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Renewable Energy in Central and Eastern Europe

„Deriving a Minimum Acceptable Rate of Return on Equity for a Wind Farm from a Comprehensive Risk Model Using Monte Carlo Simulation"

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Affidavit

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Abstract

Investments in renewable energy are a relatively new asset class with only a decade of experience from private investors. It is distinctive to other investments in infrastructure and companies in their risk return profile.

This paper outlines a comprehensive framework of risk management and allocation. Based on this model, a Monte Carlo simulation is run in order to calculate the expected values and the standard deviation for key target ratios for liquidity and return. The expected internal rate of return (IRR) and the standard deviation are compared to the respective figures from an investment in a S&P 500 portfolio by calculating the respective Sharpe ratios. From this comparison a minimum acceptable rate of return for this wind park investment is derived.

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Executive Summary

Investments in renewable energy are a relatively new asset class with only a decade of experience from private investors. Its risk return profile is different from other investments in infrastructure and companies. The markets for renewable energy investments are still subject to constant change in terms of regulatory framework, technologies and investor base.

With the government support schemes being reduced constantly, cost of renewable energy has to come down. Technological development is a key driver for cost reduction, but cost of capital is highly important, too. Reducing risk and a full understanding and pricing of the remaining risk are important in order to keep this field attractive for private investors.

This Master Thesis outlines a comprehensive framework of risk management and allocation. Due to the maturity of the technology and well established market standards, many risks of a wind farm can reasonably be avoided, mitigated or transferred. Still, as of today, production risk and regulatory risk are major risks that stay with the project sponsor. This also holds true for inflation and price risk after the feed in period.

These risks have to be quantified in order to set reasonable return targets and make rational investment decisions. With all the information on the relevant variables integrated in a standard cash flow model, static results for the main target ratios are calculated. The probability distributions derived from historic data and from validated models used in wind studies are assigned to the most relevant variables.

Based on this model, a Monte Carlo simulation is run in order to calculate the expected values and the standard deviation for key target ratios for liquidity and return. The expected internal rate of return (IRR) and the standard deviation are compared to the respective figures from an investment in a S&P 500 portfolio by calculating the Sharpe ratios.

The simulation for the wind farm investment shows a 10.9% return (IRR), a standard deviation of 3.3% and a corresponding Sharpe ratio of 2.65. The long term average return of an investment in a S&P 500 portfolio shows a return of 9.8%, a standard deviation of 3.9% and a corresponding Sharpe ratio of 1.94. The investment in the wind farm therefore is to be preferred over the investment in the public market.

At this standard deviation an internal rate of return (IRR) of 8.5% would translate in the same Sharpe-ratio as the public market investment and therefore can be considered as the minimum acceptable rate of return (MARR) for the risk profile of this wind farm.

Overall, Monte Carlo simulation based on this risk model can make risk much more transparent to the investor or, as the case may be, to the lender. It also provides a powerful tool in order to set rational expectations for return on equity and to decide between two investment alternatives. It is of course subject to the general limitations of models that the quality of the output is limited by the quality of input. Its complexity might also compete with the temptation of decision makers to look for simple and widely accepted tools and not necessarily for accurate and comprehensive ones.

Monte Carlo simulation opens valuable insights in the financial analysis of wind farms with regard to the risk return profile. As for the return expectation, the results of the case study show that the actual return of the wind farm is above the calculated minimum acceptable rate of return (MARR) of 8.5% and therefore can be rated as an attractive investment.

1 Introduction and research question

Historians tend to describe early human history in terms of the key materials used (Stone Age, Bronze Age, Iron Age). More recent historical ages are named according to the state of empires (Antic Ages until the fall of the Roman Empire, New Age from the global expansion of the European empires on). It might well be that future historians will categorize the next ages according to the dominant fuel: Coal Age, Oil Age, Solar Age. Anyhow, they will certainly state that fuel is shaping modern society probably more than anything else: coal was the source for the industrial revolution, oil for the revolution of individual mobility (and numerous wars during the past six decades).

Electricity generation was highly decentralized in its early days, with small power plants providing electricity for nearby (industrial) consumers. This pattern changed when large hydro power stations were built in the early 20th century and later large carbon, oil and gas firing plants in the 1950s and nuclear power plants in the 1970s. Production became highly centralized, with large distances between production and consumption.[1]

This pattern held true until the electricity generation from renewable sources was gaining importance starting in the early 2000s. This also leads to a shift back to more distributed power generation, changing gradually the design of power supply.

The share of electricity in total power consumption has increased steadily and will do so in the future. The reason for this is both its transportability and its versatility. Electricity can be easily transported by wire over many hundreds of kilometers and it can be transformed easily in various services like lightning, mechanical power and information. The massive deployment of electricity generation from renewable energy could be a turning point economically, as well politically.

Size and technology of power generation have far reaching implications on its economics. It is hard to think of any other industry, where there is such a wide range of production technologies available, as in electricity generation. This has an impact on cost and economics, degree of centralization of production, distribution, safety of supply and environment. The introduction of electricity generation from renewable

[1] William (2006)

sources with a completely different cost and risk structure compared to fuel-based power plants, has aggravated this fact.

During the past two decades, Germany, Austria and other early adopters have seen different phases of electricity production from renewable energy sources (RES): In the 1990s, RES experienced a *pioneer phase* in many countries.[2] In fact, it turned the cycle back to the very beginning of the production of electricity, starting as a quite decentralized undertaking, with small production units widely dispersed and usually close to the consumer of power, who happened quite often to be the owners / investors. Renewable energy has (partly) shifted energy production from large centralized units back to small, decentralized units with different ownership and financing structures. Investments were mainly driven by pioneers with motives of technological interest and small production units with a close loop of production, consumption and *ownership by individual investors*.

In the early 2000s, the *scaling up* of production units lead to increased capital needs, mainly provided by local structures with participation of *private local investors*. Local project companies raised private money. Large, non-hydroelectric renewable energy projects were developed, owned and financed by private non-utility investors.

Since the mid 2000s, further scaling up of production, *mature* technologies and feed-in regimes turned the business into an attractive arena for *financial investors*. In Germany for example, many special purpose funds were set up in order to collect investors money and invest in renewable energy projects.[3] Later in this phase, private equity funds entered the business and tried to jump on the RES bandwagon.

Again further scaling up of production units and *integration* in the overall energy infrastructure are about to close the circle, bringing renewable energy to the level of conventional power plants. *Utilities are becoming significant investors* in this field. Utilities, like "Stadtwerke" in Germany, have begun to consider owning and financing their own wind power facilities rather than only purchasing power from independent renewable energy suppliers. Renewable energy has now grown into a regular part of energy business.[4]

The "Energiewende" (transition to renewable energy sources) in Germany is still setting the regulatory and technical pace and direction in Europe in terms of regulation, deployment and integration of RES. It is common sense that this

[2] Kaldellis et al (2011)
[3] Enzensberger et al (2003)
[4] ECOFYS (2011)

transition will only work with the optimal use of *all* renewable energy sources. Bio - energy, solar energy and wind energy have to be integrated at various levels into the energy system. With the public support schemes being confronted both with increased political pressure and a dwindling trust from investors, market cost and risk assessment are becoming a highly important part of further deployment.

The risk premium in lending rose sharply during the past five years and policymakers and consumers still show an increasing reluctance to pay a huge premium on green electricity. Cost efficiency therefore will be a key priority for further deployment of renewable energy sources, and the cost of capital is an important part of it. Therefore, providing capital at low cost is a key factor for the further spreading of renewable energy.[5]

As for the relevance of financing cost and structures, there are considerable differences between the various sources of renewable energy:[6]

Bio - energy quickly reaches its limits in large scale plants both in terms of ecological sustainability and economics. It will, however, play an important role on local and regional energy concepts in countries with abundant biomass resources, especially in Central and Eastern Europe and countries like Brazil. The major cost drivers for bio – energy are the prices for the input material, financing and related cost are not that important.

Photovoltaic (PV) will shift closer to the end user with both subsidies and system prices being cut rapidly, bringing cost of electricity produced close to grid parity in many southern European countries and in general in the global sun belt. This will also shift the way PV projects are financed. It will take both scale and risk out of this production technology, making financing a less critical issue for deployment of photovoltaic.

Wind energy tends to be the technology that will be part of the large scale renewable energy “back bone”, with large off-shore wind farms on the grid as well as ever larger on shore wind farms.[7] The issues of operational risk and capital cost are most relevant for wind energy. The right profiling of risk for investors and financiers in wind farms therefore is a topic of major concern, not least because currently it accounts for 2/3 of all investment in renewable energy.[8]

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[5] Justice (2009), p. 17ff
[6] Kaltschmitt et al (2009), p. 551ff
[7] Madlener et al (2009)
[8] United Nations Environment Program (2011), p. 13

The answers translate directly into access and the cost of capital. Valid risk models should translate to right pricing. However, there are numerous barriers that still have to be addressed and to be overcome: [9]

- *Cognitive barriers*, which relate to the low level of awareness, understanding and attention afforded to RES financing and risk management instruments.
- *Political barriers*, associated with regulatory and policy issues and governmental leadership.
- *Analytical barriers*, relating to the quality and availability of information necessary for prudent lending, developing quantitative analytical methodologies for risk management instruments and creating useful pricing models.
- *Market barriers*, associated with a lack of financial, legal and institutional frameworks to support the uptake of RES projects in different jurisdictions.[10]

The focus of this paper will be on the analytical barriers. Experience shows that they seem to be underestimated since the policy driven top down introduction of RES promotion has a "natural" focus on political, market and cognitive barriers. And, as in many government and subsidy driven industries, economic actors tend to neglect the underlying economics of the business.

As already discussed, the investor base for renewable energies is changing with reduced feed in tariffs drive down returns and increased uncertainty about regulatory risk brings private investors to doubt the adequacy of returns in renewable energy production.[11]

Utilities might have different return expectations compared to private non-utility investors for several reasons:

- They have usually favorable conditions to raise capital in the market.
- With energy production being their core business for many years, their risk (perception) is different.
- With many of these companies being state owned and / or having close ties to policymakers, their perceived (and maybe actual) regulatory risk is lower.
- Finally, since they often have carbon based production, they will benefit from producing from own renewable sources, through fulfilling emission targets.

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[9] United Nations Environment Program Division of Technology, Industry and Economics (2004), p. 16
[10] United Nations Environment Program Division of Technology, Industry and Economics (2004), p. 18
[11] Böttcher (2009), p. 15

There is no doubt that technological progress will drive the spreading of renewable energy. Still, whatever may be achieved on this side, capital requirements will remain very substantial. Both availability and cost of capital therefore will be crucial.[12] The overall level of interest rates is set exogenous and cannot be influenced within that framework. However, the cost of capital can be brought down by two factors: one way is to bring down factual risk. In fact, considerable efforts are made in technological development to make the technology reliable and endurable and also in terms of business models to pass on risk to those agents who can care for and carry them best. The other factor is to have a full understanding of the risks involved in investing into the specific technologies and therefore avoiding miss- and eventually overpricing of capital.

The aim of this Master Thesis is to derive a well based risk model for renewable energy projects in order to quantify the involved risks and calculate a minimum acceptable rate of return (MARR) for investors. Right pricing is of high importance especially for non-utility investors to further take part in this market. This should prevent private investors from getting too low returns out of ignorance of the risks involved or asking to high returns and getting crowded out of the market by other players like big utilities. Therefore, risk adequate pricing is of high importance for further non-utility private funding of renewable energy production.

This Master Thesis focuses on wind farm projects for several reasons: first, wind energy is still a major field for equity investment from private sources. Second, the risk profile for wind energy production is higher than e.g. for PV-production. In terms of investment size and risk management it probably is the most challenging source of renewable energy. Wind energy, finally turned into a business that will be viable only in a large-scale integration into large networks. All this makes wind power still very challenging in terms of financing and risk assessment.[13]

Further on this paper focuses on the *operating phase* of the wind farm only, excluding project development and construction. This is mainly because the risks related to the project development (e.g. permitting/planning delays, contractual risks, engineering risks, contractor non-performance) are by nature entrepreneurial and very much dependent on the experience and professionalism of the developer. This risk cannot be described within the framework of probability distributions as proposed in this paper.

[12] United Nations Environment Program (2011), p. 4ff
[13] Economist Intelligence Unit (2011), p. 9

2 Integrated risk management model

The cost and availability of capital is a key issue for the deployment of wind energy. As already pointed out, the barriers are manifold, but the analytical barrier is probably the one that got too little attention so far. This is because the industry is driven by subsidies and government support, idealism and greed, a quite different setting from what usually is the basis for equity investments. A sound analytical framework for risk is becoming more important with a shift of renewable energy production towards market terms and conditions and a fading belief in state infallibility.

Historically, the concept of risk has changed considerably. In ancient times, the experience of uncertain events was more associated with Fortuna, a rather capricious goddess that would give or take good or bad fortune. The modern concept of risk appears to take hold in the 16th century, being associated with *difficulties to avoid at sea*. With commercial activities following the trails of the explorers in uncharted waters, the word got an abstract meaning, referring to the possibility of gains and losses from economic activities.[14] This relates to the overall transformation from medieval to modern patterns of thinking, taking human destiny out of the hands of a goddess and making it subject to human control or at least calculation.

This concept of risk has been developed further with mathematicians like Blaise Pascal defining the concept of probability in the late 17th century. These concepts made uncertainty calculable and therefore manageable. The prevailing idea at that time was that everything that happened in the world could be explained and measured.

The first commercial application of this knowledge was the beginning of modern insurance industries. In 1693, the astronomer Edmond Halley created a basis for underwriting life insurance by developing the first mortality table. This turned insurance business from a simple bet into a business based on objective facts.[15]

The final step to modern risk perception was the full integration of statistics and probability in economics in the midst of the last century with the famous "Black-

[14] http://en.wikipedia.org/wiki/Risk
[15] http://www.thehistoryof.net/the-history-of-insurance.html

Scholes" formula, valuing the future value of an asset considering its specific risk. This formula can be used to fairly price options on assets.

Risk has now become the keyword in the description and analysis of modern economies. The ability of economic actors to take risk opens the space for decision-making and action necessary to fuel growth and development. At the same time risk had to be fundamentally bounded with regard to the limited ability of the economic actors to bear losses. The possibility to take risks is closely tied to techniques to understand, manage and restrict risks.

Today, risk is at the core of every economic activity. It can be defined as the range of uncertain events, which can influence the objectives of an undertaking.[16]

This definition already includes the key concepts:

- Range of *uncertain events*: something that may happen or not
- *Influence*: the event has a specific influence on the objective of the undertaking; this influence has to be understood and quantified
- *Objective*: the undertaking has a clear objective, in today's project finance it is mainly the return on equity.

More specifically, in this paper risk is defined as the probability distribution of expected returns and the related standard deviation of the mean value.

2.1 Risk model

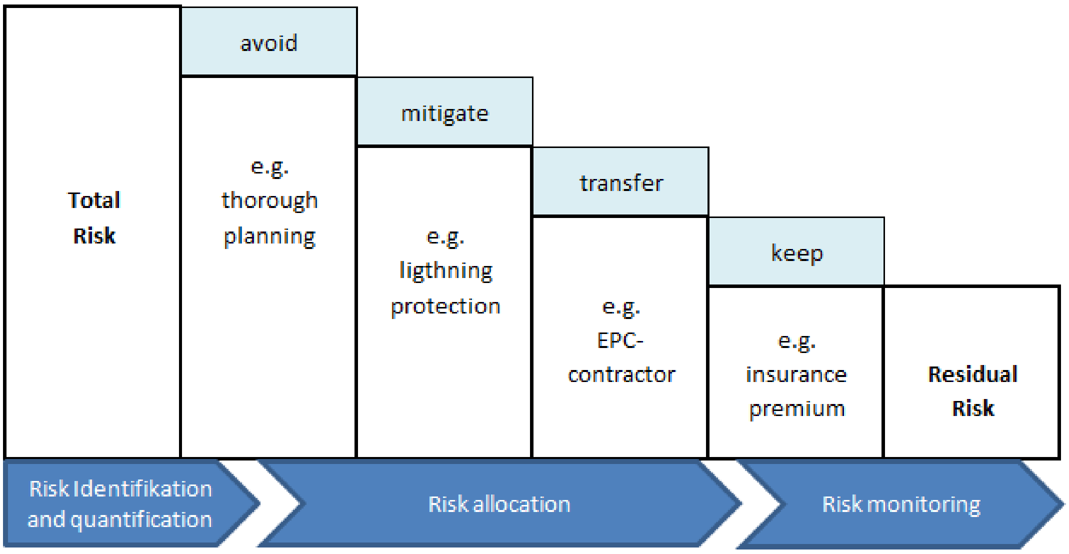
The first wind turbines were used for electricity generation from the early 20th century on and the wind-power industry as we know it today started in the late 70s of the 20th century. On-shore wind projects hence have quite some track record. It therefore is reasonable to assume that all relevant risks for on–shore wind power plants are essentially known by their nature and by their extent[17] and therefore can well be described in a risk model.

In the context of this paper, the aim is to develop a comprehensive, but still manageable risk model. Risk management is the umbrella term for the set of procedures and tools that make investment decisions subject to systematic "identification, analysis, assessment, control, and avoidance, minimization, or elimination of unacceptable risk. Risk assumption, risk avoidance, risk retention, risk

[16] Jutte (2009) p. 3
[17] See European Wind Energy Association (2009)

transfer are the strategies in discussions for a proper management of future events.[18]

Figure 1: Risk management process



Source: Own diagram based on Romeike (2002)

A well defined risk management process is an essential effect of the learning curve, albeit underestimated, since the most common learning curve concepts are focusing only on the reduction of production cost with the number of units produced. There are two important effects of the learning curve on projects risks: First, the occurrence of risk events can be mitigated through experience. This mainly relates to a number of reliability issues of wind turbines resulting from gear box designs, dimensioning of foundations and many turbine control issues.[19] Second, the knowledge how to and the willingness of third parties to resume risks is increasing over the learning curve. It is important for all participating parties to have a good common understanding of the risks involved in a certain technology. The better a market is understood by its participants, the more possibilities there are to distribute risks to those agents who can best judge/ influence / bear them, the lower the overall risk involved in an economic activity. This includes the risk of not perceiving / assessing risk properly.[20]

However, the availability of hard data could still be improved. This is mainly due to the fact that the market players do not have an intrinsic incentive to make their data

[18] http://www.businessdictionary.com/definition/risk-management.html#ixzz1xJBurjnw
[19] McMillan (2008)
[20] United Nations Environment Program Division of Technology, Industry and Economics (2004), p. 17ff

public. This is not different from many other industries. However, since the wind industry is highly subsidized on grounds of learning curve effects, one could argue that it is essential to make information public, not least for regulators to set realistic targets for return on equity in order to both promote the use of renewable energy sources and protect consumers from overpaying energy.

2.1.1 Risk identification

The starting point of the model is to *identify* the range of uncertain events that can influence the objectives of an undertaking within the lifetime of the project. Wind farms are now in operation for many years, the associated risks are therefore quite well known by wind farm operators. With stable and clear boundaries, little external effects and a defined lifetime, it is possible to make a quite comprehensive and reliable identification of the risks involved. During the due diligence performed in the course of acquisition/investment all issues that might cause a risk during operation of the wind farm shall be identified. The space of possible risk will be already quite well defined at that point, through customary due diligence check lists and the results from the due diligence. However, since this process usually is very formal, it might be helpful to bring experts together for a more informal brainstorming session. All significant risks identified shall be recorded in a *risk register.* [21]

The next step will be to qualify the risks properly according to their nature by setting relevant variables.

The process of setting variables includes:[22]

- the definition *of* variables that can be used to *quantify* the uncertainty. The variable has to relate to the output of interest. Since the output of interest in an economic analysis is cash-flow related, the variable must relate to a cost or revenue. For example, the reliability of the wind turbines is translated into downtimes as % of total hours of a year. This again translates into a corresponding reduction of annual production, reducing the cash-flow generated by a project.
- the distinction of the *nature* of variables
    - o decision variables

[21] United Nations Environment Program e-Learning Course on Insurance Risks Management for Renewable Energy Projects Case study, p. 8
[22] Rodger et al (1999), p. 5ff

Some risks are attached to decision variables (decision maker has direct control, e.g. the type of wind turbine used). These decisions can also be included in the cash flow model but should be dealt with separately in a ceteris paribus analysis. Given a certain set of assumptions the optimal technological set up can be identified by calculating the relevant parameters for alternative set-ups.

- o value parameters

  Models may include value parameters, which are set by the decision maker according to his preferences or investment guidelines. Value parameters cannot be derived from the model itself but have to be set externally. The valuation of a potential threat to human life would be such an example (highly relevant for an atomic power plant, rather irrelevant for wind power plants). For wind power plants usually the cost of equity is the most important value parameter. It is at the core of this paper to derive the minimum rates from the risk profile of the project and *internalize* it in the model to give it an objective foundation, i.e. that it is not derived from arbitrary guessing.

- the check for *completeness* of variables

  As already mentioned, there is a long standing experience in wind farm operation and most of the relevant risks are well known. Still, there might be issues with new turbine designs that are unknown so far or there might be site specific risks that have not been considered properly.

- the check for *correlation* of variables

  Correlation is an important issue in model building. Correlation means that the state of one variable gives us information about the likely occurrence of another.[23] In mathematical terms, a correlation coefficient of 1 signifies perfect correlation, i.e. the change of 2 variables is always identical. A correlation coefficient of 0 signifies completely independent variables. Correlation between two variables is not sufficient to establish any causal relationship in either direction. Still, correlation can be taken as an indication for a causal relationship.[24]

[23] Rodger et al (1999), p. 18
[24] Rodger et al (1999), p 19

Correlation is an important tool for building forecasting models, especially in economics. It can be of high importance in many projects, too.

The most important correlation in a business plan is the one between product prices and quantities. Higher prices usually translate in lower demand. This is basically not applicable for wind power plants, since

- the producer is a price taker (the company cannot set prices) and
- and the overall elasticity of demand is very low (consumption is not highly correlated to the price of electricity).

There is, however, a correlation of total electricity from intermitting sources produced and the sport market price for electricity. This effect is called merit order effect[25] and will be discussed later.

The second important correlation in business plan assumptions is the one between interest rates and inflation. However, it is very common to have long term fixed interest rates also in order to get inflation protection from this side.

The check for correlation of variables is important in order to avoid double counting of risks, as well as to see “natural hedges”. There also might be amplifying effects even if events are not correlated. A delay in the construction process might for example lead to a loss of a higher feed-in tariff.

- the decision of inclusion or not of *rare events*[26]

A rare event is an event occurring with a very small probability, the definition of ‘small’ depending on the application. For the purpose of risk analysis, rare events are of interest, if their probability is small but the impact is very large. This is highly relevant for technical systems where failures have catastrophic consequences. As for wind power plants, rare events can be relevant in case of destruction from natural disaster (mainly storm). This risk, however, is almost always insured and shall therefore not be considered. Regulatory risk is different: the possibility that feed in tariffs (FIT) and priority for feeding in the electricity might be altered and abandoned in the future has to be taken serious. In fact, this risk cannot be insured and usually is not taken into account at all. Given

[25] European Wind Energy Association, Pöyry (2010)
[26] See Rubino et al (2009)

the quite considerable impact of these arrangements on the return of a wind power plant and the fact that the probability might be small but still exists (and in fact already happened), it should be considered.

2.1.2 Risk quantification

Those risks that are not subject to decisions and values set externally from the decision makers are to be quantified in the next step. Quantification in this context means to attach a probability distribution to the specific risk, to describe the uncertainty around the value of a variable.[27] A probability distribution describes the probability that a variable will have a given value or occur within a given range.

If possible, data for quantification should be derived from historical data. Historical data can be analyzed in order to define the distribution that represents the uncertainty in the variable. This can be done by fitting an empirical distribution, i.e. the distribution of the empirical date is used itself as the probability distribution. The other method is using a theoretical distribution to represent the data.[28] The parameters that describe the distribution (for example, the mean and standard deviation for a normal distribution) must then be determined from the data. This approach is applicable to historic return data of investments in the stock market and for reliability data for wind turbines.

The major issue with this method is that it assumes that future events show the same patterns as past events. This has its obvious limitations with the prediction of economic variables like energy prices, since patterns may change considerably for various reasons, and they in fact did. The issue is less obvious with technical variables, but even there we have to consider two distinct trends. On the one hand, the technical reliability of parts and machines is increasing with installed base due to learning curve effects. Therefore, many parts in modern wind turbine generators are becoming more reliable. On the other hand, turbine size is increasing rapidly and many new components are introduced, bringing in new risk factors in the whole technical system. This leaves a key factor for economic return highly uncertain since the expected useful life of a wind turbine is 20 years, but none of the current design out there has a track record of this length.

The other way to quantify risk is to use expert assessments. This method, too, has its flip sides. On the one hand, experts also tend to extrapolate the past into the future. The "memory effect" might even be stronger with human judgment than with

[27] Rodger et al (1999), p. 12
[28] Rodger et al (1999), p. 18

time series, simply because it is not always that obvious. Experts tend to judge a risk also from their specific position, which might lead to distortions of the relevance of the specific risk to the whole project. Finally, human risk perception is not linear, i.e. usually is biased to avoid potential losses over the maximization of the expected value of a project. There are several other biases in human judgment: we consider those events more likely that we remember; we consider things more likely we have more information about; we generalize probabilities from small samples; once estimated probabilities tend not to be questioned and related information neglected or downplayed; we tend to look for patterns even if there are none etc.[29] The consequence from this is the necessity to cross check expert opinions, proxy data and possible indicators for biases.

Reasonable quantification of risks is a considerable effort. Therefore it makes sense to focus on risks with a high likelihood to occur and / or a high impact on the result. Other risks should be separated out or modeled in the cash flow model.

2.1.2.1 Describing risk with a probability distribution

Once risk is quantified, i.e. outcomes and probabilities of occurrence are set, this risk can be described using a probability distribution. There are many forms and types of probability distributions, each of which describes a range of possible values and their likelihood of occurrence.

There are three basic characteristics of classifying probabilistic risk distributions used in this paper:

> *Bounded and unbounded distributions*[30]:
> Unbounded distributions extend theoretically to minus infinity and/or plus infinity. In order to avoid values that are nonsensical unbounded distributions can be constrained. Normal distribution and logistic distributions are examples for unbounded distributions.
>
> *Continuous and discrete distributions*[31]:
>
> Profiles, in which any value within the limits can occur, are described as continuous, whereas if the variable can only represent discrete items, for example the number of warehouses in use, a discrete distribution is more appropriate;

[29] See Renn (1995), Kahnemann (1982)
[30] van Hauwermeiren et al (2009), p. 9
[31] van Hauwermeiren et al (2009), p. 7

A *continuous distribution* is used to represent a variable that can take any value within a defined range. For example, the production of a wind power plant picked at random has a continuous distribution because the output is essentially infinitely divisible. The scale can be repeatedly divided up generating more and more possible values. Properties like time, mass and distance, that are infinitely divisible, are modeled using continuous distributions. In practice, continuous distributions can also be used to model variables that are, in truth, discrete but where the gap between allowable values is insignificant: for example, project cost, number of employees in a large organization, etc.

A *discrete distribution* may take one of a set of identifiable values, each of which has a calculable probability of occurrence. Discrete distributions are used to model parameters like the number of wind turbines in a wind farm.

Parametric and non-parametric distributions[32]:

A *parametric distribution* is one that has been theoretically derived, for example an exponential distribution, after making assumptions about the nature of the process that is being modeled or by fitting historical data. These model based assumption require reliable historical data or a deeper knowledge and understanding of the underlying models and assumptions. The most common parametric distribution are Normal distributions, Weibull distributions etc.

Nonparametric distributions are those that have been derived from empirical knowledge. They are usually intuitively easy to understand and rather flexible. Triangular distributions are one of the most used empirical distributions, assuming a lower value, a mid value and a maximum value of a given parameter.

2.2 Risk allocation

Once major risks are identified, the next step will be to look into measures that explain *how to handle risks*. The first step would be, of course, to avoid risks. This can usually be done through thorough planning, tight project management and careful execution. Risks that can't be avoided at all or only at unreasonable cost can be mitigated. Lightning, for example, can't be avoided, but its effects can easily be

[32] van Hauwermeiren et al (2009), p. 10

mitigated by installation of lightning protection. Still, lightning may cause damages. This risk can be *transferred* to an insurance company.[33]

The remaining risk has to be retained by the project owner. During the past decades, a range of new products and services have emerged that allow economic actors to distribute and share risks from their own economic activities with others.[34] Insurance companies and the financial industry provide an array of services unheard of so far on technical risk, elementary risk, credit risk, interest rate and exchange rate risk. The possibilities are not limited to these providers. It became very common with large projects to balance economic interest and risk bearing capacity of all participants (developer, supplier of machinery and equipment etc.).

It is at the core of modern project risk management, that that party should care for the risk that has the best knowledge and capacity to influence the respective risk. E.g., in terms of construction risks this means that it shall be borne by an experienced Engineering-Procurement-Construction (EPC)-contractor, as for the maintenance of the turbines the turbine manufacturer should best care it for.[35]

Usually, the process of risk allocation is very closely linked to the process of project structuring and due diligence. Lenders, equity investors and other parties involved look in a distinct way at the risk of a wind farm project. Perspectives will differ depending on who assesses the risks involved and what the specific perspective and interest is. What might be an unacceptable risk to one investor may be part of the business of another investor. And it also has to be kept in mind, that some risks can never be properly assessed or quantified.

The final step will be to *integrate* all the information in the cash-flow model of the project company. By then, a comprehensive list of cash flow relevant items should be set up. All items can be linked to a severity, the impact of a risk on the project translated into a corresponding cash flow, and a frequency, the likelihood of risk occurring translated into a percentage probability.

[33] For a comprehensive overview of traditional insurance products available for renewable energy projects see: United Nations Environment Program Division of Technology, Industry and Economics (2004), p. 23
[34] For a comprehensive overview of emerging financial risk management instruments for renewable energy projects see United Nations Environment Program Division of Technology, Industry and Economics (2004), p. 30
[35] Böttcher (2009), p. 24f

2.3 Major risks of a wind farm

The following section will discuss the process of assessing, avoiding and distributing the major risks of a wind farm.

2.3.1 Wind risk

2.3.1.1 How to assess wind risk

Good wind resources are the key to the commercial success of a wind park. There are some important characteristics of wind power that are unique:

Low power content of wind

With air density at standard conditions being 1.2 kg/m³ the energy content of wind is rather low compared to water with a density of 1,000 kg/m³. With the kinetic energy

$$E_K = \frac{m}{2} \times v^2$$ [36]

where m is the mass and v the velocity of the body,

the kinetic energy of water is roughly 800 times larger than that of air. Therefore, the size of a wind-turbine has to be much larger compared to a hydro-turbine.

Sharp increase / decrease of power content depending on wind speed

The energy content of wind is increasing at the third square. Doubling the wind speed leads to eight times the energy content.

According to the equation

$$P = \frac{p}{2} \times A \times v^3 \times c_p \times n$$ [37]

where p is the density of air, A is the rotor area, v is the velocity of air, c_p is the power coefficient and n is the dimensionless efficiency of the turbine,

the Enercon E101 shows the following power curve:

Table 1: Power curve Enercon E-101

Windspeed at hub height (m/s)	Power Output (kW)
4	118
6	479
8	1.200
10	2.340
12	3.034

Source: Enercon [38]

[36] http://en.wikipedia.org/wiki/Kinetic_energy
[37] Kaltschmitt et al (2009), p. 204

Doubling the wind speed from 4 to 8 m/s leads to ten times power output! Wind at sufficient speed is not a continuous phenomenon, with squally occurrence being the norm rather than the exception. This makes wind studies and forecasts also difficult and systematically error-prone and less reliable than investors would like them to be. For example, a measurement error of 5% of wind speed can translate into an error of production forecast of 14%[39].

Total annual production of this turbine at a wind site with an average wind speed of 6 meters/s would be 2.252 MWh. Given again, the distribution of wind speed at this site, 80% of its production would be made in only 30% of the time.[40]

Very high degree of location dependence of wind resources

Wind is a very location dependent resource. This is important on the scale of the design and development of a national grid. Regions with the best wind resources may not be situated next to industrial and population centers, where demand is highest. From the perspective of risk assessment of the individual wind farm, it is even more important that wind is a very local phenomenon, impacted by the landscape, trees, hills, buildings. Considering that only several dozen meters already have serious impact on wind, micro-sighting is of high importance for the commercial success of a project.[41]

Wind energy is highly weather dependent

Finally, wind is a highly weather dependent resource since wind is one of the core weather phenomena. Wind speeds fluctuate on a very short term scale, as well as diurnal, seasonal and even inter-seasonal. And the patterns of these changes are highly site and region specific.[42]

The power output of a wind turbine is highly volatile even in short-term intervals, but highest in longer periods of multiple hours due to weather dependency. Since the dominant weather conditions can be quite uniform in larger areas, one can observe a high correlation between the production of a single turbine, a group of wind plants and all German wind power. There is a smoothing of variability of production, but interestingly the normalized level of the aggregate plants (group of wind plants and

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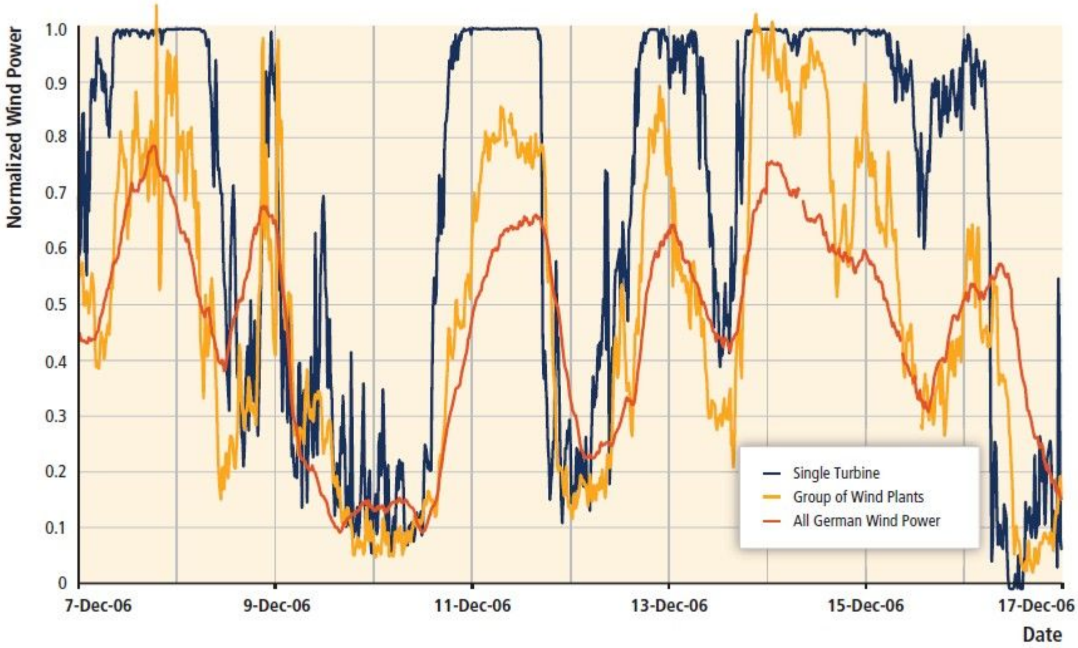
[38] http://www.enercon.de/p/downloads/EN_Productoverview_0710.pdf
[39] Own calculation based on a project wind study
[40] Own calculation based on E70 power curve and Weibull distribution of wind speed at a specific site according to corresponding wind study.
[41] Kaltschmitt et al (2009), p. 199ff
[42] Kaltschmitt et al (2009), p. 201ff

all German wind power) is lower than a single turbine. The aggregate plants therefore might have to be adjusted for availability.[43]

Figure 2: Example time series of wind power output in Germany over a 10-day period in 2006



Source: Intergovernmental Panel on Climate Change[44]

This result is highly relevant for grid operators, since there is only moderate smoothing of production even on a national scale. This picture is likely to be the same for most of Northern European wind farms since they depend on the global westerly winds coming from the Atlantic. The production of a wind farm in Ireland is 71% correlated with a farm in Sweden. The picture is completely different in Southern Europe, with regional wind patterns and microclimates. The correlation of one Spanish wind farm with another is only 13%.[45]

As for the long-term trend, windiness indices have become a widely used tool in the industry as a benchmark for long-term forecast. Looking at the data series of the German wind index, a clear downward trend since the 1990s can be stated.

However, there is reasonable doubt arising on how robust the historical data is and how future winds may vary from historical winds. Reliable wind speed measurement is done only for the last two decades. Therefore time series are limited in reliance. Looking into long-term proxies, it can be shown that there are indications that the

[43] Intergovernmental Panel on Climate Change (2012), p. 562
[44] Intergovernmental Panel on Climate Change (2012), p. 561
[45] Dunlop (2004), p. 92

early 1990s have exceptionally strong wind years. The 2000s shows consistent below average wind speed.

Table 2: Wind speed in % of long term average, Germany

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Percent of long term average	111	116	106	88	93	110	103	102	94	98	86	98	89	90	104	99	86	74

Source: Betreiber-Datenbasis (DBD) [46]

The strong wind years in the 1990s led to a tendency of overestimating the potential returns of wind farms due to too optimistic wind models. Therefore, there is a discussion going on whether there are long-term decline in wind speeds due to climate change.[47] Albeit there is quite some room for methodological discussions, there so far is no evidence for a long term decline:

"The downward trend observed in the windiness indices for the period 1990 to 2005 is also reflected in the North Atlantic Oscillation, Grosswetterlagen and Jenkinson Lamb data. However, these proxies for wind speed indicate that there was an upward 'blip' in wind speeds centred on the early 1990s, which suggests that this recent downward trend in mean annual wind speed may represent a return to the longer-term mean. It is therefore concluded that a continued ramp down of future wind speeds should not be assumed."[48]

Still, variation of wind speed is considerable both in the short-term and the long-term and there might well be periods of several years with below (and above) average wind speeds. Even if this levels out over a project life, the distribution of wind years make a difference consequences for financial covenants like minimum debt service cover rations, and discounted return indicators like internal rate of return and net present value of the project.[49]

The main conclusions are that wind is a very flighty resource that can vary considerable over time and is hard to predict and that wind is very location dependent, wrong choices cannot be made up.

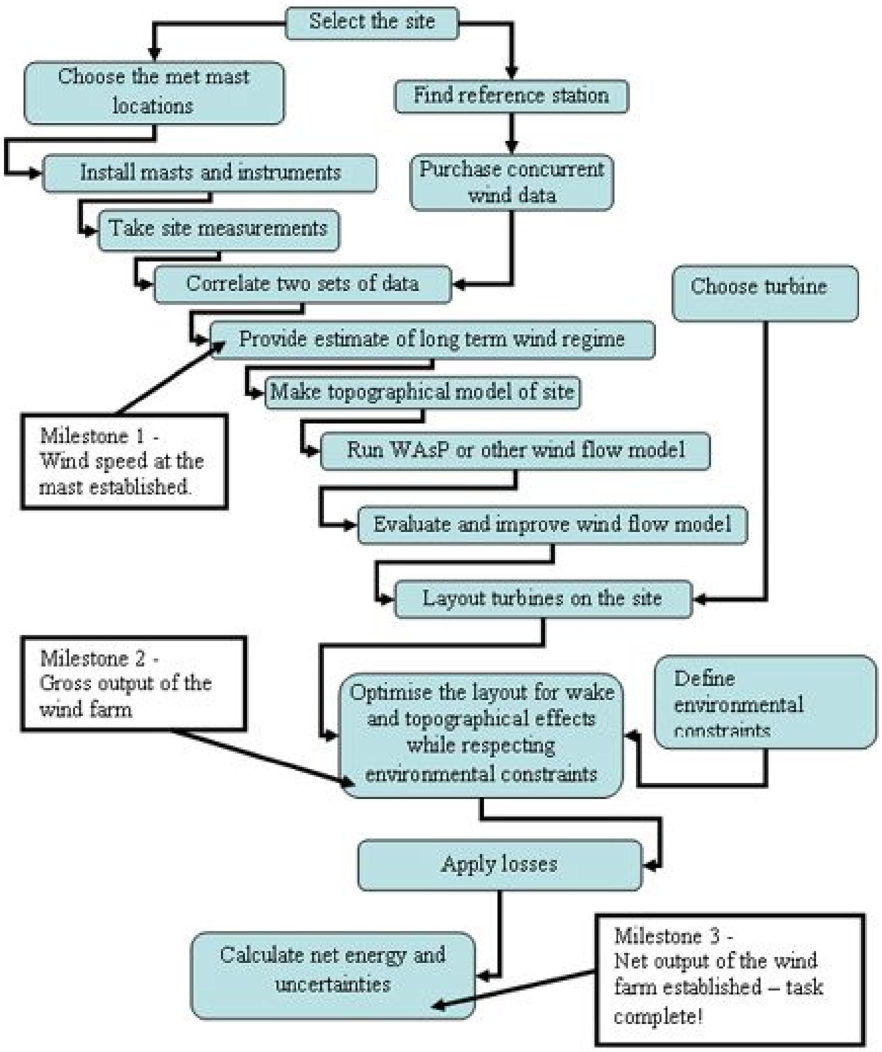
2.3.1.2 How to avoid / reduce wind risk

For this reasons, the proper assessment of wind resources is the key to the success of a wind farm. This is of course of highest importance in the project development

[46] http://www.wind-energie.de/infocenter/statistiken/deutschland/windjahr-prozent-zum-langjaehrigen-mittel
[47] Winkler (2010)
[48] Thomas et al (2009), p 4
[49] Böttcher (2009), p. 123

phase, but still very important if a wind farm is acquired by an investor in its early years of operation.

Figure 3: Energy prediction process



Source: Garrad Hassan[50]

As can be seen from Figure 3, the energy prediction process is already quite standardized. In a first step, all available meteorological data from meteorological stations nearby and data from existing wind farms are used for a rough model. If this model supports economic viability of the site, it is standard to have on site wind measurement done for at least 6-12 month, depending on the complexity of the site and the availability of other data. For a small wind farm one wind mast might be sufficient, for larger farms and more complex terrains several mast will be necessary. The minimum period of wind measurement is one year in order to capture seasonal variation properly.

[50] http://www.wind-energy-the-facts.org/de/part-i-technology/chapter-2-wind-resource-estimation/local-wind-resource-assessment-and-energy-analysis/

The measurements are done with an anemometer that ideally is positioned on a mast at hub height ("best practice"). If this is not possible, the height of the measurement shall be at least 75% of hub height. Increasingly, remote sensing techniques like Sodar (SOund Detection And Ranging) or Lidar (LIght Detection and Ranging) are used to assist measurements done with the anemometer on a mast to get additional data in order to improve the model for complex terrains. There are no masts needed and wind speeds can be measured at different heights from the ground. The disadvantage of these systems is basically the high costs and measurement results are not beyond any doubt.[51] With costs coming down and further improvement in the accuracy, these techniques will make detection and development of high quality sites easier and cheaper in the future.

The measured data are correlated with all the other existing data and the data of the chosen wind turbines (power curve, thrust curves etc.) and entered in the wind flow model.[52] If this is not the case, wind measurements reduce uncertainty in the predicted energy production of the site considerably, bringing down the meteorological uncertainty in the wind model. The estimate for the energy production of the site therefore is considered with fewer risks.

Based on the available parameters, the layout of the park can be optimized with regard to wake effects, turbulences and environmental constraints.

The final results include calculated losses and uncertainties, resulting in an estimated net energy output described along an exceedance distribution.

For an investors due diligence, it is important that the whole wind assessment process has been performed carefully and by experienced people and in accordance with industry standards as published by IEC and the IEA. It is still very important to look into the methodology and data of wind studies performed for the plant.

Wind measurements are usually very significant in the beginning of a project development since the results decide if a project is commercially viable at all and what the reasonable expectations for the site are.

At certain locations with a high density of windmills already in place, especially in Germany and Denmark, developers may decide to make a wind study without any measurements at all. This can be done if the terrain is not too complex and the

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[51] Lang et al (2011), p. 1893ff

[52] http://www.wind-energy-the-facts.org/de/part-i-technology/chapter-2-wind-resource-estimation/local-wind-resource-assessment-and-energy-analysis/best-practice-for-accurate-wind-speed-measurements.html

production results of the surrounding wind farms show that the location is reasonably above doubt for commercial viability of the project.

Technique and compliance with standard procedures is a necessary but not a sufficient condition. Experience, credibility and independence are also very important from an investor's point of view who relies on the expertise of these experts. As for the turbine manufacturers, many players and investors have their own "white list" of experts and consultants whom they trust.

2.3.1.3 How to distribute / share wind risk

Financial products on long term wind

Insurance against natural events has a very long history. It was in fact the starting point of the insurance industry. It also turned out that derivative financial products on the development of the weather are an increasingly attractive line of business in the Chicago Mercantile Exchange.[53]

The wind power industry could well need an instrument that takes part of the production risk (i.e. the overall wind intensity in a given year relative to the long term index). Still, the use of these instruments in the wind power industry is quite limited.[54]

There are probably a bundle of reasons why these instruments still need to be developed and why the market is lagging behind its potential. From the demand side, a key driver for a project owner would be better / cheaper access to bank finance if he would use this type of securing the cash flows. Bank lending behavior would need to be based on related questions, where there is no evidence so far. Pricing is another issue. If a derivative would not lower the cost for bank lending, it would be borne entirely by the equity owner. Probably the equity owners were not ready to pay this price, especially since they did not estimate the risk of systematic low returns to be realistic.[55]

This may have changed over the past years, with a number of wind farm showing poor returns and a systemic over-estimation of wind production being proven.[56]

As for the supply side, there are also some prerequisites for a performing market for derivatives. First, a significant portfolio effect would create incentives for all market

[53] http://www.investopedia.com/articles/optioninvestor/05/052505.asp
[54] https://financere.nrel.gov/finance/content/weather-derivatives-insurance-products-wind-industry
[55] http://www.windprognose.de/english/Leistungen/windderivate.php
[56] Tindal et al (2007)

participants since the gain for the individual wind farm would be high at moderate costs.

For hedges of wind turbines using wind derivative, it is particularly difficult to find appropriate wind indices. From the perspective of the plant owner, the index has to be highly relevant for the actual production of the wind farm. The index therefore needs to be as local as possible and even has to reflect wind direction and possibly the power curve of the wind farm.

In mature wind countries like Germany and Denmark, already several wind indices are available for various purposes such as earnings forecasts, earnings comparisons, or have been designed directly as a basis for wind derivatives.[57]

They can be divided into two categories, namely wind measurement indices and production indices, which are fundamentally different from each other.

The availability of reliable, long-term measurement series is a great advantage of wind measurement indices compared to production indices. However, this contrasts with the lack of availability of official wind monitoring stations in the immediate vicinity of wind farms. Furthermore, wind speed usually is measured at an altitude of ten meters, so a conversion is needed on the wind conditions at higher altitudes.[58]

However, there are tests to overcome the lack of availability of wind measurement sites in many regions through the construction of spatially resolved indices such as the Euro wind index[59]. However, it is still very difficult to choose an appropriate period to determine the long-standing mean values.

To the knowledge of the author there are no liquid and standardized products out in the market that would allow the wind risk to be passed on to third parties.

However, the more specific the indicator is, the less liquidity in the market and the less likely that there is counterparty out there in the market.

2.3.2 Technology risk

2.3.2.1 How to assess technology risk

The technological risk refers to the mechanical, electrical and aerodynamic properties of the single turbine and the whole equipment of the farm. It also refers to sound engineering with all the risks associated to the farm layout, grid connection

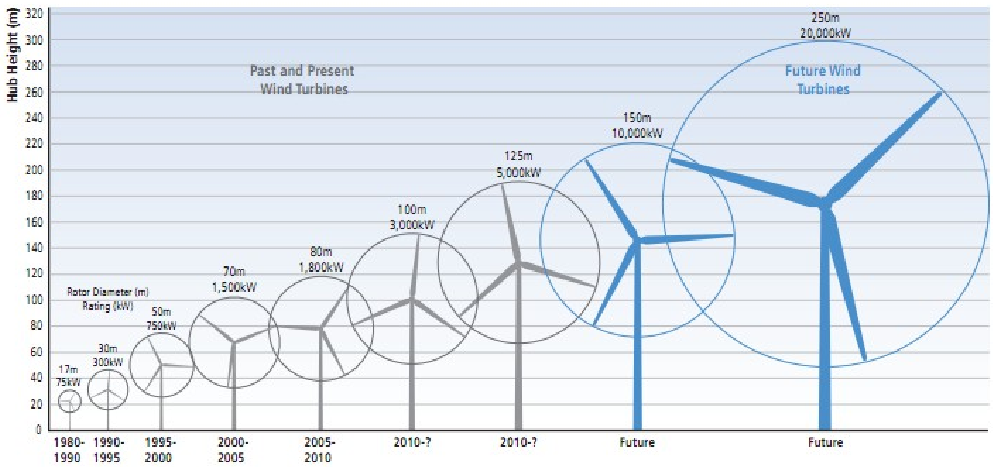
[57] http://www.windprognose.de/Leistungen/windderivate.php
[58] Fraunhofer Institut für Windenergie und Energiesystemtechnik (2012), p. 65
[59] http://www.windprognose.de/english/Loesungen/eurowindindex.php

and so on. On shore wind is a rather mature technology, where the risks associated with it are quite well - known.

The problem is easing since we see the industry maturing, with larger and more experienced suppliers and a large installed base in on-shore wind farms. However, there is still technological progress going on, with the increasing size of the turbines shifting, technological frontiers bear risks.

The size of turbines has increased rapidly, as has the height of the towers. Average installed power of newly built wind turbines in Germany doubled from around 500kW in 1995 to 1.1 MW in 2000 and again to 2.1 MW in 2010.[60] The largest on-shore turbines are currently Enercon E-126 at a rated power of 7.6 MW.

Figure 4: Growth in size of typical commercial wind turbines



Source: Intergovernmental Panel on Climate Change[61]

Larger designs need to push frontiers into construction to new limits in terms of material efficiency and weight. Design flaws still might happen with less proven designs.

This especially holds true with off-shore wind, where major challenges[62] still lie ahead:

- The size of the turbines is way above the one usually installed in on-shore sites.
- Extreme weather conditions put a heavy strain on all material employed (corrosion, heavy storms etc.).

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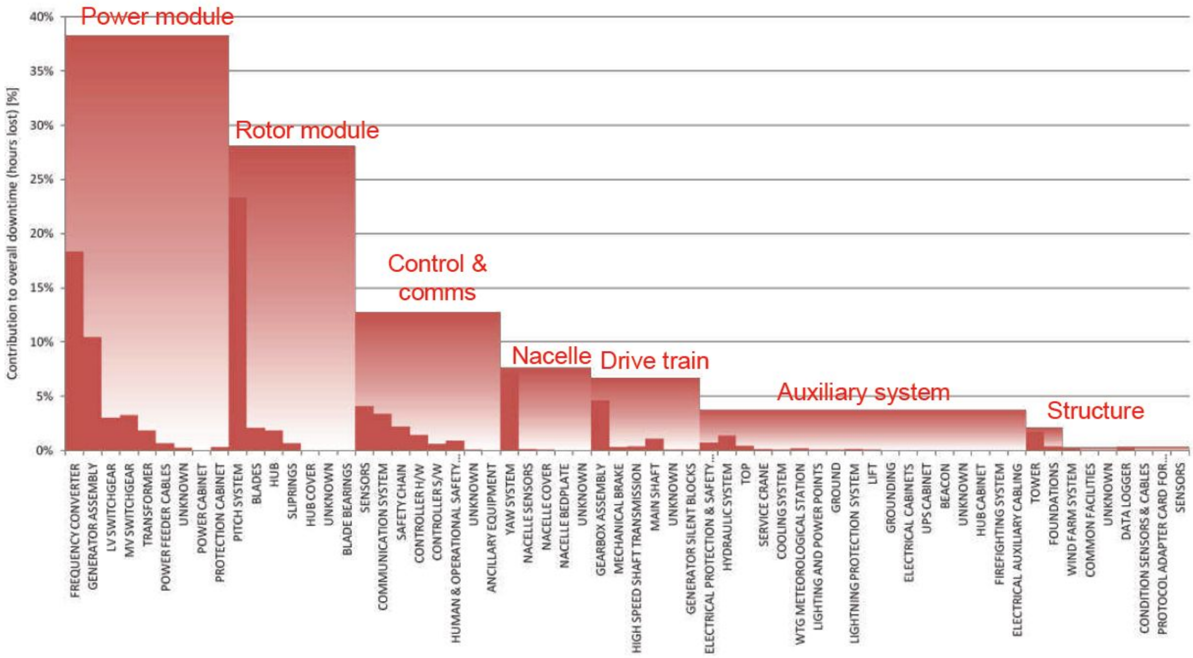
[60] www.wind-energie.de/infocenter/statistiken/deutschland/
[61] Intergovernmental Panel on Climate Change (2012), p. 553
[62] Intergovernmental Panel on Climate Change (2012), p. 554, Fraunhofer (2012), p. 35 ff

- Finally, the cost to fix any failure is much higher than in on-shore farms, as accessibility is limited.

Sensitive parts of the wind farm and associated risks according to the Reliawind project

There is a large EU project ("EU FP 7 Reliawind") going on in order to identify and understand critical failures and their mechanisms through quantitative studies and detailed wind farm data.[63] From around 35,000 downtime events, the following distribution of failure rates and downtimes were identified:

Figure 5: Normalised failure rate of sub systems



Source: Wilkinson (2012)[64]

It has to be kept in mind that these results represent the contribution to overall downtime, and *not* the economic damage in terms of cost of repair.

- *Power module:*

  Has the largest contribution (38%) to overall downtime from all subsystems with the frequency converter being the most vulnerable part.

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[63] Wilkinson et al (2012)
[64] Wilkinson et al (2012), p. 6

- *Rotor module:*

  The pitch system is the most vulnerable part of the rotor module, accounting for about 23% of all downtime. There is also technical risk associated with the blades, often connected to lightning.

- *Control and Communications*

  Wind turbines are becoming more and more complex systems with numerous electronic parts, all of them with some default potential.

- *Nacelle*

  The yaw system is the component responsible for the orientation of the wind turbine rotor towards the wind, accounting for about 8% of the downtime.

- *Auxiliary systems*

  The auxiliary system most likely to fail is the hydraulic system. Overall, these systems cause only little concern.

- *Drive train:*

  The lower the rotations per minute (rpm), the larger the size of the generator needs to be in order to produce the same output. A gearbox translates the optimal rpm of the rotor to the optimal rpm of the generator. However, the gearbox is one of the most sensitive and mechanically exposed parts of a wind turbine, because a slow rotation of the blades has to be transformed in a typical rotational speed of the generator of 1000 to 1500 rpm. Therefore, a gearbox with a quite large gearbox ratio of more than 1:50 is needed in between, for the Vestas V90 the gearbox ratio is 1:104.5.[65] High thrust on large diameters at low rotational speed results in very high torque, putting a very high mechanical strain on the gearbox.

  In fact, many designs had considerable problems with gearboxes that had to be changed as early as after 3-6 years in operation.[66] This led to a trend towards gearless designs. Enercon is one of the leaders in this trend, making the turbine appealing especially to financial investors who like to avoid as many risks as possible. The gearless design tends to be more costly, mainly because the generator needs to be much bigger and therefore more material (copper, steel) is needed.

[65] http://www.wind-energy-market.com/de/wind-turbines/big-plants/details/details/bp/vestas-v90-30-mw-2/
[66] http://www.northernpower.com/pdf/the-gearbox-problem.pdf

The Reliawind project shows that the gearbox accounts for about 5% of all downtime. However, this figure does not represent the cost involved. Gearbox failure caused severe economic problems for early generation wind turbines.

- *Tower / Structure*

  With the height of the turbines increasing dramatically, the challenges on the tower construction are still considerable and the pressure to bring down the cost of material employed is increasing.

  This holds true for the tower, consuming tons of concrete and steel and heights of >100m; and also for all parts in the drive train from rotor to generator.

  The foundation of the tower might also be a source of risks. In fact, a planning failure of a renowned turbine manufacturer led to damages in the foundation and expensive repair measurements. The key trade off is cost and stability.

2.3.2.2 How to avoid / reduce technology risk

Investors today basically rely on technology providers with a proven track record and with certified designs. Along with the engineering, there are now well-established standards for design and testing methods, codified in International Electronical Commission (IEC) standards for Conformity Testing and Certification of Wind Turbines. (IEC, 2010).

"IEC 61400-22:2010 defines rules and procedures for a certification system for wind turbines (WT) that comprises both type certification and certification of wind turbine projects installed on land or off-shore. This system specifies rules for procedures and management for carrying out conformity evaluation of wind turbines and wind farms, with respect to specific standards and other technical requirements, relating to safety, reliability, performance, testing and interaction with electrical power networks." [67]

As can be seen from this norms [68], there is a comprehensive regulatory for wind turbine manufacturers and wind farm developers. Financing banks have an approval process for the turbines which they put on their "white list" and which they are ready to finance. They have basically three core criteria[69] according to which they decide:

[67] IEC Definition http://www.iec-normen.de/217227/iec-61400-22-2010-05-ed-1-0-zweisprachig.html
[68] http://en.wikipedia.org/wiki/IEC_61400
[69] http://www.munichre.com/corporate-insurance-partner/en/business-and-solutions/special-enterprise-risk/green-tech-solutions/wind-power/default.aspx

- *Compliance* with all the relevant norms in design and engineering and wind farm development and construction.
- Satisfactory *track record* of the turbine manufacturer, the developer and the EPC contractor.
- Sufficient *financial standing* in order to fulfill the customary guarantees of the relevant parties.

The technological risk for wind power was considerable in the beginning of the industry, with little experience, no proven standards and design models. This has improved considerably with producers going down the learning curve. With the number of wind turbines installed globally at 160 GW (2008)[70] and some dozen companies operating on a global basis, the business has both matured and grown into a major industry.

Table 3: Wind turbine manufacturers ranked by global market share

Turbine Manufacturer	Market Share 2011 (2010) - %	Comment
Vestas	*12.7 (14.8)*	Despite a tough year and disappointing financial results, Denmark's Vestas held on to its position as the world's leading wind turbine manufacturer in 2011, maintaining the lead over challenger for the Number 1 slot, China's Sinovel.
Sinovel	*9.0 (11.1)*	China's Sinovel overtook GE of the US in second place in 2010 and retained the number two slot in 2011 - while the US company fell down the ranks to number 6 position, having slipped to number 3 in 2010.
Goldwind	*8.7 (9.5)*	China's Goldwind moved ahead to take the number 3 slot in 2001, following the lead of fellow Chinese company, Sinovel - and consolidating the position of the Chinese in the global market.
Gamesa	*8.0 (6.6)*	Spanish manufacturer, Gamesa, moved up the ranks in 2011, to rank number 4. Gamesa was number 3 in the world back in 2008, but had slipped down the ranking until 2011's recovery.
Enercon	*7.8 (7.2)*	Germany's Enercon (which operates in the fast growing Brazilian market, which it was one of the first to enter, as Wobben Windpower) has been a steady performer and held on to its number 5 place in 2011.
GE	*7.7 (9.6)*	GE's market share has suffered from the tough market conditions in the US, with the group falling down the ranks to number 6 position from 3 in 2010 and 2 in 2008 and 2009.
Suzlon	*7.6 (6.9)*	India's Suzlon ranked number 7 in 2011. Suzlon has been ranked between 6 and 8 for four years. China's Dongfang had appeared at 7 in 2009 and 2010, but slipped out of the top 10 in 2011.
Guodian United Power	*7.4 (4.2)*	Guodian United Power, of China, first appeared in the top 10 list in 2010, at number 10 and in 2011 moved up to number 8, ranking as the number 3 Chinese manufacturer in 2011.
Siemens	*6.3 (5.9)*	German's Siemens had fallen from number 5 in the world to number 9 in 2009. It has retained the number 9 position for three years now - but has failed to deliver on its ambitions to rise up the ranks again.
MingYang Wind Power	*3.6 (n.a.)*	China's MingYang Wind Power made a first appearance in the top ten list in 2011, at number 10. German firms Nordex and Repower, which respectively held this slot in 2008 and 2009 have not reappeared in the top 10.

Sources: Cleantech Investor, IHS Emerging Energy; BTM Consult; MAKE

Source: Cleantech Investor[71]

[70] Intergovernmental Panel on Climate Change (2012), p. 556
[71] http://www.cleantechinvestor.com/portal/wind-energy/10502-wind-turbine-manufacturers-global-market-shares.html

2.3.2.3 How to distribute / share technology risk

Long term service contracts

Long-term full service contracts with turbine manufacturers have become a very popular mean of protection from a range of technological risks. This instrument has become an industry standard for many industrial and nearly all financial investors. It also has established reasonable standards for most of the key issues. There remain some risks with the owner. Insurances are, however, more and more willing to step into these contracts with an overall coverage. As long as the manufacturer has the solvency to keep his promises, there is still the risk of default. Systematically, the issue lies with the period after the expiry of the full service contract, which is usually after 10-15 years. This period up to 20 or more years is the period where the loans are paid off and the equity investor gets his largest returns. The service and maintenance cost for this period of operation can only be estimated with a large degree of uncertainty. This is due to a lack of experience with modern turbines over this period of time.[72]

2.3.3 Counterparty risk

2.3.3.1 How to assess counterparty risk

Counterparty risk is the risk that one party does not live up to its contractual obligations. This risk can easily be minimized in a delivery versus payment type of transaction. The risk is both getting larger and more complicated to deal with if the contractual obligations are to be fulfilled over a longer period of time since the ability (and the willingness) to do so might change considerably over time. As do most infrastructure type of projects, the major contracts for wind farms have a very long term character. Therefore, the risk of default or non-performance of parties involved has to be considered seriously.

This holds true especially for the *turbine manufacturer*, who provides guarantees and services, which sometimes cannot easily be substituted for in the market. For the operational phase, *warranty non-performance* is the most important contractual risk.[73] With long-term warranty agreements of five years plus maintenance and repair agreements of 15 years and more, this is a major concern for wind farm projects. Since this types of arrangement is the industry standard today, the manufacturers take considerable future liabilities. This is partly offset by the

[72] Harman et al (2008), p. 4
[73] United Nations Environment Program e-Learning Course on Insurance Risks Management for Renewable Energy Projects Case study, p. 12

experience and track record of the larger manufacturers. Still, with ever-larger designs offered in the market, a design flaw with the new machines could well threat even larger manufacturers.

The second major counterparty risk is that of *off-taker default and withdrawal*. This risk depends very much on the respective green energy regime and can reach from negligible to very substantial. It is insignificant in regimes like in Austria, where a government agency is obliged according to the law to buy the electricity at a fixed feed in tariff for a fixed period of time.[74] All the extra cost is passed on to the final consumer of electricity. In this scenario, which is applicable to the case study, this part of the counterparty risk is negligible.

The picture might be different where the off-take agreement is only subject to private treaties between a local utility and the producer. Relying on private companies with no special legal protection and eventually no second potential buyer for your energy, the counterparty risk might be very substantial.

2.3.3.2 How to avoid / reduce counterparty risk

Counterparty risk can be reduced considerably when treated properly. Starting with a certification system for the parties involved, only parties that qualify for the roles they shall play in the project (including the role of being a reliable counterparty for an adequate period of time) will be certified. This may be a very formal procedure with an official white list of developers, turbine manufacturers, EPC contractors and consultants accepted. It is mainly larger equity investors and banks that do this kind of formal assessment. Others may have a less formal approach of assessing the track record and credibility of the parties involved. This usually includes a rating of the creditworthiness of the counterparty.

2.3.3.3 How to distribute / share counterparty risk

Credit insurance and bank guarantees are common instruments to distribute counterparty risk to other parties.[75] This works well for any short to medium term obligations. It is hardly possible for long term obligations like the power purchase contracts of the electricity off-taker. The room to reduce or pass on this risk is very limited. The size of this risk is mainly determined by the selection of the country of investment and by the selection of the respective counterparty.

[74] Bundesgesetz über die Förderung der Elektrizitätserzeugung aus erneuerbaren Energieträgern (Ökostromgesetz 2012 – ÖSG 2012),
http://www.parlament.gv.at/PAKT/VHG/XXIV/I/I_01223/index.shtml
[75] United Nations Environment Program Division of Technology, Industry and Economics (2004)

2.3.4 Regulatory risk

2.3.4.1 How to assess regulatory risk

Regulatory risk is another key risk for wind farm development and operation. The term "regulatory" signifies a rather broad range of issues that are basically settled by the state. In the development phase, mainly the approval process, which usually involves different state authorities and parties, needs to be considered. During operation, it is about feed-in rights, purchase obligations and tariffs. The risk during construction and development will increase the cost for the development; the risk during operation will increase the return expectation for the investors.

Regulatory risk during development

This paper focuses on wind farms in operation, but it is important to understand the specifics of the development risk of wind farms since it is a very important cost factor in the overall calculation of the wind farm, and might influence the regulatory risk during operation phase.

Successful wind farms depend on good sites, which are scarce and usually also rather concentrated within one country. Therefore, the overall impact is also concentrated, making the approval process not only a technical and environmental but also a political issue.[76] People, i.e. voters, are only willing to accept wind power in their neighborhood if they see a specific benefit for themselves or their community. Therefore, it is usually of high importance to convince the community of the value of the projects. Still, the benefits from the wind farm will most likely not be distributed evenly among the local population. Therefore it might make sense to look into the situation and bring a structure relevant to everybody on the place.[77]

Windmills are large buildings with noticeable impact on neighbors and wildlife in their environment. Therefore, most countries have a comprehensive list of surveys and studies to be performed by the developer.

In Austria this includes permits according to

- electricity law (including building standards, noise and safety issues),
- environmental legislation (including bird studies) and
- legislation on aviation.

The risk associated to this process is manifold. First, the developer needs sufficient experience and a strong professional background in order to perform and steer the

[76] Intergovernmental Panel on Climate Change (2012), p. 559
[77] Bundesverband für Windenergie (BWE) (2012)

whole process properly. Second, it might turn out that the necessary approvals can´t be obtained for good reasons. Finally, it might happen that the necessary approvals cannot be obtained for irritating reasons. This includes red tape or outright corruption, blackmailing and other illegal practices.

The success of a development depends on the approval of grid access of the subsidies in the tariff. Getting all the necessary approvals is subject to the regulatory risk, so far that the developer has to rely on the authorities to act in accordance with the rule of law.

Regulatory risk during operation

For an operating wind the major regulatory risk is a change in the regulatory framework safeguarding its revenues.[78] Most wind farms in Europe are operating under a policy mechanism designed to encourage renewable energy development by securing above market rates for the electricity produced.

Under a *feed in tariff regime*[79], a specific tariff exists for a minimum of years - set by law - which has to be paid directly to the electricity producer by the grid operator, the utility or, as is the case in Austria, by a special authority. The tariffs are usually set at a cost plus profit basis. Therefore the rates are different for different types of renewable energy reflecting the underlying LCOE (levelized cost of energy).[80] Tariffs for electricity gained from PV are highest; wind is at the lower end. Some countries also differentiate according to the location and the size of the plant. The off-taker is usually required to purchase all power produced under a standard contract at a fixed rate for the contract period of up to 20 years and therefore providing a key fact for FIT is to free the producer of any price and market risk for the contract period. The system is designed to set price incentives and bring stability to the producers.

Under a *certificate system*[81], quotas are set for the portion of electricity from renewable energy sources sold to consumers. The producers are awarded with green electricity certificates, with the number depending on the technology employed, thus reflecting different levelized cost of production. The utilities are obliged to produce a certain quota of electricity from renewable energy sources or buy the corresponding certificates from the market. If they can do neither, they are

[78] Böttcher (2009), p. 96
[79] ECOFYS (2011), p. 153
[80] International Energy Agency, Nuclear Energy Agency, Organisation for Economic Co-Operation and Development (2010), p. 29ff
[81] ECOFYS (2011), p. 153

usually obliged to pay a fine. This fine also sets the minimum price for the certificates.

The advocates of the quota system claim that the actual price for the electricity produced (market price + price for the certificate) is set by market forces rather than by regulators. Critics point out that the fundamental problem with the quota scheme is that there is no long-term certainty on the price for the certificates, increasing the risk in the investment. This results in a reluctance of independent investors to get involved in the first place. Those that do get involved are short-term speculators and large, vertically integrated generators and multinational electric utilities.

The discussion of the efficiency of the various promotion schemes is not within the scope of this paper, but there are two fundamental issues with green certificates, that tend to bring more risk in the system: price risk and counterparty risk. The producer does not have a fixed price he can calculate with and he needs an off-taker for the certificates, who then has to pay for it.[82]

It turned out that risk has not gone even under a FIT scheme, with lawmakers in Spain and in the Czech Republic interfering retroactively in the FIT compensation. It is now obvious that producers are facing a regulatory risk, meaning that the law might be changed or other measures might be taken that diminish their revenues.

Reasons for regulation in electricity markets

Producers of electricity face a very unique market for two main reasons: their product can´t be stored and it can only be delivered through a system. So it can be described as a natural monopoly.[83]

- Electricity can't be stored; this means that production and consumption have to be equal at every moment. The load curves are predictable to a high degree. However, with the increase of intermitting production sources like wind energy and photovoltaic, this picture changes. This leads to highly volatile spot markets with prices that even might tend to be negative.
- Transmission systems are a "natural monopoly": Electricity can only be transported grid-bound. It is economically most efficient (involving the lowest long-term average cost) running only one grid. A new entrant would have to build an entirely new net, which obviously is neither affordable nor efficient. Access to the grid, cost of transmission and capacity of the grid are key issues for any producer of electricity. Due to the monopolistic nature of the

[82] ECOFYS p. 102ff
[83] For a discussion on natural monopoly in the electricity industry see Tomin (2002), p. 443ff

grid, these issues can only be dealt with by state regulation if competition is wanted at the production side.

The economics of the various generation technologies varies considerably. There are technologies that bear high investment cost at low marginal operating cost like large hydro and nuclear energy. These used to be the base load technologies. On the other side there are technologies with low investment cost per installed power unit but high marginal cost. These technologies used to be peak load technologies such as gas power plants. Power plants from renewable energy sources like photovoltaic and wind have medium to high investment cost but low marginal cost.[84]

The producer of electricity from renewable energies is in many respects in opposition to most of the features of the existing energy system, putting him in a weak position unless he is protected by a specific regulation. Levelized cost of electricity from wind power in Austria is currently about 50% above the market price and still well above large hydro, coal and gas.[85]

The quantity of electricity produced from wind has a highly stochastic nature, with very limited ways to store electricity so far. This would put the producer of wind energy in a position of a price taker, since he has already invested in the power plant, he can't store the product and finally he has very low marginal costs, making him better off even at very low prices compared to not producing at all.

Therefore, the producer of wind power is very much exposed to a moderating framework provided by the authorities granting higher and stable prices and preferred access to the grid.

Quantification of regulatory risk

As shown above, wind energy is very exposed to regulatory risks at basically all levels and phases of the business. Therefore, any risk model needs to integrate assumptions on the regulatory risk in the respective markets. On the other hand, regulatory risk is a typical rare event risk and there is no meaningful statistical ground for quantifying this risk.

As for the country level, there are basically three "clusters" of measures of country risk available.[86] The first are sovereign ratings provided by rating agencies. The second are broader indices that indicate the economic, political and legal risks of a

[84] International Energy Agency, Nuclear Energy Agency, Organisaiton for Economic Co-Operation and Development (2010), p. 90-97
[85] Kaltschmitt et al (2009), p. 552-553
[86] Damodaran (2012) p. 45

specific country. The third are market based indices derived from various variables like currency volatility and interest rate spreads.

There are three sets of assumptions made here to quantify the regulatory risk:

- *Low sovereign default risk translates in low regulatory risk*

  A country would only interfere retroactively in its regulatory framework if the potential losses (loss of national and international reputation, higher cost for future projects, law suits etc.) are outnumbered by potential gains or simply by sheer need. Therefore, a sovereign default event would probably put a very high pressure on a government to reschedule all its direct and indirect obligations, including feed in tariffs. The probability of default therefore can be considered the "dummy variable" for the basic regulatory risk. This figure can be derived from credit default swap spreads, which are widely available for numerous countries.[87]

  A credit default swap (CDS) insures against losses from a loan default, protecting against default of the issuing government. The premium (spread) the policyholder. (e.g. a bank) is paying to the insurer (e.g. an insurance company) is a market price, which depends on the expected probability of default of the country. Therefore, CDS spreads are a good indicator of the market's assessment of the country risk. It should be noted, however, that CDS spreads also depend on other factors such as market liquidity, counterparty risk and the global financial environment, especially that of international interest rates and investors' risk appetite. DB Research translated CDS spreads online in implied default probabilities, so that they can be interpreted in an illustrative manner. Thus e.g. a spread of 200 basis points, equivalent to saying that the market is pricing in an annual default rate of about 3%. For such calculations a so-called "recovery rate" must be assumed - the amount that a creditor can expect in the case of a debt restructuring. In the above example, we are here assumed 40%. This is in many CDS contracts the common market convention. [88]

- *Sound and proper governance translates in low regulatory risk*

  The second assumption is that those countries who have proper and sound governance and are seen as willing and able to fulfill their long term obligations also have a sound fiscal balance and therefore a low incentive and need to

[87] http://en.wikipedia.org/wiki/Credit_default_swap
[88] http://www.dbresearch.com/servlet/reweb2.ReWEB?rwnode=DBR_INTERNET_DE-PROD$NAVIGATION&rwobj=CDS_INFOTEXT_DE.calias&rwsite=DBR_INTERNET_DE-PROD

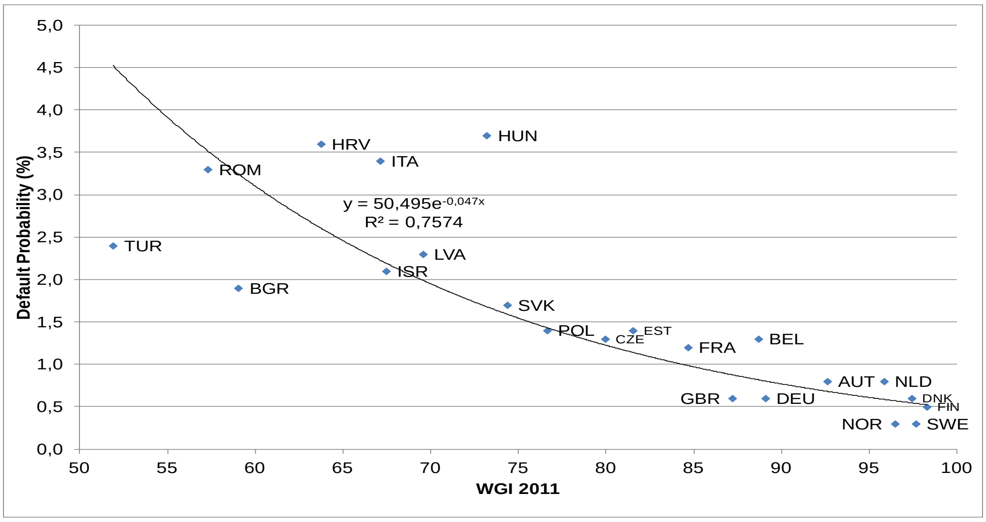
interfere in existing regulatory regimes. The World Bank is publishing Worldwide Governance Indicators (WGI)[89] project *"reporting aggregate and individual governance indicators for 215 economies over the period 1996–2011, for six dimensions of governance:*

- *Voice and Accountability*
- *Political Stability and Absence of Violence*
- *Government Effectiveness*
- *Regulatory Quality*
- *Rule of Law*
- *Control of Corruption*

These aggregate indicators combine the views of a large number of enterprise, citizen and expert survey respondents in industrial and developing countries. They are based on 30 individual data sources produced by a variety of survey institutes, think tanks, non-governmental organizations, international organizations, and private sector firms." [90]

All of these individual indicators are relevant for the regulatory environment and therefore can be combined at an equal weighting to one governance indicator. It can be shown that this indicator has a high correlation (-0.75) with the default probability for a series of selected European countries. Calculating a trend line from both inputs the following graph can be drawn:

Figure 6: Regulatory risk: Default probability and governance quality



Source: Own calculations, Deutsche Bank[91], World Bank[92]

[89] Kaufmann (2010)
[90] http://info.worldbank.org/governance/wgi/
[91] http://www.dbresearch.com/servlet/reweb2.ReWEB;jsessionid=CCF8D26F52657EF6A433AE53979E246B.srv-loc-dbr-com?rwnode=DBR_INTERNET_DE-PROD$NAVIGATION&rwobj=CDS.calias&rwsite=DBR_INTERNET_DE-PROD

- *Good grid quality, flexible energy system and aligned renewable penetration reduce regulatory risk*

  At the level of the energy system, there is no third party assessment available. Therefore, the investor has to do his own assessment using certain key criteria.

  Renewable penetration

  There is a systemic conflict in the energy system between the wind energy producers and the remaining energy system. Due to preferred feed-in, wind crowds out other forms of production, leading to decreasing margins with the owners of other production resources. In addition, the electrical grid may not be able to transport the electricity produced. The higher the share of production form intermitting sources (wind, PV), the weaker the grid and the more base load oriented (less flexible) the existing production and consumption system is, the higher will be the conflicts between the parties in the energy system and the higher will be the risk for wind power producers, since they need protection due to the character of their product.[93] High penetration with renewable energy will also lead to lower prices at the market due to the merit order effect.[94]

  Grid quality and flexibility of the energy system

  The above mentioned conflicts and issues may be reduced by a corresponding grid quality providing sufficient capacity and avoiding bottlenecks through a great flexibility both on the production and the consumption side.

The most common way to introduce the specific regulatory risk into the cash flow model is to ask for “country risk premiums” in the discount rate. This, however, this does not really reflect the nature of the regulatory risk since it may be of little probability but of a significant influence if it becomes effective. Within the proposed framework, the regulatory risk also increases the standard deviation of the expected returns if integrated in the model.[95]

The approach proposed is a two step one:

Exclude all countries with a high regulatory risk

The analysis should identify “red flags”, i. e. a ranking and a rating below an acceptable level and the balance of grid quality and renewable energy penetration. Countries with “red flag” results should not be considered at all.

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[92] http://info.worldbank.org/governance/wgi/
[93] European Wind Energy Association (2010), p. 55ff
[94] European Wind Energy Association, Pöyry (2010)
[95] Damodaran (2012), p. 42

Pricing in of the regulatory risk

For the remaining countries, the annual sovereign default probability could be taken as a proxy to price the probability that all preferential treatment of green power would be withdrawn. This price tag would be either the implicit market default probability or the calculated default probability according to the ranking in the world government index, depending on what probability is higher. In addition, the risk from the structure of the energy system (grid quality, flexibility, renewable penetration) should be taken into consideration. If there are large imbalances, a mark up on the regulatory risk probability should be made or, if more specific information is already available, future provisions in the business plan should be made as well.

Countries with a higher regulatory risk have to boast higher returns in order to compensate investors for this higher risk. At the same time, higher tariffs increase the incentive for the country to intervene in the renewable energy promotion systems. This results in only very limited tolerance of the whole business model for regulatory risk.

2.3.4.2 How to avoid / reduce regulatory risk

The amount of regulatory risk is directly associated to the host country of the investment. This risk can mainly be mitigated by choosing a sound and reliable legislation for the investment. To some extend some of the regulatory risk could be passed on to the developer of the farm. This, however, will probably cover only a minor share of the total risk and might be connected to considerable counterparty risk since the developer may not have the ability to bear this risk in the case of becoming effective.

Given a certain location, the major share of the risk, however, cannot be passed on. In order to protect foreign investors there are numerous investment protection agreements, both bilateral and multilateral. However, their focus is mainly to protect foreign investors against any discriminatory action of the local authorities. In the case of the Czech Republic, a law was passed that imposed retroactively an additional tax on revenues for PV plants with a certain tariff only.[96] Economically, this has the same effect as a reduction of the feed in tariff. It came into effect in December 2010 and applied retroactively to projects commissioned in the previous two years. The constitutional court upheld the tax in May after solar plant operators threatened to sue.

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[96] http://www.corporatelivewire.com/top-story.html?id=developments-in-czech-renewables

"Bilateral agreements on the promotion and protection of investments increase legal certainty for businesses investing abroad, thus affording protection against discrimination and expropriation without compensation - a factor of great importance, especially for small enterprises venturing into foreign markets. At the moment, Austria has 60 bilateral investment protection agreements."[97]

From practical experience as well as from surveys it is obvious, that the regulatory risk of government policy changes is a key concern for investors in the renewable energy sector. This relates to the fact that an investment made under a certain set of policies might be subject to many changes and reviews between the time of investment and the end of the project lifetime. The RES regulation usually promises the investor a "protective" period of 10 to 15 years, usually enough to secure pay back of invested capital.

2.3.4.3 How to distribute / share regulatory risk

The possibility to distribute or share the regulatory risk is quite limited. Depending on the home country of the investor, there might be certain insurance programs for foreign investments.[98]

Given the framework discussed above, taking out credit default swaps also might be a way to get coverage for regulatory risk. It is, however not an insurance but a kind of hedge against the regulatory risk.

2.3.5 Operational risk

2.3.5.1 Hot to assess operational risk

The operational risk of wind farms is closely related to the technical risk of availability. Operational risk is related to the way technical issues are handled organizationally. In this notion, it is a issue of optimization within technical constraints.

Wind farms have developed from rather "homegrown" facilities into utility size power plants. Along with this, the operation and maintenance level have improved dramatically. This is due to bad experience in the past and increased demands for investment security and reduction of maintenance costs.

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97 http://www.en.bmwfj.gv.at/ExternalTrade/InvestmentPolicy/Seiten/Bilateralinvestmentprotectionagreements.aspx

98 United Nations Environment Program (2011), p. 16

It is mainly about keeping production losses due to unavailability of the turbines as low as possible and above the level that is guaranteed by the turbine manufacturer and by keeping maintenance cost as low as possible.

2.3.5.2 How to avoid / reduce operational risk

To reach this goal, problems need to be detected before they lead to failures of components or systems. Gathering and analyzing data of critical components and "smart" plans for exchange or refurbishment is gaining importance.[99] "Smart" indicates setting service at times of low production, made possible through predictive and preventing maintenance. Overall, this should bring production up and cost down.

2.3.5.3 How to distribute /share operational risk

Long term service contracts are the key instrument in order to distribute / share the operational risk with the service partner. This is very common for financial investors, who neither have existing resources nor the knowledge to build own resources for this task.

2.3.6 Macroeconomic environment

2.3.6.1 How to assess macroeconomic risk

Price risk

Price Risk is a risk that is often underestimated for wind energy producers. This is mainly due to the fact that most wind farms are operating under promotion schemes for renewable energy, which mitigate this risk considerably. Still, price risk has to be considered for two reasons: first, it is the benchmark for the size of the regulatory price risk, i.e. what is the expected price level for wind energy if there is no government protection / promotion? Second, the period of government protection is usually shorter than the expected lifetime of the project. Therefore, there will definitely be a period where the power produced has to be sold at market conditions without preferences.

The electricity produced from wind power will then have to be sold at spot market conditions. It is very unlikely that it will be possible for producers to conclude contracts that give them fixed prices because they cannot offer a fixed and guaranteed supply. If the share of wind power in total supply is low, it is very likely that the producer can sell its full production at spot rates that follow similar patterns

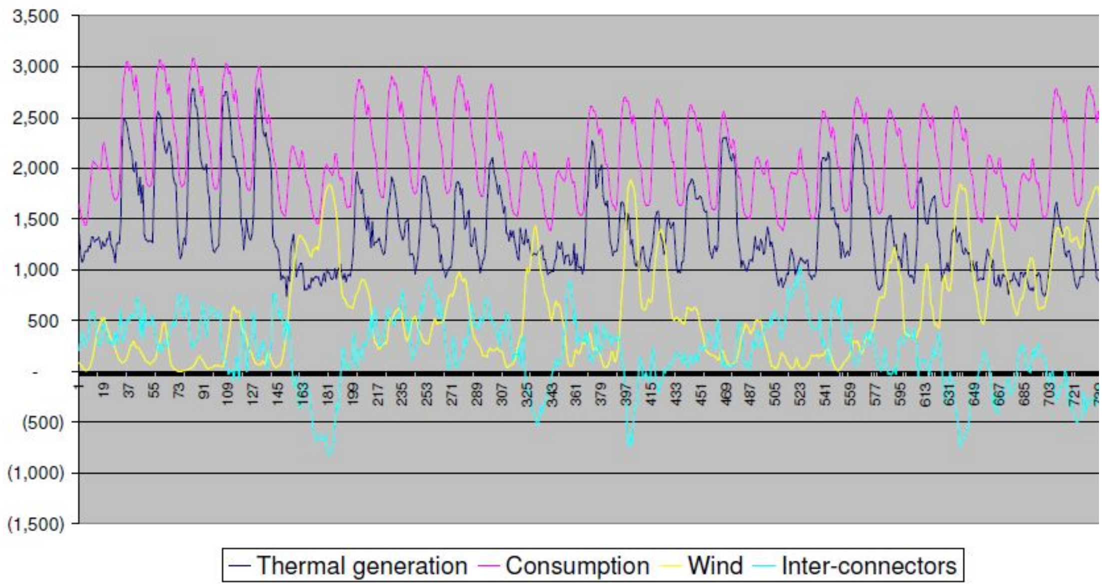
[99] Hameeda et al (2009)

as today, which means that the price is basically set by the marginal cost of gas power stations.

The picture might be different in a mature market with a high penetration of wind power and a larger share of producers already beyond the promotion schemes time lines. With a share of wind power of more than 20% of total annual electricity production, Denmark has already reached a very high penetration.[100] Considering the fact, that the capacity factor of wind power plants is between 25% and 30%[101], this means that at periods with strong winds, more than 100% of the demand is covered by wind power.

At periods with low wind, the contribution of wind power may be 0. The power plants currently in place cannot be entirely shut down for several reasons (they may have long term contractual obligations to provide electricity but also heat, since many thermal power plants are run as CHPs). Therefore, there may be both short-term oversupply and shortage in the spot markets for electricity.

Figure 7: West Denmark Electricity Production and Consumption July 2007



Source: Center for Politiske Studier (2009)

As shown before, there is a high correlation between the productions of wind farms in northern Europe. This means that there is very little smoothing of the production curves within large regions. Hence, smoothing of supply can only be reached by other forms of electricity production.

[100] http://www.windpower.org/en/knowledge/statistics.html
[101] Kaltschmitt et al (2009), p. 216

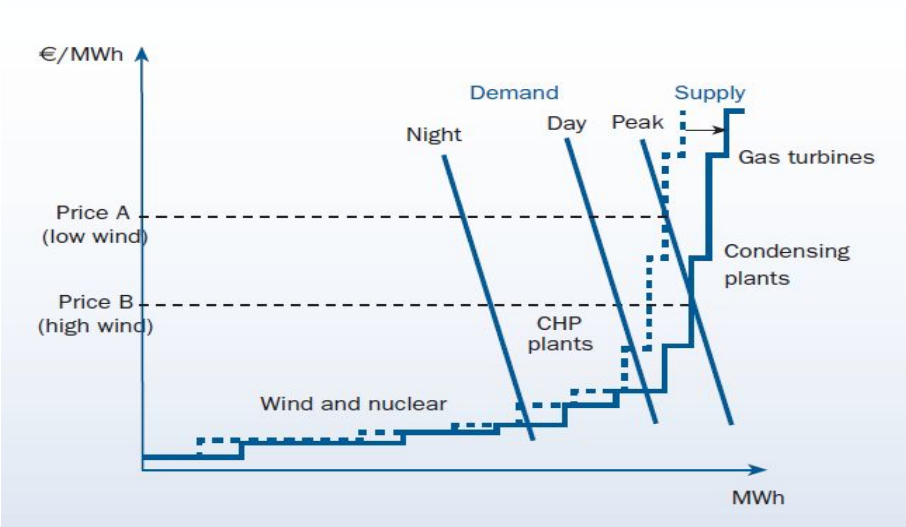
Countries with high wind penetration are therefore left to export their excess supply to countries with a different structure in their power system. Norway can absorb part of this excess electricity in their hydro power plants, as can Austria. Others substitute electricity from thermal plants. It is the Danish consumers who subsidize cheap electricity for their neighboring countries.[102]

The higher the wind penetration the higher is the risk for wind power producers, that they might not be able to sell their production in case of oversupply in the network unless the transmission system operators are obliged to do so by law and contract.

The aggregate supply function of electricity is generally equal to its marginal cost. The demand is inelastic and is initially met by the sources with low marginal cost, which are hydro power, wind power and PV. The residual demand - the so-called residual load - is borne by the conventional power generators.

Beginning at the plant with the lowest marginal costs, power plants with higher marginal costs are switched on until demand is met. At the current electricity exchange, the last bid, which still receives a bonus, determines the price of electricity. The price of electricity will be determined by the marginal cost of the most expensive power plant, which is still required to meet the demand for electricity. Usually these plants are gas-fired plants, therefore the marginal cost of production of electricity in gas fired plants sets the price for electricity.[103]

Figure 8: The influence of wind power on electricity prices



Source: European Wind Energy Association, Pöyry[104]

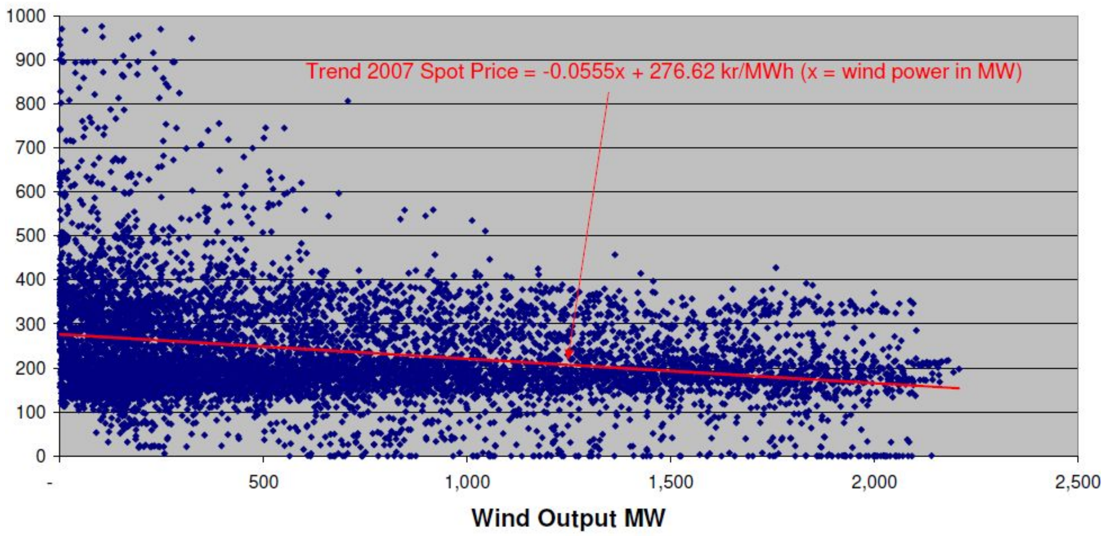
[102] Center for Politiske Studier (2009), p. 16
[103] European Wind Energy Association, Pöyry (2010), p. 10
[104] European Wind Energy Association, Pöyry (2010), p. 11

This reduces the contribution of affordable base load power plants such as running water, nuclear and lignite-fired power plants. Since wind power plants have very low marginal costs, they enter at the bottom of the supply curve, shifting the whole curve to the right. At a given demand, this leads to a lower equilibrium price. The Merit-order effect may thus reduce the market price for electricity at the expense of the power plant operators and may even over-compensate the increase in the price of electricity from the subsidized tariffs.[105]

According to various studies, the merit-order effect is already quite significant. For the year 2010, a study of the TU Berlin shows of savings in the range from an average of EUR 8 EUR / MWh[106]. This would result in saving in Germany of EUR 1.78 billion. Other studies show a reduction on prices of electricity in the range of EUR 3 /MWh to as much as EUR 23 / MWh.[107]

This effect can also be shown in Denmark, where negative correlation between wind output and spot prices for electricity can be shown. On average, higher production from wind results in lower prices in the spot market for electricity. Looking at the wind penetration of Denmark, there is clear evidence that a merit order effect of a substantial magnitude of some 15%-20% exists.

Figure 9: West Denmark spot prices 2007 (kr/MWh)



Source: Center for Politiske Studier (2009)[108]

Still, the long-term effect is unknown since in the long run the full cost for production has to be taken into account, especially when new investment decisions are made.

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[105] European Wind Energy Association, Pöyry (2010), p. 13
[106] Erdmann (2011), p. 51
[107] European Wind Power Association, Pöyry (2010), p. 7
[108] Center for Politiske Studier (2009), p. 29

The necessary investments into replacement power plants can only be financed if the expected wholesale electricity prices have a sufficient contribution margin. The failure to cover the electricity demand by new power plant investments would lead to upward trend in whole-sale electricity prices and neutralize the short-term on-the price-dampening effect of EEG development. At times of high wind and photovoltaic supply very low - or even negative - wholesale prices are expected. But in the other times the wholesale price will be very high when investment omitted to meet demand in the necessary replacement power plants.[109]

Another important restriction is that the merit order only is true for electricity sold at the stock exchange, which is only a fraction of the total electricity production. In Austria, the volume of the electricity traded at the EXAA in 2008 was about 4% of total electricity consumption.[110] However, the prices at the exchange might be of relevance for much larger quantities, if the pricing of long term contracts is tied to the prices at the electricity exchange.

It may be assumed that we will see additional markets emerging in the future, which will consist in reserve capacity provided to the market. Especially wind power does need corresponding reserve capacities or storage capacities in the market. In the case of Denmark, Norwegian hydro-power provides this reserve and storage capacities.[111] In the case of Germany, probably conventional power plants will have to complement the residual load curve.

The discussion in Germany now is very much focusing on the systemic issues of renewable energy, with quite some studies focusing on systemic and distributional effects of the “Energiewende”.[112] As for the systemic effect, the focus is on bringing in line time and place of production and demand. Distribution effects can be observed on the level of production, with the owners of production facilities fired with fossil fuels facing decreasing full load hours, and therefore decreasing profits, due to the feed in priority for electricity from renewable sources. On the level of consumption, many industrial consumers are exempt from extra charges, thereby increasing the load on private consumers.

It can be assumed that the price for electricity from wind energy under market conditions would be traded at a significant discount unless the operators are forced to buy all the electricity form wind energy at first hand. In this case, there might be

[109] Erdmann (2011), p. 53
[110] Own calculation from www.exaa.at and Energie-Control Austria (2011)
[111] Center for Politiske Studier (2009), p. 22
[112] Fraunhofer Institut für Windenergie und Energiesystemtechnik (2010)

an overall merit order effect dampening the prices for electricity, including wind power.

The very nature of wind power also poses a serious stress on the electricity network. With stochastic peaks and lows as high as the full demand of a large area, the design of the network has to be completely different.[113]

Network costs are higher for wind energy, since there have to be large reserves in the network to carry all the peak energy. It might be economically more viable to cut the very peaks and compensate the producer for the lost earning.

It is hard to predict a market value for wind energy, however the model used here is the following:

The Danish market shows that wind production already influences the spot market price for electricity. In general, the wind power industry focuses on the produced quantity of electricity, neglecting the fact that the quality of electricity produced makes a big difference in market value of energy:

- to produce close to the user
- to produce when needed
- to produce in predictable and stable quantities (spot market prices usually have a lead time of 24 hours, which is often out of range of the predictability of wind production)

None of these criteria can be stated for wind energy. The market value for wind energy in 10-15 years time is hard to predict. But if the energy system (production, distribution and consumption patterns) is not developed accordingly with wind penetration, producers will face severe discounts on the spot market prices that may go far beyond the 25% assumption made above.

Therefore, the level of predicted wind energy penetration and the ability / willingness to cope with this situation on a political level is highly important for the future price and market risk incurred by a wind farm operator. Increased wind energy deployment will require improvement at all levels: Active demand management in the sense that the demand curve may follow the supply to some extent and introducing storage capacity in the whole system (from large hydro storage plants to batteries for e-mobility to heating boilers only with peak production) will be a very important element for reducing risk for wind power producer: The better the

[113] European Wind Energy Association (2010), p. 56

transmission network, the more flexible the power system and the lower the risk for the wind producer. [114]

Interest rate risk

Typically, in the first year of operation interest payment accounts for 2/3 of the total cost of a wind farm.[115] This exposure fades over time, however, due to long term financing it remains considerable. The risk of changes in interest rates can be avoided by making an interest swap, locking in a fixed interest rate for the whole duration of the loan. Since this risk can be passed on, there will be no risk assessment for interest rate changes done.

Inflation

Maintenance, land lease, insurance and other costs are still important, when talking about wind power, accounting for 1/3 of total cost.[116] These costs are usually subject to inflation. In fact, taking into consideration that most of the feed - in tariffs are fixed for the whole period, inflation might cause a considerable threat to the overall profitability of a wind power plant operator. Costs subject to an annual increase of 3% are 34% higher in nominal terms after 10 years and 56% after 15 years. These costs typically account for 15-20% of the total cost[117]. This results in a reduced profit by 7% after 10 years and 11% after 15 years. There is no easy hedge for these cost increase and they have to be fully considered in the project calculation. This effect is especially harmful to return on equity since it fully cuts into free cash flow to equity.

Inflation rate forecasts are usually available from various sources for a time period of one to five years. It therefore makes sense to choose the most reliable source for the respective country available and integrate this in the model. However, any long-term inflation forecast is not possible. The procedure suggested here, is to take historical time series[118] as a proxy for the range and occurrence of inflation rates in a specific country. As for Austria, there is a time series available from 1947 on. With the post-war years until 1955 skipped, we have 55 years of historical data that give us a pattern for inflation rates in a long - term time period. With short term inflation rates being a technical phenomenon, long term level of inflation are more a political phenomenon depending on the tolerance of the political and society as a whole towards inflation and the overall means of a society to tackle economic problems

[114] Intergovernmental Panel on Climate Change (2012), p. 564
[115] Own calculation from a sample of Austrian and German wind farms
[116] Own calculation from a sample of Austrian and German wind farms
[117] Own calculation from a sample of Austrian and German wind farms
[118] Source:
http://www.oenb.at/de/stat_melders/datenangebot/preise/preise_wettbewerbsfaehigkeit.jsp

and crisis by other means than inflation. It is very much about the whole institutional setting of central bank's independence, industrial relations, wage setting policies etc. Historical data therefore are a proxy for the inflationary track record of a country.

From this long term data we can derive a historic distribution of inflation rates that will be used for the model. Using the mean value from the historical data - for Austria is 3.5% - and the standard deviation.

Exchange rate

The nature of an investment project involves capital that is tied up for many years. In the case of investments outside the Euro zone, this involves exchange rate risks. The revenue is in foreign currency. Hence the investment also has to be made in the local currency. The free cash flow has to be converted. Therefore it is subject to an exchange rate risk. This risk used to be seen diminishing with the enlargement of the Euro zone and an overall stable macroeconomic environment. This has changed dramatically during the past months. Exchange rate risks are now considered as real and considerable.[119] They could be hedged against, however, this would be expensive given the long term nature, and, since the expected revenues are not certain at a given point of time in the future, one might end up having an open position in the end due to not having enough or too high cash flows in order to reward the forward contracts.

2.3.6.2 How to avoid / reduce macroeconomic risk

Price risk

Unless protected by a fixed tariff (as is the case in Austria), the operator is subject to a price risk. The price risk during the period of the feed - in tariff is considered as regulatory risk and can only be reduced by choosing good and reliable jurisdictions.

The market price risk can only be reduced within the project to a very limited extend. The lower the levelized cost of electricity produced and the higher the market price for electricity, the lower the default probability because of pricing issues. The more open the electricity market in a country and the lower the access barriers to the grid (in terms of capacity restrictions and price) the better are the options for the power producer to get a good price for the electricity produced. So the price risk is set mostly with the choice of the location of the wind power plant.

[119] Böttcher (2009), p. 104

Inflation risk

As discussed, there is a wide range of tariff models for renewable energy globally. At this point, the focus shall be on the effect of inflation under various systems. Many countries, including Germany and Austria, provide attractive, albeit fixed tariffs over the whole period of the feed - in tariff. Irrespective what the inflation rate is, the tariff does not change. Since the cost usually is not fixed on the other hand, these projects are exposed to an inflation risk of about 20% of the total cost subject to inflation.[120] This usually will cause no threat to profitability in low inflation scenarios or countries. In high inflation scenarios this may eat into profitability. We also have to consider the exchange rate risk given an investment in a high-inflation non Euro country.

Typically electricity prices grow at a rate along with inflation or even above. This is not possible under the feed - in tariff regimes of many countries.[121] And since the tariffs are above market rates, this remains the case until the market rate is above the feed - in tariff.

Many countries have a mixed system, with a part that ties tariff to the market rate of electricity, which can also increase over the time period, and a fixed subsidy rate that remains unchanged over the whole feed - in period. This system is applied in Italy and on a quota system basis, in Poland. There are countries like the Czech Republic, who provide inflation protection under their feed - in system.[122]

Interest rate risk

By definition, leverage is not a project specific risk, but a question of risk distribution between equity and debt owners. Assuming efficient capital markets, higher leverage results in higher risks and returns for the equity, but for a lower amount of money.

However, in reality there are usually covenants tied to the debt financing, that might shift additional risk to the equity holder in case that the project dies or does not fulfill certain financial ratios. From the dynamic character of the financing structure, a progressive nature of the risk for the equity holder has to be assumed.[123]

This can be illustrated with the following example: it is common, to increase the margins for debt financing if certain debt service cover ratios are not met. Higher

[120] Own calculation from a sample of Austrian and German wind farms
[121] ECOFYS (2011), p. 154 ff
[122] ECOFYS (2011), p. 154 ff
[123] Böttcher (2009), p. 269

margins will increase the debt service, increasing the probability that the debt service can't be met and that the project would default.

Therefore, setting the right level of leverage is an essential part of the financial engineering as well as the risk management of a project.

Exchange rate risk

The exchange rate risk can be a considerable one, especially if the investment is done in a high inflation country. It is therefore highly advised to get debt in local currency. Exchange rate risk is not handled in detail within the scope of this paper, but it can be substantial and therefore should be handled properly.

2.3.6.3 How to distribute / share macroeconomic risk

Price risk

Power purchase agreements are long - term contracts between an electricity producer (usually and independent power producer) and a power purchaser (a utility, a large industrial buyer or an energy trader).[124] Power purchase agreements are very common, and very often a prerequisite for non-recourse finance, in countries where there are no feed - in tariffs. The key content of these contracts are long - term agreements on prices and quantities. The price risk and the risk of finding an off-taker for the electricity are thereby reduced considerably. It is, however, traded against a counterparty risk that arises since the contract partner has to be willing and able to fulfill the contract over a period of time.

The contract requires the seller to meet certain performance standards, especially the quantities delivered. Since it is impossible for a wind farm operator to promise fixed quantities of energy produced, there are usually other types of agreements that are more appropriate for the nature of wind power, like availability and power-curve covenants.

Typically not all the price risks can be shifted to the buyer, but enough, to give the seller a sufficient downside protection for the project not to fail. This comes at the cost of leaving upside potential to the buyer.

Interest rate risk

Interest rates risks are considerable for a long - term project and can threaten both the liquidity and equity returns. Therefore, it is common practice for long - term project finance structures to pass on at least parts of the interest rate risk to third

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[124] http://www.windustry.org/community-wind/toolbox/chapter-13-power-purchase-agreement

parties. Technically, this is done by interest rate swaps, a widely used instrument in order to exchange floating interest rates against fixed interest rates. Two parties swap interest cash flows of a notional amount with a certain maturity, whereas one interest cash flow is based on a fixed interest rate and the other on a floating rate.[125]

Usually the long - term fixed rates are higher than short - term floating rates, due to the upwards slope of the interest curve. This means that lending money for longer terms, asks for higher interest rates than for shorter periods.

The market started in the 1980s and is highly liquid and standardized now since there are enough market participants for both sides of the transaction.[126]

From the perspective of an investor in a wind farm, fixed rates pay off if the reduced risk - in terms of a smaller standard deviation of the equity - compensates for the higher interest rate paid. This could be tested within the framework of this paper.

Inflation risk

Inflation risk cannot easily be shared or distributed. One way is to pass on the risk of cost inflation to suppliers. Sometimes long - term lease contracts and O&M contracts are tied to the revenue. There are countries where the feed - in tariff is pledged to the inflation rate, thus providing the producer a natural hedge against inflation.

Exchange rate risk

As for interest rate risk the currency risk, too, is of major importance, if cash flows are denominated in different currencies. As for the project company, debt is almost always denominated in the currency of the revenue. This is the major way of taking currency risk away from the project. On the level of the equity owner, this is more difficult, if he is resident in a different currency regime. He is fully exposed to the exchange rate risk with his equity investment. The dividends paid out have to be converted if repatriated. And the equity value of the company denominated in the currency of the investor also depends on the exchange rate applied on the discounted cash flows in the currency of the host country.

In principle, the currency risk could be hedged against with a currency swap. The price is calculated from the interest differential of the two currencies involved for the period of time a protection is looked for. This works fine if the period and the amount

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125 Böttcher (2009), p. 106

126 http://www.tradeweb.com/uploadedFiles/Tradeweb/Content/Blog/Data%20Points%206%20-%20Interest%20Rate%20Swaps%20Market%20Maintaining%20Liquidity%20Amid%20Strain%20in%20Euro-Zone%20%28Jun10%29.pdf

of currency that will be swapped is defined. Since any proceeds from equity are less certain in terms of amount and timing, taking a currency swap position might be useless since there are no returns. If the owner decides to hedge the currency risk, it might make sense only to hedge part of the risk in order to minimize losses but also cost.

3 Monte Carlo simulation of a model wind farm

The previous chapter was focused on assessment and distribution of risk. The final step is to quantify the remaining risk in order to set a reasonable return target for risks that cannot be avoided economically or distributed to other parties. This is done by integrating all the information on the relevant variables in a *standard cash flow model*. This will result in a standard scenario static work sheet showing results for the main target ratios.

The probability distributions derived from historic data and from validated models used in wind studies are assigned to the most relevant variables. With this model, a M*onte Carlo simulation* is run in order to derive a mean value, a probability distribution and a standard deviation of the main target ratios. The mean IRR and its standard deviation of the wind farm as the key target ratio is compared to the reference mean IRR from an equity investment and its standard deviation, formulated as the respected *Sharpe ratio*, will show weather the expected return on equity for the wind farm is above the minimum acceptable rate of return (MARR).

Monte Carlo simulation is a stochastic methodology that relies on repeated random sampling. From a defined set of inputs showing a specific probability distribution, values are chosen randomly but according to the distribution. The frequency of picking a specific value relates to its probability of occurring. If and when a sufficient number of iterations has been done, a probability distribution of the output of interest is produced. Having its origins in physical sciences, Monte Carlo simulation is used today in many fields, including finance and business.[127]

Compared to scenario analysis, that usually attaches best guess values to the relevant variables and models a best, most likely and worst case, Monte Carlo simulation produces a probability distribution of the target variable instead of only one or a limited number of outputs. The advantage of Monte Carlo simulation clearly lies in the fact that it can incorporate lot more information (a real probability distribution for each variable and also correlations between the individual variables).

[127] Rodger et al (1999), p. 24-25

From the perspective of this paper, there are two sets of questions that are relevant for the owner/investors in the project:

- What is the likelihood that certain financial covenants are not met and the sponsor therefore has to put extra money in the project during the project lifetime or lose his investment?
- What is the expected return on equity and is it sufficient to make the project attractive compared to other equity investments?

3.1 Financial model

3.1.1 Model input

The case study is based on real data from wind farms in Germany and Austria. They are chosen to represent a typical project for private investors in these markets, but do not correspond to a specific project.

The major assumptions and static model inputs are derived from the reference projects and shown in Table 4. In addition, for the major return drivers, i.e. production, availability, price for electricity, regulatory risk and cost inflation, probability distributions are derived from empirical studies and historical data.

These data and probability distributions are the input for the Monte Carlo simulations run with the model. There are mathematical considerations how to set the minimum number of iterations, but these are beyond the scope of this thesis. The approach chosen here is pragmatic in that sense that the number of iterations is set at a number where the results between one and the next simulations differ only marginally, i.e. increasing the number of iterations would not change the result. At the chosen number of 10,000 iterations the results are reproducible with every single run with only very small deviations.

Table 4: Major assumptions and model inputs used

Production	Input	Unit	Source
Number of Wind Turbines	10	#	assumption
Power of Wind Turbines	3	MW	assumption
Distribution of production	Normal		wind study
Annual production mean value	75.000	MWh	wind study
Standard deviation yiel forecast	10,50%		wind study
Standard deviation of annual production	15,00%		Garrad Hassan
System losses	3%		wind study
Availability	97%		Garrad Hassan; manufacturer guarantee
Start of production	01.01.2013		assumption
Useful life of turbines	20	years	turbine manufacturer
Revenue			
Feed in Tariff	93,00	EUR/MWh	Ökostromverordnung Austria
Period	13	years	Ökostromverordnung Austria
Regulatory Risk	1,0%	p.a.	regulatory risk model
Current Price for Electricity	51,68		2011, average spot market EXAA
Indexation Price for Electricity	4,53%		price of electricity model
Terminal value	0,00		assumption, netted with dismantling cost
Dismantling	0,00		assumtion, netted with terminal value
Operational cost			
Operation and Maintenance	10,00	EUR/MWh	estimate based on comparable project data
Maintenance allowance	2	years	estimate based on comparable project data
Grid services, own power consumption	187.500	EUR	estimate based on comparable project data
Land Lease	150.000	EUR	estimate based on comparable project data
Tech. and comm. Mgmt. and Admin.	2	%	estimate based on comparable project data
Insurance	70.000	EUR	estimate based on comparable project data
Security	-	EUR	estimate based on comparable project data
Reserves for repair and maintenance	49.200		
Indexation of Cost	3,30%		inflation model
Taxes			
Corporate tax rate	25%		current corporate tax rate Austria
Depreciation	3.280.000	EUR	assumption
Depreciation mode	linear		assumption
Depreciation period	15		assumption
Depreciation base	49.200.000		estimate based on various project data
Investment			
Land	-		lease
Grid connection, cabling	8.500.000		estimate based on comparable project data
Roads, civil construction	2.500.000		estimate based on comparable project data
Wind turbines	36.000.000		estimate based on comparable project data
Development	2.000.000		estimate based on comparable project data
Transaction costs	200.000		estimate based on comparable project data
Other			
Total investment	49.200.000		
Equity			
Equity ratio	25%		assumption based on market standards
Debt			
Debt ratio	75%		
Maturity	13	years	
Interest rate	4,0%		estimate based on project data / market
Other cost	1,00%		
DSRA as % of total debt service	50%		
Balance of DSRA as of 1.1.	0	EUR	

3.1.1.1 Production

Wind resources

The projected production of the model wind farm is based on wind studies for a typical site in Central Europe. The method used in the wind studies is to calculate a non site-specific and generalized wind climatology, using data from the measured wind conditions, the existing topography and obstacles. In a second step, the results of the wind atlas are applied on the proposed wind farm, taking into account the local conditions and the power curve of the wind turbine. Based on this set and the calculated uncertainties of wind farm energy yields a probability distribution for the achievement of the projected output is calculated. The uncertainties are intended to provide a reference value for the stability of the calculated energy yields. The total uncertainty of the yield forecast is evaluated on the basis of a detailed analysis of all standard uncertainties.

Breaking down the combined standard uncertainties for the model site into its components shows the following picture:

Meteorological input data (standard uncertainty of 6.5%)
At the site itself, a wind measurement was performed. The long-term climate was determined by interpolation using the reanalysis data. Both measured data and meteorological data used from nearby stations are subject to uncertainties. As for the measured data, measurement errors are the most prominent source of uncertainty. As for meteorological data, interpolations between the stations and the site, extrapolations of data to hub height and corrections for long-term climate trends all contribute to the uncertainty of meteorological input data. Only the latter would apply to larger geographical areas and therefore probably showing a correlation between different wind farms.

Modelling wind field (4%)
This includes any type of topographic uncertainty with the input data as well as the analytical and numerical modeling with the input data for transmission of the position and connected to hub height uncertainties.

Modelling farm efficiency (6%)
The calculation of the uncertainty farm efficiency depends both on the location of characteristic conditions (turbulence, wind conditions, topography, etc.) and from the uncertainty of the model used.

Input data wind turbine generator (4%)

For the calculation power curves under standard conditions IEC 61400-12 [8] or IEC 61400-12-1 are used. Still, real power curves may show a variation from this standard and this has to be considered.

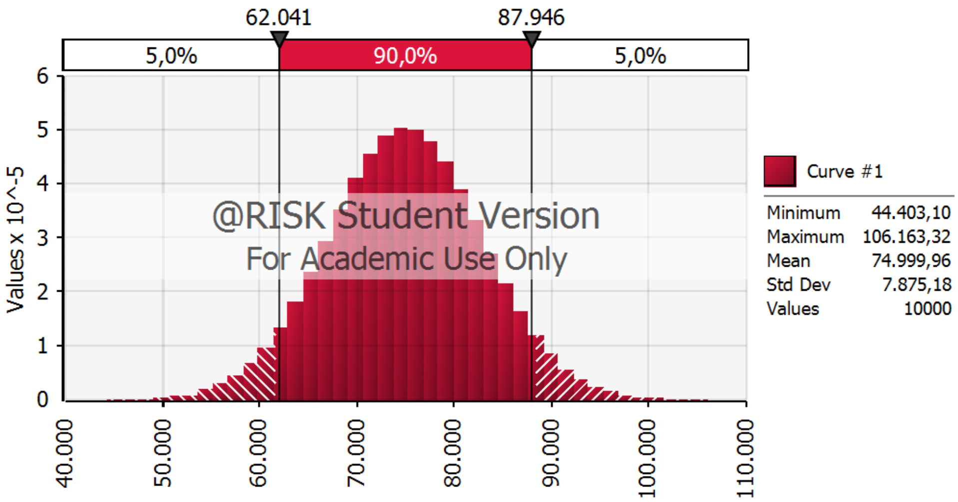
Combined uncertainty of the yield (10.5%)

The combined total uncertainty is calculated as the root sum of the squares. Seasonal Fluctuations with this value would not be recognized. Based on the available and accessible to the previous input data uncertainties for the determination of wind speed were determined. Additional uncertainties, including long term climate change, are not included. This combined total uncertainty applies to the long annual yield. Seasonal variations are not covered by this value.

The wind study defines an estimated production of the wind farm that is normally distributed around a mean value with a standard deviation in the amount of the combined uncertainty of the estimate. The resulting probability function defines a value, at which a certain production level will be exceeded, the so-called exceedance probability (also p-value). This allows a risk assessment of the expected returns.

The P-50 (mean value) for the model wind farm is 75.000 MWh / a. at a 10.5% standard deviation of the annual production. The probability distribution for this wind farm shows that the gross production is with a 90% probability larger than 62,041 MWh and smaller than 87,946 MWh and can be drawn as follows:

Figure 10: Probability distribution of expected gross production (MWh/a)



Source: Own calculation

Inter-Annual variability

Thomas et al (2009) conclude that

"The standard deviation of the windiness indices varied between 3.9 % and 5.8 %. When it is recognised that indices represent a large region of a country a lower variability would be expected that that observed on an individual wind farm site. These results are considered to be broadly consistent with a 6 % figure for individual wind farm sites which is a commonly used assumption." [128]

Using a wind speed to energy sensitivity ratio of 2 [129], this would translate in a standard deviation of annual production of about 12%. Adding a margin for the uncertainty of long term climate change, a 15% standard deviation of annual production is assumed in the model.

Long term climate change

Along with the discussion of climate change and also because of a series of very weak wind years in the 2000s, there is also research going on whether there is a long term trend of changing wind speeds.[130]

However, there are little reliable long term wind data available for this type of study and any forecast would be subject to rather great uncertainties. So far, there is no clear evidence for a trend of increasing / decreasing long term wind speeds. Still, wind is a flighty resource and the expected climate change is very likely to influence the global dynamics of winds. To account for this, the standard deviation of annual production was increased by 3%.

Technical efficiency / availability

Most efficiency parameters (power curve of the wind turbine, transmission losses etc.) are already included in the wind study and they are static parameters that do not hardly not change over time of operation of the wind farm. The most important dynamic factor for technical efficiency over time is availability of the wind turbine.

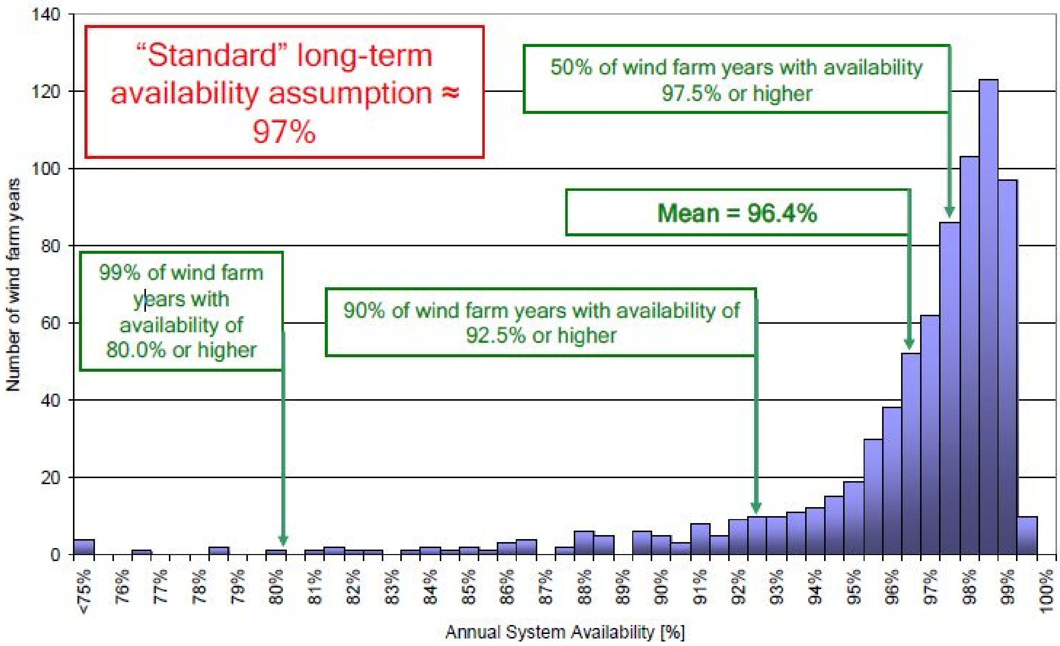
Availability is a performance measure related to the potential of a wind turbine or a wind farm to produce electricity. There are various uses of availability to calculate performance figures, including energy estimates, revenue projections, turbine design performance evaluation, warranties and performance bonuses or penalties. The many uses have led to various calculation methods based on different

[128] Thomas et al (2009), p. 5
[129] Thomas et al (2009), p. 4
[130] Winkler (2009)

definitions. The major differences are the following: wind turbine vs. wind farm availability, time-weighted vs. energy-weighted; wind-in limits vs. full period availability.[131] In this model it is assumed that the respective availability figures represent energy-weighted wind farm availabilities, i.e. an availability of 97% results in an annual production of 97% of potential output at full availability of the wind farm.

There are only few publicly available studies on the availability of wind turbines. The most comprehensive one has been done by Garrad Hassan, a consultancy, assessing the performance of over 14.000 MW of operating wind farms which is approximately 15% of the total global capacity, with 1.000 wind farm years of availability statistics and 250 wind farms across Europe, US and Asia.[132] The results of the study are shown in Figure 12 and the probability distribution of the availability is used in the model.

Figure 11: Probability distribution of average annual availability



Source: Harman[133]

The model has to be adapted for the period of the full service contract of 15 years Since the manufacturer guarantees a wind farm availability of 97%. During that period, the actual availability is assumed to be the higher of the guaranteed or the one from probability distribution. For the remaining years of operation (year 15-20)

[131] Wright (2009) p11 ff
[132] Harman et al (2008), p 1
[133] Harman et al (2008), p 4

there is no minimum availability, availability therefore equals the probability distribution of the Garrad Hassan Study.

3.1.1.2 Revenue

Feed in tariff and regulatory risk

The feed in tariff is set according to the Austrian *Ökostromverordnung* which currently sets the price for electricity from wind farms at EUR 93 / MWh for a period of 15 years.

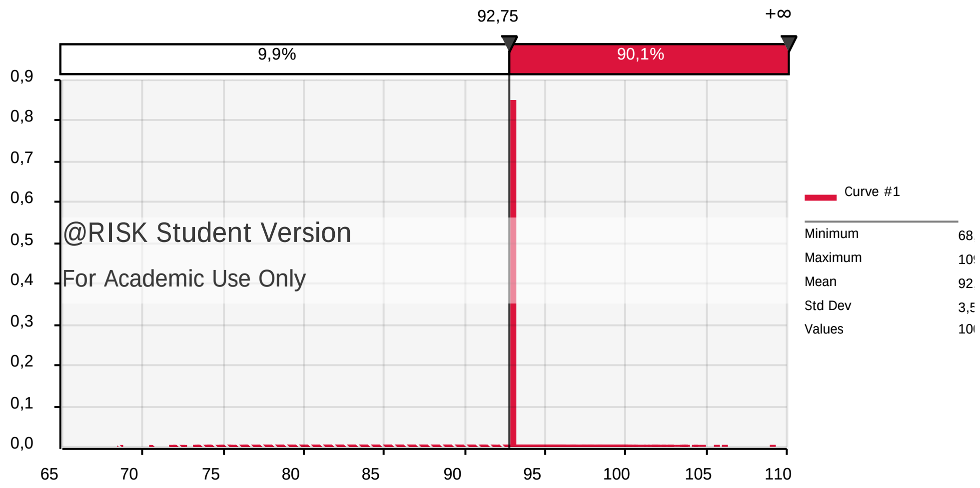
Following the model for regulatory risk, the results for Austria would be as follows:

- Austria ranks very high in the World Government Index.
- Renewable energy penetration (PV, wind) is currently at about 3%[134] of total domestic electricity consumption and therefore rather low. Based on the projections of the Austrian Wind Power Association[135], in 2020 the installed wind power capacity will be 3.300 MW, producing then an estimated 8% of total electricity consumption in Austria. Even if the deployment of photovoltaic generation of electricity is gaining momentum, the overall share of PV and wind of total power consumption will probably not exceed 12% in 2020.
- As for the grid quality, the total consumption of electricity is estimated by e-control to grow moderately by 1.1% p.a. through 2020, giving the grid operators enough time to adapt to changing needs.
- Overall, the regulatory risk can be considered quite low in Austria (moderate penetration with renewable, high grid quality, high peak capacities due to storage power stations.)

Therefore, the probability of any retrograde government intervention in the renewable energy act (Ökostromgesetz) is assumed to be not more likely than a sovereign credit default, which currently is estimated at 1% p.a.[136]. In the model, this would result for example in a 9.9% probability that the price for electricity is below the feed in tariff of EUR 93 in 2022.

[134] Own calculation from Energie-Control Austria (2011): Ökostrombericht
[135] Hantsch et al (2007)
[136] www.dbresearch.com

Figure 12: Probability distribution of revenue for electricity sales 2022 (MWh/a)



Source: Own calculation

Market price for electricity

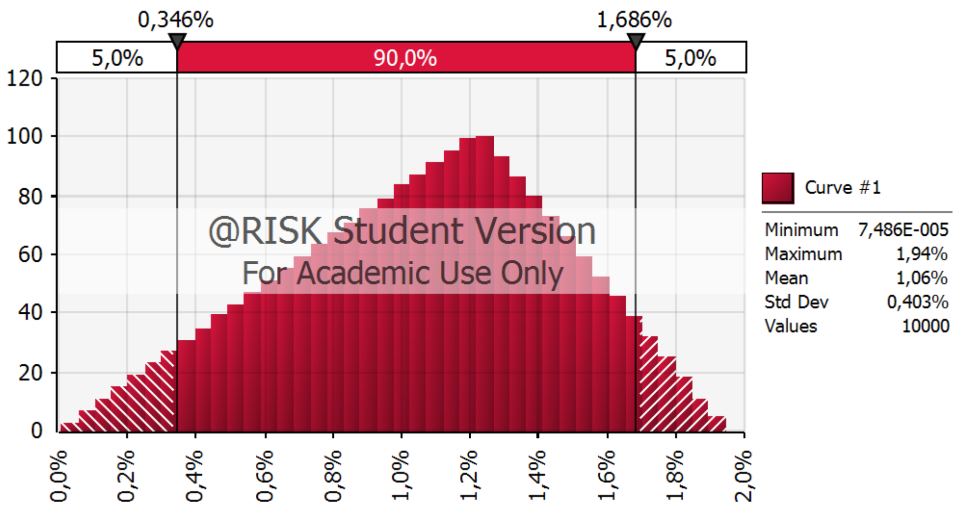
The project has a guaranteed feed in tariff for 13 years. Since the useful life of the project is longer than that, an assumption has to be made for the market price of electricity for the period after the feed in tariff is expired. This price model is also used in the model in case the feed-in tariff is abolished.

The model assumption is that the price for electricity follows the general price level with specific markup and markdown. Initial point is the average spot market price for electricity on the Energy Exchange Austria (EXAA) in 2011.

There is empirical evidence that the spot market price for electricity is set by the marginal production cost of electricity in gas fired power plants.[137] However, for the broader market and in the long run, the total generating cost of CCGT power plants will probably a better proxy for the market price for electricity. The current price of electricity in Austria is about EUR 51.8 / MWh.[138] The average generation cost of electricity from gas in the period of 2015 to 2035 is estimated by the International Energy Agency[139] at $ 96 to $ 114 which is about EUR 69 to 82 / MWh[140]. This would translate in a real increase of prices for electricity of about 1.2% to 2% p.a. As for the mark up, a triangular distribution with 1.2% being the most likely, no mark up and 2% mark up being the alternatives. This increase is added to the annual inflation rate in order to derive nominal prices for electricity in the next 20 years.

137 Redl et al (2007)
138 Own calculation of 2011 average from Energy Exchange Austria (www.exaa.at) data
139 International Energy Agency (2011), p 90
140 Converted from 2009 constant dollars at the average exchange rate USD/ EUR of 1.39 in 2009.

Figure 13: Probability distribution of energy price mark up on inflation



Source: Own calculation

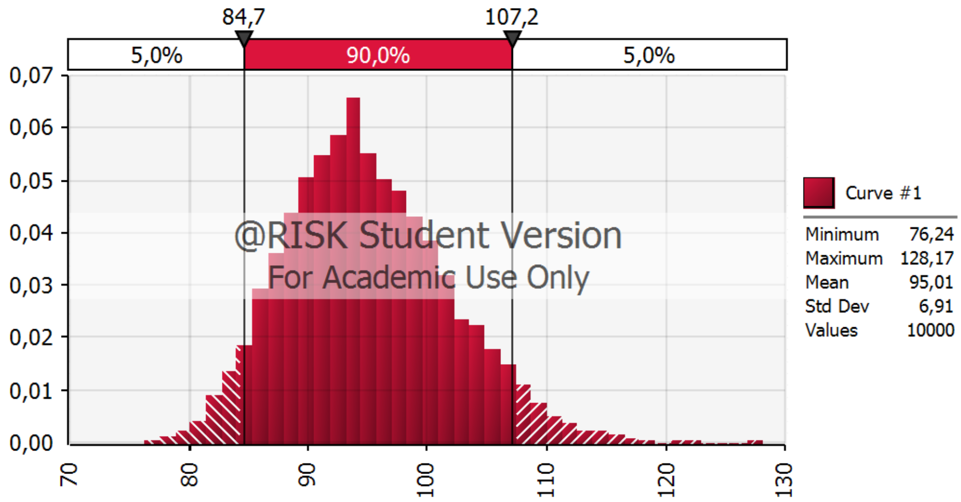
On this price a discount for a merit order effect and in the long run discount on the market price for electricity form intermitting sources is applied. As argued above, there are several effects that might dampen the market prices for electricity in general and for electricity from intermitting sources like wind and PV. From experience in Denmark and in Germany, there is a *merit order effect* from increasing renewable penetration in the order of 1% of each percentage of RES penetration in electricity production, and the assumption is that the penetration will grow in Austria by *1%*[141] a year over the next 15 years, this has to be considered accordingly.

The merit order effect might be reduced in the long term since it is related to marginal production cost and may change over time with the change of composition of the power plant composition. But it might well be replaced by charges for higher infrastructure cost for producers of renewable energy. The discount from the merit order effect of 15% therefore is set constant from year 15 on, reflecting the fact that the pure economic value of electricity from intermitting sources is lower than that of sources that can be well planned ahead.

To sum up, the scenario for the electricity prices in the model is rather conservative, with an upward component coming from above inflationary growth of gas prices but being moderated by dampening effects like the merit order effect.

[141] Estimated from Energie-Control Austria, Wien (2011a)

Figure 14: Probability distribution of market price for electricity in 2025 (EUR/MWh)



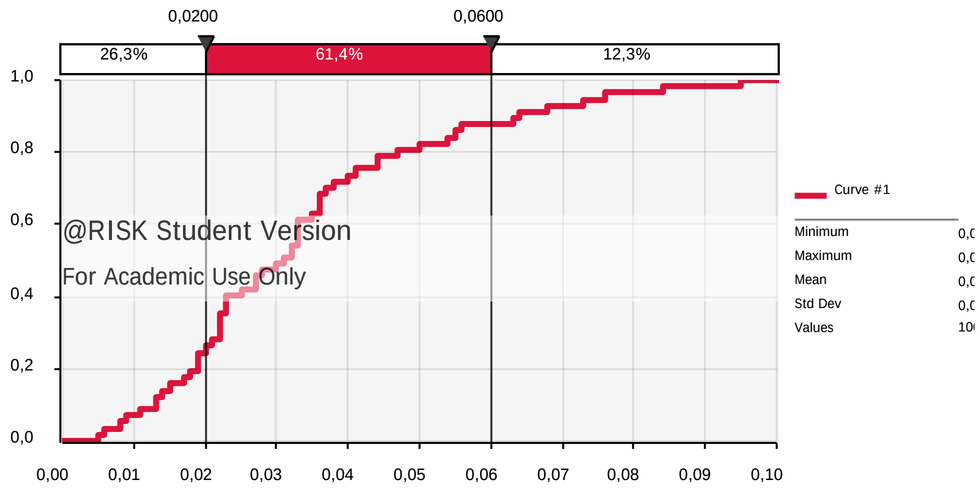
Source: Own calculation

3.1.1.3 Operational cost

Repair and maintenance is an important cost factor. The model assumption is that there is a full service contract with the turbine manufacturer for 15 years, this fee will cover all relevant expenses. These contracts are currently priced at a rate of EUR 10 per MWh produced. The calculated useful life of a wind farm is 20 years (and only then it makes decent profits for its investors). Maintenance and repair expenses have been increased by 50% in that period in order to keep availability and production at the expected levels.

All the cost are subject to inflation. The distribution of inflation rates are derived from historic inflation rates. There is not specific inflation forecast done, but the model assumes that historic inflation rates will occur in the future at the same probability as in the past. This is a simplification both in terms of the assumed historical pattern and neglects path dependency in the sense, that the inflation rate of t1 is correlated to the inflation rate in t0. However, these effects will be smoothened out since the period of consideration is 20 years. The model assumption is a mean inflation rate of 3.3% with the following probability distribution:

Figure 15: Probability distribution of inflation rates (%)



Source: Own calculation

Debt and interest rates

Interest rates do have a major influence in the performance of wind power plants. Since it is possible to fully hedge this risk in the markets with fixed interest rates over the whole period of debt financing, the price for this risk is already included in the fixed interest rates and need not be considered separately. The interest rates in the model reflect market conditions in Austria as of mid 2012.

The leverage in the model is set at 75%, a level where the minimum debt service cover ratio (DSCR)[142] in the standard scenario is 1.24. This is in line with the current expectation of financing banks to have this ratio at 1.2-1.3[143] A lower level of leverage would reduce the IRR on equity but also the variability of returns and therefore the standard deviation. Therefore, the risk attached to leverage is fully integrated in the model.
The DSCR indicates the ratio of the free cash flow available to meet the total debt service of interest and principal payments on the outstanding debt. This ratio is commonly used to set the level of leverage that a project can bear. The higher the amount of debt in a project at a given free cash flow, the lower this ratio is. It also is used as a performance figure for covenants in the loan agreement, resulting in a ban of payout to equity owners if a threshold is not reached.

[142] Böttcher (2009), p. 121ff
[143] Derived from own experience with financing structures and financing offers for comparable projects.

Transaction cost

Since the model assumes an acquisition of an existing wind farm, due diligence cost and legal cost are assumed.

Exchange rate

It is assumed that the investment is done in the investor's currency and therefore no currency risk is incurred.

3.1.1.4 Cost of equity

The cost of equity has two major components. One is to compensate the owner / beneficiary for deferring consumption, the so called "time value of money". This is due to the individual preference for current over future consumption. This magnitude of this preference can vary considerably, but on the level of the whole economy it has a price tag, which basically corresponds to the risk free rate of investment. At this rate, investors decide not to consume now but to consume later. This part also includes the expectation of inflation of the investors since the purchasing power of the funds will change (decrease) over time and the investors will expect to be compensated for this. The second major component of the cost of equity is compensation for risk, the equity risk premium. An investment is considered riskless if the actual return always equals the expected return. A cash flow that is expected in the future is subject to the risk that it will not happen in the expected amount. There is a long standing debate on a consistent equity risk premium going on, not least because this is a corner stone in the nowadays mostly accepted capital asset pricing model. Still, as of today, there is no generally accepted methodology of calculating the equity risk premium nor is there a figure that is undisputed.

In the model the cost of equity is derived from historic total returns after tax in the S&P index.[144] This index is chosen because it represents the most liquid and diversified stock markets and therefore can be taken as a proxy for *the* abstract equity investment. In addition, there are the most representative long term data available for this index. It has to be kept in mind that long term equity returns in Europe are lower than in the US (by 1.6% according to a study by Credit Suisse [145]).

[144] www.ifa.org
[145] Credit Suisse Global Research (2012)

Table 5: Total returns on S&P 500

As Of	Index 1.1.1928=1	Y-0-Y	Pre-tax 10 y average	15y average	20y average	Post-tax 15y average	20y average
12/31/1955	12,09	31,56%	16,70%	16,78%	12,48%	14,81%	11,05%
12/31/1956	12,89	6,62%	18,45%	18,27%	11,21%	16,23%	9,83%
12/31/1957	11,50	-10,78%	16,44%	15,88%	12,99%	13,95%	11,53%
12/31/1958	16,48	43,30%	20,05%	16,92%	13,50%	14,94%	12,02%
12/31/1959	18,45	11,95%	19,34%	16,40%	14,14%	14,45%	12,64%
12/31/1960	18,54	0,49%	16,17%	14,05%	14,77%	12,22%	13,25%
12/31/1961	23,53	26,91%	16,43%	16,54%	16,88%	14,57%	15,29%
12/31/1962	21,47	-8,75%	13,45%	15,38%	15,23%	13,48%	13,70%
12/31/1963	26,37	22,82%	15,92%	16,55%	15,11%	14,59%	13,58%
12/31/1964	30,72	16,50%	12,83%	16,40%	14,96%	14,44%	13,43%
12/31/1965	34,54	12,43%	11,07%	15,19%	13,85%	13,30%	12,36%
12/31/1966	31,06	-10,08%	9,19%	12,74%	13,73%	11,00%	12,25%
12/31/1967	38,51	23,99%	12,85%	13,10%	14,63%	11,33%	13,11%
12/31/1968	42,77	11,06%	10,01%	13,96%	14,92%	12,14%	13,39%
12/31/1969	39,13	-8,51%	7,81%	10,14%	13,43%	8,59%	11,95%
12/31/1970	40,70	4,01%	8,18%	8,43%	12,11%	7,04%	10,69%
12/31/1971	46,53	14,32%	7,06%	8,93%	11,64%	7,50%	10,25%
12/31/1972	55,36	18,98%	9,94%	11,05%	11,68%	9,42%	10,28%
12/31/1973	47,24	-14,67%	6,00%	7,27%	10,85%	6,01%	9,49%
12/31/1974	34,74	-26,46%	1,24%	4,31%	6,87%	3,45%	5,79%
12/31/1975	47,66	37,19%	3,27%	6,50%	7,10%	5,33%	6,00%
12/31/1976	59,02	23,84%	6,63%	6,32%	7,90%	5,17%	6,74%
12/31/1977	54,78	-7,18%	3,59%	6,44%	8,12%	5,28%	6,93%
12/31/1978	58,38	6,57%	3,16%	5,44%	6,53%	4,41%	5,48%
12/31/1979	69,14	18,43%	5,86%	5,56%	6,83%	4,51%	5,75%
12/31/1980	91,56	32,43%	8,45%	6,72%	8,31%	5,52%	7,12%
12/31/1981	87,06	-4,91%	6,47%	7,11%	6,76%	5,87%	5,69%
12/31/1982	105,70	21,41%	6,68%	6,96%	8,30%	5,74%	7,10%
12/31/1983	129,50	22,52%	10,61%	7,67%	8,28%	6,36%	7,09%
12/31/1984	137,62	6,27%	14,76%	8,75%	7,79%	7,33%	6,63%
12/31/1985	181,87	32,15%	14,33%	10,50%	8,66%	8,92%	7,44%
12/31/1986	215,46	18,47%	13,82%	10,76%	10,17%	9,16%	8,85%
12/31/1987	226,73	5,23%	15,26%	9,86%	9,27%	8,33%	8,01%
12/31/1988	264,85	16,81%	16,33%	12,18%	9,55%	10,47%	8,26%
12/31/1989	348,46	31,57%	17,56%	16,62%	11,55%	14,65%	10,16%
12/31/1990	337,65	-3,10%	13,94%	13,94%	11,16%	12,12%	9,79%
12/31/1991	440,51	30,46%	17,60%	14,34%	11,90%	12,49%	10,49%
12/31/1992	474,08	7,62%	16,19%	15,47%	11,34%	13,57%	9,96%
12/31/1993	521,86	10,08%	14,96%	15,72%	12,76%	13,80%	11,32%
12/31/1994	528,75	1,32%	14,41%	14,53%	14,58%	12,67%	13,07%
12/31/1995	727,44	37,58%	14,87%	14,82%	14,60%	12,94%	13,08%
12/31/1996	894,46	22,96%	15,30%	16,80%	14,56%	14,83%	13,05%
12/31/1997	1.192,88	33,36%	18,06%	17,54%	16,65%	15,53%	15,08%
12/31/1998	1.533,79	28,58%	19,20%	17,91%	17,75%	15,89%	16,15%
12/31/1999	1.856,53	21,04%	18,21%	18,94%	17,88%	16,87%	16,27%
12/31/2000	1.687,50	-9,10%	17,46%	16,01%	15,68%	14,08%	14,14%
12/31/2001	1.486,93	-11,89%	12,94%	13,74%	15,25%	11,93%	13,71%
12/31/2002	1.158,31	-22,10%	9,34%	11,49%	12,72%	9,83%	11,27%
12/31/2003	1.490,57	28,68%	11,07%	12,21%	12,99%	10,50%	11,54%
12/31/2004	1.652,77	10,88%	12,07%	10,94%	13,23%	9,32%	11,77%
12/31/2005	1.733,95	4,91%	9,07%	11,52%	11,93%	9,87%	10,53%
12/31/2006	2.007,82	15,79%	8,42%	10,64%	11,81%	9,05%	10,40%
12/31/2007	2.118,13	5,49%	5,91%	10,49%	11,82%	8,92%	10,42%
12/31/2008	1.334,47	-37,00%	-1,38%	6,46%	8,42%	5,29%	7,22%
12/31/2009	1.687,63	26,46%	-0,95%	8,04%	8,21%	6,70%	7,02%
12/31/2010	1.941,84	15,06%	1,41%	6,76%	9,14%	5,56%	7,89%
12/31/2011	1.982,85	2,11%	2,92%	5,45%	7,81%	4,42%	6,65%
Mean rate of return		11,4%	10,3%	10,7%	10,9%	9,8%	9,9%

Source: http://www.ifa.com/portfolios/PortReturnCalc/index.aspx, own calculations

The total returns on the S&P 500 portfolio are calculated as the mean of the geometric average of a 15 year tenure for the period from 1955-2011. The geometric average of returns for an investment period from 1955 to 1969, from 1956 to 1970 and so on is calculated. This results in a reference rate of return on equity of 9.8%.

An investment in a wind farm has to be considered less liquid than an investment in a blue chip company. However, it is hard to define exactly how illiquid this investment is, since there are secondary markets for investments in renewable energy investments, and they are becoming increasingly liquid. Therefore no mark up an illiquidity premium on the wind farm investment is made, since any figure would be arbitrary and hard to justify except for the fact that it might seems intuitively correct. The approach is to compare the wind farm investment to a long term investment in public market. We look into the reward that an investor would gain from accepting a lock up in the public market for the same period of investment as the wind farm.

3.1.2 Model output

Table 6: Static model output

IRR (project)	7,3%	
IRR (equity)	10,9%	
EBITDA margin (average)	10,5%	
Payback time equity	12	years
Total Investment / Anual Energy Production	697	EUR per MWh
Total Investment / Capacity	1.640.000	EUR per MW installed
Total Cash flow to equity as % of equity investment	374%	
Net Present Value @ 9,8%	1.412.069	EUR
Total Net CF to Equity	33.651.238	EUR
Total Equity Multiple	3,7	
Levelised cost of electricity	68,4	EUR / MWh
Weighted average cost of capital	4,7%	
Mean return S&P500 (15 years tenure geometr. average)	9,8%	
MIRR	7,5%	

Source: Own calculations

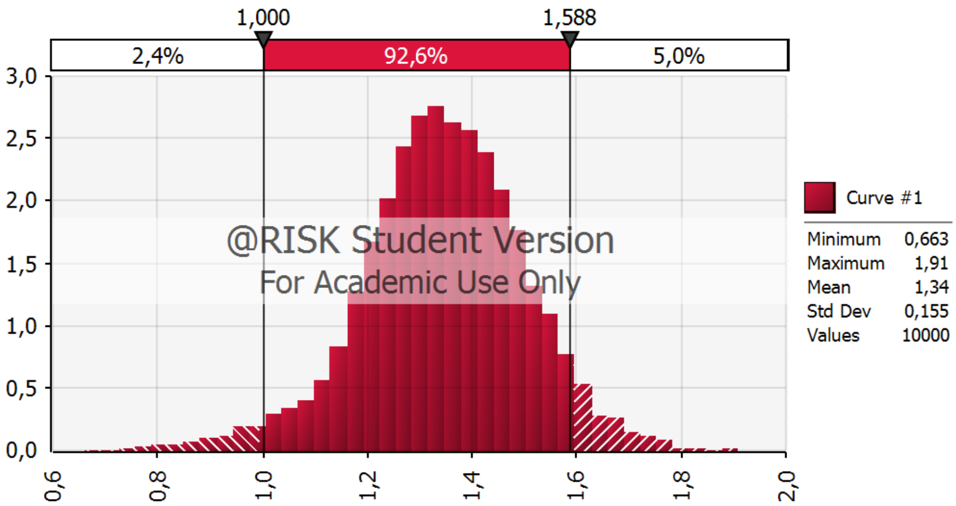
3.1.2.1 Selected results for ratios indicating liquidity constraints

The project produces cash flows over its lifetime, which is usually an outflow (the investment) at the beginning and a series of inflows over the lifetime of the project. The cash flow generated by a project typically is distributed according to a “cash flow waterfall”, paying all operational expenses first, then paying for the debt service and finally paying equity. The corresponding target ratios are important sind they tell about the debt service capacity of the project and the likelihood that the project will survive without additional equity injection.

Debt Service Cover Ratio (DSCR)

The mean DSCR over the financing period calculated from the simulation is 1.34 and therefore on the upper edge of this range. With a probability of about 97.6% the mean DSCR of the project will be above 1.

Figure 16: Probability distribution of mean DSCR over financing period

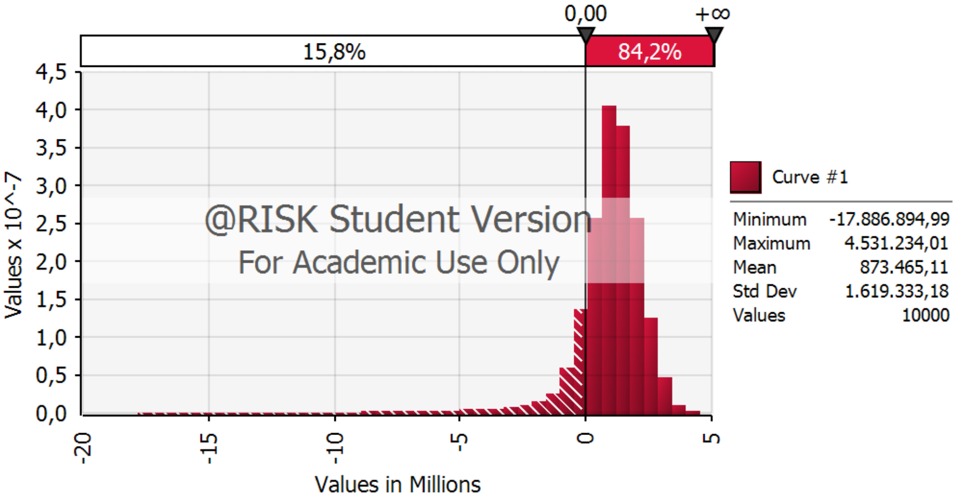


Source: Own calculation

Additional equity injection

Finally, from the project sponsor perspective, it is also very important to get information on the probability that he might need to inject further equity in the project. In a non - recourse finance structure he is likely not obliged to do so, however, it might be economically reasonable to do so in order to save the project. In the model the probability that the cumulated cash flow available for equity is below zero at any given year is 15.8%. In this case, the owners would have to inject additional equity. However, the probability that at the end of the project live time the invested money has not at least been earned back is 0%.

Figure 17: Probability distribution of minimal cumulated cash flow (EUR)



Source: Own calculation

Debt Service Reserve Account (DSRA)

It is very common for non-recourse finance structures to have the requirement to endow a special account with cash in order to safeguard debt service even in case that the cash flow generated by the project is not sufficient in a certain period. It is very common to have a DSRA of about 50% of an annual debt service, and this is also what is assumed in the model.

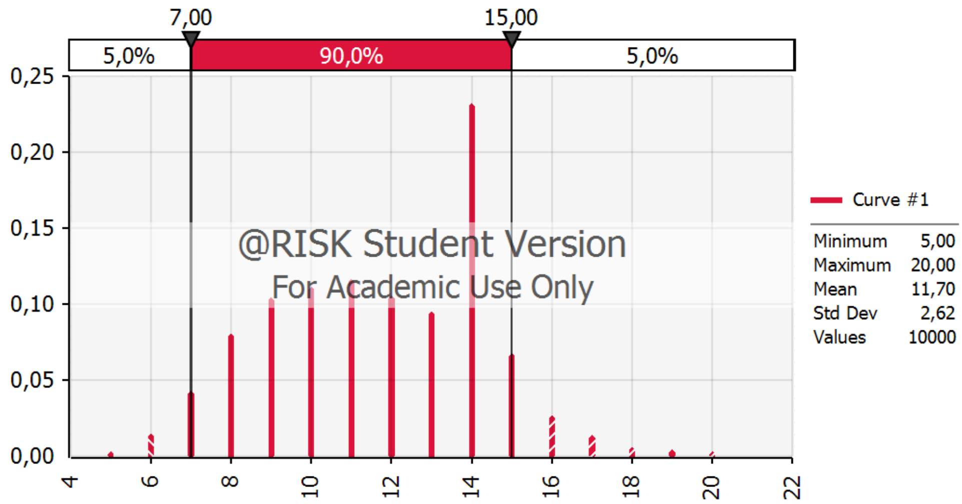
3.1.2.2 Selected results for ratios indicating return constraints

The goal of a financial investment is to produce free cash flows in excess to the need of debt service in order to earn a return on equity employed that is above a set return target. An evaluation of the attractiveness of an investment proposal, using methods such as average rate of return, internal rate of return (IRR), net present value (NPV), or payback period.

Equity Payback

The time taken to recover the cost of the investment (non-discounting) is an important risk indicator for the investor, since the longer it is the longer he is exposed to the project risk. The mean payback time of 11.7 years is within the feed in tariff period and also within the tenure of the loan. The payback time will be not longer than 15 years at a probability of 95%.

Figure 18: Probability distribution of equity payback time (years)

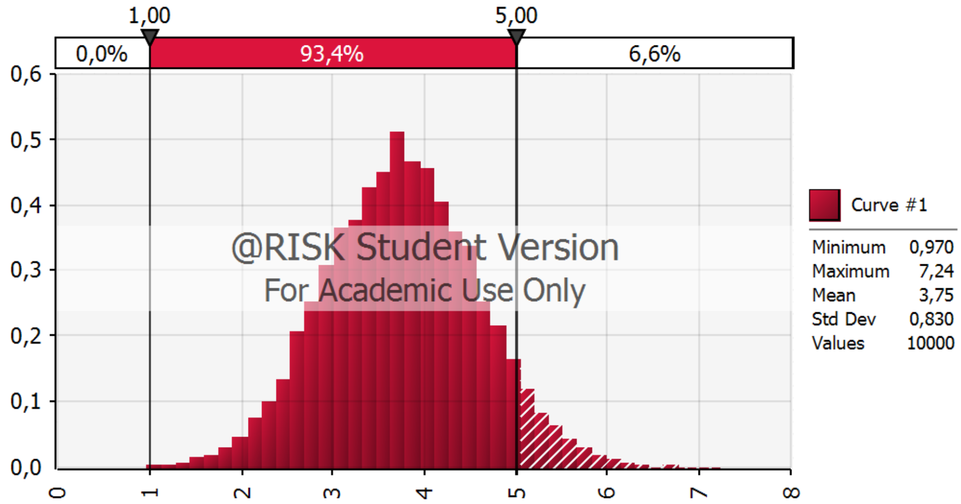


Source: Own calculation

Total equity multiple

The total equity multiple indicates how often the equity investment is covered by the total free cash flow to equity through the lifetime of the project. The probability that the project does earn back less than the initial investment is 0%.

Figure 19: Probability distribution of total equity multiple

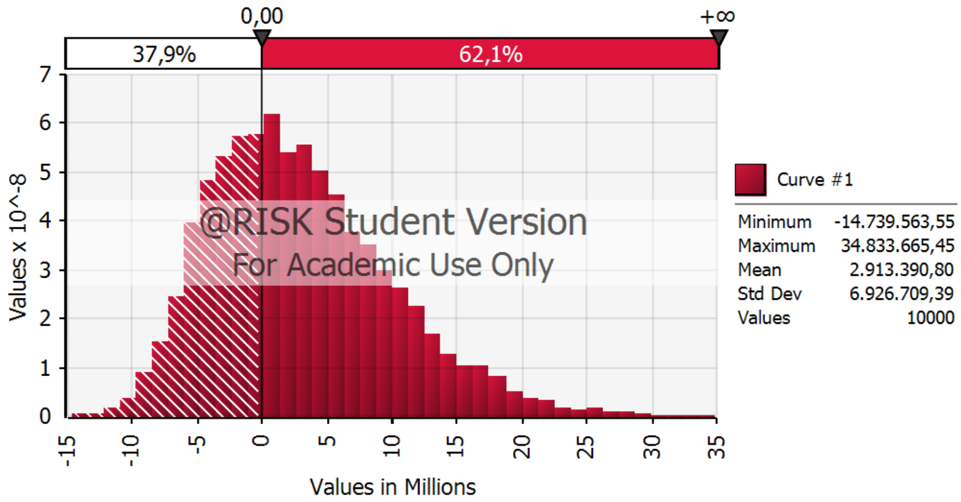


Source: Own calculation

Net present value

The present value of the free cash flows received in the future less the initial cost of the investment is positive if the investment earns the target return. The discount rate in the model equals the total return of a S&P investment net of tax of 9.8%. The project is likely to exceed this rate of return with a probability of 62.1%.

Figure 20: Probability distribution of net present value (EUR)

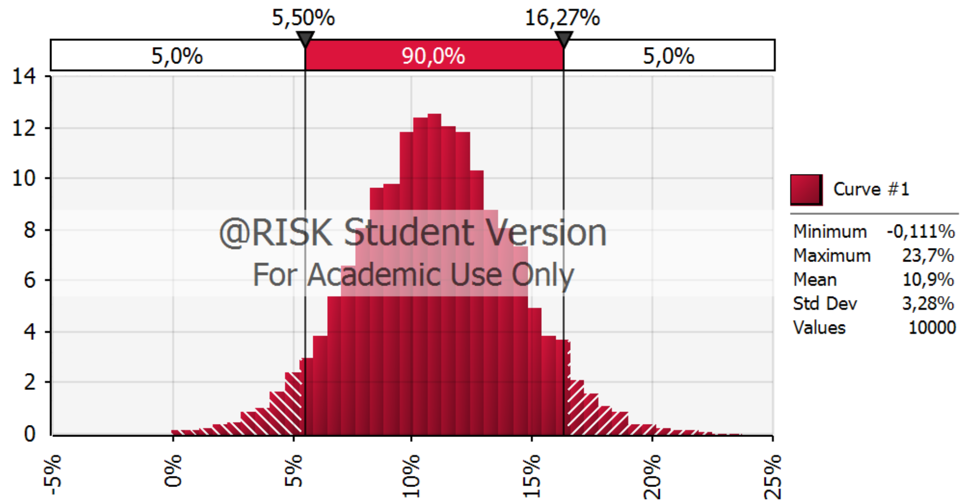


Source: Own calculation

Internal rate of return (IRR)

The IRR is the discount rate that causes the net present value of an investment to be zero. Within the concept of IRR it is assumed that the returns are reinvested at the same rate of return as the IRR. The mean value of the IRR on equity for the model is 10.9% at a standard deviation of 3.28%. The IRR would be above 5.5% at a 95% probability.

Figure 21: Probability distribution of IRR on equity (%)

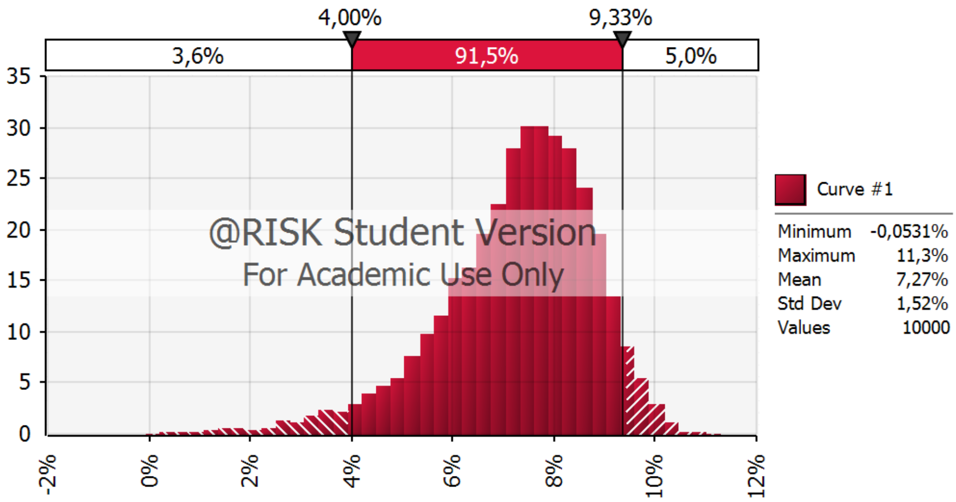


Source: Own calculation

Modified internal rate of return (MIRR)

If the assumption of reinvestment at IRR does not look realistic, a modified internal rate of return may be used to calculate the expected return of the project. In this case, all negative cash flows are discounted to the present value at the weighted average cost of capital or an external reinvestment rate, and all positive cash flows are added up at the same rate to the final period. The terminal value is divided by the present value. From the resulting multiple the interest rate is calculated at which the present value of this terminal value would be equal to the present value of the cash outflows. The appropriate reinvestment rate could be the rate of return in the reference asset class (S&P 500). In this case, the risk of this investment (standard deviation of returns) has to be taken into consideration too. The other approach is to assume a reinvestment at a risk free rate. Since this rate is low, this brings down the rate of return to 7.27%. However, since there is no risk in return rates, overall risk in terms of standard deviation is down to 1.52%.

Figure 22: Probability distribution of MIRR (%)



Source: Own calculation

3.1.3 Possible gains of diversification of risk through building a portfolio

The probability distributions assumed so far are aimed at the profile of a single wind farm. However, there are portfolio effects from a diversified portfolio. Given the assumption, that there is no correlation between the underlying uncertainties of one wind farm to the other, the portfolio effect would be quite considerable as can be shown with an isolated test run of the probability distribution of production. The standard deviation of the average production of a portfolio would be reduced from 10.5%, as assumed for the model wind farm, to 4.8% for a portfolio of 5 wind farms and thus be nearly half of the original value. For 10 wind farms, the standard variation would be reduced to 3.4%.

However, only a part of the underlying uncertainties can be assumed independent. As for the "model" uncertainty, Marco et al (2009) come to the conclusion that

"The relation between the different sources of the "model" uncertainty of the different projects is very difficult to assess as it is not clear how to determine it. For instance, how to determine if the uncertainty of the measurements of two sites are mitigated in some degree when considered together (independent) or the opposite. Same logic applies to the other uncertainties and therefore, assumptions need to be made for the dependency relation between projects for this type of uncertainties which are not related to wind variability. It is recommended to consider these "model" uncertainties as dependent, as there is no proven way to assess the degree of independency."[146]

So there is no ground for assuming a portfolio effect for the "model uncertainty". The risk from electricity prices and inflation can also hardly be diversified.

The regulatory risk could well be diversified on the contrary. However, in the model we already have assumed the lowest risk level possible since the project is located in Austria. Any diversification therefore would likely bring in countries with a higher risk level, thus not lowering the regulatory risk.

However, as for the wind variability a partial dependent relation and therefore a portfolio effect can be assumed. Dunlop concludes that the uncertainty of a geographically diversified portfolio can be reduced by 30%. Marco et al. calculate a 25% reduction in overall uncertainty from a geographically diversified portfolio.

For an investor it would be very interesting to a research effort beyond the scope of the paper to derive empirically founded assumptions on what risks are diversifiable and what risks are not. What can be done here is to test the following simple assumption that the production risk due to location can be diversified by 35% as shown in the study of Dunlop.

"Northern European wind farms are all highly correlated with each other, offering very little in the way of diversifiable production risk…In contrast, Southern European wind farms are out of synch with Northern European wind farms and are out of synch with each other, offering the most in terms of diversification value…A portfolio

[146] Marco et al (2009), p. 7

with half of its wind farms in Northern Europe and half in Southern Europe will have 35% less production risk than a single large farm investment in Northern Europe"[147]

This would reduce the annual variability of production from 15% to 10%. Running the model with this reduced standard deviation of annual production, the standard deviation of IRR would only be reduced by 0.1%, thus lowering the "correct" return expectation by about 0.5 percentage points.

3.2 Deriving a MARR from the simulation

Having derived a probability distribution of equity returns in the most liquid public market, the US stock market and a probability distribution of equity returns in the specific wind power projects, both needed to be compared in order to decide which investment to choose, or, in order to define the minimum acceptable rate of return on the wind power project.

The Sharpe ratio, also called Reward-to-Variability Ratio, measures the excess return per unit of risk of an investment.

The Sharpe ratio is defined as:[148]

$$S = \frac{E\left[R - R_f\right]}{\sigma}$$

with R the asset return
R_f the risk free rate of return
σ the standard deviation of the asset return.

For example, if an investor has the choice of two funds, both of which have made an annual return of 15 percent over the past three years, he would prefer the funds, which yield such a return at a lower volatility. But if the investor has to choose between two funds, one of which is somewhat weaker in the return, but also a little less risky, the decision depends on the valuation of the trade off. The Sharpe ratio is a dimension-less figure representing a risk/return profile of an investment that makes it comparable to another investment.

First of all, it contains the so-called excess return on the risk free rate in the numerator. If the risk-free rate is at three percent and the selected investment produces returns of ten percent, the latter has an excess return of seven percent. This is compared to the risk in terms of volatility. A positive Sharpe ratio indicates that the risk was rewarded and that the excess return was larger than the excess

147 Dunlop (2004), p 94
148 http://en.wikipedia.org/wiki/Sharpe_ratio

risk. Conversely, a negative Sharpe ratio indicates that the risk free rate was not beaten. Thus deciding between two investments, other things equal, the investment with the higher Sharpe ratio should be chosen.

Table 7: Total returns, standard deviation and Sharpe ratio on S&P 500 portfolio from 1955-2011

	Pre-tax				Post-tax	
	Y-0-Y	10 y average	15y average	20y average	15y average	20y average
Mean rate of return	11,4%	10,3%	10,7%	10,9%	9,8%	9,9%
Standard deviation of	17,3%	5,4%	4,0%	3,3%	3,9%	3,2%
Risk free rate	2,2%	2,2%	2,2%	2,2%	2,2%	2,2%
Sharpe ratio	0,53	1,50	2,11	2,65	1,94	2,40

Source: http://www.ifa.com/portfolios/PortReturnCalc/index.aspx, own calculations

The post-tax mean return for a 20 year tenure period (distribution of the geometrical average of a 15 year lock-up period) is 9.9% with a standard deviation 3.9%. At a risk free rate of 2.2% a Sharpe ratio of 1.94 is calculated.

The mean value of return on a long term tenure is slightly lower than on y-o-y, which is also attributable to the methodological approach of calculating geometrical averages for the long term tenure. The more obvious thing is that the risk of the investment measured by the standard deviation decreases considerably. Calculating the sharp ratio shows that a short term investment strategy with a tenure of one year does not. In fact, the investor should be compensated for the illiquidity with lower volatility. Therefore, the Sharpe ratio taken as the benchmark for the investment in the wind farm should be the one with a 15 year tenure in the public market.

Following the above considerations, the minimum acceptable rate of return for a wind park at a certain standard deviation would show a Sharpe-ratio of 1.94.

Table 8: Equity rates of return, standard deviation and Sharpe ratio on model wind farm investment

	Post-tax		
	IRR (equity)	MIRR (equity)	IRR (unlev.)
Mean rate of return	10,9%	7,3%	7,2%
Standard deviation of	3,3%	1,5%	1,5%
Risk free rate	2,2%	2,2%	2,2%
Sharpe ratio	2,65	3,34	3,35

Source:Own calculations

From the Monte Carlo simulation we have derived the following mean rates of returns and the corresponding standard deviations. Comparing the results, we see that the IRR of the project is by about 1.1 percentage points higher than the benchmark investment in the S&P 500 index portfolio at a lower standard deviation of 3.3%, resulting in a higher Sharpe ratio of 2.65.

A reduction in risk would translate in lower standard deviation of the expected returns of the investment, translating in a higher Sharpe ratio. Reduction of risk on the other hand most likely would cause additional cost or reduce revenue, reducing the free cash flow to equity and therefore reducing the expected returns of investment. Any strategy of risk avoidance or distributions would be advisable within the framework of this paper if it increases the Sharpe ratio of the project and would not be advisable if it lowers the Sharpe ratio. The MIRR is calculated at a risk free reinvestment assumption, therefore the rate of return is lower, but so is the standard deviation and therefore the Sharpe ratio is even higher at 2.72.

If the project were unlevered, the mean rate of return would be 7.2% at a standard deviation of 1.5% and a Sharpe ratio of 3.35.

4 Conclusions

Due to the maturity of the technology and well established market standards, wind farms investments are now accessible for private investors. Many risks of a wind farm can reasonably be avoided, mitigated or distributed. The major remaining risks are production risk and regulatory risk. Inflation and price risk after the feed in period are also important.

The risk model of a wind farm is well suited for a Monte Carlo simulation since major risks can well be described in a probability distribution function. The proposed model is aimed to be a useful tool in order to make a series of decisions during the investment process of a wind farm. It can provide useful information for the optimal technical set up of the wind farm, comparing various turbine manufacturers on a ceteris paribus basis. It can provide a useful analytical framework for the decision how to handle risk and to find an economically optimal mix of mitigating, distributing and keeping risks.

In order to assess the risk profile of the investment, two sets of target ratios should be analyzed. The first set are liquidity ratios since for the project sponsor it is important to know if he will need to inject extra capital in the project during the life time in order not to lose the project. This is an important difference between an investment in the stock market and one in a wind farm. The simulation shows the probability of additional equity need during the project life of about 16%. This is still a low probability and for the most likely events the amount of equity injection would be low compared to the additional investment. However, if the sponsor cannot afford this, he might run the risk to lose the project and his initial investment. The investor does not run this type of liquidity risk in a stock market investment.

The second set of target ratios are return ratios and the corresponding standard deviations. The expected internal rate of return (IRR) and the standard deviation are compared to the respective figures from an investment in a S&P 500 portfolio by calculating the Sharpe ratios. It has to be kept in mind that research shows that the long term average returns for equity investments in Europe are lower than in the US.

The model for the wind farm investment shows a 10.9% return (IRR), a standard deviation of 3.3% and a corresponding Sharpe ratio of 2.65. When calculating a modified IRR with a very conservative reinvestment assumption, the Sharpe ratio of the wind farm investment is even at 3.33 due to a much lower standard deviation in return. The long term average return of an investment in a S&P 500 portfolio shows a return of 9.8%, a standard deviation of 3.9% and a corresponding Sharpe ratio of only 1.94. To put it different: at this standard deviation an IRR of 8.5% would translate in the same Sharpe ratio as the public market investment and therefore be the minimum acceptable rate of return (MARR) according to the model for the risk profile of this wind farm. The investment in the wind farm therefore is to be preferred over the investment in the public market.

The model fully reflects the risk of leverage. A lower level of leverage of the wind farm would reduce the IRR on equity but also the variability of returns and therefore the standard deviation.

Overall, Monte Carlo simulation based on this risk model can make risk much more transparent to the investor or, as the case may be, to the lender. It also provides a powerful tool in order to set rational expectations for return on equity and to decide between two investment alternatives.

There are, however, a few caveats. Those relate to the limitations of any model in general. The quality of the output is limited by the quality of the input. Since wind farms have a very long project life, many assumptions need to be rough. It is also important that the model is integrated in the decision process. Any representations of decision makers about the project need to be included in the model and the model again has to be tested against these representations. Trust and transparency with regard to the model have to be built during the whole decision process.

This refers to a second possible shortcoming of this approach. A drive for accuracy and comprehensiveness might bring models beyond what many people are able and willing to follow. In fact, what makes many decision making tools and models so attractive is not necessarily that they are accurate and comprehensive, but that they are simple and widely accepted.

To conclude, Monte Carlo simulation opens valuable insights in the financial analysis of wind farms with regard to the risk return profile. With the sophistication of the whole project development and investment process, which clearly can be seen in the market, the acceptance and the value of this type of tools will increase.

As for the return expectation, the results of the case study show that the actual return of the wind farm is close to the theoretical MARR. A significant shift therefore cannot be expected and would not be rational from the project risk perspective. It would only be justified if there would be a clear indication that the long term returns that were achieved in the public equity markets will be significantly lower in the future due to deep structural changes.

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Master Thesis
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ANNEX Cash flow projection

Wind Farm Austria

Cash Flow Calculation in EUR

	Jahr	0	2012	2013	2014	2015	2016	2017	2018	2019	2020
	Index										
Production											
Gross Electricity yield p.a. MWh	100,0%		75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000
Standard deviation of annual production	15,0%		1	1	1	1	1	1	1	1	1
Degradation	0,0%		100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%
System Losses, Availability	97,0%		97%	97%	97%	97%	97%	97%	97%	97%	97%
Availability	97,0%		97%	97%	97%	97%	97%	97%	97%	97%	97%
Net Energy yield			70.568	70.568	70.568	70.568	70.568	70.568	70.568	70.568	70.568
Feed in tariff	100,0%		93,00	93,00	93,00	93,00	93,00	93,00	93,00	93,00	93,00
Market price electricity	104,5%		54,06	56,42	58,87	61,44	64,12	66,92	69,83	72,88	76,06
Regulatory risk	1,0%	100%	99%	98%	97%	96%	95%	94%	93%	92%	91%
			1%	2%	3%	4%	5%	6%	7%	8%	9%
Risk adjusted price electricity	100,0%		93,00	93,00	93,00	93,00	93,00	93,00	93,00	93,00	93,00
Total Compensation Electricity /MWh		93	93,00	93,00	93,00	93,00	93,00	93,00	93,00	93,00	93,00
Total revenue			**6.562.778**	**6.562.778**	**6.562.778**	**6.562.778**	**6.562.778**	**6.562.778**	**6.562.778**	**6.562.778**	**6.562.778**
Operation and Maintenance	100,0%	10	352.838	352.838	705.675	705.675	705.675	705.675	705.675	705.675	705.675
Grid services, own power consumption	100,0%		187.500	187.500	187.500	187.500	187.500	187.500	187.500	187.500	187.500
Land Lease	100,0%		172.151	172.151	172.151	172.151	172.151	172.151	172.151	172.151	172.151
Technical and commercial Management and	100,0%		131.256	131.256	131.256	131.256	131.256	131.256	131.256	131.256	131.256
Insurance	100,0%		70.000	70.000	70.000	70.000	70.000	70.000	70.000	70.000	70.000
Reserves for repair and maintenance	100,0%		49.200	49.200	49.200	49.200	49.200	49.200	49.200	49.200	49.200
Annual Inflation Rate	100,0%		3,30%	3,30%	3,30%	3,30%	3,30%	3,30%	3,30%	3,30%	3,30%
Price Index		100,00%	100%	103%	107%	110%	113%	117%	120%	123%	126%
			962.944	943.898	1.350.176	1.391.973	1.433.770	1.475.568	1.517.365	1.559.162	1.600.959
Total operating expenses			**-962.944**	**-943.898**	**-1.350.176**	**-1.391.973**	**-1.433.770**	**-1.475.568**	**-1.517.365**	**-1.559.162**	**-1.600.959**
- Depreciation			**-3.280.000**	**-3.280.000**	**-3.280.000**	**-3.280.000**	**-3.280.000**	**-3.280.000**	**-3.280.000**	**-3.280.000**	**-3.280.000**
EBIT			**2.319.833**	**2.338.880**	**1.932.602**	**1.890.804**	**1.849.007**	**1.807.210**	**1.765.413**	**1.723.616**	**1.681.818**
Interest for long term debt			**-1.419.231**	**-1.305.692**	**-1.192.154**	**-1.078.615**	**-965.077**	**-851.538**	**-738.000**	**-624.462**	**-510.923**
Interest income for DSRA			**24.986**	**45.586**	**44.337**	**43.088**	**41.839**	**40.590**	**39.341**	**38.092**	**36.843**
EBT			**925.589**	**1.078.773**	**784.784**	**855.277**	**925.769**	**996.262**	**1.066.754**	**1.137.246**	**1.207.739**
Corporate income tax			**-231.397**	**-269.693**	**-196.196**	**-213.819**	**-231.442**	**-249.065**	**-266.688**	**-284.312**	**-301.935**
EAT			**694.192**	**809.080**	**588.588**	**641.458**	**694.327**	**747.196**	**800.065**	**852.935**	**905.804**
Cash available for interest service			5.368.436	5.349.187	5.016.405	4.956.985	4.897.565	4.838.145	4.778.724	4.719.304	4.659.884
Cash available for debt repayment			3.974.192	4.089.080	3.868.588	3.921.458	3.974.327	4.027.196	4.080.065	4.132.935	4.185.804
cash available for equity			**0**	**314.272**	**1.086.896**	**1.139.765**	**1.192.635**	**1.245.504**	**1.298.373**	**1.351.242**	**1.404.112**
Debt I	Interest		-1.419.231	-1.305.692	-1.192.154	-1.078.615	-965.077	-851.538	-738.000	-624.462	-510.923
DSRA +/-			1.135.730	936.347	-56.769	-56.769	-56.769	-56.769	-56.769	-56.769	-56.769
DSCR	**1,24**	1,34	1,26	1,29	1,24	1,27	1,29	1,31	1,34	1,36	1,39
Free cash flow											
Cash flow from operations			5.368.436	5.349.187	5.016.405	4.956.985	4.897.565	4.838.145	4.778.724	4.719.304	4.659.884
Cash flow from investments		-49.200.000									
Total free cash flow		**-49.200.000**	**5.368.436**	**5.349.187**	**5.016.405**	**4.956.985**	**4.897.565**	**4.838.145**	**4.778.724**	**4.719.304**	**4.659.884**
Total free cash flow cumulated			**-43.831.564**	**-38.482.377**	**-33.465.972**	**-28.508.987**	**-23.611.422**	**-18.773.277**	**-13.994.553**	**-9.275.249**	**-4.615.365**
Cash flow f/t equity											
Cash flow from operations			0	314.272	1.086.896	1.139.765	1.192.635	1.245.504	1.298.373	1.351.242	1.404.112
Cash flow from investments		-12.300.000									
Total cash flow f/t equity		**-12.300.000**	**0**	**314.272**	**1.086.896**	**1.139.765**	**1.192.635**	**1.245.504**	**1.298.373**	**1.351.242**	**1.404.112**

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Production											
Gross Electricity yield p.a. MWh	75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000
Standard deviation of annual production	1	1	1	1	1	1	1	1	1	1	1
Degradation	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%
System Losses, Availability	97%	97%	97%	97%	97%	97%	97%	97%	97%	97%	97%
Availability	97%	97%	97%	97%	97%	97%	97%	97%	97%	97%	97%
Net Energy yield	70.568	70.568	70.568	70.568	70.568	70.568	70.568	70.204	70.204	70.204	70.204
Feed in tariff	93,00	93,00	93,00	93,00	-	-	-	-	-	-	-
Market price electricity	79,37	82,83	86,44	90,21	94,14	98,25	102,53	107,00	111,67	116,54	121,62
Regulatory risk	90%	90%	89%	88%	0%	0%	0%	0%	0%	0%	0%
	10%	10%	11%	12%	100%	100%	100%	100%	100%	100%	100%
Risk adjusted price electricity	93,00	93,00	93,00	93,00	94,14	98,25	102,53	107,00	111,67	116,54	121,62
Total Compensation Electricity /MWh	93,00	93,00	93,00	93,00	94,14	98,25	102,53	107,00	111,67	116,54	121,62
Total revenue	**6.562.778**	**6.562.778**	**6.562.778**	**6.562.778**	**6.643.519**	**6.933.162**	**7.235.432**	**7.511.958**	**7.839.462**	**8.181.245**	**8.537.929**
Operation and Maintenance	705.675	705.675	705.675	705.675	705.675	705.675	1.058.513	1.053.056	1.053.056	1.053.056	1.053.056
Grid services, own power consumption	187.500	187.500	187.500	187.500	187.500	187.500	187.500	187.500	187.500	187.500	187.500
Land Lease	172.151	150.000	150.000	150.000	150.000	150.000	150.000	150.000	150.000	150.000	150.000
Technical and commercial Management and	131.256	131.256	131.256	131.256	131.256	131.256	131.256	131.256	131.256	131.256	131.256
Insurance	70.000	70.000	70.000	70.000	70.000	70.000	70.000	70.000	70.000	70.000	70.000
Reserves for repair and maintenance	49.200	49.200	49.200	49.200	49.200	20.000	220.000	220.000	220.000	220.000	220.000
Annual Inflation Rate	3,30%	3,30%	3,30%	3,30%	3,30%	3,30%	3,30%	3,30%	3,30%	3,30%	3,30%
Price Index	130%	133%	136%	140%	143%	146%	150%	153%	156%	159%	163%
	1.642.756	1.655.093	1.696.159	1.737.225	1.778.291	1.819.357	2.387.916	2.432.288	2.484.818	2.537.348	2.589.878
Total operating expenses	**-1.642.756**	**-1.655.093**	**-1.696.159**	**-1.737.225**	**-1.778.291**	**-1.819.357**	**-2.387.916**	**-2.432.288**	**-2.484.818**	**-2.537.348**	**-2.589.878**
- Depreciation	**-3.280.000**	**-3.280.000**	**-3.280.000**	**-3.280.000**	**-3.280.000**	**-3.280.000**	**0**	**0**	**0**	**0**	**0**
EBIT	**1.640.021**	**1.627.685**	**1.586.619**	**1.545.552**	**1.585.228**	**1.833.804**	**4.847.516**	**5.079.670**	**5.354.644**	**5.643.897**	**5.948.051**
Interest for long term debt	**-397.385**	**-283.846**	**-170.308**	**-56.769**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Interest income for DSRA	**35.594**	**34.345**	**33.096**	**31.848**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
EBT	**1.278.231**	**1.378.184**	**1.449.407**	**1.520.631**	**1.585.228**	**1.833.804**	**4.847.516**	**5.079.670**	**5.354.644**	**5.643.897**	**5.948.051**
Corporate income tax	**-319.558**	**-344.546**	**-362.352**	**-380.158**	**-396.307**	**-458.451**	**-1.211.879**	**-1.269.917**	**-1.338.661**	**-1.410.974**	**-1.487.013**
EAT	**958.673**	**1.033.638**	**1.087.056**	**1.140.473**	**1.188.921**	**1.375.353**	**3.635.637**	**3.809.752**	**4.015.983**	**4.232.923**	**4.461.038**
Cash available for interest service	4.600.463	4.563.139	4.504.267	4.445.395	4.468.921	4.655.353	3.635.637	3.809.752	4.015.983	4.232.923	4.461.038
Cash available for debt repayment	4.238.673	4.313.638	4.367.056	4.420.473	4.468.921	4.655.353	3.635.637	3.809.752	4.015.983	4.232.923	4.461.038
cash available for equity	**1.456.981**	**1.531.946**	**1.585.363**	**1.638.781**	**5.916.537**	**4.655.353**	**3.635.637**	**3.809.752**	**4.015.983**	**4.232.923**	**4.461.038**
Debt I	-397.385	-283.846	-170.308	-56.769	0	0	0	0	0	0	0
DSRA +/-	-56.769	-56.769	-56.769	-56.769	-1.447.615	0	0	0	0	0	0
DSCR	1,42	1,46	1,50	1,54	100,00	100,00	100,00	100,00	100,00	100,00	100,00
Free cash flow											
Cash flow from operations	4.600.463	4.563.139	4.504.267	4.445.395	4.468.921	4.655.353	3.635.637	3.809.752	4.015.983	4.232.923	4.461.038
Cash flow from investments											
Total free cash flow	**4.600.463**	**4.563.139**	**4.504.267**	**4.445.395**	**4.468.921**	**4.655.353**	**3.635.637**	**3.809.752**	**4.015.983**	**4.232.923**	**4.461.038**
Total free cash flow cumulated	**-14.901**	**4.548.237**	**9.052.504**	**13.497.899**	**17.966.820**	**22.622.173**	**26.257.811**	**30.067.563**	**34.083.546**	**38.316.469**	**42.777.507**
Cash flow f/t equity											
Cash flow from operations	1.456.981	1.531.946	1.585.363	1.638.781	5.916.537	4.655.353	3.635.637	3.809.752	4.015.983	4.232.923	4.461.038
Cash flow from investments											
Total cash flow f/t equity	**1.456.981**	**1.531.946**	**1.585.363**	**1.638.781**	**5.916.537**	**4.655.353**	**3.635.637**	**3.809.752**	**4.015.983**	**4.232.923**	**4.461.038**