MSc Program

Renewable Energy in Central & Eastern Europe

model for quantification of risk for a wind power plant in operation

A Master Thesis submitted for the degree of
"Master of Science"

supervised by

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Affidavit

I, **Markus Satzer**, hereby declare

1. that I am the sole author of the present Master Thesis, "model for quantification of risk for a wind power plant in operation", 74 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master Thesis as an examination paper in any form in Austria or abroad.

Vienna, ________________ ______________________________

Date Signature

Acknowledgement

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Abstract

The motivation for this master thesis is my work in the field of investment analysis in the renewable energy sector. If looking at a wind power plant in operation for sale multiple risk factors come in mind of different sources. The core objective of current work was to find a systematic approach to collect and condense these risk factors, finally leading into a rating number, an important instrument for an equity investor to take an investment decision. The method of approach consisted of literature study to come up to definitions of the main topics and to get an overview over the status of risk models already published it the wind power sector. A top down approach was chosen, deriving the main risk drivers from a conceptional level, leading into a description of specific risks, leading into a matrix, displaying only one aggregated number with the needs of the addressee in mind. Data were chosen from a literary analysis. The result is on the one side a custom-made model weighting and displaying managed and not managed risks, ready to be used for quick checks, on the other side the following conclusion was made: risk factors are linked directly to the technology but the interpretation of legal framework, economic circumstances and soft factors play truly an important role which depends on the risk awareness of the assessor. Generally said, factors influencing the revenues or the capital costs are most threatening in the case of a wind power investment and need most attention.

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Acronyms

CPI - Corruption Index

DA – analysis of decisions

DROI - discounted return on investment

DSCR – Debt Service Cover Ratio

DSRA – debt service reserve account

E – Expected

e.g. – example given

EEG – Erneuerbare Energien Gesetz

E_{kin} – kinetic energy

EMV – expected monetary value

EV– expected value

IOU – investor owned utility

IRR – internal rate of return

J – Joule

m² - squaremeter

m^3 - kubicmeter

MW – Mega Watt

NGO – Non-Governmental Organisation

NPV – Net Present Value

NPV – Net Present Value

NUG – non utility generator

O&M – operation and maintenance costs

P_{kin} – kinetic Power

PPA – power purchase agreement

PRI – Political risk insurance

PRM - Project Management

PV – present value

RES – Renewable Energy Sources

RM – Risk Management

ROE (S. 26) – Return on equity

SPV – special purpose vehicle

UNEP - United Nations Environment Program

V or v – Volume

v^2_{mom} – current speed

VAR – value-at-risk

VAT – value added tax

W – Watt

WACC – Weighted Average cost of capital

WPI – wind power indices

ρ – Density

1 Initial Situation and Methodology

1.1 Introduction

During my work for an investor into renewable energy I am strongly involved in the acquisition of wind power projects in different stages (in planning, in construction or in operation phase). During the acquisition process it is my task to analyze all fundamental risks having a strong impact on the economic success of a project. In practice this means that in a very short time the key risk drivers have to be identified and assessed. To be able to do the risk assessment in future in a more objective and scientific way I started to seek for a state to the art model enabling an assessment of that kind in a proper way but didn't find such a model. A high sophisticated model was not build in one day, needs revisions field tests, but it needs an initial step with fundamental considerations, being the focus of this work.

1.1.1 Motivation

During my work in the field of equity financing of power plant projects I am strongly involved in the acquisition of wind power projects in different stages (in planning, in construction or in operation phase). During this due diligence processes it is my task to highlight and quantify risks, which have a possible economic effect on the profitability of the wind power project. Because of the knowledge I gained during the course "Renewable Energy in Central and Eastern Europe" I maid a point to go deeper into the risk assessment of for wind power plants.

1.1.2 What are the core objectives / the core question?

The core question of this work is to develop a model for measuring the risk for the purpose of an investment decision in a wind power plant in operation. Hence the big questions are: which risks exist, how they can be managed (can the risks be managed fully or which of them can't be covered). After highlighting the risks a scale should be developed by which the impact of risk on the project profitability can be measured.

The objective of the work is to create a model by which during due diligences the risk of an offered wind power project can be quantified in one number. The model should enable in future to compare the risk of different wind power projects more objective.

1.1.3 Structure of work

The work starts in an initial part with definitions, necessary to understand the term risk and risk management in general and in detail for projects. In the following paragraphs the field of research will be displayed. It follows an overview on the state of reach in this specific field. After just mentioned overview an analysis of risk sources takes places, starting with a top-down approach leading into a detailed assessment of risk factors with mayor impact. The outcome of the detailed risk factor analysis is the basis for the creation of a model with the aim to first structure the risk factors and then quantify them systematically. In the last chapter the outcome of the work, so called “key findings” are discussed.

1.2 Definitions

The scope of this work, as defined in chapter 1.1 is to display the risk factors linked to an investment into a wind farm. The term risk therefore plays an important role. Before talking about specific risk the questions: “What does risk mean”? has to be answered.

Various definitions exist in literature:

According to Preiss (2010): “risk is defined as product of probability multiplied with extent of loss.” This definition focuses on the technical constraints, the methods of statistics.

According to Baccarini (2004): “Project risk is the chance of a future event occurring that has unfavourable affects on the project.”

This definition focuses on the negative effects of project results in relation with risks.

According to Harding (1998): “a combination of the probability, or frequency of occurrence of a defined hazard and the magnitude of the consequences of the occurrence; how often is a particular potentially harmful event going to occur and what are the consequences of the occurrence."

In Harding's definition not only the size and frequency of potential negative happenings are included, he goes a step further then the others including considerations about the actions when risks becomes strikingly.

Although risk can include also positive effects for the focus of this thesis the examination of risk only includes negative effects. For the purpose of this work I define risk as: probable negative effects of success drivers and want to focus on size and frequency.

The definition of risk, narrowing the area of research leads to description of state of the art instruments able to handle risk Therefore in the next section the idea and instruments of risk management is announced.

1.2.1 Definition of risk management in literature

"Most companies have insurances for their risks. The closing of an insurance contract is the last step in risk management" and further points out: it makes not lot's of sense to insure for loss of receivables and to do nothing according security and availability – a long lasting still stand of plant is in most cases threatening for the company then an unpaid outgoing invoice "according to Preiss (2010), leader business unit plant safety at TÜV Austria. Preiss want's to make clear risk that it the fully restrain and not the coverage of all risk is central for a company. Before going deeper and understanding the subject risk assessment some definitions in front.

Definition of Risk Management

"Risk management is part of an integrated management-system. For the purpose of long term persists security of a company besides cash control, success, present and future profit potential the management of risks is crucial."(Guserl, 1996).

1.2.2 Definition of risk management for projects in literature

What does project risk management mean? To come up to a roadmap for doing a risk assessment the PMBOK® 2000 (2001) gives a good guidance. The PMBOK® 2000 (2001) defines project risk management very broad as: "systematic process of identifying, analyzing and responding to project risk."

For the purpose of this work I resort to the structure for a risk management process on the basis of PMBOK® 2000 (2001) and therefore display in the following paragraphs in detail on the basis of PMBOK® 2000 (2001) the structure of the risk management process.

Risk Management Process

Operational Risk Management starts with a systematic (and later ongoing) risk analysis of all business processes. Goal of the risk identification process is to identify all for the continuance of the company threatening risks, which means listing up as detailed as possible all risk sources, sources of damage, perturbation potential.

From terms of methodology two approaches are feasible: “top-down” or “bottom-up”. The “top-down” approach has the surplus that it enables quickly an assignment of the main risks. Last mentioned macro-perspectives gives in the first step not the opportunity to evaluate the correlation risks in a first step, hence this has to be done in a second step. In relation to the “top-down” approach the “bottom-up” enables to display all risk potentials in all business areas in detail but therefore is much more costly. (Brühwiler/Romeike, 2010).
For purposes of this work the “top-down” approach is chosen because of the following reasons: the scope of this work is to identify the main risk drivers for the decision to invest equity into a project in a given amount. Hence the scope of risks should be straightforward, although all big issues concerning an investment into a wind power plant should be clear and the list open to future adaptions. Very important and implemented like in a “bottom-up” process the correlation between different risks should be displayed to enable a clear calculation of the maximum damage in relation to operating or investment costs. The envisage space of this work won’t give enough room to do think deeply about the correlations; therefore this point has to be reduced to a minimum in the following chapters.

If looking at the following figure 1 “Project Risk Management – an overview”, we conclude project risk management starts with a planning phase, looking first at the things already done in the field risk management in the company, containing: the structure of the project and the risk appetite of stakeholders involved in the projects. In the overall process, as later described more clearly the Project cash flow can be actual cash or cash flow equivalents, important to look at from the perspective of many stakeholders (debt financing bank, shareholders, deliverers, etc.).

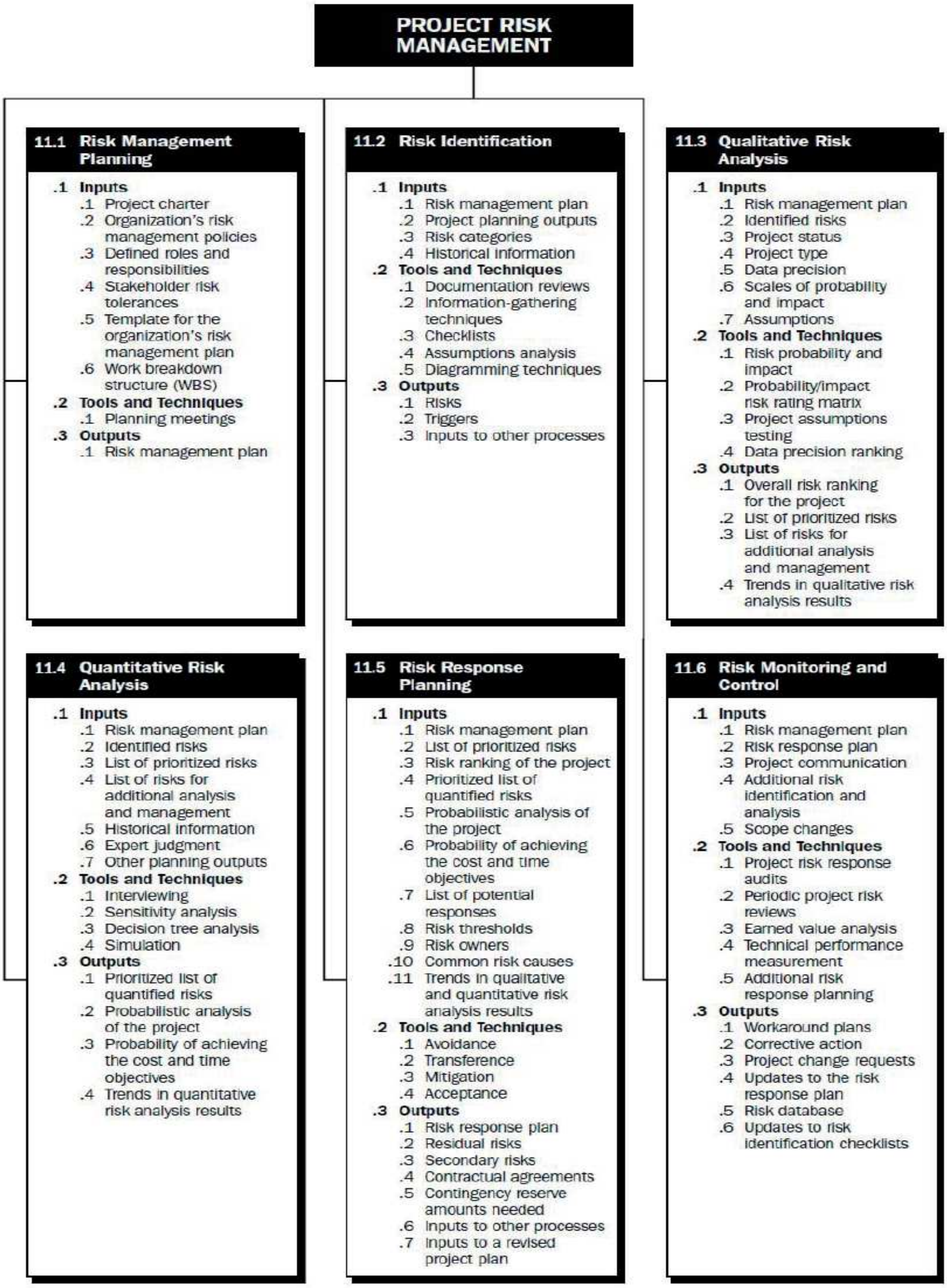


Figure 1 - Project Risk Management – an overview (PMBOK® Guide 2011)

According to PMBOK® Guide (2001) risk management hast to be split into six phases and a pre-Risk management phase, displayed in figure 1.

The **pre-Risk management phase** it that important because fundamental spots are defined there (PMBOK® Guide, 2001):
A project model including time and cost distribution is created. For the main drivers (variables) of the project probability distributions are fixed.

During the **project risk management (as followed defined as PRM)** follows up **6 phases** (PMBOK® Guide, 2001**:)**

First Phase: Risk Management Phase:
In that phase formal implementation of risk-management methodology happens, furthermore fundamental topics as roles and responsibilities, databases and control reporting are defined.

Second Phase: Risk Identification
At that point a risk identification of every input variable takes place. Instruments used in the phase are: checklists from previous projects for starting phase, influence diagrams are drawn, classification of risks to avoid redundancies

Third Phase: Risk Assessment
On the basis of the project plan a base scenario, in concrete EVs for change variables are fixed. The Assessment needs also a classification of each input variable in either: “important”, “possibly important” and “non important”. Judgements on all values of the model are needed, done by persons with best knowledge available. The Judgement in the form of an assessment consists of:

- Single values for variables not that important,
- Probability distributions for important values of project model,
- Probabilities for discrete risk events,
- Probabilities for variables becoming relevant when a specific risk event occurs,
- Single values or probability distributions for emergency plan implementation costs.

In PRM risks description is split in 2 parts:

a) Discrete **risk events** with a probability of occurrence assumed – in most affording contingency plans when occurring,

b) The **impact** on time and costs on the overall project in the event **on condition** (a) happens

It's possible that those interactions between variables can take place, hence they may be considered in separate interrelation maps.

Fourth Phase: Risk Analysis

In that phase the overall project risk should be understood. A proper instrument to get a good overview is a cumulative distribution diagram. In the distribution diagram the influences of risk-mitigation actions (list of actions with influence specified on the project performance) are displayed. Sensitivity analysis displays the effect on the change of variables in numbers. Results of sensitivity analysis enable to rank input variables and model construction details based on their possible impact on the overall project performance.

The aim in the phase is first step is prioritizing risk events, in a second step risk mitigating actions are discussed. The importance of risk is depending on probability and impact of the risk, means a once occurring event can kill because of it's big impact the whole project as an small event accoutring steadily.

Risk mitigation has an influence on the probability of the risk event or its impact seldom on both.

Fifth Phase: Risk Response Planning

By using instruments as checklists of brainstorming possible actions to deactivate or reduce risk are discussed. The discussion process focuses also on the costs or let's say price of the mitigation action, the set up of actions adding most value to the organization has to be found.

The assessment of risk mitigation actions should not stop on one-dimensional level, meaning only implementation of actions adding more EV benefit than their EV cost, it is advisable to have a spot on the correlations, for different reasons:

- One risk mitigation action may affects more than one risk,
- Several actions may diminish the return,
- Implementation of actions could reduce feasibility of mitigation of another risk, including impact on the effectiveness of other actions.

The implementation of all risk mitigation actions is in most cases not possible, if mitigation costs delete economic feasibility of the project. As a result we have to prioritize, most commonly with a return on investment-like criterion, for example the discounted return on investment (DROI).

The DROI is defined as:

$$DROI = \frac{EMV}{E\ (PV\ Investment)}$$

Sixth Phase: Risk Monitoring and Control

To generate an inventory of risks and actions logical next step. The database includes:

- Various classifications
- Watch points
- Time windows

Status reports and comparison of original estimates and actual outcomes, leading in judgements is essential. Reviews have to take place regularly, because basic conditions can change as new risk drivers could occur or alternative more efficient of effective mitigation actions.

1.2.3 Methods for displaying risk

Different approaches and instruments exist to display risk. Risk, as above mentioned is displayed as random variable, an expected value (EV) for each alternative. One option is to display risk in a **decision tree**. A decision tree enables to follow visual step by step the impact of different risk related decisions and displays their impact on the project. The decision tree has the advantage of a simple visualization of outcomes of all possible risk related questions, fitting perfect to project types dealing only with a couple kind of risks.

Wind power projects are by their nature very complex frameworks, raising multiple risk related questions with multiple questions and therefore leading in confusing diagrams. Decisions can't display to approximate EVs, therefore the **simulation technique Monte Carlo**, going back mainly to mathematician John von Neumann (1903-1957), fits better because easily dealing with many possible outcomes and allowing more detailed presentation.

How works Monte Carlo Distribution? (Montes/ Martin, 2007)

Monte Carlo Distributions is best described in three steps: Step one is the definition of inputs as distributions, second step is a simulation process and step three is the interpretation of the results.

In above mentioned sensitivity analysis an interval of possible values was defined for each variable, following a profitability calculation. This was done variable by variable. The ideal situation analysis the sensibility of profitability on a higher level, doing considerations on affects of modifications of variations of more than one variable at once. The Herz Model (Monte Carlo simulation) is a simulation technique, requiring the use of a computer because trying to solve the problem numerically based on chance.

The methods core purpose is creating random numbers, ready for transformation into series of numbers formed by possible values for variables. For each interaction a random value is selected for each probability distribution of the variables and the outcome with effect on profitability is calculated.

Density functions for each variable lead into a project investment model, defining likely interconnections between the variables. In the last step density functions of the overall project profitability are calculated.

Monte Carlo simulation does not only summarize information of initial variables regarding their statistical trait because increases the number of variables determining risk by going back with an analysis to the variables determining the values, providing always density function for profitability.

1.3 Objectives for a risk management model for wind power plant in operation

The objectives, as in the introduction announced are to identify the main risk drivers, the key drivers which threaten the success of the project. As later defined the analysis will focus on all issues in big blocks. It’s not the goal to analyze all risk drivers related to this business model; it’s the intention to focus on the main ones, to identify and scale them and to discuss mitigation strategies and measures. A wind power plant in operation has discard lot’s of big risk drivers past construction phase but there are still lot’s of them left. Most space of this work is used for the risk drivers, specific for this kind of investment and technology.

1.4 Methodology

1.4.1 General Overview

A lot of literature is available on the market for risk management in general and specific for projects, so for technical literature about the generation process of wind energy. In most books the economic analyses of a wind power project stops at very general level and risk drivers for wind parks are not analysed in the scientific community, exception is offshore wind energy, not focus of this work. Therefore I used for the specific risk management topic relating wind energy sources available, consisting mainly of studies of big consulting companies and one graduate thesis.

1.4.2 Literature and Information Research

As stated the state of the art of research and literature is not very broad. Two important works were available for me: One work (Marsh Ltd/ UNEP, 2007) was commissioned by UNEP, UNEP is the United nations Environment Program and therefore wanted to evaluate the risk drivers for wind power plants in operation generally on the focus of developing countries. The second extensive work was done by Clejne/Rujgork (2004) with the aim of creating a model to assess and quantify the risks in renewable energy technology, in detail also for wind energy.

Table 1 - Risk List for wind power plant in operation according (Marsh/ UNEP, 2007)

Risk Identifier	Risk Description	Detail of Risk
A	process interruption	risk of complete plant shut down (total process interruption) at any time due to unscheduled maintainance.
B	natural hazards	risk of physical loss and /or damage of the plant and / or machinery breakdown caused by natural hazards /catastrophes (e.g. fire, lighting, explosion, windstorm, flooding)
C	design / engineering risk	risk of physical loss and /or damage of the plant and / or machinery breakdown caused by design / engineeering perils (e.g. defective design, faulty parts and workmanship all occurring outside the scope of any warranty protection)
D	physical hazard (caused by third party)	risk of physical loss and / of damage to the plant caused by human hazards external fo the project (e.g. strikes, riots, civil commotion, war)
E	wind volatility	risk that average wind speed falls below required thresholds to generate economically efficient power outputs / electricity.
F	offtaker default	Risk of the electricity offtaker defaulting on contractual obligations under PPA.
G	Warranty non-performance	Risk of the warranty provider failing fo meet contractual obligations.
	legal liability	risk of the legal liability caused by bodily injury property damage to third parties.

UNEP has done risk assessment with the aim to establish a model for analyzing the effects of risk mitigation strategies. They first analyzed the payment waterfall of the project; they then assumed specific project performance numbers for a wind park, technical numbers followed by cost and revenue assumptions, displayed in currency. UNEP made a calculation on the basis of the usage of insurances and derivates to secure electricity revenues. They then started a simulation process via Monte Carlo according change of revenues and costs with or without the usage of instruments of Financial risk management as insurances and derivates and came up to the following conclusion: When checking the impact on default rate and DSCR, NPV and equity return (IRR) UNEP registered:

- a combination of standard insurance, political risk insurance and futures for certified emission reduction futures (CER)
- Best IRR achieved is with standard insurance and political risk insurance. Expensive wind derivate insurance leads to significant declining IRR.

- ❖ The Political risk insurance (PRI), provided by commercial political risk insurer is an expensive product in case of developing countries, but has a positive impact on default rate and DSCR.

The main message of the UNEP study is that a lot of risk mitigation instruments considered as turbine warranty insurances are not yet marketable as not enough historical data are available for commercial insurance providers necessary to classify risk and calculate risk premiums. UNEP further came to the conclusion for a wind power project in China that 8 fundamental risk drivers within investing into a wind power plant exist, displayed in table 1.

For the purpose of deriving optimal promotion strategies for increasing the share of RES-E in a Dynamic European Electricity Market a survey to analyze the conditions was done under the label Green-X. Cleijne/Rujgrok (2004) tried to describe methods to describe and quantify the risks of investments in renewable energy technology. The method of approach was a questionnaire of 650 stakeholders who are involved in RES, additionally expert interviews relating risk in the investments RES were taken.
Cleijne/Ruijgrok (2004) at first seek for the various sources of risks influencing the renewable energy market, positions or market players are analyzed in detail. In a second step they focus on methods to assess and model the effects of risk on the financial performance of a project. In step three they display risk handling strategies of different stakeholders and the effect on the project costs. In the following last chapter the financing part in renewable energy financing with WACC sensitivity analyzes is displayed.

Cleijne/Rujgrok split the risk for an investment into renewable energy projects with the view of a risk adverse investor into:

- – Regulatory risks, means possible changes of financial support due to changing government policies.
- – Market and operational risks, causing cost increases.
- – Technological risks, caused by malfunctioning of technology used (especially for new technology)

Cleijne/Rujgrok (2004) see a direct link between financial value of an investment and the risk. The view of Cleijne/Rujgrok fits to me, as trained during analyzing projects to seek for cash expenditures and revenues best. Although NPV is most commonly used measure for financial value of the project, it is surely not the only number counting, but surely most relevant for an investor. Three methods are evaluated by Cleijne/Rujgrok (2004) as displayed in figure 2:

– Scenario analysis,
– Value-at-risk or profit-at risk assessment,
– Required green price calculations.

	advantages	disadvantages
scenario analysis	• simple method • easy to understand	• may overestimate risk • no information on probability of risk
Value-at-Risk (or profit-at-risk)	• both risk and its probability is measured • can calculate probability of loss/inadequate financial returns	• complex • requires information on distribution of uncertain input
required green price	• allows calculation of risk premiums	• use is limited to some situations only

Figure 2 - Overview of advantages and disadvantages of variours approaches to estimate risk (Cleijne/Ruijgrok. 2004)

The report of Cleijne/Ruijgrok (2004) discussed in detail the technology risk of electricity production and the regulatory risks in terms of support skims.

The supporting skims were identified as a key criterion for a renewable energy project because two very different systems exist in the European Union:

- fixed feed in tariffs on the one side and
- a certificate system

Depending on which support skim system an investment is taken the financial return and risk will be very different (see figure 3), the overall risk in a certificate scheme in relation to fixed feed in tariff is in the case of revenues surely higher. The higher risk leads to higher weighted average cost of capital (WACC) because of it's effect on the β-factor(see figure 4), an important cost factor within a wind power project. The WACC is proposed as the factor to absorb the influence of risk via β-factor.

	Feed in tariffs	Certificate scheme
Common characteristics	Fixed rates Usually fixed period Fixed technologies	Fluctuating prices Period not determined Fixed technologies
Guarantees	Government	Supplier
IRR	Maximised by law Minimum set by investors and banks	Maximised by market conditions Minimum set by investors and banks
Largest risk	Site/technology	Regulatory change

Figure 3 - Overview of financial risk return and risk under different support mechanisms (Cleijne/Ruijgrok. 2004)

	Wind onshore		
	TGC	**FIT**	**Wind fund**
$ß_{eq} = ß_{base} \cdot a_{tech} \cdot a_{support}$	1.60	1.44	0.80
Required Return on Equity	10.4%	9.5%	6.3%
Post tax cost of debt	3.3%	3.3%	3.3%
Weighted Average Cost of Capital	5.4%	4.9%	4.0%

Figure 4 - estimated average cost of capital for different technologies and support mechanisms (Cleijne/Ruijgrok. 2004)

"Our assessment of funds offered is based on long term industry experience in the position of initiator or agent for close environmental funds with the aim form more security and transparency for the investor based on the offer" says Umweltfinanz, investor in renewable energy projects.

Umweltfinanz points out that popular ratios as costs per kWh are opened to influence of different factors and depending on the initiator, audits, contracts and prospects, an assessment for the investor is in most cases nearly impossible. Umweltfinanz established a rating system with the aim for more security and transparency. Let's have a look what Umweltfinanz means by that. Rating, an overview for the purpose to form one's opinion with a focus broader than tax effects and predicted dividends. Umweltfinanz set up a rating with the aim to compare different funds by that. Most possible Rating on a scale is five stars. The information, basis for the rating is the sale prospect or additional info from the issuer.

assessment criteria

The criterions are weighting by Umweltfinanz according their importance to the overall conclusion. The weighting scales are the numbers 1 to 5, 1 is less important, 5 is very important. Criterions used in evaluation process are based on branch experience of Umweltfinanz, of the sales prospect or possibly additional information according trade balance or project progress, weighting with (not available, bad) to 3 (best). The score for a criterion calculates as follows: weighting * weight. Rating number is total marks in relation to minimum score. For total marks from:

- 10-15 Umweltfinanz grants no star
- 16-19 Umweltfinanz grants one star
- 20-21 Umweltfinanz grants two stars
- 22-23 Umweltfinanz grants three stars
- 24-25 Umweltfinanz grants four stars
- 26-30 Umweltfinanz grants five stars

General contractor

- *Rating general contractor/initiator:*

  Focus of assessment is: experience of the initiator at installation, financing and operation of plants for renewable investment funds. General contractors are rated according numbers like realised plans and qualitative criterions of Umweltfinanz according to long term experiences of Umweltfinanz. weighting factor 5

- *Track record*

  Do current projects of the general contractor/initiator reach goals proposed in sales brochures (target – performance comparison)? Are available target – performance comparisons or comparable information significant? Weighting factor 5

Sales documents

- *forecasting*

  Is a solid and detailed forecast for the whole project time available? Are all current expenses as operation and maintenance displayed in detail? weighting factor 2

- *information design*

  Is all information relating political and tax condition, according site and technical equipment as the conditions for taking the investment defined coherent? weighting factor 2

- *contracts*
  Are all contracts regarding justifications of ownership available? Are any important, “non usual” contracts already in force? weighting factor 2

- *contractors*
  Are all relevant contract partners (general contractor, tax advisors etc.) listed and is information about credit rating and reliability available? weighting factor 2
- *risk hints*

  Are opportunities and risks of the investment clearly announced? Weighting factor 2

country risk

- *corruption index*

  The security of the investment is measured at the law system and reliability of the authorities. Indicator is the corruption index (CPI), available since 1995. Transparency International, an accredited NGO is fighting world wide against corruption and collects data in 180 countries. An index with 4,9 or worse is graded 1 (bad), 5 to 6,9 is graded 2 (average) and index better than 7 is graded with 3 (good). weighting factor 5

- *legal stability*

  Focus of assessment is stability of the legal framework of the specific county for the investment, effecting the yield of the investment fund.. The German green electricity act "Erneuerbare Energien Gesetz" (EEG) is used because of its clear wording and stability over the last years as benchmark worldwide from Umweltfinanz. Germany gets a maximal grading of 3. Frameworks of other countries are measure on the stability of Germany. The overall score of points for concrete criterion is not focused simply on the level of current „promotion“, the adjectives stability of the framework and continuity have same status by reason of their impact on the conditions of the investment. Changing conditions and funding mechanisms therefore lead to low grading. weighting factor: 5

Status of the project

- *construction permit and operating licence*
  Before starting construction and operation of a plant different permissions have to be obtained. Only final permissions for the overall wind park gives legal security to the investor, threats are the chance of plant size or plant type till the order to cancel the whole project. weighting factor 5

- *energy off take*

  Grid operator is obliged in many countries to take of electricity by law, in others only because of private law contract. Grid connection delays can become reality. Secured electricity off take (construction of transformer station, grid access etc.) raises security in planning phase. weighting factor 2

- *construction progress and commissioning*

  Each step forward at the point of investment leads to more security for completion of construction and commissioning in time. In contracts with general contractor and plant manufacturer penalties are fixed in case of late commissioning, giving security to the investor. If all mills operate at the point of investment and credible production data already exist specific project risk are not applicable. weighting factor 5

Technical equipment

- *Manufacturer and model*

  The series product is well known on the market and the manufacturer does financial well. Are guarantees or commitments of the manufacturer collectible?
  waging factor 4

- *Service and maintainace*

  Trouble free long term operation is first interest of an environment fund. Supervision and technical checks take place steadily ? Are long term service and maintainace contracts in place?
  weighting factor 5

- *insurances*
  Is the project sufficient insured, e.g. business interruption insurance? Manufacturer guarantee need to be supported by special insurance covering specific risks and cover different loss of revenues.
  weighting factor 3
- *performance guarantee*

  Additional is gained if manufacturer gives a performance guarantee for the engines.
  weighting factor 4

financial planning

- *equity*

  For achieving an optimal return a maximum leverage effect makes sense. For the single investor a higher percentage of equity on the investment costs gives more security.
  weighting factor 5

- *agreement to provide funds*

  An undertaking of a bank (with fixed interest) is an important factor because of just described big part on the investment costs. weighting factor 4

- *interest debt*

  Are the costs for debt in line with the market and what's the suggestion for interest costs after end of fixed term? weighting factor 3

- *fees*
  Is the fee for produced electricity assumed with the current price or an historical average. What's the basis for the calculations? weighting factor 2

- *cost adjustment*

  What's the basis for yearly adoption for the costs (assumptions for cost increase) – contractual fixed or market indicator chosen by the arranger (Optimum related to specific indicator of country and industry, mean related to the contractor of the project e.g. three percent for Germany)? weighting factor: 2

- *Accruals*

  Are sufficient accruals for contractual or regulatory obliged dismantling made and are reserve funds for general overhauls etc. fixed in the financial plan. weighting factor 2

- *Haircuts*

  Are haircuts used to prevent the operation company from liquidity problem problems in case of weak earning years. weighting factor 5

- *Reserves*

Are reserve funds available in case of unpredicted happenings?
weighting factor 5

law

- *Liability for the investor*

  Is the liability of the investor limited to the deferred funds of the investor or not?
  weighting factor 2

- *Commercial register*

  Is the investor registered in the company register? (Property apparent)
  weighting factor 1

- *Placement guarantee*

  Exists a placement guarantee and is the paper recoverable??
  weighting factor 4

- *Control rights*

  Is it in practise for the investor possible to exercise his control law and his voting rights? Is an advisory council installed? Is it possible for all shareholders' to attend shareholders' meetings or are they compulsory represented by a trustee ?
  weighting factor 1

- *Share transfer/sale*

  How's the sale of shares fixed in the contract? Is the sales price fixed? Is the sales procedure contractual fixed in front?
  weighting factor 1

The practical part of this work focuses on the assessment of risks, possible risk instruments to handle the identified risks and tries to condensate the findings in a general model.

Going forward to chapter 2. the current work is driven by a couple of assumptions. It is specified to focus the investment into a wind power plat only from the perspective of an equity investor. An equity investor is a natural or legal person, interesting in getting a return on investment on it's invested risk capital. For the purpose of an investment the equity investor carefully analyses the pros and cons of the investment and has a special focus on the cash flows, influencing the return on equity (ROE). As Umweltfinanz, investor in wind power displays in their rating model besides cash flow also criterions, so called "soft facts" play an important role for them and also for other players on the market, that's an interesting new aspect.

A classification in technical, economic and legal risks is made with the background to highlight the sources of risks, although the final purpose of this work is to highlight economic effects and therefore all risks are measured in money.

Technical risks
Production of electricity form wind power is very investment driven; hence it is clear that solid assumptions concerning investment costs play a big role. During the operation of a plant

1.4.3 Method of Approach

To enable the reader a good access to area of research this work is spitted into 4 paragraphs: **In Paragraph 1.** Initial Situation and Methodology basic topics are specified, including a general overview, a description of literature and information research and the method of approach.

Furthermore important topics are defined and narrowed:

- risk management generally and in relation to area of investigation, done in Paragraph 1.2.
- Production of energy via wind power plants in Paragraph 2.2.
- The business model for an equity investor into renewable power plants I Paragraph 2.4.

In Paragraph 2 at first a mind map displaying all relevant risks connected with an investment into an operating wind mill is done, spitted into the legal, economical and technical, in a second step possible risk strategies for the deducted risks are developed.

Paragraph 3 uses the results for from paragraph 2 to come up to a model, quantifying and scaling the risk

At the end **Paragraph 4** will summarize the outcome of all paragraphs before and give a future prospect.

2 Risk sources during investing into a wind power plant

2.1 Transition theoretical fundamentals to approach chosen for risk assessment

For the purpose of structured risk identification and by the way keeping creativeness in the whole process I suggest establishing and dividing the operation risk of the project into the different risk clusters as displayed in figure 5.

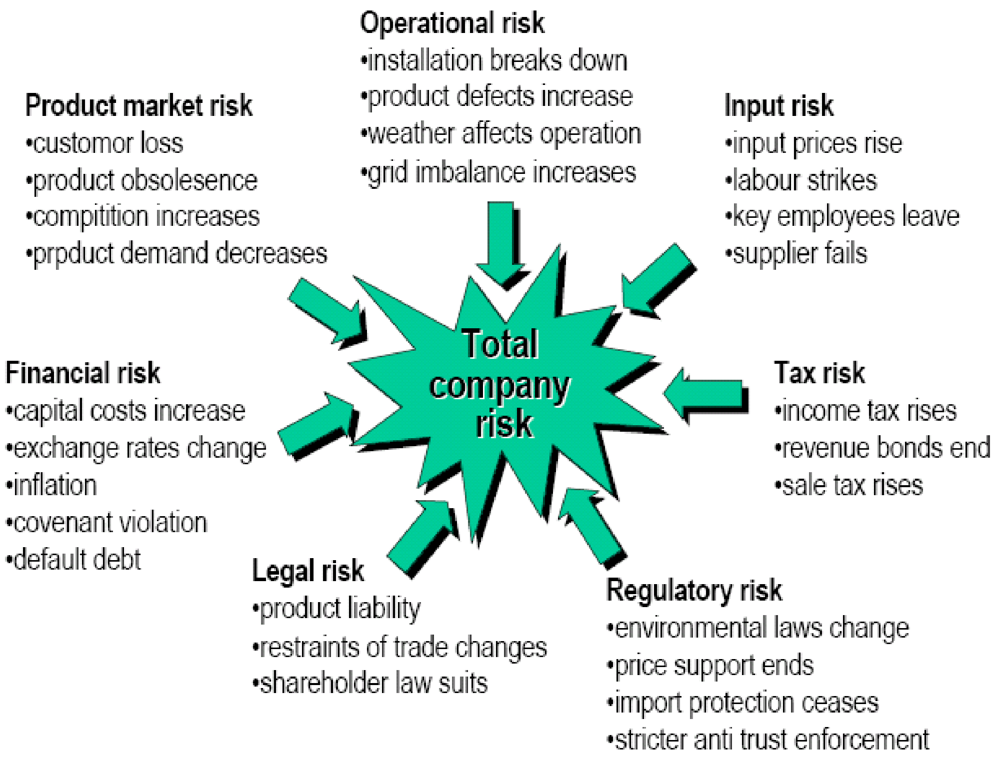


Figure 5 - sources of risk leading to total risk of a company (Meulbroek, 2000)

The risk management process is in practise a dynamic and revolving process, adoption need to me made in the model at least in a yearly review because of changes in the company and in the surrounding. The goal of a risk process (as displayed in figure 8. below) is to give transparency of the current risk situation to the investor, in most cases the board of directors and furthermore an information basis for initial and future decisions.

Phase “Risk identification”

The first phase of and RM (Risk Management)-process is the collection of all substantial risks in relation with a wind power plant in operation. This phase is a sensitive phase because its range and preciseness influences the efficiency of the whole process (Brühwilder/Romeike 2010), in other words: a unknown risk can’t be neither assigned a probability nor an extend of loss. Hence the point of deduction of risks gets is granted a lot’s of space in the following paragraphs a deduction of all risks related to a wind power plat in operation happens.
The analysis should therefore take place structured in different ways. To keep the blind spot as small as possible different new paths: e.g. questioning of employees,

questioning of other stakeholders have to be taken besides well known old methods: e.g. literature research, check of contracts, experiences from past projects.

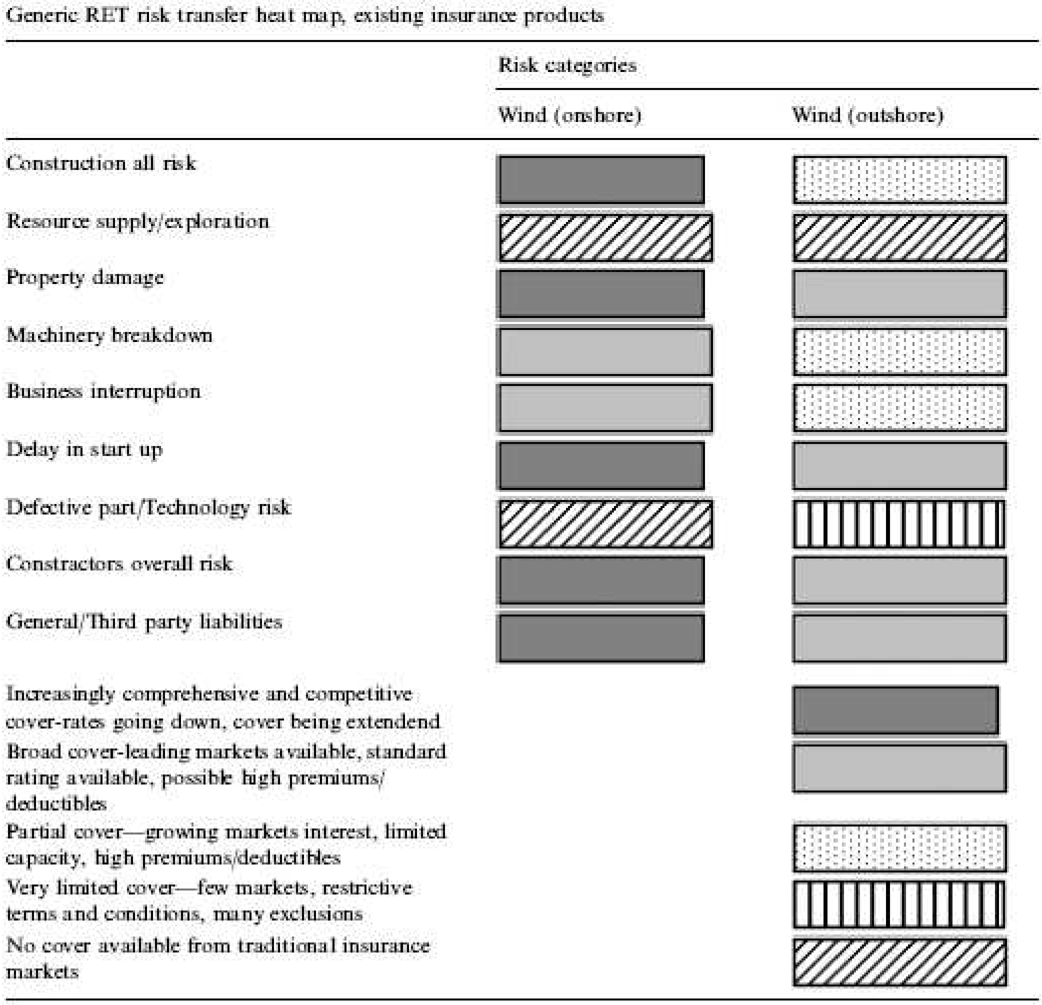


Figure 6 – Generic RET risk transfer heat map, existing insurance products (Montes/Martin 2007)

Figure 6. shows, even offshore plant insurances are not willing to take all risks related to wind energy production. Although couple of products already exist on the market, traditional products as new, tailored especially for wind power product, especially the resource supply/exploration and defective part/ technology risk the insurance industry is not willing to take for a premium.

Phase "Risk assessment"

For coming up to analyse strategies to handle risk we need a step in between. This step should come up to quantify the key factors: "probability of occurrence" and "possible damage". Goal of the risk assessment is to give a well overview about the core risks, display it in numbers and visually, leading finally into do's.

For the chosen evaluation approach: "Top-Down" different risk evaluation-Methods exist on the market. In the first step we can decide between quantitative and qualitative approaches. Quantitative approaches rely on mathematic-statistic methods and mainly make sense in the banking and insurance business if lots of data are available. Qualitative Approaches in comparison relay on subjective suggestions and make sense if no valid data are available (Brühwiler/Romeike 2010).

On the basis of the data available the approach of this work is to use a qualitative risk evaluation approach. After evaluation of different methods decided for a scoring model in combination with a scenario analysis. Although a scenario analysis is not that objective it has the surplus to highlight the main risk drivers very easily and without a big data base. A value-at-risk (VAR)-approach, detailed quantitative method for the following reasons would also be an option because:

- The VAR is gain in the banking industry
- It enables at one glance with one number to get a good impression for an investor whether he is able to take the possible risk in the amount of X or not.

Because of the not available data from a significant random sample the VAR-approach hast to be skipped.

Analysis

After the brief introduction into the term risk management we register that risk management is a profession, which consists of the analysis of decisions (DA). DA provides logical, in consistent way to incorporate judgements about risks and uncertainties into an analysis (Schuljer, 2001). To come up to a credible analysis for a forecast the principals (Schuljer, 2001):

- Objectivity
- Precision is important to be followed.

Objectivity tells us about the error of estimations compared to what actual values result.

Low bias is demonstrated in an average forecast error of around zero. Precision represents the magnitude of the errors, we desire small errors.

In the field of risk management we want to reduce the probability and impact of threat and increase the probability and impact of an opportunity. For most people risk is a synonymous for uncertainty. Uncertainty is hence variability in some value. Uncertainty can have two different parameter-values: positive (opportunities) and negative (risks/threats). To measure the uncertainty we can rely on different measures from statistics to display the outcome in numbers. One of the most popular measures is the expected value (EV), the probability-weighted average of the distribution, as Schuljer (2001): says: "it is the best measure of value under uncertainty.

Discrete events

Risk can be displayed as continuous distribution of values, there is a continuum of possible outcomes.
Often risk can also be a binary event – it occurs or not. We have a discrete (probability) distribution when we have two to many (usually countable) possible specific outcomes. Project risk management also in the wind energy business is in the first step about considering discrete risk events and their impacts, in a second step cost effective actions and mitigation of such risks are considered.

Starting with discrete risk events the sources of risk need to be classified. Because of my professional background and the scope to define risk categories for an investor I'd like to relate on a clustering state of the Art during Due Diligence processes: technical, legal and financial. The clustering derives from the original source, the original risk driver, e.g. the wind at site available influencing the park layout in the planning phase and influencing the profitability of an wind park in the operation phase has a technical origin and therefore is clustered to technical questions.

2.2 Technical risk sources

The generation of wind energy is a technical process; therefore an introduction into wind energy conversion is given, necessary for an approach to the key risk drivers.

Wind energy derives from sun energy. The different warming of the earth's surface via the sun causes differences of density and pressure, resulting in fluctuating airflows representing the balancing medium. The wind speed generally increases and the wind turbulences decrease with the height. Near ground wind speed is nearly 0. Electricity production from wind energy takes place during multiple conversion steps:

First step is a conversion of moving air, kinetic energy to a mechanical energy, resulting in the movement of turbine shaft. The kinetic energy, measured in Joule per kubicmeter is defined as the product of mass density of air divided by 2, multiplied with the square of current wind speed (at hub height).

$$E_{kin}/V = \rho/2 * v^2_{mom} [J/m^3].$$

ρ = mass density of the air (1,225 kg/m³ above sea level at outside temperature of +15ºC),
V: = volume, v: = speed.

$$P_{kin}/F = v_{mom} * \rho/2 * v^2_{mom} [W/m^2].$$

P_{kin}/F is the output of the energy stream based on surface density.

Most relevant factor for energy production from wind energy is the **mean value** $v_{f,T}$, means mean wind speed depending on disc area and time of circulation. Best effectiveness have propeller turbine with 2 or 3 rotor blades, theoretical maximal effectiveness is 59,3% (Betz'sche effectiveness value), in practise 80% of the theoretical maximal value can be reached by state of the art wind mills.
Not the whole kinetic energy can be used in practise, because part of the air hast to flow as v_{post} for the purpose, that all air can flow off again

Useable kinetic energy: $\Delta E = \rho/2*(v^2_{pre} - v^2_{post})$.

$$V_{mean} = ½ * (v_{pre} + v_{post}).$$

The mean wind speed it the part of the available, current wind speed useable for production.

$$P_0 = \rho/2 * v^3_{pre*} F[W]$$

The perfect wind turbine (theoretical value) reaches its maximum at **16/27*P_0**, if the tip velocity v_{pre} is decelerated to **1/3 * v_{pre}**

$$P_{Turb}/F = \rho/2 * v^3_{pre} * ½*(1 + x^2 - x^3).$$

$x = v_{post}/v_{pre}$ = is brake-ratio.

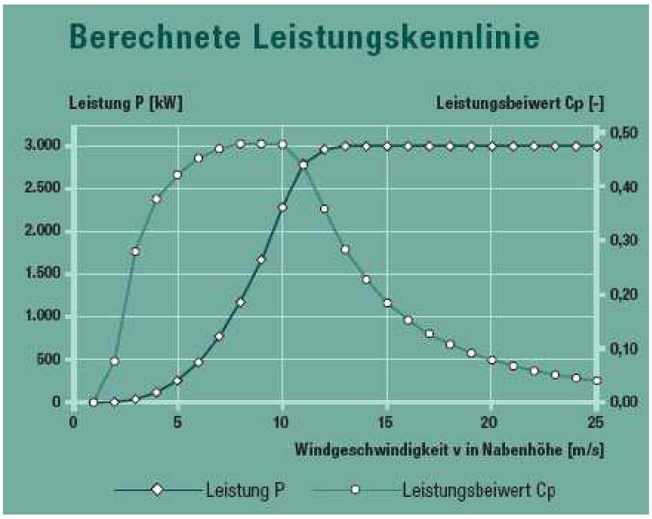


Figure 7 – ENERCON E101 – 3 MW data sheet (ENERCON, 2011)

The real rate, wind energy converted to electricity is defined as **power coefficient: c_p.**

Figure 7 displays in detail the power coefficient of ENERCON – 101m hub high/3 MW showing that at about 11 m/s the wind mill reaches its maximum power coefficient at 0,5, above the Betz'sche effectiveness value (Jarass, 2009)

Second step in conversion process is from turbine till three-phase a.c. output: performance curve:

The wind conditions at site change immediately during the day or during the year. According to conversion and power coefficient three goals should be obtained (Jarass et al., 2009):

- maximise yearly energy yield at the site,
- exclude a mechanical and electrical overstress of equipment (e.g. by storm),
- generator produces always 50 Hz alternating current at any capacity and inductive reactive power is given steadily.

Just mentioned goals: optimisation of energy yield and prevention of overstress are reached mainly by regulation of the power coefficient of the turbine, in concrete by adjustment of rotor blade. The pitch is called “pitch control”, regulating α depending on wind speed and wind direction.

The power coefficient is strong depended on the current wind speed:
$\mathbf{c_p = c_p (v_{mom})}$.

The **engine power at the turbine shaft with a rotor face: F = π * r² (r= blade length)**
$\mathbf{P = c_p\ v_{mom} * \rho/2 * v^3 * F[W]}$.
To display the electrical output after the generator we have to multiply with the effectiveness ŋ(P) of the generator and if applicable with effectiveness ŋ (R) of the gearbox .

$\mathbf{P_{el} = \eta(P) * \eta\ (R)\ c_p(v) * \rho/2 * v^3 * F[W]}$.
$\mathbf{\eta * c_p}$ … effective power coefficient or overall efficiency c_{pges}.

Power coefficient is measured area capacity of wind turbine at wind speed v, divided trough high surface density **ρ/2* v³** of untroubled air flow at current speed.

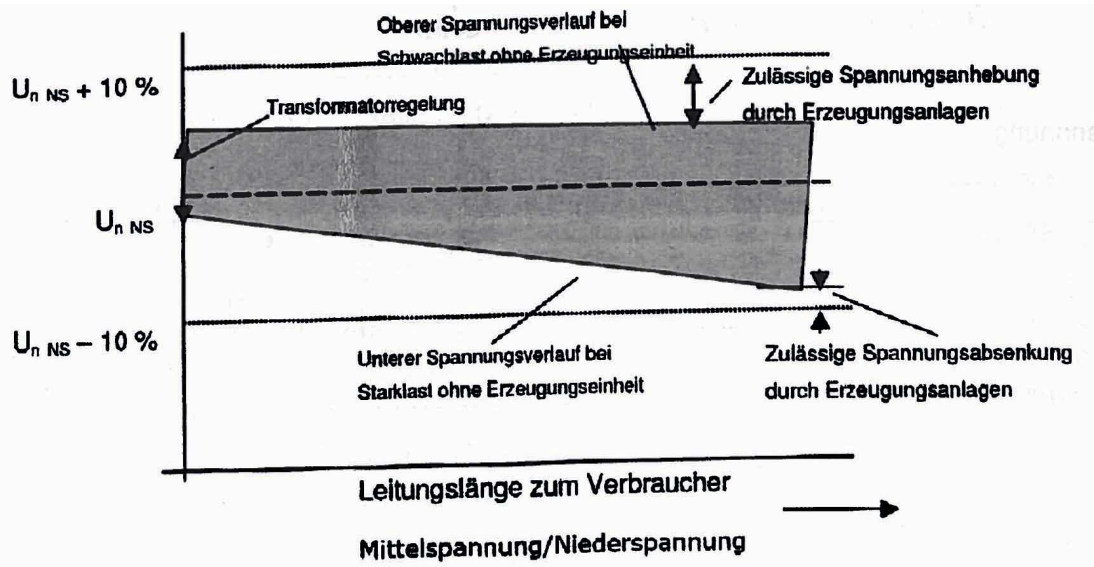


Figure 8 - overview voltage level scope (Gansch/Twele, 2009)

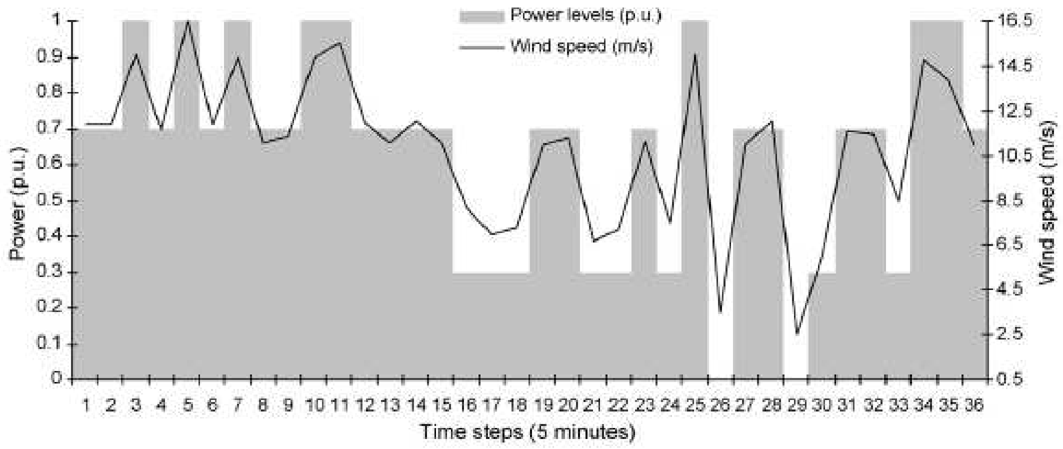


Figure 9 - Wind series discrete power levels (Gouveia/ Matos 2008)

The maximum energy yield and prevention of overstressing are managed by regulation of power coefficient. Regulation of power coefficient takes place via modification of blade pitch angle α, called "pitch control" at big wind turbines. Wind speeds below rated speed afford a flat pitch angle α. flat pitch angle increases with wind speed, finally reaches its maximum at the point tangential force $F_{A,s}$ reaches the value necessary for moving current generator.

The transformation process as just analysed is not only a formula, high end mechanical and electronically equipment, commonly called as wind converter, colloquial called windmill is needed. A shown in figure 10 a wind converter consist of

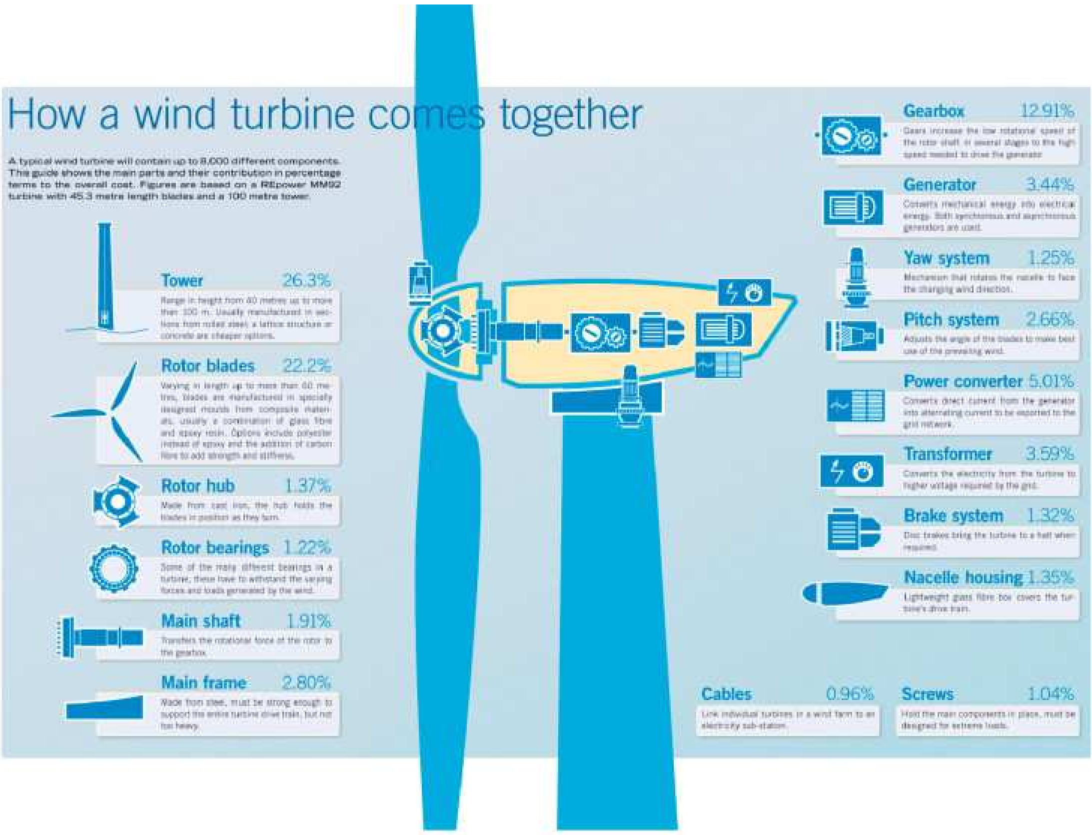
- foundation
- tower
- rotor blades
- nacelle machinery
- electricity grind connection system

Figure 10. points out the part in % of the investment costs of each big part. It is shown that the rotor blade and the tower together are the most expensive parts, expressed in 48,5% of the total investment costs.

As many types of wind energy converters exist I want to focus during my following technical risk assessment on parts which are

- weak points of a wind energy converter and

- with a big spot at the very expensive parts in terms of maintenance and reinvestment



Source: Wind Directions, January/February 2007.

Figure 10 - investment costs splitting wind energy converter model 5 MW RE Power (Wind Directions, 2007)

Availability of wind energy, measured at average wind speed in m/s p.a. at hub height is a very good indicator.
Full load hours, the full load hours p.a. are a very good indicator for the wind conditions at site, the higher the more load of the machine.

A small amount of parameters, assumed in the construction phase, so called imput data influence the layout a wind park. Figure 12. displays the different key variables

Second step consists of calculation of density functions of the aforementioned variables. For the purpose of a wind power plant project starting with analysis of wind velocity data is best. The variation of wind speed variation is displayed best by Weibull Distribution:

$$p(V) = \frac{c}{a}\left(\frac{V}{a}\right)^{c-1} e^{[-(V/a)^c]},$$

V …wind velocity

c … form factor

a … scale factor

On the basis of the above mentioned the following deduction is possible:

$$p(V \geqslant V_0) = e^{[-(V/a)^c]}.$$

Equation is utilized to lineally adjust the empirical data and gain Weibull form and scale factors (figure 11.)

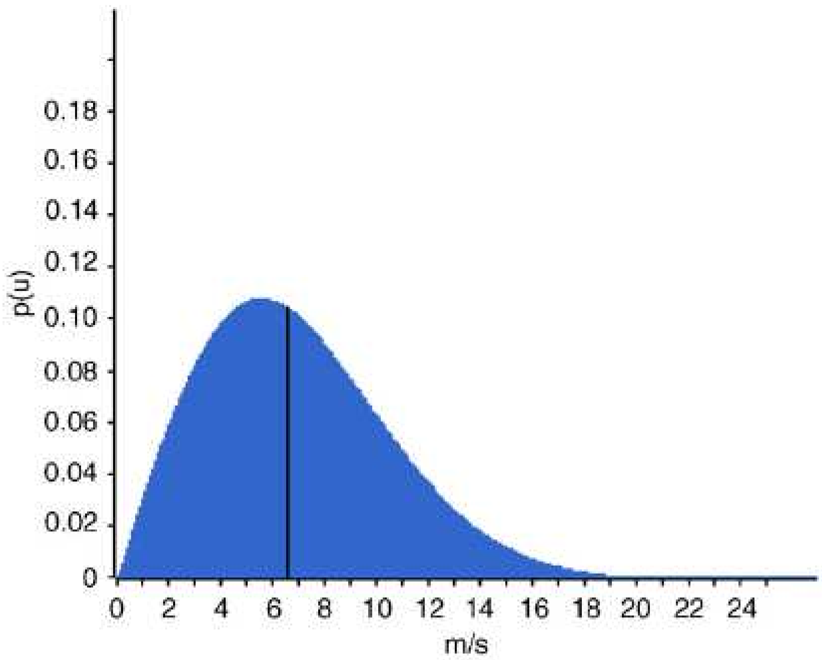


Figure 11 - Weibull distribution (Montes/Martin 2007)

Step three includes seeking for dependences between different variables.
Step four and last step marks simulation of real situation using Monte Carlo model. A specific large number of scenarios, depending on desired confidence (interval) are calculated. Result of simulations is a density function of the profitability via frequency of each profitability value. In addition the method is, if using alternative investment cost parameters a good economic-decision making tool.

The total generation costs for an electricity producing wind turbine system are determined according to Manwell/Mcgowann (Manwell/Mcgowann, 2009):

- wind regime;
- energy capture efficiency of the wind turbine(s);
- availability of the system;
- lifetime of the system;
- capital costs;
- financing costs;
- operation and maintenance costs.

Figure 12 - generation costs splitting for wind turbine system (Manwell/Mcgowann 2009)

Figure 12 gives no indication on the height of the costs, so does the formula, shown in figure 13. pointing out the relative importance of a cost criterion.

$$\text{Cost} = \begin{pmatrix}\text{Calibration}\\ \text{coefficient}\end{pmatrix} \times (\text{Weight}) \times \begin{pmatrix}\text{Cost per}\\ \text{unit weight}\end{pmatrix} \times \begin{pmatrix}\text{Complexity}\\ \text{factor}\end{pmatrix} \qquad (11.2)$$

Figure 13 - expression of the costs of each subsystem (Manweell/Mcgodwan 2009)

The formula shows that there is a link between costs and size of a component. For more complex components analytical expressions are not sufficient, look up tables according component size to loadings are used (Manwell/Mcgadwan, 2009). At first the size has to be calculated, followed the weights. Weights are used to calculate loading factors of other components but their primary purpose is to estimate wind turbine costs. The calibration coefficient is a constant for each subsystem, determined by statistical analysis of existing wind turbine costs and weight data. The complexity factor reflects the value allocated during component sizing phase directly sized by amount of work required for installation of the whole subsystem. The sum of all systems leads to the overall costs of a wind turbine. The system is proven and adopted by practise steadily.

We can conclude that once the weight and the size of a part is fixed it’s flexibility in the cost structure is going to value of 0.

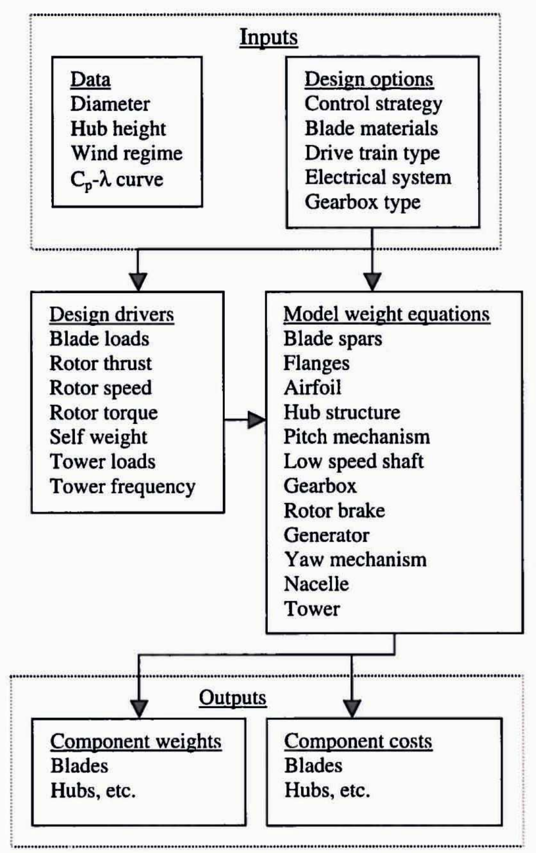


Figure 14- flowchart of Sunderland cost model (Manwell/Mcgowan 2009)

Summed up in other words, the data, input variables, fixed initially after assessment of site conditions lead to decide on design options. The decision on the design is influenced by design drivers, finally leading to model weight equations and finally leading to component weights and component costs. The decision process is displayed in figure 14.

Summarized, a wind power plant is a tailor-made product, best fitting to site conditions of area located; key drivers for the costs are weight and manufacturing time.

For the purpose of a profound analysis of the technical risk a look at the cost structure is necessary.

Critical parts in the wind generation process are:

+ Rotor blades – adaptation to wind speed and security device (in combination with pitch control).

+ breaks (for shutting down rotor speed quickly).

+ gearbox – transforming the speed of the well into movement suitable for electric generator.

+ overall security system (warning lights).

2.3 Legal risk sources

Legal risks consist in every business area, so does in the wind energy investment branch. Deriving form the technical risk resources the reliability of the parts play an enormous important role for an overall success of the investment and therefore the performance has to be secured. Furthermore the revenues of the project have to be secured, influencing the contractual bank ability of the project, discussed in detail in the following paragraphs.

Warranty non-performance
Although in most cases a (general) contractor is commissioned with construction of plant and gives security to the project in the form of a warranty, the general contractor has a big open exposure from warranties related that kind of projects on the market. If the mill doesn't work there is the vital possibility that (general contractor) can't meet its obligation from the warranty contract, e.g. because of bankruptcy.

The **contractual bank ability** is that important because, without needed funding the project is impossible. Risk is given especially by big losses through bankruptcy if the bank cuts all credit lines.

The **off taker default** is that important because big losses through bankruptcy of the off taker, followed by a still stand till new off taker is found including the transaction costs for new off taker contract are vital.

Different sources are taken to come up to the really important criterion for an investment producing. Parameters affecting the success of wind energy investment are derived form different resources: insurance industry, 3 interviews with experts in the finance sector and the experiences of the author. The criterion catalogue of 20 items is the outcome of the research work.

According different groups the suggestions are summed up:

Tariff level (after taxes). The funding level is a basic indicator for the political will to support renewable energy in a county. It is extended to political influence (e.g. VAT, energy transfer tax,…)

Tariff duration. The tariff duration gives an important number for funding; it is base for calculation duration for most projects.

The main possible strategies on the market are **warranties or insurances** on the market for the time of operation, the options displayed in detail follow in chapter 3. Model.

2.4 Economic risk sources

Before starting to look at first hand economic risk drivers a brief introduction into the aims of an equity investor is necessary.
Defining the business model of an equity investor is important, because main targets of the investor are made clear, ownership and financing structures have an important impact on the cost structure, scope of interest and therefore also on the risk drivers. Equity investors are natural personas or corporations investing money, called risk capital into wind power projects with the aim to receive a specific rate, depending on the overall risk of the project, called return on equity per year (ROE) for their invested money. The return on equity is calculated as follows:

$$\text{ROE} = \frac{\text{Annual net income}}{\text{Invested equity}}$$

$$CRF = \begin{cases} r/[1-(1+r)^{-N}], & \text{if } r \neq 0 \\ 1/N, & \text{if } r = 0 \end{cases} \quad (11.12)$$

The inverse of the capital recovery factor is sometimes defined as the series present worth factor, *SPW*.

Net Present Value

The net present value (*NPV*) is defined as the sum of all relevant present values. From Equation (11.8), the present value of a future cost, *C*, evaluated at year *j* is:

$$PV = C/(1+r)^j \quad (11.13)$$

Thus, the *NPV* of a cost *C* to be paid each year for *N* years is:

$$NPV = \sum_{j=1}^{N} PV_i = \sum_{j=1}^{N} \frac{C}{(1+r)^j} \quad (11.14)$$

If the cost *C* is inflated at an annual rate *i*, the cost C_j in year *j* becomes:

$$C_j = C(1+i)^j \quad (11.15)$$

Thus, the net present value, *NPV*, becomes:

$$NPV = \sum_{j=1}^{N} \left(\frac{1+i}{1+r}\right)^j C \quad (11.16)$$

Figure 15 - NPC Calculation (Manwell/Mcgowan 2009)

It’s the goal of an equity investor to reach at least the assumed ROE of the design phase.
Furthermore for the investor the Net Present Value (NPV) is an important decision benchmark for the investment. The NPV is calculated as shown in figure 15.

All future positive and negative cash flows (e.g. dividends and initial investments, payback investment) are discounted with the rate of (a secure) alternative investment (e.g. state bond) to the day of initial investment. NPV shows how much cash flow the initial investment will generate, assessed on the day of initial investment. The number is basis for the investor to decide taking the investment or not, means if the NPV is negative a rationally investor won’t take the investment because the secure Alternative would have a bigger return.

By reason that equity investors in most cases don’t take the investments on their own, for different reasons as diversification of risk and lower capital costs, financing banks play a big topic at assessment of project success. Banks in comparison are typically not interested in ROE-rates or NPVs. Banks focus basically on the topic debt servicing, is the debtor able to pay his interests and redemption and will he be able to do so in future. The view of a bank is also important for the investor, because if banks are involved in financing the project via debt to certain extend their rules and criterions have to be fulfilled by the operating company, in behind the equity investor. Therefore the interests or the equity investor have to correspond in the case of payback of loan.

In the field of equity investors in energy plants in the eyes of banks it has to be differentiated according to Wiser (1997) between:

- non utility generator (NUG),
- investor owned utility (IOU) and
- public utility ownership and financing of wind power projects

Project financing and private NUG ownership nowadays is still the most dominant renewable energy finance structure. In a project financing model the individual project is analysed on a stand alone basis, not only because of its separate legal entity. The project company (SPV), legal platform for the investment is borrower of senior loan. As the project is strict decoupled from the investor behind the cash flow for debt service is limited to the cash flow of the project and the securities are only the assets of the wind park, the cash flow model is clearly analysed by the lender. During Decision process besides production cost and corporate financing modelling a variety of quantitative criteria are used in the decision process.

Typically in the sector of private wind power ownership for calculating bid prices and during financial due diligences (Wiser, 1997) is the creation of a cash flow model with a fixed project time, displaying yearly revenues, expenses, debt service and tax expenses, finally leading into a net equity cash flow. The power purchase price is assumed with a price covering costs and debt service, all related to the initial cash flow model assumptions.
As just pointed out, the securities within project financing are limited and the success of the wind park project is strongly depended on the validity of the initial assumptions, especially on the technical terms, for the set up of the plant. Banks invest only into projects with are strongly able to pay interests and repayment on time according to initial fixed schedules. For classical project financing for a wind park long term security for different cost and revenue positions is therefore an absolute must. To stay bankable for the revues needed, in concrete long term power purchase agreements of a fixed feed in tariff are standard. In the view of the debt financer the risk fund is limited and therefore extensive restrictions, called loan covenants in their agreements with borrowers are standard, to highlight any anomaly to the set up. To reduce the risk for the debt financer he demands the reserve of a defined percentage of the annual cash flow reserved for yearly debt

service, the credit constraint is called debt service coverage ratio (DSCR). The requirements for DSCR limit the developer's intent to maximize the debt leverage and therefore influences the equity-ration for project setup.

Electrical utilities, investor owned utility (IOU) calculate different, as they start their analysis with calculation of the direct costs of the individual project and calculate with a corporate finance constraints. The corporate financing has in relation to project financing a couple of surplus in economic way, because of depreciation of the new assets in group balance sheet and prospective cash flows. In Corporate finance credits are bared to the income stream of the entire company (generation, transmission and distribution) and not on the individual project, assets are not specific funded. Project financing leaves more liberty for the investor, the borrower has a broader liability fund and therefore assesses the wind park assets funded not insulated but on company level, therefore the finance indicators are analysed on group level instead of project level.

Public utilities usually finance their projects fully with equity, in most cases with bonds. In the bond sector strict covenants don't exist. Additional debt hurts the bondholders securities fund and therefore touch company wide capital structure constraint, equal to implicit DSCR requirements. To reduce corporate liabilities and risk public utilities use public finance for power plant development.

Project financing is usually more costly than internal financing for public utilities because of higher risk premium of the lender because of limited risk fund (limited to the assets and revenue stream of the individual project).

Project financing has some pros and cons (Wiser, 1997):
Pros:

+ non recourse to parent company: Trough new senior loan for wind farm financing there is no impact on the balance sheet and creditworthiness of the mother company,
+ flexible capital structure: The capital structure can be optimized to minimize overall project costs,
– large transaction costs, costs for contract arrangement: Because of complex arrangements for security and loan documentation necessary because of stand alone basis,

– high debt and equity costs plus loan covenants: The higher capital costs arise because of high risk premium because of stand alone basis of the project.

Current assessment of this thesis is limited to private **power producers with project financing on a stand alone basis**. The focus in the risk assessment will therefore be cash flow numbers and specific loan covenants assets of the specific project.

Summed up, objective of a private equity investor is maximizing shareholder value, therefore focusing in its decision policy on an expected monetary value (EMV). EMV as a single number includes the objectives: time, cost and performance. EMV is the expected value (EV) of the present value (PV) of net cash flow:

EMV = EV (PV)

What not will be analyzed in this thesis are tax affects because of contrived form.
The following resources were taken into account for different reasons:
Classical project finance criterions: Equity-ratio, DSCR, DSRA

$$- \textit{Debt Service Cover Ratio}\ (\text{DSCR}) = \frac{\text{EBIT} + \text{depreciation}}{\text{interest} + \text{debt repayment}}$$

Figure 16 - definition of DSCR

DSCR indicates the factor by with the available cash flow exceeds the payments for interest and redemption. Commonly, according the research done by Hau (2000) banks require DSCR ratios above 1,3. A very prominent
Classical equity investor Criterion are furthermore: IRR and break even, last marking the point where accumulated cash flows exceed the equity invested.

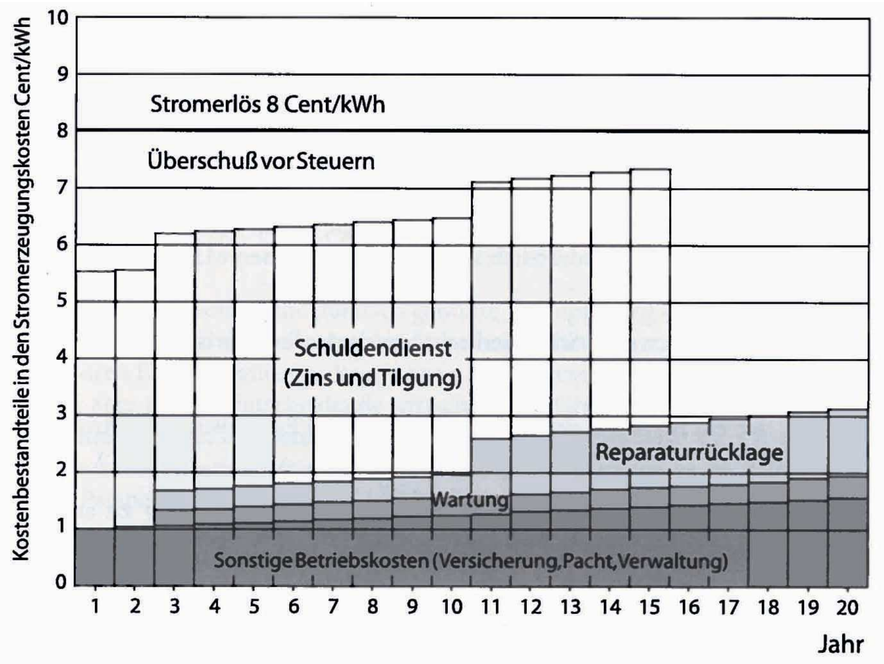


Figure 17 - cost splitting of a wind power plant with 15 MW nominal capacity accoriding to Gasch/Twele (2009)

A wind power generation plant is a very investment intensive venture. Assuming a project lifetime of 20 years and a credit period of 15 years as we see in figure 17. more than about half of the revenues is needed for debt service (in German called “Schuldendienst”). The importance of the debt service reflects the importance of the investment costs. We conclude steadily revenues are very important within the first 15 years of operation for the proposed project displayed in figure 17, means the buffer for cost increases or revenue reductions is very limited within the credit period.

The operation and maintenance costs, in German called “Wartung”, displayed in figure 13. are an important issue cost side. The level of operation and maintenance costs is related to size and age of turbines. The longer turbines are in operation, the more maintenance has to be done, shown by figure 18, a study done by the Danish Energy Association.

Turbine size	Years from installation				
	1–2	3–5	6–10	11–15	16–20
150 kW	1.2	2.8	3.3	6.1	7.0
300 kW	1.0	2.2	2.6	4.0	6.0
600 kW	1.0	1.9	2.2	3.5	4.5

Note: O&M costs are expressed as a percent of total wind farm installation costs.

Figure 18 - comparison of total O&M costs as a function of size and age of turbine (Manwell/Mcgowan, 2009)

As displayed in front the only income source of a wind park is its energy production. In the sense of UNEP study 2007 secured revenues on behalf of wind available are key risk driver 3rd rank, therefore I'd want to take lot's of afford and space to analyze risk mitigation strategies in the following paragraphs.

As seen in figure 16 the mean wind speed at hub height (mittlere Windgeschwindigkeit in Narbenhöhe) is even more decisive than the electricity generation costs (Stromerzeugungskosten). Figure 19 shows with bird' eye view depending on the pay back period of the investor maximal electricity generation costs and minimum annual wind speed. The surplus of the electricity generation costs is that the operator of a wind park can influence them, including securing them whereas for mean wind speed a risk mitigation done only by him is not possible.

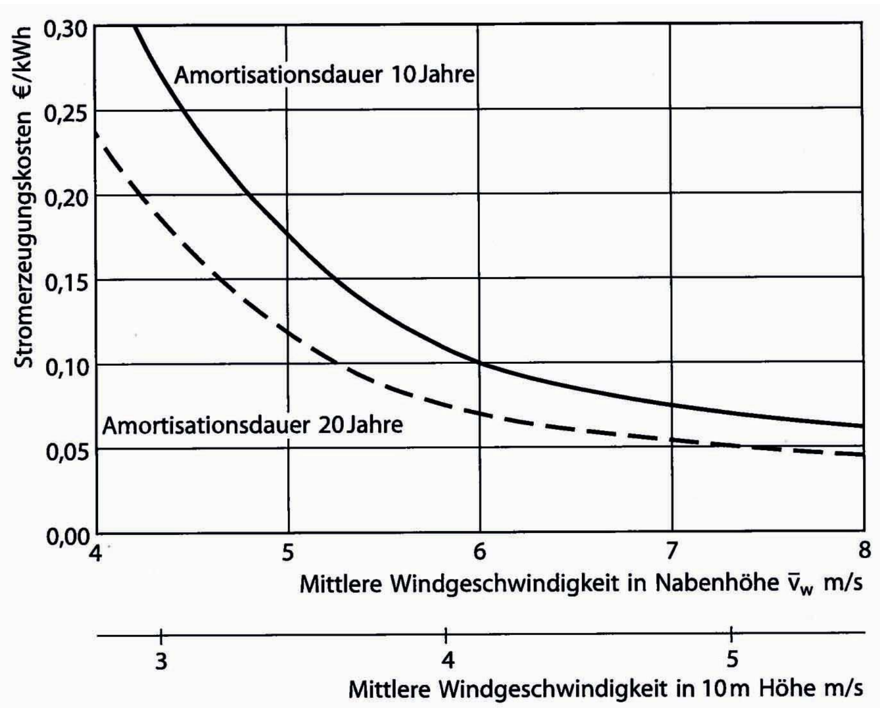


Figure 19 – electricity generation costs for a wind mill 77m rotor diameter, 1.500 kW nominal capacities depending on mean annual wind speed at hub height (80 m) and 10 m above sea level (height formula: z_0 =0,1m) (Hau, 2004)

A secured production is a key element for a successful wind power project. Classical instruments out of construction industry, available only once like:

– Retention money guarantee,
– Performance guarantee,
– Power test run,

and ongoing

– Fixed price maintenance contract.

Focus the technical availability, including a potential effectiveness of the equipment, meaning the plant is ready for production as planned.

Ready for operation is required to produce electricity if the wind blows; the latter is a parameter, not in the influence of human beings. In the first step, if wind measurement were taken wrong by a certified wind expert that expert can be charged, with the effect that he only once will have to pay a big compensation allowance after a proposed long lasting trial. The funds of the wind expert won't be sufficient to secure an economic feasible operation of the plant for project lifetime and wind conditions change over time (e.g. global warming,…), hence another solution has to be found.

If not interested in accepting actual wind speed as "god granted" and also the economic effects, measures can be take to stabilize cash flows of a project. Reserve funds are first options when thinking about a security. Reserve funds in cash are very expensive and are in most cases designed to secure debt service only for one year of operation (if wind yield slumps), surely an option for years after credit period but not for the "decisive years", when Free cash flow is very limited. A proficient alternative to reserve funds are weather derivatives, they are not that expensive and represent an access to bigger reserve funds and can provide security over the project life time, risk is totally transformed for a specific extent to third party.

Weather derivatives as an additional security can furthermore reduce the capital costs, including smaller margins.

For the purpose of discussing different hedging options solid sources are needed: wind assessment reports and cash-flow models are key elements to calculate sensitivity analysis coming up to park specific wind speed variability.

The specific data for analysis of a hedging demand requires the knowledge of the following data:

– Power curve of the wind mills (wind speed at which engines start and stop to produce energy)

- Wind measurement data at site or close wind parks already in operation (the data become part of the hedging contract).
- Calculated wind park production, using data of installed wind turbines, park specific data, wind situation, technical specifics) leading by multiplication with remuneration for feeding into a cash-flow model of revenues.
- Target park production: On the basis of cash flow model of last step a sensitivity analysis is made regarding negative changes of wind situation. The aim of the calculation is getting an idea for kind, duration and design for developing a wind-hedge.

Aim of Hedge according Priermeier (2003) is:

- Securing target production with
- Lowest possible effort
- And lowest possible alternative costs.

Key element of all hedging instruments (Priermeier, 2003)

The strike (for options) or structure (for swaps) is a key element. Strike and structure have to be defined to secure target production with a glance at alternative costs.

Hedging partner has to define redemption values for different wind speeds.

Maturity has to be defined, because of poor solvent markets and high fees of long term hedging periods revolving products can be used.

The market for weather derivatives is straightforward. The main products on the market are (Priermeier, 2003) SWAP, Put-Option and Range-Option. Differences between products are: redemption profile and premium.

Swaps show the same risk for both Parties, having a systematic Risk. Options dealing are limited forward contracts. The buyer acquires the right to get to use it's right at a specific date or not, all for the payment of a premium, the seller gets the premium and has the obligation to perform if the buyer directs, for the seller the risk is higher than for the buyer.

Wind Swaps (Priermeier, 2003) are absolute forward contracts with symmetric payment profile. At an early stage theoretical production output in Kilowatt hours on behalf of given wind conditions, evaluated by wind assessments is fixed. The fixing at an early stage gives security for the revenues. Big disadvantage of a Swap is that also the potential yield is limited, the wind mill operator (buyer of the SWAP) gets fixed his payments from the seller, but return of each additional produced Kilowatt hour above the fixed level goes directly to the seller of the SWAP. Because of critical points: judgement of where the critical production level is and limited potential yield for the investor SWAPS are seldom used in practise.

Put-Option (Priermeier, 2003)

The Buyer gains via derivative at an early stage secures for the event of declining production based on bad wind conditions. For an option premium on the basis of evaluated wind conditions for a theoretical production amount security is achieved, the seller has to pay the difference between fixed theoretical production and actual production within a specific period of time. The pros of put-options are gained security and still existing chance for surplus. The con of put-option is the high risk premium, the higher earlier the compensation payments are fixed the higher is the premium.

To come up to a strike fitting best to the wind park investment the cash flow should be assessed with answers to question behind: "what amount of decline in production can be taken as risk from the investor (risk bearing ability) and how much risk is the investor prepared to take (risk disposition). Guideline in most cases, when cash flow model is basis is economic break even or a defined return on equity (ROE).

Range-Option (Priermeier, 2003)

Range-options are a combination of two options, one option for hedging against bad wind conditions and one option limiting potential yield at good wind conditions. The effect of the combination is a reduced risk premium for a defined range in comparison to swap and put-option with high risk premiums. Proceeding for implementation of range-option is following: first stage is evaluation of put-option-strike via cash flow simulation model, followed by the pricing for the put option. Second stage is calculation of level of cut for potential yield, following discussions on reduction of overall premium for range-option.

Approaches to Hedging (Priermeier, 2003)

Proxi-Hedge

Method Proxi-Hedge uses as basis for calculation of risk premium wind data of the region or effective production data of wind parks in operation nearby proposed to be secured wind park, range of data is known as WPI (wind power indices). Furthermore an analysis about correlation of WPI with data of proposed wind power station happens. After closing, during operation correlation between performance Wind Park and WPI has to be done regularly, eventually hedge has to be modified during contract period.

Individual hedge for single wind park

For an individual hedging offer more data have to be evaluated but restrictions of finance can be considered for the set up. The output is unique and correlation analyses are not necessary at any stage.

3 Model

3.1 General introduction into the model

The overall scope of the model, pointed out already in the chapter before is the cash flow, generated by the asset wind power plant. In a life-cycle analysis the business value depending on completion date a chances in asset's functionality of performance is displayed. The time before completion date is excluded, in the work, meaning the construction risk and testing phase risks are not part of the assessment. Many risks related with running a wind power plant have it's seed in the planning and construction phase, therefore only the risk drivers whose power expires after testing phase are excluded in the assessment.

Asset models are best stochastic models, an aggregation of probability distributions, therefore analysing all main question marks of a project:

- cost, time and performance
- value of early performance (not applicable for a discussion in detail in this work, because happening before operation)
- impact of parameters trough change of scope
- project projection, including critically indexes

For the purpose of creating a project risk management model I rely on PMBOK® Guide (2011) and it's 6 phases.

Phase 1., Risk Management Planning has already been done in chapter 1., defining the top down approach and qualitative approach as a tool.

Phase 2., Risk Identification was done in chapter 2., talking generally about the risk factors but not in a weighting manner, therefore leading to Phase 3., Qualitative Risk Analysis now, necessary for assigning the different risk factors probabilities and impact as creating a risk matrix, ready for testing with real cases and numbers.

Going back to the risk Identification phase, Phase 2.,
according to the "risk map" of Meulbroek (2000), the risk of each company is split into 7 clusters (see figure 5). Because of Meulbroeks general approach a transformation into the specific company in the focus of this work; wind park operation company, owned by private investor, financed mainly with debt has to be done. Although risk drivers within a wind park operation investment surely often have different, multiple affects, as announced by UNEP (Marsh Ltd/ UNEP, 2007) they have their origin in one specific profession. In each of the professions during the whole lifetime of the project (even decision from times before project start) have influence on the success of the project. To keep it short and simple 3 risk categories are drawn up by me: legal, economical and technical.

My experience in the renewable investment scene showed that these three main categories of risk exist and a splitting in these 3 categories is state to art, not only because these categories are treated separately by professionalisms (lawyers, tax advisers and banking specialists, technical experts) during due diligence processes in acquisition phases of wind power plants.
With the help of the outcomes of literature analyzed available the main risks, threatening an equity investor into wind energy generators are derived.

The current work focuses on the scope of an equity investor, financing its power plant with project finance, interested in a long term investment for the overall project lifetime. The goal as announced at the very beginning of this work is achieve by a model through assessment of main criterions.
If going back to figure 17 "cost splitting for generation of one kW" we clearly see that revenues and debt service (reflecting the very high investment costs) are because of

their importance, expressed in cash topic number one for each wind power investor. A wind power project has only one source of income: sales of electricity. The electricity sale is depended on the factor generation and off take. Due to the revenue and cost diagram, displayed in figure 17. I chose to have the focus of my analysis on four main fields: generation, off take, debt service and risk related to specific operation. In that step I also made a hint to the decision disciplines relevant.

The generation is depended on:

- On **the current wind speed**. If no wind is available the wind generator can't start working and production of electricity is not available, a big issue if considering that e.g. in the area of Austria only 2.600 full load hours per year are realistic, in other words about 30% of the year time. → technical problem

- the **design of the wind park and type of wind generators**: The design affects air flow within the wind park, if not proper designed losses can occur. The type of generator is very decisive if going back to chapter 2.2., each type of wind mill is designed for specific wind conditions, starts operation and switches off at specific wind conditions → technical problem

- the **quality of the whole equipment**: the overall quality of the parts → technical problem

- **if maintenance is not done according time schedule** the wind mills stands still → technical problem

- **link to the grid**: The whole generation system always has to deliver a specified quality of electricity plus so called reactive current and off take via grid has to be possible→ technical problem

- **natural hazards**: a still stand occurs because of damage of the plant trough e.g. fire, lightning, explosion, windstorm, flooding → economic problem

- **physical hazards**: risk of damage by man made: e.g. fire, explosion. → economic problem

The off take is depended on:

- **off taker withdraws from the contract after financial closure** → economic problem

- **off taker defaults on contractual obligations** (e.g. bankruptcy of off taker) → economic problem

- the price for electricity goes down because of **change of regulatory support skim** (amendment) for feed in tariff (or green certificates) → legal problem

- the price for electricity goes down because of **decreasing market prices for electricity**→ economic problem

Furthermore the debt service, indirectly reflecting the high investment costs, based on overall costs of production of one kWh is an important issue.

Debt service:

- **affected by all risks linked with operation and off take**. The debt service is in most cases the buffer for cost increases or decline in revenues → economic problem

- risk of **rising interests**: Due to funding linked to changing key rates the project threatens interest increases, especially during the first years of high debt service. → economic problem

The power plant does demand presence of personnel steadily, it's surrounding is however in case of short visits risky for people employed or pedestrians.

Risks related to specific operation:

- **Risk of injured people** affected by plant e.g. through ice fall → legal problem

In step two I made my suggestions on indicators for the risk and specified the risk with the help of UNEP (Marsh Ltd/ UNEP 2007). This step was helpful to think in a broader sense about the different risks, especially about their input.

I assigned the effect of the risk, where it hits the economic success, either cost side or revenue side or both.

3.2 Quantification of the possible risks via a scale

All the following chapters concerning the first steps of displaying quantitative risk analysis, the pre-model phase are display in table 2.

In the first step of quantitative risk analysis the possible effects of risk factors are differentiated. As displayed in table 2. in the first step the source category of the risk factor is fixed, in concrete technical, economic and legal.

The step two the risk drivers are linked to the source category. For the purpose of indicating the relevance the risk indicator has to be defined in a further step. To get a first guess about the possible risk effect, the risk effect has to be written down as detailed as necessary.
In the case of an investment two general effects can be measured, if focusing the cash effect – cost effects on the one side and revenue side on the other side, indicated if applicable with “1”.
Within the last step of the pre-model phase, a term originally relating to Phase 5. in the sense of PMBOK® Guide (2001) is the collection of risk mitigation strategies, displayed in the last row of table 2.

Table 2 - List of risks, classification to cost or revenue effect and possible risk mitigation measures (own creation)

	source	risk driver	risk indicator	possible risk	risk cost side	risk revenue side	risk limitation possible in front
1	technical	no wind available	wind audit	difference between annual wind potential (PXY) used for business plan and P(99)		1	weather derivate
2	technical	design of the wind park	none	turbulences within the park, wind mills are not appropriate for given site conditions		1	liability of the designer
3	technical	bad quality of the equipment	track record, plants in operation	additional maintainace, chage of spare parts	1	1	proven technology, well known producer, insurance for still stand
4	economic	operation and maintainance	operation costs	rising costs for operation and maintainance	1		fixed price service contract
5	economic	natural hazard	weather records	damage of the plant	1	1	insurance
6	economic	physical hazard	in case or employees: track record	damage of the plant by human action against property such as strikes, riots, civil commotion and war.	1	1	insurance
7	economic	off taker default (not applicable for fixed feed in tariff support skim)	credit rating offtaker	loss of revenues		1	not possible
8	economic	rising interests	DSCR	rising interests	1		possible
9	legal	damage of people	permissions	damage of persons, e.g. by ice fall	1		security systems, insurance
10	legal	change of support skim legislation	consistency of legislation in the last years	feed in tariff (price for electricity delivered) goes down		1	not possible
11	legal	corruption	corruption index	loss of ownership	1		not possible

Table 3 - scoring model for wind power plant in operation - leading into rating number – part 1 (own creation)

			minimal open risk					**medium open risk**					**maximun open risk**
importance grade	topic	**scale**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
3	technical	no wind available	P99	P95	P90	P85	P80	P75	P70	P65	P60	P55	P50
1	technical	design of the wind park	0%-10% left of planned operation period	10-20% left of planned operation period	20-30% left of planned operation period	30-40% left of planned operation period	40-50% left of planned operation period	50-60% left of planned operation period	60-70% left of planned operation period	70-80% left of planned operation period	80-90% left of planned operation period	90-100% left of planned operation period	full project lifetime (100%) of planned operation
2	technical	bad quality of the equipment	full guarantee by a solid bank for overall project lifetime	full guarantee by a solid bank for 90% of project lifetime	full guarantee by a solid bank for 80% of project lifetime	full guarantee by a solid bank for 70% of project lifetime	full guarantee by a solid bank for 60% of project lifetime	full guarantee by a solid bank for 50% of project lifetime	full guarantee by a solid bank for 40% of project lifetime	full guarantee by a solid bank for 30% of project lifetime	full guarantee by a solid bank for 20% of project lifetime, alternative guarantee of the manufacturer	full guarantee by a solid bank for 20% of project lifetime, alternative guarantee of the manufacturer or retention money guaranteee	not security annouced in 0-9
1	economic	operation and maintainance costs	fixed price for ordinanary maintainance for project lifetime	fixed price for ordinanary maintainance for 90% of project lifetime plus repair reserve for one year	fixed price for ordinanary maintainance for 80% of project lifetime plus repair reserve for one year	fixed price for ordinanary maintainance for 70% of project lifetime plus repair reserve for one year	fixed price for ordinanary maintainance for 60% of project lifetime plus repair reserve for one year	fixed price for ordinanary maintainance for 50% of project lifetime plus repair reserve for one year	fixed price for ordinanary maintainance for 50% of the most costly maintainance periods lifetime plus repair reserve for one year, additional price fixing clause for the rest period	fixed price for ordinanary maintainance for 40% of the most costly maintainance periods lifetime plus repair reserve for one year, additional price fixing clause for the rest period	fixed price for ordinanary maintainance for 30% of the most costly maintainance periods lifetime plus repair reserve for one year, additional price fixing clause for the rest period	repair reserve for one year and price fixing clause for the wohle period	no price fixed for maintainance and no price fixing clause
2	economic	natural hazard	fully insured	insured with participation									no insurance
2	economic	phsyical hazard	fully insured	insured with participation									no insurance

Table 4 - scoring model for wind power plant in operation - leading into rating number – part 2 (own creation)

			minimal open risk					**medium open risk**					**maximun open risk**
importance grade	topic	**scale**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
3	economic	offtaker default	fixed feed in tariff for whole project lifetime	fixed feed in tariff for 90% of project lifetime	fixed feed in tariff for 80% of project lifetime	fixed feed in tariff for 70% of project lifetime	fixed feed in tariff for 60% of project lifetime	fixed feed in tariff for 50% of project lifetime	fixed feed in tariff for 40% of project lifetime	fixed feed in tariff for 30% of project lifetime	fixed feed in tariff for 20% of project lifetime	fixed feed in tariff for 10% of project lifetime	no security for feed in tariff of any kind
3	economic	rising interest rate	fixed interest secured, DSCR always below 1,3	fixed interest secured, DSCR always below 1,28	fixed interest secured, DSCR always below 1,26	fixed interest secured, DSCR always below 1,24	fixed interest secured, DSCR always below 1,22	fixed interest secured, DSCR always below 1,18	fixed interest secured, DSCR always below 1,16	fixed interest secured, DSCR always below 1,14	fixed interest secured, DSCR always below 1,12, alternatively DSRA for a year interst reserve	fixed interest secured, DSCR always below 1,11, alternatively DSRA for half of a year interst reserve	fixed interest secured, DSCR always below 1,10
	economic	rising interest rate	fixed interest secured, below 10% to end of credit period	fixed interest secured, below 20% to end of credit period	fixed interest secured, below 30% to end of credit period	fixed interest secured, below 40% to end of credit period	fixed interest secured, below 50% to end of credit period	fixed interest secured, below 60% to end of credit period	fixed interest secured, below 70% to end of credit period	fixed interest secured, below 80% to end of credit period	fixed interest secured, below 90% to end of credit period	fixed interest secured, below 100% to end of credit period	fixed interest not secured
1	legal	damage of people	no attendance of personell	all possible dangers evaluated and full insurance	all possible dangers evaluated and full insurance with deceisive participation (above 50%)							security system and security personnel	no security system
3	legal	change of support skim	own energy consumption or not applicable because sale only on free market	no changes in the past affecting already taken investments				changes in the past affecting already taken investments high properly (supranation al authority can sanction)					changes in the past affecting already taken investments high properly (no supranational authority can sanction)
3	legal	corruption, based on corruption index	10	9	8	7	6	5	4	3	2	1	0

In the second phase of qualitative risk analysis a numeric component plays
In step three I decided to rank the risk drivers according their influence on the yearly turnover of the project company.

To keep the whole model simple I graded the criterions according their risk from 0 to 10. 10 is most risky, full risk and 0 negligible risky, no risk to be considered in calculation. A scale form 0 to 10 is not always possible, for some criterions a differentiation on that detailed level is not possible. For that fact the scale is not used fully. It’s vital for the whole model that terminology and system is homogeneous, therefore I can’t see a problem in that topic.

Before going into details for the measurement of the risk of different factors I want to state that the materiality limits surely reflect the risk appetite of an investor and have to be defined by the investor, best after checking the whole overall rating model via a couple of practical example, one or two loops with the people in charge of decision surely will improve the overall fit of the model to suggestion of the investor.

In a further step I divided the criterions into three categories of different importance:

- Waging factor 3 is linked to events extremely hurting the overall project cause a negative turnover till the rest of the project lifetime and destroy the economic feasibility of the project
- Waging factor 2 is linked to events causing negative turnover for a couple of years but don’t destroy economic feasibility of the project
- Waging factor 1 is linked to events causing fundamental influence on negative turnover but don’t turn it in ordinary operation year into negative zone and have minimal influence on economic feasibility of the project.

Going trough the risk factors I’d start with the technical ones, specific for wind power plants in operation.

No wind available:

A wind power plant can’t work without wind of specific speed; therefore wind audits are necessary to get security about the conditions at site. Assumed reliability of wind audits, at best more than one, annual wind potential at site is calculated with the help of statistics in the form of a density function, a normal curve of distribution. The normal curve of distribution enables to display the annual wind potential available for different stages of probability. P99 defines the wind potential value at site with a probability of 99%. In Practice investors seldom achieve economic feasible projects when using P99 for their business plan, standard in project calculation are P75 or P50, which leave if relying on the calculated values lots of risk on the investor level. The investor seeking for solid calculation base has the option to secure annual wind potential with the help of derivates (as announced in chapter 2.4.). If the investor does so, securing its revenues for a given P-Value, he receives a better grading for this factor. The risk although declining by project lifetime is always big and therefore is weigthed with 3.

Design of the wind park:

Regarding not predictable wind conditions at site, assumed on the basis of wind audit for installation of wind mills the design is proven by time going by. The risk loses its importance therefore by time, displayed in %-ages of time left of the planned project lifetime finding its impact in the scale. The risk can’t be controlled; only minimal risk fund available is liability of plant designer. The risk, declining by project lifetime and having a steadily impact on yearly turnover is weighted with 1.

Bad quality of the equipment:

The functionality of the whole equipment is vital for the production of the plant. If not proper designed still stands occur, causing decrease of revenues and higher maintenance costs and may lead to replacement investments. The open risk can be reduced by bank guarantees, representing an external liability fund, guarantees of the manufacturer or the retention of money, with different effects on the security as . A bank represents a solid and broad liability fund, a manufacturer is less credit worth and the retention of money is only once applicable and therefore least preferred. Because of the overall big impact of the topic on revenues and costs it is weighted with 3.

Operation and maintenance costs (o&m):

The costs for o&m are a decisive cost block after the first years of operation, in most cases increasing steadily. As a matter of fact these costs really can decrease the annual profit if scope of service and price is not clearly fixed and long time secured. Fixed contracts over a specific period of the project are therefore standard. Additionally repair reserves in cash are formed to secure the project for unpredicted maintenance events, not only the costs for material and work also for lost profits during unscheduled maintenance are big issues. Because of its big cost block but its limited effect on the overall yearly turnover weight factor 1 is granted.

Natural hazards:

Natural hazards are in most cases unpredictable, e.g. fire, storms, floods etc. Although records form the past exist for most sites they can't be measured by the investor. Only option, indicator and risk mitigation instrument is an insurance of a capable insurance company. The option is to secure or not secure the risk. Because of its big impact, up to need to reinvest the whole assets and long term still stand a big impact on the project, long lasting negative effects has to be faced if no insurance is installed. Because of very seldom total loss of assets in the past weight factor 2 is assigned.

Physical hazards:

Physical hazards are in most cases unpredictable, e.g. riots, war, strikes etc. Although records form the past exist for most countries they can't be measured by the investor. Only option, indicator and risk mitigation instrument is an insurance of a capable insurance company. The option is to secure or not secure the risk, at least part of the risk. Because of its big impact, up to loss of ownership of the plant no insurance will be available on the market. Because of very seldom total loss of assets in the past weight factor 2 is assigned.

Off taker default:

The off take has to be done steadily within a wind power plant; stocking of electricity is at present not possible. For that fact a fixed price for calculation base is best. Most security contains a fixed feed in tariff, granted by law. Second option is a long term contract, so called power purchase agreement (PPA), the risk is much more higher for the PPA because of solvency risk of the purchaser. Because of the big importance of the sales price (see figure XY) on the overall success of the project the topic is weighted with 3.

Rising interest rate:

As already announced the debt service plays an important role on the overall costs of a wind power investment. Interest rates are usually linked to key interest rates. The interest rate should be fixed that kind for the purpose of planning stability with instruments like SWAPS or other derivates. A small risk option but in most cases more expensive then a derivate is a cash reserve, called DSRA debt service reserve account, absorbs interest increases for a short period of time. Because of the importance on the overall profitability of the project, declining by time, strict focus at the start of debt service is necessary because big burden at that time. The topic is weighted with 3.

Damage of people:

As not all time people attend at site it is still a big issue in case of operation personnel or stranger passing at site. A security system can help to limit the risk; a real option is only full insurance, available on the market. The topic is rated with 1 because of its overall impact on yearly revenue of the project.

Change of support skim:

The change of support skim (only applicable if sale is done under support skim), especially if a feed in tariff system is installed is really threatening, no risk mitigation strategy besides own energy consumption is available on the market. The benchmark to evaluate is the record of law changes in the specific field in the past. If a supranational authority is installed like in EU-countries, e.g. the current court case according the "special tax on revenues from production of Photovoltaic" in Czech Republic the risk is surely lower. Because of the importance, especially the high of revenues and maybe additional costs the topic is weighed with 3.

Corruption:

The last point consists of an assessment of corruption situation in the investment country. The effects of corruption are threatening. At the top the loss of ownership of the plant marks the high end of this phenomenon. A very good indicator and best instrument for assessment in that case is the annual corruption index of Transparency international, a multinational acting NGO fighting against corruption, recording the current situation very clearly. Because of the importance and it effect in any field the topic is weighed with 3.

Because of the importance of different topic minimum value should be defined according the possible effect, size of damage for the project.
At first I'd suggest that each risk should be considered for risk mitigation, resulting in risk mitigation actions, therefore a 10 is not acceptable in each case.

3.3 Scale

For the different weighting categories the minimal grade to be achieved is:
For weighting factor 1: below grade 10
For weighting factor 2: below grade 7
For weighting factor 3: below grade 6

The projects are evaluated with Austrian school mark system: 1 is best and 5 worst. An assessed project can reach maximum 240 points, that's the worst 5 can be achieved. Because of the risk awareness of equity investor I'd suggest the following grading:

overall score absolute	overall score in %	grade
144	(60%-70%)	4
72	(70%-80%)	3
48	(80%-90%)	2
24	(90%-100%)	1

Table 5 - grading system for rating number (own creation)

Model for the purpose of generating a rating number:

The aim of this chapter is the development of a scoring model, adapted to the conditions of a wind power project in operation with the view of an equity investor as defined in chapter 2.4. Following the establishment of a scoring model a Rating model is added, for the purpose to compare the risk of different projects.

Methodology of benefit analysis according to Utermarck (1995).

1. determination of criterions for assessment of alternatives
2. weighting of criterions
3. evaluation of possible characteristic values of criterions
4. declaration and of evaluation of characteristic values for different alternatives
5. calculation of part-worth and total use value of different alternatives via rule of association
6. model check (sensitivity analysis)
7. result interpretation

ad 1.) determination of criterions for assessment of alternatives

This first step the overall validity of the scoring model is very important because only criterions be considered in the result considered important.

The criterions should be choose according Utermarck (1995) deductive, reducing the danger of forgetting important criterions.

ad 2.)

Different methods exist to derive importance of different criterions. A couple of approaches, one more complex than the other are introduced:

Method of direct weighting

If only a couple of criterions exist creation of a ranking through the author is an option. The traceability for this method lacks.

Method of singular comparison

In contrast to the prior method an initial step is introduced. Before setting up a ranking the criterions are compared directly.

Method of absolute weighting

The criterions are not compared any more, with the help of a "grades" absolute weights are assigned directly on the basis of weighting factors

Method of gradual comparisons

In comparison to all other just mentioned methods, surely most costly the method starts with definition of a ranking of single criterions, following an ordinal paired comparison of weighting factors of final weighting factors.

ad 3.) evaluation of possible characteristic values

During this step criterions are in the way adjusted leading into possibility of addition of single values in line with overall benefit analysis, the overall results of single action alternatives should be comparable.

Diller (1998) proposes 6 fundamentals:

- point scale should be same for all criterions, no indirect weighing possible

- point scale should start at 1, weightings for all numbers
- only one evaluation device for all criterions
- point scale has to be adopted to situation, promoting acceptance and validity
- graduation of scale should have hardly weighting skips
- transformation from point values to percentage points strengthens clearness

Furthermore in the phase: level of measurement, scale direction and number of valuation classes are specified.

Ad 4.) declaration and of evaluation of characteristic values for different alternatives
Characteristic values of Single criterions are defined.

Ad 5.)calculation of part-worth and total use value of different alternatives via rule of association.
In this step use values of all criterions are added to get an overall value of benefit.

Ad 6.)model check (sensitivity analysis)
During the step impacts of variation of input parameters to performance of the overall project are observed, arising because of check of validity and precision of assumptions as different opinions on criterion system or weighting exist.

Ad 7.) result interpretation
Gained results are discussed and further proceeding decided.

Development of a scoring model for wind energy projects in operation

Created scale on my own surely reflects the risk strategy and risk appetite. To my mind it is decisive to fix minimum grades for each category (as done by me in the last chapter), means risks not threatening that much are possible to be more open than risk threatening most. The scaling system as announced by literature should be tested in practise, which was not possible because of missing data.

4 Conclusion

Setting up a risk management system for a wind park in operation focuses on various aspects. For equity investors a secured return on investment is decisive. The highest risk in the overall investment into wind energy conversion plant is surely related to the revenues, on the one side the level of the revenues and the production hours. Different instruments exist on the market so secure most of the risks; the extension how much risk is secured is a decision of each investor based on risk awareness and the price for risk mitigation. What is taken into account for risk assessment is different in practise and literature. Soft factors surely play a role in the rating of projects; my opinion is that they should not play that big role in a decision system, maybe deciding only about one grade up or down for a rating number.

The scope of this work was to set up a rating system working easily and which is ready for examination in practise, a step which was not possible because of missing data. As in every other market a solid source of historical data is needed to calculate on a solid basis numbers for future events, projection into future. As wind energy conversion via large scale plants is a relatively new business, these data don't exist at all, therefore it is maybe the best option to calculate expectancy values on a subjective basis. What has to be considered for risk assessment and mitigation is, that some risks loose their impact over the lifetime of a project, a factor to be considered in grading.

I hope that current work is impulse to risk owners to think focused on their key risk drivers before acquisition of wind power plants, the model is at least free for adoptions, based on specific needs and visions.

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6 Annexes

6.1 Appendix

Umweltfinanz: Portrait wind park "Bliesdorf-Ketzin" - Rating

		Rating	Rating weighted
intitiator			
	Till now realised projects	3	9
	Trade balance	3	9
sales records			
	forecasting	2	4
	information	1	2
	contracts	2	4

	Contract partners	2	4
	Risk hints	3	6
	Audit reports	None	grading
site			
	Wind assessment report	3	9
	Measurements at site	1	3
	Haircut measurement data at site	1	5
	Construction permit	3	15
	Current collection	3	6
	Construction progress	3	15
	operation	3	15
wind mill			
	producer and type	2	6
	Service-, maintainance- and repoar contracts	2	10
	insurance	3	9
	Performance guarantee	1	4
financial planning			
	equity ratio	3	15
	Agreement to provide funds	3	6
	Interest terms	2	4
	Renumeration electricity	1	2
	Adjust cost leave (indexation)	3	6
	accruals	3	6
	Haircuts	1	5
	Reserve funds	2	10
legal			
	Liability of shareholders	3	6
	Extract from Company register	3	3
	Placement fee	3	6
	Supervision	3	3

Sale of shares	1	1
	Overall score:	208
	rating: 22,86	