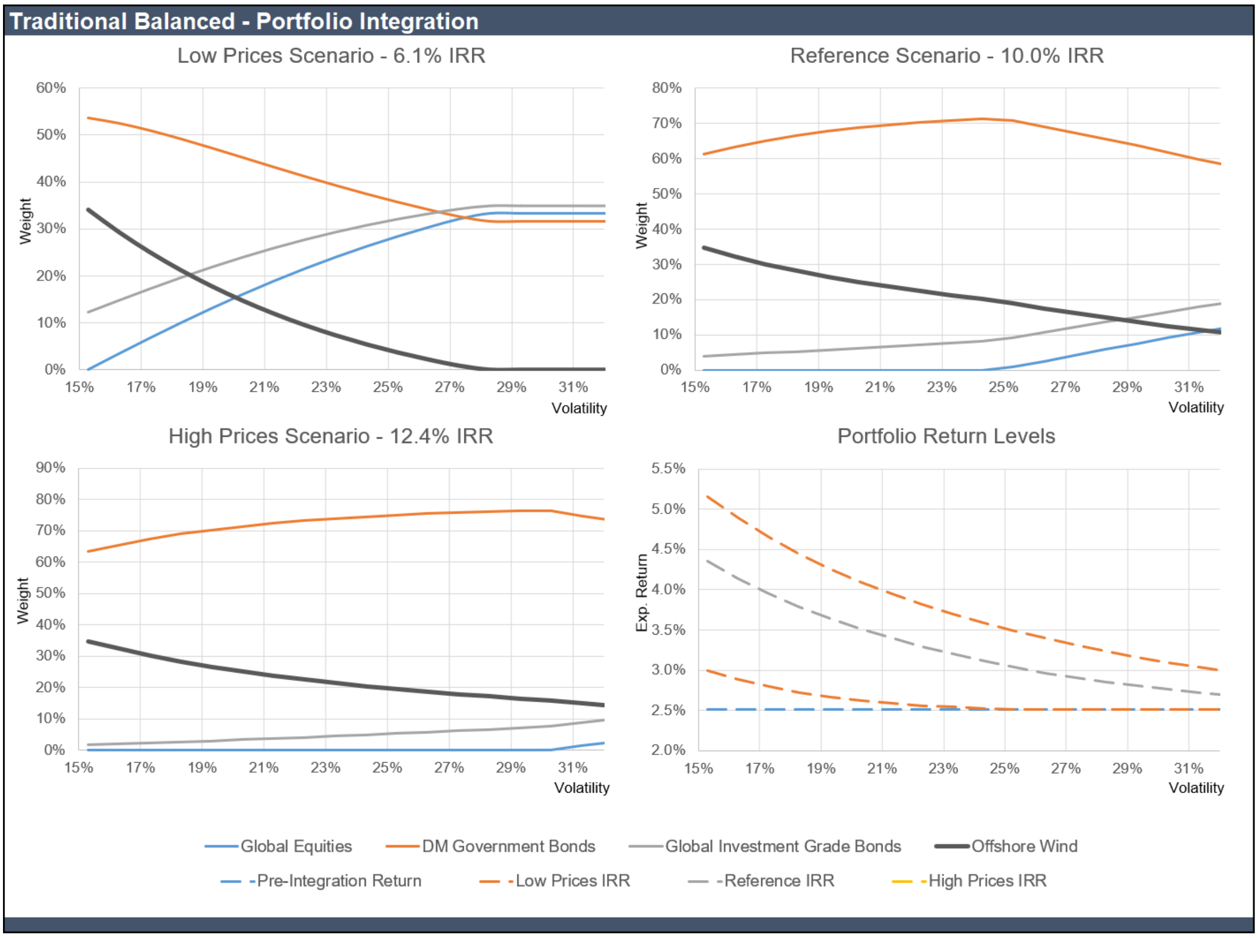

Figure 8.3 Source: Own depiction (more detail in Appendix 15)

Independently from the return scenario, at low levels of project volatility, approximately one third of the portfolio weight is allocated to offshore wind as can be seen in Figure 8.3. It is interesting to note how under this circumstance Global Equities are excluded from the optimal portfolio in favor of the new asset class. At the minimum level of project volatility, Offshore Wind presents a better risk-return profile than Global Equities and hence fully substitutes the latter in the portfolio. As the project's volatility increases, the weight in Offshore Wind is reduced while Global Equities gets introduced again in the portfolio. Not surprisingly, this effect is much slower with better expected return scenarios. Around the average value of volatility (22%) the weight allocated to Wind is 10% in the low return scenario and around 20% in the other two. Higher returns from the project enable pension funds to allocate more funds to Offshore Wind even at higher volatility levels. However, as can be seen from the graph, this has to be balanced with increased allocations to Government Bonds that reduce the total portfolio volatility at the required risk level. In terms of increased portfolio returns, the additional asset class in Offshore Wind carries many benefits, as it is the asset class with the higher expected return. This is especially true in the high expected return scenario, where the total portfolio return experiences a substantial jump upwards.

8.4.2. Modern Balanced Portfolio

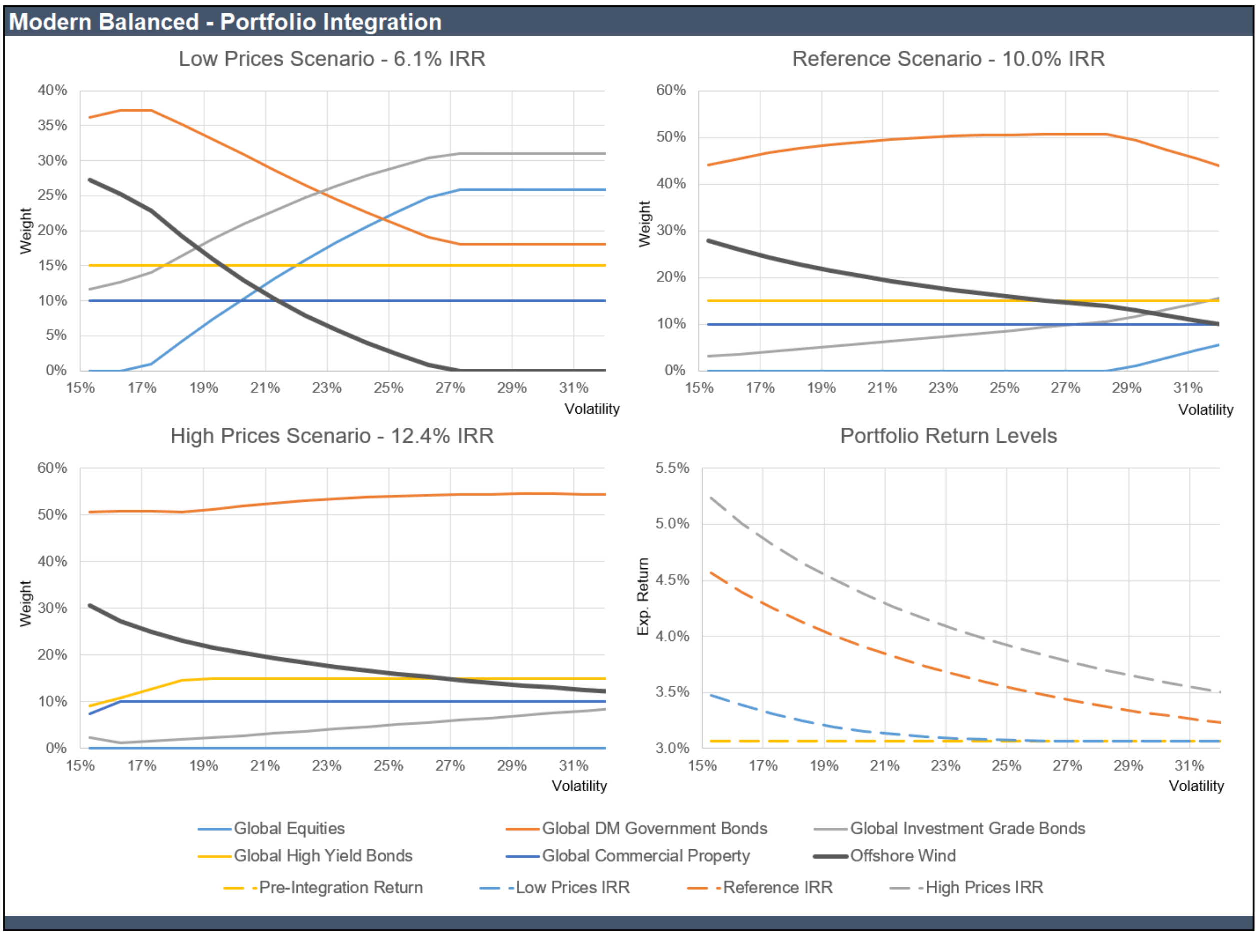

Figure 8.4 Source: Own depiction (more detail in Appendix 15)

Similarly to the Traditional portfolio, at the minimum level of project volatility, the allocation to Offshore Wind accounts for almost a third of the total weight. When the project volatility reaches its average value around 22%, the weight in Offshore Wind is substantially scaled down in the low return scenario, while only a smooth decline in weight can be appreciated in the other two scenarios. Global Equities are again substituted by Offshore Wind in the portfolio and only being reintroduced once the project's volatility increases above a certain threshold. The same consideration can be done with regards to Investment Grade Bonds. In the two cases where the Offshore Wind expected return is at and above 10%, the portfolio risk is mainly constituted by the volatility coming from Offshore Wind. The portfolio requires therefore a considerable allocation to Government Bonds for the 6% portfolio volatility constraint to be respected. Due to their appealing risk-return profiles which makes them good diversifiers, Commercial Property and High Yield Bonds maintain fairly constant weights in the Modern portfolio across the three scenarios. When looking at the increased portfolio returns, we can still notice major benefits from the additional asset class in the portfolio mix.

8.4.3. Diversified Growth Portfolio

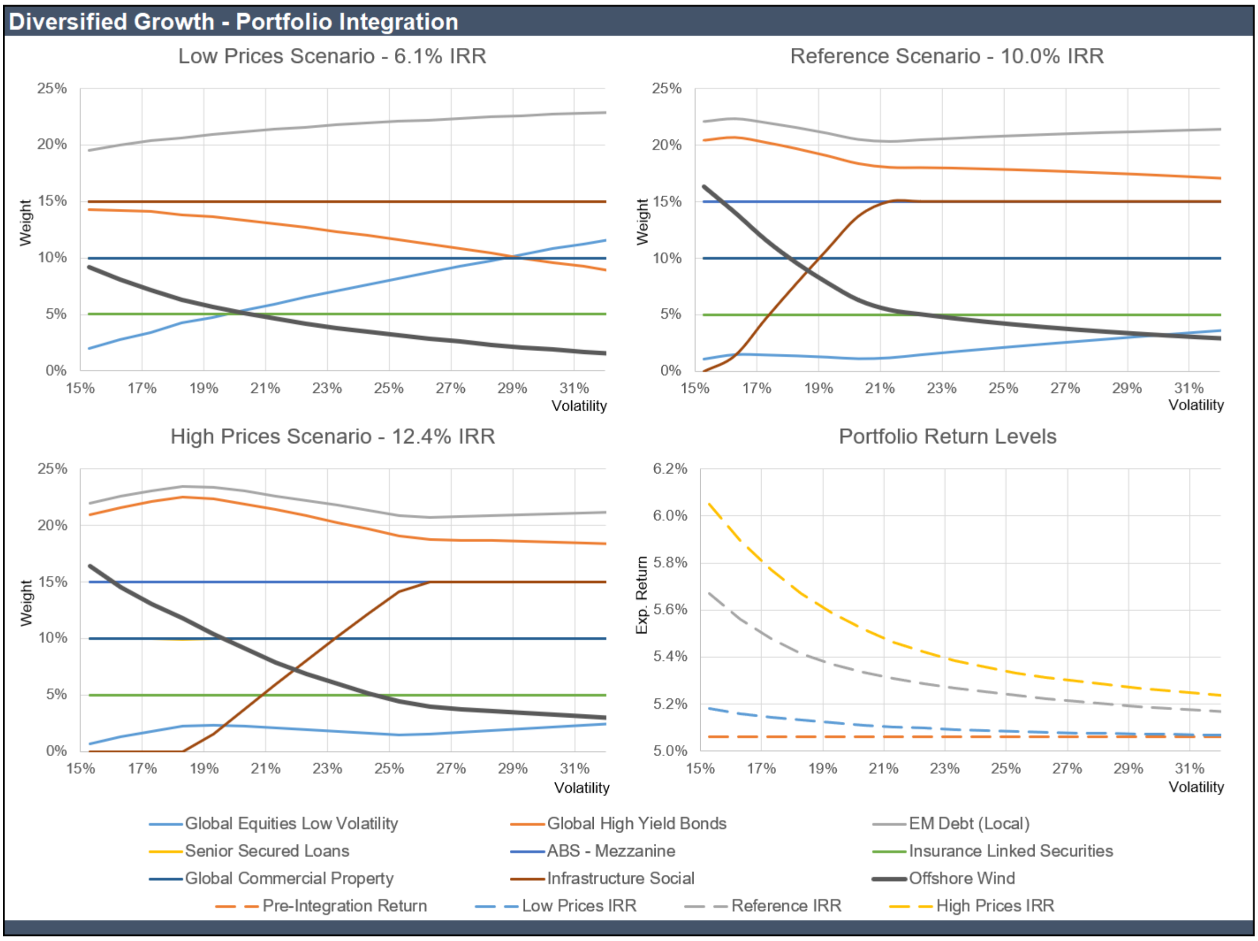

Figure 8.5 Source: Own depiction (more detail in Appendix 15)

Due to the more sophisticated approach to diversification of the Diversified Growth portfolio, the additional benefit of another asset class is lower than in the previous two cases. This is clearly visible in Figure 8.5 from the general weight assigned to Offshore Wind compared to the other two cases. When volatility is at its lowest, the portfolio's optimal weight to the new asset class is between 10%-17%, depending on the scenario. At an average level of volatility around 22%, the portfolio optimization allows only 2.5%-7.5% of the total wealth to be allocated to Offshore Wind. Despite presenting a better risk-return profile in their Low Volatility version, Global Equities are still the ones suffering from the introduction of Offshore Wind in the portfolio. Senior Secured Loans (10%), Asset Backed Securities (15%), Insurance Linked Securities (5%) and Commercial Property (10%) all maintain a constant allocation to their maximum weight allowed in the portfolio. Infrastructure Social is optimized at its maximum weight in the low IRR scenario. However, when Offshore Wind is characterized by low volatility and higher expected returns, Infrastructure gets discarded from the portfolio mix. The reason for it is that the two asset classes have a high correlation and when Offshore Wind presents a better risk-return profile, it is preferred in the portfolio at the expense of Infrastructure Social. Being the least volatile asset classes in the portfolio, High Yield Bonds and Emerging Market Debt are essential for the 6% portfolio volatility constraint to be respected. Their weight in the portfolio does therefore not suffer in absolute terms. Not surprisingly, the Diversified Growth portfolio experiences the least benefits out of the 3 portfolios in terms of increased returns from the additional asset class. In the low IRR scenario, the change in the portfolio return is minimal. However, when the expected return from Offshore Wind is higher, margins increase.

In the next chapter we will further elaborate on this chapter's findings and their implications for both pension funds interested in Offshore Wind projects, and policy makers aiming to reach the goals and targets they have set in terms of renewable energy capacity expansion.

9. Discussion

When looking at the results of the portfolio analysis, a few points are worth being discussed.
The three investigated portfolios are generalizations of different investment strategies Institutional Investors might pursue. In today's reality investment portfolios are very complex and diverse. It is especially noteworthy saying that examples of pure Traditional Balanced portfolio with positions only in equities and bonds are quite rare nowadays. The Traditional investment strategy was included in the analysis mainly to cover the full spectrum of the available investment portfolios in the market and prove the benefits of strategic asset allocation. Having acknowledged this, the findings with regards to the Modern Balanced portfolio and the Diversified Growth portfolio might be more relevant for pension funds today. The Modern portfolio represents a realistic example of DC pension schemes' investment strategy, in which asset class diversification is medium and alternative investments are indirectly limited by regulations that impose a maximum charge cap of 0.75% in their default funds (APPG, 2019). The reason why the charge caps represent an obstacle for alternative investments is that finding asset classes that consistently present better risk-return profiles than traditional investments is not an easy task and comes at a price. The best performing alternative asset managers generally charge higher fees that hinder DC pension funds from accessing these investments.
DB schemes are not subject to the same regulatory limits and are consequently more diversified. They can be therefore associated with the Diversified Growth Portfolio.

For a better interpretation of the results, an additional reflection with regards to liquidity must be made. Equity investments in an offshore wind project fall in the category of illiquid alternative investments. Despite appreciating the attractivity of positive illiquidity premiums, pension funds might have constraints regarding how much capital they can allocate to illiquid investments. This can be an indirect consequence of regulations as seen above, or due to the scheme's liabilities, which demand liquidity in order to be met. This argument would be in favor of putting constraints to the maximum weight to be allocated to Offshore Wind. When looking at an offshore wind investment however, provided that there is any capital left to distribute after servicing debt, equity investors receive regular cash-flows that might resemble the structure of bonds' coupons. These cash-flows are much more volatile than under a subsidy support scheme, but are still fairly regular in-flows that can be utilized to cover pension fund's liabilities. For these reasons we decided to not put any maximum cap on the portfolio weight assigned to Offshore Wind, as it is part of individual considerations each pension fund makes based on their specific strategies and liquidity constraints, of which we are unaware. This being said, it can be argued nonetheless that allocations to Offshore Wind in the order of 25%-30% of the total portfolio and 0% allocations to global equities do not represent a realistic outcome and are the product of a purely theorical exercise that is a simplification of the real world. This consideration is correct. As a matter of fact, even though the allocation to Global Equities has been decreasing throughout the years as additional asset classes with better risk-return profiles were introduced in pensions' investment portfolios, every institutional investor has maintained at least a fraction of the portfolio invested in the stock market (OECD, 2019). The reason for it is that the equity market is highly liquid and allows for a greater diversification of risk at a cheaper cost compared to alternative investments. The average UK pension fund's allocation to Global Equities has been around 32% in 2018 considering both DB and DC Pension Schemes (Thinking Ahead Institute, 2019). Considerations regarding liquidity differ from scheme to scheme. However, if we acknowledge the fact that allocations to Global Equities cannot fall to zero, the weight to Offshore Wind has to be reduced accordingly. As portrayed by the analysis, Global Equities and Offshore Wind are the two most volatile asset classes and therefore directly compete for weight in the optimal portfolio.

One final consideration has to be made with regards to the probability of occurrence of the three different price scenarios. The current market developments, the COVID-19 economic slow-down and the fear of a global recession lead to believe that the high price scenario is much more unlikely to occur than the reference and low prices scenarios, in which Offshore Wind's expected returns were respectively 10,0% and 6,1% on average. Both low and reference scenario bring benefits to the portfolios in terms of increased total portfolio return at all volatility levels. In the low-prices scenario however, the investment decision might be compromised by a negative final APV due to a higher cost of capital.

At the average volatility value of 22%, the weight assigned to Offshore Wind is 8%-18% in the Modern Balanced portfolio (depending on the price scenario) and around 2,5%-5% for the Growth portfolio. In the eventuality that regulatory and liquidity constraints at the individual pension fund level require higher allocations to Global Equities at the expense of more illiquid investments, Offshore Wind would be the one impacted as it's the most volatile asset class along with equities. Increasing the allocation to Global Equities would consequently set to zero the weight on Offshore

Wind in the Growth portfolio and hence prohibit a direct investment in an unsubsidized project. A slightly different consideration can be made for the Modern Balanced portfolio. Considering an increased allocation to Global Equities, the Modern portfolio might still be willing to allocate a small percentage of the total capital to Offshore Wind as the diversification benefits coming from the additional asset class are higher than in the Growth portfolio. The value of the allocation depends on regulatory and liquidity constraints, the expected return scenario and the project volatility.

The key finding from the portfolio analysis is that except for the low-price scenario where the investment decision might be prohibited by a negative APV, returns continue to remain attractive under full merchant risk exposure. A too high average level of volatility however represents the real obstacle for pension funds considering an investment in subsidy-free offshore wind project. DC funds characterized by Traditional or Modern portfolios might enjoy the benefits of a potential investment, while DB funds with Growth portfolios would not consider the investment in the first place. The more the project's volatility can be reduced, the more attractive the investment is to the portfolios and consequently the higher the allocation to the asset class.

Potential ways to address the project's cash flow volatility will be presented in the next paragraphs. These could prove to be effective solutions to the increased volatility arising from the full exposure to merchant risk and are therefore relevant topics for future research.

9.1. Power Purchase Agreements

Corporations generally purchase electricity directly from utilities with price uncertainty and no control over the source of generation. With more attention to energy costs and trying to stay ahead of ESG trends by lowering their environmental footprint, organizations are increasingly purchasing "green" electricity directly from renewable energy generators (Weber, 2019). This is done through contracts known as Power Purchase Agreements or PPA's. PPA's are long-term contracts with which companies purchase electricity at agreed volumes and agreed prices directly from the sources that produce it (GE, 2020). These contracts provide financial benefits to the acquiring corporates and reduce their CO_2 emissions footprint through green certificates that prove the renewable energy purchase. On the other hand, they allow the generator to secure a steady stream of cash-flows for the energy produced. Power Purchase Agreements have been used in combination with subsidies to guarantee the project's bankability and secure debt and equity financing. In a context where subsidies will no longer be awarded to offshore wind projects, PPA's could assume an even more important role as they provide a fixed revenue stream that reduces the volatility of the project's cash-flows. However, as renewable energy generation expands and wind farms' capacities increase, industry experts wonder if there is going to be enough corporate demand for PPA's to have a significant effect on the cash-flows' volatility (McWhirther, 2020). As of now, the largest offshore wind power purchase agreement has been signed in December 2019 by Ørsted and Covestro. Through a 10-year contract Covestro will offtake the output of 100MW from the Borkum Riffgrund 3 offshore wind farm, which has a planned total capacity of 900 MW (Ørsted, 2019). Provided that there will be enough demand to cover a significant share of the total electricity output, Power Purchase Agreement strategies could represent a valid tool to reduce the project's volatility but its implications on the project's profitability need to be investigated. Fixing a long-term price on the electricity output might reduce the IRR of the project as they remove the upside reward of the price fluctuations. On the other hand, less volatile returns translate into lower financing costs. The combination of these effects needs to be analyzed in order to evaluate the impact of PPAs on the project's investment case.

9.2. Energy Storage and Power to X

With an increased number of renewable energy sources connected to the grid, both price cannibalization effects and price volatility increase. Being able to store the electricity produced and sell it when its more valuable could stabilize prices and smooth grid volatility, which is natural consequence of non-dispatchable sources of energy. Batteries and Power-to-X are two technologies that aim to do so.

The levelized cost of electricity for Lithium-ion batteries has fallen sharply by 76% since 2012 and stands now around USD 187 MW/h according to BNEF (2019). This is a remarkable achievement, but still not enough. In order to assess if battery storage solutions could be an answer to the volatility issue, costs need to fall further down at the level in which batteries in combination with offshore wind are an economically viable solution.

Power to X on the other hand refers to the concept of converting electricity into hydrogen or other chemical energy sources, for a longer-term storage and later use of the electricity produced. These technologies are already available (State of Green, 2019). However, they are considered unprofitable with the existing plants which are too small for the technology to have a commercial utilization (en:former, 2019). Two large-scale Power-to-X projects are in the pipeline in Denmark under the support of the Danish government, who granted the equivalent amount of EUR 17.1 billion for the further development of the technology (State of Green, 2019).

Renewable energy storage solutions are still at their early stages. A few companies however are already making some bold moves in that direction, trying to anticipate the industry transformation, and locking in a strategic advantage. An example of it is Ørsted, who inaugurated in late 2018 its first large scale battery solution in the UK. The goal is to enhance, through an increased flexibility, the value of its large renewable portfolio (Spector, 2019). Earlier on in the same year, Equinor installed the first ever offshore wind battery solution to its Hywind Windfarm in Scotland (Equinor, 2018). The objective is the same: store electricity when prices are inconvenient and, in this way, increase the value of the power.

9.3. Pooled Investments and Risk Appetite

Demonstrated that an increased level of risk is the obstacle that could retain pension funds from investing in unsubsidized offshore wind, pooling several projects in a fund structure might be an effective way to reduce the exposure to single geography power markets and thereby mitigate the volatility. Smaller direct equity investments in several offshore wind projects or pooled investment vehicles might allow pension funds to increase their exposure to this asset class category and provide sufficient capital for the further expansion of the industry. These instruments are currently not largely available in the market since the industry is developing at a fast pace and has not yet reached maturity. It is characterized on the contrary by limited accessibility to a niche group of investors and hence still remains an illiquid investment space. Future developments might create opportunities for pension funds to diversify across multiple projects and different geographies reducing in this way the overall risks to better fit their risk appetite.

pension funds’ low risk aversion might also be subject to changes in the future. As estimated by ASI (2019) in their report, expected returns from more conventional investment categories are shrinking compared to the past. This systematic phenomenon might force predominantly risk-averse actors such as pension funds to take on more risk in order to receive the adequate rates of return that will allow them to meet their liabilities in the future. This argument is especially relevant for Defined Benefits schemes. However, a validation of the claim needs to be made against the other available asset classes in the portfolio mix, their risk-return profile and the liabilities that each pension fund is obliged to meet. Strategic allocation to selected asset classes has then to be defined accordingly.

10. Conclusion

The results of the analysis confirmed that the average volatility level of the unsubsidized project is too high for pension funds to allocate a significant weight of their total portfolio to it. It is interesting to note how the project competes for allocation in the portfolio with the asset class Global Equities. That is due to their similar risk-return profiles, however, if additional regulatory and liquidity constraints are applied by the individual pension fund, Global Equities might be favored leading to a total exclusion of the unsubsidized Offshore Wind project. An exception could be represented by those pension schemes who hold more traditional portfolios characterized by lower levels of asset class diversification. These funds could be able to better amortize the risks of the investment and hence benefit from the additional asset class in their portfolio in terms of diversification and increased returns.

Different measures could be employed to reduce the risk of the investment and increase its appeal to pension funds. This research discussed Power Purchase Agreements, storage solutions and the creation of pooled investments that reduce the exposure to single projects. Another alternative that could amplify the attractivity of unsubsidized offshore wind projects would be an increase in pension funds' risk appetite, driven by the search of higher rates of return.

As a final statement it appears logical to say that if the risks related to offshore wind projects under full merchant risk are not reduced, pension funds will very limitedly, or not at all, allocate capital through direct equity injections. Considerations at the country level must then be made if the capital required to foster additional capacity growth can be found elsewhere, or if pension funds' contribution is required for the targets to be reached. An extension of the support schemes that have attracted them in the first place would have then to be evaluated. In the event that support schemes cease and pension funds are not a necessary condition to reach renewable energy generation targets, other less risk averse investors could take their place as providers of capital. Assessing who these actors would be could represent an interesting topic for further research. Established instead that pension funds' capital is still required to foster additional growth and other volatility-reduction measures don't take the leap, support schemes might still be a necessary tool to protect those risk averse investors from the high volatility of the wholesale electricity markets. Full subsidy-free projects would in that case be a far into the future reality.

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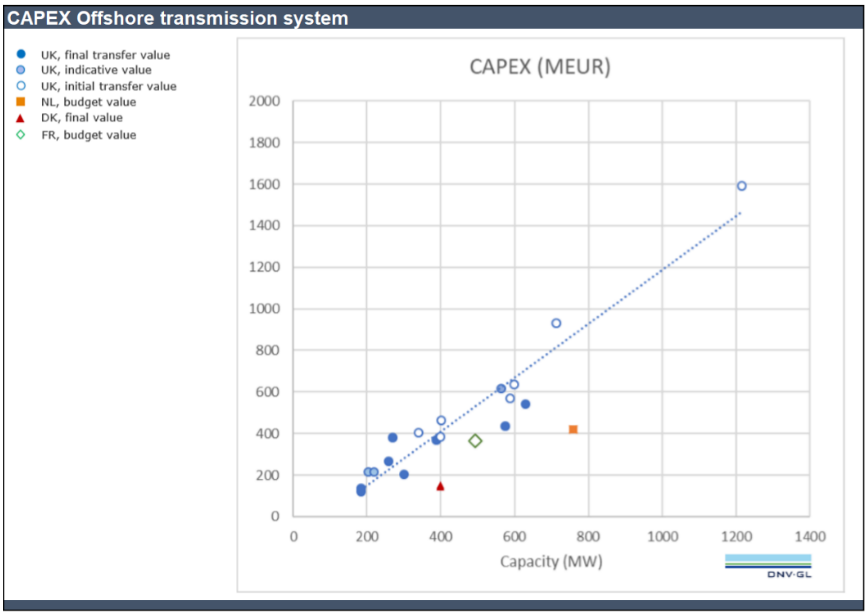
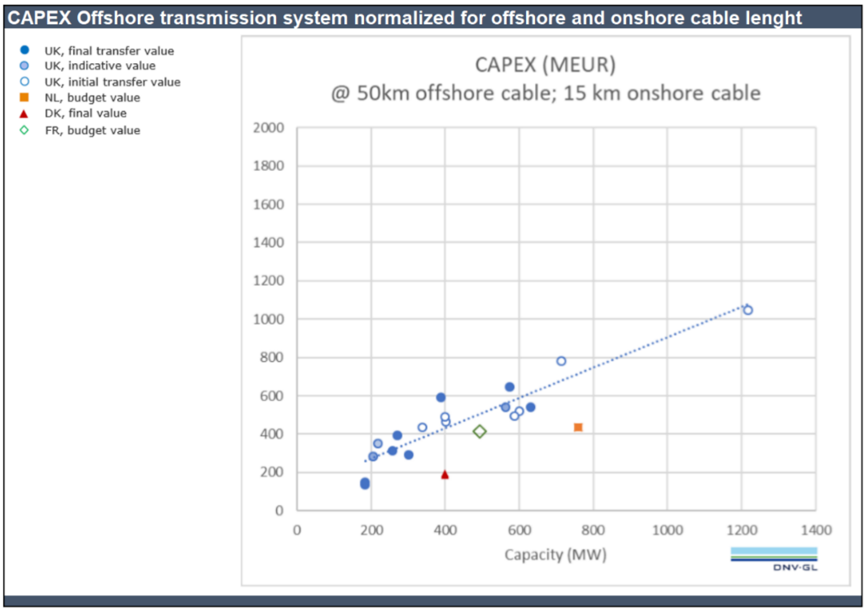
12. Appendix

12.1. *Appendix 1: CAPEX estimation of offshore transmission assets*

Source: *Cleijne (2019)*

The following figures represent historical evaluations of capital expenditures for offshore transmission assets of wind farm in the UK, Netherlands, Denmark and France. The first graph provides actual historical values while the second delivers value normalized for cable length. Under the average exchange rate of EUR/GBP 0.88 (Statista, 2020), the transmission assets for a 1000 MW wind farm average GBP 1 billion in the first case and GBP 750 million in the second.





12.2. **Appendix 2:** *Wholesale Electricity Price Projections*

Source: *Own depiction based on BEIS (2019) and expert estimate (McWhirther, 2020)*

The following table represent the data series for the wholesale electricity price projections employed in the calculations. Data up to 2035 are derived from a BEIS report. Then, prices are expected to grow at 1% in real prices as suggested by industry expert. Transformation from real to nominal prices was provided by multiplying real values by the inflation index presented in Appendix 3.

Wholesale Price Projections							
Real Prices 2018 (GBP/MWh)				Nominal Prices (GBP/MWh)			
Years	Reference	Low Prices	High Prices	Years	Reference	Low Prices	High Prices
2022	52.7	41.9	64.1	2022	56.9	45.3	69.3
2023	53.2	42.6	64.6	2023	58.6	46.9	71.1
2024	55.7	43.5	66.5	2024	62.6	48.9	74.7
2025	57.0	43.4	66.7	2025	65.3	49.8	76.5
2026	56.8	43.2	64.5	2026	66.4	50.5	75.5
2027	59.2	44.1	66.8	2027	70.6	52.6	79.6
2028	56.7	43.1	61.8	2028	68.9	52.4	75.2
2029	56.7	42.6	59.6	2029	70.4	52.8	74.0
2030	57.9	44.5	60.7	2030	73.3	56.3	76.9
2031	59.0	47.1	61.9	2031	76.2	60.8	79.9
2032	58.6	47.7	59.6	2032	77.2	62.9	78.5
2033	60.6	50.6	61.8	2033	81.4	68.0	83.0
2034	58.0	50.6	60.7	2034	79.5	69.3	83.2
2035	56.1	50.4	59.2	2035	78.4	70.4	82.7
2036	56.7	50.9	59.8	2036	80.8	72.5	85.2
2037	57.2	51.4	60.4	2037	83.2	74.7	87.8
2038	57.8	51.9	61.0	2038	85.7	76.9	90.4
2039	58.4	52.4	61.6	2039	88.3	79.3	93.1
2040	59.0	52.9	62.2	2040	91.0	81.7	96.0
2041	59.5	53.5	62.8	2041	93.7	84.1	98.9
2042	60.1	54.0	63.4	2042	96.6	86.7	101.8
2043	60.7	54.5	64.1	2043	99.5	89.3	104.9
2044	61.3	55.1	64.7	2044	102.5	92.0	108.1
2045	62.0	55.6	65.4	2045	105.6	94.8	111.4
2046	62.6	56.2	66.0	2046	108.8	97.6	114.7

12.3. ***Appendix 3:*** *Inflation Multiplier*

Source: *Own depiction based on Statista (2019) and Bank of England (2019)*

The following table represents the inflation multiplier that was applied to nominalize the price projections applied in the model. Inflation was considered 1.81% for the year 2019 (Statista, 2019) and assumed equal to the target 2% for the remaining years (Bank of England, 2019).

Inflation Multiplier (2018 = 100%)					
Years	Inflation	Inflation Index	Years	Inflation	Inflation Index
2019	1.8%	101.8%	2033	2.0%	134.3%
2020	2.0%	103.8%	2034	2.0%	137.0%
2021	2.0%	105.9%	2035	2.0%	139.8%
2022	2.0%	108.0%	2036	2.0%	142.6%
2023	2.0%	110.2%	2037	2.0%	145.4%
2024	2.0%	112.4%	2038	2.0%	148.3%
2025	2.0%	114.7%	2039	2.0%	151.3%
2026	2.0%	116.9%	2040	2.0%	154.3%
2027	2.0%	119.3%	2041	2.0%	157.4%
2028	2.0%	121.7%	2042	2.0%	160.5%
2029	2.0%	124.1%	2043	2.0%	163.8%
2030	2.0%	126.6%	2044	2.0%	167.0%
2031	2.0%	129.1%	2045	2.0%	170.4%
2032	2.0%	131.7%	2046	2.0%	173.8%

12.4. ***Appendix 4:*** *Historical Daily rates for the UK 10-Year Govt Bond*

Source: *Own depiction based on Investing.com (2020)*

The following table represents the historical daily rates for the UK 10-Year government bond which was used as a proxy for the risk-free rate. The data extracted refer to the year 2019 which was deemed appropriate for an investment starting at the beginning of 2020.

United Kingdom 10-Year Bond Yield Historical Daily Values											
Date	Yield	Date	Yield	Date	Yield	Date	Yield	Date	Yield	Date	Yield
31/12/2019	0.83	27/10/2019	0.66	30/08/2019	0.48	27/06/2019	0.82	24/04/2019	1.18	20/02/2019	1.18
30/12/2019	0.87	25/10/2019	0.68	29/08/2019	0.44	26/06/2019	0.83	23/04/2019	1.23	19/02/2019	1.17
27/12/2019	0.76	24/10/2019	0.62	28/08/2019	0.44	25/06/2019	0.79	22/04/2019	1.19	18/02/2019	1.17
24/12/2019	0.77	23/10/2019	0.69	27/08/2019	0.50	24/06/2019	0.82	21/04/2019	1.20	17/02/2019	1.16
23/12/2019	0.78	22/10/2019	0.71	26/08/2019	0.57	21/06/2019	0.84	18/04/2019	1.20	15/02/2019	1.16
22/12/2019	0.78	21/10/2019	0.75	23/08/2019	0.48	20/06/2019	0.81	17/04/2019	1.24	14/02/2019	1.15
20/12/2019	0.78	20/10/2019	0.71	22/08/2019	0.52	19/06/2019	0.87	16/04/2019	1.22	13/02/2019	1.18
19/12/2019	0.80	18/10/2019	0.71	21/08/2019	0.48	18/06/2019	0.81	15/04/2019	1.22	12/02/2019	1.19
18/12/2019	0.78	17/10/2019	0.68	20/08/2019	0.45	17/06/2019	0.85	13/04/2019	1.22	11/02/2019	1.18
17/12/2019	0.76	16/10/2019	0.72	19/08/2019	0.47	16/06/2019	0.85	12/04/2019	1.21	08/02/2019	1.15
16/12/2019	0.83	15/10/2019	0.69	18/08/2019	0.47	14/06/2019	0.85	11/04/2019	1.15	07/02/2019	1.18
13/12/2019	0.79	14/10/2019	0.64	16/08/2019	0.46	13/06/2019	0.84	10/04/2019	1.10	06/02/2019	1.22
12/12/2019	0.82	13/10/2019	0.71	15/08/2019	0.41	12/06/2019	0.87	09/04/2019	1.10	05/02/2019	1.23
11/12/2019	0.78	11/10/2019	0.71	14/08/2019	0.45	11/06/2019	0.86	08/04/2019	1.12	04/02/2019	1.28
10/12/2019	0.80	10/10/2019	0.59	13/08/2019	0.49	10/06/2019	0.84	07/04/2019	1.12	02/02/2019	1.25
09/12/2019	0.77	09/10/2019	0.46	12/08/2019	0.49	07/06/2019	0.81	05/04/2019	1.12	01/02/2019	1.25
08/12/2019	0.76	08/10/2019	0.42	10/08/2019	0.49	06/06/2019	0.83	04/04/2019	1.09	31/01/2019	1.22
06/12/2019	0.77	07/10/2019	0.45	09/08/2019	0.49	05/06/2019	0.87	03/04/2019	1.10	30/01/2019	1.26
05/12/2019	0.78	06/10/2019	0.44	08/08/2019	0.52	04/06/2019	0.90	02/04/2019	1.01	29/01/2019	1.27
04/12/2019	0.74	05/10/2019	0.45	07/08/2019	0.49	03/06/2019	0.86	01/04/2019	1.05	28/01/2019	1.27
03/12/2019	0.67	04/10/2019	0.44	06/08/2019	0.51	02/06/2019	0.89	30/03/2019	1.00	27/01/2019	1.31
02/12/2019	0.74	03/10/2019	0.47	05/08/2019	0.51	31/05/2019	0.89	29/03/2019	1.00	25/01/2019	1.31
01/12/2019	0.70	02/10/2019	0.50	02/08/2019	0.55	30/05/2019	0.90	28/03/2019	1.00	24/01/2019	1.27
29/11/2019	0.70	01/10/2019	0.47	01/08/2019	0.60	29/05/2019	0.89	27/03/2019	1.02	23/01/2019	1.33
28/11/2019	0.68	30/09/2019	0.49	31/07/2019	0.61	28/05/2019	0.92	26/03/2019	1.01	22/01/2019	1.32
27/11/2019	0.68	29/09/2019	0.48	30/07/2019	0.64	27/05/2019	0.96	25/03/2019	0.99	21/01/2019	1.32
26/11/2019	0.65	28/09/2019	0.48	29/07/2019	0.66	24/05/2019	0.96	22/03/2019	1.02	19/01/2019	1.36
25/11/2019	0.70	27/09/2019	0.50	26/07/2019	0.69	23/05/2019	0.95	21/03/2019	1.06	18/01/2019	1.35
24/11/2019	0.70	26/09/2019	0.52	25/07/2019	0.71	22/05/2019	1.01	20/03/2019	1.16	17/01/2019	1.34
22/11/2019	0.71	25/09/2019	0.53	24/07/2019	0.68	21/05/2019	1.08	19/03/2019	1.19	16/01/2019	1.31
21/11/2019	0.76	24/09/2019	0.53	23/07/2019	0.69	20/05/2019	1.06	18/03/2019	1.20	15/01/2019	1.26
20/11/2019	0.73	23/09/2019	0.55	22/07/2019	0.71	19/05/2019	1.04	17/03/2019	1.22	14/01/2019	1.30
19/11/2019	0.73	22/09/2019	0.63	19/07/2019	0.73	17/05/2019	1.04	15/03/2019	1.21	11/01/2019	1.29
18/11/2019	0.75	20/09/2019	0.63	18/07/2019	0.76	16/05/2019	1.07	14/03/2019	1.22	10/01/2019	1.28
17/11/2019	0.72	19/09/2019	0.64	17/07/2019	0.76	15/05/2019	1.07	13/03/2019	1.20	09/01/2019	1.26
15/11/2019	0.73	18/09/2019	0.64	16/07/2019	0.82	14/05/2019	1.11	12/03/2019	1.16	08/01/2019	1.27
14/11/2019	0.71	17/09/2019	0.70	15/07/2019	0.80	13/05/2019	1.10	11/03/2019	1.18	07/01/2019	1.26
13/11/2019	0.76	16/09/2019	0.69	13/07/2019	0.84	10/05/2019	1.14	08/03/2019	1.19	06/01/2019	1.28
12/11/2019	0.81	15/09/2019	0.76	12/07/2019	0.84	09/05/2019	1.12	07/03/2019	1.17	04/01/2019	1.28
11/11/2019	0.81	13/09/2019	0.76	11/07/2019	0.84	08/05/2019	1.14	06/03/2019	1.23	03/01/2019	1.19
10/11/2019	0.79	12/09/2019	0.67	10/07/2019	0.76	07/05/2019	1.16	05/03/2019	1.29	02/01/2019	1.21
08/11/2019	0.79	11/09/2019	0.64	09/07/2019	0.72	06/05/2019	1.22	04/03/2019	1.28	01/01/2019	1.28
07/11/2019	0.79	10/09/2019	0.64	08/07/2019	0.72	05/05/2019	1.22	03/03/2019	1.30		
06/11/2019	0.72	09/09/2019	0.59	07/07/2019	0.74	03/05/2019	1.22	01/03/2019	1.30		
05/11/2019	0.77	08/09/2019	0.51	05/07/2019	0.74	02/05/2019	1.19	28/02/2019	1.30		
04/11/2019	0.72	06/09/2019	0.50	04/07/2019	0.68	01/05/2019	1.15	27/02/2019	1.27		
01/11/2019	0.66	05/09/2019	0.60	03/07/2019	0.69	30/04/2019	1.19	26/02/2019	1.21		
31/10/2019	0.63	04/09/2019	0.49	02/07/2019	0.72	29/04/2019	1.16	25/02/2019	1.17		
30/10/2019	0.69	03/09/2019	0.41	01/07/2019	0.81	27/04/2019	1.15	23/02/2019	1.16		
29/10/2019	0.71	02/09/2019	0.42	29/06/2019	0.83	26/04/2019	1.14	22/02/2019	1.16		
28/10/2019	0.72	01/09/2019	0.48	28/06/2019	0.83	25/04/2019	1.16	21/02/2019	1.20		
Average	**0.88**										

12.5. ***Appendix 5:*** *Beta Calculation – Ørsted A/S*

Sources: *Own calculation based on Yahoo Finance* (2020b, 2020c), *Thomson ONE (2020), KPMG (2020) and Ørsted (2020)*

The following presents the calculation for the Beta factor of Ørsted. Estimate of the levered beta was obtained through a 4-year regression of the daily returns between Ørsted and MSCI World Index ETF (XWD.TO). Prices of the stocks were extracted from Yahoo Finance (2020b, 2020c). Calculation of the unlevered Beta then required the Debt to Equity ratio which was extracted from Thomson ONE (2020) and the corporate tax rate of Denmark obtained from KPMG (2020).

Ørsted is a global leader in the development, building and operation of offshore wind farm playing a fundamental position in the United Kingdom since 2004. Ørsted currently operates 15 offshore wind farms in the region for a 4.6 GW total capacity of which 50% is owned directly by the company. The company core activities also expand to onshore wind and bioenergy. (Ørsted, 2020).

Ørsted A/S

Regression Statistics	
Multiple R	0.277717721
R Square	0.077127133
Adjusted R Square	0.076159761
Standard Error	0.014924445
Observations	956

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.017758654	0.017758654	79.7285163	2.16695E-18
Residual	954	0.212493057	0.000222739		
Total	955	0.230251711			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95,0%*	*Upper 95,0%*
Intercept	0.000982946	0.000482949	2.035300082	0.042096659	3.51811E-05	0.001930711	3.51811E-05	0.001930711
X Variable 1	0.390010309	0.043678654	8.929082613	2.16695E-18	0.304292971	0.475727647	0.304292971	0.475727647

$$\beta_U = \frac{\beta_L}{\left(1+(1-T)\frac{Debt}{Equity}\right)}$$

Debt/Equity			
2019	2018	2017	Average
0.74	0.56	0.71	**0.67**

Levered Beta	Corporate Taxes	Unlevered Beta
0.39	22%	**0.26**

12.6. *Appendix 6: Beta Calculation – RWE AB*

Sources: *Own depiction based on Yahoo Finance* (2020b, 2020d), *Thomson ONE (2020), KPMG (2020) and RWE (2020)*

The following presents the calculation for the Beta factor of RWE. Estimate of the levered beta was obtained through a 5-year regression of the daily returns between RWE AB and MSCI World Index ETF (XWD.TO). Prices of the stocks were extracted from Yahoo Finance (2020b, 2020d). Calculation of the unlevered Beta then required the Debt to Equity ratio which was extracted from Thomson ONE (2020) and the corporate tax rate of Germany obtained from KPMG (2020).

RWE became a key player in the generation of electricity from clean energy as a result of the acquisition of both Innogy and E.ON. The company currently holds the second position in the offshore wind segment with regards to current assets owned. In addition, several large projects are in developments. RWE also operates onshore windfarms as well as solar, hydro and biomass power plants. (RWE, 2020).

RWE AG

Regression Statistics	
Multiple R	0.35353078
R Square	0.124984013
Adjusted R Square	0.124273195
Standard Error	0.022606429
Observations	1233

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.089858765	0.089858765	175.8314384	1.30829E-37
Residual	1231	0.629103306	0.000511051		
Total	1232	0.71896207			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95,0%*	*Upper 95,0%*
Intercept	-4.13314E-05	0.000644036	-0.064175619	0.94884081	-0.001304862	0.001222199	-0.001304862	0.001222199
X Variable 1	0.80504831	0.06071188	13.26014473	1.30829E-37	0.685938101	0.924158518	0.685938101	0.924158518

$$\beta_U = \frac{\beta_L}{\left(1+(1-T)\frac{Debt}{Equity}\right)}$$

Debt/Equity 2019	2018	2017	Average
0.18	0.21	2.02	**0.80**

Levered Beta	Corporate Taxes	Unlevered Beta
0.81	30%	**0.52**

12.7. *Appendix 7:* *Beta Calculation – Siemens Gamesa Renewable Energy*

Sources: *Own depiction based on Yahoo Finance* (2020b, 2020e), *Thomson ONE (2020), KPMG (2020) and Siemens Gamesa (2019)*

The following presents the calculation for the Beta factor of Siemens Gamesa. Estimate of the levered beta was obtained through a 5-year regression of the daily returns between Siemens Gamesa and MSCI World Index ETF (XWD.TO). Prices of the stocks were extracted from Yahoo Finance (2020b, 2020e). Calculation of the unlevered Beta then required the Debt to Equity ratio which was extracted from Thomson ONE (2020) and the corporate tax rate of Spain obtained from KPMG (2020).

Siemens Games is a leader manufacturer and service provider for both the offshore and onshore wind industry. Since 1991 the company connected 13 GW worth of offshore wind turbines and provided services beyond manufacturing covering a total of 57 GW. The company currently holds the contract to supply the world´s largest offshore wind farm. (Siemens Gamesa, 2019).

Siemens Gamesa Renewable Energy S.A.

Regression Statistics	
Multiple R	0.264547478
R Square	0.069985368
Adjusted R Square	0.069229873
Standard Error	0.025089781
Observations	1233

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.05831352	0.05831352	92.63508893	3.42861E-21
Residual	1231	0.774910937	0.000629497		
Total	1232	0.833224457			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95,0%*	*Upper 95,0%*
Intercept	-0.000119201	0.000714785	-0.16676502	0.867582331	-0.001521532	0.00128313	-0.001521532	0.00128313
X Variable 1	0.648524445	0.067381176	9.624712407	3.42861E-21	0.51632979	0.780719101	0.51632979	0.780719101

$$\beta_U = \frac{\beta_L}{\left(1+(1-T)\frac{Debt}{Equity}\right)}$$

Debt/Equity 2019	2018	2017	Average
0.08	0.14	0.08	**0.10**

Levered Beta	Corporate Taxes	Unlevered Beta
0.65	25%	**0.60**

12.8. *Appendix 8: Beta Calculation – Vestas Wind Systems A/S*

***Sources:** Own depiction based on Yahoo Finance* (2020b, 2020f), *Thomson ONE (2020), KPMG (2020) and Vestas (2020)*

The following presents the calculation for the Beta factor of Vestas. Estimate of the levered beta was obtained through a 5-year regression of the daily returns between Vestas and MSCI World Index ETF (XWD.TO). Prices of the stocks were extracted from Yahoo Finance (2020b, 2020f). Calculation of the unlevered Beta then required the Debt to Equity ratio which was extracted from Thomson ONE (2020) and the corporate tax rate of Denmark obtained from KPMG (2020).

Second only to Siemens Gamesa, Vestas is worldwide leader in the manufacturing and servicing of wind turbines. In particular, the company is involved in the offshore business through the joint venture MHI Vestas Offshore Wind A/S established in 2014. As of 2019 the company totaled an order backlog of 2,870 MW. (Vestas, 2020).

Vestas Wind Systems A/S

Regression Statistics	
Multiple R	0.300354419
R Square	0.090212777
Adjusted R Square	0.089463981
Standard Error	0.020770057
Observations	1217

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.051973252	0.051973252	120.4770976	8.59706E-27
Residual	1215	0.524145272	0.000431395		
Total	1216	0.576118523			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95,0%*	*Upper 95,0%*
Intercept	0.000371666	0.000595598	0.624021349	0.532730706	-0.000796849	0.001540181	-0.000796849	0.001540181
X Variable 1	0.610195401	0.055592561	10.97620597	8.59706E-27	0.501127334	0.719263469	0.501127334	0.719263469

$$\beta_U = \frac{\beta_L}{\left(1+(1-T)\frac{Debt}{Equity}\right)}$$

Debt/Equity			
2019	2018	2017	Average
0.20	0.16	0.16	**0.17**

Levered Beta	Corporate Taxes	Unlevered Beta
0.61	22%	**0.54**

12.9. ***Appendix 9:*** *Beta Calculation – EDP Renováveis S.A.*

Sources: *Own depiction based on Yahoo Finance (2020b, 2020a), Thomson ONE (2020), KPMG (2020) and EDPR (2020)*

The following presents the calculation for the Beta factor of EDPR. Estimate of the levered beta was obtained through a 5-year regression of the daily returns between EDP Renováveis and MSCI World Index ETF (XWD.TO). Prices of the stocks were extracted from Yahoo Finance (2020b, 2020a). Calculation of the unlevered Beta then required the Debt to Equity ratio which was extracted from Thomson ONE (2020) and the corporate tax rate of Spain obtained from KPMG (2020).

EDPR plays an important role in the production of power from sustainable sources. Currently the company holds the fourth position in the global production of wind energy (considering both onshore and offshore). The company is currently developing offshore project in the US, UK, France, Portugal, Poland and South Korea. (EDP Renováveis, 2020).

EDP Renováveis S.A.

Regression Statistics	
Multiple R	0.395233046
R Square	0.156209161
Adjusted R Square	0.155530327
Standard Error	0.012911992
Observations	1245

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.03836448	0.03836448	230.1138836	8.14388E-48
Residual	1243	0.207232385	0.00016672		
Total	1244	0.245596865			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95,0%*	*Upper 95,0%*
Intercept	0.000318609	0.000366071	0.870346643	0.384279042	-0.000399577	0.001036794	-0.000399577	0.001036794
X Variable 1	0.523569091	0.03451458	15.16950505	8.14388E-48	0.455855824	0.591282359	0.455855824	0.591282359

$$\beta_U = \frac{\beta_L}{\left(1+(1-T)\frac{Debt}{Equity}\right)}$$

Debt/Equity			
2019	2018	2017	Average
0.40	0.55	0.54	**0.50**

Levered Beta	Corporate Taxes	Unlevered Beta
0.52	25%	**0.38**

12.10. ***Appendix 10:*** *Financial Model on Excel*

Sources: *Own Calculation*

Purposed of this appendix is to provide a guide to the excel spreadsheet attached to this thesis. In the file, a detailed representation of the financial model as well as the results from the Monte Carlo simulations could be found. These follow the glossary presented below.

Sheet 1: Title and Glossary
Sheet 2: Price Projections
Sheet 3: Financial Model – Reference Scenario
Sheet 4: Financial Model – Low Prices Scenario
Sheet 5: Financial Model – High Prices Scenario
Sheet 6: Full Representation of Tables Displayed in the Thesis
Sheet 7: Monte Carlo Data – Reference Scenario
Sheet 8: Monte Carlo Data – Low Prices Scenario
Sheet 9: Monte Carlo Data – High Prices Scenario

12.11. ***Appendix 11:*** *Sensitivity Analysis Data Table*

Source*: Own Calculation*

The following data table refers to the tornado plot displayed in the sensitivity analysis proposed in Chapter 7.

Parameter Results			
Parameter	**Base Case**	**-10 Pct**	**+10 Pct**
Net Energy Output	4,471,000.00	4,023,900.00	4,918,100.00
Capex	1,641,000,000.00	1,476,900,000.00	1,805,100,000.00
Cost of Equity	0.080	0.072	0.088
Fixed Opex	76000000.00	68400000.00	83600000.00
Cannibalization effect	0.100	0.090	0.110
Tax Rate	0.190	0.171	0.209
Cannibalization growth rate	0.035	0.032	0.039
Cost of Debt	0.040	0.036	0.044

APV Results			
Parameter	**Base Case**	**-10 Pct**	**+10 Pct**
Net Energy Output	43,234,873	(179,838,586)	266,308,332
Capex	43,234,873	185,359,723	(98,889,978)
Cost of Equity	43,234,873	173,795,654	(72,077,193)
Fixed Opex	43,234,873	119,859,994	(33,390,248)
Cannibalization effect	43,234,873	83,409,020	3,060,725
Tax Rate	43,234,873	61,689,580	24,780,165
Cannibalization growth rate	43,234,873	60,641,778	24,853,082
Cost of Debt	43,234,873	39,705,408	46,631,328

12.12. ***Appendix 12:*** *ETF Selection and Correlation Estimates*

Source*: Portfolio Visualizer (2020)*

The following represent the lists of personally chosen ETF with regards to each asset class employed in the analysis of the three benchmarked portfolios. The appendix also includes the calculation of the relative correlation coefficients between the selected ETFs which were extracted from the online tool Portfolio Visualizer (2020).

ETF Selection for each Asset Class		
Portfolio Asset Classes	**Referenced ETF**	**Ticker**
Global Equities	Vanguard Total World Stock ETF	VT
Global Equities Low Volatility	BMO Low Volatility Int´l ETF	ZLI.TO
Global DM Govt Bonds	Janus Henderson Developed World Bond A	HFAAX
Global IG Bonds	Fidelity Investment Grade Bond	FBNDX
Global High Yield Bonds	iShares International High Yield Bd ETF	HYXU
EM Debt	iShares JP Morgan EM Corporate Bond ETF	CEMB
Senior Secured Loans	Invesco Senior Loan ETF (BKLN)	BKLN
ABS - Mezzanine	Vanguard Mortgage-Backed Secs ETF	VMBS
Insurance Linked Securities	iShares US Insurance ETF	IAK
Global Commercial Property	iShares Global REIT ETF	REET
Infrastructure Social	iShares Global Infrastructure ETF	IGF
Wind Energy	First Trust Global Wind Energy	FAN

Asset Correlations for the time period 09/09/2015 - 01/01/2020 based on daily returns

Name	Ticker	VT	ZLI.TO	HFAAX	FBNDX	HYXU	CEMB	BKLN	VMBS	IAK	REET	IGF	FAN	Annualized Return	Daily Standard Deviation	Monthly Standard Deviation	Annualized Standard Deviation
Vanguard Total World Stock ETF	VT	-	0.55	-0.08	-0.16	0.33	0.22	0.52	-0.21	0.75	0.64	0.79	0.74	11.05%	0.82%	3.35%	11.60%
BMO Low Volatility Int'l ETF	ZLI.TO	0.55	-	0.05	-0.05	0.23	0.14	0.22	-0.07	0.41	0.41	0.47	0.48	7.61%	0.69%	2.56%	8.86%
Janus Henderson Developed World Bond A	HFAAX	-0.08	0.05	-	0.63	0.05	0.21	-0.02	0.52	-0.16	0.15	0.10	0.04	4.90%	0.15%	0.86%	2.97%
Fidelity Investment Grade Bond	FBNDX	-0.16	-0.05	0.63	-	0.08	0.22	-0.05	0.76	-0.30	0.16	0.10	0.02	3.97%	0.20%	0.90%	3.10%
iShares International High Yield Bd ETF	HYXU	0.33	0.23	0.05	0.08	-	0.17	0.20	0.01	0.16	0.22	0.40	0.40	4.28%	0.57%	2.36%	8.18%
iShares JP Morgan EM Corporate Bond ETF	CEMB	0.22	0.14	0.21	0.22	0.17	-	0.15	0.20	0.06	0.23	0.30	0.25	6.50%	0.35%	1.53%	5.31%
Invesco Senior Loan ETF	BKLN	0.52	0.22	-0.02	-0.05	0.20	0.15	-	-0.12	0.39	0.35	0.45	0.40	3.67%	0.20%	1.09%	3.78%
Vanguard Mortgage-Backed Secs ETF	VMBS	-0.21	-0.07	0.52	0.76	0.01	0.20	-0.12	-	-0.34	0.10	0.01	-0.08	2.55%	0.15%	0.61%	2.10%
iShares US Insurance ETF	IAK	0.75	0.41	-0.16	-0.30	0.16	0.06	0.39	-0.34	-	0.46	0.52	0.50	11.04%	0.93%	3.83%	13.28%
iShares Global REIT ETF	REET	0.64	0.41	0.15	0.16	0.22	0.23	0.35	0.10	0.46	-	0.70	0.55	9.03%	0.78%	3.30%	11.45%
iShares Global Infrastructure ETF	IGF	0.79	0.47	0.10	0.10	0.40	0.30	0.45	0.01	0.52	0.70	-	0.74	9.04%	0.74%	2.97%	10.30%
First Trust Global Wind Energy ETF	FAN	0.74	0.48	0.04	0.02	0.40	0.25	0.40	-0.08	0.50	0.55	0.74	-	11.30%	0.95%	4.48%	15.52%

12.13. *Appendix 13: Calculation of Covariance from Correlation*

***Source**: Own calculation based on Bodie et al, (2014) and ASI (2019)*

The following represent the calculation of the covariance matrix from the correlation matrix for the three benchmarked portfolios. The estimate was then employed for the optimization of each portfolio. Volatility data were extracted from ASI (2019). Calculation was then provided according to the following formula:

$$\rho_{x,y} = \frac{Covar_{x,y}}{\sigma_x * \sigma_y}$$

Traditional Balanced - Correlation Matrix

	volatility	Global Equiti	Global DM G	Global IG Bo	Wind energy
Global Equities	0.16	1	-0.080	-0.160	0.740
Global DM Govt Bonds	0.04	-0.080	1	0.630	0.040
Global IG Bonds	0.08	-0.160	0.630	1	0.020
Wind Energy	0.12	0.740	0.040	0.020	1

Traditional Balanced - Covariance Matrix

	Global Equiti	Global DM G	Global IG Bo	Wind energy
Global Equities	0.026	0.000	-0.002	0.014
Global DM Govt Bonds	0.000	0.002	0.002	0.000
Global IG Bonds	-0.002	0.002	0.006	0.000
Wind Energy	0.014	0.000	0.000	0.014

Modern Balanced - Correlation Matrix

	volatility	Global Equiti	Global DM G	Global IG Bo	Global High '	Global Comr	Wind Energy
Global Equities	0.16	1	-0.080	-0.160	0.330	0.640	0.740
Global DM Govt Bonds	0.04	-0.080	1	0.630	0.050	0.150	0.040
Global IG Bonds	0.08	-0.160	0.630	1	0.080	0.160	0.020
Global High Yield Bonds	0.09	0.330	0.050	0.080	1	0.220	0.400
Global Commercial Property	0.10	0.640	0.150	0.160	0.220	1	0.550
Wind Energy	0.12	0.740	0.040	0.020	0.400	0.550	1

Modern Balanced - Covariance Matrix

	Global Equiti	Global DM G	Global IG Bo	Global High '	Global Comr	Wind Energy
Global Equities	0.026	0.000	-0.002	0.005	0.010	0.014
Global DM Govt Bonds	0.000	0.002	0.002	0.000	0.001	0.000
Global IG Bonds	-0.002	0.002	0.006	0.001	0.001	0.000
Global High Yield Bonds	0.005	0.000	0.001	0.008	0.002	0.004
Global Commercial Property	0.010	0.001	0.001	0.002	0.010	0.007
Wind Energy	0.014	0.000	0.000	0.004	0.007	0.014

Diversified Growth - Correlation Matrix

	volatility	Global Equit	Global High	EM Debt (Lc	Senior Secu	ABS - Mezza	Insurance L	Global Com	Infrastructu	Wind Energy
Global Equities Low Volatility	**0.14**	1	0.230	0.140	0.220	-0.070	0.410	0.410	0.470	0.480
Global High Yield Bonds	**0.09**	0.230	1	0.170	0.200	0.010	0.160	0.220	0.400	0.400
EM Debt	**0.09**	0.140	0.170	1	0.150	0.200	0.060	0.230	0.300	0.250
Senior Secured Loans	**0.07**	0.220	0.200	0.150	1	-0.120	0.390	0.350	0.450	0.400
ABS - Mezzanine	**0.10**	-0.070	0.010	0.200	-0.120	1	-0.340	0.100	0.010	-0.080
Insurance Linked Securities	**0.08**	0.410	0.160	0.060	0.390	-0.340	1	0.460	0.520	0.500
Global Commercial Property	**0.10**	0.410	0.220	0.230	0.350	0.100	0.460	1	0.700	0.550
Infrastructure Social	**0.11**	0.470	0.400	0.300	0.450	0.010	0.520	0.700	1	0.740
Wind Energy	**0.12**	0.480	0.400	0.250	0.400	-0.080	0.500	0.550	0.740	1

Diversified Growth - Covariance Matrix

	Global Equit	Global High	EM Debt (Lc	Senior Secu	ABS - Mezza	Insurance L	Global Com	Infrastructu	Wind Energy
Global Equities Low Volatility	0.019	0.003	0.002	0.002	-0.001	0.004	0.006	0.007	0.008
Global High Yield Bonds	0.003	0.008	0.001	0.001	0.000	0.001	0.002	0.004	0.004
EM Debt	0.002	0.001	0.009	0.001	0.002	0.000	0.002	0.003	0.003
Senior Secured Loans	0.002	0.001	0.001	0.005	-0.001	0.002	0.002	0.003	0.003
ABS - Mezzanine	-0.001	0.000	0.002	-0.001	0.010	-0.003	0.001	0.000	-0.001
Insurance Linked Securities	0.004	0.001	0.000	0.002	-0.003	0.006	0.003	0.004	0.005
Global Commercial Property	0.006	0.002	0.002	0.002	0.001	0.003	0.010	0.007	0.007
Infrastructure Social	0.007	0.004	0.003	0.003	0.000	0.004	0.007	0.011	0.009
Wind Energy	0.008	0.004	0.003	0.003	-0.001	0.005	0.007	0.009	0.014

12.14. *Appendix 14: Efficient Frontiers Data Tables*

***Source**: Own calculation*

The following tables represent the data series for the efficient frontier for the three benchmarked portfolios. These were obtained from a weight combination between the minimum variance and the tangency portfolio. Displayed is also the data point of the portfolios with volatility fixed at 6%

Traditional Balanced - Efficient Frontier

Portfolio	Variance	Std. Dev.	Exp. Return
MinVar	0.138%	3.709%	1.523%
Tangency	0.388%	6.226%	2.571%
Traditional	**0.360%**	**6.000%**	**0.000%**

Covar between MinVar and Tangency 0.001375862

MinVar	Tangency	Variance	St.Dev	Exp. Ret
-2.0	3.0	2.388%	15.453%	4.669%
-1.9	2.9	2.240%	14.968%	4.564%
-1.8	2.8	2.098%	14.484%	4.459%
-1.7	2.7	1.960%	14.002%	4.354%
-1.6	2.6	1.828%	13.520%	4.249%
-1.5	2.5	1.700%	13.040%	4.144%
-1.4	2.4	1.578%	12.561%	4.039%
-1.3	2.3	1.460%	12.084%	3.935%
-1.2	2.2	1.348%	11.610%	3.830%
-1.1	2.1	1.240%	11.137%	3.725%
-1.0	2.0	1.138%	10.667%	3.620%
-0.9	1.9	1.040%	10.199%	3.515%
-0.8	1.8	0.948%	9.735%	3.410%
-0.7	1.7	0.860%	9.275%	3.305%
-0.6	1.6	0.778%	8.819%	3.201%
-0.5	1.5	0.700%	8.368%	3.096%
-0.4	1.4	0.628%	7.923%	2.991%
-0.3	1.3	0.560%	7.484%	2.886%
-0.2	1.2	0.498%	7.054%	2.781%
-0.1	1.1	0.440%	6.634%	2.676%
0.0	1.0	0.388%	6.226%	2.571%
0.1	0.9	0.340%	5.832%	2.466%
0.2	0.8	0.298%	5.455%	2.362%
0.3	0.7	0.260%	5.100%	2.257%
0.4	0.6	0.228%	4.771%	2.152%
0.5	0.5	0.200%	4.473%	2.047%
0.6	0.4	0.178%	4.214%	1.942%
0.7	0.3	0.160%	4.001%	1.837%
0.8	0.2	0.148%	3.842%	1.732%
0.9	0.1	0.140%	3.743%	1.628%
1.0	0.0	0.138%	3.709%	1.523%
1.1	-0.1	0.140%	3.743%	1.418%
1.2	-0.2	0.148%	3.842%	1.313%
1.3	-0.3	0.160%	4.001%	1.208%
1.4	-0.4	0.178%	4.214%	1.103%
1.5	-0.5	0.200%	4.473%	0.998%
1.6	-0.6	0.228%	4.771%	0.894%
1.7	-0.7	0.260%	5.100%	0.789%
1.8	-0.8	0.298%	5.455%	0.684%
1.9	-0.9	0.340%	5.832%	0.579%
2.0	-1.0	0.388%	6.226%	0.474%

Modern Balanced - Efficient Frontier

Portfolio	Variance	Std. Dev.	Exp. Return
MinVar	0.128%	3.576%	1.787%
Tangency	0.181%	4.249%	2.516%
Modern	**0.360%**	**6.000%**	**0.000%**

Covar between MinVar and Tangency 0.00127844

MinVar	Tangency	Variance	St.Dev	Exp. Ret
-2.5	3.5	0.774%	8.797%	4.339%
-2.4	3.4	0.737%	8.587%	4.266%
-2.3	3.3	0.702%	8.379%	4.193%
-2.2	3.2	0.668%	8.172%	4.120%
-2.1	3.1	0.635%	7.966%	4.047%
-2.0	3.0	0.602%	7.762%	3.974%
-1.9	2.9	0.571%	7.559%	3.901%
-1.8	2.8	0.541%	7.357%	3.829%
-1.7	2.7	0.512%	7.157%	3.756%
-1.6	2.6	0.484%	6.959%	3.683%
-1.5	2.5	0.457%	6.763%	3.610%
-1.4	2.4	0.432%	6.569%	3.537%
-1.3	2.3	0.407%	6.378%	3.464%
-1.2	2.2	0.383%	6.189%	3.391%
-1.1	2.1	0.360%	6.003%	3.318%
-1.0	2.0	0.339%	5.820%	3.245%
-0.9	1.9	0.318%	5.641%	3.172%
-0.8	1.8	0.299%	5.465%	3.099%
-0.7	1.7	0.280%	5.294%	3.027%
-0.6	1.6	0.263%	5.127%	2.954%
-0.5	1.5	0.246%	4.965%	2.881%
-0.4	1.4	0.231%	4.808%	2.808%
-0.3	1.3	0.217%	4.658%	2.735%
-0.2	1.2	0.204%	4.514%	2.662%
-0.1	1.1	0.192%	4.378%	2.589%
0.0	1.0	0.181%	4.249%	2.516%
0.1	0.9	0.171%	4.130%	2.443%
0.2	0.8	0.162%	4.020%	2.370%
0.3	0.7	0.154%	3.920%	2.297%
0.4	0.6	0.147%	3.832%	2.225%
0.5	0.5	0.141%	3.755%	2.152%
0.6	0.4	0.136%	3.692%	2.079%
0.7	0.3	0.133%	3.641%	2.006%
0.8	0.2	0.130%	3.605%	1.933%
0.9	0.1	0.128%	3.583%	1.860%
1.0	0.0	0.128%	3.576%	1.787%
1.1	-0.1	0.128%	3.583%	1.714%
1.2	-0.2	0.130%	3.605%	1.641%
1.3	-0.3	0.133%	3.641%	1.568%
1.4	-0.4	0.136%	3.692%	1.495%
1.5	-0.5	0.141%	3.755%	1.422%
1.6	-0.6	0.147%	3.832%	1.350%
1.7	-0.7	0.154%	3.920%	1.277%
1.8	-0.8	0.162%	4.020%	1.204%
1.9	-0.9	0.171%	4.130%	1.131%
2.0	-1.0	0.181%	4.249%	1.058%

Diversified Growth - Efficient Frontier

Portfolio	Variance	Std. Dev.	Exp. Return
MinVar	0.279%	5.281%	4.697%
Tangency	0.304%	5.512%	4.986%
Growth	**0.360%**	**6.000%**	**5.100%**

Covar between MinVar and Tangency 0.00278899

MinVar	Tangency	Variance	St.Dev	Exp. Ret
-4.5	5.5	1.032%	10.159%	6.290%
-4.4	5.4	1.005%	10.025%	6.261%
-4.3	5.3	0.978%	9.891%	6.232%
-4.2	5.2	0.952%	9.758%	6.203%
-4.1	5.1	0.927%	9.626%	6.174%
-4.0	5.0	0.901%	9.494%	6.145%
-3.9	4.9	0.877%	9.363%	6.116%
-3.8	4.8	0.853%	9.234%	6.087%
-3.7	4.7	0.829%	9.105%	6.058%
-3.6	4.6	0.806%	8.976%	6.029%
-3.5	4.5	0.783%	8.849%	6.000%
-3.4	4.4	0.761%	8.723%	5.971%
-3.3	4.3	0.739%	8.598%	5.942%
-3.2	4.2	0.718%	8.474%	5.913%
-3.1	4.1	0.697%	8.351%	5.884%
-3.0	4.0	0.677%	8.230%	5.855%
-2.9	3.9	0.658%	8.109%	5.826%
-2.8	3.8	0.638%	7.990%	5.797%
-2.7	3.7	0.620%	7.873%	5.768%
-2.6	3.6	0.602%	7.756%	5.739%
-2.5	3.5	0.584%	7.641%	5.710%
-2.4	3.4	0.567%	7.528%	5.682%
-2.3	3.3	0.550%	7.417%	5.653%
-2.2	3.2	0.534%	7.307%	5.624%
-2.1	3.1	0.518%	7.198%	5.595%
-2.0	3.0	0.503%	7.092%	5.566%
-1.9	2.9	0.488%	6.988%	5.537%
-1.8	2.8	0.474%	6.886%	5.508%
-1.7	2.7	0.460%	6.785%	5.479%
-1.6	2.6	0.447%	6.687%	5.450%
-1.5	2.5	0.435%	6.592%	5.421%
-1.4	2.4	0.422%	6.499%	5.392%
-1.3	2.3	0.411%	6.408%	5.363%
-1.2	2.2	0.399%	6.320%	5.334%
-1.1	2.1	0.389%	6.235%	5.305%
-1.0	2.0	0.378%	6.152%	5.276%
-0.9	1.9	0.369%	6.073%	5.247%
-0.8	1.8	0.360%	5.996%	5.218%
-0.7	1.7	0.351%	5.923%	5.189%
-0.6	1.6	0.343%	5.854%	5.160%
-0.5	1.5	0.335%	5.787%	5.131%
-0.4	1.4	0.328%	5.725%	5.102%
-0.3	1.3	0.321%	5.665%	5.073%
-0.2	1.2	0.315%	5.610%	5.044%
-0.1	1.1	0.309%	5.559%	5.015%
0.0	1.0	0.304%	5.512%	4.986%
0.1	0.9	0.299%	5.469%	4.957%
0.2	0.8	0.295%	5.430%	4.929%
0.3	0.7	0.291%	5.395%	4.900%
0.4	0.6	0.288%	5.365%	4.871%
0.5	0.5	0.285%	5.340%	4.842%
0.6	0.4	0.283%	5.319%	4.813%
0.7	0.3	0.281%	5.302%	4.784%
0.8	0.2	0.280%	5.291%	4.755%
0.9	0.1	0.279%	5.283%	4.726%
1.0	0.0	0.279%	5.281%	4.697%
1.1	-0.1	0.279%	5.283%	4.668%
1.2	-0.2	0.280%	5.291%	4.639%
1.3	-0.3	0.281%	5.302%	4.610%
1.4	-0.4	0.283%	5.319%	4.581%
1.5	-0.5	0.285%	5.340%	4.552%
1.6	-0.6	0.288%	5.365%	4.523%
1.7	-0.7	0.291%	5.395%	4.494%
1.8	-0.8	0.295%	5.430%	4.465%
1.9	-0.9	0.299%	5.469%	4.436%
2.0	-1.0	0.304%	5.512%	4.407%
2.1	-1.1	0.309%	5.559%	4.378%
2.2	-1.2	0.315%	5.610%	4.349%
2.3	-1.3	0.321%	5.665%	4.320%
2.4	-1.4	0.328%	5.725%	4.291%
2.5	-1.5	0.335%	5.787%	4.262%
2.6	-1.6	0.343%	5.854%	4.233%
2.7	-1.7	0.351%	5.923%	4.204%
2.8	-1.8	0.360%	5.996%	4.175%
2.9	-1.9	0.369%	6.073%	4.147%
3.0	-2.0	0.378%	6.152%	4.118%
3.1	-2.1	0.389%	6.235%	4.089%

12.15. *Appendix 15: Portfolio Asset Allocation Data Tables*

***Source**: Own calculation*

The following tables represent the data series for the portfolio asset allocation as a result of the integration of the offshore wind alternative investment. Divided by each benchmarked portfolio the data details the weight allocated under the three different scenarios for different levels of volatility in the offshore wind investment. Included in the tables are also the expected return for the portfolio as well as the volatility which was fixed at 6%.

Traditional Balanced - Portfolio Integration

Return Offshore Wind	Volatility Offshore Wind	Weight Global Equities	Weight Global DM Govt Bonds	Weight Global IG Bonds	Weight Offshore Wind	Volatility Optimized Portfolio	Return Optimized Portfolio	Sharp Ratio Optimized Portfolio	Return Pre-Integration Portfolio
6.10%	15.30%	0.00%	53.62%	12.37%	34.01%	6.00%	2.99%	0.352	2.51%
6.10%	16.30%	3.41%	52.48%	14.88%	29.23%	6.00%	2.88%	0.334	2.51%
6.10%	17.30%	6.75%	50.95%	17.33%	24.97%	6.00%	2.79%	0.319	2.51%
6.10%	18.30%	9.99%	49.16%	19.70%	21.15%	6.00%	2.72%	0.307	2.51%
6.10%	19.30%	13.10%	47.23%	21.93%	17.74%	6.00%	2.67%	0.298	2.51%
6.10%	20.30%	16.08%	45.22%	24.02%	14.68%	6.00%	2.62%	0.291	2.51%
6.10%	21.30%	18.89%	43.20%	25.96%	11.94%	6.00%	2.59%	0.285	2.51%
6.10%	22.30%	21.54%	41.22%	27.74%	9.50%	6.00%	2.56%	0.280	2.51%
6.10%	23.30%	24.01%	39.32%	29.35%	7.33%	6.00%	2.54%	0.277	2.51%
6.10%	24.30%	26.31%	37.50%	30.80%	5.40%	6.00%	2.53%	0.275	2.51%
6.10%	25.30%	28.43%	35.78%	32.10%	3.69%	6.00%	2.52%	0.273	2.51%
6.10%	26.30%	30.38%	34.19%	33.25%	2.18%	6.00%	2.51%	0.272	2.51%
6.10%	27.30%	32.18%	32.70%	34.27%	0.86%	6.00%	2.51%	0.272	2.51%
6.10%	28.30%	33.38%	31.69%	34.93%	0.00%	6.00%	2.51%	0.272	2.51%
6.10%	29.30%	33.38%	31.69%	34.93%	0.00%	6.00%	2.51%	0.272	2.51%
6.10%	30.30%	33.38%	31.69%	34.93%	0.00%	6.00%	2.51%	0.272	2.51%
6.10%	31.30%	33.38%	31.69%	34.93%	0.00%	6.00%	2.51%	0.272	2.51%
6.10%	32.30%	33.38%	31.69%	34.93%	0.00%	6.00%	2.51%	0.272	2.51%
10.04%	15.30%	0.00%	61.27%	4.05%	34.68%	6.00%	4.35%	0.579	2.51%
10.04%	16.30%	0.00%	63.35%	4.43%	32.23%	6.00%	4.14%	0.543	2.51%
10.04%	17.30%	0.00%	65.08%	4.84%	30.08%	6.00%	3.95%	0.512	2.51%
10.04%	18.30%	0.00%	66.54%	5.28%	28.18%	6.00%	3.79%	0.485	2.51%
10.04%	19.30%	0.00%	67.75%	5.75%	26.50%	6.00%	3.64%	0.461	2.51%
10.04%	20.30%	0.00%	68.77%	6.24%	24.99%	6.00%	3.52%	0.439	2.51%
10.04%	21.30%	0.00%	69.63%	6.73%	23.64%	6.00%	3.40%	0.420	2.51%
10.04%	22.30%	0.00%	70.35%	7.23%	22.42%	6.00%	3.30%	0.403	2.51%
10.04%	23.30%	0.00%	70.94%	7.75%	21.31%	6.00%	3.20%	0.387	2.51%
10.04%	24.30%	0.00%	71.43%	8.27%	20.30%	6.00%	3.12%	0.373	2.51%
10.04%	25.30%	0.83%	70.83%	9.28%	19.05%	6.00%	3.04%	0.360	2.51%
10.04%	26.30%	2.51%	69.16%	10.75%	17.59%	6.00%	2.97%	0.348	2.51%
10.04%	27.30%	4.17%	67.40%	12.21%	16.21%	6.00%	2.91%	0.338	2.51%
10.04%	28.30%	5.84%	65.55%	13.69%	14.92%	6.00%	2.85%	0.329	2.51%
10.04%	29.30%	7.48%	63.71%	15.10%	13.71%	6.00%	2.81%	0.321	2.51%
10.04%	30.30%	9.11%	61.82%	16.50%	12.57%	6.00%	2.76%	0.314	2.51%
10.04%	31.30%	10.73%	59.90%	17.88%	11.49%	6.00%	2.73%	0.308	2.51%
10.04%	32.30%	12.32%	57.98%	19.23%	10.48%	6.00%	2.69%	0.302	2.51%
12.36%	15.30%	0.00%	63.39%	1.82%	34.80%	6.00%	5.16%	0.713	2.51%
12.36%	16.30%	0.00%	65.58%	2.07%	32.35%	6.00%	4.89%	0.668	2.51%
12.36%	17.30%	0.00%	67.44%	2.36%	30.20%	6.00%	4.65%	0.629	2.51%
12.36%	18.30%	0.00%	69.01%	2.68%	28.31%	6.00%	4.44%	0.594	2.51%
12.36%	19.30%	0.00%	70.35%	3.02%	26.64%	6.00%	4.26%	0.564	2.51%
12.36%	20.30%	0.00%	71.48%	3.38%	25.14%	6.00%	4.10%	0.536	2.51%
12.36%	21.30%	0.00%	72.46%	3.75%	23.79%	6.00%	3.95%	0.512	2.51%
12.36%	22.30%	0.00%	73.28%	4.14%	22.58%	6.00%	3.82%	0.490	2.51%
12.36%	23.30%	0.00%	73.99%	4.54%	21.47%	6.00%	3.70%	0.470	2.51%
12.36%	24.30%	0.00%	74.58%	4.95%	20.47%	6.00%	3.59%	0.451	2.51%
12.36%	25.30%	0.00%	75.09%	5.36%	19.55%	6.00%	3.49%	0.435	2.51%
12.36%	26.30%	0.00%	75.51%	5.79%	18.71%	6.00%	3.40%	0.420	2.51%
12.36%	27.30%	0.00%	75.85%	6.22%	17.93%	6.00%	3.31%	0.406	2.51%
12.36%	28.30%	0.00%	76.15%	6.65%	17.21%	6.00%	3.24%	0.393	2.51%
12.36%	29.30%	0.00%	76.37%	7.09%	16.54%	6.00%	3.16%	0.381	2.51%
12.36%	30.30%	0.18%	76.34%	7.62%	15.87%	6.00%	3.10%	0.370	2.51%
12.36%	31.30%	1.45%	74.84%	8.80%	14.91%	6.00%	3.04%	0.360	2.51%
12.36%	32.30%	2.71%	73.33%	9.96%	14.00%	6.00%	2.98%	0.350	2.51%

Modern Balanced - Portfolio Integration

Return Offshore Wind	Volatility Offshore Wind	Weight Global Equities	Weight Global DM Govt Bonds	Weight Global IG Bonds	Weight Global High Yield Bonds	Weight Global Commercial	Weight Offshore Wind	Volatility Optimized Portfolio	Return Optimized Portfolio	Sharp Ratio Optimized Portfolio	Return Pre-Integration Portfolio
6.10%	15.30%	0.00%	36.12%	11.66%	15.00%	10.00%	27.21%	6.00%	3.47%	0.432	3.07%
6.10%	16.30%	0.00%	37.13%	12.63%	15.00%	10.00%	25.24%	6.00%	3.38%	0.417	3.07%
6.10%	17.30%	0.98%	37.13%	14.05%	15.00%	10.00%	22.84%	6.00%	3.31%	0.404	3.07%
6.10%	18.30%	4.22%	35.13%	16.47%	15.00%	10.00%	19.18%	6.00%	3.24%	0.394	3.07%
6.10%	19.30%	7.34%	33.00%	18.77%	15.00%	10.00%	15.89%	6.00%	3.19%	0.386	3.07%
6.10%	20.30%	10.32%	30.83%	20.91%	15.00%	10.00%	12.93%	6.00%	3.16%	0.379	3.07%
6.10%	21.30%	13.16%	28.66%	22.90%	15.00%	10.00%	10.28%	6.00%	3.13%	0.374	3.07%
6.10%	22.30%	15.82%	26.55%	24.71%	15.00%	10.00%	7.92%	6.00%	3.10%	0.371	3.07%
6.10%	23.30%	18.31%	24.52%	26.36%	15.00%	10.00%	5.81%	6.00%	3.09%	0.368	3.07%
6.10%	24.30%	20.62%	22.59%	27.85%	15.00%	10.00%	3.94%	6.00%	3.08%	0.366	3.07%
6.10%	25.30%	22.76%	20.78%	29.18%	15.00%	10.00%	2.28%	6.00%	3.07%	0.365	3.07%
6.10%	26.30%	24.73%	19.10%	30.35%	15.00%	10.00%	0.82%	6.00%	3.07%	0.365	3.07%
6.10%	27.30%	25.88%	18.10%	31.02%	15.00%	10.00%	0.00%	6.00%	3.07%	0.365	3.07%
6.10%	28.30%	25.88%	18.09%	31.02%	15.00%	10.00%	0.00%	6.00%	3.07%	0.365	3.07%
6.10%	29.30%	25.88%	18.10%	31.02%	15.00%	10.00%	0.00%	6.00%	3.07%	0.365	3.07%
6.10%	30.30%	25.89%	18.10%	31.02%	15.00%	10.00%	0.00%	6.00%	3.07%	0.365	3.07%
6.10%	31.30%	25.88%	18.10%	31.02%	15.00%	10.00%	0.00%	6.00%	3.07%	0.365	3.07%
6.10%	32.30%	25.89%	18.10%	31.02%	15.00%	10.00%	0.00%	6.00%	3.07%	0.365	3.07%
10.04%	15.30%	0.00%	44.05%	3.04%	15.00%	10.00%	27.91%	6.00%	4.56%	0.614	3.07%
10.04%	16.30%	0.00%	45.49%	3.54%	15.00%	10.00%	25.97%	6.00%	4.40%	0.586	3.07%
10.04%	17.30%	0.00%	46.67%	4.06%	15.00%	10.00%	24.28%	6.00%	4.25%	0.562	3.07%
10.04%	18.30%	0.00%	47.63%	4.60%	15.00%	10.00%	22.78%	6.00%	4.12%	0.541	3.07%
10.04%	19.30%	0.00%	48.40%	5.15%	15.00%	10.00%	21.44%	6.00%	4.01%	0.522	3.07%
10.04%	20.30%	0.00%	49.03%	5.72%	15.00%	10.00%	20.25%	6.00%	3.91%	0.505	3.07%
10.04%	21.30%	0.00%	49.53%	6.30%	15.00%	10.00%	19.17%	6.00%	3.82%	0.490	3.07%
10.04%	22.30%	0.00%	49.92%	6.89%	15.00%	10.00%	18.20%	6.00%	3.73%	0.476	3.07%
10.04%	23.30%	0.00%	50.21%	7.48%	15.00%	10.00%	17.31%	6.00%	3.66%	0.463	3.07%
10.04%	24.30%	0.00%	50.42%	8.08%	15.00%	10.00%	16.50%	6.00%	3.59%	0.452	3.07%
10.04%	25.30%	0.00%	50.56%	8.69%	15.00%	10.00%	15.75%	6.00%	3.53%	0.442	3.07%
10.04%	26.30%	0.00%	50.64%	9.29%	15.00%	10.00%	15.07%	6.00%	3.47%	0.432	3.07%
10.04%	27.30%	0.00%	50.66%	9.90%	15.00%	10.00%	14.43%	6.00%	3.42%	0.424	3.07%
10.04%	28.30%	0.00%	50.64%	10.51%	15.00%	10.00%	13.85%	6.00%	3.37%	0.415	3.07%
10.04%	29.30%	1.12%	49.31%	11.70%	15.00%	10.00%	12.88%	6.00%	3.33%	0.408	3.07%
10.04%	30.30%	2.77%	47.33%	13.14%	15.00%	10.00%	11.77%	6.00%	3.29%	0.402	3.07%
10.04%	31.30%	4.40%	45.34%	14.55%	15.00%	10.00%	10.71%	6.00%	3.26%	0.396	3.07%
10.04%	32.30%	6.01%	43.35%	15.92%	15.00%	10.00%	9.72%	6.00%	3.23%	0.391	3.07%
12.36%	15.30%	0.00%	50.58%	2.38%	9.04%	7.48%	30.52%	6.00%	5.24%	0.726	3.07%
12.36%	16.30%	0.00%	50.78%	1.20%	10.89%	10.00%	27.14%	6.00%	5.01%	0.688	3.07%
12.36%	17.30%	0.00%	50.75%	1.53%	12.76%	10.00%	24.96%	6.00%	4.82%	0.657	3.07%
12.36%	18.30%	0.00%	50.51%	1.89%	14.58%	10.00%	23.02%	6.00%	4.65%	0.629	3.07%
12.36%	19.30%	0.00%	51.11%	2.30%	15.00%	10.00%	21.59%	6.00%	4.51%	0.605	3.07%
12.36%	20.30%	0.00%	51.87%	2.73%	15.00%	10.00%	20.40%	6.00%	4.38%	0.583	3.07%
12.36%	21.30%	0.00%	52.49%	3.18%	15.00%	10.00%	19.33%	6.00%	4.26%	0.564	3.07%
12.36%	22.30%	0.00%	53.00%	3.64%	15.00%	10.00%	18.36%	6.00%	4.16%	0.547	3.07%
12.36%	23.30%	0.00%	53.42%	4.10%	15.00%	10.00%	17.48%	6.00%	4.06%	0.531	3.07%
12.36%	24.30%	0.00%	53.75%	4.57%	15.00%	10.00%	16.68%	6.00%	3.98%	0.516	3.07%
12.36%	25.30%	0.00%	54.01%	5.05%	15.00%	10.00%	15.94%	6.00%	3.90%	0.503	3.07%
12.36%	26.30%	0.00%	54.21%	5.53%	15.00%	10.00%	15.26%	6.00%	3.83%	0.491	3.07%
12.36%	27.30%	0.00%	54.35%	6.02%	15.00%	10.00%	14.63%	6.00%	3.76%	0.480	3.07%
12.36%	28.30%	0.00%	54.44%	6.51%	15.00%	10.00%	14.05%	6.00%	3.70%	0.469	3.07%
12.36%	29.30%	0.00%	54.48%	7.00%	15.00%	10.00%	13.51%	6.00%	3.64%	0.460	3.07%
12.36%	30.30%	0.00%	54.49%	7.50%	15.00%	10.00%	13.01%	6.00%	3.59%	0.451	3.07%
12.36%	31.30%	0.00%	54.47%	7.99%	15.00%	10.00%	12.54%	6.00%	3.54%	0.443	3.07%
12.36%	32.30%	0.00%	54.41%	8.49%	15.00%	10.00%	12.10%	6.00%	3.49%	0.435	3.07%

Diversified Growth - Portfolio Integration

Return Offshore Wind	Volatility Offshore Wind	Weight Global Equities Low	Weight Global High Yield Bonds	Weight EM Debt Local	Weight Senior Secured	Weight ABS Mezzanine	Weight Insurance Linked Securities	Weight Global Commercial	Weight Infrastructure Social	Weight Offshore Wind	Volatility Optimized Portfolio	Return Optimized Portfolio	Sharp Ratio Optimized Portfolio	Return Pre-Integration Portfolio
6.10%	15.30%	1.99%	14.25%	19.55%	10.00%	15.00%	5.00%	10.00%	15.00%	9.21%	6.00%	5.18%	0.717	5.06%
6.10%	16.30%	2.74%	14.21%	19.99%	10.00%	15.00%	5.00%	10.00%	15.00%	8.07%	6.00%	5.16%	0.714	5.06%
6.10%	17.30%	3.42%	14.10%	20.35%	10.00%	15.00%	5.00%	10.00%	15.00%	7.13%	6.00%	5.14%	0.711	5.06%
6.10%	18.30%	4.26%	13.81%	20.62%	10.00%	15.00%	5.00%	10.00%	15.00%	6.32%	6.00%	5.13%	0.709	5.06%
6.10%	19.30%	4.72%	13.65%	20.94%	10.00%	15.00%	5.00%	10.00%	15.00%	5.69%	6.00%	5.12%	0.707	5.06%
6.10%	20.30%	5.33%	13.37%	21.18%	10.00%	15.00%	5.00%	10.00%	15.00%	5.12%	6.00%	5.11%	0.705	5.06%
6.10%	21.30%	5.92%	13.06%	21.39%	10.00%	15.00%	5.00%	10.00%	15.00%	4.62%	6.00%	5.10%	0.704	5.06%
6.10%	22.30%	6.50%	12.72%	21.59%	10.00%	15.00%	5.00%	10.00%	15.00%	4.18%	6.00%	5.10%	0.703	5.06%
6.10%	23.30%	7.08%	12.35%	21.78%	10.00%	15.00%	5.00%	10.00%	15.00%	3.79%	6.00%	5.09%	0.702	5.06%
6.10%	24.30%	7.62%	11.99%	21.94%	10.00%	15.00%	5.00%	10.00%	15.00%	3.44%	6.00%	5.09%	0.701	5.06%
6.10%	25.30%	8.17%	11.59%	22.11%	10.00%	15.00%	5.00%	10.00%	15.00%	3.13%	6.00%	5.08%	0.701	5.06%
6.10%	26.30%	8.71%	11.23%	22.22%	10.00%	15.00%	5.00%	10.00%	15.00%	2.84%	6.00%	5.08%	0.700	5.06%
6.10%	27.30%	9.24%	10.83%	22.36%	10.00%	15.00%	5.00%	10.00%	15.00%	2.58%	6.00%	5.08%	0.700	5.06%
6.10%	28.30%	9.75%	10.41%	22.51%	10.00%	15.00%	5.00%	10.00%	15.00%	2.33%	6.00%	5.08%	0.699	5.06%
6.10%	29.30%	10.28%	10.01%	22.61%	10.00%	15.00%	5.00%	10.00%	15.00%	2.10%	6.00%	5.07%	0.699	5.06%
6.10%	30.30%	10.80%	9.60%	22.71%	10.00%	15.00%	5.00%	10.00%	15.00%	1.89%	6.00%	5.07%	0.699	5.06%
6.10%	31.30%	11.25%	9.24%	22.80%	10.00%	15.00%	5.00%	10.00%	15.00%	1.71%	6.00%	5.07%	0.698	5.06%
6.10%	32.30%	11.73%	8.83%	22.92%	10.00%	15.00%	5.00%	10.00%	15.00%	1.53%	6.00%	5.07%	0.698	5.06%
10.04%	15.30%	1.08%	20.45%	22.10%	10.00%	15.00%	5.00%	10.00%	0.00%	16.37%	6.00%	5.67%	0.798	5.06%
10.04%	16.30%	1.47%	20.71%	22.35%	10.00%	15.00%	5.00%	10.00%	1.39%	14.08%	6.00%	5.56%	0.780	5.06%
10.04%	17.30%	1.44%	20.26%	22.00%	10.00%	15.00%	5.00%	10.00%	4.66%	11.63%	6.00%	5.48%	0.766	5.06%
10.04%	18.30%	1.36%	19.71%	21.56%	10.00%	15.00%	5.00%	10.00%	7.79%	9.58%	6.00%	5.42%	0.756	5.06%
10.04%	19.30%	1.25%	19.07%	21.06%	10.00%	15.00%	5.00%	10.00%	10.80%	7.82%	6.00%	5.37%	0.748	5.06%
10.04%	20.30%	1.11%	18.38%	20.51%	10.00%	15.00%	5.00%	10.00%	13.70%	6.29%	6.00%	5.34%	0.743	5.06%
10.04%	21.30%	1.19%	18.05%	20.33%	10.00%	15.00%	5.00%	10.00%	15.00%	5.43%	6.00%	5.31%	0.738	5.06%
10.04%	22.30%	1.46%	18.02%	20.48%	10.00%	15.00%	5.00%	10.00%	15.00%	5.04%	6.00%	5.29%	0.735	5.06%
10.04%	23.30%	1.71%	17.99%	20.60%	10.00%	15.00%	5.00%	10.00%	15.00%	4.70%	6.00%	5.27%	0.731	5.06%
10.04%	24.30%	1.95%	17.92%	20.73%	10.00%	15.00%	5.00%	10.00%	15.00%	4.40%	6.00%	5.25%	0.729	5.06%
10.04%	25.30%	2.18%	17.84%	20.84%	10.00%	15.00%	5.00%	10.00%	15.00%	4.14%	6.00%	5.24%	0.726	5.06%
10.04%	26.30%	2.41%	17.75%	20.94%	10.00%	15.00%	5.00%	10.00%	15.00%	3.90%	6.00%	5.22%	0.724	5.06%
10.04%	27.30%	2.63%	17.65%	21.04%	10.00%	15.00%	5.00%	10.00%	15.00%	3.68%	6.00%	5.21%	0.722	5.06%
10.04%	28.30%	2.84%	17.54%	21.13%	10.00%	15.00%	5.00%	10.00%	15.00%	3.49%	6.00%	5.20%	0.720	5.06%
10.04%	29.30%	3.06%	17.43%	21.20%	10.00%	15.00%	5.00%	10.00%	15.00%	3.31%	6.00%	5.19%	0.719	5.06%
10.04%	30.30%	3.26%	17.31%	21.28%	10.00%	15.00%	5.00%	10.00%	15.00%	3.15%	6.00%	5.18%	0.717	5.06%
10.04%	31.30%	3.46%	17.18%	21.36%	10.00%	15.00%	5.00%	10.00%	15.00%	3.00%	6.00%	5.17%	0.716	5.06%
10.04%	32.30%	3.67%	17.04%	21.43%	10.00%	15.00%	5.00%	10.00%	15.00%	2.86%	6.00%	5.17%	0.714	5.06%
12.36%	15.30%	0.67%	20.93%	22.00%	10.00%	15.00%	5.00%	10.00%	0.00%	16.40%	6.00%	6.05%	0.862	5.06%
12.36%	16.30%	1.27%	21.60%	22.58%	10.00%	15.00%	5.00%	10.00%	0.00%	14.55%	6.00%	5.90%	0.836	5.06%
12.36%	17.30%	1.79%	22.12%	23.05%	10.00%	15.00%	5.00%	10.00%	0.00%	13.04%	6.00%	5.77%	0.816	5.06%
12.36%	18.30%	2.23%	22.53%	23.44%	10.00%	15.00%	5.00%	10.00%	0.00%	11.80%	6.00%	5.67%	0.799	5.06%
12.36%	19.30%	2.31%	22.36%	23.37%	10.00%	15.00%	5.00%	10.00%	1.54%	10.42%	6.00%	5.59%	0.785	5.06%
12.36%	20.30%	2.22%	21.90%	23.06%	10.00%	15.00%	5.00%	10.00%	3.73%	9.09%	6.00%	5.52%	0.773	5.06%
12.36%	21.30%	2.10%	21.41%	22.62%	10.00%	15.00%	5.00%	10.00%	5.95%	7.92%	6.00%	5.47%	0.764	5.06%
12.36%	22.30%	1.96%	20.85%	22.24%	10.00%	15.00%	5.00%	10.00%	8.06%	6.89%	6.00%	5.42%	0.757	5.06%
12.36%	23.30%	1.81%	20.27%	21.81%	10.00%	15.00%	5.00%	10.00%	10.14%	5.97%	6.00%	5.39%	0.751	5.06%
12.36%	24.30%	1.65%	19.67%	21.36%	10.00%	15.00%	5.00%	10.00%	12.18%	5.14%	6.00%	5.36%	0.746	5.06%
12.36%	25.30%	1.49%	19.05%	20.90%	10.00%	15.00%	5.00%	10.00%	14.17%	4.40%	6.00%	5.33%	0.742	5.06%
12.36%	26.30%	1.52%	18.77%	20.75%	10.00%	15.00%	5.00%	10.00%	15.00%	3.97%	6.00%	5.31%	0.739	5.06%
12.36%	27.30%	1.69%	18.72%	20.83%	10.00%	15.00%	5.00%	10.00%	15.00%	3.76%	6.00%	5.30%	0.736	5.06%
12.36%	28.30%	1.86%	18.66%	20.91%	10.00%	15.00%	5.00%	10.00%	15.00%	3.56%	6.00%	5.28%	0.734	5.06%
12.36%	29.30%	2.02%	18.60%	20.99%	10.00%	15.00%	5.00%	10.00%	15.00%	3.39%	6.00%	5.27%	0.731	5.06%
12.36%	30.30%	2.18%	18.53%	21.06%	10.00%	15.00%	5.00%	10.00%	15.00%	3.23%	6.00%	5.26%	0.729	5.06%
12.36%	31.30%	2.34%	18.45%	21.13%	10.00%	15.00%	5.00%	10.00%	15.00%	3.09%	6.00%	5.24%	0.727	5.06%
12.36%	32.30%	2.50%	18.37%	21.18%	10.00%	15.00%	5.00%	10.00%	15.00%	2.95%	6.00%	5.23%	0.726	5.06%

13. Glossary

ABS	Asset Backed Securities
APPG	All-Party Parliamentary Group[2]
APV	Adjusted Present Value
ASI	Aberdeen Standard Investments
BEIS	Department for Business, Energy and Industrial Strategy
BNEF	Bloomberg New Energy Finance
BSUoS	Balancing Use of System
BVCA	British Private Equity & Venture Capital Association
CAPEX	Capital Expenditures
DM	Discount Margin
DOE	U.S Department of Energy
DWP	Department for Work and Pensions
ESG	Environmental, Social and Governance
ESO	Electricity System Operator
ETF	Exchange Traded Fund
FCFE	Free Cash Flow to Equity
FCFF	Free Cash Flow to the Firm
FTV	Final Transfer Value
GE	General Electric
HMRC	Her Majesty´s Revenue and Customs
HVAC	High-Voltage Alternating Current
HVDC	High-Voltage Direct Current
IDC	Interest During Construction
IEA	International Energy Agency
IG	Investment Grade
IRENA	International Renewable Energy Agency
IRR	Internal Rate of Return
LCOE	Levelized Cost of Energy
OECD	Organization for Economic Co-operation and Development
OPEX	Operational Expenditures
PPA	Power Purchase Agreement
SPV	Special Purpose Vehicle
OFGEM	Office for Gas and Electricity Market
OFTO	Offshore Transmission Asset Owner
OTC	Over the Counter
TNUoS	Transmission Network Use of System
TPR	The Pensions Regulator

[2] For the purpose of the thesis, “APPG” referenced the “All-Party Parliamentary Group on Alternative Investment Management”.