Swedish University of Agricultural Sciences
Faculty of Natural Resources and Agricultural Sciences
Department of Economics

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- A case study about profitability and risk in inland wind power

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Summary

Wind power is a relatively young industry that has had a fast development the last three decades. It has got much attention the world over because of its environmental and political advantages. Several governments have therefore put an effort into developing incentive systems in order to increase wind power investments. Due to the novelty of the wind power industry and the new technical solutions that are constantly presented on the market, wind power investors have little or no reference data when making investment decisions. In addition wind power investments are characterized by much uncertainty due to the nature of the production relying on weather conditions which cannot be controlled.

In order to make a rational investment decision an investor needs to have a comprehensive understanding of the possible outcomes of the investment. It is therefore the aim of this thesis to develop a method of analysing the economic feasibility of a wind power investment in regard to profitability and risk. Further the thesis uses the developed method to investigate the profitability and economic risk involved in a particular wind power project. This is the project of Saimaan Woima Oy which is a new wind power company in South Savo in Finland owned by three farmers and the local electricity company Suur Savon Sähkö Oy. The company plans to build Finland’s first large scale inland wind power plant which would consist of two 3 MW wind turbines. Similar projects have been dismissed in the past due to lack of profitability. The belief in Saimaan Woima Oy is though that the technical development of wind turbines in combination with an optimal location and government support can today result in a profitable investment.

The developed model is based on a net present value calculation done as a Monte Carlo simulation. Also payback time and stochastic efficiency in respect to a function (SERF) is used to evaluate and rank the investment alternatives. For Saimaan Woima Oy’s investment seven scenarios based on different electricity price levels and support systems have been analyzed. In addtion three real discount rates (4.70, 5.20 and 6.93) responding to different levels of a required return on equity by owners have been used for the calculations. The two support systems that have been compared are a government investment subsidy and a tariff price system that runs over the first 12 years of production.

The results attained in this thesis show that the investment would in fact be feasible for most scenarios even with the highest required return on equity of 17 %. The only exception is the investment subsidy based support system which in the case of a slow development of electricity prices would not be feasible even with the lowest required return on equity of 8 %. The analysis shows further that some kind of governmental support is a condition for the investments feasibility because without any external support the investment would not be profitable. The results also show that the tariff based support system is to prefer over the investment subsidy. This is duet to the fact that it has lower dispersion, it contains fewer uncertain variables, has a shorter payback time and higher probability to be profitable.

Sammanfattning

Vindkraft är en relativt ung industri som haft en snabb utveckling de senaste tre årtiondena. Industrin har fått mycket uppmärksamhet över hela världen på grund av dess politiska och miljömässiga fördelar. Därmed har flera regeringar satsat på att utveckla incitamentsystem för att stimulera vindkraftsinvesteringar. På grund av att vindkraftsindustrin är så ung och nya tekniska lösningar konstat presenterats på marknaden har investerare oftast väldigt lite referensdata eller inget alls när investeringsbeslut ska tas. Till detta tillkommer risker förknippade till vindkraftproduktionens karaktär eftersom denna baseras på ett väderfenomen som ej går att styra.

För att en investerare ska kunna göra ett rationellt investeringsbeslut måste denna ha en helhetsförståelse av investeringens möjliga utfall. Det är därför syftet med denna uppsats att utveckla en metod för att analysera den ekonomiska genomförbarheten av en vindkraftsinvestering när det gäller lönsamhet och risk. Denna uppsats kommer vidare använda den utvecklade metoden för att analysera lönsamheten och risken i ett specifikt investeringsprojekt. Detta projekt är Saimaan Woima Oys vindkraftsinvestering. Saimaan Woima Oy är ett nytt energibolad i Södra Savolax i Finland som ägs av tre lantbrukare och det lokala energibolaget Suur Savon Sähkö Oy. Aktiebolaget ämnar bygga Finlands första storskaliga inlandsvindkraftverk som ska innefatta två 3 MW vind turbiner. Liknande projekt har tidigare avvisats på grund av att de inte visat på någon lönsamhet. Tron i Saimaan Woima Oy är dock att turbiner baserat på nya tekniska lösningar i en kombination med en optimal placering och statligt stöd kan idag resultera i en lönsam investering.

Modellen utvecklad i denna uppsats är baserad på en nuvärdeskalkyl gjord i en Monte Carlo simulation. Därtill har payback-metoden samt stochastic efficiency in respect to a function (SERF) använts för att utvärdera och rangordna investeringsalternativen. Sju skenarion baserade på olika elektricitetspriser och stödsystem har analyserats för Saimaan Woima Oys investering. Också tre reala kalkylräntor (4,70, 5,20 och 6,93) baserade på olika avkastningskrav på eget kapital av ägarna har används. De två stödsystemen som jämförs i arbetet är ett statligt investeringsstöd samt fasta tariff-priser som löper de första 12 produktionsåren.

Resultaten i denna uppsats visar på att investeringen de facto är lönsam även med det högsta avkastningskravet på 17 % för de flesta skenariona. Det finns endast ett undantag och detta är ifall investeringsstödet väljs istället för tariff priserna och elektricitetspriserna har en långsammare än förväntad utveckling. Detta scenario är inte lönsam ens med det lägsta avkastningskravet på 8 %. Analysen visar dock att någon typ av statligt stöd är en förutsättning för att investeringen ska bli lönsam. Resultaten visar vidare att stödsystemet baser på tariffpriser är att föredrar över investeringsstödet på grund av att denna har en mindre spridning, den har färre osäkra variabler, dess tillbakabetalningstid är kortare och den har högre sannolikheter att vara lönsam.

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1 Introduction

The world's population is growing and with it its energy consumption. It is predicted that between the years 2007 and 2035 energy consumption will increase 49 % (www, EIA 1, 2010). This rapid increase has led to concerns about how future energy demand will be satisfied. Today, a great majority of the world's energy is produced from fossil fuels (www, IEA 1, 2009, 6) which are a major source of green house gasses (www, EPA 1, 2009). Since many countries today try to reduce their negative environmental impact more environmentally friendly alternatives are demanded. In addition, fossil fuels can only be found in some parts of the world making countries without natural oil resources dependent on others (www, IEA 1, 2010), a situation that can be less than desirable. Finally, fossil fuels are a finite recourse and thus cannot, according to thermodynamic laws, satisfy an exponentially growing demand making it impossible to satisfy future energy demand solely on these recourses (Nelson, 2009, 18). They will simply not suffice.

A possible solution to the dilemmas above is represented by renewable energies such as solar, wind and hydro power. In contrast to fossil fuels these resources have the advantage that they are infinitive, they can be found all over the world and they do not pollute the environment (Nelson, 2009, 13). The drawback on the other hand is low density and high variability (ibid) which have resulted in high production costs (www, IEA 2, 2010). However, much research and development has been, and is, done all over the world to enhance the efficiency of renewable energy systems in order to make them feasible alternatives for future energy supply (ibid). As a result more and more renewable energy systems are reaching the market (ibid) of which wind power is the fastest growing industry (www, IEA 2, 2010; Motiva, 1999, 6).

1.1 Development of wind power

"The wind is a vast untapped resource capable of supplying the world's electricity needs many times over."

(www, GWEC, 2010)

The above statement implies that wind power by itself can, if harnessed, produce all the electricity demanded in the world and much more. This was the conclusion of two independent studies carried out by *Stanford University's Global Climate and Energy Project* and the *German Advisory Council on Global Change* (www, GWEC, 2010). The potential of wind power seems thus to be great and utilizing it has both environmental and political advantages. Why is it then that in 2009 wind power only accounted for approximately 1,5 % (WWEA, 2009, 4) of the worlds electricity consumption? The answer lays in a combination of politics and technical development.

Wind power is a relatively young industry. Though mankind has long utilized wind to help it with its work, for example for transportation by boat or pumping water from wells (Wizelius & Karlsson, 1992, 16) it wasn't until the oil crisis in the 1970's that wind power became an attractive alternative for producing energy in a larger scale in the form of electricity (Motiva, 1999, 6; Wizelius, 2007, 35). At that time wind power wasn't commercialized and the technology and the size of power turbines was inadequate for large scale production. The oil crisis, however, resulted in that several governments started to work with wind power research in the hope of developing feasible power turbines which could reduce their dependency on fossil fuels (Wizelius, 2007, 35-36). Investment support schemes of different kinds were put into action with the aim of building a stable foundation for the new industry.

These efforts were more successful in some countries than in others. For example, in Denmark a decision was made to focus on power turbines of a smaller scale for which the technical knowledge already existed (Wizelius, 2007, 36-37). This led to that commercial wind turbines which small groups of citizens could afford to invest in quickly reachied the Danish market. Furthermore a support system was developed with clear directions for investment plans, investment support and tariff prices (Wizelius & Karlsson, 1992, 39-21). This straight forward energy policy made it possible for Denmark to become the leading country in wind power production at the time (Wizelius & Karlsson, 1992, 39). The opposite was true for the neighbor country Sweden where focus of the research was on big megawatt sized power turbines and the responsibility of industry development was laid on the energy companies (Wizelius, 2009, 20; Wizelius & Karlsson, 1992, 13-14). This in combination with an inconsistent support system led to a slow development of the wind power industry in Sweden (Wizelius & Karlsson, 1992, 26-27).

The second thrust for the wind power industry came along with the discussion of green house gases (Wizelius, 2007, 35). Green house gases are a topic that has gained much attention the last decade and international agreements have been made in effort to reduce them. With this “new view” of a more environmentally friendly world, wind power got, along with other renewable energy forms, an important role in reducing CO2 emissions. Energy policies were once more renewed which led to a relaunch of wind power investments in a number of countries. For example, Sweden has now after renewing its energy policy to include greater support to renewable energies finally got its wind power industry on its feet (Wizeliuz, 2007, 39).

The efforts made globally under the last 30 years in both investment support and research have resulted in a rapid growth in the wind power industry. Whilst the average wind power turbine in the 1980s was 50 kW it had grown to 250 kW by the next decade and further to 1 MW in 2000 (Wizelius, 200, 143). Today, still 10 year later, the effect of a commercial wind turbine can be up to 3 MW (www, ST1, 2010). At the same time the technology has developed and the turbine efficiency has enhanced (Wizelius, eng, 2007, 3). This has made it possible for locations other than those with the most optimal wind conditions to be utilized. Also the average cost of investment per MWh produced has sunk (Wizelius, eng, 2007, 3) and wind power is today competitive with other energy production forms when compared to the costs of a new power plant (Wizelius, eng, 2007, 4). As a result from these changes, the cumulative global wind power capacity has grown exponentially from 6,1 GW in 1996 to a capacity of 120,8 GW in the year 2008 (www, GWEC, 2010) and is expected to continue its growth in the future.

1.2 Problem

Despite the efforts put into research and development and the growth of the industry during the last decades, wind power investments still rely heavily on government support. This is due to the fact that it is a capital intensive investment associated with great uncertainty (Montes and Martin, 2007). It is not only the common risk factors such as market prices and capital cost that are relevant for wind power projects but also risk factors such as annual production and technical reliability. For example, for most production forms the produced amount of output is regulated by the producer. This is however not true in wind power investments due to the fact that the production is based on an environmental phenomenon, the wind. It is thus impossible for the owner of a wind turbine to decide in forehand at what level the production will be. Further there is a great variability in wind conditions that create variations in production from one time period to another (Wizelius, 2007, 72-73). It follows that the annual income is beyond the control of the owner. In addition to this, there is an uncertainty of the technical reliability of the investment since there is at this point in time no larger pool of comparison to how well and how long the investment will work.

Investors thus need incentives to invest in wind power and it is due to this that government support is required. Incentives themselves are however not enough to encourage economically rational investors into investing. In addition it is of great importance for the investors to be able to evaluate the profitability and risk in an adequate matter (Montes and Martin, 2007). In order to correctly manage the risks associated with a wind power investment the investors need to have a clear and comprehensive understanding of how the different risk factors affect the profitability of the investment. It is only through this understanding that an economically rational investment decision can be made.

1.3 Aim

To make an economically rational investment decision an investor needs to have a good understanding of the risks and profits associated with the investments. As mentioned above wind power investments are complex systems with much uncertainty. It thus follows that a thorough investigation of all possible outcomes is needed before taking any decisions regarding the investment.

The aim of this thesis is to develop a model of analyzing the economic feasibility of a wind power investment in regards to profitability and risk. Further, the aim is to use this method to investigate the profitability and economic risks involved in a real life wind power project in the Finnish inland.

The profitability and risk analysis will take into account the specific economic conditions prevailing in Finland as well as the specific conditions for this unique investment alterative in order to include all relevant information in the calculations. The empirical information collected and the methods developed will thus be chosen so that the results be as relevant as possible for this particular wind power investment in contrast of giving a more general view of the industry environment today.

The specific analysis is done with the purpose to give the owners of Saimaan Woima a valid economical analysis upon which an economically rational investment decision can be made. It will also serve as an example of how well the developed model can incorporate the real life complexity and risk aspects of an investment such as this. The thesis can also serve as an example for investors in general of which factors have to be taken into account when considering wind power investments.

1.4 Demarcations

This thesis is done as a case study and has therefore no ambitions of making any general conclusions of wind power investments in Finland or the rest of the world. It may, however, serve as an example of important aspects that have to be taken into account in making such assessments.

Only one wind power model is used in the analysis of this thesis. The primary objective is to compare different models for their profitability and risk, but as only one manufacturer was willing to provide the needed information at this point of the project, the analysis concentrates on this manufacturer.

Further the investment analysis is focused on the economic effects of the investment and does not take into account other decision factors such as for example environmental concerns or organizational aspects.

2 Literature review

This chapter presents earlier research done on wind power investment feasibility in terms of wind conditions, profitability and risk.

Wind power is, like most rural industries, dependent on the environment, a fact that makes the investment situation risky as the environment is a factor beyond the decision maker's control. Therefore much of the research done within wind power economics is about how to deal with the risks involved in an investment. Being aware of the complexity and the uncertainty in a wind power investments and how this can affect the probability of getting short term financing Montes and Martin (2007) conducted a theoretical study of investment analysis methods. The study was based on literature research and aimed at finding the most suited analysis method for wind power investments. They concluded that statistical methods such as the Hiller method and Monte Carlo simulation were the most appropriate choices in respect to the type of risk factors that are associated with wind power projects.

The Monte Carlo simulation has in fact been used in many wind power feasibility studies. In a study from Croatia Ognjan, Stanić and Tomšić (2008) analyzed the effects of feed-in tariffs on profitability on wind power projects. Using net present value calculations and Monte Carlo simulation they calculated the profitability for a Croatian wind power park and investigated the risk factors with the largest effects on the results. The annual production in the calculations was defined as a static value and the effects of different production levels were investigated with a sensitivity analysis approach changing the value manually. The investment cost, electricity price, feed-in tariff and the operating and maintenance costs were defined as risky input factors that could vary with +/- 20 % from the expected value. A sensitivity analysis showed that the profitability was most sensitive to the feed-in tariff followed by the investment costs and the electricity price. The operating and maintenance costs on the other hand could rise up to 20 % before they would have any impact on the profitability. As the most risky factor defined by the results was the tariff price which is beyond the investor's control, Ognjan, Stanić and Tomšić conclude that guaranteeing a feasible payment for the produced electricity is the most important incentive the government could employ in order to increase investments in wind power projects.

A similar study was conducted in Turkey 2005 by Ozerdem, Ozer and Tosun (2006). They analyzed the feasibility of three power production alternatives in respect to profitability and risk. Also in this study the annual production was defined as a static value based on wind measurements on site. In contrast to the Croatian study, Ozerdem, Ozer and Tosum did not use Monte Carlo simulation but applied instead a simple net present value calculation with a sensitivity analysis and payback time calculation. Variables defined as risky were the electricity price, the operating costs, capital cost, inflation rate, dept rate and repayment period. The study concluded that the price of electricity was the main factor affecting the profitability of the project followed by the capital cost. The study however did not include uncertainty for the investment costs in contrast to the Croatian study.

The studies described above have, allthough taking some risk factor into account, not analyzed the effect on profitability by the variability in annual production. Recognizing the large uncertainty in the wind power potential of a site Kwon (2010) conducted a study in

Korea 2008 on how to use uncertainty analysis to generate production assessments. He used probability models to define the variability of wind conditions including variables such as mean wind speed, air density and surface roughness. He then combined these probability models in a Monte Carlo simulation to an empirically defined production curve for a wind turbine in order to produce a probability for the annual production. The study showed that the method developed could in fact take into account specific conditions prevailing at a site and produce a reliable estimate for the annual production. The analysis did however not extend to showing the effects of the variability in wind conditions on the economical feasibility of wind turbines.

In contrast a study carried out in Greece 1999 by Kaldellis and Garvas (2000) made an attempt to incorporate both the economic variables and the technical variables affecting the production of the wind turbines. They conducted a cost-benefit study investigating the most important techno-economic factors including inflation rate, capital cost, electricity price, turbine efficiency and availability, nominal power, maintenance and operating costs, and investment cost. The study was carried out as a sensitivity analysis and concluded that the profitability in wind projects was most sensitive to changes in capital cost, the capacity factors, electricity price and investment costs. Changes in maintenance and operating costs had a smaller effect whilst the effect of changes in nominal power and inflation rate was of little importance.

Finally, a master´s study analyzing the feasibility of a wind power investment in the Swedish inland was carried out by Jensen at the Swedich University for Agricultural Science (2007). Jensen used the Monte Carlo simulation technique and defined the electricity price, the electricity grid price and the annual wind variation as risky factors. The factors were defined based on expert opinions and six stochastic variables were used as the electricity price was modeled for four separate points in time. The conclusions of the study was that the wind power investment would be profitable with a discount rate somewhere under 8 % and that the electricity price in the first year of production had the greatest impact on profitability.

3 Theory

This chapter presents the theoretical framework which is used for the analysis of the wind power investment. The logics behind the net present value (NVP), the Monte Carlo simulation, the payback method and the stochastic efficiency in relation to a function (SERF) are developed and calculation principles explained. These methods are then used to produce the results in chapter 8.

An investment is a long term venture of bound capital which is expected to produce cash flows over its lifetime that will return the invested capital with interest (Persson & Nilsson, 1999, 73). That an investment is *a long term* venture gives it specific characteristics that distinguish it from more frequently made operating decisions. Firstly, the binding of capital often poses significant demands on a company's ability for long term financing and secondly, the uncertainty of future conditions creates economic risks that cannot be eliminated. A careful review of the investment's effects on the company, with all the benefits and risks associated with it, is therefore needed before any investment decisions can be taken. This is in contrast with operating decisions that usually can be made more routinely on basis of experience.

When evaluating an investment many different factors have to be taken into consideration (Olsson, 2005, 199). It is not only the investments profitability, but riskiness, environmental impact, operational implications and other factors that should be taken into consideration. An investment calculation is however a valuable tool when assessing the worth of the investment. To approximate the profitability different kind of methods can be used. The most common of these are net present value (NVP), annuity, internal rate of return and payback, all of which have their benefits and drawbacks (Persson & Nilsson, 1999, 73; Ross et al, 2008, 161-183). The results are presented a little different depending on the method used, sometimes even giving slightly different results. This is due to that the approach of the assessment differs between the methods, giving a little bit different views of the investment (Ross et all, 2008, 161-183). Which method is chosen depends on the decision maker's preferences and skills. However, NPV is usually recommended by investment theory literature (Olsson, 2005, 220; Ross et al, 2008, 163). The methods superiority is based on its choice of input values. NPV analysis uses cash flows that are real occurrences in a business in contrast to earnings which are really just a concept. NPV also takes into account <u>all</u> cash flows that occur due to the investment and discounts the cash flows thus including all consequences of the investment in the analysis as well as the time aspect of money (ibid). The method has however a weakness in that it disregards the investor's possibility to take further action once the decision is made (Ross et al, 2008, 241). These actions could include abandoning the project before the economic lifetime is over, expanding the project or waiting for the perfect timing instead of implementing the project immediately (Ross et al, 2008, 241-245).

A method that does allow for these adjustments in decision making is the real option which is a method where options in different places in time can be included in the investment evaluation (Ross et al, 2008, 241). In the case of the analysis in this thesis the real option is however of limited interest. This is due to the fact, that there is no possibility for expanding the project further on. The geographical location is simply too restricted to expand to more turbines than planned and regarding upgrading to larger turbines in the future, there is not enough information available today to estimate neither production nor cost. Timing is also restricted as the choice between support systems (presented in chapter 6.5) is only available at the present when a transformation from the old support system to the new will be taken. The only real option available is thus abandoning the project, but since 70 % of the wind power investment occurs before start (see chapter 4.2), abandoning the project mid way would have little effect on the investments value. Thus it follows that net present value is chosen as the method for assessing the profitability of the wind power project.

3.1 Net present value

Before a more detailed review of the NPV, two things are important to remember when using investment assesment. First, as mentioned above, the results of the calculations should not be treated as the sole decision criteria when assessing an investment. Instead it should be weighed in with other factors such as environmental impact and operational consequences (Olsson, 2005, 198). And secondly, the input of an investment calculation always relies on expectations and approximations since it's an assessment of the future economic consequences which cannot be known for certain (Persson & Nilsson, 1999, 58). The result should therefore never be taken as an absolute truth but rather as a means of getting a better understanding of the investment and its possible outcomes.

The logic behind an NPV calculation is simple. The idea is to shift all the cash flows occurring due to the investment to the same point in time and summing them together. If the sum of the cash flows is equal to or greater than zero, the investment meets the requirements the owners have set on it, and is profitable (Olsson, 2005, 211).

The general formula for the NPV is:

$$NPV = -G + \sum_{k=1}^{n} \frac{a_k}{(1+i)^k} + \frac{S}{(1+i)^n}$$

$G = initial\ investment$
$a = annual\ cash\ surpluss$
$n = year$
$i = discount\ rate$
$S = residual\ value$

(Persson & Nilsson, 1999, 74)

It follows that five things have to be known in order to make a NPV calculation: 1) the cost of initial investment, 2) the annual cash surpluses, 3) the economic life time, 4) the residual value and 5) the discount rate.

3.1.1 Cost of initial investment

The cost of initial investment includes all the expenses that have to be made before the investment can be taken into use (Olsson, 2005, 201). These costs are usually relatively easy to estimate by acquiring tenders (ibid). In a NPV calculation these costs are estimated to the beginning of the first year when the investment is taken in use, marked as year 0 (ibid).

3.1.2 Annual cash surplus

The annual cash surpluses are summarizations of all the in and out payments, cash flows, that occur during a year due to the investment. In contrast to the initial investment, cash flows cannot be approximated by collecting tenders but must instead be based on carefully made predictions. Especially cash flows that take place many years into the future are hard to estimate and are characterized by much uncertainty.

Though one of the strength of NPV is that it takes into account all cash flows resulting from the investment there is some cash flow that are characterized by so much uncertainty that they are often left out of the calculations. These are for example tax payments. Taxes are extremely hard to predict due to the complexity of the system and are therefore often ignored in NPV calculations (Olsson, 2005, 247). The cash surpluses are summarized to the end of the year in question, labeled year 1, 2, 3 and so on.

3.1.3 Economic lifetime

When carrying out profitability calculations the results have to be referred to a certain time span in order to have any significance (Olsson, 2005, 193). For an investment analysis this time span is the economic lifetime of the investment, which represents the time the investment is estimated to be economically feasible to keep in operations (Olsson, 2005, 206). This is approximated based on prior experience and knowledge of the investment.
The economic lifetime can be shorter, but never longer, than the technical life time, which in turn is the time period the investment is expected to actually work (Persson & Nilsson, 1999, 56). For most investments the economic life time is somewhat shorter due to that the profitability decreases towards the end of the investment's technical lifetime due to increased maintenance and production costs (ibid).

3.1.4 Residual value

At the end of the economic lifetime of the investment might have a residual value (Olsson, 2005, 207). This can be due to the existence of a second hand or spare part market where the investment or parts of it can be resold, or the investment has a scrap value that can be obtain. The residual value might also be negative if taking the investment out of use costs more than what can be obtained as income from the residue parts.

It is difficult to estimate the residual value of on investment, since it occurs a long period after the investment is made. Thus the residual value is often overlooked in investment calculus despite the fact that it may have a great impact on the result (ibid).

3.1.5 Discount rate

Because of the fact that money can be invested today to produce an interest in the future, money at the present has a different value than the same amount a few years into the future (Olsson, 2005, 207). As a result of this cash flows that occur in different years have to be shifted to the same point in time in order to have values that are comparable. This is done with the discount rate.

The discount rate is a factor that contains the investors' demands for return on invested capital. It includes possible interests that have to be paid for loans taken to finance the investment as well as the required return on equity by owners (Olsson, 2005, 207). The loan rates are straight forward to estimate since they can be obtained from the loan contracts. The required return by the owners, in contrast, is harder to define. In theory it is said that the return should be equal to an alternative investment opportunity with the same amount of risk, but in practice it is difficult to find such an object of comparison (Ross et al, 2008, 163). In general a guideline exists that the owner's rate of return can be set to 5-10 percent units higher than the loan rates due to the fact that the owner takes a higher risk than the lenders (Olsson, 2005, 207).

The discount rate covering both interest rates and the demanded return on equity is calculated as follows:

$$r = a * b + (1 - a) * c$$

$r = discount\ rate$
$a = share\ of\ equity$
$b = required\ return\ on\ equity\ from\ owners\ (RROE)$
$(1 - a) = share\ of\ extern\ financing\ (loan)$
$c = interest\ rate$

Depending on how the cash flows are defined in the calculation the discount rate also has to account for inflation. If the cash flows are expressed in the value of year 0, the inflation rate should not be included in the discount rate and it's labeled the real discount rate. However, if the cash flows are expressed in the value of the specific year when they occur (year 1, 2, 3…), the effect of inflation has to be included in the discount rate and the so called nominal discount rate should be used. How the two discount rates relate to each other can be seen from the following equation:

$$r_n = r_r + i + r_r * i$$

$r_n =$ nominal discount rate
$r_r = real\ discount\ rate$
$i = inflation\ rate$

3.2 Payback time

Another aspect of an investment that should be paid attention to is how long it takes for the investment to pay itself back e.g. how long it takes for it to start to generate profits. This can be a very important factor relating to the question how the investment will be financed (Ross et al, 2008 165). Calculating payback is a much more crude method of evaluating an investment in comparison to methods such as the NVP and should not be used as the sole decision criteria, but it can still offer valuable information for the decision maker (ibid). For example, in the case where two investment alternatives with different initial investments and cash flows result in the same NPV the payback method would reveal which investment pays itself back the fastest (Narayanan, M. P, 1985, 310). The payback method thus incorporates a preference for the timing of cash flows in the decision criteria (ibid, 314) and can be used as a decision tool if there is a preference for a short payback period.

Payback is computed simply by subtracting each year's cash flow from the initial investment (Ross et al, 2008 164). Once the result is positive the investment is paid back. Commonly the subtracted cash flows are undiscounted in order to exclude the means of financing from the calculation. Commonly a payback period of n years is set by the decision maker as the decision criteria. Any investment alternatives that have a payback time which exceeds the decision criteria are disregarded. Since the initial investment stands for a large part of the cost structure in a wind power investment (see chapter 5.2.1) it creates great pressure on the firm in financing the project. Payback time will therefore be used in this thesis to investigate the differences in the cash flow structures between the alternatives analyzed.

3.3 Risk and Monte Carlo simulation

As demonstrated above, the difficulty in a NPV calculation is not the mathematics but the correct assessment of the empirical data. Since an investment runs for several years it is hard to estimate the cash flows due to that price, market shares, the political environment etc cannot be foreseen with an absolute certainty. Also a correct estimation of the discount rate can be problematic. This uncertainty creates risks that have to be taken into account when evaluating the result of a NPV calculation.

Risk is often defined as a situation where the outcome is unknown, but the possible results and their probabilities can be identified (Debertin, 1986, 303). The probabilities being based on the decision maker's subjective estimations (Hardaker, 1997, 41). Therefore risk is something that can be examined and used to evaluate investments. In contrast there are uncertain events, like natural catastrophes, for which probabilities cannot be issued, and therefore cannot be predicted, and easily used in an analysis (Debertin, 1986, 303).

In order to incorporate risk in NPV calculations different methods can be used. In a *sensitivity analysis* input data associated with risk are varied one at the time in order to examine how this affects the output (Ross et al, 2008, 229). A *scenario analysis* is a further development of sensitive analysis where different scenarios are created varying several inputs at the same time (Ross et al, 2008, 233). Another approach is to conduct a *break-even analysis* where the input values that yield a NVP of zero are sought thus showing the minimum values needed for a profitable investment (ibid).

All of the above methods are frequently used by companies due to their simple approach. However, although they are a means of highlighting some important aspects of an investment, they all represent a rather simplified version of the real world able to show only snap shots of the possible outcomes. A method that attempts to more accurately take into account the complexity of the real world is the *Monte Carlo simulation* (Ross et al, 2008, 237). This method allows for all the uncertain inputs, labeled stochastic variables, to vary at the same time following a probability distribution and covariance that have been specified for each variable (Hadaker, 2004, 158). In this way all the possible outcomes are taken into account and the result is not a single value but a continuous range of possible values with associated probabilities.

The base structure for a Monte Carlo simulation is a regular NVP calculation (Ross et al, 2008, 237-241). This structure is developed further by defining the stochastic variables (ibid). This is done by instead of defining the uncertain variable with its most likely value all the possible values are taken into account and fitted with a probability distribution. Further, when the probability distributions have been defined, the covariance between the uncertain variables are defined (when existing). So, if the values of two uncertain variables are expected to co vary, whether it is positively or negatively, this is defined mathematically in the calculation. The last step of the Monte Carlo simulation is the calculation itself, but in contrast to a normal NVP calculation where the computation is done only once with the expected values as input values, the Monte Carlo simulation runs several computations letting the uncertain variables vary within their defined probability distribution (ibid). Each computation results in a different NPV with a corresponding probability (based on the probabilities of the stochastic variables' values that the computer has randomly picked out). When enough computations have been performed the result represents a continuous range of possible NPVs with corresponding probabilities (Hadaker et al, 2004, 158).

3.4 Interpreting risk and the SERF model

As described in the previous section the Monte Carlo simulation gives a range of values and a probability distribution for the investments NPV. This not only shows the expected and mean NPV but also gives an expression for the amount of risk that is associated with the investment. There are two measures of risk that are revealed by the simulation results. The first is the probability for the NVP to be less than 0 (P<0), which is the measure of the likelihood of the investment being unprofitable (Persson & Nilsson, 1999, 168). The smaller the probability is, the less the risk in the investment. The second measure of risk is the standard deviation which quantifies the variation of the possible NVPs from the mean (ibid). The larger the standard deviation is, the more risky the alternative is in that the most likely outcomes are spread on a large range.

But what is the proper amount of risk? For a NPV calculation there is a simple rule for deciding if the investment is profitable or not: if the NVP is equal or larger than 0, the investment is profitable and should be pursued. In contrast, for risk there is no such decision rule for what is the allowed amount of risk. The amount of risk an investment can contain depends on the decision makers risk preferences. This is so because although all people are expected to be economically rational in that they prefer more wealth to less not all have the same preference to risk. Some are risk averse and therefore willing to exchange some of their wealth for less risk and some are risk neutral prepared to take great risk in the hope of gaining more wealth (Hardaker et al, 1997, 93). Different decision makers might therefore choose differently between the same options. It is therefore not possible to determine if an investment with high profits and risk is better than one with less profit and risk unless the decision makers risk preferences are known.

There are ways of uncovering a decicion makers preferences in respect to outcome and risk and define them mathematically. This is called the decicion makers utility function (Hardaker et al, 2004, 35). But defining a utility function is a difficult task and an impossible one if there are more than one decision maker (Hardaker et al, 2004 140). Another method for ranking risky alternatives is to use a so called efficiency criteria. This is a method that can be used when no utility function can be defined for the DM (Hardaker et al, 2004, 140).

There are several different methods for efficiency analysis, one of them being *stochastic efficiency with respect to a function* (SERF). This method is based on comparing the certainty equivalents (CE) of alternatives for different levels of risk aversion where the alternative with the highest CE is preferred. The method has its strength in that all alternatives can be compared at the same time in contrast to the more commonly used *stochastic dominance in respect to a function* (SDRF) (Hardaker et al, 2004, 155). In SDRF the comparison is done pair wise thus often resulting in a larger pool of efficient alternatives than the SERF does (ibid).

In order to use an efficiency criteria assumptions must, however, be made about the form of the utility function to be used as well as the boundaries of the amount of risk aversion that will be analyzed (Hardaker et al, 2004, 140). Though there are many different utility functions, experience has shown that in practical application the choice of utility function has little effect on the result of the efficiency analysis (Hardaker et al, 2004, 153). Therefore a negative exponential utility function is often chosen due to that it is easy to use in mathematical applications (ibid). The range for the risk aversion should be defined so it is relative for the analysis (ibid). For example the boundaries for risk aversion from 0,5 to 4 proposed by Andersson and Dillon could be used where 0,5 is very risk averse and 4 is risk lover.

The function used to calculate the CE of alternatives in the SERF method is as follows:

$$CE\big(w, r_a(w)\big) = ln\left\{\left(\frac{1}{n}\sum_{i}^{n} \exp\left(-r_a(w)w_i\right)\right)^{-1/r_a(w)}\right\}$$

$CE = certainty\ equivalent$
$w = wealth$
$r_a(w) = absolute\ risk\ aversion\ coefficient$
$n = number\ of\ risky\ alternatives$

(Hadaker et al*, 2004, 257)

By varying the absolute risk aversion coefficient within the predefined range the CEs of each alternative are calculated corresponding to each level of risk aversion. The CEs are then compared to each other revealing which alternative has the highest value and thus is the most efficient for a particular level of risk aversion (Hadaker et al*, 2004, 258). The preferred choice can vary between levels of risk aversion giving different efficiency sets for DMs with different risk attitudes (Hadaker et al, 2004, 154-155).

4 Background

This chapter gives a short presentation of the historical development and present stage of the Finnish wind power industry. It also gives some background information of the wind power project in the Finnish inland analyzed in this thesis.

Finland is one of the European countries that have lagged behind in the development of the wind power industry and here too the critics point to an insufficient energy policy with an inadequate support system (www, Ilmasto, 2010; www, Vihreät, 2010). The first national wind power program was already formed in 1993 and then renewed in 1999 with a concrete goal of 500 MW wind power capacity in 2010 (www, Ilmasto, 2007). The failure to form a consistent energy policy has however led to that there were only 117 wind power stations with a cumulative capacity of 146 MW in Finland in the end of 2009 (www, TY 1, 2010). A restructuring of the energy policy was made in 2008 with a new ambitious goal of producing 6 TWh with wind power in 2020, which corresponds to an increase in wind power capacity by 2 100 MW (TE 1, 2008, 50). In order to be able to reach this goal the Finish government is restructuring the support system for wind power and the current proposition is to replace the investment subsidy with tariff prices for wind power stations undertaken from 2009 and forward (TE 2, 2009, 5-6). These types of tariff price systems have proven to be very successful in other countries such as Denmark, Germany, and Spain (www, Global feed in tariffs, 2010). A decision on the new support system will be taken by the government sometime in the year 2010.

Wind power production in Finland is currently focused to the vicinity of the coast where the wind conditions have proven to be favorable (www, TY 1, 2010). Only a few exceptions have been made where stations have been built in the ocean and on the mountains of Lappland where the wind conditions are found good (ibid). The lack of a well developed infrastructure causes however an increase in investment costs. This has resulted in that no larger ventures have yet been taken in these areas. In contrast, the fact that no bigger investment in wind power has been made in the inland is due to weaker wind conditions.

This might, however, change in 2011 when Finland's first megawatt sized inland wind power station is built. It is three farmers in Southern Savo that have come together with the local energy company and started a corporation, Saimaan Woima Oy, with the aim of building two 3 MW wind turbines in the middle of the forest in the Finish sea district. The energy company, SuurSavon Sähkö Oy, has previously made investment assessment for a wind power station in the area but found at the time the investment to be unprofitable (pers. Lohja, 2010). Now, a new attempt is made based on the beliefs in Saimaan Woima that the technical development of wind turbines in combination with an optimal location can results in a profitable investment.

The three farmers are organic dairy farmer with an interest in developing their companies into sustainable businesses in both an environmental and financial sense. The driving forces for the wind power project are thus to take a step in making the farms self sufficient in energy supply as well as build an economically stable branch which can become a support for the rest of the operations in the farm companies (pers. Grotenfelt, 2010).

5 Wind power

This chapter contains a review of wind power investments. It starts with general information about wind power production and then gives a more detailed literature review of factors affecting the profitability of a wind turbine. The factors detected in the literature review are used as a base when gathering the empirical information presented in chapter 7.

Energy can neither be created nor destroyed; it can merely be transformed from one form to another (The first law of thermodynamics). Producing wind power is thus a process of transforming the wind's kinetic energy to another, for humans more usable form (www, TY 2, 2010; Wizelius & Karlsson, 1992, 23). Today this is usually done with wind turbines that produce electricity. There are several different types of wind turbines but the most commonly used model for commercialized purposes is a three blade horizontal turbine (Motiva, 1999, 11; Wizelius, 2007, 96). The main parts of this model consist of a foundation, a tower, the blades and a nacelle which contains among other things a gear box and a generator (figure 1) (Motiva, 1999, 11; Wizelius & Karlsson, 1992, 18).

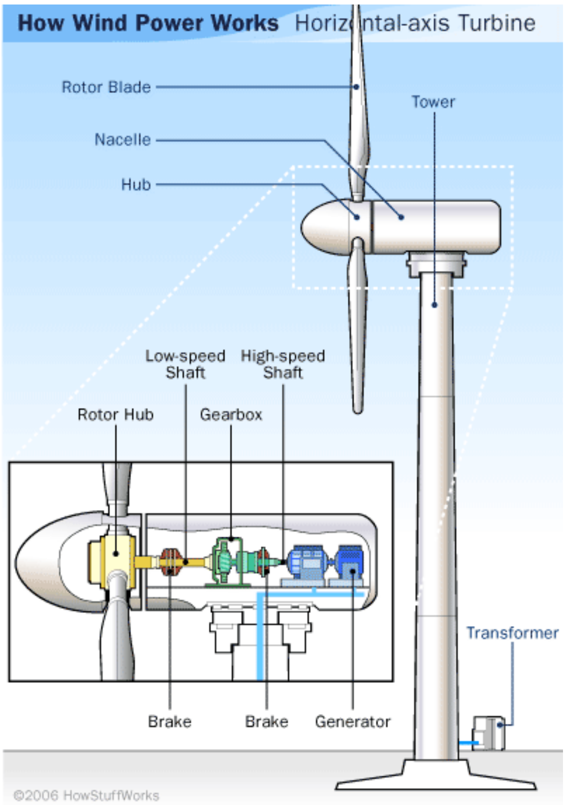

Figure 1. Wind turbine parts (www, How stuff works, 2010)

5.1 Wind power production

The principle of producing wind power is as follows: The power in the wind pushes the rotor blades and puts them into motion. The slow rotational movement of the blades is then led into the nacelle where the gear box increases the speed in order to meet the requirements of the generator, which in turn produces the electricity. The electricity is then transported down the tower, through a transformer and out on the grid.

The most significant factor affecting the amount of energy a wind turbine can produce is how much power there is available in the wind for transformation (Motiva, 1999, 9; Wizelius, 2007, 67). The power is a product of wind speed and the rotors swept area and can be expressed by the following function:

$$P = \frac{1}{2}\rho A w^3$$

$P = power$
$\rho = air\ density$
$A = rotor\ swept\ area$
$w = wind\ speed$

(Wizelius, 2007, 67)

Since the power is a product of the cube of wind speed small changes in the wind speed result in major changes in production capacity (Vaughn, 2009, 36; Wizelius, 2007, 68-69). An extensive investigation of the prevailing wind conditions has therefore to be done before starting to build any turbines (Motiva, 1999, 11; Vaughn, 2009, 36). In this investigation the different wind speeds and their frequency is recorded as well as the direction and the amount of turbulence (Wizelius, 2007, 70). The wind speeds and their frequency are then summarized in a histogram called the frequency distribution of wind speed (figure 2).

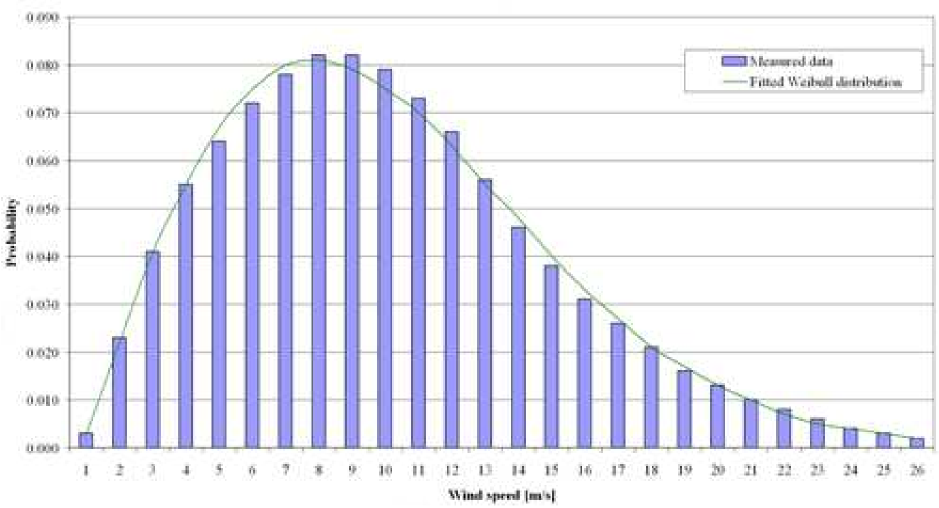

Figure 2. Frequency distribution histogram for wind speeds. (www, WE 2, 2010)

For a site where no prior investigation has been done and where no object of comparison can be found a measuring period up to 5 years is needed for an accurate estimation (Vaughn, 2009, 46). It is however, not economically sound to do a 5 year measuring before starting a wind power project (Wizelius, 2007, 73). Therefore the practice is to measure the wind conditions under 1-2 years and then using these measurements together with measurements from another location to make a normal year adjustment (Wizelius, 2007, 74). The normal year adjustment is done by comparing the wind measurements from the specific site with measurements from the same period for an other location. When choosing a site of comparison it is important that it has measurements from a long time period since the following step is to use the other locations long time average wind speed to adjust the studied sites measurements. This leads to an estimate of the long time average wind speed and a frequency distribution for the site which in turn can be used to estimate the production capacity of different turbines at that specific site.

In addition from the power capacity, the choice of wind turbine determines the energy produced on the chosen site. The height of the tower and the size of the rotor swept area impact how much wind power is captured by the turbine. However, not all of the power can be exploited. Theoretically it is possible for a turbine to utilize 59 % of the power flowing through the rotor (Vaughn, 2009, 36; Motiva, 1999, 10), but in practice the maximum is closer to 50 % (Motiva, 1999, 10). The efficiency of the gear box and generator also vary with the wind speed resulting in the turbine producing different amounts of energy depending on the wind speed (Wizelius, 2007, 147). All of the factors above lead to the fact that each turbine model has a specific power curve which shows how much energy the turbine produces at different wind speeds. The expected production of the site is calculated by multiplying the production curve with the frequency distribution of wind speed (Wizelius, 2007, 150). Thus it is possible to maximize the expected production by matching the optimal wind turbine with the frequency distribution of the site.

The expected production calculated from the frequency distribution and the power curve assumes that the wind turbine is always available for production. This is however not the case in the real world. There are production stops that occur due to failures, repairs and, if nothing else, due to the scheduled maintenances that take place a couple times of the year. Because of this the production is always somewhat lower than the maximum capacity of the site. Production stops at the wrong time have a severe impact on production and therefore it is important to have a high availability. Availability is an expression of the turbines reliability and is an essential factor when choosing a turbine (Vaughn, 2009, 89)). Availability is calculated by subtracting the turbines down time from the hours of the year.

5.2 Economics of wind energy

When it comes to profitability, wind energy differs from many other energy production forms in that the initial investment represents a major part of the investments total life time costs. In general the initial investment corresponds to about 70 % of the total costs for a wind turbine investment (Motiva, 1999, 39). Therefore the profitability of a wind turbine much relies on minimizing the initial investment and maximizing the production. From this follows that reaching profitability is not done by maximizing efficiency but optimizing the relationship between cost and efficiency.

Following in this chapter is a closer description of the cost and income factors that affect both the initial investment and the annual cash surpluses of a wind turbine.

5.2.1 Initial investment costs

The initial investment costs are all the costs that occur from the point of the investment idea to the point where the power station starts to produce energy (Wizelius, 2009, 58).

The wind turbine
The wind turbine itself stands for about 80 % of the initial investment costs for a land based station and is thus the single biggest cost of the whole wind power investment (Motiva, 1999, 39; Wizelius, 2009, 59). Included in the price are usually the work incurred with the

installation and the erection of the wind turbine as well as putting it into operation (Wizelius, 2009, 59). As mentioned above, when choosing the wind turbine it is important to match the prevailing wind conditions to the right wind turbine model so that the turbine utilizes the wind power as efficiently as possible. Also it is important that the wind turbine is reliable so that the availability is high. A match between the price level of the wind turbine with its efficiency and availability is a vital factor in creating profitability in wind power (Motiva, 1999, 39).

A warranty for the first couple of years is usually included in the purchase price as well as a guarantee of availability around 95-97 % for the first 10 years (Motiva, 1999, 13). A service contract of approximately 2 years is normally included, but contracts up to 5 years also occur (Motiva, 1999, 41).

Infrastructure

Prior to erecting the wind turbine it is of course important to build a firm foundation upon which it can stand. The cost of the foundation varies with the chosen model where a bigger turbine requires a more robust foundation. Also a road has to be built to the site to allow for transport of the power station as well as the building equipment (Motiva, 1999, 35). The road has to, for example, be able to carry the mobile crane that is used to raise the wind turbine.

An electrical connection is needed from the wind turbine to the power grid so that the produced electricity can be transported to consumers. For this a transformer is needed to make the current of the produced electricity compatible with the power grid. In larger power stations, over 1 MW, the transformer is often built in to the turbine and the cost is imbedded in the price of the wind turbine (Wizelius, eng, 2007). Whichever is the case a buried cable to the power grid has to be drawn and the work has to be done by a licensed electrician.

In addition a telecommunication line has to be drawn so that the wind power station can be monitored and controlled from remote locations. If a remote control system is not included in the wind turbine price, additional costs for this will occur.

For a smaller wind power station with just a few wind turbines minimizing infrastructure costs has a major impact on profitability (Motiva, 1999, 39). Also, increasing the number of turbines with just one unit lowers the infrastructure costs per unit significantly (ibid). In contrast, more wind turbines increases the transportation and erection costs dramatically (ibid). For larger power plants the infrastructure costs do not have as big an effect due to scale advantage.

Planning

Planning cost include pay for the project planner, fees for permits and such, and any additional investigations that are undertaken, such as measuring wind conditions or exploring the ground composition (Motiva, 1999, 40). The cost of planning varies with the size of the projects, but is normally very small ranging from under 1 % to a few percents (Motiva, 1999, 39).

Other costs

In addition to the wind turbine, the infrastructure and the planning, there are other costs that occur before the wind power station is ready for production. Depending on the location of the planned wind power station there might occur some costs for transportation that is not included in the wind turbine price (Motiva, 1999, 40). Also insurance for the transport and erection time is needed (ibid).

A critical factor for both the planning process and the costs when building the wind power station, is renting the mobile crane that is used for assembling the wind turbines (Motiva, 1999, 106). If weather conditions are unfavorable with high winds at the time of the assembly and the work is thus delayed, the cost for the mobile crane easily becomes large.

In addition to the costs mentioned above there are some costs related to preparations that must be undertaken to make sure that once the power station is taken into use, everything will run as smoothly as possible. For example, the operating personnel will have to undergo training (Motiva, 1999, 39). Depending on the service contract included in the wind turbine purchase there might also be a need to buy the special equipment that is used for the service as well as an initial stock of spear parts and consumables (ibid**).** Finally, to actually be able to send the electricity out on the power grid a contract with the local net owner has to be made including a network tariff paid by the electricity producer (ibid).

5.2.2 Annual operating costs

The annual operating costs occur after the power station has been taken into use and are on a yearly basis only about 2 % of the initial investment (Motiva, 1999, 12).

Service and repairs
Service for the first years of operation is usually included in the wind turbine purchase and therefore the service costs only consist of consumables like oils (Motiva, 1999, 41; Wizelius, 2009, 62). After the first years a service contract should be made with the supplier or some other able actor (Wizelius, 2009, 62). A wind turbine needs to be serviced a couple of times a year to ensure that no unnecessary operating stops occur.

The repair costs are hard to estimate since these are usually not planned events, but they are generally low the first 5-10 years of operation (Motiva, 1999, 41). Also, most repairs are covered by the warranty the first years.

Later on, after 10-15 years, the need for repairs will increase and some parts will have to be replaced all together (Motiva, 1999, p 41). These parts are most likely the gear box, the generator and the blades, and thus the owners should prepare for 1-2 major repairs at this time (ibid). If there is a lot of turbulence on the site, replacements probably have to be done even earlier than this (ibid).

Production costs
As mentioned previously the production costs of a wind turbine are very low since no cost for the “fuel” occur. There is however a couple of costs related directly to the amount of energy produced. For example a fee for the produced electricity is paid to the network owner for the use of the power grid. Also, a cost will occur for the electricity that the turbine itself consumes for heating et cetera (www, WE 1, 2010). Furthermore, the power grid owner usually takes a yearly fee for metering the electricity as well as the losses occurring in the transformer (Wizelius, eng, 2007, 63).

Other costs
The insurance is the single biggest source of costs of the annual costs, being around 25-33 % (Motiva, 1999, 111). Machine, fire and responsibility insurances is needed except during the

first years when a machine insurance is not needed due to the warranty (Wizelius, 2009, 62). Thus the insurance costs are lower the first years.

A telecommunication cost for the remote control system occurs annually. Other administrational costs depend on the size of the power plant and the complexity of the company structure (Motiva, 1999, 42).

Costs for land depends on what land is used. If the wind power station is built on the investors own land, the costs depend on whether or not there is a lost alternative income. If the power station is built on a field, for example, the costs are diminishing, since a wind power station with its foundation only takes up a small area and surroundings can continuously be utilized as before the power station was built (Wizelius, 2009, 60). If the land is leased, an annual rent cost will occur.

A wind power station might also be subject to property tax as well as different kind of environmental and energy taxes (Motiva, 1999, 42; Wizelius, 2009, 63). Some communities also require yearly environmental inspections of the station (Motiva, 1999, 42).

5.2.3 Income

As previously mentioned, the income for a wind power station is based on the wind turbines annual production. But in order to actually make any profit one must get paid for the energy produced.

The basis for payment is naturally the general electricity price which is determined on the Nordic power exchange market, Nordpool (Wizelius, 2009, 64). It is however sometimes possible to make a contract with a power company where a fixed price for several years is agreed upon (ibid).

To make a profitability calculation, the electricity prices during the entire economic lifetime have to be known. It is very hard if not impossible to estimate future energy prices, but most people expect them to keep increasing (ibid).

In addition to the electricity price wind electricity is often subject to additional payment due to its believed positive impact on the environment and other political issues. Add-ons can be in forms of for example electricity certificates, like in Sweden (Wizelius, 2007, 347-350), or tariff prices like in Germany (www, GB1, 2010). Also environmental bonuses or tax reliefs can be used (Wizelius, 2007, 346). Another support system often used is to subsidize the initial investment (www, TT 1, 2010).

5.2.4 Economic lifetime, residual value and discount rate.

Three additional factors that impact the profitability of a wind power project is the expected lifetime of the turbine, its residual value and the demanded return on investment. The technical life expectancy for commercial wind turbines is today 25 years (Wizelius, 2009, 62). In contrast, the economic life time generally used is 20 years (Motiva, 1999, 13; Wizelius, 2009, 26) though there is today not any certainty for this since few larger wind turbines have operated this long. Due to this lack of references and uncertainty of future conditions the residual value is also impossible to estimate why it is left out from wind power investment assessments. The real discount rate generally used for wind power investments is around 5 % (Motiva, 1999, 43).

6 Method

This chapter contains the choice of methods used for this thesis and the sources for the information collected.

6.1 Choice of method

The thesis is a qualitative analysis which aims to investigate thoroughly the economic consequences of Saimaan Woima's wind power project. Therefore a case study approach has been chosen. The choice of method is based on the main characteristics of case study research which are that it is *particularistic*, meaning that it focuses on examining a single phenomenon, and it is *heuristic* thus aiming to increase the researcher's and readers' knowledge of the studied phenomenon (Merriam, 1994, 25-27). Since the purpose of this thesis is to investigate the unique case of Saimaan Woima Oy's wind power project it was essential that the method chosen enables the researcher to collect specified data relating to the project in contrast of using general data that reflects more universal situations. Moreover, a case study is *descriptive*, as it portrays the phenomenon in great detail and depth, and *inductive* since most of the reasoning in a case study is based on the researcher's intuition (Merriam, 1994, 26-27).

Though the thesis is a qualitative study quantitative methods such as the NPV, Monte Carlo simulation, SERF and payback have been chosen to illustrate and quantify the profitability and risk of the investment. Also other quantitative methods such as linear regression have been used to define input variables in the calculations. The risk analysis program @Risk from Palisade Corporation was used to implement the Monte Carlo simulation (www, Palisade, 2010). The other calculations were executed in Microsoft Excel.

Most of the empirical information has been collected following principles of qualitative research. All interviews have been done without a strict interview formula rather following themes of interest and letting the interviewees talk freely about predefined subjects (Ying, 2009, 106). Also the work of collecting and defining the input data has followed a pattern of learning by doing building up the researchers knowledge of needed information as the work has proceeded.

6.2 Sources of data

Information about the turbine itself is based on tenders from the wind turbine manufacturer whereas information about the grid connection is from the electrical company Suur Savon Sähkö Oy. Tenders have also been collected from insurance companies and the local telecommunication company. Most of the contact has been made through mail between either the writer and the companies or Saimaan Woima and the companies.

The information about the wind conditions are based on the wind measurements made at site between 21st of July 2009 and 22nd of May 2010. A normal year adjustment has been done using geostrophic winds in the area from the time 1st of January 1979 to 22nd of May 2010. The data for the geostrophic winds are collected from the Earth System Research Laboratory web site (www, ESRL, 2010). The data is collected and defined by Professor Hans Bergström from Uppsala University. More information of the normal year adjustment is found in chapter 6.3.2.

Five interviews have been conducted. The four first where individual interviews with the owners of Saimaan Woima (Nils Grotenfelt, Anssi Laamanen, Matti Paunonen and Juha Lohja representing SuurSavon Sähkö Oy) in order to collect their perspectives of the investment. The interviews were conducted in person in Juva and Mikkeli in Finland the 8th and 9th of March 2010. Questions such as the driving force for the investment, the required return on equity, financing structure and already existing cost information was discussed. The last interview was a telephone meeting with all the four owners conducted the 28th of May 2010. The purpose of the meeting was to go through all the collected input data in order to verify their relevance for the investment.

7 Empiri

This chapter contains the empirical information and input data that was used for the analysis of the wind power investment. It gives a detailed description of all the input data and how they were defined. If nothing else is indicated, all the information in this chapter is in real terms.

7.1 Investment costs

The total investment cost for the two wind turbines accumulated to approximately 8,2 € million. A list of all the investment costs is found in table 1 followed by a more detailed description.

Table 1. Investment costs

Source	**Cost (€)**
Wind turbines	6 680 000
Foundation	78 000
Road	20 000
Telecom network	20 000
Electrical grid	632 500
Project planning	14 866
Lawyer	5 000
Training	32 750
Other costs (10%)	748 312
Total	8 231 428

1. The wind turbine, 6 680 000 €
   The cost is based on a tender from a wind turbine manufacturer (pers, Grotenfelt, 2010). In addition to the turbine cost the tender included parts of the foundation, transportation to the location, the assembly and the internal electrical work, as well as insurance for the transportation and erection period.
2. Foundation cost, 78 000 €
   A part of the foundation is included in the tender for the wind turbines (pers, Grotenfelt, 2010). The remaining cost is an approximation of Saimaan Woima for the cost of building the concrete platform upon which the foundation will be fixed (pers, Saimaan Woima, 2010).
3. Road costs, 20 000 €
   The road costs are minimal due to the fact that there already is an existing road to the site and only minor improvements are needed (pers, Laamanen, 2010). The costs are approximated by Saimaan Woima.
4. Telecommunication network, 20 000 €

A new telecommunication network has to be built to the area in order to meet the requirements of the turbines´ remote control system (pers, Grotenfelt, 2010). The cost is based on a tender from a local telecommunication company.

5. Electrical grid, 632 500 €
   The electrical network in the area has to be upgraded in order to be able to receive the produced electricity (pers, Lohjala, 2010). The cost is based on information from the grid owner Suur Savon Sähkö.
6. Project planning, 14 866 €
   A part of the project planning is done by an outside company which has given a tender to Saimaan Woima (pers, Laamanen, 2010). The costs included from the tender in the NVP calculation are inspection of the turbines both before and after erection. Other costs included in the tender are sunk cost at the time the thesis was written and is therefore not included.
7. Layer, 5 000 €
   A layer will be hired to draw up contracts for Saimaan Woima. The cost of which is approximated by Saimaan Woima (pers, Grotenfelt, 2010).
8. Other costs, 748 312 €
   In addition to the costs mentioned above an extra post of “Other costs” with the value of 10 % of the above costs was added due to the request of Saimaan Woima (pers, Saimaan Woima, 2010). This post will cover some unexpected costs as well as minor costs which have not been displayed separately above.

7.2 Annual operating costs

The annual operating costs are hard to define specifically for Saimaan Woima´s wind power project due to the fact there are no objects of comparison in the area. Therefore a lot of the cost information is based on national assessments collected from literature and discussions with people working in the industry. A list of the annual operating costs is found in the table 2 followed by a more detailed description.

Table 2. Annual operating costs

Source	Time	Cost
Service contract		
	Year 1-2	6 €/MWh
	Year 3-5	10 €/MWh
	Year 6-	812 €/MWh
	Year 9-10	15 €/MWh
Service costs		
(without contract)		14 €/MWh
Insurance		
(when guarantee)		11 268 €/a
(when no guarantee)		38 032 €/a
Grid payment		0,3 €/MWh
Intern consumption		1 600 €/a
Administration		1 000 €/a
Telecommunication		1 000 €/a
Energy balancing		2 €/MWh
Land cost		0 €/a
Property tax		1,6 €/MWh

- Service contract, 6-15 €/MWh
  The wind turbine manufacturer offers a service contract for the first 10 years of the turbines lifetime (pers, Grotenfelt, 2010). Under this time both the scheduled maintenances and the needed repairs are included in the price. Also the remote control system is included in the contract. Under the time a service contract is running there is a guarantee on the turbines and also major repairs such as replacing the rotor blades and the transformer are included.
- Service costs, 14 €/MWh
  An approximation of the service costs is needed for the years when no service contract is running. There is little information of actual service and repair costs for wind turbines in Finland. The figure used in this thesis is an approximation that, according to Yrjö Halttunen at FCG Planeco, is generally used in Finnish wind power investment calculations (pers, Halttunen , 2010).
- Insurance 11 268/38 032 €/MWh
  The insurance costs are based on a tender from a incurance company with prior experience of insuring wind turbines (pers, Grotenfelt, 2010). When a guarantee is running no insurance for machinery brake down is needed and therefore the insurance cost is lower the first years.
- Grid payment, 0,3 €/MWh
  Suur Savon Sähkö will charge Saimaan Woima 0,3 € for every MWh it sends out on the grid (pers, Lohja, 2010).
- Intern consumption, 1 600 €/a
  Wind turbines always consume some energy for example for heating and control systems (www, Wind energy the fact, 2010). When the turbine is not producing any energy itself, it takes the electricity from the grid. The wind turbine manufacturer

approximates the intern consumption to cost 800 € per year for one turbine (pers, Grotenfelt, 2010).

- Administration, 1 000 €/a
  The approximation is based on information from the governments wind power production cost calculation which is used as the basis for constructing the tariff price proposal (TE 2, 2010).
- Telecommunication, 1 000 €/a
  The telecommunication cost is based on an estimate by Saimaan Woima (pers, Saimaan Woima, 2010).
- Energy balancing, 2 €/MWh
  Since wind power production is relies on weather conditions, a factor that cannot be controlled, the energy companies have to make estimates on the expected production for the coming day in order to be able to calculate how much energy is needed from other sources (pers, Lohja, 2010). If this estimate is wrong and more energy is needed than estimated, the energy company has to buy this extra energy and for this they charge the wind producers (ibid). The estimated cost of 2 € per MWh is based on the governments wind power production cost calculation mentioned above (TE 2, 2010).
- Land cost, 0 €/MWh
  Since the land the wind turbines will be built on is owned by one of the owners of Saimaan Woima, no costs for land use will occur (pers, Saimaan Woima, 2010).
- Property tax, 1,6 €/MWh
  The estimate for the property tax is based on the governments wind power production cost calculation (TE 2, 2010).

7.3 Income

In order to calculate the income the annual production and the price of electricity is needed.

7.3.1 Electricity price

The future price of electricity is very hard to predict since it is not expected to follow any historical movements. Often expert estimates are used as a base for setting future prices in investment calculations. In this thesis results from a scenario analysis is used. The analysis is made by Power Deriva OY, an organization working with analyzing the electricity market, and it examines the development of the Nordic electricity market for the coming 20 years (Power Deriva, 2009).

The analysis is based on a complex computer model that incorporates several different factors affecting the electricity market such as future demand, the neighboring countries market development, building of new grids to other market areas and the development of other electricity production forms (Power Deriva, 2009). It uses a base scenario, BASE, built on certain assumption giving the expected electricity price for the Nordic market the coming years. A sensitivity analysis is then developed changing the assumption and creating three other possible scenarios. These scenarios are called LOW, BASE2 and HIGH. For this thesis three scenarios are used, BASE, LOW and HIGH. These scenarios show the effect on the electricity prices in the case of an expected market development, in the case market changes lead to a slower price development and in the case they lead to a faster development respectively. The common nominator in these scenarios is that the electricity price is expected go up under the coming 20 years. The prices resulting from these scenarios will not be displayed in this thesis due to that it is confidential information.

7.3.2 Annual production

To calculate the annual production the long term frequency distribution of the location's wind speed, the production curve of the turbine and the availability of the turbine is needed. The annual production is best estimated with specially programmed computer software like $WA^{S}P$ (Motiva, 1999, 32). The input data in these software's are the wind measurements at the location taking into account all factors such as wind speed, duration of each wind speed, turbulence and wind direction. The programs are very complex and even with a powerful computer it takes several days to finish the calculations. Since the wind measurements at Loukeenvuori were only recorded during a limited time (five months) at the time that this thesis is written, this estimation is not done due to limited resources. Instead a simpler normal year adjustment that only accounts for wind speed and duration is done by the author. The long term frequency distribution is thus a result of a normal year adjustment based on a comparison of the measured wind speeds from the Loukeenvuori with wind speeds at a reference point.

Long term frequency distribution
The wind measurements started at Loukeenvuori the 21st of July 2009 and the wind speed and direction has been recorded for every ten minutes. The measuring mast was, however, at the starting point only 50 meters high, half of the planned hub height. It was the 18th of December 2009 that the mast was lifted to 100 meters. Therefore the measured wind speeds used for predicting the annual production at Loukeenvuori are only from approximately 5 months from the 18th of December 2009 to 22nd of May 2010 (the date when the calculations for this thesis were finished). It should be noted that the mast was down during the period 12th of January to 10th of February, so no measurements exists form this period. The reference winds used in this thesis are the geostrophic winds from the coordinates 28.333:31.667 (www, ESRL, 2010). The data on the geostrophic winds are mean wind speeds from every sixth hour for the period 1 of January 1979 to 22 of May 2010.

In more detail the normal year adjustment has been done by the following steps:

1) Wind measurements from 100 m at Loukeenvuori have been compared with the geostrophic winds in the period 18 of December to 22 of May with a simple regression analysis. This resulted in the regression function

$$Loukeenvuori = 4{,}60 + 0{,}325 * Geostrophic$$

$$Loukeenvuori = wind\ speed\ at\ 100m\ at\ Loukeenvuori$$
$$Geostrophic = wind\ speed\ of\ the\ geostrophic\ winds$$

with R(sqr)=25,1 %.

2) The geostrophic winds from 1 of January 1979 to 22 of May 2010 have been transformed to the equivalent wind speeds at Loukeenvuori with the regression function.
3) A long term frequency distribution function was generating by summing the resulting wind speeds.

Due to the fact that the regression function disregards wind speeds less than 4 m/s an adjustment to the resulting wind speeds has been done. The measured wind speed at Loukeenvuori was 13 % of the time under 4 m/s during the measurement period. Therefore all wind speeds resulting from the normal year adjustments have been deducted with 13 % in order to correct that the adjustment only result in wind speeds of 5m/s of higher.

Availability
The availability for the turbine was based on down time data from the Finnish statistical data base for wind power maintained by Finland's technical research center, VTT (Holttinen, 2008, 2/1-2/3; Holttinen & Stenberg, 2009, 2/1-2/3; Stenberg & Holttinen, 2010, B/1-B/3). The availability for 1 MW wind turbines or larger from the year 2007 and forward was collected. The reason that data only from wind turbines equal to or larger than 1 MW were used is that the size of the turbine follows closely the development of turbine technology. Therefore wind turbines under 1 MW were judged by the author to be built on technology not relevant for the study. Further, that data was collected from the year 2007 and forward was simply because wind turbines of that size hardly existed in production before 2007.

The collected data resulted in 130 observations. Some observations were eliminated, however, due to that they had values either more than 30 % or equal to 0. The reason down time observations equal to 0 were eliminated was because it is highly unlikely these values are true. If nothing else, there should be some down time due to scheduled maintenance. The reason observations with down time more than 30 % was eliminated was that the turbines with a down time that high probably have some larger defect and can be judged as a random event that should not be included in the investment calculation. These limitations resulted in that 125 observations were left for calculating availability for the turbine. A final comment on availability is that it would have been preferable to calculate the availability for the particular wind turbine model used for the project, but not enough observations existed at the time to give a result with any statistical meaning.

7.4 Economic lifetime and discount rate

The economic lifetime was defined as 20 years according to both the information given in wind tubine manufacturers tender and wind power literature (pers, Grotenelt, 2010; Motiva, 1999, 13; Wizelius, 2009, 26). There is, though, no real life observation of the actual economic life time since no wind turbines with over 1 MW effect has been operating that long. The 20 year life expectancy is instead based on the expected endurance of the turbine construction and technology (pers, Lohja, 2010).

The discount rate was based on a loan share of 75 % with a loan rate of 5 % (pers, Grotenfelt, 2010). Three different required nominal returns on equity (RROE) were defined: 8 %, 10 % and 17 %, due to that the four project owners seemed to have slightly different expectations for the investment. Grotenfelt (2010) based his RROE of 8 % in that that was the return he got from other of farm investments. Lohjala (2010) on the other hand based his RROE of 10 %

on that that was the return that was required for SuurSavon Sähkö OY's other operations such as operating the grid. The RROE of 17 % is a construction of the thesis writer based on the initial results of the Monte Carlo simulations.

Using the function described in chapter 3.1.5, $r = a * b + (1 - a) * c$, where a=0,75 (share of loan), b=5% (loan rate) and c= 8%, 10% and 17% (owners required return on equity) gives a nominal discount rates of 5,75, 6,25 and 8 respectively. With a long term inflation of approximately 2 %, which is the goal of the European Central Bank (pers, Rouhiainen, 2010), the real discount rates become 4,70, 5,20 and 6,93 respectively.

7.5 Support systems

At the moment there are two support systems available for wind power investments in Finland. The first is a government subsidy for the initial investment which in theory can amount up to 40 % of the initial investment (www, TT 1, 2010). In practice, though, the amount has been somewhere between 20-35 % (ibid). This support system also includes a tax return for sold electricity. The nominal amount of the tax return is 6.90 €/MWh. In the NPV calculations the tax return has been transformed to a real return using the inflation rate of 2 %.

The second support system is a feed-in tariff for electricity prices which is under construction within the government right now and a decision about the amount and duration of the tariff prices will be taken sometime in the year 2010. The current proposition is that the tariff price would be 83,5 €/MWh for the first 12 years of production (TE 3, 2009, 20). No correction for inflation will be done on the tariff price under this period meaning that the suggested tariff prices are nominal. Therefore the tariff prices have been adjusted with an inflation rate of 2 % to produce real tariff prices which have been used in the NPV calculations. In addition the proposition includes a suggestion of a quick start bonus for those investors that initiate their wind power project within the first three years from that the new law is implemented (ibid). The amount of this quick start bonus is a tariff price of 103,5 €/MWh and would be paid for the first three years of production. Also this amount has been adjusted with a 2 % inflation rate.

All wind power investments over 1 MW initiated from 2009 and forward will be eligible for the tariff prices support system. However, investments initiated between 2009 and the date when the new law will be taken into use have the possibility of choosing between the two support systems of either the initial investment subsidy or the tariff price. In addition to the governmental subsidy, Saimaan Woima can apply for a separate investment subsidy from a local energy foundation, Energiasäätiö, which supports the local development of new energy technologies (pers, Grotenfelt, 2010).

7.6 Defining the stochastic variables

In order to use the stochastic variables in the NPV calculation the possible values and their probabilities have to be defined. The majority of the input data for the NPV calculation in this thesis are static variables, in other words they are fixed within the assumptions set for the calculations. There are, however, four variables that can vary within the assumption and are therefore defined as stochastic variables. These values are *the government investment subsidy*, *the annual production*, *the availability* and *the electricity price*. Below is a description on how these variables were defined. No co-variances were defined for these variables since no connection between the variables movements were assumed.

In defining the possible values and their probabilities for the stochastic values the program @Risk's functions "Fit distribution" and "Define distribution" have been used. The first function "Fit distribution" was used to create a distribution for the annual production and down time. Here all the observations for each variable were taken and by using the @Risk distribution fitting program a distribution was defined for the variables (@Risk manual, 2010). For the annual production the lowest value was set to 0 and the highest was defined as "fixed, but unknown". The expected value was set to the mean of the data set. The lower limit for the down time was set to 0 and the highest to 0,3. The expected value was set to the mean of the data set, 7,09 %. The distributions fitted to the two variables as illustrated in @Risk can be seen in the following figures (figure 3 and figure 4).

(the figure has been consealed due to confindental information)

Figure 3. Probability distribution for the stochastic variable "Annual production"

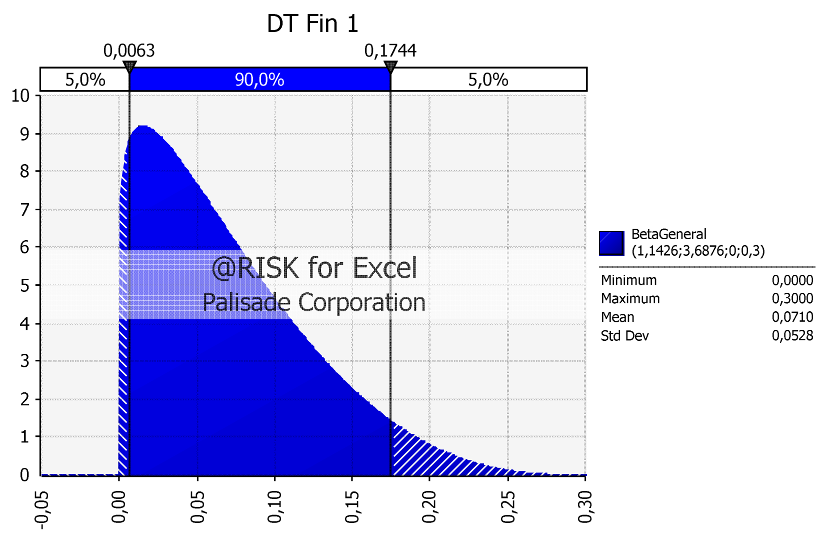

Figure 4. Probability distribution for the stochastic variable "Down time"

For the variables *government investment subsidy* and *electricity price* there was no pool of observations for which a distribution could be fitted, so instead the function "Define distribution" was used. Here the form of the probability distribution is predefined for the variable and the possible range of values is defined by the user according to the characteristics of the variable (@Risk manual, 2010). For the *government investment subsidy* the distribution "Uniform" was chosen due to the fact that each value given was equally likely to occur. The distribution was defined whit the lower limit of 0,2 and highest of 0,35 relating to the fact that the subsidy could be 20-35 % of the investment. The expected value was set to 30 %. For the *electricity price* a normal distribution was chosen due to the fact that phenomena like the electricity price often varies in the form of a normal distribution. The distribution was defined by its mean, which was each years' expected electricity price defined by Power Deriva's scenario analysis, and the variance, which was 9,6. The variance was estimated from a simple regression done on the observed electricity spot prices in Finland from the last nine years, 2000-2009 (www, NordPool, 2010). The resulting regression equation is:

$$Spot\ price = 1{,}71 + 3 * Year$$
$$Rsq(adjs) = 58{,}7\%$$

The distribution curves as illustrated in @Risk can be seen in the two following figures (figure 5 and figure 6).

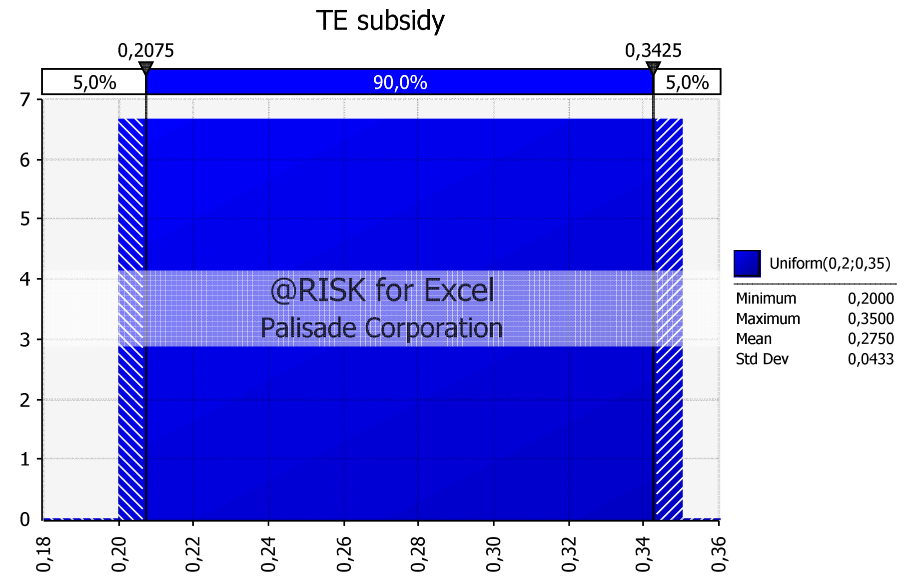

Figure 5. Probability distribution for the stochastic variable "Government investment subsidy"

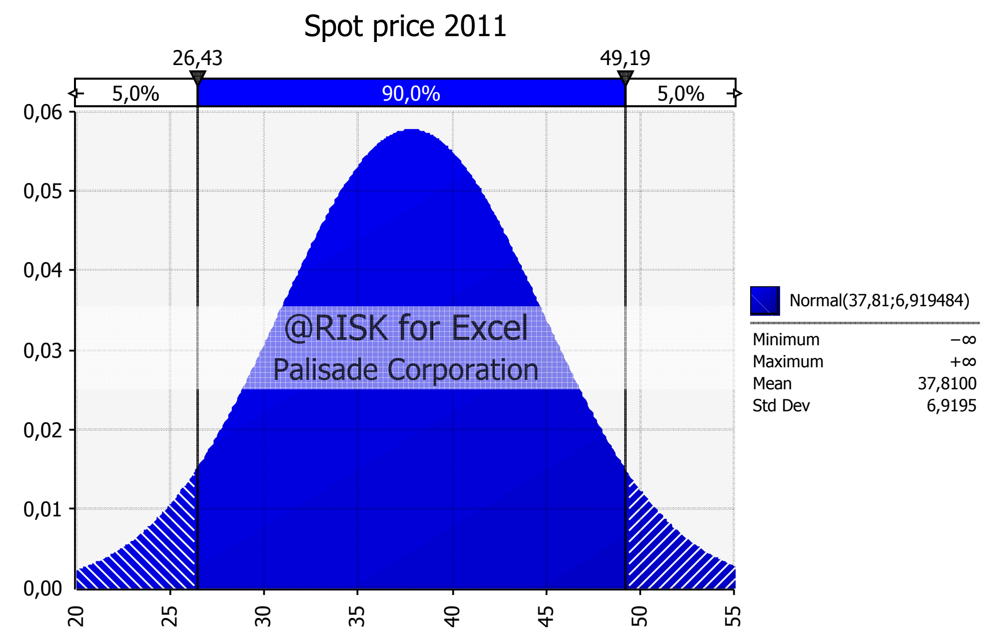

Figure 6. Probability distribution for the stochastic variable "Electricity prices"

8 Results and Analysis

This chapter presents the results of the net present value calculations done as a Monte Carlo simulation, the payback time calculations and the SERF model. It also contains an analysis of the presented results. It first analysis the relation between the different scenarios using only the calculations based on a required return on equity (RROE) of 10 % taking into account both profitability and risk. This is followed by an examination of how the choice of RROE affects the profitability of the investment. The chapter ends with an analysis of the payback time.

The NPV calculations for this thesis are done in @Risk with 5000 iterations. The input variables are based on the information presented in chapter 5 and three discount rates are used; 4,70, 5,20 and 6,93 responding to a required return on equity (RROE) of 8 %, 10 % and 17 % respectively. In the SERF model a range of relative risk aversion of approximately 04 to 4 was chosen. Eight different scenarios were examined:

1. Sub BASE
   A scenario based on the support system with a government investment subsidy. The electricity prices are according to the scenario BASE and the subsidy from the local energy foundation is set to 15 % of the investment costs.
2. Sub LOW
   A scenario similar to the previous with the exception that the electricity prices follow the scenario LOW.
3. Sub HIGH
   A scenario similar to the two previous scenarios with the exception that the electricity prices follow the scenario HIGH.
4. Tariff BASE
   A scenario based on the support system with tariff prices and electricity prices that follow the scenario BASE. The subsidy from Energiasäätiö is 15 % of the investment costs.
5. Tariff LOW
   A scenario similar to the previous with the exception that the electricity prices are based on the scenario LOW.
6. Tariff HIGH
   A scenario similar to the two previous scenarios with the exception that the electricity prices are base on the scenario HIGH.
7. Tariff NO
   A scenario similar to the fourth scenario with the exception that the tariff prices do not include a quick start bonus.
8. No SUPP
   This scenario does not include any type of investment support, neither from the government nor the local energy association. It is based, similar to the BASE scenarios, on the expected development for electricity prices.

8.1 Results of the Monte Carlo simulation

(the contents of this chapter and the following have been consealed due to confidential information)

8.2 Analysis of profitability and risk with regards to the results from the Monte Carlo simulation and the SERF model

8.3 The effects of the required return on equity (RROE)

8.4 Payback time

9 Conclusions

This chapter presents the conclusions that are made from the analysis in chapter 8.

The aim of this thesis was to develop a method of analyzing the economic feasibility of a wind power investment in regards to profitability and risk. The developed model included a net present value calculation run in a Monte Carlo simulation with specifically defined stochastic variables. This simulation resulted in an illustration of the investment profitability with associated probability. It also highlights the most important risk factors in a sensitivity analysis. The model was further developed with the stochastic efficiency in respect to a function (SERF) which enabled a ranking between the alternatives in respect to both profitability and risk. The specific characteristic of a wind power investment of being capital intensive gave further incentives to also include a payback time calculation in the model.

Further, the aim was to use the developed model to investigate the profitability and economic risks involved in Saimaan Woima Oy´s wind power investment.

The main conclusions regarding Saimaan Woima's wind power investment in this thesis are:

- With a require return on equity of 8 or 10 % the investment is profitable for all but one of the scenarios. The exception is Sub LOW that not only has a very low expected NVP but also has high probabilities for the result to be negative.
- Even with a required return on equity as high as 17 % all scenarios but Sub LOW seem feasible. The probability for scenario Sub BASE to result in a negative NPV has risen to 20 % with the higher required return on equity. This is probably an acceptable risk for most investors, but it indicates that the alternative does not give room for a much higher required return on equity.
- Even though the investment shows strong signs of profitability, it would not be feasible without government support.
- The support system based on tariff prices is to prefer to the government investment subsidy (for all except close to risk neutral investors). A result generated by the fact that the tariff price alternative has lower dispersion, less stochastic variables, a shorter payback time and higher probabilities for profitability.
- The subsidy based support system is only interesting in the case that the electricity prices follow the scenario HIGH. And even then there has to be no quick start bonus in the tariff price alternative for it to be interesting for anyone except risk neutral decision makers.
- The largest risk factors differ between the two alternatives. For the subsidy based alternative the major risk factors are the investment subsidy itself and the electricity price of the early years of production. Factors that are completely eliminated from the tariff price alternative. For the tariff price the risk factors consist instead of the remaining stochastic variables that are production, down time and the electricity prices of the last years of production.

An important fact to keep in mind when contemplating the analysis and conclusion of this thesis is that the results are based on several assumptions (presented and constructed in chapter 7). It is only if these assumptions hold that results are relevant. Special attention should in this thesis be given to the estimation of the annual production. Estimating future wind conditions and production is a complicated procedure that due to restrictions in time, knowledge and equipment has been simplified in this thesis. It thus follows that any addition information on the production should be taken into consideration and weighted in when considering the results of this thesis.

10 Discussion

This study has developed a model for analysing the profitability and risk in a wind power investment and used this model to analyze the economic feasibility of Saimaan Woima Oy's wind power project. The Monte Carlo simulation has proven to be a simple way of applying the effect of several risky factors in the same calculations. Though the variables themselves were hard to define and finding the most suitable empirical data wasn't straightforward, implementing the input data in the program was quite easy. This thus confirms Montes and Martins (2007) conclusions that statistical methods such as the Monte Carlo simulation would be appropriate for the analysis of an investment of this kind. Making it possible to insert lots of information in the model but still producing easily understandable results seems to be the strength of the Monte Carlo simulation. The method gives comprehensive results that increase the decision makers understanding of the possible outcomes in a project. The development done in this thesis to complement this method with the SERF model further clarified the overview of the investment alternatives.

The analysis of this thesis has concentrated to investigating a limited amount of the variable factors in a wind power investment. These are the economic input and output prices, the annual production and the availability. Further research could go even deeper in the analysis and expand it with factors such as the efficiency factor of the turbine, turbulence effects and year to year variability in mean wind speed. It would also be interesting that instead of doing a separate annual production evaluation, which was done in this thesis, to integrate the calculation into the Monte Carlo simulation using the model suggested by Kwong (2010).

The aim of this thesis was not to produce generally applicable profitability and risk results for wind power projects or even to compare Saimaan Woima Oy's wind power project with others. The results are however somewhat surprising in that they show strong possibilities for a profitable investment. It would therefore be of interest to try to analyze what this is based on. Is it based on good wind conditions on site, a stronger than expected support system or a favourable tender from the wind turbine manufacturer? After all the Finnish wind power association has commented on the new support system not to be adequate enough for assuring feasibility for inland wind power investments (TY 4, 2010).

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