The relation between risk and return in wind park investments

Master thesis
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## Colophon

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### Front page table
Clean Technica, Siemens (2016)
“For finance is, at its core, a way to understand the role of risk and randomness in our lives and a way to use the dominance of patterns in our advantage”

- Mihir Desai
Preface

While finishing this thesis, I can reflect on a six-month journey in which a new world opened up to me. The world of risk and return has many interesting aspects, and its omnipresence in everyday life truly excited me. Not only is this relation quantifiable, it also has many qualitative, social aspects which make the relation multi-layered and extremely interesting. I was lucky to research this relation for wind park investments. With this, my technical background from the Master Construction Management and Engineering (CME) has been combined with my interest in finance and economics, in which Ernst & Young (EY) has considerable expertise.

Throughout the research process, I have been coached by a team of inspiring, enthusiastic members, who were always there to help. I especially liked that the members also got along well together. Therefore, the meetings were not only helpful, but also a lot of fun. First of all, I want to thank Daan Schraven as my first supervisor for being always very enthusiastic yet realistic about my ideas. Whenever I saw limitations, you saw the opportunities. You always stimulated me to work hard and to get the best out of my work. Secondly, I would like to thank Jan Kees van den Akker from EY to coach me during the process. We have spent much time discussing, deliberating and analysing all the different directions and options of my research. You were always interested in my work, and helped me to discover the world of finance. Next, I would like to thank Hans Bakker as chair for your advice during the meetings, and especially in the beginning when I was searching for the right direction. You were also the supervisor for my internship report, which acquainted you with my working style, about which we have made several jokes during the meetings. Also, I would like to thank Errol Scholten of EY to hire me to do this research for EY, even though you were not completely sure in the beginning whether I could help you with no true background in finance. Soon you assured me that I caught up with the 1-0 disadvantage which I initially had, also thanks to your patience in explaining me how wind park investments work in practise. Last, but definitely not least, I want to thank Émile Chappin as my second supervisor in sharpening my research, providing me very helpful feedback, and stimulating me to work hard until the final deadline for this thesis.

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Furthermore, I want to thank all the investors which I was allowed to interview. You have provided me invaluable insight into the wind sector and the investment mechanisms of wind parks. I enjoyed the visits and interesting conversations, and learning about the activities of an institutional investor.

Finally, I want to thank my parents and sister for always believing in me, supporting me in everything I do, and bringing me to where I am today. Also, I want to thank my friends which I can always count on, and with whom I feel blessed.

Arlette Westhoff
Delft, March 2018
Executive Summary

**Introduction and problem statement**
In the light of governmental supports, technological advancements, and the low interest rate environment, many institutional investors are attracted to invest in wind parks. For this, investors require a return for lending their money and bearing the risks. Generally, the higher risk perception, the higher the return requirement. As much as the valuation of listed assets with available public information has been researched, relatively little attention has been given to the asset class of unlisted assets of which no market information is available. Wind parks are often unlisted, and therefore valuation of these assets to calculate the required return can be problematic as limited information is available. Furthermore, wind parks contain many project-specific, unsystematic risks which increase the risk perception of the investor, especially when he is not completely diversified, and invests directly in the wind park. Diversified investors invest in many different types of assets and industries in order to reduce risk, and therefore unsystematic risk is assumed to be eliminated because the risks of the assets cancel each other out. Investors who are not completely diversified are therefore exposed to residual unsystematic risks. Investing directly in wind parks make the return highly dependent on the actual performance of the wind park and its underlying risks. Taking all these aspects into account, there is a research gap in the theory on the relation between risk and return of wind park investments. Furthermore, there is a practical need for an alternative method to calculate the return of wind park investments in which all the risks are included to which an investor is exposed. Herewith, the main research question was composed as follows:

- **What is the relation between risk and return in wind park investments?**

In order to answer the main research question, four sub-questions have been answered in four chapters. Herewith, this research has provided insight into the relation between risk and return of wind park investments by:

- Identifying the risk characteristics of wind parks (RQ 1);
- Assessing the risks which should be translated in the return calculation (RQ 2);
- Selection of a model which can translate these risks into a return (RQ 3);
- Describing the effect of risks on the return for four wind parks (RQ 4).

1. **What are the risk characteristics of wind park investments?**

Wind parks are part of the asset class of renewable energy, which belong to infrastructure assets. There are several characteristics of wind parks that pose risks to an investor. As compared to regulated infrastructure assets, wind parks are also dependent on electricity prices and nature’s input in the form of wind. Furthermore, direct investments through non-recourse finance contracts result in a return that is highly dependent on the performance of the wind park, and leave little liability of the wind park’s company to repay the investor in the case of default. This research focuses on infrastructure fund investors investing directly in operational onshore and offshore wind parks through unlisted equity. These investors are aiming at low-risk, steady-return investments. Therefore, they often only invest in the operational phase, as the risk perception here is lower than in the previous stages. All in all, understanding of the risks of the investment is very important as these affect the return requirement of the investor.
2. **Which risks in wind parks investments should be included in the return on equity?**

In order to assess the risks which should be included in the return of an investor, an in-depth risk assessment has been conducted in chapter 3. Through a literature study, analyst report assessment, and exploratory interviews, a list of risks has been identified to which an investor is exposed when investing in the operational phase. These are as follows:

- **Resource risk**: Risk of wind input, leading to uncertainty in the production of electricity.
- **Technology risk**: Risk in the availability of the technical components of the wind parks for energy production due to damages, delays, failures, etc.
- **O&M risk**: Risk in operation & maintenance of the wind park, depending on the capability of operators and their maintenance strategy, and the contract terms including gearing. Here, gearing is the amount of leverage, or debt versus equity of the wind park.
- **Merchant risk**: Risk of the amount of energy that can be sold, and against which price. This is partly determined contractually, and partly by the market.
- **Financial risk**: Risk of a change in the value of the investment due to currency risk and inflation risk.
- **Regulatory risk**: Risk of a change in public policy in the form of subsidies, taxes and energy supply regulations.

The first four risks are project-specific risks and therefore unsystematic. Financial risk and regulatory risks are systematic risks since they affect all investments. Theses six risks serve as input for answering the fourth research question.

3. **How can the risks of wind park investments be translated to the return on equity?**

There are several models to calculate the return on equity based on the risks of an investment. A literature study has been conducted in the corporate finance models, project finance models and alternative models, addressing the assumptions, strengths and weaknesses of each model. Three selection criteria were composed to which the model should adhere. The model:

1. Incorporates both systematic and unsystematic risks to which an investor is exposed when investing directly in wind parks for a total risk inclusion;
2. Is suitable for unlisted assets, as wind parks are mostly unlisted;
3. Is suitable for the evaluation of all different types of European wind parks by using the same approach.

Whereas corporate finance models generally apply a high-level, top-down market approach, project finance models are highly specific and apply a bottom-up approach. Corporate finance models generally only take systematic risks into account, are unsuitable for unlisted assets, but can be applied to various types of assets. Project finance models can take all risks into account, are suitable for unlisted assets, but due to their specificity it is difficult to compare different wind parks in the same manner. Most alternative models adapt corporate finance assumptions and apply proxies to calculate returns. The formal risk analysis in the form of the Analytical Hierarchy Process (AHP) is an established model for decision making, but never has been applied before to calculate the return based on risks. However, it adheres to all three selection criteria, and has recently been recommended in the literature to apply this model to calculate the risk and return of unlisted assets. Therefore, the AHP is selected in this research to quantify the six risks as identified in the risk assessment into the return on equity for wind park investors.
The relation between risk and return in wind park investments

The AHP has been applied to calculate the return on equity for two onshore wind parks and two offshore wind parks based on the six risks. First, nine infrastructure fund investors have been interviewed, resulting in a range of returns for onshore and offshore wind park investments for several levels of risk. Furthermore, the investors have conducted comparative judgements for the risks, in which the risks attained weights. By multiplying the risk weight from the comparative judgement with the risk level for the specific wind park, a risk premium has been derived for each risk. By adding these six risk premiums to the risk-free rate of the country, the return on equity has been calculated. The risk-free rate is the maturity risk of an investment, and is determined by the investment term. In this way, the return on equity captures the total risk of an investment, as maturity risk is captured by the risk-free rate, and systematic and unsystematic risks in the risk premium. The AHP results indicate that merchant risk and resource risk have the largest effect on the return on equity, especially for offshore wind parks. For offshore wind parks, O&M risk and technology risk are more important than for onshore wind parks, as their operations are technologically more challenging. For onshore wind parks, regulatory risk is more important as these more heavily rely on subsidy schemes and are subject to stricter regulations.

The AHP results also have been compared to CAPM calculations for the same four wind parks. The AHP returns of the onshore wind parks are lower than the CAPM returns, whereas for offshore wind parks they are higher, showing a larger range of returns with the AHP for this research set. The AHP offers in-depth insight into the composition of the returns for the wind parks, as the risks can be quantified individually and directly translated to the return. When comparing the wind parks, their differences in terms of risk and return are highlighted. In this way, it does better than CAPM in explaining the return composition of wind park investments. Therefore, it is a good model to the relation between risk and return of wind park investments while including the total risk to which an investor is exposed.

Conclusion
From this research it followed that the relation between risk and return of wind parks may seem ambiguous and subjective at first, but in fact the risks can be quantified. With the AHP, risks obtain a numerical value in terms of their effect on the return, but also insight is obtained in the qualitative aspects of the risk and return of wind park investments. Unsystematic risks take up more than half of the return in this research, and therefore they should play a more central role in wind park investments. Both a bottom-up approach should be applied in which risk assessment is central, as well as a top-down down approach in which market movements are combined, and the place of the asset can be determined. With AHP, both approaches are combined, while offering quantification of the risks, as well as a direct translation of these risks into the return.

Recommendations
Three recommendations are made for wind park investors:
1. Apply the AHP for obtaining insight in the risk-return profile of your investment - The AHP serves as a good model to value investment and calculate the return that reflects the investment risks.
2. Know where you put your money in - Investors should be aware of the exact risks of an investment to which they are exposed, and in what way these affect their return.
3. Be aware of the market, and decide your place in it - Investors should not regard their investment in isolation, but also look at the wind sector developments and competition for a full understanding of their investment.

4. How is the return on equity affected when accounting for various types of risks?

4. How is the return on equity affected when accounting for various types of risks?
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List of terms

AHP    Analytical Hierarchy Process
APM    Arbitrage Pricing Model
CAPEX  Capital Expenditures
CAPM   Capital Asset Pricing Model
DNPV   Decoupled Net Present Value
FCF    Free Cash Flows
FCFE   Free Cash Flows to Equity
FIP    Feed in Premium
FiT    Feed in Tariff
IRR    Internal Rate of Return
MPT    Modern Portfolio Theory
MRP    Market Risk Premium
NPV    Net Present Value
NWC    Net Working Capital
OPEX   Operating Expenditures
O&M    Operations & Maintenance
RADR   Risk Adjusted Discount Rate
ROC    Renewable Obligations Certificate
SPV    Special Purpose Vehicle
TVM    Time Value of Money
WACC   Weighted Average Cost of Capital
Research design

Chapter 1
1 Research design

1.1 Introduction to wind park investments

With ambitious European climate goals, the development of renewable energy has increased over the last decades. Wind energy is considered a relatively stable and efficient source of energy, and it is the fastest growing energy source in Europe (Gatzert & Kosub, 2016). Public stimulants in the form of subsidies, as well as the improvement of efficiency and reliability of the technologies, have been the drivers of wind energy developments (Turner et al., 2013). As these subsidies are slowly diminishing, considerable amounts of capital from the private sector are necessary in the coming years to reach the desired climate goals (Wuester, Jungmin Lee, & Lumijarvi, 2016). The low interest rate environment, reduced risk perception, as well as the improved cost competitiveness of wind parks have gradually attracted institutional investors in the wind sector. However, considerable amounts of invested capital have been lost in the wind sector since not all risks have been properly incorporated in the valuation process (Hürlimann & Bengoa, 2015). When investing in wind parks, investors require a return for lending their money and bearing the risk. Generally, the higher the risk perception, the higher the required return (Noothout, de Jager, Tesnière, van Rooijen, & Karypidis, 2016). Wind park investments are subject various risks, affecting the risk perception and thus the return requirement.

The energy market is undergoing significant changes, affecting the risk profile for wind park investments (Turner et al., 2013). As governments are moving away from subsidy schemes offering a fixed price for the produced electricity of the wind park, the price against the produced electricity can be sold increasingly depends on volatile market prices. This places more risk at the special purpose vehicle (SPV), and its investors as there is exposure to market risk. The SPV is a temporary company set up for the wind park transactions. Due to international promotion of renewable energy, the supply of electricity is increasing. However, with a stable electricity demand, its price is under pressure. Additionally, wind energy is an intermittent energy source since it highly depends on the wind input, and poses a curtailment risk when electricity cannot be sold to the grid (Nicolosi, 2010). Therefore, wind park investors are increasingly exposed to market risk, also called systematic risk.

Furthermore, wind parks contain a high degree of project-specific, or unsystematic risks. Wind parks are typically financed as individual assets, apply non-recourse financing, meaning that financing is dependent on the performance of the wind park, and require long-term funding (Noothout et al., 2016). Investors can invest in a wind park in several stages, but most step in at the operational phase, as the risk perception is here the lowest as compared to the other stages. In case the investor does not have a fully diversified portfolio of assets, there are residual unsystematic risks. Also, direct investments in wind parks exposes an investor further to the underlying unsystematic risks as it increases the dependency on the performance of the wind park. Therefore, next to systematic, market risks, investors demand compensation for the unsystematic risks prevailing in wind park investments.

The compensation for bearing these risks is provided in the risk premium, which is the additional return an investor requires above a return of a risk-free asset (Damodaran, 2017). However, the question remains how the high premium should be. Wind parks are mostly unlisted, meaning that they are not traded on a public exchange, and therefore no market data is available (Newell, Peng, & De Francesco, 2011).
As much as the valuation theory for listed assets has been researched, as little attention has been given to the asset class of unlisted assets (Hürlimann & Bengoa, 2015). As a result, little is known about the relation between the total risk to which an investor is exposed when investing in wind parks, and the required return.

1.2 Problem statement

The relation between risk and return of unlisted assets, including wind parks, has been given little in the literature. As such, determining the required return of a wind park investment which reflects the risks to which an investor is exposed can be problematic as:

- There is limited information about the asset class of unlisted assets. As wind parks are mostly unlisted, information is difficult to obtain because it is mostly private and confidential, or it does not yet exist;
- Investors of wind parks are often not fully diversified, leaving residual unsystematic risks;
- Investments in wind parks are often direct, exposing investors further to unsystematic risk;
- Wind parks contain many project-specific, unsystematic risks. These affect the investors risk perception and the required return on equity.

Therefore, there is a scientific need to identify the relation between risk and return of wind park investments, as well as a practical need for an alternative model to valuate these type of investments in which both systematic and unsystematic risk are included to which an investor is exposed.

1.3 Research gap and objective

An initial literature study has been conducted about the risks of wind parks, returns of wind parks, and methods to translate the risks into returns. This is to identify the research gap, and formulate the objective of this research.

Risk of wind parks

Research from Hastak and Shaked (2000) offers a multi-criteria method to analyse all the risks in construction projects on macro, market and project level, in order to assess the total project risk. This offers an initial starting point for analysing risks at different levels, including systematic and unsystematic risks. Gatzert and Kosub (2016), Wuester et al. (2016), Watts (2011) and Rolik (2017) have analysed the risks of wind parks in all phases, and have made risk management recommendations based on these risks. Furthermore, considerable research has been conducted about the risks of wind parks from a political perspective, like research from Gatzert and Vogl (2016) and Cleijne and Ruijgrok (2004). These studies mostly describe the risks from a technical or project management perspective, but very little has been written about the risks to which an investor is exposed.

Quantification of risk

Some research has been conducted to quantify risk, such as sensitivity analyses (Ilou and Csiminga (2009), Marrison (2001) and Afanasyeva, Saari, Kalkofen, Partanen, and Pyrhões (2016)), value at risk methods (Mishra, Khasnabis, and Dhintra (2013)), or Monte Carlo simulations (Michelez et al. (2011)). Cleijne and Ruijgrok (2004) additionally describe several methods to quantify renewable risk, such as scenario analyses or required green price analyses. However, the step towards a quantification of the return on equity is not discussed in these research methods.
Ways to quantify risk into return
Extensive research has been conducted in the valuation and returns of listed assets. Models such as the Capital Asset Pricing Model (CAPM), Arbitrage Pricing Model (APM), and Proxy models have been researched broadly (Brealey, Myers, and Allen (2011), Damodaran (2014), Fama and French (2004), Meier and Tarhan (2005)). However, in the field of unlisted assets, limited research has been conducted. Furthermore, for these types of assets, relatively little is known about the risk and return characteristics, investor's risk perceptions, and the wind sector characteristics (Hürlimann & Bengoa, 2017).

Relation between risk and return in wind park investments
Qualitative research about the risk-return relation of renewable energy assets in general has been conducted by Helms, Salm, and Wüstenhagen (2014), in which the return requirement for different investors has been analysed through interviews. In research from Noothout et al. (2016) and Oxera (2011) interviews with banks and project developers have been conducted on their idea of the risks of wind park investments, and the return calculation. Angelopoulos et al. (2016) have calculated the required return of equity of European onshore wind parks through regression analyses of the betas of selection of firms in the energy sector to conduct a Capital Asset Pricing Model (CAPM) calculation. A beta is a measure of risk of the asset concerns, as it measures the volatility of the asset against market movements. The focus lies especially on political risks, and how to mitigate these risks. The authors recommend the quantification of the required return on equity for other, less mature, renewable energy investments, like offshore wind or ocean energy technologies as potential fields for further research. In their research, the return on equity for onshore wind parks can be calculated per country, but not for other technologies or wind parks in the same country with different characteristics.

All in all, it can be concluded that:
- There is a research gap in the theory on the relation between risk and return of wind park investments in which both systematic and unsystematic risk are included to calculate to required return of a specific wind park.

Therefore, the objective of this research is to describe the relation between risk and return of wind park investments by:
- Applying a model to calculate the required return on equity for wind park investments while considering the total risk to which the investor is exposed;
- Giving insight into the risk perception of investors in the wind sector and the required return.

1.4 Definitions and scope
Several terms are used throughout this report. In this section, these terms and their meaning are defined, also offering insight into the scope of this research.

Definition of wind parks
The scope of this research concerns both onshore and offshore wind parks. Throughout the report, “wind parks” therefore refers to both onshore and offshore wind parks. In case one of the two is mentioned, reference will be made to either “onshore wind parks” or “offshore wind parks”.
Definition of risk
For an investor, risk can be defined as the uncertainty of the realization of expected returns (Pratt & Grabowski, 2014). Therefore, the required rate of return has to be higher for riskier projects, as there is less certainty about the expected returns.

Definition of the return
In this research, the return refers to the required return on equity. This is the return which investors demand for investing in a wind park. The actual return is paid out to the investors through dividends. The required return on equity is also called the opportunity cost, as it is the return which could have been generated by investing in other projects or assets with an equal risk profile. The weighted average cost of capital (WACC) is the discount rate for the entire project, which often is a mix between debt and equity. This rate is used to discount the cash flows of the project to calculate its value. Debt is generally provided by banks in the form of loans or bonds, and equity by equity investors such as pension funds and private equity funds. In this research, the return on equity is referred to the return which equity investors demand when investing in wind parks. It is the discount rate that the investors use to discount the equity cash flows.

Definition of the relation between risk and return
As has been described in the definitions, the return of an investment is inherently related to risk. Risk is difficult to quantify though, as the effect is difficult to measure, and it also is a perception. In this research, the relation between risk and return is defined as the quantitative effect that risks have on the return, and on the other hand as the qualitative effect of these risk on the return due to the risk perception of the investor.

1.5 Research questions
After analysis of the context of wind park investments, definition of the problem statement and the research gap, and statement of the research objective, the main research question is derived:

- What is the relation between risk and return in wind park investments?

The following sub-questions are composed to answer the main research question, and reaching the research objective:

1. What are the risk characteristics of wind park investments?
2. Which risks in wind parks investments should be included in the return on equity?
3. How can the risks of wind park investments be translated to the return on equity?
4. How is the return on equity affected when accounting for various types of risks?
1.6 Research strategy

This research is a mixed method approach in which both qualitative and quantitative methods are applied, as neither one of the two types is sufficient to capture the details of the complex and dynamic risk and return relation of wind park investments (Harrison, 2013). The research consists of three parts: the research design, the research execution, and the research review (figure 1). As part of the research design, the problem is introduced, along with the research gap and research questions (chapter 1).

The research execution starts with an analysis of the risk characteristics of wind park investments through a literature study (chapter 2). Several investment decisions of an investor are described when investing in a wind park. This includes the investment mechanisms, vehicles, and the risk-return strategy. This chapter provides further delineation of the research scope, and serves as a starting point for the further course of the research. Furthermore, it provides an answer to the first research question.

Since the total risk to which an investor is exposed when investing in wind parks is not fully described in theory, these are analysed in-depth as first step to describe the risk-return relation of wind parks (chapter 3). Data is collected through a literature study, analyst report analysis, and exploratory interviews with wind park investors. From these three methods, a list of risks of wind park investments is selected which should be translated to the return, providing an answer to the second research question.

In chapter 4, research is conducted into the models in which total risk is included for the return calculation of wind park investments. Next to the literature study, the results from the exploratory interview serve as input. A model is selected based on three selection criteria which is most suitable for wind park investments, while considering the investment characteristics as described in chapter 2. This provides an answer to the third research question.

In chapter 5, the model is formed by conducting in-depth interviews with wind park investors, from which both qualitative and quantitative data is derived. Secondly, the model is applied to several case studies in order to assess the impact of total risk on the return.

Finally, the conclusions to the four sub-questions are aggregated to answer the main research questions (chapter 6). Furthermore, the research approach and results are evaluated, providing limitations and recommendations for further study in this research context. This provides a contribution to closing the research gap.
Figure 1 - Research strategy (Author's figure)
Risk characteristics of wind park investments

Chapter 2
2 Risk characteristics of wind park investments

2.1 Introduction
As has been described in section 1.3, there is a research gap on the relation between risk and return of wind park investments in which the total risk is included to calculate the return. The aim of this chapter is therefore to analyse the risk characteristics of wind park investments, and provide further delineation of the research scope. The characteristics of wind park investments are described according to several investment decisions of an investor. This illustrates the different investment opportunities, and the rationale of the investor for making these decisions. First of all, the investor has to decide in which asset he wants to invest, as each asset type has different characteristics (section 2.2). When investing in wind parks, there are several additional decisions. The investor has to choose which investment mechanisms he will deploy (section 2.3), and in which phase of the wind park he will invest (section 2.4). All these choices affect the investor’s investment strategy, and required rate of return (section 2.5). This offers a first, high-level insight into the risk characteristics of wind park investments, providing a conclusion to the first research question:

1. What are the risk characteristics of wind park investments?

2.2 Wind energy as an asset class
There are several asset classes that an investor can invest in. The most common asset classes are illustrated in figure 2. An asset class is a group of investments with the same financial characteristics and behave similarly in the market (Drexler et al., 2013). Cash and cash equivalents are investments like certificates of deposits, or savings accounts. Stock, also called equities, are shares of ownership in listed companies. Fixed incomes or bond investments are debt instruments, including

Figure 2 – Main assets classes for investments, and the place of wind energy (Author’s figure, information based on Drexler, Noble, and Bryce (2013))
“risk-free” assets. These are characterized by a set interest rate, their dependence on current interest and inflation rates, and are less risky than stocks due to their lower market volatility. Real estate investments are investments in buildings. These assets are less volatile than bonds and stocks since they generally generate a fixed income, but are subject to various types of additional risks. Commodities are physical goods such as gold, copper, ore, crude oil, and become more volatile as their prices rise. Infrastructure assets are fixed assets for a society to function. These assets are typically require long-term investment due to long-term liabilities, and have a low correlation with “traditional” listed assets such as stocks and bonds. Infrastructure assets consist of social infrastructure, transportation, communication and energy & utilities (Drexler et al., 2013). Energy and utilities consist of gas and electricity networks, power generation, water and sewage, and renewable energy. Wind energy belongs to the asset class of renewable energy, along with hydropower, solar power, geothermal energy, bio energy, and tidal energy. Each renewable energy type has several advantages and disadvantages, risk perception to investors, and required return on equity (Appendix A). Compared to other renewable energy types, wind energy is regarded as low in risk for onshore wind, and medium for offshore wind.

Infrastructure investments, to which wind parks belongs, have the following characteristics, distinguishing them from traditional stocks and bonds investments (Fight, 2006):

- **Capital intensive**: Large amount of capital is required to finance these large-scale projects.
- **Long term**: The development, construction, operation, and decommissioning of projects can account for 20 or 30 years, in which project financing is required.
- **Independent entity with a finite life**: A project company is set up for the development of the project, and this entity has a finite life, often ended when the project assets are transferred.
- **Many stakeholders**: There are many stakeholders involved in the project finance structure, each with his own expertise and interests (section 2.3.3).
- **Costly**: The capital necessary for project finance is commonly more costly than for typical corporate finance capital. The transaction costs are higher since more information, monitoring and contractual agreements are needed, and the projects are highly specific, and need a special financing structure.
- **Controlled dividend policy**: The dividend to be paid out as a return on equity to sponsors is strictly regulated, however they are subordinated from debt. This means lenders (debt) will be paid first from the projects revenues, and afterwards the sponsors (equity).
- **Highly leveraged**: Leverage means the capital provided is a mixture of debt and equity. Infrastructure projects often contain large amounts of debt, usually of 65% to 80%.
- **Non-recourse or limited recourse financing**: The borrowers of the project have no, or only a limited liability for repaying the lenders. The financing therefore is dependent on the project’s performance in terms of cash flows. This type of financing is often found in long-term projects concerning a stabilized and performing asset.
- **Allocated risk**: Risk allocation is based on the principle that risks should be carried by the actor who is the most capable of successfully managing them in terms of knowledge, experience, and financial resources.
Additional characteristics for renewable energy investments are that they do not only depend on macro-economic developments, but also on regulatory regimes, energy supply and demand, and nature’s input in the form of sun, wind, waterpower etc. Due to these characteristics, wind energy is regarded as a relatively risky investment. Generally, the earlier in the project the investment takes places, and the higher it is affected by market demand, the higher the expected risk and expected return (figure 3). Greenfield infrastructures are new assets that require design, development, construction and operation (Drexler et al., 2013). Brownfield infrastructures are maturing assets that already exist and are more mature. Social infrastructures are mostly mature assets which are highly regulated, have a good track record, and therefore the risks are mitigated. On the other side of the spectrum, there are greenfield renewable energy investments which are highly depending on electricity prices.

![Risk-return profiles for different types of infrastructure investments, as compared to traditional assets](Author's figure, based on Russ, Thambiah, and Foscarì (2010))
2.3 Investment mechanisms

2.3.1 Corporate finance versus project finance transactions

There are generally two financial mechanisms by which a financial transaction of wind park investments can take place; corporate finance and project finance (table 1). Corporate finance consists of the financial activities required to run a business (Pratt & Grabowski, 2014). It considers the sources of funding, capital structure and management actions which the corporation should take in order to increase value for its shareholders, and allocate financial resources. Corporations hold a portfolio of assets, and can finance these by borrowing, retaining cash flows, or selling shares to its shareholders (Brealey et al., 2011). Whereas corporate finance decisions concern a large amount of assets in a portfolio, project finance focuses on one project, and lasts only during the project’s time horizon. Project finance is a method for raising long-term financing for the development of major projects (Yescombe, 2002). The largest differences between corporate finance and project finance are (table 1):

1. In corporate finance, the investment is assessed from the company's perspective, and its own balance sheet and cash flows, whereas in project finance, the project itself is studied in-depth, and determines the valuation decision.
2. Corporate finance transactions are indefinite, whereas in project finance they last during the lifetime of the project.
3. Corporate finance structures are easily replicated, whereas in project finance, they are highly specific for the asset.
4. In corporate finance, investment decisions are made top-down which are opaque to creditors, whereas in project finance the creditors, or investors, are highly involved and investment decisions are therefore transparent to them.
5. In corporate finance, corporate management makes autonomous decisions about the investment and dividend policy, whereas in project finance, the dividend policy is determined contractually at the start of the investment.

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Corporate finance</th>
<th>Project finance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Basis for credit evaluation</td>
<td>Overall financial health of corporate entity; focus on balance sheet and cashflow</td>
<td>Technical and economic feasibility; focus on project's assets, cash flow and contractual agreements</td>
</tr>
<tr>
<td>2 Type of capital</td>
<td>Indefinite - an indefinite time horizon for equity</td>
<td>Finite - time horizon matches life of project</td>
</tr>
<tr>
<td>3 Financial structures</td>
<td>Easily replicated; common forms</td>
<td>Highly-tailored structures which cannot generally be re-used</td>
</tr>
<tr>
<td>4 Investment decisions</td>
<td>Opaque to creditors</td>
<td>Highly transparent to creditors</td>
</tr>
<tr>
<td>5 Dividend policy and reinvestment decisions</td>
<td>Corporate management makes decisions autonomous of investors and creditors</td>
<td>Fixed dividend policy - immediate payout; no reinvestment allowed</td>
</tr>
</tbody>
</table>

Table 1 - Corporate finance versus project finance (Serghini (2017))
2.3.2 Financing vehicles

Investors can invest either directly, indirectly or semi-directly in wind parks. Corporate investment is indirect, and occurs through publicly traded shares (equity) or bonds (debt) of corporations involved in wind parks, and through corporate equity and bond funds (Kaminker & Stewart, 2013). Investment funds are semi-direct investments, meaning that some investments are direct, and some indirect. Investment happens through pooled funds that invest in companies (indirect) or projects (direct), or a combination of the two. Finally, project investment is a type of direct investment, and is established through equity or debt funding of wind parks. Corporate investors who invest indirectly generally have a low connection to the wind park, whereas investors who invest directly have a high connection. Direct investment in wind parks occurs through project finance transactions. The returns of direct investments are susceptible to total risk, as they depend on the project's characteristics, developments, and profitability. As the aim of this research is to assess the relation between total risk and returns of wind parks, the scope of this research is direct investment through unlisted equity (figure 4).

2.3.3 The SPV

For the establishment of a wind park a temporary company structure or Special Purpose Vehicle (SPV) is set up. The SPV involves many parties, including lenders (often banks), sponsors, contractors, power purchasers and regulatory authorities such as governments (figure 5). Lenders (debt) and sponsors (equity) can invest in the project by providing capital to the project, and require a return for their invested money. For the SPV this return is called the cost of capital, as this is the money they have to pay back to the investors for borrowing. The SPV repays the equity sponsors in the form of dividends, which is the return on equity from the perspective of the investor. This return is the focus of this research, and is influenced by the performance of the SPV and risks of the wind park.
The development of a typical wind park contains several phases, from development, construction, and operation to decommissioning. The operation phase is the longest phase, and consists of 20 to 25 years, which is determined by the asset life. This phase commences as the construction of the wind park has been completed, and is ready to deliver electricity to the grid. The generated electricity is sold, maintenance is conducted for optimal performance of the wind turbines, and the wind park is monitored. Many investors step in at this point, as the risk perception here is much lower than in the previous stages (figure 6). This is because there are many uncertainties about the development of the wind park, what revenues will be generated, and thus how much return the investors will receive from their investment. The required return is therefore also lower in this phase, as the uncertainties are reduced. This research focuses on investments in wind parks in the operational phase.

2.4 Wind park phases

Figure 5 - A typical SPV structure (Author’s figure, based on Miceli (2012))

Figure 6 - The indicative risk premium and timeline for an infrastructure investment varies by project phase (Déau & Touati, 2014) (bp = basis point)
2.5 Investment strategy

As has been described in section 2.1, the investment decision of an investor consists of several choices. Different types of investors are attracted to finance wind parks in different countries, through different mechanisms, at different engagement levels, and in different stages. These choices form the investment strategy of the investor, and determine the overall risk perception of the investment, and the associated required return. Different types of wind park investors therefore invest at different times, and require different returns (figure 7).

Large utility companies are electric, gas or water firms (Moessner, 2014). Independent power producers (IPPs) are private entities which are active in the development, construction and operation of facilities generating electricity. Utilities and IPPs are most active in the development stage, and invest long-term. Original Equipment Manufacturers (OEMs) such as turbine manufacturers are suppliers and installers of wind park equipment. They are typically short-term asset holders, exit the wind park shortly after commissioning. Private equity companies are more risk-seeking, and therefore invest earlier in the project, sell after only a few years, and require relatively high returns. Pension funds are risk averse, and only invest when enough certainty has been derived.

Infrastructure funds are companies investing often directly in different infrastructure assets with the aim to generate returns for their creditors. Their main focus lies on operational wind parks providing long-term, low-risk and stable returns for their lenders (Moessner, 2014). The fund manager is actively involved in the investment, and promises returns to its lenders. Investments in wind parks are often direct, and committed in the late construction or operational stage. The holding length of these investors is generally 20-25 years, also called “buy-and-hold” or “hold-to-maturity”. The investors generally have proper knowledge about wind parks, and typically invest in partnerships with experienced operators such as utility companies. The geographical focus of these funds is in mature markets with regulatory regimes which are considered stable. This research therefore focuses on European infrastructure fund investors investing directly in wind parks in the operational phase.

Figure 7 - Entry and exit timings for equity investors with target risk-adjusted returns for onshore wind investments (2015) (Author's figure, based on Oxera (2015))
2.6 Conclusion

In this chapter, the risk characteristics of wind park investments have been analysed by looking at the different investment choices which an investor has to make when investing in wind parks. This leads to an answer to the first research question:

1. What are the risk characteristics of wind park investments?

An investor has to decide in which asset he wants to invest, through which mechanisms, in which phase, and determine its risk-return strategy. This research focuses on direct investments in European wind parks in the operational phase through unlisted equity. Wind parks are part of the renewable energy asset class, which belongs to the infrastructure asset class. Compared to other infrastructure assets, wind parks are regarded as a relatively risky investments, as they are dependent on electricity supply and demand, and highly depend on the wind input. Furthermore, they are financed as independent entities with a finite life. Therefore, its transactions are highly specific as they are specialized for the specific wind park. The dividend policy is controlled, but equity investors only receive their returns after the debt has been financed. As wind parks are typically non-recourse financed, this means that the return of the investor is highly dependent on the performance of the wind park in generating profits, especially when investing directly. The earlier the investment in a wind park, the higher the risk perception. Therefore, most investors invest during the operational phase, as here the risk perception is highly reduced as compared to earlier project phases. Especially infrastructure fund investors are aiming at long-term, low-risk and stable return investments. The funds make promises to their lenders to generate the returns against a low risk. Therefore, insight into the risks of wind park investments, and the effect on the return are therefore very important. In the next chapter, the risks of wind parks in the operational phase are therefore assessed in more detail.
Risks of wind park investments

Chapter 3
3 Risks of wind park investments

3.1 Introduction

In the previous chapter, the risk characteristics of wind park investments have been assessed. This serves as a theoretical background to identify the risks categories of wind park investments, and gives insight into the perspective of an investor. Investors are inherently exposed to risks in an investment, especially when they invest directly, and when they are not completely diversified. Furthermore, there are many project-specific, unsystematic risks involved in wind park investments, since they are dependent on electricity prices, wind input, and the operational performance of the wind park itself. The aim of this chapter is therefore to assess the risks to which an infrastructure fund investor is exposed when investing directly in a wind park in the operational phase through unlisted equity.

A definition and categorization of risk is formed through a literature review (section 3.2). This provides a framework for the rest of the chapter. Subsequently, the risks of wind park investments are assessed through three different methods (figure 8). First of all, the risks are assessed through a literature study (1) (section 3.3). Secondly, the risks are analysed through assessing analyst reports (2), offering a more practical perspective (section 3.4). The scientific and practical results are combined by including all the risks found in the two methods, resulting in an intermediate list of risks (3). This list serves as a starting point in three exploratory interviews with wind park investors (section 3.5). The investors were asked which risks they include in their return calculation, and which are therefore important to them when investing in wind parks (4). From this, a list of main identified is derived which includes all the risks from the three methods (5) (section 3.6). In order to limit overlap, risks are combined, resulting in a final list of six risks (6). The risks are described in section 3.7, and in section 3.8, the chapter is concluded by providing an answer to the second research question:

2. Which risks in wind parks investments should be included in the return on equity?
3.2 Definition of risk

For an investor, risk is the level of uncertainty of the realization of expected returns (Pratt & Grabowski, 2014). Therefore, the rate of return has to be higher for riskier investments than safe investments, as there is less certainty about the expected returns. In this chapter, an analysis is conducted about the risks of wind park investments in the operational phase which affect this uncertainty of the realization of expected returns for infrastructure fund investors. As described in section 2.3.1, there are generally two approaches for wind park investment transactions: corporate finance and project finance. In this research, both mechanisms are included. In corporate finance, decisions are made about a large amount of assets in a portfolio. Here, a top-down approach is maintained, by analysing the performance of the assets against similar assets trading in the market.

In project finance, risk evaluation is one of the key aspects as there are many risks involved in the financing of wind parks (Yescombe, 2002). Risk analysis involves the process of gathering all the information about the project, the identification of project risks, allocation of risk, and the quantification and consideration of the residual risks. Both perspectives maintain a different categorization of risk.

Corporate finance theory distinguishes three risk categories (Pratt & Grabowski, 2014):

- **Maturity risk**, or horizon or interest rate risk. The longer the term of an investment, the more risk is associated with it.
- **Systematic risk**, or market risk. This is the uncertainty of future returns of the investment due to market movements.
- **Unsystematic risk**, or residual risk. This the company or project-specific risk.

In project finance, the following project risk categories are distinguished (Yescombe, 2002):

- **Commercial risk**, also known as project risk. This is the risk occurring in the project itself, such as project viability or revenue risk.
- **Macro-economic risk**, or financial risk. This risk relates to external economic effects, such as inflation, interest rates and currency-exchange rates.
- **Political risk**, or regulatory risk. These are risks concerning the country’s stability and political decisions, such as changes in the law or effects of government regulations.

The aim of this research is to include the total risk to which an investor is exposed when investing in wind parks. In most corporate finance models, the return on equity (ROE) is calculated by adding the risk-free rate to a risk premium (Damodaran, 2011) (figure 9). The risk premium is the additional return an investor demands for bearing additional risk in an investment. In this research, the risk categorization of corporate finance maintains a high-level approach, and serves as a main categorization of the risks of an investment. Here, maturity risk serves as the risk-free rate, as the risk-free rate concerns the theoretical return of an investment which is considered risk-free for a specific period of time (Damodaran, 2014). Therefore, this horizon risk is captured in the maturity risk. Any additional risk the investor takes is included in the equity risk premium. This consists of unsystematic and systematic risks. The project finance risk categorization serves as a sub-categorization for this research, in which commercial, or project-specific risk is applied as unsystematic risk, and macro-economic and political risk as systematic risks.
The relation between risk and return in wind park investments

The distinction between systematic and unsystematic risk is illustrated in figure 10. Unsystematic risk is the project-specific risk which affects only one wind park. The wind park may do better or worse than expected, and the competition may be weaker or stronger than anticipated. Systematic risk is market risk, affecting all investment assets and all wind parks. These are the risks that affect the entire wind sector, currency rates and political risk, and interest rate and inflation risks. There is a thin line between unsystematic and systematic risk, as some risks affect only a few wind parks, and some risks affect all wind parks. In this research, unsystematic risk is the risk which can be handled in the wind park itself, such as in contractual arrangements, wind studies, or the financial structure of the SPV. Systematic risks are the risks occurring inherently in all investment assets, including wind parks. These risks include currency rate risk, political risk and inflation risk, and these can partly be hedged.

Figure 9 - Categorization of risks in wind parks investments (Author’s figure)

Figure 10 - The distinction between unsystematic and systematic risk for wind park investments (Author’s figure, based on (Damodaran, 2014))
Herewith, the risk categories for this research are described as:

- **Commercial risk**: unsystematic risks occurring in the wind park itself which directly influence the profitability of the wind park and thus the investor’s return;
- **Macro-economic risk**: systematic risks due to market developments, affecting all investment assets (section 2.2), including wind parks, but some assets are more exposed to these risks than others;
- **Political risk**: systematic risks in terms of political stability and regulatory regime. These risks affect all investment assets, including wind parks, and are therefore considered systematic.

### 3.3 Literature study

As a first step to identify the risks in wind park operations, a literature study has been carried out. Considerable amounts of research have been conducted about the different risks in wind parks from a technical or project management perspective, but very little has been written about the risks to which an investor is exposed. Therefore, the literature study is supplemented by the assessment of analyst reports (section 3.4) and exploratory interviews (section 3.5). From the literature study, a list of risks in the operational phase has been derived (table 2). Wuester et al. (2016), Turner et al. (2013), Michelez et al. (2011), Angelopoulos et al. (2016) and Liebreich and Young (2005) have been selected in this research as they generally describe the risks from the perspective of the investor. With this, nine risks have been distinguished: resource risk, technology risk, grid access risk, counterparty risk, O&M risk, electricity price risk, financial risk, incentive scheme risk and political risk. This list serves as a theoretical classification of the risks in wind park operations.

<table>
<thead>
<tr>
<th>Risk classification of wind park investments - Literature study</th>
<th>Author’s table</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial</td>
<td>Resource risk</td>
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<tr>
<td></td>
<td>Technology Risk</td>
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<tr>
<td></td>
<td>Grid and Transmission Risk</td>
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<td></td>
<td></td>
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<tr>
<td>Counterparty Risk</td>
<td>Counterparty risk</td>
</tr>
<tr>
<td>Macroeconomic</td>
<td>Liquidity Risk</td>
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<td></td>
<td>Refinancing Risk</td>
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<tr>
<td>Political</td>
<td>Policy or Regulatory Risk</td>
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<td></td>
<td>Support cuts</td>
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</table>
3.4 Analyst report assessment

Next to the theoretical perspective gained by the literature study, a more applied perspective is required to understand the risks to which investors are exposed when investing in wind parks. For this, nine reports of financial analysts have been assessed (table 3). Financial analysts work for banks and investment companies. By gathering and analysing financial data, and continuously looking for market trends, they create financial models to estimate future economic conditions for businesses, sectors and industries (Ramnath, Rock, & Shane, 2008). These analyses provide recommendations to take a course of action, such as buy or sell a company’s shares based on its overall performance and outlook. Risks of onshore and offshore wind parks in the operational phase have been assessed in this way, leading to a list of risks. These include: resource risk, technology risk, grid access risk, curtailment risk, management risk, O&M risk, counterparty risk, electricity price risk, financial risk, regulatory risk, incentive scheme risk and country risk. The Harvey balls (#) indicate how often the risks are mentioned in the reports, and therefore this represents their importance. Resource risk has been mentioned in all nine reports, electricity price risk in seven reports, and regulatory risk in six reports. After that, both technology risk and O&M risk are mentioned five times, and incentive scheme risk four times. Therefore, these risks should at least be included in the return calculation. The other risk are mentioned three times, and country risk only once.

Risk classification of wind park investments - Analyst report assessment

<table>
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<th>Cat</th>
<th>Risk</th>
<th>Mentioned in</th>
<th>#</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial</td>
<td>Resource risk: Weather conditions</td>
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<td>●</td>
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<tr>
<td></td>
<td>Technology risk: technological performance</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grid access</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Management risk: contractor experience</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>O&amp;M capability, costs and contract term</td>
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<tr>
<td></td>
<td>Counterparty risk of default</td>
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<td></td>
<td>Curtailment risk: regional grid oversupply</td>
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<td>Macro</td>
<td>Electricity price risk</td>
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<td></td>
<td>Inflation risk</td>
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<td></td>
<td>Currency risk</td>
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<td></td>
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<tr>
<td>Political</td>
<td>Regulatory risk: energy strategy, and market regulation</td>
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<td></td>
<td>Policy incentive scheme risk, certificates, tax credits</td>
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<tr>
<td></td>
<td>Country risk: political stability</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Name</th>
<th>Analyst type</th>
<th>Date</th>
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<tr>
<td>1</td>
<td>PWC</td>
<td>Financial services</td>
<td>2012</td>
</tr>
<tr>
<td>2</td>
<td>Deloitte</td>
<td>Financial services</td>
<td>2014</td>
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<tr>
<td>3</td>
<td>Fitch rating</td>
<td>Credit assessor</td>
<td>2016</td>
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<tr>
<td>4</td>
<td>Bloomberg</td>
<td>Research organization</td>
<td>2017</td>
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<tr>
<td>5</td>
<td>Norton Rose Fulbright</td>
<td>Financial services</td>
<td>2015</td>
</tr>
<tr>
<td>6</td>
<td>UBS</td>
<td>Financial services</td>
<td>2016</td>
</tr>
<tr>
<td>7</td>
<td>Renewables Infrastructure Group</td>
<td>Financial services</td>
<td>2017</td>
</tr>
<tr>
<td>8</td>
<td>J.P. Morgan</td>
<td>Financial services</td>
<td>2016</td>
</tr>
<tr>
<td>9</td>
<td>Credit Suisse</td>
<td>Financial services</td>
<td>2016</td>
</tr>
</tbody>
</table>

Table 3 - Result from analyst report assessment on risks of wind park investments in the operational phase (Author’s table)
3.5 Exploratory interviews

3.5.1 Interview preparation

As a third method to assess the risks of wind park operations, exploratory interviews have been conducted. There were two objectives for these interviews: to gain insight into the perspective of the investor when investing in a wind park, and to find the risks which affect this investment, and should be included in the return. Three infrastructure fund investors have been interviewed with experience in direct wind park investments in Europe. An interview protocol has been set up and has been sent a few days before the interview date (Appendix B). The protocol contains introductory questions, questions about how the investors value a wind park (serving as input for chapter 4), and questions about the risks of wind park operations. The protocol includes confidentiality statements, a description of the research topic, and the purpose of the interview. The investors were asked whether the interview could be recorded. Due to confidentiality reasons, the names of the investors and their companies are not mentioned in this report, and only aggregated results are presented. This is what the investors agreed to.

In order to prepare for the interviews and to derive the most out of the hour, a list of twelve risks has been prepared based on literature study results and analyst report results (table 4). The nine risks from the literature study, and the twelve risks from the analyst reports are similar, and to get the most out of the interview, all twelve risks have been included in the list for the exploratory interviews. This list has been taken to the interviews as a backup in case the interviews did not run smooth, and investors needed more guidance.

<table>
<thead>
<tr>
<th>1. Literature study results</th>
<th>2. Analyst reports results</th>
<th>3. List of risks for interviews</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource risk</td>
<td>Resource risk</td>
<td>Resource risk</td>
</tr>
<tr>
<td>Technology risk</td>
<td>Technology risk</td>
<td>Technology risk</td>
</tr>
<tr>
<td>Grid access risk</td>
<td>Grid access risk</td>
<td>Grid access risk</td>
</tr>
<tr>
<td>O&amp;M risk</td>
<td>O&amp;M risk</td>
<td>O&amp;M risk</td>
</tr>
<tr>
<td>Management risk</td>
<td>Management risk</td>
<td>Management risk</td>
</tr>
<tr>
<td>Counterparty risk</td>
<td>Counterparty risk</td>
<td>Counterparty risk</td>
</tr>
<tr>
<td>Curtailment risk</td>
<td>Curtailment risk</td>
<td>Curtailment risk</td>
</tr>
<tr>
<td>Electricity price risk</td>
<td>Electricity price risk</td>
<td>Electricity price risk</td>
</tr>
<tr>
<td>Financial risk</td>
<td>Inflation risk</td>
<td>Inflation risk</td>
</tr>
<tr>
<td>Currency risk</td>
<td></td>
<td>Currency risk</td>
</tr>
<tr>
<td>Regulatory risk</td>
<td>Regulatory risk</td>
<td>Regulatory risk</td>
</tr>
<tr>
<td>Incentive scheme risk</td>
<td>Incentive scheme risk</td>
<td>Incentive scheme risk</td>
</tr>
<tr>
<td>Country risk</td>
<td></td>
<td>Country risk</td>
</tr>
</tbody>
</table>

Table 4 - The results of the literature study and analyst report assessment serve as input for the exploratory interviews

3.5.2 Interview results

The interview protocol served as a guideline throughout the interviews, and was not strictly followed. This semi-structured interview approach resulted in valuable additional information, as many follow-up questions emerged, and interesting discussions were held. This led to a better insight into the wind sector, and all the different aspects that wind investments depend on like the electricity price, demand and supply of energy, the bidding procedures of investors, and descriptions about their funds. For each question, the aggregated answers of the three investors are described.
Question 1 - What is your experience in wind park investments, which region, and in which phase?
The investors have experience in wind park investments for several years, and especially focus on West-Europe. Most of them invest at the start of the operational phase, but some are also preparing to invest in wind parks in the construction phase. The development phase for these investors is still too risky. This is because at this phase there are still many uncertainties in the development of the wind park, and therefore there is a higher uncertainty about the expected returns.

Question 2 & Question 3 - How do you value a wind park, and calculate the required rate or return?
The investors apply two methods to value the wind park and to determine the return. The CAPM is applied as a general indication of the return as based on market movements. Secondly, a detailed calculation of the financials is used to generate insight into the wind park, and possible risks which can occur which affect the investor's return. Risk is very important to the investors, and determines their return calculation. However, due to recent developments in the wind sector such as lower electricity prices, a higher energy supply than demand, and increasing competition, there is more pressure on the returns, especially in the offshore wind sector. Developers of wind parks are underbidding each other, resulting in smaller returns for investors. Due to low interest rate environment, investors are looking for alternative investments to generate returns, and therefore are sometimes willing to accept a return which is lower than their initial accepted required return due to these strategic reasons. Thus, the return that the investors demand is also a market bid. These answers generate input for the model exploration in chapter 4.

Question 4 - Which risks do you take into account into the return calculation?
This open question was asked to receive information about the risk, and to have a third, independent source of information. However, the investors were not very open during the interview, and did not provide a lot of detail about the risks themselves. Therefore, a list has been shown to the investors which had been derived from the literature study and analyst reports (table 4). With this as a starting point, the investors have provided the risks which are important to them, including additional risks (table 5). The investors argued that contractual agreements, captured by the O&M contract risks, are very important, as these mostly determine how much the investor is exposed to risks. Furthermore, they highlighted the importance of the electricity price risk, as this greatly affects the wind park's revenues.

Question 5 - How do you incorporate unsystematic risks in the return calculation?
As mentioned in question 2 and 3, the investors use both CAPM and project finance models. First of all, the investors arrange contractual agreements to which they are as least exposed to risks as possible. To the risks which cannot be mitigated, they model the effect of the risks on the value of the wind park, and the associated return.

Question 6 - Do you make a distinction between onshore and offshore wind park return calculations?
When comparing the risks of onshore and offshore wind parks, the investors suggested that offshore wind parks have a higher technology and O&M risk. However, wind input is more reliable for offshore than for onshore wind parks. Also, due to the economies of scale, the marginal costs of offshore wind parks are smaller. All in all though, the risk perception for offshore wind investments is higher than for onshore investments due to the higher technology and O&M risk, and because of the fact that there simply is less investment experience in the offshore wind sector in general. Therefore, the returns for offshore wind parks should be higher on average.
Question 7 - How should risks ideally be incorporated in the return calculation?
The investors argued that there is no ideal situation. You can design perfect financial models including all the cash flows of the wind park and their volatilities, however, in the end the return requirement is based on the requirement of other investors: it is also a market bid.

Question 8 - Do you have suggestions for further research (materials, case studies, other contacts)?
The investors suggested talking to other parties, looking into project finance models, and have sent reports about the wind sector after the investor.

3.5.3 Interview limitations
The interviews served as a third source of information for the identification of the risks of wind park operations. In order to be able to compare the results from the three methods, open questions were mostly asked in order to receive new information. However, throughout the interviews, the investors were unexpectedly hesitant in providing information. They were not very willing to provide information about the valuation methods, how they incorporate risks, and which risks are the most important to them. A list of risks from the literature study and analyst report assessment was therefore introduced. This helped to arrive at a list of risks which are important to the investors when investing in wind parks. Reflecting on the interviews, the stance of the investors can be explained by the sensitive information associated with wind park investments, and investments in general. Furthermore, the wind sector is changing rapidly, and the competition is high. The calculation methods and assumptions are only used internally, and therefore this information is confidential. Nevertheless, the interviews have been valuable and serve as input in arriving at a list of risks for this research (section 3.6). Furthermore, some insight into the valuation methods has been gained, which serves as input for chapter 4.

3.6 Main identified risks
The investment risks of wind park operations have been investigated through three different research methods. The aim was to triangulate the risks found in the three different methods which are from three independent sources, in order to arrive at a final list of risks. However, the investors of the exploratory interviews were not very open, and therefore no input has been gained from them initially. Therefore, an intermediate list of risks (3) was shown which is based on the aggregated results of the literature study and analyst reports which had prepared in advance just to make sure the interviews were fruitful. The investors gave their input on these risks from this point (4), and with this, a list of main identified risks (5) has been derived (table 5). All the risks of interviews and the output of the interviews have been used. However, many of these risks are interrelated or belong to each other. For example, asset life risk concerns the technical life time of the components of the wind park, and therefore belongs to technology risk. For the quantification of the risks with a model found in chapter 4, overlap between the risks should be mitigated. Therefore, the risks which are interrelated or belong to the same risk category are combined (table 6). Herewith, the interrelations are limited, and the risks can serve as input chapter 5, in which the aim is to quantify risks by their impact on the return. The commercial risks obtain code A, macro-economic risks code B, and political risks code C. The six risks are: resource risk, technology risk, O&M risk, merchant risk, financial risk and regulatory risks. In section 3.7, the six risks are described, and why they are combined.
The relation between risk and return in wind park investments

5. Main identified risks

<table>
<thead>
<tr>
<th>5. Main identified risks</th>
<th>6. Final list of risks of this research set</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource risk</td>
<td>A1 Resource risk Risk of wind input, leading to uncertainty in the production of electricity</td>
</tr>
<tr>
<td>Technology risk</td>
<td>A2 Technology risk Risk in availability of the technical components of the wind parks for energy production due to damages, delays or failures</td>
</tr>
<tr>
<td>Asset life risk</td>
<td>A3 O&amp;M risk Risk in operation &amp; maintenance of the wind park, depending on the capability of operators and their maintenance strategy, and the contract terms including gearing</td>
</tr>
<tr>
<td>O&amp;M risk</td>
<td>A4 Merchant risk Risk of the amount of energy that can be sold and against which price, which is partly determined contractually, and partly by the market</td>
</tr>
<tr>
<td>Maintenance cost risk</td>
<td></td>
</tr>
<tr>
<td>Management risk</td>
<td></td>
</tr>
<tr>
<td>Gearing risk</td>
<td></td>
</tr>
<tr>
<td>Counterparty risk</td>
<td></td>
</tr>
<tr>
<td>Curtailment risk</td>
<td></td>
</tr>
<tr>
<td>Merchant risk</td>
<td></td>
</tr>
<tr>
<td>Electricity price risk</td>
<td>B1 Financial risk Risk of a change in the value of the investment due to currency risk and inflation risk</td>
</tr>
<tr>
<td>Inflation risk</td>
<td></td>
</tr>
<tr>
<td>Currency risk</td>
<td></td>
</tr>
<tr>
<td>Regulatory risk</td>
<td>C1 Regulatory risk Risk of a change in public policy in the form of subsidies, taxes and energy supply regulations</td>
</tr>
<tr>
<td>Incentive scheme risk</td>
<td></td>
</tr>
<tr>
<td>Tax rate risk</td>
<td></td>
</tr>
<tr>
<td>Country risk</td>
<td></td>
</tr>
</tbody>
</table>

Table 5 - Combining the inputs from the literature study (1) and analyst reports (2) for the interviews (3) with the output of the interviews (4) to arrive at a list of main identified risks (5) (Author's table)

Table 6 - Combining risks to limit interrelations, resulting in a final list risks for this research (Author's table)
3.7 Description of risks

3.7.1 The way the risks affect the return on equity

Six risks have been identified to which an investor is exposed when investing in a wind park. The risks are important to the investor since they have an effect on the return on equity, which in turn depends on the operational cash flows and their volatility (table 7). The return that the investors receive is derived from the Free Cash Flows to Equity (FCFE), which depends on several cash flows of the project. The revenue of the project is the most important driver of the return, as this is the base line from which all the costs are deducted and return on equity is derived. The operating expenses (OPEX) are deducted from the revenues, resulting in the Earnings Before Interest and Tax (EBIT). By subtracting the difference in working capital, the Free Cash Flows (FCF) are derived. Working capital are the SPV’s assets minus liabilities. Debt service is provided in the form of interest expenses and paying of debt. These are tax deductible, offering a tax shield. When subtracting the debt services, and adding the tax shield, the FCFE are derived. These are the cash flows which are repaid to the equity providers in the form of dividends, and are the return on equity form the perspective of the investor. Resource risk (A1), technology risk (A2), merchant risk (A4), and financial risk (B1) affect the amount of revenues generated. These are also called the selling power of the wind park, and determine the price and volume of the wind electricity that is generated. Furthermore, technology risk (A2) and O&M risk (A3) affect the Operating Costs (OPEX). Taxes are influenced by the regulatory regime (C1). The debt service depends on the amount of leverage as determined contractually (A3). Financial risk (B1) affects all cash flows, as currency risk and inflation risk can affect the value of all cash flows.

Main cash flows from the SPV of a wind park, and the risks influencing the return on equity

<table>
<thead>
<tr>
<th>Cash flow</th>
<th>Risk*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project revenues</td>
<td>A1, A2, A4, B1</td>
</tr>
<tr>
<td>- OPEX</td>
<td>A2, A3, B1</td>
</tr>
<tr>
<td>EBIT</td>
<td>B1, C1</td>
</tr>
<tr>
<td>- Taxes</td>
<td>B1, C1</td>
</tr>
<tr>
<td>NOPLAT</td>
<td></td>
</tr>
<tr>
<td>- Change in working capital</td>
<td></td>
</tr>
<tr>
<td>FCFs</td>
<td></td>
</tr>
<tr>
<td>- Interest Expenses</td>
<td>B1</td>
</tr>
<tr>
<td>- Pay off debt</td>
<td>A3, B1</td>
</tr>
<tr>
<td>+ Tax shield</td>
<td>B1, C1</td>
</tr>
<tr>
<td>FCFE → Return on equity</td>
<td>All six risks</td>
</tr>
</tbody>
</table>

* A1 = resource risk, A2 = technology risk, A3 = O&M risk, A4 = merchant risk, A5 = financial risk, A6 = regulatory risk

Table 7 - The effect of the risks on the operational cash flows of the SPV, and with this the return on equity (Author’s table)
3.7.2 Resource risk (A1)

“Resource risk” is described as the risk of wind input, leading to uncertainty in the production of electricity. Wind is the driver for the wind park’s electricity generation. Wind input is hard to predict, as the wind speed, direction and shear, or variation in wind velocity are stochastic variables, and therefore can vary greatly. Wind data is often measured before constructing or even development of the wind park. Over the past years, wind data of parks are measured over bigger time spans in order to increase reliability of the wind input data. Onshore wind input is less reliable than offshore wind, as thermal currents, buildings and levels of the landscape have an enigmatic effect on the wind input (Bilgili, Yasar, & Simsek, 2010). Generally, offshore wind has higher wind speeds, especially when moving further from the shore. Also, the wind-shear, or differences in wind speed, is lower for offshore wind parks.

3.7.3 Technology risk (A2)

Technology risk and asset life risk are combined as “technology risk”, which is described as the risk in the availability of the technical components of the wind parks for energy production due to damages, delays or failures. A wind park consists of several components, including several wind turbines (figure 11) which are connected to the grid. In case one of the components fails, the electricity generation is stalled, affecting the revenues. A wind turbine contains three blades (nr. 6) which turn around a rotor (nr. 5), which is connected to a low-speed shaft. The wind blades typically turn at a low speed (rotation per minute or rpm) due to the mechanical strength and noise issues, especially for onshore wind parks. The speed is increased in a gear box which connects the low-speed shaft to the high-speed shaft in order to generate the right rotational speed for electricity generation produced in the generator (nr. 1) (Santjer, Gerdes, Christiansen, & Milborrow, 2001). In the generator, the electricity is directed to a transformer (nr. 2) and then to the wind parks’ subsystem. From here, electricity is transferred to the main electricity grid. In case the wind direction changes, the yaw drive (nr. 3) can change the position of the wind turbine into the new optimal position for power generation. Furthermore, the controller (nr. 4) can start or stop the wind turbine from working, depending on wind conditions. The turbine is connected to a tower (nr. 7) and a foundation (nr. 8) bearing all the static and dynamic loads from the wind turbine. The wind park components should all be available for electricity generation, and therefore they require regular maintenance checks.

Figure 11 - Main components of a wind turbine (Enercon (2017))
3.7.4 O&M risk (A3)

"O&M risk" is described as the risk in the operations and maintenance (O&M) of the wind park. O&M risk, maintenance cost risk, management risk, and gearing risk are combined as “O&M risk”. The track record and experience of the operator determine their capability in maintaining a good maintenance strategy. This affects the operational performance of the wind park, affecting revenues and costs. Furthermore, O&M risk includes the contractual arrangements concerning the operations of the wind parks with the actors of the SPV affecting the investor. The amount of leverage is also determined contractually with the bank, leading to a gearing risk for the investor. As has been described in section 2.2, wind parks are often highly leveraged, usually between 65% and 80%. Gearing risk works in two ways. Generally, the higher the leverage, the higher the risk perception of the investor, as equity is repaid after debt has been serviced (table 7). On the other hand, this also means that the bank has a large stake in financing the wind park. Banks generally have strict lending terms and conditions as they are risk-averse, and therefore they do not invest in very risky assets. Banks only enter wind park investments in case certainty has been provided about interest and repayments, and therefore they determine the bandwidth of the amount of leverage in wind park investments.

3.7.5 Merchant risk (A4)

"Merchant risk" includes counterparty risk as the risk of default of the off-taker, curtailment risk in case electricity cannot be sold to the grid, and electricity price risk in case the selling price of the produced electricity is lower than expected. Therefore, merchant risk is the risk in the amount of electricity that can be sold, and against which price, and it directly influences the revenues of the wind park. Electricity price risk is a macro-economic risk, but since the prices are partly determined in the contracts with the government, it is combined in merchant risk as a commercial risk.

Wind parks can receive government support for the electricity they sell in the form of a subsidy scheme, which is determined contractually at the start of the operational phase. Each European member state employs different policy instruments for reaching renewable energy targets. Generally, there are four different types of instruments: Feed-in Tariffs (FiT), Feed-in Premiums (FiP), quota and tenders (Fruhmann & Tuerk, 2014). FiT are low-risk schemes for the SPV and its investors, as they provide a fixed price for each unit of electricity generated, irrespective of the market electricity price (Turner et al., 2013). With a FiP, the SPV receives an electricity price directly from the electricity market, and receives an additional payment on top of that. This subsidy scheme has a higher revenue risk than the FiT scheme. Whereas FiT and FiP are price-driven incentive schemes, quotas are quantity-based incentive schemes. Quota obligations are based on Tradable Green Certificates (TGC). A wind park receives a number of TGC’s based on its annual electricity production (MW) (Resch, Ragwitz, Held, Faber, & Haas, 2007). A market price is received for each TGC the wind park holds. This subsidy scheme has a higher revenue risk than FiTs or FiPs, but the advantage is that the TGCs are highly compatible with market principles, and a competitive price can be established. Finally, there are tender or auction schemes for renewable energy support. Different parties can submit a bid containing all the information for the development of the wind park, including prices and electricity generation, from which the government selects a bidder.

As the development of wind energy has been instigated over the last decades, governments are gradually withdrawing incentive schemes. As a result, revenues are more and more based on market prices. This poses more risks to the wind park’s revenues, as the price of electricity sold is not fixed,
but depends on volatile market prices. All in all, the lower the exposure of revenues to the market, and the longer the subsidy scheme contract, the lower the merchant risk.

Furthermore, there are risks in the amount of electricity that can be sold to the off-taker. This depends on the supply and demand of energy. Energy supply depends on merit order regulations. The merit order is the ranking of energy-producing sources according to their production cost, or selling price (figure 12). The marginal cost for producing electricity from wind and solar energy is very low, as the wind or solar input is free (Sensfuß, Ragwitz, & Genoese, 2008). Nuclear energy comes after, followed by hydropower, coal, gas and finally oil. The average electricity demand remained steady over the last years. However, the electricity supply has risen due to an increase of renewable energy sources. This drives down the costs of electricity, and pushes coal and gas out of the market, as these are more expensive. Furthermore, as the wind input is uncertain, it cannot always be sold to the grid, or only at low prices.

![Figure 12 - The merit order (German Energies Agency, 2011)](image)

### 3.7.6 Financial risk (B1)

Inflation risk and currency risk are combined as “financial risk”. This risk is described as the risk of a change in the value of the investment can due to currency risk and inflation risk. This is a macro-economic risk, as external economic effects affect the wind park’s cash flows. The currency rate and inflation rate are macro-economic factors affecting all financial assets, including wind parks. In most European countries the Euro is handled. However, countries like the United Kingdom, Switzerland, and the Nordics have their own currency, except for Finland. Investing in these countries with Euros can pose a currency risk, as the value of the investment can change during the investment period (Verdouw, Uzsoki, & Dominguez Ordonez, 2015). Inflation risk has the same effect on the cash flows, as it is the risk of erosion on the returns by inflation. Inflation can lead to higher OPEX than anticipated, reducing the return for investors (Yescombe, 2002). Investors can hedge against these risks in order to protect the returns against decreasing values. Volatilities of the currency can be hedged to ensure a higher certainty in the returns (Thomas & Bosse, 2014).
3.7.7 Regulatory risk (C1)
Governments determine the form of the incentive scheme and generate income for the wind park. Tax rate risks are regulations of the governments which affect the cash flows of the wind park. Country risk is the safety and stability of a country in keeping its promises. Regulatory risk is an overarching theme of these risks, and therefore they are combined as “regulatory risk”. This risk is described as the risk of a change in public policy in the form of subsidies, taxes and energy supply regulations. It concerns the stability of a country in maintaining its promises for renewable energy generation. Investors prefer investing in countries which are stable and have a low business risk, as these have a higher certainty of the subsidy scheme pay-outs and tax regulations. Political instability can pose risks of lower or withdrawal of these incentive schemes, as has happened in the Spanish wind industry from 2008 to 2012 (Mahalingam & Reiner, 2016). Additionally, governments can control the level of energy supply through merit order regulations through the opening or closing of energy generating sources, influencing merchant risk of a wind park. Furthermore, tax regulations affect the cost and revenues of the wind park, as higher taxes lead to diminishing returns.

3.8 Conclusion
In this chapter, the risks have been assessed to which an investor is exposed when investing directly in a wind park in the operational phase through unlisted equity. Through a literature study, analyst report assessment, and interviews wind with park investors, a list of the main risks has been drafted. As most of the risks overlap, they have been combined. This limits overlap between the risks, also offering a more solid list of six risks which can be applied in chapter 5 to be translated to the return on equity. With this, the second research question can be answered:

2. Which risks in wind parks investments should be included in the return on equity?

The six risks which have been determined are: resource risk, technology risk, O&M risk, merchant risk, financial risk and regulatory risk. These risks are important to the investor since they affect the wind park’s cash flows, and ultimately the investor’s return. Some risks are more important than others, as some can be mitigated, but others inherently pose risks to the investor when investing directly in a wind park. The first four risks are commercial risks or unsystematic risks, financial risk is a macro-economic risk, and is therefore systematic. Regulatory risk is a political risk and is also systematic.

Resource risk is important to an investor as this determines how much wind input the wind park receives in order to generate electricity. Technology risk concerns the availability of the technical components of the wind park. O&M risk includes the contractual arrangements between the actors, and therefore the risk exposure of the investor. Merchant risk consists of the price against which the wind parks’ generated energy can be sold, and the amount. This is partly determined contractually with the government and energy off-taker, and partly by the macro-economic developments due to energy supply and demand, and the market price for electricity. Resource risk, technology risk, and merchant risk are respectively the amount, availability and price of the wind energy. These three aspects form the revenue stream for the SPV. Additionally, technology risk and O&M risk affect the OPEX and also the wind park’s availability. Financial risk includes currency and inflation risk, affecting all cash flows. Finally, regulatory risk is an indicator of the country’s stability, and can affect subsidy schemes, tax regulations and merit order regulations. These six risks serve as input for the model in chapter 5.
Models for risk and return

Chapter 4
4 Models for risk and return

4.1 Introduction

In order to describe the relation between risk and return in wind park investments, a literature study is desirable of the models which are suitable for valuing these type of assets, while including the total risk to which an investor is exposed. In the previous chapter, the risks of wind parks in the operational phase have been explored. In this chapter, several models are explored in which these risks can be translated to the return on equity. From the problem statement of this research, it followed that there is limited information about the asset class of wind park investments since these are often unlisted, investors are often not fully diversified and when investing directly, the investment contains residual unsystematic risk. Additionally, wind park investments have different risk characteristics than traditional asset classes, as elaborated in chapter 2, and therefore an investor is exposed to several systematic and unsystematic risks.

From this problem statement, and the findings of chapter 2 and 3, the aim of this chapter is therefore to select a model which is most suitable for calculating the return on equity of wind parks which adheres to three selection criteria. The model:

1. Incorporates both systematic and unsystematic risks to which an investor is exposed when investing directly in wind parks for a total risk inclusion;
2. Is suitable for unlisted assets, as most wind parks are unlisted;
3. Is suitable for the evaluation of all different types of European wind parks by using the same approach.

For this model exploration, the results from the first round of interviews (section 3.5) serve as input. Three investors were asked about their valuation models for wind park investments. From the interviews it followed that generally, a wind park can be evaluated in two different ways. The first method is from a corporate finance perspective by using a top-down approach by comparing the wind park to similar assets in the market. The second method is from a project finance perspective by using a bottom-up approach by forecasting the wind park’s cash flows (section 2.3.1). Often both methods are applied to complement each other. In the following sections, the different types of models in both corporate finance (section 4.2) and project finance (section 4.3) are analysed. Furthermore, alternative models are explored which offer another perspective (section 4.4). Finally, a selection is made for the model which best adheres to the three selection criteria (section 4.5). An overview of this assessment is provided in table 8. The chapter is concluded in section 4.6 by answering the third research question:

3. How can the risks of wind park investments be translated to the return on equity?
4.2 Corporate finance models

4.2.1 Risk and return in corporate finance

In corporate finance, investment decisions are made on a high-level basis, in which the return of the investment should be higher than the company’s minimum acceptable rate of return (Brealey et al., 2011). The modern portfolio theory (MPT) as designed by Markowitz (1991) are the foundations for corporate finance’s understanding of risk and return. The MPT is a mathematical framework for gathering assets in a portfolio in order to maximize the expected return of the portfolio for a given level of risk (Schulderlich, 2015). Risk is expressed as the volatility or variance of the returns. The key concept is that the risk of an asset should not be assessed individually, but by its contribution to the overall risk of the portfolio. Consequently, only systematic risk and maturity risk exist in an investment, as unsystematic risk can be eliminated by holding a well-diversified portfolio (figure 13). There are several acknowledged models describing risk and return in corporate finance, and they all share two common views. First, risk is defined as the variance of the actual returns on the expected returns (Damodaran, 2014). In case the actual returns are equal to the expected return, the investment is regarded as riskless. Secondly, risk should be measured by holding the perspective of a marginal investor holding a well-diversified portfolio. Only the marginal risk that an investment adds to the portfolio should be measured and compensated (Damodaran, 2014).

There are several models which prevail in corporate finance, such as the Capital Asset Pricing Model (CAPM), the Arbitrage Pricing Model (APM), and proxy models (Damodaran, 2014). There are many alternatives, but these three models are largely applied and capture the characteristics of the corporate finance models. In the corporate finance models, a risk premium is added to the risk-free rate. The risk-free rate is the return of a risk-free asset such as a government bond, which is considered riskless. The risk premium is the additional return above the risk-free rate. It is the extra return that investors demand for taking the risk. The size of the risk premium depends on the level of risk in a specific portfolio, and changes over time due to market movements. These models measure risk by the volatility of listed assets against market movements. The models assume that the investor is well-diversified. Therefore, the models generally only incorporate systematic risk, as according to the portfolio theory, unsystematic risk can be diversified away.

![Figure 13 - The elimination of unsystematic risk by holding a diversified portfolio according to MPT (Author’s figure, based on Falkenstein (2009))](image-url)
4.2.2.1 The CAPM

The Capital Asset Pricing Model (CAPM) is the most common model used in corporate finance. The model is developed by Sharpe (1964) and Lintner (1965), and builds upon the MPT from Markowitz. The risk premium is calculated by multiplying the beta with the market risk premium (equation 4.1). Beta is a measure of the volatility, or systematic risk of an asset as compared to the market as a whole (Damodaran, 2014). This is done by taking a peer set of similar assets or companies and analysing their volatility. The higher the beta, the more it fluctuates with the market. A beta of 1 means the asset moves equally with the market. A beta lower than 1 means that the asset is less volatile than the market, and therefore is considered less risky than an asset with a beta higher than 1. The expected market return is the additional return the investor demands above the risk-free rate.

\[ r_e = r_f + \beta_a (r_m - r_f) \]  
(4.1)

Where:
- \( r_e \) = required return on equity
- \( r_f \) = risk-free rate
- \( \beta_a \) = beta of the asset
- \( r_m \) = expected market return

The CAPM assumes that investors hold a completely diversified portfolio, operate in a perfect equilibrium market in which all information is available, have the same portfolio opportunities, assess the market in the same way on the same decision horizon, and have homogenous expectations (Brealey et al., 2011). Furthermore, the CAPM assumes that there are no transaction costs or taxes, meaning that trading is costless and tax-free (Fama & French, 2004). Additionally, CAPM assumes that all risk is captured in the beta through the measurement of the volatility of an asset’s systematic risk (Palmiter, 2003). Some strengths of the CAPM are that it is easy to apply, and extensive empirical research and tested has been conducted about the relation between systematic risk and return (Pratt & Grabowski, 2014). According to critics of the CAPM, its weaknesses are the oversimplified assumptions, that it is not suitable for valuating an investment in isolation, its inapplicability of non-diversified investors, and that it insufficiently describes the return of an investment (Hürlimann & Bengoa, 2017). When comparing the CAPM to the selection criteria, it does not include total risk but only systematic risk (criterion 1 not met), it is only applicable for listed assets (criterion 2 not met), but it can be applied for valuing all different types of assets with the same method (criterion 3 is met).

4.2.2.2 The APM

The Arbitrage Pricing Model (APM) as developed by Ross (1976) includes several individual unspecified systematic, macro-economic risk factors (Dash & Mahakud, 2013). The APM calculation starts with identifying the risk factors which could affect expected returns. No more than five risk factors should be included in the calculation (Brealey et al., 2011). The expected return is a linear function of the risk factors, with the assumptions that the pricing of the assets do not include arbitrage (Damodaran, 2012). Arbitrage is the price difference of buying an asset in one market and selling it in another market (Ross, 1976). Each risk factor has a different risk premium, and a different exposure to that factor (equation 4.2). By adding these risk premiums to the risk-free rate, the return can be calculated.

\[ r_e = r_f + \beta_1 * \lambda_1 + \beta_n * \lambda_n \]  
(4.2)

Where:
- \( r_e \) = required return on equity
- \( r_f \) = risk-free rate
- \( \beta_n \) = exposure to factor
- \( \lambda_n \) = factor risk premium

In the APM, it is assumed that the investor holds a fully diversified portfolio, that the market is in perfect equilibrium that there is no arbitrage, no taxes are transaction costs, and the return is
affected by several systematic risk factors with different sensitivities (Ross, 1976). The strength of the APM is that more exact statements about the returns can be made as multiple systematic risk factors are included, and therefore is generally does better in explaining returns than CAPM (Damodaran, 2012). Its weaknesses are that it is more complex to calculate the return, and the risk factors are not specified. The APM also only incorporates systematic risk (criterion 1 is not met), is only applicable for listed assets to calculate the betas (criterion 2 not met), but is applicable to value different types of investments in the same manner (criterion 3 is met).

4.2.2.3 Proxy models
Proxy models differ from the CAPM and APM as these do not assume markets in perfect equilibrium, zero transactions costs and no taxes, or that all investors have access to the same information (Fama, 1996). Rather, they built up from scratch by return estimations of stock prices with observable variables (Damodaran, 2012):

\[ r_e = a + b(\text{Proxy 1}) + c(\text{Proxy 2}) \] (4.3)

Where:
- \( r_e \) = required return on equity
- \( a \) = baseline for the calculation
- \( b, c \) = weight of the proxy

A proxy is a representation of the value of a metric in a calculation. In this case, the proxies are firm-specific metrics such as the market capitalization of the firm, which is the price of the company’s shares multiplied by the number of shares. Another metric is the price to book ratio, which is the current share price of the company divided by its latest quarter’s book value per share (Damodaran, 2012). Additional factors can be included in the proxy models, such as the company’s liquidity, which the CAPM does not include. Weaknesses of the proxy models are that they are more complex than CAPM calculations, and the assumptions are subjective and firm specific. The proxies are determined by market or systematic risk (criterion 1 not met), is only applicable for companies with listed assets (criterion 2 not met), but the proxy models could be applied to value different types of assets in the same manner (criterion 3 is met).

4.2.3 Conclusion corporate finance models
After analysis of three corporate finance models, it can be stated that these models only incorporate systematic risk, and assume that unsystematic risk can be diversified away. The CAPM and APM assume that the investor is completely diversified, eliminating unsystematic risk. The proxies for the proxy model are obtained by measuring market risk, which is systematic. However, wind park investors often invest larger amounts of capital in fewer projects, and therefore the diversification assumption does not always hold. Therefore, criterion 1 for these models is not met. The models require information from listed assets or companies, and therefore are not suitable for valuing wind parks which are often unlisted assets (criterion 2 is not met). Valuing unlisted assets with corporate finance models is possible, but information is restricted due to confidentiality reasons, and often is difficult to obtain (Hürlimann & Bengoa, 2015). Furthermore, these calculations will not reflect the characteristics of unlisted assets. In principle, the corporate finance models could be applied to all different types of assets, including European wind parks (criterion 3 is met). All in all, it can be concluded that the corporate finance models are not suitable for calculating the return on equity for wind parks for this research.
4.3 Project finance models

4.3.1 Risk and return in project finance

In project finance, the investment decision for an investor follows from an estimation of the economic value or profitability of an investment (de Wachter, 2013). For this, a bottom-up analysis is conducted in which the costs and revenues of the project during the investment period are forecasted, and converted into cash flows (Piel, Humpert, & Breitner, 2016). In these models, the time value of money (TVM) is incorporated. According to the TVM theory, a dollar invested today is worth more than a dollar invested tomorrow (Brealey et al., 2011). This means that projects who generate positive cash flows in an earlier period are more desirable than alternatives. In order to account for risk in the investment, uncertainties can be included in the cash flows (McKinney, 2012). There are several project finance models that account for risks, of which the Risk Adjusted Discount Rate (RADR), the Decoupled Net Present Value (DNPV) and Certainty Equivalents (CE) are most commonly applied (Espinoza & Morris, 2013).

4.3.2 Project finance models for risk and return

4.3.2.1 The RADR

In the RADR model, differential project risk is incorporated by changing the discount rate of the project. Projects which are considered with average risk are discounted with the company's cost of capital, projects with high risk with a higher discount rate, and projects with low risk with a lower discount rate. This method is mostly used by listed companies, as the RADR can be estimated from the company's market data (Ehrhardt & Brigham, 2016). This model therefore includes a top-down approach similar to the corporate finance models, but is applied to the project's cash flows:

$$NPV_{RADR} = \sum_{t=0}^{T} \frac{FCFE_t}{(1 + RADR)^t}$$ (4.4)

Where:

- $RADR =$ risk-adjusted discount rate, $a =$ investor-specific factor for adjusting for risks in the cash flows, $FCFE_t =$ free cash flows to equity

In the RADR model, it is assumed that the company's cost of capital is a good determinant of the risk-adjusted return, and that this single RADR captures all the risks (Gallagher, Miao, & Ryan, 2018). The model is easy to apply in case market data is available (Ehrhardt & Brigham, 2016). However, the assumptions of the RADR for riskier and less risky projects is subjective and firm specific. To determine the RADR, market data of the investor's company is required, which are only systematic risks (criterion 1 is not met). With this information, the RADR can be applied to unlisted assets based on their relative level of risk (criterion 2 is met). Also, the model can be applied to value all different types of assets, and investments are evaluated from the same company's point of view (criterion 3 is met).

4.3.2.2 The DNPV

The cash flows can also be adjusted by extracting costs associated with risk $(V_t)$ from the operational cash flows, also called the Decoupled NPV (Espinoza and Morris (2013). In the DNPV, costs and revenues obtain a distribution type, mean and standard deviation. With this, the likelihood of the risk in the cash flows can be calculated, and the effect of risks on the required return of the
investor. This supports investors in negotiations of the required return for the project which is adjusted for risk that the investor takes (Piel, Humpert, & Breitner, 2016).

$$DNPV = \sum_{t=0}^{T} \frac{FCFE_t - V_t}{(1 + r_e)^t}$$  \hspace{1cm} (4.5)

Where:

- \(r_e\) = required return on equity, \(V_t\) = costs associated with risk, \(FCFE_t\) = free cash flows to equity

The strength of the DNPV is that the risks can be quantified individually, and their direct impact on the return of the investor (Piel et al., 2016). However, its weaknesses are the subjectivity of the risk distributions and standard deviations. Furthermore, the DNPV is highly specific for a single project, and therefore it is difficult to apply the same model in the same manner for valuation different kinds of projects. Overall, the total risk of a wind park investment can be included (criterion 1 is met), and the model can be applied to unlisted assets (criterion 2 is met). The model is highly specific though, and therefore it is difficult to compare different types of wind parks in the same manner (criterion 3 is not met).

4.3.2.3 The CE

In the CE model, the investor evaluates the risks of all the cash flows. From this, it can be specified how much money he wishes to receive with certainty, and which will make him indifferent between riskless and risky cash flows (Ehrhardt & Brigham, 2016). This depends on the investor’s risk perception and strategy (section 2.5). Cash flows which are regarded as risky are scaled down, since the riskier these cash flows, the lower their certainty equivalent values. Therefore, the more risk-averse the investor is, the more conservative its CE estimations will be. The FCFE are adjusted for risk by multiplying them with a factor \((a)\). This factor is applied by the investor itself, and is based on its risk perception its strategy:

$$NPV_{CE} = \sum_{t=0}^{T} \frac{a \cdot FCFE_t}{(1 + r_e)^t}$$  \hspace{1cm} (4.6)

Where:

- \(a\) = investor-specific factor for adjusting for risks in the cash flows, \(FCFE_t\) = free cash flows to equity, \(r_e\) = required return on equity

The CE model is simple and risks can easily be incorporated (Ehrhardt & Brigham, 2016). Weaknesses of the CE models are that the application and determination of the certainty equivalents for risky cash flows is relatively difficult, subjective, and project-specific (Benth, Cartea, & Kiesel, 2008). Therefore, the model is not applied often in practise. In the CE model, the total risk can be included (criterion 1 is met), and it can be applied to unlisted assets (criterion 2 is met). However, the modelling and determination of the risk factors is project-specific (criterion 3 is not met).

4.3.3 Conclusion project finance models

In the project finance models, an in-depth analysis of the project is conducted in order to compute the cash flows. With the RADR, a top-down approach is used by applying the company’s cost of capital, however this method only captures systematic risk (criterion 1 is not met). The DNPV and CE models include total risk, and are suitable for unlisted assets, but are highly specific for the project. Therefore, it is difficult to value different wind parks with the same approach (criterion 3 is not met).
All three models are applicable for valuing unlisted assets though (criterion 2 is met). An additional limitation is that considerate information is necessary about the wind park’s revenues and costs in order to conduct the calculation, and risk adjusting factors or cost reductions are subjective. Therefore, the project finance models are also not suitable for the wind park valuations in this research.

4.4 Alternative models

4.4.1 Alternative models for risk and return

In the following sections, alternative models are discussed which provide another approach to value assets, including unlisted assets. The first one is called the indirect approach, the other five are proxy models.

4.4.1.1 The indirect approach

The indirect approach is a model for assessing the return characteristics of financial assets in the market. In the corporate finance models as described above, the historical performance data can be reviewed to draw conclusions for future performance (Nielsen, 2010). For these corporate finance models, information about the beta can be problematic, as there are only a few peer companies suitable to use in the analysis (Pratt & Grabowski, 2014). Therefore, often the industry betas of a single asset class are used to resemble the beta (Koller, Goedhart, & Wessels, 2015). The model only considers systematic risks and the returns of listed assets (criterion 1 and 2 are not met). The calculation of the beta is based on data of the peer companies, and therefore depends on the selection of the peer group, of which information often is hard to attain since there is little evidence of returns of wind parks. The model assumes that different projects of the same industry all have the same beta. Due to the restricted amounts of information, this also limits the applicability to different types of wind parks (criterion 3 is met).

\[ r_e = r_f + \beta_{industry}(r_m - r_f) \]  \hspace{1cm} (4.7)

Where:
- \( r_e \) = required return on equity,
- \( r_f \) = the risk-free rate,
- \( \beta_{industry} \) = the beta of the industry,
- \( r_m \) = expected market return

4.4.1.2 The bottom-up beta technique/ pure-play technique

The first proxy technique is called the bottom-up or pure-play technique, which is based on CAPM and uses an adjusted beta. Betas of listed companies are applied which operate in the same industry, are of similar size, and a proxy of their betas is used to generate the beta for the project (Hürlimann & Bengoa, 2017). The theory assumes that the operative risk of all the assets held by the investor in a portfolio have the same risk as the project concerned, even though the project is part of a different industry. The model is quite simple, but may not be accurate for wind park investments as it is difficult to find suitable companies (Cotner & Fletcher, 2000). All in all, only systematic risk is considered and the returns of listed assets (criterion 1 and 2 are not met). The method can be applied to different types of wind parks, but this also depends on the information available (criterion 3 is met).

\[ r_e = r_f + \beta_{peers}(r_m - r_f) \]  \hspace{1cm} (4.8)

Where:
- \( r_e \) = required return on equity,
- \( r_f \) = the risk-free rate,
- \( \beta_{peers} \) = the beta of the indicative peer set,
- \( r_m \) = the expected market return
4.4.1.3 Accounting beta method

The second proxy theory is the accounting beta method, which uses a regression of several key performance metrics of the investor’s company (EBIT/ total assets), and the return rates of the market index to estimate the beta (Ehrhardt & Brigham, 2016). In this way, the calculation is based on the company’s accounting data, and not on market data (criterion 2 is met). However, unsystematic risk is not incorporated in this method (criterion 1 is not met). Also, using company metrics for evaluating wind parks seems illogical, as the differences between the wind parks cannot be explained (criterion 3 is not met).

\[ r_e = r_f + \beta_{company} (r_m - r_f) \]  

(4.9)

Where:
\( r_e \) = required return on equity, \( r_f \) = the risk-free rate, \( \beta_{peers} \) = the beta of the company, \( r_m \) = the expected market return

4.4.1.4 Cost of debt plus a risk premium

The third proxy technique is called the equity premium technique, in which the judgemental equity risk premium is added to the return rate of the company’s long-term debt (Ehrhardt & Brigham, 2016). The method includes unsystematic risks, and it can be applied to unlisted companies (criterion 1 and 2 met). In theory, the method could be applied to all different types of wind parks. However, the method is highly subjective, and assumes the wind park is unlevered (all equity financed), or only has a small amount of debt, which is unrealistic in practice (section 2.2) (criterion 3 is not met).

\[ r_e = r_d + Equity\ risk\ premium \]  

(4.10)

Where:
\( r_e \) = required return on equity, \( r_d \) = the company’s return on long-term debt, 
\( Equity\ risk\ premium \) = judgemental equity risk premium above the return on debt

4.4.1.5 Illiquidity risk premium

The fourth proxy technique adjusts for an illiquid asset by adding a illiquidity risk premium of one to three percent to the return on equity of the investor’s company (Ehrhardt & Brigham, 2016). In the model, it is assumed that unlisted companies have a lower liquidity than listed companies. In practice, estimation of the illiquidity risk premium is difficult though. The total risk is not captured in this method, as only an illiquidity risk premium is added (criterion 1 is not met). In theory, the model can be applied to unlisted assets (criterion 2 is met) in the same manner (criterion 3 is met).

However, the estimation of the premium is difficult, and the validity of this method is questioned, as there is no methodological approach for determining the risk premium.

\[ r_e = r_{e,company} + Illiquidity\ risk\ premium \]  

(4.11)

Where:
\( r_e \) = required return on equity, \( r_{e,company} \) = the company’s return on equity, 
\( Illiquidity\ risk\ premium \) = illiquidity risk premium of 1-3%
4.4.1.6 Formal risk analysis technique or AHP

Finally, there is the formal risk analysis technique. Here, the incomplete information problem is overcome (Hürlimann & Bengoa, 2017). For this technique specifically, Cotner and Fletcher (2000) and Palliam (2005b, 2005a) suggest to apply the analytical hierarchy process (AHP). The AHP was developed by Saaty (1980) for decision-making purposes based on mathematics and psychology. However, it can be applied to calculate the return of an investment as it decomposes the decision problem, or required return, to calculate the equity risk premium. The total risks are assessed, and organized hierarchically according to their priority by the comparative judgement of one or multiple experts. The AHP assumes that these decision makers reflect the market for these type of assets. Analogous to the CAPM, the established risk premium is added to the risk-free rate to calculate the return on equity for the project. The strengths of the AHP are that risks can be quantified individually, and risk is directly reflected in the return on equity. Furthermore, the equity risk premium can be seen as an unstructured problem which can be structured with the AHP, and insight information from experts is elicited by performing the pair-wise comparison. A weakness of the AHP may be that the multi-objective analysis can lead to a large number of paired comparisons to be asked from the decision makers (Olson, 1988). Therefore, focus on important objectives would reduce the amount of required comparative judgements. Additionally, the risk factors of the AHP are not specified (Cheng, Li, & Ho, 2002). These should therefore be defined as a first step in order to apply the AHP. All in all, the AHP assesses the total risk (criterion 1 is met), is applicable for unlisted assets (criterion 2 is met), has a methodical approach, and can be applied for evaluating different types of wind parks (criterion 3 is met), as the weight of the risks will be different for each project.

\[
    r_e = r_f + \sum_{i=1}^{n} (a_i \times \text{Equity risk premium}_i)
\]

Where:
\( r_e \) = required return on equity, \( r_f \) = risk-free rate, \( a \) = weight of the equity risk premium
\( \text{Equity risk premium} \) = premium for risk that the investor is exposed to when investing

4.4.2 Conclusion alternative models

Six different models have been described in this section which can be used as alternatives of the corporate finance and project finance models. The indirect approach, bottom-up beta technique and accounting beta methods are variants of the CAPM, and use different proxies in order to calculate the beta of the asset. The proxies are high-level though, and do not sufficiently describe the risk characteristics of wind park investments which contain unsystematic risks and are often unlisted. The cost of debt plus risk premium and illiquidity risk premium models apply risk premiums above available data of the company. These also apply a high-level, top-down approach and assume that the company’s long-term debt or return on equity are adequate for valuing all different types of wind parks. Finally, the formal risk analysis in the form of the AHP is described. This approach combines a top-down market view through expert judgements, as well as a bottom-up approach through the different risk factors of an investment to calculate the return on equity. The AHP adheres to all three selection criteria.
The return can be calculated by:

\[ \text{Return} = \left( \frac{a \times \text{FCFE}}{1 + r} \right) / \text{RADR} \]

Suitable peers are not always required. Return on equity is easy to apply. No market data is necessary, as the chosen key performance indicator is cost of capital. Project finance models are suitable for unlisted assets. Total risk is included. Adherence to selection criteria is model specific for one asset. The company's cost of capital is determined by Beta which resembles the systematic risk factors. Beta is a full measure of risk. No taxes or transaction costs. Perfect market in equilibrium. Investor holds a completely diversified portfolio. Beta is used which resembles the factor. Project is has no, or only a small amount of debt. Company's metrics do not seem as independent analysable sub-companies. Risk is directly reflected in the return. Additional factors can be included as input. Risk can easily be incorporated. No arbitrage. Returns since multiple factors can be accounted for. No differences between projects. Assumptions are subjective and firm. Assumptions are subjective and firm. No differences between projects. Assumptions are subjective and firm. Assumptions are subjective and firm. Model highly specific for one asset. Total risk is included. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets. Suitable for unlisted assets.
4.5 Selection of model

In the previous sections, the most common valuation models of corporate finance and project finance are evaluated and assessed on their suitability for wind park valuations according to three selection criteria. An overview of the models, their formula, assumption, strengths, weaknesses and adherence to selection criteria are illustrated in table 8. Whereas the corporate finance models take a top-down approach from the market, the project finance models generally have a bottom-up approach by evaluating the cash flows of a project. The corporate finance models do not meet all selection criteria as unsystematic risk is generally not incorporated (criterion 1 not met), and are not suitable for unlisted assets (criterion 2 not met). Furthermore, project finance models are highly specific and therefore not easily applied in the same manner for all different types of wind parks (criterion 3 not met). From the alternative methods, some include total risk, are applicable for unlisted assets, and can be applied to different types of wind parks in the same manner. However, only the formal risk analysis technique in the form of the AHP adheres to all three criteria. From the models which have been assessed, the AHP is therefore selected to calculate the return on equity for wind parks for this research.

The AHP is a multi-criteria decision analysis tool for making complex decisions by using mathematics and psychology as developed by Saaty (1980). The AHP methodology has three main functions; to structure complexity, measure on a scale of ratios, and to synthesize the results (Betancur, 2009). A number of alternatives are selected based on their rating against a pre-determined set of criteria (Palliam, 2005a). The criteria obtain a weight factor in terms of their importance to the decision-maker. The overall score of an alternative is obtained by adding its rating against each criterion. The method has been applied to many different fields, such as management strategies, healthcare decisions, and financing decisions. The AHP enables both objective and subjective criteria to be incorporated into a comprehensive model of a decision problem (Saaty, 1980). In a very recent study, Hürlimann and Bengoa (2017) have recommended to use the AHP to calculate the equity risk premium for renewable energy projects. According to Cotner and Fletcher (2000), "The AHP is well suited for the task of estimating an equity risk premium, and is a workable alternative to the various proxy approaches". Cotner and Fletcher (2000), Palliam (2005a, 2005b), and Betancur (2009) apply the AHP to compute the cost of capital for unlisted firms. Decision making is done collectively by several decision makers or employees of the firm. According to Betancur (2009), the AHP enables the quantification of both tangible and intangible risk factors which have a direct or indirect effect on project risk. From all the models described, the AHP seems as an interesting candidate. The AHP adheres to all three selection criteria, and has never been conducted before to calculate the return on equity different types of wind parks. The AHP has several strengths and weaknesses, and seems to explain the risk-return relation well as compared to the other models. The AHP will therefore be applied in this research to calculate the return on equity for an investor when investing in wind parks, while including the total risk.


4.6 Conclusion

In this chapter, corporate finance models, project finance models, and alternative models have been analysed on their suitability for valuing wind park investments. The models were assessed whether they include the total risk to which an investor is exposed when investing wind parks, whether they are suitable for unlisted assets, and whether they are suitable for valuing all different types of European wind parks by using the same approach. From the first round of interviews, the investors argued that they apply two types of approach for valuing wind parks, corporate finance approach and a project finance approach, which are often used both to complement each other. Therefore, several models have been assessed on the selection criteria in order to answer the third research question:

3. How can the risks of wind park investments be translated to the return on equity?

Whereas corporate finance models take a high-level, top-down approach and measure risk in terms of the effects of market volatility, project finance models apply a bottom-up approach measuring risk in terms of cash flow volatility. Corporate finance models require data from listed companies or assets in order to calculate the beta. Project finance models are highly specific, and therefore it is difficult to compare different types of wind parks using the same approach. These results highlight the initial research gap, which states that additional research is required about the risk-return relation of wind parks in which total risk is included. Furthermore, the models of both corporate finance and project finance do not adhere to all three selection criteria. Therefore, alternative models have been evaluated. The formal risk analysis in form of the AHP adheres to all three criteria. It is a common method for decision making, but could also be applied for valuing unlisted assets while including the total risk. In a very recent study, Hürlimann and Bengoa (2017) have recommended to use this method to calculate the equity risk premium for renewable energy projects. This model has not been applied before to calculate the return on equity for renewable energy investments, or even wind parks. The AHP will therefore be applied in this research in order to contribute to solving the research gap on the risk-return relation of wind park investments.

With the AHP, both a high-level market approach can be taken by the decision makers as in corporate finance models, as well as a bottom-up project-specific approach as in project finance models. Risks can be quantified individually, and directly translated into the return. Furthermore, insight information is elicited from experts by the comparative judgements. The AHP therefore seems as a suitable model to explain the risk and return of wind parks for this research, as a direct quantification is risk is possible, as well as underlying reasons for the constitution of the return through expert judgements. For this research, the AHP is therefore applied to quantify the risks of onshore and offshore wind parks which have been attained in chapter 3, into the return on equity (chapter 5).
The return on equity for various types of risk

Chapter 5
5 The return on equity for various types of risk

5.1 Introduction

From the model analysis in the previous chapter, the AHP has been selected to calculate the return on equity for a wind park based on its risk characteristics. In this chapter, the aim is to assess the effect of various types of risks on the return to further describe the relation between risk and return of wind park investments. The AHP is an established method for decision making in several sectors and businesses. However, it has never been applied as a method to calculate the return on equity for wind parks. Therefore, a literature study on the AHP has helped to make decisions which are suitable for this research in calculating the return on equity for different wind parks according to their underlying risks. With this, the decision has been made to conduct in-depth interviews with European wind investors, and consequently apply the results from the interviews to several case studies in order to calculate the return. The interview preparations are described in section 5.2, and preparation of the case studies in section 5.3.

The AHP is applied by merging the interview results and input from the case studies by carrying out several steps in section 5.4 (figure 14). First of all, the range of required equity risk premiums is determined for European onshore and offshore wind parks in the operational phase (step 1). These are the alternatives of the AHP, and are derived from the interview results. Secondly, the alternatives for the AHP are selected (step 2). In chapter 3, a list of six risks has been attained through a literature study, analyst report assessment, and exploratory interview. These six risks are the alternatives of this AHP. Thirdly, the risks obtain a weight by comparative judgements of the investors in the interviews (step 3). Fourth, the risks are ranked qualitatively in terms of low, medium and high risk by aggregation of the interview results (step 4). Next, four wind parks are analysed in terms of their exposure to each risk (step 5). The risk weight of each risk factor is obtain by multiplying the general weight of the risk with the weight of the risk for the wind park (step 6). Finally, the equity risk premium is calculated by summing up the weights of the risks of the wind park (step 7). By adding this equity risk premium to the risk-free rate, the return on equity is calculated for each of the four wind parks (step 8). In section 5.5, the return on equity for the four wind parks from the AHP are compared to the returns from the CAPM. A final conclusion is drawn in section 5.6, regarding the added value of the AHP for the valuation of wind parks, and by answering the fourth research question:

4. How is the return on equity affected when accounting for various types of risks?
Calculation of the return on equity with the AHP

Figure 14 - Steps in this research of the AHP to calculate the return on equity (Author’s figure)
5.2 Setting up the in-depth interviews

5.2.1 Interview form

Input for the AHP can be generated by judgements of one individual, or by multiple decision makers (Condon, Golden, & Wasil, 2003). In this research, the objective is to find a new valuation method for European wind parks. Therefore, the judgements of several investors, or decision makers, are desirable in order to provide a reliable reflection of the European wind sector. The judgements can be obtained through an online survey, or through one-to-one interviews (Saaty, 2008). Since risk is ambiguous and can be interpreted in several ways, the chance of getting the desired results is higher by conducting interviews. This could also help to understand the reasons of the investors behind the different risk weightings. Several investors have been contacted who are active in the European wind sector. Since not all investors are located in the Netherlands, some interviews have been conducted face to face, and some via conference calls. The investors in the exploratory interviews were not very open, especially when they were asked whether the interview could be recorded. In this second interview round, the interviews are therefore not recorded, and company-specific information has not been asked. In this way, the aim was to create a more open atmosphere in which the investors were encouraged to be more outspoken about their experience and to provide more detailed answers to the interview questions. Due to confidentiality reasons, the names of the investors are not provided, and only aggregated results are presented.

5.2.2 Setting the weights

There are four ways to set weights of the alternatives and decision criteria (step 1 and 3): through a group process, consensus, vote or compromise, geometric mean of the individual judgments, and weighted arithmetic mean (Condon et al., 2003). The first two methods require the investors to come together and by this vote or reach consensus about the risk premium sizes. Based on experience from the exploratory interviews (section 3.5.3), the group session is not a suitable method for this research, as the investors will probably be even less open in this interview form. The weighted arithmetic mean is a method in which weights are given to different decision makers and their judgements. There are no reasons in this research why the ranking of one investor should be higher than the other. Therefore, the geometric mean of the individual judgements of the investors will be applied. This is the most common approach used by groups to set priorities (Condon et al., 2003). Each investor will provide a judgement into a separate model, and the weights will then be averaged by taking the geometric mean. In this equation, the central tendency or typical value of a set of numbers is calculated by multiplying them, as opposed to the arithmetic mean where the values are summed. The geometric mean is defined as the nth root of the product of n numbers:

\[ \left( \prod_{i=1}^{n} a_i \right)^{1/n} = \sqrt[n]{a_1a_2 \ldots a_n} \]  

Where:
\[ a_n = \text{numerical value}, \ n = \text{number of values} \]
5.2.3 Number of interviews

Cheng, Lee, and Kreng (2010) apply the AHP to seventeen alternatives which obtain a weight through the geometric mean of the weights of seventeen individual judgements. Also, Lai, Wong, and Cheung (2002) apply the geometric mean of six individual judgements for six alternatives. For the application of the AHP in this research, also six alternatives or risks have been derived. The aim was therefore to interview at least six investors. For the exploratory interviews, not all investors have responded. For the in-depth interviews, twelve investors have therefore been contacted in order to guarantee sufficient response. Nine investors have agreed to the interview, and therefore nine interviews have been conducted. Also for this interview round, an interview protocol has been set up (Appendix F). First of all, general questions were asked about the investors’ experience in wind park investments and valuation methods. Secondly, the ranges of equity risk premiums were asked (section 5.4.1). Thirdly, the investors were asked to rank the risks against each other in order to arrive at a weight (section 5.4.3). Finally, qualitative descriptions for the different risk ranges were asked (section 5.4.4).

5.3 Setting up the case studies

In the first steps of the AHP (step 1-4), the alternatives (risk premiums), criteria (risks), criteria weights, and criteria ranges are identified. In the next steps (5-8), the specific return on equity can be determined for all different types of wind parks in Europe, either onshore or offshore. For this, the AHP is applied to several case studies in order to assess the relative risk premium of each risk according to the prescribed risk premiums.

The added value of the AHP as compared to traditional valuation methods, such as the CAPM, is that the share of unsystematic risks can be determined, as well as the composition of the risks for a specific wind park. In order to provide evidence of this added value, multiple cases are selected which have contrasting results for predictable reasons (Yin, 2003). This helps to illustrate the similarities and differences between the case studies. For this, two onshore wind parks and two offshore wind parks are selected which can be analysed within the timeframe of this research. With this, the differences between the two onshore wind parks can be illustrated, as well as the differences between the two offshore wind parks. Additionally, the differences between the onshore and offshore wind parks can be highlighted. The wind parks are analysed on several risk components, and therefore this is an embedded, multiple-case analysis (Yin, 2003). As the four wind parks have different risk profiles, their return on equity composition will be different. Two onshore case studies and two offshore case studies are selected from which a CAPM calculation is available, and contain enough information in order to assess their risk situation. Because of confidentiality reasons, the names of the wind parks and their exact sizes are not mentioned. All the information necessary for the AHP calculation is provided in this research. The two onshore case studies are a German onshore wind park “Alpha” with a size of 50-100 MW, and a French onshore wind park “Beta” with a size of 10-50 MW. The two offshore case studies are a German offshore wind park “Gamma” with a size of 200 - 300 MW, and an English offshore wind park “Delta” with a size of 300 - 400 MW.

In this research, it is assumed that the wind parks are optimally financed (Modigliani & Miller, 1958). This means that the weighted average cost of capital (WACC) of the wind park remains constant with changes in the capital structure of the wind park (Brusov, Filatova, Orelova, & Brusova, 2011). Therefore, the amount of leverage of the wind park does not affect the WACC or return.
As has been explained in section 3.7.4, the amount of leverage, or gearing risk, works in two ways. First of all, the return on debt is lower than the return on equity. Additionally, the interest costs can be deducted from taxable profits, whereas the return on equity in the form of dividends are not interest-deductible. For optimal financing, it is therefore aimed to finance as much as possible with debt. On the other hand, the higher the leverage, the more risk for the equity investor in not receiving their returns, as debt is services first, and equity comes after. Banks as debt providers set the boundaries of the financing structure of wind parks. In case a wind park is regarded as risky, banks are not willing to put large amounts of capital in it. In case a wind park is regarded low in risk, banks are more willing to provide capital. Banks are very strict on their lending terms, and set several terms and conditions on their loans. Therefore, in case a wind park is highly leveraged, this one on hand poses risk to the investors as a large amount of capital is repaid first to the banks, but on the other hand the wind park will be relatively safe as banks have set strict lending terms. In case a wind park has a low leverage, the investor has more certainty to receive his return in theory, but the lending terms of banks are limited. Therefore, banks often set the standard or bandwidth in which the wind parks are financed, and thus the amount of leverage of wind parks are within a predetermined range. For this research it is therefore assumed that the wind parks are optimally financed, and thus the amount of leverage does not affect the return on equity.

5.4 Application of the AHP

5.4.1 Step 1 - Range of equity risk premiums

The first step of the AHP is to set the range of the equity risk premiums appropriate for onshore and offshore wind parks. These various levels of risk are called the alternatives of the AHP (Palliam, 2005b). By conducting all the steps of the AHP, the equity risk premium for a specific wind park can be calculated. By adding this to the risk-free rate, the return on equity for a wind park is derived. This is analogous to the different model descriptions mentioned in chapter 4, where the equity risk premium is added to the risk-free rate to arrive at the return on equity (Hürlimann & Bengoa, 2017).

There are various ways to apply the risk-free rate and the risk premium. Yet, the return on equity is a more generic metric for all investors. Therefore, in the interviews the investors were asked to provide the return on equity for onshore and offshore wind parks, considering different levels of risks. The risk levels have a qualitative description; very low risk, low risk, medium risk, high risk and very high risk. For example, “Medium risk” means that this level of risk is illustrative of the investor’s average wind park investment, and “Very high risk” is associated with a wind park which the investor considers very risky (Cotner & Fletcher, 2000). Most investors found this difficult to answer, as this spectrum is very broad, and depends very much on the wind park itself. This illustrates the importance of unsystematic risk in wind park investments. Therefore, it was emphasized that the different kinds of risk levels are for European wind parks in general, ranging from wind parks with very low risk to wind parks with very high risk.

<table>
<thead>
<tr>
<th>Level of risk</th>
<th>Onshore (%)</th>
<th>Offshore (%)</th>
<th>Difference (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very low</td>
<td>4.6</td>
<td>6.2</td>
<td>1.6</td>
</tr>
<tr>
<td>Low</td>
<td>6.3</td>
<td>8.1</td>
<td>1.8</td>
</tr>
<tr>
<td>Medium</td>
<td>8.1</td>
<td>9.9</td>
<td>1.8</td>
</tr>
<tr>
<td>High</td>
<td>9.9</td>
<td>11.7</td>
<td>1.9</td>
</tr>
<tr>
<td>Very high</td>
<td>11.9</td>
<td>13.6</td>
<td>1.7</td>
</tr>
</tbody>
</table>

Table 9 - Ranges of return on equity for onshore and offshore wind parks (Author’s table)
With this, a range of returns on equity for onshore and offshore wind parks has been obtained in each interview. For each level of risk, the geometric mean of all the interview results has been taken, resulting in the ranges of return on equity for onshore and offshore wind parks (table 9). For onshore wind parks, the return on equity for wind parks with very low risk is 4.6%, for medium risk 8.1%, and for very high risk 11.9%. For offshore wind parks, the return on equity for wind parks with very low risk is 6.2%, for medium risk 9.9%, and for very high risk 11.1%. The results illustrate that there is a large range of returns for wind parks for the different levels of risk. Also, the returns for offshore wind parks are significantly higher than for onshore wind parks, ranging from a 1.6 to a 1.9% difference. Six of the nine investors are also active in offshore investments, and all of them have more experience in onshore wind investments than offshore wind investments. The investors only active in onshore wind park investments refrain from offshore wind park investments, as they still perceive it as risky due to higher technological risks, and the guarantees of their returns due to high competition in the offshore wind sector.

In order to calculate the risk premiums for the onshore and offshore wind parks for the purpose of the AHP application, the risk-free rate is subtracted from the return on equity. The risk-free rate is the theoretical return of an investment which is considered risk-free for a specific period of time. The actual return of a risk-free asset is equal to the expected return, and therefore there is no variance around the expected return (Damodaran, 2014). The risk-free rate is the minimum return an investor demands when making an investment. Any additional risk the investor takes is included in the equity risk premium. A risk-free investment does not exist in practice since even the safest investments carry some risk (Pratt & Grabowski, 2014). Therefore, the yield to maturity, or interest rate, on the government bond of the specific country of investment is often used as the risk-free rate for investors. These bonds are risk-free in nominal terms, but not in real term, as inflation can be volatile (Damodaran, 2014). Therefore, the nominal risk-free rate is calculated by adding the inflation rate to the real risk-free rate. For this research, the risk-free rate of EY is applied as calculated on the 31st of December, 2017. In these calculations, the nominal risk-free rate is applied, consisting of the real risk-free rate, the long-term inflation and the country risk premium (Eales, Nicholls, Patel, & Mills, 2015):

\[ \text{Riskfree rate} = \text{Real riskfree rate} + \text{Longterm inflation rate} + \text{Country risk premium} \quad (5.2) \]

The country risk premium (CRP) is the default risk of a country in paying the yield of the bonds to its investors (Damodaran, 2014). This differs from regulatory risk (C1), as the CRP offers insight into the default risk of a country, whereas regulatory risk is an indicator of the country's compliance with agreements concerning subsidies and tax regulations. Since wind park investments are long-term, EY applies a 30-year inflation rate for the Eurozone. This average long-term inflation rate for the Eurozone is 1.94%. A real risk-free rate of 0.5% is applied. Furthermore, a country risk premium is calculated per country by taking the default spread of the government bonds (Damodaran, 2014). To calculate the equity risk premiums for the wind parks, the real risk-free rate of 0.5% is applied, a

<table>
<thead>
<tr>
<th>Level of risk</th>
<th>Risk premium (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Onshore</td>
</tr>
<tr>
<td>Very low</td>
<td>2.2</td>
</tr>
<tr>
<td>Low</td>
<td>3.8</td>
</tr>
<tr>
<td>Medium</td>
<td>5.6</td>
</tr>
<tr>
<td>High</td>
<td>7.4</td>
</tr>
<tr>
<td>Very high</td>
<td>9.5</td>
</tr>
</tbody>
</table>

Table 10 - Ranges of equity risk premiums for onshore and offshore wind parks (Author's table)
long-term inflation rate of 1.94% for the Eurozone, and a country risk premium of 0%. This leads to a nominal risk-free rate of 2.44%, which is subtracted from the return on equity rates, resulting in a range of equity risk premiums for European onshore and offshore wind parks in the operational phase (table 10).

5.4.2 Step 2 - Selection of risks
In the second step of the AHP, the alternatives are selected. For this research, these are the six risks which have been attained in chapter 3 (table 11). Cheng et al. (2002) have recommended to limit overlap between the criteria for an effective AHP application. Therefore, overlap between the risks has been limited by combining related risks while offering a large amount of diversity. Moreover, this improves the workability of the AHP, as the amount of comparative judgements necessary from experts is reduced. The risks are applicable for both onshore and offshore wind parks, but all to a greater or lesser extent. Therefore, for both onshore and offshore wind parks, the weights of the risks are analysed.

<table>
<thead>
<tr>
<th></th>
<th>Description of the risks for the AHP application (Author's table)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Resource risk</td>
</tr>
<tr>
<td>A2</td>
<td>Technology risk</td>
</tr>
<tr>
<td>A3</td>
<td>O&amp;M risk</td>
</tr>
<tr>
<td>A4</td>
<td>Merchant risk</td>
</tr>
<tr>
<td>B1</td>
<td>Financial risk</td>
</tr>
<tr>
<td>C1</td>
<td>Regulatory risk</td>
</tr>
</tbody>
</table>

Table 11 - Description of the risks for the AHP application (Author's table)

5.4.3 Step 3 - Weight of risks
5.4.3.1 Comparative judgements
In the next step, the relative importance of each risk is measured by comparing it to another risk. This is done through pairwise comparison, in which the relative weights of the risks are generated. In the interviews, the investors are asked to rank the risks against each other by giving a risk a relative importance against the other risk by a numerical value (table 12). In case a risk is much more important than the other, investors can give it a high rate (e.g. 9, meaning much more important) (Palliam, 2005a). In case a risk is much less important than the other risk, a low rate can be given (e.g. 1/9, meaning much less important). In case the risks are of the same importance, a rate can be given which is close to 1 (e.g. 1, meaning equally important). The rating is conducted for onshore wind parks. In case the investor also invests in offshore wind parks, then it is also conducted for
offshore wind parks. All nine investors have filled in the comparative judgement of onshore wind parks, and six for offshore wind parks, resulting in nine tables for onshore wind parks, and six for offshore wind parks.

<table>
<thead>
<tr>
<th>Definition</th>
<th>Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolutely the most important</td>
<td>9</td>
</tr>
<tr>
<td>Much more important</td>
<td>7</td>
</tr>
<tr>
<td>More important</td>
<td>5</td>
</tr>
<tr>
<td>Slightly more important</td>
<td>3</td>
</tr>
<tr>
<td>Equal importance</td>
<td>1</td>
</tr>
<tr>
<td>Slightly less important</td>
<td>1/3</td>
</tr>
<tr>
<td>Less important</td>
<td>1/5</td>
</tr>
<tr>
<td>Much less important</td>
<td>1/7</td>
</tr>
<tr>
<td>Absolutely the least important</td>
<td>1/9</td>
</tr>
<tr>
<td>Intermediate judgements between two adjacent judgements</td>
<td>8, 6, 4, etc.</td>
</tr>
</tbody>
</table>

*Table 12 - Comparative judgment numerical equivalent (Saaty, 2008)*

5.4.3.2 Consistency rating

In order to test whether the investors’ ratings are reliable, the consistency of the comparative judgements is measured. If the consistency ratio (CR) does not reach a required level, the answers of the comparisons need to be re-examined (Saaty, 1980). Consistent ranking means that in case A1 > A2, and A2 > A3, then A1 > A3. The consistency index (CI) is gained by subtracting 1 from the maximum eigenvalue ($\lambda_{\text{max}}$), and dividing this by the number of criteria ($n$) minus 1 (equation 5.3). The maximum eigenvalue is the criterion which has the largest inconsistency measure. The consistency measure is generated by the product of two matrices; the horizontal sum of the criteria against the weights of all the criteria. In order to arrive at the consistency ratio (CR), the CI is divided by the random index (RI) (equation 5.4). The RI has a value for the number of criteria ($n$). In this research, six criteria are applied, and therefore the RI is set at 1.24 (table 13). Saaty (1980) proposes that the CR should be below 0.1 for the rating to be consistent. For this research, the consistency ratings of the investors have been checked against this rate. In case the CR did not reach a level below 0.1, the investor have been asked to fill in the rating again. With this, all interview results are consistent. Only two investors were asked to conduct the comparison again during the interview.

$$CI = \frac{(\lambda_{\text{max}} - 1)}{(n - 1)}$$  \hspace{1cm} (5.3)

$$CR = \frac{CI}{RI}$$  \hspace{1cm} (5.4)

<table>
<thead>
<tr>
<th>n</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>RI</td>
<td>0.00</td>
<td>0.00</td>
<td>0.58</td>
<td>0.9</td>
<td>1.12</td>
<td>1.24</td>
<td>1.32</td>
<td>1.41</td>
<td>1.46</td>
<td>1.49</td>
</tr>
</tbody>
</table>

*Table 13 - Random index (RI) for the number of criteria applied (Author’s table, based on Saaty (1980))*
5.4.3.3 Risk weights from the interviews

In order to calculate the weights of the criteria, all tables are normalized. This means that the ratings are divided by the total rating of the column, so they add up to 1 (Appendix D). Next, the ratings are added horizontally, and added up to arrive at a weight for the criterion. This is an indicator of the relative importance of the various criteria being compared (Saaty, 2008). The elements of the normalized numbers are the termed weights with respect to the criteria (risks) and ratings with respect to the alternatives (equity risk premiums). By taking the geometric mean of the risk weights of each interview, the risk weights are derived (table 14).

<table>
<thead>
<tr>
<th>A1 Resource risk</th>
<th>Onshore</th>
<th>Offshore</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>A2 Technology risk</td>
<td>7.7</td>
<td>9.1</td>
<td></td>
</tr>
<tr>
<td>A3 O&amp;M risk</td>
<td>6.9</td>
<td>10.3</td>
<td></td>
</tr>
<tr>
<td>A4 Merchant risk</td>
<td>30.6</td>
<td>31.5</td>
<td></td>
</tr>
<tr>
<td>B1 Financial risk</td>
<td>7.2</td>
<td>5.6</td>
<td></td>
</tr>
<tr>
<td>C1 Regulatory risk</td>
<td>15.0</td>
<td>9.3</td>
<td></td>
</tr>
</tbody>
</table>

Table 14 - Weight of risks through the geometric means from the comparative judgements of all interviews (Author’s table)

5.4.3.4 Explanations for the ratings

During the pairwise comparison of the risks, the investors were asked to provide reasoning behind the numerical values. In this way, an explanation is sought for the relative importance of one risk against the others. Resource risk and merchant risk for both onshore and offshore wind parks are by far the most important risks to the investors, as is reflected in table 14. The investors clarify that these are the two risks which cannot be completely controlled. The wind input simply cannot be completely determined, even with the most detailed wind studies, since actual wind input is uncertain. Furthermore, subsidy schemes and electricity prices affect the wind park’s revenues. These can partly be determined contractually, but complete certainty cannot be guaranteed. The other risks are less important to the investors, as these can mostly be mitigated through contractual agreements (technical risk and O&M risk) or hedging (financial risk). Regulatory risk is also important, as this determines the certainty of the subsidy schemes of the project, and tax regulations affecting the cash flows. When comparing the weights of the risks for onshore and offshore wind, the resource risk is slightly more important for offshore wind parks. Offshore wind parks are generally larger in scale than onshore variants. The size of the investment is therefore relatively higher, placing a higher importance at the wind input in order to generate revenues. Furthermore, technology risk and O&M risk are more important for offshore wind parks. This is because offshore wind parks are considered technologically more challenging than onshore wind parks due to their larger scale, distance to the shore, and higher maintenance requirements. Furthermore, in case a technical component fails offshore, the contractor has to travel to the site with a vessel which takes more time. The vessel needs to be rented in advance which requires adequate planning, and is very expensive. The vessel can also be bought by the O&M provider, but this is even more expensive. Financial risk and especially regulatory risk are less important for onshore wind parks than for offshore wind parks. This is because offshore wind parks are less regulated in terms of size, location, noise and visual regulations, and are more commercially driven than onshore wind parks (Kaldellis & Kapsali, 2013).
5.4.4 Step 4 - Risk ranges
As a next step, the six risks obtain a qualitative description for each of the risk levels as determined in step 1. During the interviews, the investors were asked what would be the situation for each risk of a wind park with a very low level of risk, a medium level of risk, and a high level of risk. The expert judgements are aggregated in order to arrive at qualitative descriptions for each risk for a low, medium and high risk level (Appendix E). For example, the low risk scenario for resource risk is a high certainty of wind data, p90 case or higher (90% certainty of the wind input), for medium risk there is some certainty of wind data, in terms of a p50 case (50% certainty of the wind input), and low risk means that there is little certainty of the wind data, as little or no data is available. Since it is assumed that the wind parks are optimally financed, gearing risk is not included in O&M risk. As the timing of the investment matters, the risk ranges apply to the moment after commissioning of the wind park, at the start of operations. This is where most infrastructure funds step in (section 2.5).

5.4.5 Step 5 - Application to case studies - risk descriptors
The four wind parks obtain a risk premium for each risk by comparing them to the risk descriptions as set in step 4. These qualitative risk descriptors for each level of risk correspond to the quantitative equity risk premiums as determined in step 1 (table 10). The wind parks are assessed from the point when they are commissioned, and the wind park goes into operation. Table 15 shows an overview of the characteristics of the four wind parks, from which the equity risk premium for each risk can be calculated. This is all the information necessary for applying the AHP to calculate the return on equity. Certainly, the more information about the wind park is available, the more insight this provides. For a good application of the AHP however, the information as provided in table 15 offers enough insight to perform the calculations.

The four wind parks have different characteristics, which determines the composition of their equity risk premium

<table>
<thead>
<tr>
<th>Type</th>
<th>Alpha</th>
<th>Beta</th>
<th>Gamma</th>
<th>Delta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Country</td>
<td>Germany</td>
<td>France</td>
<td>Germany</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>Size indication (MW)</td>
<td>50 - 100</td>
<td>10 - 50</td>
<td>200 - 300</td>
<td>300 - 400</td>
</tr>
<tr>
<td>Wind data (A1)</td>
<td>p50</td>
<td>p50</td>
<td>p50</td>
<td>p50</td>
</tr>
<tr>
<td>Availability (A2)</td>
<td>97% availability warranty</td>
<td>97% availability warranty</td>
<td>95% availability warranty</td>
<td>95% availability warranty</td>
</tr>
<tr>
<td>Turbines (A2)</td>
<td>Gamesa G80 &amp; Vestas V80</td>
<td>Senvion MM92</td>
<td>Siemens SWT-3.6-120</td>
<td>Siemens</td>
</tr>
<tr>
<td>O&amp;M (A3)</td>
<td>full lifetime O&amp;M</td>
<td>15 years O&amp;M</td>
<td>13 years O&amp;M</td>
<td>15 years O&amp;M</td>
</tr>
<tr>
<td>Merchant (A4)</td>
<td>20 years FiT</td>
<td>15 years FiT</td>
<td>8 years FiT</td>
<td>15 years ROC</td>
</tr>
<tr>
<td>Financial (B1)</td>
<td>Very low risk</td>
<td>Very low risk</td>
<td>Very low risk</td>
<td>Low risk</td>
</tr>
<tr>
<td>Regulatory (A3)</td>
<td>Very low risk</td>
<td>Low risk</td>
<td>Very low risk</td>
<td>Medium risk</td>
</tr>
</tbody>
</table>

Table 15 - Overview of the four wind parks and their characteristics (Author's table)

5.4.5.1 Resource risk (A1)
The wind data as of operations is set at p50 for all wind parks. This means that the net energy production is just as likely to not be met as to be exceeded (Klug, 2006). P50 is determined with an energy yield production, in which the probability of reaching a higher or lower annual production is both 0.5. P75 means the annual energy production is reached with a 75% probability, p90 means that the risk of not reaching the predicted net energy production is 10%. Therefore, the higher the probability of reaching the annual energy production, the lower the uncertainty or risk of a lower
The relation between risk and return in wind park investments

energy production. With an annual energy production of p50, the resource risk for all wind parks corresponds with medium risk (Appendix E). For the onshore wind parks Alpha and Beta, this this is a risk premium of 5.6%, and for Gamma and Delta 7.4% (table 10).

5.4.5.2 Technology risk (A2)

Alpha has a warranty for an availability rate of 97% for the full lifetime of the wind park, as set contractually. The wind park has Gamesa G80 turbines, which have an acceptable track record, and Vestas V80 wind turbines, which have a very good track record. Therefore, the risk level is set at low, corresponding with a risk premium of 3.8%. Beta also has a warranty for an availability rate of 97% for the wind park’s lifetime. Furthermore, the wind turbines have a good track record. Therefore, the risk level is also set at low. Gamma has a 95% availability warranty, and Siemens SWT-3.6-120 wind turbines with a good track record. Siemens will conduct the operation for 5 years, after which the O&M provider takes over. This poses some uncertainty to the availability of the wind parks since the wind turbine manufacturer opts out after 5 years already. However, the O&M provider is presumed to have sufficient knowledge about the wind turbines. Therefore, the risk level is set at medium, with a risk premium of 7.4%. Delta has a warranty for an availability rate of 95% also for the full lifetime of the wind park with a performance incentive mechanism. This incentivises the contractor to keep the availability rate as high as possible, as this will offer him benefits. The wind park has Siemens wind turbines, also with a good track record. Therefore, the risk level of Delta in terms of technological risk is set at low, with a corresponding risk premium of 5.6%.

5.4.5.3 O&M risk (A3)

O&M risk contains the contractual arrangements for the operations and maintenance of the wind park. In case the contracts are set for a long period, there is less uncertainty or risk about the continuation of the wind park. Alpha has an O&M contract for the lifetime of the wind park, the supplier has a good track record. The risk level is therefore set at low, with a risk premium of 3.8%. The O&M contract for Beta is set at 15 years. The contractor who constructed the wind park will also conduct the O&M of the wind park for these first 15 years. Therefore, the risk level is set at medium, with a risk premium of 5.6%. Gamma has an O&M contract for 13 years, and a possible extension of 7 years. The contractor has a good track record. Therefore, the risk level is set at medium, with a risk premium of 7.4%. Delta has an O&M contract for 15 years with a supplier with an acceptable track record. Therefore, the risk level is also set at medium.

5.4.5.4 Merchant risk (A4)

The subsidy guarantees are very important to the investor, as this determines the exposure to electricity prices. The electricity price is volatile, and due to the merit order, the prices may be lower than expected. Alpha has a FiT scheme for 20 years. This is a very steady income stream for the wind park, and since wind parks have an asset life of 25 - 30 years, it covers a large part of the wind park’s lifetime. After the 20 years, the electricity prices will depend on the market. Therefore, the level of risk is set at low, with a risk premium of 3.8%. Beta has a 15 years FiT scheme. Therefore, the risk level is set at medium, with a risk premium of 5.6%. Gamma has a FiT scheme for 8 years, after which a floor tariff of the price is prescribed (lower price boundary). Therefore, the risk level is set at high, with a risk premium of 9.3%. Delta has a ROC scheme for 15 years. The electricity price of the project depends on the market electricity prices, but is protected with a cap and floor price (higher and lower boundary). The scheme is not very certain, and lasts for 15 years, after which the project is exposed to the market prices, without caps and floors. Therefore, the risk level is set at medium, with a risk premium of 7.4%.
5.4.5.5 Financial risk (B1)
Financial risk consists of the macro-economic risks posed to a wind park, including currency risk and inflation risk, affecting the value of the investment. Alpha, Beta and Gamma have very little currency risks, as the Euro has remained stable over the last years. Delta has some currency risks due to the Brexit. There is no information about inflation hedging for the projects. The risk level for Alpha and Beta is therefore set at very low, with a risk premium of 2.2%. Gamma also has a very low risk, with a risk premium of 3.8%. The risk level for Delta is set at medium, with a risk premium of 7.4%.

5.4.5.6 Regulatory risk (C1)
Regulatory risk depends on stability of the country of the wind park in keeping its promises for subsidy schemes and tax regulations. In a study from Coface (2017), 160 countries have been assessed on their stability of keeping financial commitments. A range of scores from A1 to E is maintained. A1 means the risk is very low, A2 means low, A3 satisfactory, A4 means reasonable, B fairly high, C high, D very high, and E extreme. When comparing Germany (wind parks Alpha and Gamma), France (wind park Beta) and United Kingdom (wind park Gamma), Germany has a score of A1, France A2, and UK A3. Therefore, the risk level for Alpha and Gamma is set at very low, with corresponding risk levels of 2.2% (onshore), and 3.8% (offshore). The risk level for Beta is set at low, with a risk premium of 3.8%. Furthermore, the risk level for Delta is set at medium, with a risk premium of 7.4%.

5.4.6 Step 6 - Equity risk premiums for the wind parks
In this step, the results from step 3 (the risk weights of the investors) are multiplied with the results from step 5 (the risk premiums for the specific wind park). This results an equity risk premium for each risk. By adding these risk premiums, the total equity risk premium for each wind park is calculated (tables 16 and 17).

5.4.7 Step 7 - The return on equity
The last step of the AHP is to add the risk-free rate to the equity risk premium of the wind park, resulting in the return on equity. The nominal risk-free rate applied is 2.44% (step 1). Furthermore, the CRP for the countries is added. For Germany, the CRP is 0%, therefore the risk-free rate for Alpha and Gamma is 2.44%. France has a CRP of 0.37%, resulting in a risk-free rate of 2.81%. The UK has a CRP of 0.48%, resulting in a risk-free rate of 2.48%. By adding these risk-free rates to the equity risk premiums are derived in step 6, the return on equity for the wind parks is derived. Alpha has a return on equity of 5.94%, Beta 7.23%, Gamma 9.23%, and Delta 9.5%. Table 9 shows the return on equity of onshore and offshore wind parks for various levels of risk. With this, the relative risk of the investment can be determined qualitatively. The risk levels of the wind parks vary from low to medium risk. This is because infrastructure fund investors have a long-term investment strategy, and aim at projects with low risk (section 2.5). Most of these investors will not invest in a wind park with a high level of risk, as they perceive this as too risky, and this is not part of their strategy.

With a return of 5.94%, Alpha is considered a low risk investment. This is because there is sufficient wind data (medium resource risk), availability guarantees (low technology risk), good contract terms with contractor (low O&M risk), a safe subsidy scheme for a long period (low merchant risk), and high political stability (very low regulatory risk).
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Beta has a return of 7.23%, and therefore it is considered a medium-low risk investment. This is because there is sufficient wind data (medium resource risk), there are good availability guarantees (low technology risk), the O&M contract period is set for 15 years (medium risk), the FiT scheme is set for 15 years (medium risk), there is very little currency risk (very low financial risk), and France is a stable country (low regulatory risk).

The return on equity for Gamma is 9.23%. Therefore it is considered a medium-low risk investment. This follows from a sufficient amount of wind data (medium resource risk), sufficient availability guaranteed (medium technology risk), a sufficient O&M contract period (medium O&M risk), a relative short term FiT subsidy scheme (high merchant risk), there is very little currency risk (very low financial risk), and German has a high political stability (very low regulatory risk).

Delta has a return on equity of 9.50%. Therefore, it is considered a medium risk investment. The p50 wind case offers sufficient wind data (medium resource risk), the availability warranty is sufficient, lasts for the lifetime of the wind park and has an incentive scheme (low technology risk), the O&M contract is set for 15 years (medium O&M risk), and the ROC scheme is set for 15 years (high merchant risk). Furthermore, wind parks in the UK have some exposure to currency risk (medium financial risk), and some uncertainty in the political stability (medium regulatory risk).

The risk weights are set by the comparative judgements of the investors, and the risk descriptor is specific for the wind park, and is linked to the range of risk premiums. Therefore, the risk weights and risk premiums are the sensitivity factors of this calculation. The risk weights determine the importance of the specific risk, and the risk premium is the exposure of the risk for the specific wind park. As is illustrated in tables 16 and 17, merchant risk and resource risk take up most of the equity risk premium. Therefore, in case the risk level for a wind park is high for these risks, this consequently results in a high risk premium. Technology risk and O&M risk are higher for the offshore wind parks. However, since the risk weight of these risks is relatively low, their effect is less high than for resource risk and merchant risk. The share of regulatory risk on the risk premium is lower for the offshore wind parks, as the risk weight for regulatory risk is lower for offshore wind. Merchant risk is all the more important, as offshore wind parks generally have a higher exposure to merchant risk than regulatory risk (step 3). Also, resource risk is higher for the offshore wind parks, due to the larger scale of offshore wind parks.
Return on equity for wind park Alpha with the AHP

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Criterium (risk)</th>
<th>Risk weight (%)</th>
<th>Risk descriptor wind park</th>
<th>Risk premium (%)</th>
<th>Product (1) x (3)</th>
<th>Share of risk premium</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Resource risk</td>
<td>22.85</td>
<td>Medium</td>
<td>5.62</td>
<td>1.28%</td>
<td>36.7%</td>
</tr>
<tr>
<td>A2</td>
<td>Technology risk</td>
<td>7.71</td>
<td>Low</td>
<td>3.84</td>
<td>0.30%</td>
<td>8.4%</td>
</tr>
<tr>
<td>A3</td>
<td>O&amp;M risk</td>
<td>6.93</td>
<td>Low</td>
<td>3.84</td>
<td>0.27%</td>
<td>7.6%</td>
</tr>
<tr>
<td>A4</td>
<td>Merchant risk</td>
<td>30.56</td>
<td>Low</td>
<td>3.84</td>
<td>1.17%</td>
<td>33.5%</td>
</tr>
<tr>
<td>B1</td>
<td>Financial risk</td>
<td>7.21</td>
<td>Very low</td>
<td>2.18</td>
<td>0.16%</td>
<td>4.5%</td>
</tr>
<tr>
<td>C1</td>
<td>Regulatory risk</td>
<td>15.03</td>
<td>Very low</td>
<td>2.18</td>
<td>0.33%</td>
<td>9.3%</td>
</tr>
</tbody>
</table>

Equity risk premium 3.50%
Risk-free rate of the country 2.44%
Return on equity (AHP) 5.94%
Return on equity (CAPM) 7.12%

Return on equity for wind park Beta with the AHP

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Criterium (risk)</th>
<th>Risk weight (%)</th>
<th>Risk descriptor wind park</th>
<th>Risk premium (%)</th>
<th>Product (1) x (3)</th>
<th>Share of risk premium</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Resource risk</td>
<td>22.85</td>
<td>Medium</td>
<td>5.62</td>
<td>1.28%</td>
<td>29.0%</td>
</tr>
<tr>
<td>A2</td>
<td>Technology risk</td>
<td>7.71</td>
<td>Low</td>
<td>3.84</td>
<td>0.30%</td>
<td>6.7%</td>
</tr>
<tr>
<td>A3</td>
<td>O&amp;M risk</td>
<td>6.93</td>
<td>Low</td>
<td>3.84</td>
<td>0.39%</td>
<td>8.8%</td>
</tr>
<tr>
<td>A4</td>
<td>Merchant risk</td>
<td>30.56</td>
<td>Medium</td>
<td>5.62</td>
<td>1.72%</td>
<td>38.8%</td>
</tr>
<tr>
<td>B1</td>
<td>Financial risk</td>
<td>7.21</td>
<td>Very low</td>
<td>2.18</td>
<td>0.16%</td>
<td>3.6%</td>
</tr>
<tr>
<td>C1</td>
<td>Regulatory risk</td>
<td>15.03</td>
<td>Low</td>
<td>3.84</td>
<td>0.58%</td>
<td>13.0%</td>
</tr>
</tbody>
</table>

Equity risk premium 4.42%
Risk-free rate of the country 2.81%
Return on equity (AHP) 7.23%
Return on equity (CAPM) 7.54%

Table 16: Calculation of the return on equity for onshore wind parks Alpha (Germany onshore) and Beta (France onshore) with the AHP (Author’s table)
### Return on equity for wind park Gamma with the AHP

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Criterium (risk)</th>
<th>Risk weight (%)</th>
<th>Risk descriptor wind park</th>
<th>Risk premium (%)</th>
<th>Product (1) x (3)</th>
<th>Share of risk premium</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Resource risk</td>
<td>24.86</td>
<td>Medium</td>
<td>7.43</td>
<td>1.85%</td>
<td>27.2%</td>
</tr>
<tr>
<td>A2</td>
<td>Technology risk</td>
<td>9.13</td>
<td>Medium</td>
<td>7.43</td>
<td>0.68%</td>
<td>10.0%</td>
</tr>
<tr>
<td>A3</td>
<td>O&amp;M risk</td>
<td>10.31</td>
<td>Medium</td>
<td>7.43</td>
<td>0.77%</td>
<td>11.3%</td>
</tr>
<tr>
<td>A4</td>
<td>Merchant risk</td>
<td>31.49</td>
<td>High</td>
<td>9.30</td>
<td>2.93%</td>
<td>43.2%</td>
</tr>
<tr>
<td>B1</td>
<td>Financial risk</td>
<td>5.57</td>
<td>Very low</td>
<td>3.80</td>
<td>0.21%</td>
<td>3.1%</td>
</tr>
<tr>
<td>C1</td>
<td>Regulatory risk</td>
<td>9.35</td>
<td>Very low</td>
<td>3.80</td>
<td>0.35%</td>
<td>5.2%</td>
</tr>
</tbody>
</table>

Equity risk premium: 6.79%
Risk-free rate of the country: 2.44%
Return on equity (AHP): 9.23%
Return on equity (CAPM): 8.62%

### Return on equity for wind park Delta with the AHP

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Criterium (risk)</th>
<th>Risk weight (%)</th>
<th>Risk descriptor wind park</th>
<th>Risk premium (%)</th>
<th>Product (1) x (3)</th>
<th>Share of risk premium</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Resource risk</td>
<td>24.86</td>
<td>Medium</td>
<td>7.43</td>
<td>1.85%</td>
<td>28.1%</td>
</tr>
<tr>
<td>A2</td>
<td>Technology risk</td>
<td>9.13</td>
<td>Low</td>
<td>5.63</td>
<td>0.51%</td>
<td>7.8%</td>
</tr>
<tr>
<td>A3</td>
<td>O&amp;M risk</td>
<td>10.31</td>
<td>Medium</td>
<td>7.43</td>
<td>0.77%</td>
<td>11.7%</td>
</tr>
<tr>
<td>A4</td>
<td>Merchant risk</td>
<td>31.49</td>
<td>Medium</td>
<td>7.43</td>
<td>2.34%</td>
<td>35.6%</td>
</tr>
<tr>
<td>B1</td>
<td>Financial risk</td>
<td>5.57</td>
<td>Medium</td>
<td>7.43</td>
<td>0.41%</td>
<td>6.3%</td>
</tr>
<tr>
<td>C1</td>
<td>Regulatory risk</td>
<td>9.35</td>
<td>Medium</td>
<td>7.43</td>
<td>0.69%</td>
<td>10.6%</td>
</tr>
</tbody>
</table>

Equity risk premium: 6.58%
Risk-free rate of the country: 2.92%
Return on equity (AHP): 9.50%
Return on equity (CAPM): 9.32%

*Table 17 - Calculation of the return on equity for offshore wind parks Gamma (Germany offshore) and Delta (UK offshore) with the AHP (Author’s table)*
5.4.8 Sensitivity analysis

The relative importance of each risk according to its effect on the return on equity is illustrated in a sensitivity analysis (figure 15). For both onshore and offshore wind parks, the risk premiums for the very low levels of risk (table 10) are multiplied with the weight of the risks (table 14). The same is done for the very high levels of risk. This provides a general overview of the importance of the risks, and why they affect the return on equity of the described wind parks. This also offers insight into future calculations and valuations of other wind parks, as further insight is provided of the constitution of the return on equity. Merchant risk is the highest indicator for the return, and has the highest sensitivity of all risks when comparing its very high risk level to its very low risk level. Resource risk has the highest sensitivity on the level of risk after that. Technology risk and financial risk for offshore wind have a higher effect on the return than for onshore wind, but O&M risk and regulatory risk have a higher effect on onshore wind parks than for offshore wind parks. Furthermore, this sensitivity analysis shows that the ranges of the effect on the return vary widely, from a 0.2% premium for the very low risk scenario for financial risk of onshore wind parks, versus a 3.5% premium for the very high risk scenario for merchant risk of offshore wind parks. The risk premiums for the very low risk scenarios for O&M risk, regulatory risk, technology risk, and financial risk are very close, whereas for the very high risk scenarios these have a wider spread.

Based on these AHP results, it can therefore be concluded that resource risk and especially merchant risk are important for the investors when investing in a wind park. Especially for offshore wind parks, they can result in a high risk premium for the investment. As an investor, it would therefore be wise to stimulate the analysis electricity price forecasts, and the mitigation of the exposure to these prices by aiming for investments with long subsidy scheme regulations. Furthermore, an in-depth, long-term analysis of the wind forecasts for a wind park is very important when investing. Additionally, more certainty about the wind data can be obtained by placing instruments on the location of the wind park long before construction and operation, or assessing wind data from wind parks which are in the neighbourhood of the specific wind park. On the other hand, financial risk has the lowest effect on the return. The investors indicate that this is because this risk can mostly be hedged, and especially the project-specific, unsystematic risks are highly important, as these often cannot be completely controlled.
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Figure 15 - Sensitivity analysis of the risks of onshore and offshore wind parks (Author's figure)
5.5 AHP versus CAPM

In the previous section, the return on equity of four wind parks has been calculated with the AHP. In order to illustrate the working of the AHP, its strengths and weaknesses, the results from the AHP are compared to the CAPM in this section. The AHP calculations of the four wind parks are compared with CAPM calculations for the same wind parks. In chapter 4, the differences and similarities between several models has been described. CAPM, as practiced in corporate finance, is widely applied and acknowledged because it is easy to apply and gives a general, top-down insight of the risk and return an investment. However, it generally only takes systematic risks into account, has many assumptions which could be questioned, it does not regard a single investment in isolation, and is mostly suitable for listed assets and diversified investors.

On the other hand, AHP offers a different insight by applying a bottom-up approach through a risk assessment of the investment, as well as a top-down market view through expert judgements. Risks can be quantified individually, as well as their effect on the return, and valuable insight information can be elicited through the expert interviews. However, the AHP assumes that the experts reflect the market, the risk factors are not specified, and a large number of comparisons may need to be asked from the experts. With the AHP, the total investment risk can be incorporated, and it is suitable for unlisted assets.

Because of the different assumptions and workability of the two models, it is interesting to compare their results. The CAPM calculations have been derived from EY, in which the return on equity calculations for the four wind parks are based on the same assumptions. The calculations have not been performed by the author since:

- This enables the CAPM calculations to be completely independent of this research, preventing bias;
- This improves the reliability of the CAPM calculation since it is conducted by an experienced analyst, and not by the author itself who has never conducted a CAPM calculation before;
- This enables a common ground on which the AHP method can be compared to a typical, routinized CAPM calculation for all types of investments, including wind parks.

5.5.1 CAPM calculation

Like the AHP equation, a risk premium is added to the risk-free rate in order to calculate the return on equity with the CAPM. However, in the CAPM the risk premium is calculated by multiplying the beta with the market risk premium (equation 4.2). The betas of the wind parks are calculated by taking a peer group of listed investment funds which are illustrative of the specific wind park. These funds often consist of a mix of wind parks, solar installations, or other renewable assets. This is because there are only a few listed funds merely with wind park investments. Furthermore, as there are limited peers in the offshore wind sector, peers with onshore wind parks have been taken, and a project risk premium has been added to the return on equity. Based on a market study, the market risk premium (MRP) has been determined. This results in the return on equity of the four wind parks with the CAPM (Appendix F). For German investments, the risk-free rate is 2.44%, for French investments it is 2.81%, and for investments in the UK it is 2.92% (section 5.4.7). EY applies a MRP of 5.0 – 6.0% (Damodaran, 2017). For this research, the average is taken, so a MRP of 5.5%. The betas of the wind parks range from 0.76 for Gamma to 0.86 for Beta. This difference is because of a different the peer selection, and leverage. With this, the return of Alpha is calculated at 7.12%, for Beta at 7.54%, for Gamma at 8.62% and for Delta at 9.32%.
5.5.2 Comparing AHP returns with CAPM returns

The results of the AHP can now be compared to the CAPM results (table 18, figure 16 and figure 17). The results illustrate that the returns for the onshore wind parks with the AHP are lower than with the CAPM, but for offshore wind parks they are higher. Therefore, it can be stated that the range of the returns with AHP is larger than the range of the CAPM returns for this research set. Furthermore, the share of unsystematic risk with the AHP for the wind parks is higher than in the CAPM calculation. The CAPM calculations for the wind parks are analogous, but a project specific risk premium for technology risk and merchant risk is added in the calculations of the offshore wind parks since there are no offshore peers available for the calculation.

The results of wind park Alpha show the largest difference between AHP and CAPM. The return on equity is 5.94% with the AHP, and 7.12% with CAPM. From the AHP calculation, it follows that it is a low risk investment, as Germany is a very stable country, and the contracts are low in risk. However, the CAPM return is 1.17% higher. The beta of Alpha (0.85) is equal to the beta of Beta (0.86), but higher than the beta for Gamma (0.76) or Delta (0.80). This seems contradictory from an AHP perspective, as Alpha has the lowest risk compared to the other wind parks. No project specific risk premiums have been added in the CAPM calculation. Since Alpha is low in risk, the ratio of unsystematic risk as compared to systematic risk is equal for the AHP. There are no unsystematic risks in the CAPM calculation of the wind park, and therefore this ratio is zero for the CAPM.

The return on equity for Beta with the AHP is calculated at 7.23%, and with CAPM at 7.54%. This is only a small difference. Also here, the results for AHP are lower than for CAPM. Beta is regarded as a medium-low investment risk according to the AHP, and this is confirmed in the CAPM calculation.

Also for Beta, the ratio of unsystematic and systematic risks is 1.0 with the AHP, and 0 with CAPM.

The CAPM calculations for Alpha and Beta are similar, since they have a similar beta (only a 0.01 difference), the same market risk premium, and no project specific risk premium. The only difference is that Beta is located in France, and therefore, a CRP of 0.37% is added. The AHP calculations for the two wind parks are different though. In the AHP it is illustrated that Alpha is a low risk investment due to its safe contracts and especially its long-term FiT, whereas Beta is a medium-low risk investment due to its medium risk contracts, and 15 year FiT. Therefore, AHP highlights the project-specific characteristics of the two wind parks, and their differences.

<table>
<thead>
<tr>
<th>Type</th>
<th>Alpha</th>
<th>Beta</th>
<th>Gamma</th>
<th>Delta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Country</td>
<td>Onshore</td>
<td>Onshore</td>
<td>Offshore</td>
<td>Offshore</td>
</tr>
<tr>
<td>AHP ratio unsys : sys risk</td>
<td>1.0</td>
<td>1.0</td>
<td>2.1</td>
<td>1.4</td>
</tr>
<tr>
<td>CAPM ratio unsys : sys risk</td>
<td>0.0</td>
<td>0.0</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Return on equity (AHP)</td>
<td>5.94%</td>
<td>7.23%</td>
<td>9.23%</td>
<td>9.50%</td>
</tr>
<tr>
<td>Return on equity (CAPM)</td>
<td>7.12%</td>
<td>7.54%</td>
<td>8.62%</td>
<td>9.32%</td>
</tr>
<tr>
<td>Difference returns AHP &amp; CAPM</td>
<td>-1.17%</td>
<td>-0.31%</td>
<td>0.61%</td>
<td>0.18%</td>
</tr>
</tbody>
</table>

Table 18 - Comparison AHP and CAPM calculation outcomes for the four wind parks (Author's table)
Figure 16 - Constitution of the risks of the AHP versus the CAPM for wind parks Alpha and Beta (Author's figure)
The relation between risk and return in wind park investments

Figure 17 - Constitution of the risks of the AHP versus the CAPM for wind parks Gamma and Delta (Author’s figure)
Gamma has a return on equity of 9.23% with the AHP, and 8.62% with CAPM. After Alpha, this 0.61\% difference between the AHP and CAPM returns is the highest. In the CAPM calculations, a project specific risk premium of 2\% is added to the return for Gamma. This consists of a technical risk premium of 1\%, and a merchant risk premium of 1\%. The technical risk premium is added as there are limited peers available for offshore wind parks, and therefore the onshore peer set is compensated with this 1\% technology premium. Merchant risk is added as a premium since the wind park has a significant risk of electricity prices since the FiT scheme is only for 8 years. However, the return for Gamma in the AHP calculation is higher, since the contracts and FiT are only set for a few years. These risks have a higher effect on the return than for the CAPM calculation. The ratio of unsystematic risk versus systematic risk is two times as high for Gamma in the AHP calculation. This is because especially merchant risk generates a high risk premium. In the CAPM calculation, this ratio is 0.2.

The return on equity for Delta with the AHP is 9.50\%, and 9.32\% with CAPM. This difference of 0.18\% is the smallest compared to the other wind parks. Also in the CAPM calculations for Delta, a risk premium of 2\% is added with technology risk at 1\%, and merchant risk at 1\%, with the same line of reasoning. The ratio of unsystematic versus systematic risks is 1.5 times as high for the AHP, and 0.2 for CAPM.

When comparing Delta and Gamma, the risk premium for Delta is slightly higher than for Gamma. This is because the beta is slightly higher, as a different peer group has been used with peers more active in the UK, which are regarded as more risky than German peers. This also follows from the AHP results, as the return for Delta is higher than for Gamma. In the AHP, financial risk, regulatory risk and the risk-free rates are higher for Gamma. Therefore, the ratio unsystematic versus systematic risk is also lower for Gamma than for Beta.

The AHP and CAPM results show differences which are explainable and interesting. The CAPM calculations offer a top-down market insight, of which the market risk premium for all investments is applied, and the beta determines the relative risk of the investment. The assumptions for the wind park calculations are similar, and only the beta affects the systematic risk premium. Yet, for the offshore wind parks a risk premium has been added to compensate for the limited amount of available offshore peers to calculate the beta. On the other hand, the AHP applies a bottom-up approach based on the risks of the wind parks, and their relative effect in terms of their risk premium. These premiums are partly determined by a top-down market view from expert judgements, as well as a bottom-up approach by the relative level of risk for a specific wind park. The relative levels of risk can be directly translated to the return of the wind park, whereas for CAPM a more general risk premium is added, from which insight into the exact risks is missing. The results show that the returns for onshore wind parks with the AHP are lower than with the CAPM. For the offshore wind parks, the returns with the AHP are higher than with the CAPM. Thus, the AHP shows a larger range of returns for the wind parks, and highlights their differences. Therefore, it can be stated that AHP offers insight into the required return for an investor which is more substantiated and detailed. Different wind parks can be compared using the same approach, and their similarities and differences in terms of their risks are illustrated. Furthermore, the AHP can be applied to unlisted assets and includes unsystematic risk in the return calculation. With this, the information problem of insufficient or inadequate listed peers in the CAPM calculation is overcome. However, the CAPM has been researched and applied extensively, and therefore has more evidence. The AHP has never been applied as method to calculate the returns for different types of assets, also not for different wind parks, and therefore the risk factors have not been specified in advance. Therefore, this research has been the first step into the application of the AHP in this form. All in all, it can be stated that the AHP shows promising results based on this research set, also as compared to CAPM.
5.5.3 AHP and CAPM as models for describing risk and return

The AHP and CAPM have been compared based on the analysis of the four wind parks. When comparing AHP and CAPM as models for describing risk and return, they can be analysed based on their adherence to the five principles for a good risk and return model from Damodaran (2014). According to Damodaran (2014), a good risk and return model should:

1. Offer a measure of risk can be applied to all different types of assets;
2. Include a rationale for the delineation of different types of risks that are included;
3. Include standardized ways to measure risk, offering the investor to draw conclusions about whether the asset is below, similar to or above average risk;
4. Translate the measured risk into a return in which an investor is compensated for bearing the risk;
5. Be able to explain not only past returns, but also to predict future expected returns.

Principle 1
The AHP has been applied in this research as a way to illustrate the relation between risk and return of wind park investments. The criteria, or risks, have been selected and are specific for onshore and offshore wind parks. The AHP can be applied to all different types of assets, including other renewable energy assets, other infrastructure assets, or even assets from a different asset class (section 2.2). For this, the risks should be identified at first for each asset types, after which an expert judgement is conducted, and the AHP can be applied to the specific asset. The AHP is very flexible in its application, as the factors are not specified before. This is an advantage as it can be applied to all different kinds of assets, but can also be a limiting factor as it depends on the approach of the user. Therefore, the selection procedure of the criteria, as well as the expert judgements to arrive at the weight of the criteria is very important. Thus, the first principle is met in the AHP. The CAPM on the other hand is a well-established model, in which the factors are specified in advance, and it holds several assumptions. The CAPM can be widely applied, and therefore also to different types of asset classes. For different asset classes, only a different peer set is required to reflect the relative risk of an investment, to form the beta of the investment. CAPM therefore also adheres to the first principle.

Principle 2
Analogous to the CAPM, an equity risk premium is added to the risk-free rate in the AHP. In the AHP, risk plays a central role, as these are the criteria for the AHP. The equity risk premium is divided into independent analysable sub-risks. The risk factors are specified for wind parks in this research, and can be altered for different types of other assets. Therefore, it adheres to the second principle. In the CAPM, this risk premium consists of the beta multiplied by a market risk premium, resulting in a systematic risk premium. The CAPM therefore adheres to this second principle. However, it misses insight information about the exact risks which determine the return, and what the differences are between assets, as all of the risks are captured in the market risk premium.

Principle 3
The strength of the AHP is that risks can be quantified individually (section 4.4.1). This is done through the comparative judgements of experts as the first step, offering additional insight information, and the application to case studies as the second step. The first step has been described extensively in theory, and therefore this is a standardized risk measure. The second step however has not been standardized in the literature, as the AHP has never been applied before to wind parks. In this research, the second measure has been standardized through interviews with investors in order to provide a qualitative assessment of the different levels of risk for each type of risk. From the
first step of the AHP, a range of returns has been established to which the asset can be compared. Therefore, there is insight into the relative risk of the investment as compared to other assets. Concluding, the risk measure of the AHP is standardized, and the relative risk of an investment can be assessed as compared to other assets. Therefore, the AHP adheres to the third principle.

In the CAPM, risk is measured by the beta. Since the CAPM is a well-established model, this risk measure is therefore also standardized. The beta is also a measure of the relative risk of an investment as compared to other assets. In case the beta is above 1, it is regarded as relatively risky. In case it is below 1, it is regarded as relatively safe. Therefore, the CAPM adheres to principle 3.

**Principle 4**

Another strength of the AHP is that risk is directly reflected into the return, as the risks obtain a risk premium. This not only offers insight into the composition of the return on equity, but also the differences in the compositions of the returns for different wind parks. With this, the investor is compensated for the risks to which he is exposed when investing in a wind park. Therefore, the AHP adheres to principle 4.

In the CAPM, the return is also calculated by quantifying risks. However, only market risk and maturity risk are reflected in the return. In case an investor is not fully diversified, the CAPM does not hold. Also, the CAPM needs market data of listed asset to calculate the beta. In case the investment concerns an unlisted asset, the CAPM calculation may be deficient. Therefore, the fourth principle is not met with CAPM.

**Principle 5**

The final principle from Damodaran (2014) is that the model should do well is not only explaining past results, but also in predicting future expected returns. This is not as simple as it sounds, as the relation between risk and return is not fixed, but rather fluctuates with market sentiments, supply and demand, risk perceptions, and investment strategies, only to name a few. In a perfect world, this relation would be constant, and past returns would reflect future expected returns, and vice versa. In reality, this is not the case though. However, patterns in risk and return can be distinguished.

In the AHP, 12 investors have been interviewed in total (three for the criteria selection, and nine for the comparative judgement). These investors have several years of experience in wind park investments, and therefore can explain past returns. On the other hand, this experience and market insight helps them to make future decisions about their investments, and therefore they also have insights into future expected returns. From this perspective, they have answered the questions of the AHP in this research. Therefore, in theory, the risks, their weights and the qualitative descriptions of the risks reflect past returns, as well as future expected returns. The AHP could be updated every month or year, according to the wishes of the investor. However, on the short term it is expected that not much will change about the AHP as it is applied in this research, as future expected returns are also incorporated.

In the CAPM, the beta and the market risk premium determine the return. The market risk premium varies only slightly. The beta depends on the peer set of the calculation. In principle, also CAPM explains the past returns and expected future return. On the other hand, it depends on the market capitalization (section 4.2) of the peer set at the moment of the calculation, and therefore also the CAPM should be updated regularly.

All in all, AHP adheres all principles, and CAPM to all expect the fourth principle (table 19). The models both have several advantages and disadvantages (chapter 4). This section illustrates the strength of the AHP in quantifying individual risk, and translating this risk into returns. Therefore, insight is gained into the composition of the return of an investor for which he is more precisely
compensated for the risks be bears as compared to the CAPM calculation. In case enough information is available about an asset, the AHP can be applied as a good model to describe the relation between risk and return of a wind park, and other assets. Only the general characteristics and contract terms suffice for the AHP calculation. More information is welcome, but the AHP calculation can be conducted with general information.

The CAPM is a more established model, and offers a standardized way to measure risk. However, the model misses depth in the translation of the different risks to which an investor is exposed into the return. Whereas CAPM applies a top-down market approach, AHP applies an approach which is more bottom-up through the different risks of an investment, while also including a top-down approach through expert judgements. In case an investor wishes to continue using CAPM, it could be applied as a general check of the return of an asset as compared to its place in the market, and be complemented with the AHP to offer further insight into the composition of the return.

Moreover, the AHP as a model for risk and return could be improved by further applying it to other types of assets. With this, both its theoretical and empirical foundations can be further enhanced.

<table>
<thead>
<tr>
<th>A good risk and return model should:</th>
<th>AHP</th>
<th>CAPM</th>
</tr>
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<tbody>
<tr>
<td>1. Offer a measure of risk can be applied to all different types of assets</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>2. Include a rationale for the delineation of different types of risks that are included</td>
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<tr>
<td>3. Include standardized ways to measure risk, offering the investor to draw conclusions about whether the asset is below, similar to or above average risk</td>
<td>●</td>
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<tr>
<td>4. Translate the measured risk into a return in which an investor is compensated for bearing the risk</td>
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<tr>
<td>5. Be able to explain not only past returns, but also to predict future expected returns</td>
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Table 19 - Adherence of the AHP and CAPM to the five principles of a good risk and return model as qualified by Damodaran (2014) (Author’s table)
5.6 Conclusion

The AHP is an established method for decision making in several sectors and businesses. However, it has never been applied as a method to calculate the return on equity for wind parks. Therefore, the aim of this chapter was to demonstrate the applicability of the AHP to calculate the return on equity while including the total risk. With this, the fourth research question can be answered:

4. How is the return on equity affected when accounting for various types of risks?

The return on equity for wind parks has been determined by applying the AHP to two onshore and two offshore wind parks. Furthermore, the AHP results have been compared to CAPM calculations for the same wind parks. The AHP results the differences of the wind parks in terms of their risks and thus the reflection on the return. The AHP results of this research set show a larger range in the returns than in the CAPM calculations. The AHP results vary from the German onshore wind park Alpha which is low in risk and has a return of 5.94%, to the UK offshore wind park Delta which is considered a medium risk investment with a return of 9.50%. The CAPM results vary from a return of 7.12% for Alpha, versus a return of 9.32% for Delta. For the onshore wind parks, the returns are lower with the AHP than with the CAPM, whereas for the offshore wind parks, the returns are higher than with the CAPM. AHP illustrates the different characteristics of the wind parks since the risks obtain a premium for the level of risk present in the wind park. According to the sensitivity analysis for the AHP, it is illustrated that both resource risk and especially merchant risk have the highest impact on the return, especially for offshore wind parks. Regulatory risk is especially important for onshore wind parks, as these still heavily rely on subsidy schemes, whereas offshore wind parks have a higher commercial viability. The AHP results highlights the importance of unsystematic risk of wind park investments, which CAPM does not take into account. For the offshore wind parks calculations with CAPM, only a project-specific risk premium is applied since there were no offshore peers available to calculate the beta. According to the investors which have been interviewed, unsystematic risk is more important than systematic risks, as systematic risk can mostly be mitigated and hedged, but unsystematic risk such as resource risk and merchant risk cannot be influenced or managed. The AHP offers insight into the constitution and importance of the risks for a specific wind park, and therefore also risk measures in the operational phase of the wind park could be taken to mitigate the risks. With this, investments can be stimulated, as well as good understanding between investors and operators.

CAPM offers a high-level, top-down approach in which the relative risk of a wind park can easily be illustrated. However, insight is missing into the constitution of the return on equity in terms of the different risks of the investment. This limitation can be filled in with the AHP, which offers both a bottom-up approach from the risks of the wind park, as well as a top-down approach from expert insights. In case an investor wishes to continue using CAPM, it can be complemented with the AHP, since the AHP offers a greater level of insight into the different risks of an investment, and can directly translate the risks into a return that reflects the risks that an investor bears. However, the AHP adheres to all the five principles of Damodaran (2014) for a good risk and return model. It offers a measure of risk that can be applied to all different types of assets, includes a rationale for the delineation of different types of risks that are included, includes standardized ways to measure risk, offering the investor to draw conclusions about whether the asset is below, similar to or above average risk, translates the measured risk into a return in which an investor is compensated for bearing the risk, and is able to explain not only past returns, but also future expected return. Therefore, the AHP offers a very good alternative to commonly applied corporate finance and
The relation between risk and return in wind park investments, and other unlisted assets containing large amounts of unsystematic risk.

The AHP is a novel approach to calculate the risk and return of investments. Further research and application of the model will improve its reliability and workability. The AHP assumes that the experts reflect the market. Therefore, by interviewing a large amount of experts for the expert judgement, these could even better reflect the market. Nonetheless, the higher the number of experts, the lower their influence on the results since the geometric mean of all results is deducted. It could be argued that the AHP may be a subjective approach. Yet, the risk and return relation of investments is inherently subjective. In order to limit this subjectivity though, the consistency of the ratings of the investors has been checked. Furthermore, a sufficient number of investors have been included, and with the analysis of four case studies, the applicability of the AHP can be demonstrated.

All in all, it can be concluded that the AHP is a beneficial and convenient approach for calculating the return on equity for wind parks. With the AHP, a top-down market approach is combined with a bottom-up project-specific approach, in which the total risk is included to which a European investor is exposed when investing in onshore and offshore wind parks. It can determine the specific return on equity while illustrating the risk profile of the specific wind park, and compare it similarly to other wind parks. The AHP could also be applied to other renewable energy types, or other investment assets to calculate the return on equity while including the total risk of these assets.
Conclusions

Chapter 6
6 Conclusions

6.1 Introduction
In this research, the relation between risk and return of wind park investments has been analysed. As this relation is complex and dynamic, a mixed method approach has been applied to capture its details. Four sub-research questions (RQ) have been composed to answer the main research question:

- What is the relation between risk and return in wind park investments?

As a result, the returns of four wind parks have been calculated by investigating the risk characteristics of wind parks (RQ 1, chapter 2), the risks which should be included in the return (RQ 2, chapter 3), and the models with which risks can be translated to the return (RQ 3, chapter 4). With this, the AHP has been applied to calculate the returns of the four wind parks, and offer insight into the relation between risk and return of wind park investments (RQ 4, chapter 5). In the following section, answers to the sub-questions are given (section 6.2). The answers from these sub-questions are aggregated to answer the main research question (section 6.3). Recommendations are made based on these conclusion (6.4). Next, the limitations of this research are discussed (section 6.5), and recommendations for further study are provided (section 6.6). Furthermore, a contribution to the initial research gap is provided by reflecting on the answers from the research questions (section 6.7). Finally, a reflection on the wind sector is provided based on the experience gained from the interviews with several wind park investors, and literature insights (section 6.8).

6.2 Answering the sub-questions
In this section, conclusions from the sub-questions are provided in order to provide an answer to the main research question. The first research question serves as a framework and scope delineation which the rest of the research is built on. The second and third research questions serve as input for the fourth research question.

1. What are the risk characteristics of wind park investments?
Wind park investments belong to the asset class of infrastructure assets, and consist of several characteristics which could pose risks to the investor. This research focuses on infrastructure fund investors investing directly in operational wind parks through unlisted equity. Herewith, there are several risk characteristics of these investments:

- Wind parks are “demand-based” assets, as they are dependent on electricity demand and supply.
- Infrastructure assets generally offer a fixed income to the investor. However, wind parks are highly dependent on the wind input as this determines the performance and financial viability of the wind park.
- Investments in wind parks contain a controlled dividend policy, or return payment to the investors, but equity providers are only serviced after debt, and therefore this poses risks to the investor in receiving its returns.
- Direct investments are highly dependent on the performance of the wind park, as returns are directly dependent on the generated cash flows.
• Investments in the operational phase of a wind park are generally regarded as less risky than investments in the development and construction phase. However, due to this reduced risk perception, the returns are also lower.
• Infrastructure fund investors generally promise low-risk, steady returns to their lenders. In order to keep these promises, they ought to comprehend the risks of their investments, and therefore a risk assessment before investing is highly important.

2. Which risks in wind parks investments should be included in the return on equity?

In order to assess the risks which should be included in the return on equity of a wind park investor, an in-depth analysis was conducted, arriving at a list of six risks which offer diversity and in which overlap between the risks is limited. Through a literature study, analyst report assessment and exploratory interviews, the risks have been selected. The six risks consist of four unsystematic risks, and two systematic risks. By adding these, the risk premium of an investment is calculated, and by adding this to the country’s risk-free rate, the return on equity of a wind park investment can be calculated. The risks are important to the investor, and they directly influence the cash flows of the wind park, and with this the required return. The six risks are described as follows:

• **Resource risk** concerns the risk of wind input, affecting the revenues.
• **Technology risk** is described as the risk of the availability of the wind park components in generating electricity, also affecting revenues.
• **O&M risk** is the risk in the operations and maintenance of the wind park, depending on the capability and experience of the operators, affecting the OPEX.
• **Merchant risk** is the risk in the price of the electricity and the amount of electricity that can be sold, affecting revenues.
• **Financial risk** is a market risk, and is the risk of the change in value of an investment due to currency risk and inflation risk, affecting all the cash flows.
• **Regulatory risk** is also a market risk, and is the risk of a change in public policy in the form of subsidies, taxes and electricity supply regulations.

The risks serve as input for the AHP in chapter 5.

3. How can the risks of wind park investments be translated to the return on equity?

Several models have been explored which could describe the relation of risk and return of wind park investments, and being able to translate the risks of wind park investments into the return on equity. For this, corporate finance models, project finance models, and alternative models have been analysed based on selection criteria: including total risk, suitable for unlisted assets, and offering a method in which different types of wind parks can be assessed in the same manner. With this, the following conclusions have been made:

• **Corporate finance models** generally only take systematic risks into account, and assume unsystematic risks can be diversified away. They are not suitable for unlisted assets, but offer a same method to value different type of assets. They apply a top-down approach, in which the perspective of the company and its own return is leading in valuing an investment. Here, market movements determine the risks of an investment.
• **Project finance models** generally can take unsystematic risks into account, and are suitable for unlisted assets. However, the models are highly specific, and therefore it is more difficult to compare wind parks in the same manner. This approach is more bottom-up, and risk is determined by the volatility of the cash flows.
The relation between risk and return in wind park investments

- **Alternative models** apply indirect calculations and proxies to calculate the return. Some are based on corporate finance models, but by applying company-specific metrics as proxies, the return can be calculated. From these models, the formal risk analysis in the form of the AHP adheres to all three criteria.
- **The AHP** is different from the corporate finance and project finance models, as the top-down approach from corporate finance is applied by its basic formula of adding an equity risk premium to the risk-free rate, as the bottom-up approach from project finance models, as the equity risk premium is divided into independent, analysable risk factors. Therefore, a selection is made for the AHP model, in which also risks can be quantified individually, and directly translated to the return. The model is well-established for decision-making, but never has been applied to calculate the return based on the risks of an investment. Therefore, in chapter 5 a first step is made in the literature to apply the AHP to calculate the return on equity through the quantification of risks.

4. **How is the return on equity affected when accounting for various types of risks?**

The six risks as identified in chapter 3, and the model selection in chapter 4, serve as input for chapter 5, in which the return on equity is calculated for four wind parks with the AHP. The AHP has been applied by following eight different steps. The six risks have attained a weight through in-depth interviews with nine European wind park investors, and have been applied to the four wind parks to determine the risk situation for each specific wind park. This resulted in an equity risk premium for each risk of each wind park, and by adding these to the risk-free rate of the country of the wind park, the required return on equity has been calculated. With this, the following conclusions are drawn:

- Unsystematic risks play an important role in the return for investors. In the onshore wind parks of this research, they account for half of the return on equity. For offshore wind parks of this research, they even account for \( \frac{3}{5} \) and \( \frac{2}{3} \) of the return.
- Resource risk, and especially merchant risk have the largest effect on the return on equity. Wind is a stochastic variable, and cannot be completely predicted. Since it is vital for the revenues of the wind park, it is therefore regarded as a high risk. Merchant risk is dependent on the subsidy schemes and electricity price of the market after the subsidy scheme expires. The subsidy schemes provide a relatively safe income for the wind park, whereas electricity prices are based on market movements and therefore volatile, posing risk to the revenues.
- In corporate finance, unsystematic risk is regarded as an inherent risk when investing in a company or industry, and it can be diversified away. However, the AHP demonstrates that unsystematic risks make up at least half of the required return, and therefore they should play a more central role in wind park investments.

Furthermore, the AHP has been compared to the CAPM by comparing their results, and considering their assumptions, strengths and weaknesses as analysed in chapter 4. This leads to the following conclusions:

- The returns for the onshore wind parks of the research set are lower than the CAPM calculations, whereas for the offshore wind parks they are higher. Therefore, the range of returns is larger for the AHP than the CAPM for this research set.
- AHP shows in-depth insight into the different characteristics of various wind parks, by showing the constitution of the return on equity and the risk premium of each risk. CAPM offers a high-level approach, and only the beta is applied as a risk variable.
When comparing the AHP and CAPM against the principles of Damodaran (2014), AHP and CAPM both adhere to four of the five principles. CAPM is well-established and extensively researched, it has a clear rationale for the different types of risks that are included in the return calculation. In the AHP, the factors are not specified in advance, and therefore is it a more flexible model.

The AHP adheres to all the five principles of Damodaran (2014), and therefore can be considered as a good model to explain risk and return of not only wind parks, but all other types of assets.

6.3 Conclusion to the main research question

The aim of this research was to apply a model to calculate the required return on equity for wind park investments while considering the total risk to which the investor is exposed, and giving insight into the risk perception of investors in the wind sector and the required return. By conducting several literature studies, assessing analyst reports, and interviewing several investors active in the wind sector, the sub-questions have been answered. These can be aggregated to answer the main research question:

- What is the relation between risk and return in wind park investments?

The relation between risk and return of investments in general has been described extensively in literature, and is dominated by the corporate finance perspective in which unsystematic risk can be diversified away, and systematic risk is an inherent market risk. Wind parks do not comply with this perspective, as they are often unlisted, have specific risk characteristics and contain many underlying risks. Therefore, further insight was necessary into this relation. A first start was made into the risks of wind park investments, giving insight into the importance of risks which cannot be controlled by an investor. Remarkably, it were not systematic risks, but in fact the unsystematic risks which the investor found the most important when calculating their required return. These risks cannot be completely hedged and controlled, as can be done with most systematic risks. With this, the corporate finance theory on wind park investments falters.

This research indicates that the relation between risk and return is not only ambiguous and multi-layered, it also much depends on the risk perception of the investor, economic developments, competition, and strategic considerations. Therefore, the return on equity is not only a reflection of the risks of an investment, but it also contains many social aspects. However, patterns in risk and return can be distinguished. It can be stated that maturity risk, systematic risk and unsystematic risks affect wind park investments, and all should be considered in the return calculation. Based on the risk characteristics of a specific wind park, the return can then be calculated which reflects this risk profile.

While corporate finance models take a high-level, top-down market approach to determine the required return of an investment, the project finance models are highly specific, and apply a bottom-up approach. The AHP combines both perspectives, as interviews with wind park investors offer high-level market insight, while considering the specific unsystematic risks of a wind park. The AHP adheres to all the principles for a good model for risk and return as distinguished by Damodaran (2014), and therefore can be applied to explain the relation between risk and return of wind park investments, as risks can be quantified individually, and directly translated to the return.
Furthermore, by applying the AHP, valuable insights from experts are elicited, offering deep insight into the risk and return characteristics of an asset. Therefore, the AHP can be applied to bridge the research gap between risk and return of wind park investments, as the total risk is directly translated to the required return on equity.

6.4 Recommendations based on conclusions

Based on the findings and conclusions of this research, several recommendations can be made for wind park investors.

1. **Apply the AHP for obtaining insight in the risk-return profile of your investment**

As compared to traditional corporate finance and project finance models, the AHP model can be applied as a good model to describe the risk and return relation. It offers in-depth information of the investment since the risks can be assessed, and directly translated to the return. With this, different types of wind parks can be assessed in the same manner, while the similarities and differences in their risk profiles is highlighted. This offers better insight into the effect that risks have on the return, especially as compared to the CAPM in which this relation is more obscure. In case the investor wants to continue using the CAPM, it can also be complemented with the AHP. The top-down market view can therefore be complemented by the AHP, offering deeper insight into the return composition.

2. **Know where you put your money in**

As logical as this may sound, investors ought to know where they put their money in. In case the investor is too distanced from its investment, he will not be able to understand the relation between risk and return of wind park investments. The investment decision may therefore not be well-founded, and returns may not reflect expectations. Therefore, it is important that the investor is aware of all the risks in the investment, and what their effects are on the investment and returns. Understanding of the wind park, its technical components, and performance indicators are therefore recommended. Herewith, the investor can assess all the risks of the wind park, identify the ones which are the most important and have the highest effect on the return. From this research, it followed that merchant risk and resource risks have the highest impact on the return. Therefore, investors are recommended to invest in wind parks of which substantial wind data is available. Furthermore, the electricity price should be hedged in order to mitigate merchant risk. The more certainty about the wind park’s performance and cash flows can be obtained, the lower the risks of the investments. Therefore, all the risks that can be controlled should be hedged, while others such as wind data should be monitored closely. Also, the investors and operators of the SPV should work together and be transparent about the developments in order to reduce uncertainties.

3. **Be aware of the market, and decide your place in it**

As important as the risks are of any investment, there is more to it. For an optimal understanding of the investment, the risks should be identified first. Secondly, market developments should be analysed. Understanding of all the forces which affect the investment is important. Wind park investments are not only dependent on the performance of the wind park, but also external factors affecting the investment indirectly. Supply and demand of electricity, regulatory arrangements, and electricity prices depend on many other aspects as well. Therefore, the investment should not be regarded in isolation, the return requirements also depends on strategic considerations, and is linked to competition. Thus, an investor should determine its investment strategy and with this how much risk he is willing to take, and against which return.
6.5 Limitations

When critically reflecting on the research approach, some limitations of this research should be mentioned.

The closed stance of the investors
In chapter 3, the aim was to assess the risks to which an investor is exposed when investing directly in wind parks through methodological triangulation. The literature study, analyst report assessment and exploratory interviews were aimed to produce three different, independent lists of risks. However, the investors of the exploratory interviews were unexpectedly hesitant in providing information about the methods they apply to calculate the return, and which risks they exactly include. This can be explained by the fact that the subject of risk and return is highly confidential, and specific for each investor. Furthermore, the interviews were recorded, making the investors even less open. This has been a limiting factor for this third research method to arrive at a list of independent risks from the interviews. Luckily, a list had been prepared in which all the risks from the literature study and analyst reports have been included in advance as a backup. This list has been therefore been shown to the investors, from which they indicated the risks which they take into account in their return calculation, and additional risks. It is difficult to overcome this limitations, and this is inherently the case for this research topic. However, by not recording the interviews, and not asked for direct sensitive information, the investors could be opened up. This has been applied in the in-depth interviews for the AHP, and with this, more insights have been attained as the investors were open. Furthermore, less specific information about the investor and its company has been asked, and the emphasis was on the wind sector as a whole.

The selection of the risks
In chapter 3, the list of risks has been combined with the interview results, leading to list of main identified risks in which all the risks of the two have been included. This list needed convergence, as all the risks from the different methods have been used, but many are interrelated or belong to each other. This is because risk is a subjective matter, and therefore the names and descriptions of the risks may be interpreted differently by different investors. Therefore, the list has been aggregated into a list of six risks. This not only limited the amount of overlap, it also improved the workability of the AHP, as too many criteria may work counterproductive (Cheng et al., 2002). Gearing risk was included in O&M risk, and has been explained as part of the contractual arrangements for the operations of the wind park. Reflecting on this choice, it may not belong to O&M risk. The AHP in this research has been validated afterwards with two additional investors. These indicated that gearing risk is not a risk by itself, but affects all risks. The AHP applies a formula which is analogous to the CAPM. In CAPM, the beta is determined by the peer set and the amount of leverage of the wind park. In the AHP, the risks are added together to form the equity risk premium. There is no scaling factor for the amount of leverage. This is a limitation of the AHP, and could be overcome by applying a scaling factor to the equity risk premium as calculated with the AHP. This needs further research though. However, for the AHP application of the four wind parks, it was assumed that the wind parks are optimally financed, which is common for infrastructure investments. Also, the betas of the wind parks were close to each other, and therefore the effect of gearing risk in this research is negligible.

Furthermore, there is a thin line between systematic and unsystematic risks, as illustrated in figure 10. Merchant risk is an unsystematic risk, but it is also affected by systematic risks. For the AHP, this does not pose a real limitation though, as the risk premium consists of both systematic and unsystematic risks, and therefore, the risk will be accounted for. However, users of the AHP should be aware of this.
The relation between risk and return in wind park investments

AHP limitations
In this research, it is demonstrated that the AHP is a promising model to calculate the risk and return for wind park investments. Like any model, the AHP has its limitations though. The AHP assumes that the experts reflect the market, which can be questioned as each investor has its own experience and opinion about investments and the wind sector. Therefore, the more investors are interviewed, the better they can reflect the market. For this research, nine investors has been interviewed to provide a comparative judgement for six criteria. As compared to other AHP applications in this research form, at least one expert has been interviewed for each criteria. In the time frame of this research, the nine interviews were therefore substantial to attain the weights of the criteria and calculate the returns for four wind parks. The AHP can also be applied in other forms, like online surveys. With this, a larger set of experts can be reached within a shorter time frame. However, the insight information elicited from experts is limited in this form. A limitation of the AHP can also be that in case a lot of criteria or risks have been selected, a large number of comparisons need to be asked from experts (Cheng et al., 2002). For this research therefore, six criteria have been applied which offer enough diversity while limiting overlap between the risks. With this, the risks of both onshore and offshore wind parks could be quantified, as “only” thirty comparisons were needed (fifteen for onshore, fifteen for offshore). In case seven criteria had been applied, 21 comparisons, or 42 were needed, and for ten criteria, this would have doubled to 90 comparisons for both onshore and offshore wind parks. Therefore, in case researchers wish to apply the AHP for a large set of criteria, it is recommended to apply the AHP in a survey form, whereas for a smaller criteria set, interviews will provide the best outcome, and also provides insight into the underlying reasons for the weights of the criteria. Another limitation of the AHP in this research could be that enough information about the wind park is necessary to assess the situation for a specific wind park, and calculate the second part of the risk premium. All in all though, the AHP is a good model to calculate risk and return when enough information is available, and offers direct insight into the effect of risks on the return, while offering valuable information from experts.

6.6 Recommendations for further study
In this research, it is demonstrated that the AHP is a suitable method for valuing wind park investments while considering the total investment risk. Based on the limitations, several recommendations can be made for further study. The closed stance of the investors could be opened up by asking for general information about the wind sector, and not be too specific for the investor and his company. Furthermore, no exact return rates or methodologies should be asked for, as this information is often highly confidential. The emphasis should lie on the research, and not to use the information for own purposes or sharing it with other parties. This will also reduce the limitation of the risk selection. When the investors are more open, the exploratory interviews can serve as a third, independent method to assess the risks of wind park investments. Thirdly, a larger amount of investors can be interviewed in a further study, to capture a greater number of investors reflecting the market.

The research has been performed for infrastructure fund investors investing directly in wind parks through unlisted equity in the operational phase. Therefore, the AHP could also be applied for different types of investors. For instance, private equity investors have a different stance towards wind park investments, as they enter the wind park in an early phase and exit already after a few years. Furthermore, wind park investments could also be analysed in an earlier phase in the project, such as the construction or even development phase. This could stimulate investors to enter the project in an earlier phase. Furthermore, the risks of the AHP could be applied in more depth. An
extra sub-categorization of each risks could be made, which further explains the differences between the risks and their effect on the return on equity. The AHP could also be applied to other renewable energy assets, such as solar plants, or even other asset types than infrastructure assets.

6.7 Contribution to the initial research gap

In chapter 1, it has been stated that there is a research gap on the relation between risk and return of wind park investments in which the total risk is included to calculate to required return of a specific wind park. The risks of wind parks have been extensively studied, but little is known about the risks to which an investor is exposed when investing in wind parks. Therefore, chapter 3 has provided insight into these risks by applying three different methods. There are many ways to quantify risk, but insufficient research has been conducted about the quantification of specific risks into the return on equity. In the model assessment in chapter 4, different models have been explored based on their assumptions, strengths and weaknesses, offering insight into the different quantification mechanisms of risks into returns. Finally, the AHP application offers a relevant contribution to the valuation theory of unlisted assets, based on the example of wind park investments. This offers a way to quantify risks in isolation based on their direct effect on the return. Moreover, valuable insights from wind park investors have been elicited, offering understanding of the relation between risk and return of wind park investments.

6.8 Reflection on the wind sector

In this research, extensive amounts of information and insights have been obtained about the wind sector and its investments. Herewith, a perspective on the wind sector has been gained which offers room for reflection. First of all, it must be said that I was impressed by the amount of subjectivity and gut feeling that most investments are based on. In theory, in-depth models and calculation mechanisms are described to calculate returns, but in the end many investors look at the market and the bids of other investors. Therefore, not only risk determines the return, but also competition and wind sector developments. Compared to the more exact studies of the TU Delft, it was surprising to find out that finance has many aspects of a social science.

Secondly, I was surprised by the different opinions of the investors. On the one hand, there are corporate finance investor types, especially focused on generating returns. They are active in many different types of investments, and are especially attracted to wind parks to keep a sustainable image and keeping their shareholders happy. On the other hand, there are the project finance investor types, highly involved in the wind park, and often paying visits to monitor its performance. These investors generally have more expertise in the technical components of the wind park, are only active in infrastructure investments, and have a closer relation with their investment. I feel more empathy for the project finance investors, as they know exactly what they are investing in, whereas corporate finance investors are far apart from their investments, and especially care about the returns. In this research, I focused on infrastructure fund investors, which mostly adopt a project finance perspective.

As for the wind sector itself, the onshore wind sector is mostly crystallized, but in offshore wind there are still many developments. The offshore wind sector is very competitive as developers are eager to set foot in this sector, and therefore offer extremely low bids. This puts pressure on the returns of the investors. Due to the low interest rate environment however, the investors often
accept these low bids. Therefore, the relation between risk and return is distorted, as investors receive a relatively low return for the actual risks they take. These bids are mostly strategic, but do not seem wise on the long-term. Many investors acknowledge that their actual returns on wind park investments are lower than expected. The question is therefore how low the bids can go before wind parks actually turn bankrupt, and investors receive no return at all. Furthermore, due to the increasing amount of renewable energy, there is more energy supply than demand, driving down electricity prices. The electricity forecasts do not seem very optimistic, and thus these should be hedged. With this, the importance of the AHP is demonstrated all the more, as it offers investors insight and negotiation terms to receive a return in which they are actually compensated for the risks they take. In case the interest rate will rise again, I am convinced that many institutional investors move away from renewable energy investments, and invest in order assets again. Infrastructure fund investors only active in this field will remain though, and the lower competition will be beneficial for their returns.

In the renewable energy sector, the focus has been on wind parks as the fastest growing source. This growth is slowing down though, and solar is catching up. Solar is becoming more competitive than wind energy as the sun input can be better predicted than wind input. For some investors, wind energy is still very risky, as others are already moving away and focusing more on solar energy.

Personally, I think that wind park investments are good investments in case enough information is available about the risks of the wind parks, and most of the risks are contractually hedged. As an investor, I would demand detailed wind studies and electricity price hedges to mitigate resource risk and merchant risk. Furthermore, I would invest in offshore wind parks, as these have the advantages of the economies of scale and therefore more revenues are generated. Most onshore wind parks are relatively small, and consist of only a few wind turbines. Offshore wind parks are becoming larger and larger, and as expertise grows and technologies advance, these seem as good, sustainable investments.
Bibliography


The relation between risk and return in wind park investments


Appendices
A Types of renewable energy sources

<table>
<thead>
<tr>
<th>Energy type</th>
<th>Sub-type</th>
<th>Generation</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Risk perception</th>
<th>Return on equity (low-high)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydro</td>
<td>Hydro</td>
<td>Energy harnessed from the movement of water through rivers, lakes and dams</td>
<td>Electricity generation can be managed</td>
<td>Expensive to build, people can oppose</td>
<td>Low</td>
<td>6 - 9%</td>
</tr>
<tr>
<td>Solar</td>
<td>Solar PV</td>
<td>Energy from sunlight is captured in solar panels and converted into electricity using panels made of semiconductor cells</td>
<td>Relatively inexpensive, solar cell efficiency increases and cost reductions</td>
<td>Efficiency is relatively low, as compared to other renewables</td>
<td>Low</td>
<td>6 - 9%</td>
</tr>
<tr>
<td>Solar heating</td>
<td>Solar heating</td>
<td>The heat of the sun is captured and converted into direct heat or into mechanical energy and then electricity</td>
<td>Efficient, 80% radiation is turned into heat energy, cheaper than solar PV panels</td>
<td>Only water can be heated, needs maintenance and replacements often</td>
<td>Medium</td>
<td>9 - 13%</td>
</tr>
<tr>
<td>Concentrated solar power</td>
<td>Concentrated solar power</td>
<td>Mirrors or lenses to concentrate a large area of sunlight, or solar thermal energy (STE), onto a small area</td>
<td>Using existing equipment (mirrors, turbines), power generation is possible all day</td>
<td>Limited locations and size limitations, high costs to construct</td>
<td>Medium</td>
<td>9 - 13%</td>
</tr>
<tr>
<td>Wind</td>
<td>Onshore</td>
<td>Wind turbines of an onshore wind park turn wind energy into electricity</td>
<td>Wind power is considered relatively reliable</td>
<td>Construction is costly, noise pollution, visual pollution, harm to birds</td>
<td>Low</td>
<td>7 - 10%</td>
</tr>
<tr>
<td>Offshore</td>
<td>Offshore</td>
<td>Wind turbines of an offshore wind park turn wind energy into electricity</td>
<td>Wind power is considered relatively reliable, the effect on humans is lowered</td>
<td>Construction is costly</td>
<td>Medium</td>
<td>10 - 14%</td>
</tr>
<tr>
<td>Geothermal</td>
<td>Geothermal</td>
<td>Heat energy is derived from the earth, usually from magma conduits, hot springs or hydrothermal circulation, to spin turbines or heat buildings</td>
<td>In adequate areas: easily accessible and cost-effective way to generate electricity</td>
<td>Energy is diffuse, and can only be cheaply harnessed in certain locations</td>
<td>Medium</td>
<td>9 - 13%</td>
</tr>
<tr>
<td>Bio-energy</td>
<td>Bioenergy</td>
<td>Contemporary biological processes, such as agriculture and anaerobic digestion, producing biofuel</td>
<td>Often a by-product, residue or waste-product of other processes</td>
<td>Harmful impact on forests and the climate</td>
<td>Medium</td>
<td>9 - 13%</td>
</tr>
<tr>
<td>Biofuels</td>
<td>Biofuels</td>
<td>Converting biomass into liquid fuels for transportation, such as ethanol, bio-oil, and biodiesel</td>
<td>In theory unlimited source, as crops can be grown each year</td>
<td>Certain feedstocks are out of the running for replacing fossil fuels</td>
<td>Medium</td>
<td>10 - 13%</td>
</tr>
<tr>
<td>Tidal</td>
<td>Tidal</td>
<td>The movement of seawater in and out of a cavity on the shore compresses trapped air, driving a turbine</td>
<td>Tides are steady and predictable, recent improvement in technologies to increase efficiency</td>
<td>Relatively high cost and limited availability of sites with sufficiently high tidal ranges or flow velocities</td>
<td>High</td>
<td>12 - 17%</td>
</tr>
</tbody>
</table>

Table 20 - Types of renewable energy sources, their advantages and disadvantages, risk perception, and general range of required return on equity (Author’s table, based on Oxera (2011))
B Exploratory interview protocol

Risk and return of wind park investments

Interview questionnaire

Introduction

Research
- This interview is part of my graduation research about the drivers of the required return of wind park investments. CAPM is often applied to calculate this return, but does not fully describe the unsystematic risks of wind parks. Therefore, the goal of this thesis is to apply a bottom-up approach which includes the characteristics and risks in order to calculate a return which included both systematic, market risks, as well as unsystematic, project-specific risks.
- This interview is the first step of the research, in which the main drivers for the return are distinguished.
- You have been selected as an investor since you have experience in wind park investments. Two other investors will be interviewed, with the aim to determine the risk of wind parks which should be included in the return calculation.
- The research is a cooperation between EY and TU Delft.

Practical issues
- The interview will approximately take one hour.
- Your data and answer are treated confidentially, and will not be shared with third parties. In the report, no names or quotes will be used, and only aggregated results are presented.
- I would like to ask for your permission to record the interview. With this, I can use the answers better in the research. I will be the only one listening to the recording, and after the finishing of the research, the recording will be deleted.
- In case you are interested, I can send you the report after finishing the research.
- Thank you in advance for your time and effort. Your participation is very useful for this research.
Questions

1. What is your experience in wind park investments, which region, and in which phase?
2. How do you value a wind park?
3. How do you calculate the required return of a wind park investment?
4. Which risks do you take into account into the return calculation?
5. How do you incorporate project risks in the return calculation?
6. Do you make a distinction between onshore and offshore wind park return calculations?
7. How should risks ideally be incorporated in the return calculation?
8. Do you have
   - Suggestions for contacting other parties or persons for this research?
   - Information or documentation for this research?
   - Information about onshore or offshore wind parks which I could consult?

Thank you a lot your time and effort!
Please let me know if you have feedback or tips in response to this research.
C In-depth interview protocol

Risk and return of wind park investments

Interview protocol - Master thesis Arlette Westhoff

Introduction
For my graduation thesis at the TU Delft and EY I am investigating the impact of risks of onshore and offshore wind parks in the operational phase on return on equity. For this, I am applying a method in which I aim to include a top-down view from the market, as well as a bottom-up view with the specific characteristics and risks of the wind park. I have analysed six different risks, including both systematic (market inherent risks) and unsystematic risks (park specific risks), which I aim to translate to the return for investors. Therefore, I would like to ask you how you perceive these risks when you invest in onshore and, if applicable, offshore wind parks.

Thank you in advance for your time and effort!

Introductory questions
1. How many years of experience do you have in investing in onshore wind parks and, if applicable, how many years in offshore wind parks?
2. Corporate finance theory distinguishes two types of risk: systematic or market risk, and unsystematic or project-specific risk. Do you also include unsystematic risk when determining the rate of return of your investment?
3. What methods do you apply when calculating your return from a wind park investment?

Range of equity risk premium of wind parks in the operational phase
Considering the European wind market, what equity risk premium would generally be illustrative for onshore parks in the operational phase containing a very high risk, and what premium would be illustrative for parks containing a very low risk? What would these rates be for offshore wind parks? For this, could you provide a numerical value to the different types of risk descriptions as described in table I for onshore wind parks, and for offshore wind parks? The equity risk premium for “Medium risk” is the typical for a park with an average level of risk. The equity risk premium for “Very low risk” is illustrative of a park with very low risk. The equity risk premium for “Very high risk” is illustrative of a park which you consider very risky.

<table>
<thead>
<tr>
<th>Onshore wind parks</th>
<th>Offshore wind parks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Descriptor term for risk</td>
<td>Risk premium (%)</td>
</tr>
<tr>
<td>Very low</td>
<td>... %</td>
</tr>
<tr>
<td>Low</td>
<td>... %</td>
</tr>
<tr>
<td>Medium</td>
<td>... %</td>
</tr>
<tr>
<td>High</td>
<td>... %</td>
</tr>
<tr>
<td>Very high</td>
<td>... %</td>
</tr>
</tbody>
</table>

Table I - Range of risk premiums for investing in onshore and offshore wind parks according to the level of risk
Risk description
Six risks has been derived in this research which occur in the operational phase of onshore and offshore wind parks, and which should be included in the return calculation (table II). Could you provide a qualitative description for each risk what the lowest risk situation would be, and the highest risk for you as an investor? For example, for resource risk, the lowest risk would be the case in which the wind forecast is almost certain (> p90 case), and the highest risk in which the wind forecast is very uncertain (< p50 case).

<table>
<thead>
<tr>
<th>Unsynchronized risk</th>
<th>Synchronized risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1 Resource risk</td>
<td>Risk of wind input, leading to uncertainty in the production of electricity</td>
</tr>
<tr>
<td>A2 Technology risk</td>
<td>Risk in availability of the technical components of the wind parks for energy production due to damages, delays or failures</td>
</tr>
<tr>
<td>A3 O&amp;M risk</td>
<td>Risk in operation &amp; maintenance of the wind park, depending on the capability of operators and their maintenance strategy, and the contract terms including gearing</td>
</tr>
<tr>
<td>A4 Merchant risk</td>
<td>Risk of the amount of energy that can be sold and against which price, which is partly determined contractually, and partly by the market</td>
</tr>
<tr>
<td>B1 Financial risk</td>
<td>Risk of a change in the value of the investment due to currency risk and inflation risk</td>
</tr>
<tr>
<td>C1 Regulatory risk</td>
<td>Risk of a change in public policy in the form of subsidies, taxes and energy supply regulations</td>
</tr>
</tbody>
</table>

Table II - Investment risks in the operational phase of wind parks

Comparative judgement
Next, I would like to ask you to rate the six different risks against each other, while considering their impact on the rate of return. Could you please do this once for operational onshore wind parks in general, and if applicable once for operational offshore wind parks in general. Table III provides an overview of the importance of one risk against the other, and the related numerical value. Please provide a numerical judgement of the importance of risk X against the importance of risk Y (table IV). In case risk X is much more important than risk Y, please give it a high rate (e.g. 9, meaning much more important). In case risk X is much less important than risk Y, please give it a low rate (e.g. 1/9, meaning much less important). In case the risks are of the same importance, please give it a rate close to 1 (e.g. 1, meaning equally important). Please aim for consistency in your rating (That is, if A1 > A2, and A2 > A3, then A1 > A3).

<table>
<thead>
<tr>
<th>Definition</th>
<th>Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolutely the most important</td>
<td>9</td>
</tr>
<tr>
<td>Much more important</td>
<td>7</td>
</tr>
<tr>
<td>More important</td>
<td>5</td>
</tr>
<tr>
<td>Slightly more important</td>
<td>3</td>
</tr>
<tr>
<td>Equal importance</td>
<td>1</td>
</tr>
<tr>
<td>Slightly less important</td>
<td>1/3</td>
</tr>
<tr>
<td>Less important</td>
<td>1/5</td>
</tr>
<tr>
<td>Much less important</td>
<td>1/7</td>
</tr>
<tr>
<td>Absolutely the least important</td>
<td>1/9</td>
</tr>
<tr>
<td>Intermediate judgements between two adjacent judgements</td>
<td>8, 6, 4, etc.</td>
</tr>
</tbody>
</table>

Table III - Comparative Judgement numerical equivalent
<table>
<thead>
<tr>
<th>Nr</th>
<th>Risk (X)</th>
<th>Risk name (X)</th>
<th>Risk weighting score onshore wind parks</th>
<th></th>
<th></th>
<th>Risk (Y)</th>
<th>Risk name (Y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A1 Resource risk</td>
<td>9 8 7 6 5 4 3 2 1 1/2 1/3 1/4 1/5 1/6 1/7 1/8 1/9</td>
<td>A2 Technology risk</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>A1 Resource risk</td>
<td>9 8 7 6 5 4 3 2 1 1/2 1/3 1/4 1/5 1/6 1/7 1/8 1/9</td>
<td>A3 O&amp;M risk</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>A1 Resource risk</td>
<td>9 8 7 6 5 4 3 2 1 1/2 1/3 1/4 1/5 1/6 1/7 1/8 1/9</td>
<td>A4 Merchant risk</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>A1 Resource risk</td>
<td>9 8 7 6 5 4 3 2 1 1/2 1/3 1/4 1/5 1/6 1/7 1/8 1/9</td>
<td>B1 Financial risk</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>A1 Resource risk</td>
<td>9 8 7 6 5 4 3 2 1 1/2 1/3 1/4 1/5 1/6 1/7 1/8 1/9</td>
<td>C1 Regulatory risk</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>A2 Technology risk</td>
<td>9 8 7 6 5 4 3 2 1 1/2 1/3 1/4 1/5 1/6 1/7 1/8 1/9</td>
<td>A3 O&amp;M risk</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>A2 Technology risk</td>
<td>9 8 7 6 5 4 3 2 1 1/2 1/3 1/4 1/5 1/6 1/7 1/8 1/9</td>
<td>A4 Merchant risk</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>A2 Technology risk</td>
<td>9 8 7 6 5 4 3 2 1 1/2 1/3 1/4 1/5 1/6 1/7 1/8 1/9</td>
<td>B1 Financial risk</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>A2 Technology risk</td>
<td>9 8 7 6 5 4 3 2 1 1/2 1/3 1/4 1/5 1/6 1/7 1/8 1/9</td>
<td>C1 Regulatory risk</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>A2 O&amp;M risk</td>
<td>9 8 7 6 5 4 3 2 1 1/2 1/3 1/4 1/5 1/6 1/7 1/8 1/9</td>
<td>A4 Merchant risk</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>A3 O&amp;M risk</td>
<td>9 8 7 6 5 4 3 2 1 1/2 1/3 1/4 1/5 1/6 1/7 1/8 1/9</td>
<td>B1 Financial risk</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>A3 O&amp;M risk</td>
<td>9 8 7 6 5 4 3 2 1 1/2 1/3 1/4 1/5 1/6 1/7 1/8 1/9</td>
<td>C1 Regulatory risk</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>A4 Merchant risk</td>
<td>9 8 7 6 5 4 3 2 1 1/2 1/3 1/4 1/5 1/6 1/7 1/8 1/9</td>
<td>B1 Financial risk</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>A4 Merchant risk</td>
<td>9 8 7 6 5 4 3 2 1 1/2 1/3 1/4 1/5 1/6 1/7 1/8 1/9</td>
<td>C1 Regulatory risk</td>
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<td></td>
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<td></td>
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<tr>
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<td>C1 Regulatory risk</td>
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</tbody>
</table>

Table IV - Rating of the importance of risk \( X \) against risk \( Y \)

Thank you for your time! Your input is very valuable for this research.
D AHP calculation - Weight of the risks

### ONSHORE

<table>
<thead>
<tr>
<th></th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
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<th>B1</th>
<th>C1</th>
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#### Normalisation

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### OFFSHORE

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<td></td>
</tr>
<tr>
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#### Normalisation

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<th>A3</th>
<th>A4</th>
<th>B1</th>
<th>C1</th>
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<th>Consistency</th>
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<td>1.00</td>
<td>1.00</td>
<td>6.00</td>
<td>1.00</td>
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<td></td>
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</tbody>
</table>

Table 21 - Calculating the weight of the risks from the results of a single interview (numbers are indicative). The final weight of the risks is obtained by taking the geometric mean from all the interview results (Author’s table)
### Qualitative risk descriptions

<table>
<thead>
<tr>
<th>Resource risk</th>
<th>Very low</th>
<th>Very much certainty about the wind data, p90 case (net energy production has a 90% chance to be exceeded) or higher</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>Some certainty about the wind data, p50 case (net energy production is just as likely to not to be met as to be exceeded)</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>Very little certainty about wind data, little or no data available</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Technology risk</th>
<th>Very low</th>
<th>Availability warranty close to 99% track record of technical components is very good</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>Availability warranty about 95%, track record of technical components is acceptable</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>Availability warranty less than 90%, no warranties, track record of technical components is very poor or unknown</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>O&amp;M risk</th>
<th>Very low</th>
<th>Contract with O&amp;M supplier is fully serviced throughout the lifetime of the project, supplier has a very good track record</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>Contract period for about 15 years, supplier has an acceptable track record</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>Contract period for one year, after that new contract should be arranged, track record of supplier is very poor or unknown</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Merchant risk</th>
<th>Very low</th>
<th>Subsidies throughout the lifetime of the wind park, offtaker has a very good track record</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>Subsidy period for about 15 years, offtaker has an acceptable track record</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>No subsidy schemes, wind park is completely dependent on the market power price, track record of energy offtaker is very poor or unknown</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Financial risk</th>
<th>Very low</th>
<th>No currency risk, inflation is fixed using inflation swaps (hedged)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>Little currency risk, some hedging of inflation</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>High currency risk, no hedging</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Regulatory risk</th>
<th>Very low</th>
<th>Country is highly developed, high political stability, tax rates stable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>Country is well developed, average political stability, tax rates somewhat stable</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>Country is less developed, high political instability, tax rates unstable</td>
</tr>
</tbody>
</table>

*Table 22 - Qualitative descriptions of the risks in terms of the low risk, medium risk and high risk scenario (Author's table)*
## CAPM calculations of the four wind parks

### CAPM calculations for the return on equity of the four wind parks

<table>
<thead>
<tr>
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<th>Beta</th>
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<td>Unlevered beta</td>
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<tr>
<td>Leverage</td>
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<tr>
<td>Levered beta</td>
<td>0.92</td>
<td>Levered beta</td>
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<tr>
<td>Risk-free rate</td>
<td>2.25%</td>
<td>Risk-free rate</td>
</tr>
<tr>
<td>Levered beta</td>
<td>0.92</td>
<td>Levered beta</td>
</tr>
<tr>
<td>MRP</td>
<td>5.50%</td>
<td>MRP</td>
</tr>
<tr>
<td>Cost of Equity</td>
<td>7.80%</td>
<td>Cost of Equity</td>
</tr>
<tr>
<td>Project specific premium</td>
<td>0.50%</td>
<td>Project specific premium</td>
</tr>
<tr>
<td>Cost of Equity</td>
<td>7.80%</td>
<td>Cost of Equity</td>
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</table>

### Gamma

<table>
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<tr>
<td>Unlevered beta</td>
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<tr>
<td>Leverage</td>
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</tr>
<tr>
<td>Levered beta</td>
<td>0.76</td>
</tr>
<tr>
<td>Risk-free rate</td>
<td>2.20%</td>
</tr>
<tr>
<td>Levered beta</td>
<td>0.76</td>
</tr>
<tr>
<td>MRP</td>
<td>5.50%</td>
</tr>
<tr>
<td>Cost of Equity</td>
<td>6.45%</td>
</tr>
<tr>
<td>Project specific premium</td>
<td>2.00%</td>
</tr>
<tr>
<td>Cost of Equity</td>
<td>8.45%</td>
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### Delta

<table>
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<td>Leverage</td>
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</tr>
<tr>
<td>Levered beta</td>
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<tr>
<td>Risk-free rate</td>
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<tr>
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<tr>
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<tr>
<td>Cost of Equity</td>
<td>9.30%</td>
</tr>
</tbody>
</table>

*Table 23 - CAPM calculations for the four wind parks (green is onshore, blue is offshore) (Author's table)*
Thank you for your time!