Felix Humpert

Masterarbeit

Analysis and Development of Investment Evaluation Methods for Onshore Wind Energy Projects

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[redacted]	[redacted]
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Betreuer:	Prof. Dr. M. H. Breitner Jan-Hendrik Piel
Prüfer:	Prof. Dr. M. H. Breitner Leibniz Universität Hannover Institut für Wirtschaftsinformatik
	Prof. Dr.-Ing. A. Reuter Leibniz Universität Hannover Institut für Windenergiesysteme

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1 Introduction

Onshore wind energy projects are technically complex, long-term, illiquid, highly leveraged and capital intensive investments, whose realization requires both technical and financial expertise. From the time a prospective project appears on the radar of a developer, to the time it is decommissioned and breaks even, a decade easily passes. This illustrates how far reaching the decision to realize an onshore wind energy (OWE) project can be, a decision closely tied to the evaluation methods that support the investment process. Although operation and maintenance is a growing sector within the wind industry, its primary driver is still the development of new projects. They are virtually the motor of the entire value chain. This includes the activities located upstream from project development as well as the activities post project commissioning. The actors steering this critical part of the value chain are project developers and increasingly wind turbine manufacturers, who are integrating forward into this part of the value chain. This thesis makes a contribution to the investment evaluation of OWE projects and is accordingly concerned with real investments, which have to be differentiated from investments in capital markets, corporate finance is often concerned with. The central hypothesis of the thesis is that commonly used frameworks for the evaluation of OWE projects are due to be replaced with more suitable methods. This hypothesis translates into the following research question:

How are investments in OWE projects commonly evaluated and how can their evaluation be improved?

In the rest of this opening chapter the research setting is described. Next, the relevance of the topic is motivated and its associated challenges are outlined. Following the opening chapter, the second chapter presents the research design of this thesis. In chapter three the literature is reviewed, finding that OWE projects are commonly evaluated based on traditional discounted cash flow (DCF) analysis. Based on the review of the literature, chapter four develops a set of selection criteria for comparing methods that represent potential improvements for the evaluation of OWE projects, which are examined in the second part of the chapter. According to the criteria defined, the decoupled net present value (DNPV) is found to be the most promising alternative among these. The DNPV is explained in detail in chapter five and applied together with traditional DCF analysis to an OWE case study in chapter seven. Before the case study, however, OWE projects are described from an investing perspective in chapter six. Chapter eight discusses of the results of the thesis and provides an outlook for future research. Finally, chapter nine provides a conclusion of this thesis and summarizes some of its main takeaways.

1.1 Research Setting

Introductions in the field of renewable energy research frequently open by reciting facts and figures illustrating the progress and prospects of this industry. I want to lead into the topic by reflecting on the notion of the techno-economic paradigm, a concept developed by Perez (2003, 2009, 2011). This approach is chosen, because the concept of the techno-economic paradigm shift lends itself to explain the rise of renewables and wind energy in particular by providing a frame of reference against which the development of renewables can be compared. This comparison in turn gives orientation with respect to past, present and possible future developments of this industry. The following passages illustrate the notion of the techno-economic paradigm shift and allow the reader to foresee how the notion relates to the rise of renewables. The passages cited were taken from Perez (2011, p.25) and recite Schumpeter (1911, 1961), who greatly influenced her work:

"The irruption of a technological revolution finds an environment that is inevitably unfavorable and even hostile. It is, by definition, a breakthrough; it is the abandonment of the accepted trajectories and practice; it means the introduction of a novel way of doing things and a set of new products, industries and infrastructures that threaten the existing ones in one way or another. It is Schumpeterian creative destruction at its most visible. It will therefore elicit ferocious resistance both from those that are really set for losing and from those that have not yet discovered they might benefit from it. […] The new firms are too small, too weak or too inexperienced to confront the resistance of the establishment by themselves. The difference between weight and rate marks the early diffusion of each technological revolution. The heavyweights that still make the bulk of the economy grow slowly or decline while those with the fast growth rates are still too lightweight to make a major difference. Only with the increasing power of financial capital on their side can they successfully wage the battles to change the socio- institutional routines, to generate the adequate manpower, to establish the new norms and other favorable conditions and to remove the many obstacles inherited from the old paradigm."

Based on the above, techno-economic paradigm shifts may be summarized as technological revolutions, reinforced by economic and societal adaptations, which fundamentally transform the economy. As a new techno-economic paradigm penetrates society at large, the frame of reference against which societal and economic decisions are made shifts, thereby rerouting society's course and mode of operation. Aside from technology, the allocation of capital is a fundamental force behind techno-economic paradigm shifts. Perez (2003, 2009) argues that the prospects for profits initially entice finance to get behind new technologies. This enables these technologies to gain momentum and in turn allows them to overcome old paradigms and barriers established by the incumbents.

In a paper based in part on the ideas of Perez, Mathews (2013) reasons that the transition to a renewable energy system - a goal pursued by a growing number of cities, states and countries - resembles the notion of a techno-economic paradigm shift. He writes that renewables already meet the following two of the three criteria identified by Perez as critical for a techno-economic paradigm shift to occur: First, the costs of the new technological paradigm must be falling and second, the effects of the new technological paradigm must be pervasive. The third criterion, renewables are still at odds with, is that costs associated with the new paradigm must undercut those of the old.

Mathews (2013) expects that once the costs of renewables are below those of fossil fuels, a shift from a technology driven expansion to an investment driven expansion will occur. With exceptions such as Uruguay, where OWE is seen as the most competitive form of electricity generation and significant investment in this technology has reduced electricity prices (cf. Martínez 2014, Parks 2015, Watts 2015), most countries have yet to reach the tipping point described by Mathews. Technological innovation is required for more countries to reach the threshold where renewables are the primary option and the foundation of a techno-economic paradigm shift. Yet, while the wind industry needs technological advances, as discussed by Campbell (2014), innovations on the business side are likely to gain in relevance as the industry expands.

According to Perez (2009) the investment driven dissemination of new technologies is often facilitated by financial innovation. She emphasizes her point with two examples. The development of medium sized export credits made by Germany to beat out Britain on the market for electric motors and the dawn of venture capital that sparked the surge of Silicon Valley. Supporting Perez' and Mathews' line of reasoning is the fact that renewables are said to require new financial vehicles to secure funding for their expansion long term (cf. Arapogianni & Moccia 2013, Kaminker et al. 2013, Sawin et al. 2015).

Financial innovation ties in with business model innovation, as the former can be part of the latter. According to theory, business model innovation is about the *"rationale of how an organization creates, delivers, and captures value"* (Osterwalder & Pigneur 2010, p.14). Some researchers claim that the extensive deployment of a new technology depends at least as much on having a suitable business model as it does on technology (cf. Teece 2010, Richter 2013). According to Pataci et al. (2015), who study the wind industry's leading turbine manufacturers and analyze the impact of business model innovation on their development, it does shape this industry considerably. From the above it can be concluded that renewables are on a trajectory towards establishing a new techno-economic paradigm, the paradigm of the renewable energy system as described and researched by Lund (2014) among others. To get there, technological innovation is key, but advances on the business side are needed as well. This thesis aims to contribute to the latter.

1.2 Motivating the Research

There are several rationales that make the investment evaluation of OWE projects a relevant, interesting and fruitful research topic. The reasoning along which the topic is motivated is summarized by the four passages below. Each of which is expanded upon in the subsequent sections of this chapter.

- The academic dialogue points to shortcomings in the evaluation of real investments, both from a theoretical and practical standpoint. New approaches try to correct some of these shortcomings and thereby may help to model the intrinsic value and risks of OWE projects more adequately.
- As capital intensive and highly leveraged investments, the characteristics of OWE projects are such that they are likely to benefit from even small improvements in their evaluation. This justifies reviewing the investment evaluation methods commonly used in order to analyze how they can be improved.
- OWE projects are increasingly realized in the less stable environments of the emerging markets, which can make the evaluation of investments more challenging. New approaches are possibly more capable at modeling and explaining investment outcomes, drivers and risks in these environments.
- Assuming the statements above are true implies that finding and developing investment evaluation methods, which allow for a more rigorous analysis of investment decisions can lead to a better allocation of resources. This can therefore benefit not only the wind energy sector and its stakeholders, but society at large.

1.2.1 Improving the Evaluation of Investments

Investment appraisal, also referred to as capital budgeting, is a discipline that assists in the allocation of resources. Capital is typically the constrained resource to be allocated. Accordingly, the goal of investment evaluations is to guide the tradeoff between consumption today and future consumption, while considering risk and uncertainty. Investment evaluations models can support this decision process by providing decision makers with insights to questions such as:

- Is the investment worth pursuing?
- How does the timing of the investment affect its value?
- How does a prospective investment compare to other opportunities?
- What are the risks, the up- and downsides of an investment opportunity?

In other words the core task of investment evaluation is to assess how, when and where to invest and divest. Generally multiple metrics and methods are used in combination when making investment decisions (cf. Gatti 2013, Yescombe 2014, Danthine & Donaldson 2015). Given the long-term impact of real investments at a micro- and a macroeconomic level, one may expect that advancing the investment decision process in theory and practice would get more attention. Yet, decades have passed since Robichek & Myers (1966) first scrutinized the theoretical foundations of what can still be considered common DCF practice today. This fact is summarized by Schwartz & Trigeorgis (2004) in the preface to their book on real options and investment under uncertainty: *"Corporate resource allocation, capital budgeting or investment under uncertainty has been a stagnant field for several decades, until the recent developments in real options [...]".* Schwartz & Trigeorgis (2004) are correct when they conclude that the real option approach was a step forward, because based on Pritsch & Weber (2001) real option analysis (ROA) is the first method that has made the transition from theory to practice since the net present value (NPV). Other methods, such as the certainty equivalent, have failed to complete this transition (Espinoza & Morris 2013). Yet, the acceptance of ROA in practice has progressed slowly (Borison 2005, Schulmerich 2010). Pritsch & Weber (2001) compare the gradual adoption of ROA by practitioners to that of the NPV. The latter, according to their research, took about 30 years until it was broadly recognized and understood. They cite the theory of the Kuhnian paradigm shift as a possible explanation and conjecture that it requires a new generation of managers for a new paradigm to materialize. Given the following words of Schulmerich (2010, p.1), who notes that the faults of traditional DCF methods are increasingly recognized and *"[…] are therefore putting pressure on academic research to improve traditional valuation tools."* it is possibly time for another paradigm shift. Supporting Schulmerich's remarks and motivating the research pursued in this thesis is the fact that traditional DCF analysis has increasingly become the target of outspoken critiques, as indicated by the literature review in chapter three.

1.2.2 Investment Evaluation & Wind Energy Projects

This section explains why OWE projects are set to profit from better investment evaluation methods, which makes them worth researching. The first reason is due to the fact that OWE projects are highly leveraged and capital intensive investments. They require capital expenditures (CAPEX) from a few million Euros upwards and are typically financed with 75% or more debt (Gillman 2011, Lüers et al. 2015). The leverage can hurt project's equity holders in particular. Therefore, from their perspective, the diligent evaluation and selection of OWE projects and their risks is critical.

The European Commission wants to make the remuneration of renewables more market based (EC 2013a, 2013b). Considering, in addition that the market environment for OWE becomes gradually more competitive as wind capacity is added (Mills & Wiser 2012, Hirth 2013, Hirth et al. 2015), the margin of error for developers and investors selecting OWE projects is shrinking. This makes a review of the investment evaluation methods currently used even more called for.

Secondly, since OWE projects are virtually build in series, they have a comparatively sound data basis, which can facilitate robust cost and revenue estimates. Robust data enhances the value of more comprehensive investment evaluations, because more precise modeling tends to require more effort. This effort is more likely to pay off with insights into the value and risk drivers of a project, when the data is sound. Another reason why OWE projects can benefit from more comprehensive investment evaluation, is that their value is significantly impacted by their financing (cf. Böttcher & Blattner 2013, Lüers et al. 2015). Since a project's financing is a function of its risks, modelling these more appropriately can lead to financing terms that are more in line with projects' true value and therefore reduce the likelihood of financial distress.

Unlike other factors, such as policy decisions, which also influence the competitiveness of the wind industry, companies from the sector have direct control over resource allocation. If the renewable industry wants to evolve and replace fossil fuels, progress in technology is the key, but progress in business models, valuation and risk management techniques are required as well. This thesis makes a contribution with regard to the latter. OWE projects selected and developed based on proper investment evaluation have a better chance of success. Successful projects are required to generate sustainable returns for the industry at large, which again are necessary to finance R&D, attract investors and ensure the continued development of the wind energy sector. Therefore, researching the investment evaluation of OWE projects is a worthwhile undertaking.

1.2.3 Investment Evaluation in an Emerging Market Context

The previous sections already show that advances in investment evaluation can create value for the wind industry by providing a better foundation for resource allocation decisions and thus increase the odds of realized projects being successful. This notion is of particular relevance as the industry's center of gravity shifts from the developed markets towards the emerging markets (cf. Kammer 2012, O'Brian 2015, Pataci et al. 2015). Although European companies want to seize the growth prospects in the emerging economies, these markets also expose them to greater risk and uncertainty. Ignoring the emerging markets is not an option unless companies want to give up market share to competitors from China and India. These are reported to fare better in emerging markets due to the similarities with their home market (Campbell et al. 2013).

Refining investment evaluations may help companies from developed economies to bridge this gap by allowing them to better assess opportunities and risks of projects in emerging market economies. Another reason why new evaluation methods can be valuable in this context is that, according to Donovan & Nuñez (2012), traditional tools to estimate the discount rate for projects in these environments work rather poorly. Therefore, emerging markets make it much harder to accurately appraise projects based on traditional DCF analysis. This further motivates searching for alternatives.

1.2.4 Stakeholder of Improved Investment Evaluations

A final point that underlines the relevance of the research pursued is the number of stakeholders in the topic. The most obvious parties to whom the topic is of relevance are:

- Project developers
- Wind turbine manufacturers
- Lenders (e.g. banks) and investors (e.g. utilities)
- Policy makers (i.e. the government)

The parties listed above are paid from the cash flows generated by OWE projects and therefore have, in one way or another, a stake in sound investment decisions by the industry taken as a whole. Many developers and turbine manufacturers are almost exclusively invested in the wind industry. As a result, they are most directly exposed to the industry's economic performance and face the greatest barriers-to-exit. From this it can be concluded that they are likely to have the greatest interest in developing more comprehensive investment evaluation methods.

Looking at the industry from a macroeconomic perspective and considering that more thorough investment evaluations can facilitate a sounder allocation of resources and thus greater industry profits, it becomes obvious that improving investment decisions at the project level benefits the entire industry. Second- and third-order effects can make this even more evident. For instance, greater industry profits mean that the industry as a whole has more equity and is better equipped to build provisions. This can prevent companies from becoming illiquid, which again reduces counterparty risk. Another example would be that greater economic prosperity leads to more funds available for R&D. This in turn leads to more competitive technology, which is the foundation for gaining market share relative to competing technologies. For these reasons it can be concluded that while those most directly involved in the investment evaluation of OWE projects have probably the greatest interest in better investment evaluations, it is actually the whole industry that benefits from these improvements. In fact, given that the state benefits through taxes and jobs, it is society at large that benefits in the end.

1.3 Challenges of the Research

The main challenges associated with writing this thesis are:

- Narrowing down the literature review
- Framing the research topic so that a coherent final thesis can be achieved
- Finding ways to improve the investment evaluation of OWE projects
- Getting suitable data to build a case study

The first challenge arises from the fact, that the topic of the thesis is rather interdisciplinary and overlaps with many adjacent disciplines. The most noteworthy overlaps exist with the following broadly framed fields of research:

- Policy & Economics – energy policy, renewable energy pricing mechanisms
- Engineering – project and risk management, power system modeling
- Business – corporate finance, project finance, operations research

The significant overlaps are best explained by what the evaluation and management of large-scale projects is concerned with at its core: decision making under risk and uncertainty (cf. Jankauskas et al. 2014). According to Koleczko (2012), the concepts of risk and uncertainty are by nature interdisciplinary and the focus of many disciplines. They are relevant to the topic at hand, so it comes as no surprise that one of the topic's challenges is interdisciplinarity. The interdisciplinary character is demonstrated by the fact that research directly related to the topic is published within each of the research domains outlined above. To substantiate this claim, below each of the disciplines is linked to a reference that is closely related to the research topic of the thesis.

- Policy & Economics: *"Application of Real Options Theory to the Assessment of Public Incentives for Onshore Wind Energy Development in Spain"* published in the International Journal of Energy Economics and Policy by Balibrea-Iniesta, Sánchez-Soliño & Lara-Galera (2015)
- Engineering: *"Wind Resource Assessment and Micro-siting: Science and Engineering"* published by Zhang (2015)
- Business: *"A Monte Carlo Model of a Wind Power Generation Investment"* published in The Journal of Applied Business and Economics (2013)

A topic at the intersection of different fields tends to lead to a greater pool of possibly relevant literature. This causes the second challenge, which is the careful drawing of the boundaries of the topic, so that a coherent thesis can be achieved.

To draw the boundaries of the topic, first of all, precise research questions and hypotheses have to be developed. Secondly, adequate methods to test these have to be selected. Aside from the literature review the main method used in this thesis is the case study method. The challenge associated with this method is to get relevant data to build a case. In addition ways to improve the investment evaluation of OWE projects have to be found. How the challenges outlined are intended to be handled, is specified in following chapter titled "Research Design".

9 Conclusion

As the generation of wind energy in Europe and Germany has expanded over the past decades, the market environment for OWE projects is becoming increasingly competitive and complex. Evidence for this trend is the introduction of auctions in Germany, which will be used for pricing the electricity of future OWE projects and which create new project risks. A more competitive and risky market environment puts pressure on the margins of OWE projects and can render them economically unfeasible. Yet, the objective in Europe and Germany is to further expand the use of onshore wind energy, which in turn requires the continued identification, development and investment in economically sustainable projects. Therefore, investment evaluation models capable of modelling the realities and risks of this new market environment are required. Against this background, the objective of the thesis is to analyze how investments in OWE projects are typically evaluated in order to improve and advance their evaluation. The goal is not to find ways for calculating higher valuations for OWE projects, which techniques such as ROA or the ESNPV can make one believe, since they emphasize the upside of investments. Instead, improving the investment evaluation of OWE projects, as understood by this thesis, means refining the assessment of the variables driving investment value in order to facilitate sounder investment decisions and a better allocation of resources.

This thesis starts out by researching the status quo of how OWE projects are commonly evaluated. It finds that traditional DCF analysis, which discounts expected future cash flows with constant RADRs or hurdle rates is most widely used in this context. In the literature review of this thesis, many flaws and shortcomings associated with traditional DCF analysis are identified. They are aggregated into a total of 14 points of criticism. These are subsequently used to derive a set of criteria for comparing the prospects of several methods and concepts discussed as potential improvements for investment evaluations. All alternatives are first reviewed before they are assessed according to the selection criteria. The method identified as most promising is called the DNPV. As explained in this thesis, the DNPV fills a void particularly with respect to infrastructure investments given that it can model systematic and unsystematic risk. Most importantly, however, the DNPV provides solutions to some of the most fundamental issues of traditional DCF analysis, which are widely discussed and recognized in academia, but have so far lacked a practical solution. The most characteristic feature of the DNPV is the decoupling of the time value of money and risk, which are normally lumped together in the discount rate. The decoupling is achieved by means of SIPs, which can systematically model the risk structure of investments and can be used to quantify risks individually and in aggregate.

After presenting and examining the theory on this new methodology, the DNPV and its associated concepts are applied to an OWE case study. The case study is predominantly based on secondary data from the German OWE market. It is developed to validate the applicability of the DNPV and compare it with traditional DCF analysis, namely, the NPV and the IRR. These two methods are found to be the most popular investment appraisal methods in practice. For the evaluation of the case study a DSS that functions as an investment evaluation model and can assess the case study both from an equity and an entity perspective was developed in MATLAB. However, within the scope of the thesis only the equity perspective is discussed. This is because the equity perspective coincides most with that of project developers and investors in OWE projects. The DSS consists of scripts for the input of data, a cash-flow-risk model for computing SIPs based on frequency distributions, which are generated via MCS and PDFs, as well as scripts for calculating the key figures and exporting selected results for further analysis to EXCEL. Aside from the NPV and the IRR, the DSS calculates several key figures specific to the DNPV, such as the implied RADR and risk performance.

The case study requires the analysis of two different configurations of an OWE project. While one PCN is characterized by lower expected expenditures and higher risks, the other is associated with higher expected expenditures, but a more favorable risk profile. Just calculating the deterministic NPV and the IRR for the two configurations clearly favors the riskier PCN. Therefore, a decision just based on these popular metrics neglects the information regarding the different risk profiles. The DNPV can model this type of information and consequently reflects the attributes of investment opportunities more fully. The results generated with the DSS demonstrate how the DNPV can support investors in the selection of projects and prioritize their risk management efforts. The latter can be achieved by computing time series of individual risks expressed as SIPs. Further, risks can be compared in terms of present value SIPs. The thesis shows how combining the DNPV with traditional approaches can help investors identify actions to improve a project's financial and risk performance. Both of which are a function of a project's DNPV and NPV.

Overall, the case study confirms the evidence from other sources that the DNPV is a substantial improvement for investment evaluations in general. For OWE projects in particular, the DNPV facilitates a more comprehensive and consistent evaluation of such investments and their associated risks. The latter makes the DNPV a great tool for project risk management. Given that the DNPV is a novel and flexible concept, there are many research domains to which it has yet to be applied. Examples are the field of energy policy research, the appraisal of infrastructure investments and project risk management.