NORGES HANDELSHØYSKOLE

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RISKY BUSINESS

The impact of the economic crisis of 2008 on renewable energy investments

in Canada and Norway

Master thesis

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NORGES HANDELSHØYSKOLE

ABSTRACT

The economic crisis of 2008 brought uncertainty to all markets. As credit markets experienced growing constraints on liquidity, debt financing became increasingly difficult to find. This had a greater impact on some industries than on others. In the summer of 2008 wind power and solar power were closer than ever before to being economically viable due to soaring energy prices. RE investments are characterized by a high degree of debt financing and high risk exposure, and when the energy prices started to decline, a credit squeeze put renewable energy (RE) investments to a full stop.

A discounted cash flow analysis and a subsequent sensitivity analysis of the critical parameters show that the profitability of RE projects is sensitive to changes in the investment cost and the electricity price. Due to high investment costs, changes to e.g. commodity prices are expected to have a great impact on the economic viability of RE projects. Political incentives targeting the price, at which the electricity generated from renewable sources can be sold, will also be successful.

Low interest rates have contributed to lower financing costs for RE projects. However, the crisis brought increased uncertainty and higher risk exposure to all industries. This uncertainty caused the total costs of financing to increase due to demands for higher equity shares and larger risk premiums. This has affected the profitability in the RE sector more than the reduction of risk free interest rates.

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Hedda Høyer

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CHAPTER 1: INTRODUCTION

Why is the topic of renewable energy investments interesting and important?

A few years ago, climate change and environmental concerns were at the top of the agenda. Al Gore's "Inconvenient Truth"[1] shocked us all back to the reality of our planet's state, and the idea of an anthropogenic[2] climate change gained increasing support. Subsequently, however, something else caught our attention and the dream of a carbon-free future seemed to collapse together with Lehman Brothers, Freddie Mac, and Fannie Mae. Does the economic crisis mean that climate change is no longer important? In the following, the interplay between the two crises; climate and economy will be discussed. Does attention to one necessarily exclude the other? Is fixing the economy more important than fixing our planet?

Whose problem is this anyway? Are governments responsible or should private investors solve the crises? The global climate crisis is an example of what economists refer to as the 1/n problem. It affects us all, but in order to solve the problem, we have to work together, since a single citizen has little impact alone. This thesis will investigate the business case for investing in renewable energy, and discuss whether or not other motives for investing in these technologies may exist.

Today, there is only one thing we know for sure about the future and that is what the future is *not*. The future is *not* business as usual, and the future is *not* fossil fuels in the way these resources are exploited today. As the share of energy generated from fossil sources, it creates a potential for RE energy technologies to play a more significant role in the future energy mix. This makes it important for any company, politician or individual that wants to survive over time in the energy industry to look towards the future and take part in the race that is developing. That is why we should care about this topic: we have no other choice.

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[1] *An Inconvenient Truth* is a 2006 documentary film about former U.S. presidential candidate Al Gore's campaign to educate citizens all over the world about global warming.

[2] Man-made

1.1 Purpose, hypothesis and research question

The purpose of this thesis is to study the effects of the world economic crisis on investments in renewable energy (RE). The current situation in two oil-producing countries, Canada and Norway, will be assessed. RE projects are characterized by large initial investments and new technology and it seems plausible to expect that some RE investments would be more influenced by liquidity shortages and falling energy prices than investments in more mature technologies or markets. Because some RE technologies are very experimental by nature, this thesis is focusing on two of the more established technologies: wind power and hydroelectricity; as well as one newer technology: solar photovoltaic (PV) electricity generation. The following will discuss the links between the economic crisis and renewable energy investments. Assuming that there is an actual and observable effect on investments due to the ongoing recession, the validity of the standard model predictions as well as ways of capturing the observed effect within the models will also be assessed.

1.1.1 Hypothesis

The renewable energy sector was hit harder by the economic crisis than other sectors due to increased risk and higher risk aversion in investment markets.

1.1.2 Research questions

The topic has been divided into three distinct research questions and sections which will highlight important aspects of the topic:

1. What are the main energy sources and who are the investors in the Canadian and Norwegian energy markets?
2. What does classic economic theory predict about the investment behaviour in this sector?
3. How can we use risk modelling to capture the observed changes in renewable energy investments following the economic crisis?

1.2 Definitions and limitations

The purpose of this paper is to discuss the parameters of the theoretical model and why deviations between what we observe and what the theory predicts exist, rather than to yield specific results. The objective is to study the effects of a *change* in the investment climate in two countries and to see whether or not specific characteristics of the countries dictate how these changes in the environment affect the overall investment in RE technologies. In order to execute the calculations a number of simplifying assumptions are necessary. This means that potential investors in these industries should carry out their own detailed project analyses.

Many RE technologies are still at an experimental stage. The following discussion will focus on the "new renewables" which have gained the most attention in recent years: solar photovoltaics; and wind power generation; as well as one established renewable resource, hydro electricity. Solar and wind power are areas which have been thoroughly researched, and seem to have come a step further toward full viability than most other RE technologies. Both solar and wind technologies have seen significant growth over the last decade and were close to become economically viable before the economic downturn altered the investment landscape.

The first part of this thesis includes detailed information on the Canadian and Norwegian energy sectors that some readers may find overly detailed. However, this thorough presentation of the data helps create a common platform and starting point for the analysis, and is helpful in order to understand the investment climate and challenges relevant to the two countries.

Unless otherwise specified, the currency used in the following is Canadian dollars (C$).

1.3 Broad outline of the paper

This thesis will be organized in three parts. The first section will address the first research question and present an overview of the commonalities and differences between the Canadian and the Norwegian energy sectors. After that, a presentation of the theoretical framework used in this analysis will serve as a common point of departure for dealing with the content of this paper.

The second section will take a look at the predictions from classic economic theory. Within the framework of a discounted cash flow analysis, the economics of six different renewable energy investments is outlined. This offers a first take on analyzing the relationship between the economic crisis and the investment incentives in the renewable energy sector.

In the third section, the results of the investment analysis will be contrasted against financial data and the observed developments in RE investments. The data will indicate a sharper decline in RE investments than for the market as a whole in the second half of 2008. Chapters 6 and 7 introduce risk as an important driver of investment behaviour and discuss ways of capturing this risk in our models. By executing a sensitivity analysis a deeper understanding can be achieved of how the uncertainty in the net present values from chapter 5 can be apportioned to different sources of variation in the input parameters. Furthermore, predictions from real options theory support the observation that risk was the main driver behind the sharp decline in RE investments from the third quarter of 2008. The last chapter includes a summary of the evidence and the thesis conclusion.

SECTION 1: BACKGROUND

Question 1: What are the main energy sources and who are the investors in the Canadian and Norwegian energy markets?

The first part of this thesis presents the framework for the following discussion by presenting the structure of the energy industry in Canada and Norway. The characteristics of three different renewable energy technologies will be presented, as well as the main assumptions of the conceptual framework. This will serve as a common point of departure for the subsequent analysis and discussion.

CHAPTER 2: WHAT ARE THE ALTERNATIVES?

In this first chapter the main concepts of renewable energy as well as the main characteristics of the three RE technologies considered in this thesis will be defined and discussed. It is useful to gain some insight into the main issues related to the energy technologies before analysing them further. For the purpose of presenting the reader with a picture of the renewable energy business that is as complete as possible within the scope of this thesis, a section is included where the most important of the RE technologies that are left out in this paper are briefly presented.

2.1 Definition

What do we mean by the terms *sustainability* and *renewable energy technologies*? This paper will consider technologies that are alternatives to the main energy sources of today, and that are sustainable. Sustainability is usually defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland Commission 1987). Following the work of David Coley (2008, p78) a sustainable energy technology is defined as a technology that is

- contributing little to manmade (anthropogenic) climate change
- capable of providing power for many generations without significant reduction in the size of the resource, and
- not leaving a burden on future generations.

2.2 Technologies

What are the serious alternatives to hydrocarbons? The applications and approaches are numerous, stretching from ways of making our everyday life more energy efficient to finding a way of transforming energy into power with minimal losses and pollution. In order to create a useful discussion, every aspect of the field of sustainable energy cannot be considered. Therefore, this thesis will focus on the technologies and applications that are of the highest relevance for the two countries studied in this paper.

The majority of renewable energy projects are very capital intensive and involve high capital costs. On the other hand, the input resource does not cost anything, making the operating costs lower than for many traditional power generation technologies. RE projects lead to sustainable resource use and environmental benefit as they are much cleaner than fossil fuels. Also, many RE projects involve local employment generation because of the local distribution of such energy sources. Also, RE investments help reducing national energy import dependence, possibly reducing political tensions due to the intense competition for energy resources between states.

2.2.1 Wind power

The energy flowing in the world's winds would be enough to meet the world's primary energy demands. Wind energy is kinetic, or in motion, energy and demands a very simple core technology; the wind turbine.

The costs of wind power generation depend on the size of the wind turbine and the wind speed which varies significantly between different locations. Wind turbines can be placed both onshore and offshore. Offshore turbines can be built much bigger, as there is no problem of disturbing people living close by, but the maintenance costs are higher. The technology of offshore wind turbines has only recently seen commercial use. The wind speeds, at which wind turbines normally operate, are between 2.5 and 25 m/s (Gül & Stenzel 2005). This makes wind power unavailable not only at times with low wind speeds, but also at times with very high wind speed due to technical limitations. As wind speed fluctuates at various intervals, and as it is subject to seasonal, diurnal and hourly changes, the cost efficiency of wind turbines vary according to location. At sites with good wind resources and convenient power grid access, wind power technology can be profitable.

2.2.2 Solar photovoltaic electricity

The energy from the sun can be transformed into solar power. Available technologies include passive solar heating, heat pumps, solar water heating, and the more complex technology of photovoltaic (PV) cells which is the primary solar technology studied in this paper. PV cells transform the energy in sunlight directly into electricity.

The maximum possible output of a PV-cell operating under standard conditions is measured in watts or kilowatts and stated as either W_p (watts, peak) or kW_p, respectively. The International Energy Agency (IEA) estimated the photovoltaic production at 17 GWh in 1990 and at 3 616 GWh in 2002, which equals an annual growth of 29%. This makes photovoltaics the fastest growing sustainable energy technology. For the last two decades, the costs of PV panels have limited the extent of this technology. In recent years however, such PV panels have become more affordable through the introduction of new technologies and materials used in production, making the expensive silica less dominant in the overall production cost.

2.2.3 Hydropower

Hydro electric power (here referred to as hydropower) can be defined as “the generation of electricity from the movement of non-tidal waters” (Coley, 2008). As water finds its way down a mountain or inside a water tunnel, its potential energy is transformed into kinetic energy. Much of this energy can be captured when the water is used to spin turbines to generate electricity.

Large-scale hydropower systems are not completely sustainable as they often involve the construction of dams and the flooding of valleys that can have substantial environmental and social consequences. Small-scale systems, however, can be applied in locations where large-scale dams would not be economically or socially viable. They have low capital costs, are reliable sources of power, and do not have the environmental impact that the larger projects sometimes do. Today, hydropower is the main energy carrier used to store electricity on a large scale. It should be noted, however; that drought periods can pose a problem if they coincide with periods of high energy demand, as there could be less water in the system than would be required to meet the energy demand.

2.2.4 Other alternatives

Exploiting the energy of the world’s oceans provides a promising approach to producing electricity. Despite the potential, technologies for extracting power from waves or tidal movements have yet to move beyond the experimentation stage. Geothermal energy is heat emitted from the core of the earth. Geothermal energy has two sources: the original heat existing from the formation of the Earth and the decay of various radioactive isotopes within the Earth's core. Today, the potential of geothermal energy for electricity production is being studied at various sites and commercial plants exist in New Zealand (Stewart 2009). The renewable energy source of highest importance in many countries today is biomass. As biomass grows, carbon is temporally removed from the cycle. This carbon is transformed to carbon dioxide (CO_2) when the biomass burns, and will then return to the cycle. Estimates show that about one third of the energy use in the developing world comes from biomass, compared to only 3% in the developed parts of the world (Coley 2008). Biomass application and technologies include direct combustion such as burning wood and dung for domestic heating and cooking, but also more refined applications such as using biomass for liquid or gaseous fuel, or for power generation.

A developed nation uses about one third of its national energy consumption on transportation (Coley 2008). Almost all of this energy is in the form of oil burned within internal combustion engines. This makes R&D related to more fuel efficient cars and alternative transport fuels an important part of creating a sustainable future. Carbon capture and storage (CCS) technologies offer a very different approach to the problem of carbon emissions; the alternative to simply venting the carbon dioxide (CO_2) from fossil energy plants or industry into the atmosphere would be to capture the CO_2 and store it underground.

2.3 The costs and difficulties of being green

Today, governments in most OECD nations are introducing regulations designed to reduce national reliance on fossil fuels. Recent trends have made the issue of alternative energy impossible to ignore, even for the established big oil companies. In response to increasing consumer demand, automotive manufacturers have rolled out a range of vehicles either completely or partially fuelled by alternative energy sources. But despite this passion for alternative fuels and renewable energy, international reliance on hydrocarbons is unlikely to abate in the near term. Some companies consider this reality a reason to maintain business as usual. Yet, without a strategic approach to the alternative energy movement, oil and gas companies may face diminishing demand for their products in the coming decades. This makes it important for these companies to make a meaningful move towards cleaner energy technologies.

CHAPTER 3: ENERGY PROFILES

This chapter examines the structure of the RE industry in Canada and Norway, and presents an overview of the most important conventional energy sources. RE investments are in fact energy investments, and their profitability is highly dependent on the development of other energy sources in the market. The impact of external shocks, such as the current recession, upon RE investments also depends on who the main investor groups are. In order to understand the incentives at work, one has to find out what the core businesses of the potential investor companies are.

3.1 Canada

3.1.1 Country facts

Canada is a federation of ten provinces and three territories. It is a constitutional monarchy and the largest of the OECD countries in terms of area[3]. Over the last two decades, Canada has experienced a relatively high rate of economic growth which has mainly been fuelled by high population growth. With large reserves of conventional and unconventional[4] oil and gas, coal, uranium and hydropower, Canada is among the largest producers worldwide for most forms of energy. The country is also a large energy exporter, mainly to the USA.

Canada is a large country and there are considerable differences among the provinces in terms of both climate as well as primary energy endowments. This represents a challenge for Canadian energy policy makers. The Canadian constitution limits the federal government's responsibilities with regards to energy to three main areas; inter-provincial trade, international trade, and the management of uranium resources. In fact, the provinces have more decision authority on energy politics than most other sub-national governments in the world (IEA 2004). The result of this is a lack of coordination and co-operation that may affect the competiveness of Canadian energy markets, thus affecting the Canadian consumers.

[3] Source: The World Factbook, CIA

[4] In Canada *unconventional* petroleum resources are usually defined as resources that are more difficult and costly to extract, thereby including the Albertan oil sands and also the offshore oil fields outside the Eastern coast. This terminology is not necessarily used elsewhere, and in the following, all forms of fossil fuels are included under the topic *conventional energy sources*.

3.1.2 Energy in numbers

Canada's total primary energy supply (TPES) was 269 Mtoe[5] in 2007 (IEA estimate). This represents a growth of almost 30 percent over the 1990 level. The total energy production the same year was 413 Mtoe. The IEA estimates that the 2008 production stayed at approximately the same level. Canada has seen no substantial change in the share of each energy source over the past 20 years. In 2006, oil and gas production made out more than 75 percent of the total energy production. The share of coal and peat to the total is slowly declining to 7.9%, and so are the shares of nuclear (6.2%), and hydro (7.4%), likely caused by the growth in oil and gas production from the Albertan oil sands which became increasingly profitable during the record high oil prices of 2008. The share of other renewables remains small, 3.1% of the total.

3.1.3 Conventional energy sources

Canada's estimated crude oil reserves were 178.6 billion barrels in 2008 (IEA). Based on this, the country is second only to Saudi Arabia, which holds the most crude oil reserves in the world. The total oil production was 2.8 mbd in 2008 (IEA estimate), and the total crude oil and natural gas production was 3.3 mbd[6]. When the conventional oil fields in Canada started to decline, the exploration and production drilling of bitumen and synthetic crude from the oil sands in Northern Alberta, as well as the east coast offshore reserves, has become increasingly important. This has managed to keep production levels growing. This growth does however rely on relatively high oil prices, as this unconventional oil is more expensive to produce.

Canadian natural gas production has increased from around 99 billion cubic metres in 1990 to 172 billion cubic metres in 2002 (IEA). Since then natural gas production has levelled off producing a similar amount in 2006 as in 2002. Canada is the world's third largest producer of natural gas (Natural Resources Canada 2009). Every year, large volumes of Canadian gas are exported to the US, creating a larger North-American market for gas where the prices are determined. Despite the high drilling levels in recent years, the production has been rather disappointing; enough to keep today's levels, but not enough to increase the export in the future.

[5] Million tonnes of oil equivalent
[6] This includes additives and other hydrocarbons (other than crude oil and natural gas liquids).

The Government of Canada views nuclear energy as an important component of a diversified energy mix. It has taken the necessary measures to ensure the long term development of nuclear energy as a sustainable energy source in meeting the country's existing and future energy requirements. Canada's nuclear program includes 22 nuclear plants, whereof 20 are located in the province of Ontario. While newer plants are performing well, some older plants are starting to experience significant problems in renovation in the form of high refurbishing costs and schedule overruns. The option of building new plants should be evaluated against other alternatives because of the country's large base of other energy sources.

Canada holds close to 10bn tonnes of coal reserves, more than the reserves of the conventional oil, natural gas and oil sands combined, and coal-fired power generation is an important source of electricity in a number of Canadian provinces. According to the National Energy Board, about 13% of Canada's generation capacity used coal in 2006. In an effort to reduce the country's green house emissions, the federal government has announced plans to phase out the dirty coal-fired power plants, introducing requirements of carbon capture technology for all new coal-fired plants. This represents an opportunity for renewables to play a more important role in the future Canadian energy mix.

Hydropower holds the largest potential for renewable energy in Canada, but the regulatory environment has made it almost impossible to exploit this resource to its full potential. The Canadian constitution states that the provinces own their natural resources alone, thereby excluding the federal government from regulating the extraction of natural resources. Local environmental opposition has made the building of more large-scale (>10MW) hydropower plants virtually impossible. The International Energy Agency (IEA) states in its 2004 review that "given Canada's large potential, hydroelectricity should receive more attention" (IEA 2004, p 9).

3.1.4 New renewable energy sources

Canada's use of solar energy has increased in recent years, although it remains relatively modest in terms of market penetration. Installed capacity for solar thermal power has seen average annual growth of 17% since 1998, reaching 290 MW in 2005. Installed capacity for solar photovoltaic power has grown by 27 percent annually since 1993, reaching 25.8 MWp in 2007, of which 89% are off-grid applications (Natural Resources Canada). In Ontario, the share of grid-connected solar PV applications is increasing due to a Renewable Energy Standard Offer Program (RESOP) from the provincial government that secures a higher price for solar generated electricity. In 2009 a new feed-in tariff (FIT) program has been launched as the continuation of the RESOP. This program, which is the first comprehensive guaranteed pricing structure for renewable electricity production in North America, also applies electricity from solar PV installations, wind projects, biomass, and small-scale hydropower.

Due to a traditional low cost of electricity in Canada, and the lack of instruments to promote its use, wind power generation has not been an economically attractive option despite the country's large resource base. With the world's longest coastline, great lakes and lots of open spaces, Canada has potentially enough space to overcome what has been the problem in many other countries with regards to wind power: localization. Wind turbine technology improvements and increasing cost for fossil fuels in recent years have made large scale wind power generation increasingly competitive with traditional sources of electricity in the Canadian marketplace. Due to increased interest from electricity producers and government initiatives such as the Ontario standard offer and feed-in tariff programmes, the country has seen a rapid expansion of installed capacity in recent years. In the end of 2007 Canada had 1400 wind turbines operating on 85 wind farms for a total installed capacity of 1 846 MW (CANWEA). As of September 2009 Canada ranks as number 11 in the world with regards to installed capacity (Reuters 2009). The provincial leader in wind power capacity is Ontario with 1162 MWe[7] installed capacity. Seven new plants are currently under planning and expected to be in production by 2012.

Other renewable energy sources in Canada include 62 bioenergy power plants with a total electricity generating capacity of 1 652 MW. In 2006, 7 million MWh of electricity were generated using wood and wood residuals. The domestic production capacity of biofuels was around 600 million litres of ethanol and 100 million litres of biodiesel in 2006. The federal and provincial governments have announced several measures that should lead to the increased production and use of biofuels in the coming years. With its only land borders in the South and Far Northwest with the continental United States and Alaska, much of Canada is surrounded by oceans, meaning it has access to another significant energy source. Canada has a tidal power plant in Nova Scotia with a generating capacity of 20 MW of electricity. Recently, a technology demonstration project using a Canadian designed tidal current turbine

[7] Megawatts of electric power

with a generating capacity of 0.065 megawatts was installed off the coast of British Columbia.

3.1.5 Electricity markets

Canadian electricity prices have traditionally been among the lowest in the OECD due to the large amount of cheap hydropower.[8] Just as for natural resources, electricity falls under provincial jurisdiction in Canada, with the exceptions of interprovincial trade and trade with the US. Through the 1990s there has been a growing interconnection between Canadian and US electricity markets. Because electricity supply is limited to provincial boundaries, it is not cost-effective and a need for closer cooperation between the federal and the provincial authorities to ensure effective competition exists. There are also important differences between provinces in terms of liberalization of energy markets, as some provinces have (successfully) reformed their energy markets, while others are still supplied by one single utility company.

The provincial governments are making an effort to secure the competitiveness of electricity generated from renewable sources through political incentives such as the Ontario RESOP and the Ontario FIT programmes which offer the producers guaranteed prices for their electricity.

3.1.6 Energy investors

The Canadian constitution has made it difficult to achieve any national coordination of energy production, and effective exploitation of natural resources has proven to be difficult in many provinces. Despite the large resource base, hydropower is little utilized in many provinces, mainly due to political opposition from the public. A lack of coordination has also led to a situation where each province and territory utilizes the diverse and unequal resources available to them. Therefore, there are large differences in the structure of the energy sector between provinces.

The Canadian petroleum sector is more diversified than its Norwegian equivalent. While all of the Norwegian resources are located offshore, Canada has both onshore and offshore oil

[8] Source: OECD, http://www.oecd.org/dataoecd/52/0/33847613.pdf

fields, as well as the unconventional oil sands in Alberta. This diversification has created a space for new energy technologies, in many cases heavily supported by the provincial governments. Three main groups of RE investors can be identified. The first group consists of multinational petroleum companies that have been active on the Canadian energy market for many years, such as EnCana, Suncor, Nexen, and Enbridge. Even though they are focusing their operations on oil and gas related activities, these companies have started to show interest in other business segments such as that of renewable energy in recent years. A second group consists of the traditional utilities, often publicly owned. Examples are Ontario Power Generation and Hydro Quebec. These companies have significant experience in electricity generation from multiple sources and invest in all forms of electricity generation projects, including renewable projects such as wind farms and solar power plants. The third group includes companies that focus mainly on generation of power from renewable sources, such as SkyPower, Invenergy Canada, Brookfield Renewable Power, and TransAlta Wind.

3.2 Norway

3.2.1 Country facts

Norway occupies the western and northern parts of the Scandinavian Peninsula, as well as Jan Mayen and the Arctic archipelago of Svalbard under the Spitsbergen Treaty. Partly owing to its wealth of natural resources and the sensible management of these, the country has one of the highest standards of living in the world today. Norway has developed an important industrial base, relying on the availability of cheap and abundant hydroelectricity for the production of energy-intensive goods, such as aluminum and ferro-alloys.

From the early 1970s Norway experienced rapid economic growth as a result of large oil and natural gas deposits discovered in the North Sea and Norwegian Sea. Today it ranks as the second wealthiest country in the world with the largest capital reserve per capita of any nation (IMF 2009). The Norwegian economy features a combination of free market and large state ownership in certain key sectors, such as the strategic petroleum (Statoil and Petoro) and the hydroelectric energy production (Statkraft).

3.2.2 Energy in numbers

Norway is the largest petroleum exporter among the IEA members, both in terms of absolute volume and share of total primary energy supply (TPES). Export revenues from oil and gas have risen to 45% of total exports and constitute more than 20% of the GDP (IEA). Norway is the world's seventh largest oil exporter and third largest gas exporter but is not an OPEC member. The country is also a net exporter of energy. In 2007, its total production stood at 211 Mtoe, which was 76% above the 1990 level of 120 Mtoe; 88% of this production, or 185 Mtoe was exported. TPES after deducting exports reached 26 Mtoe in 2007 (IEA).

To reduce "over-heating" from oil revenues and the uncertainty from the oil income volatility, in 1995 the Norwegian state started to save the petroleum income[9] in a sovereign wealth fund. The fund is earmarked pensions for the country's aging population and has later been renamed "Government Pension Fund – Global" (NBIM). The budgetary rule is to spend no more than 4% of the yield from the financial fund each year, which is assumed to be the normal long term yield. The market value of the pension fund was NOK 2549bn (C$ 473bn[10]) on September 30 2009 (Norges Bank). In August 2009 the fund announced that it owned approximately 1% of all the publicly traded stocks in the world.

3.2.3 Conventional energy sources

Norway's main energy resource consists of the offshore reservoirs of oil and gas, and these are under government control. Access to these resources is on the basis of regular licensing rounds for acreage for exploration in Norwegian waters. Norway is producing oil, gas and coal (Svalbard), with almost the whole production for export. Since the start-up of the activities on the Norwegian Continental Shelf (NCS), the industry has been characterized by rapid growth and increased production, and it is today close to its peak. The economically efficient development of oil and gas on the NCS has contributed to make the country among Europe's largest exporters of petroleum[11] and an important contributor to European energy security. Today, Norway has 7.8 billion barrels of proven oil reserves, the largest in Western Europe. The income from oil and gas was 18% of GDP and 23% of government revenue in 2004 (IEA 2005). Oil production is expected to rise until 2011 and then fall gradually, while gas production should grow rapidly until 2013 before stabilizing.

[9] Income includes taxes, dividends, licensing and sales.
[10] Currency rate Sep 30 (Norges Bank): NOK/CAD = 5.3854
[11] Oil, oil products and natural gas

As fields mature, the government has opened new licence areas for oil companies to develop outside the North Sea region. The country has 84.3 trillion cubic feet of proven natural gas reserves. The North Sea holds the majority of these reserves, but there are also significant quantities in the Norwegian and Barents Seas. The use of natural gas in Norway is very limited, but has increased slightly in the past years (IEA 2005). The government authorized the construction of gas-fuelled power stations in the 1990s, but these have been delayed because of environmental concerns about CO_2 emissions. The construction of an onshore gas supply network has also been delayed because of regulatory and economic uncertainties. Increasing the share of natural gas in the Norwegian energy mix is possible in the future.

Hydropower is a conventional and commercial energy source in Norway and the domestic production of electricity comes almost exclusively from this source. Due to the abundance of hydroelectric power production capacity, Norway is among the OECD-countries with renewable energy sources accounting for more than 50% of total energy production in 2007 (IEA). Large-scale hydro capacity will be increased considerably over the next few years, under authorizations given by the regulatory body Norwegian Water Resource and Energy Directory (NVE). The large resource bases of hydro and petroleum has led to a high level of security of supply.

3.2.4 New renewable energy sources

There are plans to increase the number of small hydro stations, with a capacity below 10 MW (Enova). Enova is not supporting any form of hydropower developments because these are seen as economically viable without government support. On the other hand, government support for micro hydro is available through tax incentives and research and development funding from the NVE.

The supply from new renewables is relatively small in Norway given the availability of cheap clean hydro-generated electricity that in the past could easily cover the country's energy requirements, including space heating. The Norwegian government, however, encourages the development of new renewables such as wind and biomass. With a very long coast line that makes a good resource base, Norway has the potential for developing wind farms onshore and offshore. More importantly however, the oil and gas industry has created a large knowledge base and network of companies with offshore competence that can be transferred to other applications such as offshore wind farms as well as wave and tidal power farms.

The utilization of wind power for power generation in Norway was almost nonexistent until 2002 when the installed capacity started to increase. Since then, the production has expanded by roughly 100 GWh per year in average and by the end of 2008, the total wind power capacity installed in Norway was 429 MW producing 966GWh of electricity, divided on 18 different wind parks[12](IEA & NVE 2009). Wind power is very compatible with the Norwegian electricity system because production from hydropower plants can be adjusted depending on the prediction for production from wind power, but there are concerns about network requirements for new wind farms. The main wind energy program is currently based on investment subsidy granted to good, cost-effective projects that would not otherwise have been realized. The maximum level of subsidy is currently 50% of the total investment. Projects have to be larger than 1.5 MWe of installed capacity, and Enova states that project economics, the likelihood of construction and the presence of a concession are important selection criteria. Most of the existing generation facilities include a small number of wind turbines. A large number of wind parks are planned, and the projected existing and planned central net will have enough space for 5-7000 MW of wind power by 2025 (NVE/Enova 2008). However, few of these parks are currently under construction, and Norway will only see a marginal increase in the wind power capacity in the next couple of years.

Solar energy plays a very minor role in Norwegian energy supply owing to the northerly location of the country. Energy supply from new renewables, excluding waste, reached 494 GWh in 2003, compared to 184 GWh in 1990 (IEA).

3.2.5 Electricity markets

Norway has the highest consumption of electricity per capita in the world; in 1998 the average Norwegian consumed more than ten times the world average of electricity (SSB). Electricity represents a much greater share of the end consumption of energy than for other countries. This can partly be explained by a large share of energy intensive industries, and that the electricity consumed by this industry represents more than 30 percent of the total consumption of power. Electricity is also used for heating to a much greater extent in Norway, which also has a cold climate that generates a greater demand for heating. This creates an opportunity for investments in energy efficiency. In addition, a history of cheap hydropower has contributed to a high share of electricity in the consumption of energy.

[12] i.e. 18 different wind plants with capacity >0.3MW.

Since 1991, Norway has been a pioneer in liberalizing its energy markets and pursuing international interconnection of the electricity market. Similar developments in other European countries made the electricity sector market based, increased cross-border trade and resulted in the development of Nordic and European electricity markets. Consequently, Norway has become an important part of the common Nordic market. Norwegian energy markets are competitive and dominated by publicly-owned enterprises.

3.2.6 Energy investors

A large part of Norway's GDP is driven by activity in the energy sector. While most of the oil and gas from the Norwegian Continental Shelf (NCS) is exported, a substantial part of Norwegian energy consumption is fuelled by electricity generated from hydropower. The two energy sources are both of immense importance for the country's economy. The petroleum is primarily used to generate national income. The availability of cheap hydropower, on the other hand, is a cornerstone of Norwegian industry. While the importance of national energy security is leading to other countries diversifying their energy supply, Norway does not experience any *urgent* need to find other sources of energy. The depletion of the petroleum on the NCS has been discussed for years, but the political discussion of Norway's energy future is characterized by an "either-or approach" more than a serious plan for diversifying the energy sector away from a one-sided dependency on oil and gas. The result is that the same companies that have been dominating the Norwegian energy sector for years are now the ones that are investing in renewable energy. Investors in energy related projects in Norway can be divided into three main groups. The first group consists of the oil and gas companies. The second consists of suppliers to the offshore industry looking to use their offshore competence in other projects such as offshore wind farms and tidal power generation. The third group is the publicly owned electricity based utility companies such as Statkraft and BKK who are looking for opportunities to use their experience from the electricity sector on other electricity generation technologies.

These three groups have different incentives for engaging in the RE business. While the investments of the oil companies and offshore suppliers seem to be determined by the profits of their core business petroleum, the utility companies are driven by high revenues from their existing business. For all categories of investors their activities within RE are influenced by the political climate towards RE investments.

3.3 Chapter summary

The beginning of this section sought to identify the main energy sources and key investors in Canada and Norway today. As the first section of this paper has illustrated, the two countries have energy sectors that are dominated by the same two energy sources: petroleum and hydropower. However, there are some important differences between the two countries. While Norway's energy sector is dominated by the operations on the NCS, Canada's energy sector is more diversified. This makes it easier to create a space for renewable technologies. Despite this difference, two out of three main investor groups identified in each country are the same: the multinational oil companies and the utilities. The next chapters will take a closer look at what these differences mean with regards to the potential profits of RE investments.

CHAPTER 4: CONCEPTUAL FRAMEWORK

This chapter will present the conceptual framework for analysing RE investments in Canada and Norway. The method of discounted cash flow (DCF) analysis has been used to estimate the profitability of six different RE investments. This is a standard economic valuation framework that will highlight the predictions of classic economic theory. The purpose of the DCF analysis is simply to estimate the returns of an investment and adjust for time value of money. Because it is a mechanical method, the DCF analysis has some important drawbacks. The parameters are often subject to high uncertainty, and because small changes in inputs can result in large changes in the estimated net present value (NPV), the quality of the results is highly dependent of the quality of the input parameters.

4.1 Economic evaluation

When looking at the relative costs of electric power, competing sources have to be compared on a similar basis of calculation if the analysis is going to yield useful and valid results. Thus, simply citing the costs of one power source without any references to the alternatives is of limited value. When comparing renewable power sources, a number of internal cost factors have to be considered;

- Capital costs
- Operation and maintenance (O&M) costs
- Expected annual hours run

Note that fuel costs are not included as the cost of fuel for most RE technologies is zero. The price, i.e. the selling price, of a unit of energy can be influenced by a number of other factors such as tax exemptions and subsidies which will be addressed later in this analysis.

Equity investment is the buying and selling of stocks in the anticipation of an income from dividends and capital gains as the stock value increases. It also sometimes refers to the ownership participation in a private company or a start-up. Investment in infant companies is usually referred to as venture capital investing. Such investments are in general more risk exposed than the investment in more established companies and requires a higher rate of return. The equity price is the profit that the owners demand in order to provide capital to a project and is determined in the stock market by the supply and demand at any given point in time.

Most RE projects require a high initial capital investment and the depreciation of this investment is important to consider. Depreciation is the accounting process in which the cost of the initial investment in a physical asset is written down over the economic life time of the asset. Because of the magnitude of the initial investment, the choice of depreciation method may directly influence the economic viability of RE projects. Also, the depreciation affects the taxation of a company. The effects of depreciation techniques or taxation on the returns of the RE investments will not be discussed in this thesis, as all numbers are assumed to be after tax values.

4.1.1 Net Present Value

This thesis is using the discounted cash flow (DCF) method to perform the economic assessment of each RE technology respectively, building the theoretical framework on the work of Mathew (2006). The DCF method uses the time value of money to convert a future cash flow into a present value at a particular discount rate. The approach is also called the net present value method. Due to the time value of money, a hundred dollars today will be worth more than a hundred dollars ten years from now. Mathematically, the present value is represented by this equation:

$$PV = \frac{FV}{(1+d)^T}$$

Here, T is the number of years in the future and d the chosen discount rate, PV and FV are the present and the future values of the cash flow, respectively.

The operation and maintenance cost, C_{OM} can be expressed as a fraction of the initial investment C_1:

$$C_{OM} = mC_0$$

Discounted at the chosen discount rate d, the present value of C_{OM} in t years from now:

$$PV(C_{OM})_t = \frac{(mC_0)_t}{(1+d)^t}$$

Discounted for T years to the year of the initial investment, the net present value of the cash flow of mC_0 of annual O&M costs equals:

$$PV(C_{OM})_{0-T} = \frac{(mC_0)_1}{(1+d)^1} + \frac{(mC_0)_2}{(1+d)^2} + \cdots + \frac{(mC_0)_T}{(1+d)^T}$$

This equals:

$$PV(C_{OM})_{0-T} = mC_0[\frac{(1+d)^T - 1}{d(1+d)^T}]$$

The NPV of all costs is the initial investment C_0 plus the O&M cost, in total:

$$NPV(C_A)_{0-T} = C_0\left\{1 + m\left[\frac{(1+d)^T - 1}{d(1+d)^T}\right]\right\}$$

A project's NPV is composed of three main parts: the net present value of the future cash flow of benefits from revenues, which is often assumed to be a constant annuity (B_A); the future outflow of annual costs (C_A); and the (negative) value of the initial investment. NPV of revenues is:

$$PV(B)_{0-T} = B(\frac{(1+d)^T - 1}{d(1+d)^T})$$

Hence, total NPV equals revenues minus costs:

$$NPV = B_A\left[\frac{(1+d)^T - 1}{d(1+d)^T}\right] - \{C_{01}[1 + m\left[\frac{(1+d)^T - 1}{d(1+d)^T}\right]]\}$$

As explained, the net present value (NPV) of a project is the difference between revenues and costs in today's money. If the NPV of a project is greater than 0, it would bring the investor a return on his money above the discount rate d. In any comparison of projects that are mutually exclusive, the project with the highest NPV is the one that should be preferred.

The discounted average of the yearly cost of the project is given by the equation:

$$NPV(C_A) = \frac{NPV(C_A)_{1-T}}{T} = \frac{C_1}{T}\left\{1 + m\left[\frac{(1+d)^T - 1}{d(1+d)^T}\right]\right\}$$

Note that the yearly cost (C_A) is simply the initial investment divided on the economic lifetime plus the annual O&M cost:

$$C_A = \frac{C_0}{T} + mC_0$$

Due to energy losses in transformation and down time for maintenance and repairs, no power generator is a hundred percent effective. A generator's efficiency in converting power into electricity is stated by its capacity factor. The installed capacity is calculated at an ideal 100% efficiency, the capacity factor is the average operating rate of that specific generator. If P_R is the rated power of any kind of electricity generator, and C_F is its capacity factor, the energy produced by the generator in one year is:

$$E = 365\, days \cdot 24 hours\ \cdot P_R C_F$$

Hence, the unit cost per kWh of generated electricity from the project is

$$c = \frac{NPV(C_A)}{E} = \frac{C_1}{365 \cdot 24T}\left(\frac{1}{P_R C_F}\right)\left\{1 + m\left[\frac{(1+d)^T - 1}{d(1+d)^T}\right]\right\}$$

4.1.2 Internal rate of return (IRR)

A project's internal rate of return (IRR) is the rate at which the costs of the investment lead to the benefits of the investment: the rate at which the investment has a NPV equal to zero. The IRR does not incorporate environmental factors such as the interest rate or the inflation. It is however a useful tool for better understanding the dynamics of a specific investment, in particular when a high degree of uncertainty is priced into the discount rate. Thus, the IRR can indicate the yield of an investment. As an investment decision tool, however, the IRR should not be used when considering mutually exclusive projects due to the fact that projects with higher initial investments in general will have a lower IRR.

If T is the economic life time of the investment, CF_t is the cash flow from the project in year t, and NPV is the project's net present value, the internal rate of return is given by *IRR* in the equation:

$$NPV = \sum_{t=0}^{T} \left(\frac{CF_t}{(1 + IRR)^t} \right) = 0$$

4.1.3 Benefit Cost Ratio

In the absence of funding constraints, the investment with the highest estimated NPV should be chosen. As Mathew (2006) notes, judging of a project solely based on its NPV might sometimes be misleading, in particular if the projects require different levels of initial investments. The project involving the higher investment may show much higher NPV than the one requiring lower capital. When budget constraints exist the project that shows the best value for money should be chosen. Under such conditions, the Benefit Cost Ratio (BCR) is a better tool to judge a project's economic viability.

The BCR of a project is "the ratio of the accumulated present value of all the benefits to the accumulated present value of all costs, including the initial investment" (Mathew 2006, p 228). The BCR therefore measures the overall value for money of a project. Let B_A be the annual benefit, C_A the annual costs of operation and maintenance, and C_0 be the initial investment. The BCR is then given by the equation:

$$BCR = \frac{NPV(B_A)_{1-T}}{C_0 + NPV(O\&M)_{1-T}}$$

Where B_A is the annuity, C_0 the initial investment, *O&M* are the annual operation and maintenance costs, and T the lifetime of the project.

A project is acceptable if the BCR is ≥ 1, since that is the same as having a return equal to or greater than d.

4.2. Data and measuring problems

Data from different sources has been used for the analyses. Technical specifications and technology market prices for the different RE technologies are based on recommendations from the literature. The financial market data in chapter 7 are derived from Yahoo!

Finance[13]. Interest rates are calculated by using historical data from the Canadian and the Norwegian central banks.

An obvious measuring problem arises with regards to the interest rates. The analysis of investments with a projected lifetime of 20 to 25 years, such as the ones studied here, demands that the relevant discount rates are of the same time perspective. Thus, very long term interest rates have to be used in the calculations. This has one important implication: we fail to pick up on the large short term interest rate changes that occurred in the fall of 2008. The years directly prior to the summer of 2008 had seen a period of artificially high interest rates, followed by a period of very low interest rates after the crisis occurred. But neither the higher rates before the crisis, nor the lower rates after would be the correct interest rates to use in the calculations here. When dealing with a longer time period, data smoothing is often used to reduce the impact of isolated incidents such as this recession on the long term rate. The theory suggests that the appropriate rate should reflect the long time horizons of the different investments, which means that there will be little or no change in the rates used in a "pre-crisis" and those used in a "post-crisis" case. Following that, any substantial effects attributed to the nominal interest rate will not be observed. But is it believable that the massive fluctuations in interest rates had no influence at all, and if not, how can it be measured? Interest levels matters because of the possibility to fix long term interest rates. In a period of historically low interest rates, investors have the opportunity to fix the debt interest at a lower level when the investment decision is being made. In general, project financing costs have increased after the financial crisis due to higher equity requirements and higher risk premiums. The importance of risk will be discussed more closely in chapter 7.

[13] www.finance.yahoo.com, data is provided by Capital IQ, a division of Standards&Poors

SECTION 2: PREDICTIONS FROM CLASSIC THEORY

Question 2: What does classic economic theory predict about the investment behaviour?

This second part will turn to the discounted cash flow model to assess six different RE investments more closely. The results and predictions will be discussed as the main drivers behind investment incentives according to the classic theory are being studied. All calculations assume that the investor is profit maximizing and would only invest if the project is expected to give him return on his investment.

CHAPTER 5: DISCOUNTED CASH FLOW ANALYSIS

This thesis focuses on three specific technologies; wind power, solar photovoltaic electricity and small-scale hydropower. These technologies are among the more mature of the RE technologies; they are in most cases no longer in the experimental end of the life cycle, but are being applied in commercial power generation projects.

5.1 Project discount rate

5.1.1 General assumptions

To compare the effects of benefits and costs that arise at different time it is necessary to use a discount rate. It is normal to use a risk free interest rate as a basis, and then add different risk premiums. A higher discount rate means that less weight is assigned to future cash flows, thus a higher discount rate is incorporating a higher future risk exposure. To arrive at the correct discount rate, it is necessary to use parameters that correspond to the cash flow used in the calculations. The following factors should be considered:

Nominal or real values:

If the cash flow is estimated in current prices, a nominal discount rate should be used. If the cash flow is estimated in fixed prices, a real discount rate should be applied. In this thesis, the cash flow is calculated in fixed prices and it is assumed that the affect of inflation is accounted for through the inflation indexed prices of the RESOP and electricity prices on the Nordic market. Thus, the cash flow will be discounted using a real discount rate (adjusted for inflation).

Pre-tax or post-tax:

Further, it is possible to estimate the profit before or after tax. The most common method is to include the tax effects because it is of great influence on the result of the analysis. Two tax effects are accounted for in this thesis: the yearly corporate income tax; and the tax deduction of capital interests.

Equity or total assets:

When estimating the cash flow of the equity the calculations will show the result for the owners. Thus, payments and interest costs are deducted before the discounting and the discount rate of the equity after is used for estimating the NPV. When estimating the cash flow of the total assets, payments and interest costs are not included. This thesis considers the cash flow of the total assets.

5.1.2 Estimating the discount rate

The project discount rate is determined by several factors such as the price on equity, the level of debt financing, taxes, and depreciation rate. The price on financing by taking up debt depends on the general interest rate as well as risk premiums based on the debt-to-equity ratio and the perceived market based risk. The price on debt (r_D) is assumed to consist of two elements: the real interest rate (r), a credit premium (R_c), and a project specific risk premium (R_p), where the latter refers to the impact of the debt-to-equity ratio on the price of debt. This allows us to study some of the market related effects of the economic crisis through changes in the components of the project discount rate. The debt interest rate is given by the equation:

$$r_D = r_F + R_c + R_p$$

Where r_F is the nominal long-term risk free interest rate.

The capital asset pricing model (CAPM)

An investor's required return on an investment is defined as the expected return offered by the market for investments of the corresponding risk exposure. Thus, the price on equity is the opportunity cost of the invested capital determined by the market. The usual practice when calculating the project discount rate is following the capital asset pricing model (CAPM):

$$d = r_F + \beta \cdot R_m$$

Where r_F is the risk free interest rate, *Rm* is the market risk premium, i.e. the expected additional return on a well-diversified portfolio, the so-called market portfolio. CAPM assumes that all investors are diversifying away all unsystematic risk, and that the investor is only exposed to systematic risk (cyclical risk) that is common for all stocks in the market portfolio. The market risk premium is therefore the additional return the market offers on investment risk that is common to all investments. β (beta) is a financial value that measures how a specific investment varies relative to the market as a whole, and thus captures this non-diversifiable risk.

When calculating the project discount rate we have to account for the effect of the debt-to-equity ratio. Using the concept of weighted average cost of capital (WACC), the discount rate (d) for the total assets is given by the equation:

$$d = D \cdot r_D + E \cdot r_E$$

Where D and E are debt ratio and equity ratio, respectively, and r_E is the cost of equity. The cost of equity (r_E) is the minimum rate of return an investor requires to compensate for waiting for the returns and for being exposed to risk. r_E reflects the opportunity cost of the investor, and will vary from business to business due to differences in risk of different companies.

Using the CAPM model and incorporating the WACC it is possible to demonstrate[14] that the relevant discount rate after tax is given by (Gjølberg & Johnsen 2007):

$$d = r_F + \beta_T \cdot R_m + \gamma + R_U$$

Where r_D is the cost of debt, R_m is the market risk premium, R_U is the unsystematic risk premium, β_T is the business beta of the specific company, r_F is the risk free interest rate, and γ is the price on debt, adjusted for taxation. The price on debt balances two effects: it increases the discount rate d due to the risk of default, but reduces d because of the tax deduction of interest payments on debt. If D is the debt ratio, τ is the income tax rate and r_D is the rice on debt, γ is given by:

$$\gamma = D \cdot [(1 - \tau) \cdot r_D - r_F]$$

[14] See Gjølberg & Johnsen 2007, p 7-14

5.1.3 Parameters

In order to estimate the cash flows, it is necessary to calculate a relevant discount rate. The previous section explained how the after-tax discount rate can be established based on the CAPM and the principle of WACC.

Risk free interest rate, r_F

Monthly data on historical interest rates from the Bank of Canada[15] has been used to derive a yearly average interest for the past decade. Based on this, a long term nominal interest rate of 5.4 % is used in the calculations, which corresponds to the calculated ten year average for the years 1999-2008.

The Bank of Canada pursues a 2% inflation-control target (BoC 2006 p 45), which has been kept relatively stable over time. Because of the long time perspective of the investments analyzed here, 2% is considered the relevant inflation rate, despite abnormal volatility in the inflation rates in the past two years.

Thus, the real interest rate is given as

$$r_{F(Canada)} = \frac{(1 + 0.054)}{(1 + 0.02)} - 1 = 3.3\%$$

In Norway, the monetary policy of the central bank, Norges Bank, is directed towards obtaining a flexible inflation target of 2.5%. This is considered the relevant inflation measure for the calculations. Yearly averages of daily data on the Norwegian Interbank Offered Rate (NIBOR) from Norges Bank from 1986 to 2008[16] have been used. Using the last decade as the most relevant for this purpose, the average over this ten year period is calculated. This results in a nominal interest rate of 5.1%.

Thus, the real interest rate is given as

$$r_{F(Norway)} = \frac{(1 + 0.051)}{(1 + 0.025)} - 1 = 2.5\%$$

[15] source: http://www.bankofcanada.ca/pdf/annual_page49_page50_page51.pdf
[16] Can be downloaded from Norges Bank's website: http://www.norges-bank.no/upload/import/publikasjoner/penger_og_kreditt/2000-04/holter.pdf

Market risk premium, R_m

A survey by Fernándes (2009) studies the market risk premium (R_m) used by professors in different countries in 2008. The first quarter average for both Canada and Norway was 5%. Since this corresponds to the recommendations made by Gjølberg & Johnsen (2007), 5% considered the relevant market risk premium in this thesis.

Debt ratio, D

RE projects are often debt-financed. A debt ratio of 75% is therefore considered relevant for the investments studied here. Over time, if payments are made on the loan, the debt and equity ratios will change, as the share of debt decreases. It is assumed that only interest payments are made on the debt and that the loan is redeemed in full on the last day of year T.

Risk premiums on debt, R_d and R_p

The creditors have priority on the company's revenues and will therefore generally have a lower risk per dollar invested than the owners. However, the creditors do require a credit premium, as well as a project specific risk premium. Following recommendations by Gjølberg & Johnsen (2007) a credit premium of 2% is considered relevant here. Due to the high debt ratio of the investments studied here, an additional project specific risk premium of 1% is added to the price on debt.

Liquidity premium and unsystematic risk premium, R_U

For projects in private companies with illiquid ownership, an additional liquidity premium should be considered. Gjølberg & Johnsen (2007) suggest that this premium should be between 1.5 – 2% after tax. Furthermore, because the investments considered in this thesis are isolated investments the investor is not able to diversify and must carry both systematic and unsystematic risk. No compensation is given for carrying unsystematic risk (Bøhren & Gjærum 2000), however, to account for this additional risk in the DCF analysis, an additional risk premium R_U can be added to the discount rate. When the debt ratio is very high, the risk exposure of the investors increases due to the fact that creditors have priority in payments. An additional risk premium of 2% is therefore assumed relevant in the following calculations.

Beta-value, β

The capital asset pricing model (CAPM) uses the β-value of a stock to quantify risk. A β larger than 1 means that the stock is more risky than the average market portfolio, while a β smaller than 1 means that a stock is less risky than the average market. If the nominal risk free interest rate is known, we can use the difference between a stocks β and the expected return on the market to quantify the price of risk on a specific stock. Formally, the beta of a stock is defines as (Gjølberg & Johnsen 2007):

$$\beta = \frac{corr(r\ r_d) \cdot \sigma(r)}{\sigma(r_m)}$$

Hence is beta the standard deviation, σ(r), of (future) percentage variation in the NPV of the investment, adjusted for the correlation, corr(r r_m), between the variation of the investment and the variation of the market portfolio, r_m, the so-called market risk.

Following the work of Gjølberg & Johnsen (2007) a beta-value of 0.70 will be considered relevant for the energy investments in this thesis. This beta-value is based on an international reference index. An international beta estimate is however lower than a beta estimated based on a national reference index. This is due to a higher diversification, and thus a lower standard deviation in the international index.

Tax rate, τ

Processing and manufacturing businesses in Canada pay manufacturing and processing taxes (MTP) to both provincial and federal governments. In 2009 the combined MPT for Ontario was 33%. This tax is however expected to decrease over the next five years (KPMG Canada), thus an income tax of 28% is used for the Canadian investments, except for the solar PV investment. Because of the small size of the solar PV project, only a 14% income tax is considered in the calculations. A general corporate income tax rate of 28% is considered for Norway. The cost of land (purchase price or land rent) has not been included in any of the examples, thus are property taxes also left out. Additional taxes such as the Norwegian natural resource tax and others are not considered. Tax benefits are in many cases an important policy incentive to promote RE technologies. Such benefits may vary with the size of the project, the technology in use as well as the location and have therefore not been considered in the following. However, such benefits may have an important effect on the profitability of a project, mainly because the DCF method can show large differences in outcome due to a small change in the input parameters.

Taxes are paid in advance so that the income tax of each year is paid continuous and not in the following year, which is the standard for Norwegian companies.

5.1.4 Depreciation

It is assumed that 1/3 of the initial investment is costs related to installation, connection costs etc. For simplicity it is assumed a linear depreciation over each project's lifetime of the remainder. This conflicts with current taxation rules of both countries. In Norway, linear depreciation is used, but generally over a longer time period than what is considered in this thesis. For certain RE projects such as smaller solar PV applications in Canada, current taxation rules allow for accelerated depreciation of the assets at a rate of up to 50%. This would reduce the payable taxes to zero over the first years of the investment. The depreciation value does not affect the cash flow of the project directly because it is a financial cost. It does however have a positive effect on the cash flow through a tax effect. There is no rest value of the project except for the salvage value.

5.1.5 Lead time

The lead time is the time from the investment project starts until the equipment is installed and energy generation can begin. The investments discussed in this thesis are of different magnitude and technology, and therefore have different lead times. For simplicity it is assumed that all projects have a lead time of one year, so that the initial investment takes place in year 0, and that production runs from the first day of year 1 through the last day of year T. It is assumed that the projects cease to exist from that time, and that all benefits and debts are settled on this last day.

5.2 Analyzing renewable energy investments in Canada

5.2.1 Discount rate

Following the discussion in the previous sections, the discount rate for the Canadian investments is given by:

$$d = 0.033 + 0.70 \cdot 0.05 + \; 0.75[(1 - 0.28)(0.033 + 0.02 + 0.01) - 0.033] + 0.02$$
$$= 0.097$$

The discount rate used for Canada is therefore 9.7%.

5.2.2 Electricity prices

The electricity prices used are the rates following the Ontario standard offer program. The 20 year contract prices under the RESOP were C$0.11/kWh for wind power projects and waterpower projects, and C$0.42/kWh for solar power projects. On October 1st 2009 Ontario launched a feed-in tariff program (FIT) as a continuation of the RESOP. The contract prices under the FIT program are more differentiated, and for most RE projects, the contract price has increased. Both programs contribute to reducing the price risk related to investing in RE project, as the contract secure a set price over the whole lifetime of the project.

5.2.3 Wind power

Base case assumptions

The analysis considers an investment in a 1.65 MW onshore wind turbine in the province of Ontario. The investment cost per kWh of a wind turbine varies with its total capacity. The Ontario Power Authority[17] suggests that the price of a small wind turbine to be between C$2000 - 2400 including installation costs. An investment cost of C$2000 per kW of installed capacity has been used in this example.

Following a report by the European Wind Energy Association (EWEA 2009) an average onshore wind turbine has a lifetime of 20 years. Developers of wind turbines often claim

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17 http://www.powerauthority.on.ca/sop/Page.asp?PageID=122&ContentID=4012&SiteNodeID=250&BL_ExpandID=159

capacity factors of 35% or more for land-based projects, but factors in the range of 20-30 is more realistic (Charron 2005). Based on Canadian statistics, it is assumed that the turbine has a capacity factor of 30 percent (Charron 2005). The annual operation and maintenance (O&M) costs and the salvage value are 2% and 10% of the initial capital cost, respectively, following suggestions made by Mathew (2006). For wind power projects, there is also a cost of land (lease fee or purchase price). The analysis is done without considering this land rent, thus are property taxes also not considered in the following calculations.

Table 5.1 summarizes the parameters used in the investment analysis.

Results

The annual after tax cash flow of the project starts with a large negative capital investment of C$ 3.3 million in year zero. Starting from year one, a positive net cash flow occurs annually as a result of earnings from energy sales. At year 20 a higher cash flow occur because of the project salvage value (10% · C$3.3 million).

The results are presented in table 5.2. The unit cost per kWh of wind-generated electricity from the project is approximately C$0.04/kWh. Assuming a price P of C$0.11/kWh, the annual revenue (B_A) from selling electricity is C$0.5 million. The net cash flow (CF) of the project after taxes is C$0.4 million. This is the yearly contribution that is covering the initial investment cost and the investor's required return on his investment. In this example, it is enough to cover the investment. The NPV per invested dollar is -0.13, which means that for each dollar invested, the loss is 12% after the investors and creditors have been served. This value can be used to compare the different investments considered in this thesis.

A positive NPV means that a profit maximizing investor would chose to invest in this project if his decision rule was based on the DCF results. However, chapter 4 introduced a different measure of the value for money; the benefit-cost ratio (BCR). Interestingly, the BCR of this project is positive and larger than 1. This is because the benefit cost ratio as used here does not consider the effects of taxes. However, an investor should refrain from investing in this project as long as the NPV is below zero. This investment has a slightly negative NPV of C$ -0.4 million and one should therefore not invest in this project. The BCR is larger than 1. This is due to the fact that the ratio is calculated without considering taxation and depreciation. Without any taxes, the value of this project would be slightly positive. The internal rate of return (IRR) is 7.6%, which means that the investment would have a positive NPV at a discount rate of 7.6% or lower.

TABLE 5.1:
WIND POWER PARAMETERS FOR CANADA

Capacity factor	Cf	0.30
Project size	kW	1650
Economic lifetime	T	20
Sales price	P	0.11
Salvage value	S	0.1
Investment cost	ci	2000
O&M %	cOM	0.02
Discount factor	d	0.097
Tax rate	τ	0.28

TABLE 5.2:
RESULTS – WIND POWER IN CANADA

Investment cost	Ci	3 300 000
Annual production	E (kWh)	4 336 200
Cost per kWh	c	0,038
Annual benefits	B_A	476.982
Annual O&M costs	$O\&M_A$	66 000
Depreciation		110 000
Taxable profit		300 982
Taxation		42 137
Annual CF after tax		258 845
Depreciation		110 000
Net CF for total assets after tax		368 845
Net present value	NPV	-414 382
NPV per invested dollar	NPV/Ci	-0.13
Benefit cost ratio	BCR	1.07
Internal rate of return	IRR	0.076

NOTE: Energy production stated as average annual generation.

In addition to Ontario's long-term power purchase agreement RESOP, wind power projects are promoted through incentive and tax write-off programs. Also, the federal government is supporting renewable energy in general and wind power in particular through various programs. According to Albadi & El-Saadany (2009), one of the most important vehicles supporting wind power in Canada in recent years has been the Wind Power Production Incentive (WPPI). This program concluded on March 31. 2007 and was replaced by a new program called ecoEnergy. Under this program, eligible projects will receive an incentive of ¢1/kWh for up to 10 years. In this analysis, this incentive has not been included. It would however increase the sales price P and thus have a positive effect on the projects NPV. Wind power projects are also eligible for an annual capital cost allowance (CCA) which can be deducted from the income before taxation. In effect the taxable income (TI) of a wind power project in Ontario is given by the equation (Albadi & El-Saadany 2009):

$$TI = R - OM - CCA - I$$

Where *R* is the annual revenues of the project, *OM* are the annual O&M costs, *CCA* is the annual capital cost allowance, and *I* is the annual interest paid for debt. However, Albadi & El-Saadany show that although it is clear that incentives will improve the wind project's viability when taxes are neglected, if taxes are considered, the effect of taxation, including tax-related incentives has a negative effect on the project NPV. Non-taxable incentives such as the RESOP improve the NPV. The same study shows that using an accelerated depreciation method would also improve the project NPV significantly. It is therefore expected that a practical application of this wind power investment would prove to be more viable than the calculations of this thesis show.

5.2.4 Solar PV power

Base case assumptions

As for most forms of RE technologies, the main cost associated with investments in solar PV is that of the initial investment. Traditionally, photovoltaic cells have been made from silicon, a very expensive material. Today new technologies such as PV thin-film that can be used in rooftop applications have been developed, using less than 1/10 of the silica needed for the traditional technology. This, however, also means a lower rate of efficiency in converting the solar radiation to electricity; while traditional PV cells are close to reaching the theoretical limit with efficiencies above 20 percent, the thin-films can only reach an efficiency of half of that amount (Coley 2008). Nonetheless, the development has contributed to reductions in the cost of energy produced.

The market price of the solar PV installation varies with its expected generation capacity. Parker (2008) suggests that a size of 3kWp[18] of installed capacity seems to be sensible in domestic rooftop applications. This would create an initial investment of C$30 000 for a 3kWp installation, considering a cost of C$10/Wp (Parker 2008).

The literature often uses an economic lifetime of 20 years for solar PV installations (Lesourd 2001). In calculations related to grid-connected and utility applications, Lesourd claims, a lifetime closer to 30 years may be more realistic. As a compromise, an expected lifetime of 25 years is applied in the calculations. Despite the lifetime of the project being longer than the contract time under the RESOP, it is assumed that the contract can be renewed at the same conditions and that the RESOP rate of C$0.42/kWh is valid for the whole lifetime. This

[18] Kilowatt, peak

assumption will only affect the calculated NPV positively, as it is very unlikely that the market price of electricity would be higher than the RESOP price in 20 years from now.

For solar power systems, two different efficiency factors are relevant; the capacity factor often referred to as the load factor, and the efficiency factor, related to losses due to the theoretical DC output, including the efficiency of the DC to AC conversion (Lesourd 2001). Kurosawa et al (1997) estimate a load factor of 0.20 for average US conditions, and Weise (1993) estimates the same for Germany. As the conditions in Canada do not differ significantly from the German solar conditions, a load factor (L) of 0.20 is used. Following Lesourd (2001), the efficiency factor (e) is 0.85. Thus, the overall capacity factor will be given by the equation:

$$C_F = L \cdot e = 0.20 \cdot 0.85 = 0.17$$

Where C_F is the overall capacity factor, L is the load factor, and e is the efficiency factor.

Operation and maintenance costs are very low for solar power, and mainly consist of maintenance costs. Chabot (1997) uses a maintenance cost of 0.5%. A solar power system is normally assumed to not have any salvage value, and, because of the materials used in producing the system, there may actually be additional costs related to the disposing of a solar PV module (Kannan et al. 2006). For simplicity, it is assumed that there is no salvage value and no salvage costs. Parameters for the solar PV base case are summarized in table 5.3.

Results

The investment in a domestic $3kW_p$ rooftop mounted distributed system would cause a negative cash flow equal to C$30 000 in year zero due to the initial capital investment. For the years 1 through 20, the annual revenues from selling electricity results in an annual cash flow of C$1 600 after taxes. There is no salvage value raising the cash flow for year 20.

As can be seen from table 5.4, the cost of electricity produced by the system is approximately C$ 0.27/kWh. The operation generates about 4 500kWh of electricity each year. Due to subsidised pricing of electricity generated from renewable sources in Ontario, this electricity can be sold at a price of C$ 0.42/kWh, making the annual revenue (B_t) from selling electricity almost C$1900. This is not enough to cover the investment over the projects economic lifetime given the discount rate of 9.7%. The NPV of the whole project is negative; C$ -16

000, with an average predicted loss of about C$0.55 per dollar invested which means that one should not invest in the project. As the IRR shows, the project would only have a positive NPV at an unrealistically low discount rate of 1.6%. The benefit cost ratio is 0.55 < 1 which also weights against the investment.

Just as for the wind power project, this project would be eligible for the ecoEnergy subsidy of ¢1/kWh, which would increase the sales price and thus the estimated NPV. However, because of the small size of the project, financial incentives lowering the initial investment cost should be of primary consideration. Again, accelerated depreciation is expected to have a significant effect on the project NPV.

TABLE 5.3:
SOLAR POWER PARAMETERS FOR CANADA

Capacity factor	Cf	0.17
Project size	kW	3
Economic lifetime	T	25
Sales price	P	0.42
Salvage value	S	0
Investment cost	ci	10 000
O&M %	c_{OM}	0.005
Discount factor	d	0.097
Tax rate	τ	0.14

TABLE 5.4:
RESULTS – SOLAR POWER IN CANADA

Investment cost	Ci	30 000
Energy production	E	4 468
Cost per kWh	c	0.269
Annual benefits	B_A	1 876
Annual O&M costs	$O\&M_A$	150
Depreciation		800
Taxable profit		926
Taxation		130
Annual CF after tax		797
Depreciation		800
Net CF for total assets after tax		1 597
Net present value	NPV	-16 399
NPV per invested dollar	NPV/Ci	-0.55
Benefit cost ratio	BCR	0.55
Internal rate of return	IRR	0.016

NOTE: Energy production stated as average annual generation.

5.2.5 Small hydropower plant (SHPP)

Base case assumptions

The next example considers the investment in a 10MW$_e$ hydropower plant. The cost of installed capital is somewhere between C$4000-7000 for small hydropower schemes up to 10MW. Since the capital investment cost decreases with the capacity of the plant, an investment cost of C$4500/kW$_e$ is applied in the example.

According to the European Union (2009) the capacity factor of a small hydropower scheme is 57% and the relevant investment lifetime 50 years. The same assumptions are made here. The electricity production of actual hydropower plants on the other hand, will vary between the years and between different locations. The power generation of one specific plant depends not only on the technology and size of the installed turbine, but is also subject to variations due to the amount of rainfall and height of the subject waterfall. This means that the same power plant will produce different amounts of electricity depending on the time of year or weather pattern. The power plant in the following analysis has been simplified, following recommendations on average values for yearly operating time and does not take these seasonal or periodical changes in weather and rainfall patterns into account.

The EU (2009) recommends an operating and maintenance cost estimate of C$130[19] for a 10MW hydropower plant. This equals an O&M percentage of 3% of the installed capacity. The Ontario standard offer program secures a price of C$0.11 per kWh for the power the project generates, the same as for electricity generated from wind power. Interest rates, as well as debt and equity ratios remain unchanged from the previous calculations. Also here, the cost of land use is not included. The parameters used in the base case scenario are summarized in table 5.5.

Results

Table 5.6 summarizes the results of the investment analysis of a SHPP in Ontario, Canada. This project shows a large and negative NPV after tax. This is surprising considering the extensive application of the technology in Ontario. One explanation could be that the capacity factor used for the calculations is too low. Newer technology can provide efficiencies in the range of 86-95% for micro hydropower plants in Ontario according to the IEA's Small Scale Hydro Annex. Increasing the capacity factor to 85% gives a significant increase in the estimated NPV toC$6.9 million. This capacity does however seem unrealistically high for a project in the example. Also, small hydro projects, i.e. projects with a maximum output less than 10MW, often have features that make them less feasible than projects of larger capacities. Several of the cost components in developing hydropower do not change according to project size (Jensen & Gjermundsen 2000). As the expected revenue is low, there is less capacity to absorb unforeseen expenses. Small-scale hydropower systems are attractive to remote communities because they are reliable sources of power. Installation

[19] €85, calculated at a currency rate of 0.65 EUR/CAD

costs can be reduced for applications that do not require the building of a dam and other large works (Coley 2008).

The very long economic lifetime and the magnitude of the initial investment represent a hurdle for small-scale hydropower schemes. The high risk exposure incorporated in the discount rate puts less weight on future cash flows. Because of this, future revenues are considered less certain, and the initial investment becomes very dominant in the calculations.

The cost of the capital investment is C$45 million and the annual O&M cost is C$13.5 million. The calculated cost of producing one kWh of electricity is C$0.018. The total electricity generated in one year is close to 50GWh. Selling this electricity at C$0.11/kWh results annual revenues of C$5.5 million over the 50 years which is not enough to cover the cost. The NPV after tax is C$ -12.9 million. A loss of 12 million seems dramatic. However, this investment is considerably better measured per dollar invested than the Solar PV investment in the previous example. The benefit cost ratio is calculated to 0.95 and just slightly below 1, the level of viability. The investment should not be considered given a discount rate higher than 6.7% after taxes.

TABLE 5.5:
SHPP PARAMETERS FOR CANADA

Capacity factor	Cf	0.57
Project size	kW	10 000
Economic lifetime	T	50
Sales price	P	0.11
Salvage value	S	0
Investment cost	ci	4 500
O&M %	cOM	0.03
Discount factor	d	0.097
Tax rate	τ	0.14

TABLE 5.6:
RESULTS - SHPP IN CANADA

Investment cost	Ci	45 000 000
Energy production	E	49 932 000
Cost per kWh	c	0.018
Annual benefits	BA	5 492 520
Annual O&M costs	O&MA	13 50 000
Depreciation		600 000
Taxable profit		3 542 520
Taxation		495 953
Annual CF after tax		3 046 567
Depreciation		600 000
Net CF for total assets after tax		3 646 567
Net present value	NPV	-12 922 020
NPV per invested dollar	NPV/Ci	-0.29
Benefit cost ratio	BCR	0.95
Internal rate of return	IRR	0.067

NOTES: *After 20% investment support, energy production stated as average annual generation

RE investments in Canada

The discounted cash flow analyses show that none of the considered projects are economically viable. The most promising investment is the wind power project. This investment is the closest to being economically viable, measured by BCR, NPV and IRR. The hydropower project has an estimated NPV of C$ -13 million and a BCR of 0.96, reflecting that the capital is not served with the discount factor d= 9.7%. Hydropower is generally not as risk exposed as wind and solar PV investments. This may mean that the discount rate used in the other examples is unrealistic for the hydropower project. The O&M costs for this project isC$130 per unit of installed capacity, which equalsC$130/4500 = 3% of the total investment. This is significantly higher than the same costs for the other proposed investments. In addition, the initial investment per unit of installed capacity is the lowest out of the three projects. The reason why the cost per kWh of electricity is so low is the long lifetime of the project. If the lifetime had been reduced to 20 years, the calculated generation cost/kWh would have been significantly higher: C$0.045 which is about twice as high as the cost of producing electricity from wind, but still much lower than the cost of producing electricity from solar power.

The solar PV investment shows a very high cost per unit of generated electricity despite its five year longer lifetime than the wind power project. This is due to a very high initial investment cost of C$10 000/ kW_p. The higher sales price P is not enough to make the project competitive. The solar PV installation does, however, have the advantage of a possibly smaller installed capacity which is more difficult to obtain using wind or water power projects. However, the internal rate of return on the project is lower than the risk free interest rate and should therefore not be considered at its present terms.

On October 1st 2009, the Ontario federal government launched a feed-in tariff (FIT) program[20]. The pricing structure for contracts under FIT is more differentiated and offers for most technologies a higher contract price than the RESOP price. Using the new pricing structure, the wind power project would obtain a NPV of C$0.3 million and a BCR of 1.31 due to an increase in the price offered on electricity from wind power of C$0.135. The solar PV investment would achieve a contract price of C$0.802, which is almost double the rate used in the previous calculations and would give a NPV of C$ -5000 and a BCR of 1.06.

[20] http://www.powerauthority.on.ca/sop/

Despite a very small increase in the offered price, from C$0.11 to C$0.131, the SHPP now has a much greater NPV of C$ -5.2 million and a BCR of 1.13.

Because the aim of this thesis is to capture the changes in RE investments following the economic crisis, RESOP pricing structure has been used in the calculations. The FIT program was introduced more than a year after the crisis broke, and it is difficult to decide whether or not the prices would have been increased as much in a different economic climate. Policy measures such as stimulus packages to support the Canadian economy can have secured the necessary funds for the FIT program.

TABLE 5.7: RESULTS CANADA

	Wind	Solar PV	SHPP
c	0.038	0.269	0.018
NPV	-400 000	-16 000	-13 000 000
BCR	1.07	0.55	0.95
IRR	7.6%	1.6%	6.7%

5.3 Analyzing renewable energy investments in Norway

5.3.1 Discount rate

Following the discussion in the previous sections, the discount rate for the Canadian investments is given by:

$$d = 0.025 + 0.70 \cdot 0.05 + \ 0.75[(1 - 0.28)(0.025 + 0.02 + 0.01) - 0.025] + 0.02 \\ = 0.091$$

The discount rate used for Norway is therefore 9.1 %

5.3.2 Electricity prices

The relevant sales price for electricity from both sustainable and unsustainable sources is the long-term market electricity price. An opportunity study prepared by the Norwegian Water Resource and Energy Directory (NVE) in conjunction with ENOVA (NVE/ENOVA 2008) assesses the prospects of investing in onshore wind power in Norway. The study uses an electricity price of NOK 0.45/kWh (C$0.083[21]), which is the average of the price on three year contracts for electricity on Nordpool the last six months before the study. It is assumed in the study that this historically high electricity price is the result of decreasing petroleum reserves, and that the price will stabilize at this level. Yearly elspot prices from Nordpool (appendix 4) confirm an increasing trend. Johnsen (2008, 2009) shows that the average the average price on the same contracts decreased after the summer of 2008, mainly due to a lower demand for electricity which was priced into the contracts. It is assumed that the reduction in electricity prices will be incidental so that the price will stabilize, but on a level slightly lower than what the NVE/ENOVA report assumes. In December 2009 the price on forward contracts on Nordpool for 2014 has been approximately NOK 0.38/kWh. This corresponds to the price of C$ 0.07 used in this example. For the purpose of comparability of the results, Canadian dollar (C$) is the relevant currency in both analyses. The exchange rate used is 5.4 NOK/CAD.

5.3.3 Onshore wind power

Base case assumptions

The Norwegian example considers an investment in a 2.6 MW onshore wind turbine, which was the average size of the turbines installed in 2008 (NVE 2009). This is a slightly higher capacity than the current average size of a Norwegian wind turbine. Due to an increase in the prices for steel and copper, and the fact that the supply has not kept up with the increase in demand for wind turbines in recent years the European market prices for wind turbines have increased in recent years (NVE/ENOVA 2009). The average price for a wind turbine in Europe installed in 2007 was €1600/kW (C$2500/kW[22]). The growth is expected to continue, but decrease some over the next five year period to an average cost of € 1950/kW (C$3050/kW (Holt et al. 2008, NVE/ENOVA 2009). An initial investment (ci) ofC$2500/kW of installed capacity is assumed relevant for the example. This is higher than the corresponding cost for Canada due to the higher demand for wind turbines on the European market.

[21] Calculated using an interest rate of 5.4 NOK/CAD
[22] Calculated at an interest rate of 0.64 EUR/CAD

The economic life time is 20 years for the installed turbine (EWEA 2009), the same as in the Canadian example. Following Mathew (2006), the same salvage value S of 10% and O&M costs of 2% of the initial investment are considered relevant for this example.

While Canada is a country with relatively good wind conditions, Norway's high occurrence of extreme wind speeds affects the capacity factor of the installed wind power farms. Following the results in the report by NVE (2009), the average capacity factor of Norwegian wind power installations in 2008 was 24.3% which is unusually low. The average capacity factor over the last eleven years is 25.7% (see appendix 1). A capacity factor of 26 % is applied in the calculations.

In Norway, current investments in wind power receive investment support from through the governmental enterprise Enova. This year, Enova has NOK 3.5 billion (C$0.65 bn[23]) to its disposal, earmarked initiatives that can increase the energy efficiency and the share of renewables in the Norwegian economy (Enova homepage). This is including an additional NOK 1.2 bn that was granted the enterprise through the Norwegian government's stimulus package. Wind power projects can receive financial support of up to 50% of the total investment cost. To qualify for Enova support, the relevant discount rate d for the project has to be no higher than 8%. In order to capture the effect of this political incentive however, it is assumed that the wind power projects studied here qualify for support despite the higher discount rate. Table 5.9 sums up the values of the parameters included in the model.

Results

Table 5.10 displays the results of the investment analysis for the Norwegian onshore wind turbine project. The first thing that is evident, is that the calculated NPV of the project is negative and that the BCR is lower than 1, which means that it would not be a good investment as long as the values of the model parameters remain at their current levels.

The initial investment cost for a 2.6MW wind turbine will amount to C$6.5 million. After deducting the 50% investment support, the cost of the initial investment is C$3.25 million, while the annual O&M is C$ 130 000. The cost per kWh of power generated from the project is C$0.03. This cost is unrealistically low. According to NWEA[24], the price of generating electricity from wind in Norway is somewhere between C$0.11 and C$0.16. The main reason for this very low average production cost per kWh is the Enova support. The cost is

[23] Calculated at an exchange rate of 5.4 NOK/CAD
[24] Interview with Ben Bjørke at Norwegian Wind Energy Association (NWEA)

calculated based on the initial investment after the support rate has been deducted. However, the total capital initially invested in the project is still C$6.5 million, even though the relevant cost for the investor is lower. Calculating this cost again based on the total capital invested, the cost is C$ 0.056 which is still significantly lower than what most studies predict. This might mean that the model is underestimating the O&M costs, and that these costs should be higher because of the rough climate of the Norwegian coastline which is likely to increase the wear and tear on the wind turbine. This example does not include land rent and that may also influence the results.

If this power is sold at a rate of 7.0 cents per kWh, the annual benefits amount to C$0.4 million. This is not enough to cover the total costs. The net present value after taking the terminal value of 10% into account is C$-1.1million. The calculated BCR is 0.98 and the IRR is 4.3%.

TABLE 5.9:
ONSHORE PARAMETERS FOR NORWAY

Capacity factor	Cf	0.26
Project size	kW	2 600
Economic lifetime	T	20
Sales price	P	0.07
Salvage value	S	0.10
Investment cost	ci	2 500
O&M %	cOM	0.02
Discount factor	d	0.09
Tax rate	τ	0.28
Enova support rate		0.50

TABLE 5.10:
RESULTS – ONSHORE FOR NORWAY

Investment cost	Ci	3 250 000
Energy production	E	5 921 760
Cost per kWh	c	0.027
Annual benefits	B_A	414 523
Annual O&M costs	$O\&M_A$	130 000
Depreciation		108 333
Taxable profit		176 190
Taxation		49 333
Annual CF after tax		126 857
Depreciation		108 333
Net CF for total assets after tax		235 190
Net present value	NPV	-1 060 524
NPV per invested dollar	NPV/Ci	-0.33
Benefit cost ratio	BCR	0.98
Internal rate of return	IRR	0.043

NOTES: *After 50% investment support, energy production stated as average annual generation

5.3.4 Solar PV

Solar PV electricity generation in Norway is limited to the development of the technology for export to other European countries. Even though Norway has important industry competence in the technology of solar PV panels, a successful large-scale application of the technology in

Norway is highly unlikely. Due to low solar radiation and cheap electricity from other renewable sources, the only solar technology relevant for the Norwegian market today is the application of small domestic solar panels to supply power to cabins and cottages without grid connection. Compared to Canada (Ontario), where the electricity building mounted solar PV panel can be sold back to the grid through the previous Renewable Energy Standard Offer Program (RESOP), and the current feed-in tariff (FIT) program, solar PV investments are not profitable in Norway as no such support mechanisms exist.

5.3.5 Offshore wind power

Base case assumptions

A second analysis on wind power projects seems more relevant for the purpose of this thesis. The last several years have seen an increasing numbers of players from the offshore industry, both suppliers to the offshore petroleum platforms as well as the large oil and gas companies themselves, investing in offshore wind power projects and technology. Because of the offshore competence of the Norwegian petroleum sector, combined with the knowledge of and experience from the world energy markets, this trend seems to represent an opportunity for expanding Norway’s role as an energy player into the future.

The analysis will consider a 3000kW ground mounted wind turbine installed in shallow waters (< 30 m) with a life time of 20 years. This is the most mature technology for offshore wind power generation. Despite a possible greater potential for floating devices and ground mounted devices on larger depths in the future, the technology is not mature enough today. The price of the initial capital investment is estimated at NOK 18,000/kW installed capacity (C$3300/kW). It is assumed that this capital investment includes the cost of grid connection, which in Norway has to be covered by the developer.

A study conducted by Enova (2007) assessed the potential for ocean energy in Norway. An operating time of 3066 hours/ year for a corresponding installation was used by Enova, which offered the capacity factor of 35% used in this analysis. Generally, offshore winds are stronger and more constant than onshore winds (Snyder et al. 2007). Therefore offshore wind turbines are expected to operate at their maximum capacity for a larger percentage of the time. The terminal value is 10%. According to Enova, the relevant yearly O&M costs are expected to be NOK 0.95million per MW per year which equals 0.95/18 = 0.0527 or roughly the 5% used in the following calculations.

Interest rates, inflation rates, risk factors and debt-to-equity ratio remain the same as in the onshore wind example. As offshore wind projects are eligible for investment support from Enova, the 50% support rate introduced in the analysis of the Norwegian onshore turbine is also included here. The input parameters for the cash flow analysis of the offshore wind project are summarized in table 5.11.

Results

The results of the investment analysis for the Norwegian offshore wind turbine project are presented in table 5.12. The total NPV of the project is C$ -3.5 million and negative, which means that a potential investor would not meet the capital return requirements on this project. The BCR is 0.80. This is improved compared to a case without investment support from the government of 50% which reduces the total capital investment cost from C$9.9 million to C$4.95 million. In this example the taxable income falls below zero. Because a linear depreciation method is used, the possibility of postponing taxes and receiving benefits in future years is ignored. The payable tax is therefore set to zero. However, in a realistic case, this negative tax could in many cases be received as a tax benefit in future years when the taxable income is positive. The IRR is negative, which means that the benefits of this project are not able to cover the costs. With an annual cash flow after tax of C$ 0.2 million over 20 years, the initial investment of C$4.95 million is not covered, despite the 50% support from Enova.

The annual O&M cost is C$0.5 million. The cost of producing one kWh of electricity is C$0.03 (NOK 0.15) and slightly lower than the same cost for an onshore wind power turbine application. Including the total investment when calculating the cost of power produced from the turbine, the cost is C$ 0.054 which is still too low compared to other studies. The initial investment however is too high to cover the total investment costs over the economic lifetime of the investment. Selling this power at a rate of 7.0 cents per kWh generates the annual revenue of C$0.6 million.

The offshore environment is considerably more uncertain than onshore, and thus more costly and risky (Snyder et al. 2007). The results in this thesis confirm this by the significantly larger negative NPV of the offshore application compared to that of the onshore application.

There are increased costs due to personnel and equipment travelling to and from offshore which increases time costs and insurance costs. Also, an increased risk of storms may be affecting the time available for maintenance and installation which in turn influences capital and O&M costs, Snyder et al. point out. In addition, the equipment is more expensive as the offshore environment is corrosive to electrical and structural installations. This requires the turbines to be treated with cathodic and humidity protection that increases the capital expenditures.

Many studies show that larger turbines are more suitable for offshore applications due to economies of scale. While cost reductions due to economies of scale are limited for onshore applications because the size of the turbines is limited to the ability to transport the blades, tower and nacelles of the turbine (Snyder et al. 2007). At sea however, transportation is much easier and these restrictions are not an issue. In the near term offshore wind investments are expected to be more expensive than onshore applications, but this can partly be balanced by stronger offshore winds that in would cause the turbine to operate at its maximum capacity for a longer period of time, thus increasing the capacity factor, Snyder et al. (2007) explain.

The primary cost drivers for an offshore wind turbine are thus the capital costs and the capacity factor.

TABLE 5.11:
OFFSHORE PARAMETERS FOR NORWAY

Capacity factor	Cf	0.35
Project size	kW	3 000
Economic lifetime	T	20
Sales price	P	0.07
Salvage value	S	0.10
Investment cost	ci	3 300
O&M %	c_{OM}	0.05
Discount factor	d	0.09
Tax rate	τ	0.28
Enova support rate		0.50

TABLE 5.12:
RESULTS – OFFSHORE FOR NORWAY

Investment cost	Ci	4 950 000
Energy production	E	9 198 000
Cost per kWh	c	0.027
Annual benefits	B_A	643 860
Annual O&M costs	$O\&M_A$	495 000
Depreciation		165 000
Taxable profit		-16 140
Taxation		0
Annual CF after tax		-16 140
Depreciation		165 000
Net CF for total assets after tax		148 860
Net present value	NPV	-3 472 501
NPV per invested dollar	NPV/Ci	-0.72
Benefit cost ratio	BCR	0.80
Internal rate of return	IRR	-0.026

NOTES: *After 20% investment support, energy production stated as average annual generation

5.3.6 Small hydropower plant

Base case assumptions

A small hydropower plant is defined as a hydropower scheme with a rated power of 3-25MW_e (OPET-India 1994). This classification differs from the one use by the Norwegian government, who classifies small hydropower schemes as the schemes with a rated power up to 10MW_e of installed capacity. For comparability purposes however, a SHPP of the same size as the one used in the Canadian example will be considered; a 10MW_e power plant. The expected lifetime of such an investment in Norway is 50 years[25].

The capital investment is normally somewhere between NOK 2.50 – 4/kWh (C$0.46-0.74/kWh). This equals a cost per installed kW_e ofC$2300 -C$3700[26]. The average cost per unit installed capacity isC$3000/$kW_e$. This is lower than the corresponding cost for Canada[27]. No salvage value on the physical capital is assumed.

Following recommendations made by Econ (2008) operation costs of NOK 0.10/kWh (C$ 0.02) of power generated by the project are used in the following calculations. In addition to this, there are costs related to land rent, normally in the scale of 10% of the gross sales. The cost of land rent has not been included in any of the other examples, and will therefore be ignored here for the purpose of comparing the different examples.

A 10MW SHPP in Norway has between 4000 and 5000 operating hours per year (Econ 2008). Assuming 5000 hours of operating time each year the capacity factor equals 5000/8760 = 57%, the same as was used in the Canadian example. A 10MW SHPP with a capacity factor of 57% will produce 50GWh each year. Considering the O&M cost of C$0.02/kWh of generated electricity, the yearly O&M cost amounts toC$1.5 million orC$150 per kW_e of installed capacity. This is slightly higher than the operating cost for a similar project in Canada. For the purpose of comparing the different hydropower analyses, the O&M costs are applied as a percentage of the installed capacity.

The parameters are summarized in table 5.13.

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[25] www.kraftverk.net/downloadfile.php?blobId=10

[26] 50GWh·C$0.46=C$23 million, 50GWh·C$0.74=C$37 million;

[27] As we remember from chapter ## the cost per unit installed capacity in the Canadian example was C$4500/$kW_e$.

Results

The results from the cash flow analysis of a small hydro power project in Norway are displayed in table 5.14. The NPV is negative with a value of C$ -8.5 million, and the calculated BCR is 0.95. This is surprisingly low, but corresponds with the results found for Canada. This strengthens the suspicion that the discount rate used may be too high for this technology and /or that a realistic capacity factor may be higher. The many high waterfalls in Norway make the installation of a SHPP possible without any serious construction work. This would in many cases mean a lower investment cost per unit of installed capacity. Given the magnitude of the initial capital investment, a lower investment cost is expected to have a strong and positive effect on the estimated NPV after tax.

As the risk exposure is lower than for most other RE investments. The IRR is 6.3%, which means that the project would have a NPV above zero at a discount rate of 6.3% or lower. However, given the current discount rate should a profit maximizing investor refrain from investing in this project. The annual O&M cost is C$0.9 million. The cost per kWh of produced electricity is C$0.012. At a sales price of C$0.07/kWh the revenues are cover the costs over the economic lifetime of the investment. The yearly revenues for electricity sales amount to C$3.5 million.

TABLE 5.13:
SHPP PARAMETERS FOR NORWAY

Capacity factor	Cf	0.57
Project size	kW	10 000
Economic lifetime	T	50
Sales price	P	0.07
Salvage value	S	0.00
Investment cost	ci	3 000
O&M %	c_{OM}	0.03
Discount factor	d	0.09
Tax rate	τ	0.28

TABLE 5.14:
RESULTS – SHPP FOR NORWAY

Investment cost	Ci	30 000 000
Energy production	E	49 932 000
Cost per kWh	c	0,012
Annual benefits	B_A	3 495 240
Annual O&M costs	$O\&M_A$	900 000
Depreciation		400 000
Taxable profit		2 195 240
Taxation		614 667
Annual CF after tax		15 80 573
Depreciation		400 000
Net CF for total assets after tax		1 980 573
Net present value	NPV	-8 503 877
NPV per invested dollar	NPV/Ci	-0.28
Benefit cost ratio	BCR	0.95
Internal rate of return	IRR	6%

NOTES: Energy production stated as average annual generation

Note, that the main reason for installing small-scale hydropower plants not always would be to make a profit as assumed in this thesis. In many cases, a SHPP is the cheaper alternative for remote communities compared to connecting to a national grid. It has however not been the objective of this analysis to consider such a case.

5.3.7 RE investments in Norway

The electricity generated from the three projects can be sold for the same price/kWh on the Norwegian electricity market. This makes it somewhat easier to compare the different investments, despite the differences in the initial investment cost and installed capacity. Hydroelectricity is, as expected, the cheapest form of electricity as it can be produced at a cost ofC$0.012/kWh. This is less than 1/3 of the cost of producing electricity from wind.

The cost of producing electricity using an offshore wind turbine is slightly lower per kWh than a project using a wind turbine placed onshore. This lower generation cost is however offset by an O&M cost of 100/kW or 3%, which is higher than the 2% O&M cost for the onshore project. The reason for this lower generation cost is a higher capacity factor due to more stable wind speeds offshore.

The NPVs of the wind projects considered here are negative. This corresponds with the author's expectations following research for this thesis. It can be questioned if investments in new renewables are economically viable in Norway today without further subsidies. The low cost of producing wind power in Norway is solely due to the high rate of support from Enova.

Currently, there are plans of introducing a new incentive system for renewable energy in Norway. Through the introduction of so-called obligatory green certificates, the renewable energy generation projects would receive an additional income. A green certificate is a proof that a certain share of the energy delivered to the grid comes from renewable sources (Ådland 2004). If all electricity generators had to buy a number of such green certificates, a market for buying and selling certificates would arise. Thus, owners of RE generation facilities could achieve an additional income from selling such certificates. Such certificates are already in effect in a number of countries, including Sweden, and the current hope is that the Norwegian market could be included in the Swedish system, thus create a common market for green certificates in the two countries. The effect of a certificate market however, depends highly on the price the market assigns to the certificates, and the importance of such a system is frequently debated in Norwegian press.

TABLE 5.15: RESULTS NORWAY

	Onshore wind	Offshore wind	SHPP
c	0.027	0.027	0.012
NPV	-1 100 000	-3 500 000	- 8 500 000
BCR	0.98	0.80	0.95
IRR	4%	-3%	6%

5.4 Summarizing the results of the investment analysis

The analyses confirm that in general, renewable energy generation is not a profitable investment. However, the profitability of RE projects seems to vary between the two countries. The Ontario RESOP and FIT programs seem to contribute positively to the results, making the Canadian projects in more profitable than the Norwegian projects considered here. The consequences of this will be discussed more closely in the following chapters.

The analyses have shown that the price at which the investor can sell the electricity generated from the RE project seems to have a large influence on the profitability of the investment. Also, the size of the initial capital investment is important for the projects' economic viability. A large share of the investment cost goes towards the equipment such as the tower and the turbine in wind power projects, the silicon based PV panels in the solar PV project and the turbine in hydroelectricity projects, as well as transport of the equipment to the project location. The initial investment is not subject of discounting because it happens today. If the investment cost is determined by the price on specific commodities, one would expect that the past two years' volatile commodity markets have affected the profitability of investing in RE generation projects. More specific; one could expect to observe an increased level of investments following the sharp decline in commodity prices starting in the summer of 2008.

The analyses in this chapter have been executed given simplifying assumptions such as no land rent, and linear depreciation. Other works have shown large and positive effects of using an accelerated depreciation technique instead of the linear method used here. In Canada, accelerated depreciation is in many cases allowed for RE projects, thus would the author expect to find a higher profitability for many projects compared to the findings of this thesis. Norwegian taxation rules do however not allow for accelerated depreciation. Other tax benefits that may apply in both cases are expected to affect the NPV positively, but not as much as non-tax related incentives (Albadi & El-Saadany 2009). A system of long-term purchasing contracts for RE has proven to be successful in Canada. Due to the planned system for green certificates in Norway, higher profitability for RE projects is a future possibility.

The discussion of the parameter values and the subsequent analysis indicate that the future cash flows of most RE projects are subject to a high degree of uncertainty. This uncertainty (risk) has to be accounted for through the discount rate. RE projects are characterized by a high initial investment, a long economic lifetime and low O&M costs. Due to this cost structure, a high discount rate disfavours RE projects as the future revenues become heavily discounted and thus less important for the overall profitability of the project. However, the very low internal rates of return indicate that higher electricity prices and lower investment costs are necessary in order for RE generation to be competitive. The two countries in this analysis have chosen two different approaches. In Canada, the Ontario provincial government have removed the price risk by securing higher long-term prices for electricity from renewable sources. The pricing contracts have so far been a success and have contributed to a massive development of the RE sector in the province. In Norway, the government have targeted the high investment costs through investment grants. According to this analysis, even a 50% investment grant would not be enough to make wind power projects competitive.

The DCF analysis shows that small-scale hydropower is not very profitable in either of the two countries studied here. The findings are in sharp contrast to what the author would expect to find based on the high level of development of this particular technologies in both Canada and Norway. It is expected that the very long economic lifetime and the high initial costs of SHPP projects will cause this lack of profitability when using a high discount rate. In the literature, SHPPs are considered stable sources of power. Further study should investigate the risk exposure of such projects more closely to determine the level of uncertainty and appropriate discount rate for such investments.

5.4.1 Changes to the model parameters following the economic crisis

The costs and benefits contribute to the project cash flow. The O&M costs do influence the results of the analyses significantly, but the large initial investment cost does. As discussed previously, the investment costs for the RE technologies considered here are highly dependent on prices on commodities such as steel and silicon. When commodity prices are falling, the initial investment cost is reduced. As the initial investment cost occurs today, it would be beneficial to proceed with the investment when the prices are at an all-time low.

The incidental changes in interest rates following the high volatility of financial markets in the past two years are not directly influencing the results, as the life times of the investments demand a long term discount rate. If this volatility is in fact a temporary phenomenon, the changes in nominal interest rates and inflation rates should not make a difference. The same goes for the sales prices of the electricity generated from the project. Low energy prices will only affect the project profitability temporarily, as the energy prices will increase again due to supply and demand factors in the world energy markets. However, interest rates and energy sales prices can be fixed using long-term contracts at the time of the investment decision and thus can a temporary lower interest rate level indirectly affect investment levels. A growing global energy demand combined with fossil fuel depletion will contribute to keep energy prices at a high level over the coming decades.

Several factors would support the evidence of the investment analysis. The drivers behind the growth in this sector before the crisis; climate change, the need for energy security, fossil fuel depletion and technological growth are still present. Also present is a strong core of demand based on renewable portfolio standards, new fuel standards and efficiency regulations. Investments in power generation projects have an expected lifetime of 20 to 50 years. Thus, short term fluctuations in interest rates and stock markets should have little or no influence on the investment level because of the long term timeline of such investments. Assuming no restrictions on the flow of capital, a rapid fall in interest rates should increase the investment level. That is, if one believes that the world is already starting to recover from the recession and that the world economy will be back on long term growth in the short to medium term. As the next chapters will show, however, an increase of RE investments is not observed in the Norwegian and Canadian investment markets.

CHAPTER 6: INVESTMENT INCENTIVES

There are several factors that contribute to making an investment economically viable. The previous chapter examined the costs and revenues of renewable power generation. This chapter will build on the results from the investment analyses of chapter 5 and discuss the motives of the investor more closely. Chapter 3 identified three different investor groups in each of the two countries subject to this discussion. In order to understand the investment behaviour following to the economic crisis, a closer look at the incentives to invest is necessary.

6.1 Multinational oil and gas companies and offshore suppliers

In recent years, multinational oil companies have shown increased interest in the RE sector. These global petroleum giants know the dynamics of the world energy markets and therefore have a clear advantage of diversification into other energy segments. In the years before the economic crisis hit, these companies seemed to react to the increased focus on climate change and sustainability by transforming into global *energy* companies and by starting to invest in more sustainable energy technologies. While new logos and branding ostensibly signalled the increased interest of these companies in sustainability, the *real* incentives behind these strategic changes are less obvious.

In the spring of 2007, the Norwegian national oil company Statoil agreed to buy the Canadian oil sands venture North American Oil Sands Corporation (NAOSC). "We are building a large resource base in the stable region which will provide long-term growth after 2010," Statoil Chief Executive Helge Lund said in an interview with Reuters (Moskwa 2007). NAOSC operates 1 110km^2 of Athabascan oil sands and is expected to produce 200 000 bpd[28] by the end of the next decade. This is a very important strategic investment for Statoil. However it does show the increased focus on sustainability in a different light. A company who is changing direction to become a more environmentally concerned and sustainable company would not invest in the most polluting oil production technology available today. Statoil's activity in the Canadian oil sands inspired activity in the Norwegian election campaign in the fall of 2009. In an article by CEO Lund (Lund 2009), the reasons behind this strategic investment is explained by what he refers to as "the realities of energy"; an

[28] Barrels per day

increasing energy demand that in the foreseeable future has to be met by fossil fuels. Renewable energy will, according to Lund, provide a larger contribution in the long-term. It is clear, that Statoil's responsibility as *the* Norwegian oil company weights heavier than environmental concerns. Oil remains Statoil's core business, and will be so for the coming decades, despite any concerns the company has communicated to the public.

Statoil is not alone. Canadian oil companies Nexen, EnCana and Suncor among others, have all signalled increased interest in cleaner energy technologies in recent years. However, despite the concerns expressed about climate change, they all have significant parts of their operations in the Albertan oil sands. The question is why they would all signal something that seems to be so at odds with their actions? Are the so-called "strategic changes" based on a genuine concern for the environment or could other motives lay behind these investments? I believe that there are two deciding factors: First, climate change has become the corporate responsibility issue of this decade, and our dependence on fossil fuels is the driver behind it. It is important for oil companies to show the public that they care and to visibly take responsibility for the climate reality that their core business has significantly contributed to. Second, record-high oil and gas prices in recent years have created huge returns for the oil companies. This profit must be reinvested to create even higher returns. With low interest rates, investors move to riskier business segments in order to achieve higher returns on their investments. RE projects have represented a suitable investment opportunity as they represented higher risk, but promised growth as long as the oil price kept rising. As they were also within the energy sector, companies were further afforded a chance of utilizing the experience and expertise gleaned from their core business.

In Norway, as the oil companies moved on to the RE markets, their suppliers followed. Ocean energy represented a possibility for companies from the offshore petroleum sector to use their offshore experience for projects in ocean energy. Tidal power, wave power and offshore wind power had created a new business with a need for suppliers that were familiar with the offshore environment.

6. 2 Utility companies

Traditionally, the utility companies in Canada and Norway are publicly owned. Both countries have however seen significant changes to their electricity markets in the last decades. Through deregulations and privatizations in the end of the 1990s the structure of the industry has changed in Norway, leading to the opening of the common Nordic electricity market. The establishment of Nord Pool, the Nordic Electricity Exchange was an important part of this change. Nordic electricity trading has contributed to more predictable market conditions, and thus a more predictable electricity price in Norway.

The Ontario electricity market opened in May 2002, moving the province from a monopoly-based electricity system to a competitive electricity market. This new efficiency created a space for electricity created from new renewable sources, since this electricity may be profitable during peak hours. There are economies of scale in production of electricity from RE. Therefore, this deregulation contributed to the creation of a RE sector in Ontario, helped by the provincial government's standard offer program.

The utility companies are electricity experts, and by combining different sources of energy, they are able to make RE profitable if produced at a scale that would fill the gap created during peak demand, where the electricity price is high enough to cover the cost of producing the energy. The majority of the utility companies are still publicly owned both in Canada and Norway. This means that in addition to these companies' experience from the electricity sector, political incentives and political will with regards to creating a base of energy created from renewable sources affect the strategic choices. However, despite the fact that the strategic choices might be coloured by the current political climate, the utilities are profit maximizing companies who invest in RE technology because it is profitable.

6. 3 The RE companies

The last group of investors consists of the companies that have chosen renewable energy as their core business. These are private, profit maximizing companies that invest in RE because they believe it is a profitable business in the long run. One could say that this group of investors has a more optimistic view of the future of RE. These companies are important, however, in order to increase the share of energy created from sustainable sources, continue the technological research and cost savings of the RE sector. The RE companies are high risk, and many will not survive more than a few years.

Because most such companies are relying on debt financed projects, this group is more exposed to changes in the credit liquidity. The RE companies are smaller and do not have the long experience that the oil companies and the utilities have. They are therefore considered as significantly riskier investments than the companies of the two other groups. That might make debt financing more difficult. The credit crunch in the fall of 2008 and the following flight to quality affected these companies more than the other groups because of this.

6.4 Chapter summary

The DCF analyses indicated that the magnitude of the initial investment seems to represent an obstacle to RE investments. Because of the high cost of generating power from new renewable sources such as wind and solar power, the price this electricity can be sold for is also crucial. There are two main ways of dealing with this politically, and the two countries studied here have each chosen one approach. In Canada, the political incentives have created by offering long-term contracts that secure a higher price for electricity created from renewable sources. This eliminates the price risk and gives incentives to invest. In Norway, the incentives are based on lowering the size of the initial investment. This aims at reducing a different source of risk: the financial risk.

Based on the results, the turbulence of financial markets and the following volatility in interest rates are not expected to affect RE investments significantly. The long-term interest rates relevant for an investment analysis have not changed drastically. However, if it was possible to fix the interest rate at a lower rate in the fall of 2008, this would create a temporary reduction in the interest rates. Also, the lower energy prices represent a window of “cheaper investments” and based on standard economic predictions, one would expect that the investments would increase during this time. Other factors will have to explain the deviations of the results from what actually happened.

SECTION 3: RENEWABLE ENERGY AND RISK

Question 3: How can we use risk modelling to capture the observed development in renewable energy investment following the economic crisis?

In chapter 5 the main parameters in the investment analysis were discussed. Since this thesis assumes that the investors are profit maximizing, this model should predict their behaviour. There is however evidence that other mechanisms may be at work here.

CHAPTER 7: THE RECESSION AND RENEWABLE ENERGY INVESTMENTS

The investment analysis of chapter 6 indicated that the situation for RE technologies was unstable at the time the financial crisis broke out. With low profitability and high capital requirements, many RE projects would not be considered good investments. The rough analysis of this thesis does however not mean that all RE investments are unprofitable. Project specific factors could give large variations in the project viability. However, the far from stable profitability of such investments in general may have increased the exposure of RE projects to dramatic changes in the financial and economic environment. Due to a high degree of debt financing, we expect to find large effects on the RE investment level following changes in the availability of credit in the markets. This chapter will discuss the financial evidence of the development in renewable energy investments.

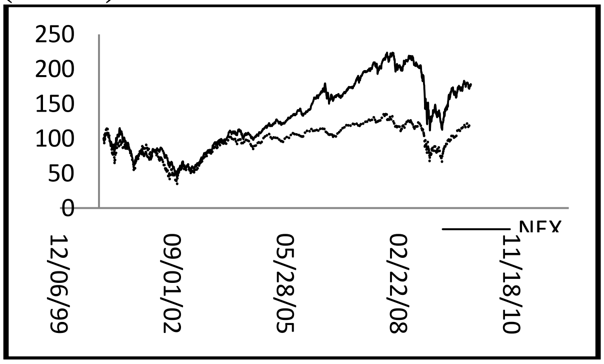
7.1 Financial evidence

The economic crisis left capital in short supply in all financial markets. A study by UNEP (2009) predicts that RE technology investments will decrease over the next two years, in particular newer technologies, due to this reduced liquidity. The situation for the technologies studied here is expected to be a little better because the roll-out of these technologies requires large amounts of capital for asset financing, compared to more RE technologies that are still on an experimental level. Such projects will be preferred by investors, as they include more experienced counter-parties and more security for the invested capital. More experimental technologies are hit harder by the investors' flight to safety. The credit crunch, combined with lower energy prices is expected to have hit the RE sector hard.

7.1.1 Changes in investor behaviour

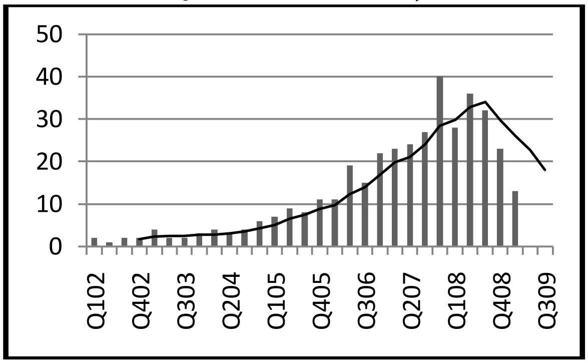
Most RE projects are debt financed and the shortage of liquidity in the markets is expected to have a large impact on the RE sector as a whole. The first question we have to ask is whether or not we can observe any changes in investment behaviour. Chart 7.1 displays the development in the Wilderhill New Energy Global Innovation Index (NEX) against the US Nasdaq composite. The Wilderhill index is comprised of companies worldwide who focus on the generation and use of cleaner energy, conservation and efficiency. There are two Canadian companies included in the index; 5N Plus, a company that produces high-purity metals and compounds used in solar energy applications among others, and Canadian Hydro Developers. The solar PV company Renewable Energy Corp. (REC) is the only Norwegian representative. The index started the year 2008 at 455.19. It stayed between 350 and 450 through the first three quarters of 2008 and at first it seemed like renewable energy resisted the credit crunch more successfully than any other sectors. The historically high oil prices contributed to the development. From September onwards however, the crisis started to show an impact. In the last quarter of 2008, the index collapsed, dropping 70% from its third quarter level. This drop was steeper than for most non-specific stock indices. In comparison, the Nasdaq only dropped by 41%. Looking at numbers for individual sectors, solar stocks fell on average by 75% through 2008, while wind stocks fell by 56% (NEF 2009).

CHART 7.1: NEX VS. IXIC 2001-2009 (US$BN)



NOTE:Indexes rebased to 100. Source:UNEP 2009

CHART 7.2: THIRD PARTY NEW INVESTMENT QUARTERLY TREND, GLOBAL



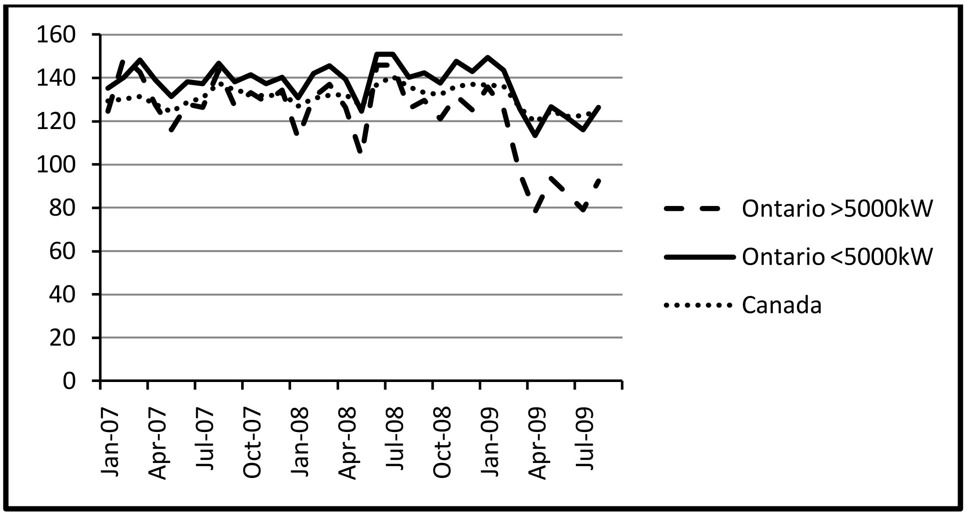
NOTE: New investment volume adjusts for re-invested equity**.** Total values include estimates for undisclosed deals. Source: UNEP 2009

By looking at indicators of clean energy asset financing, we can get an idea about the situation for the more mature RE technologies. Chart 7.2 shows the quarterly trend in new investments from Q1 2002 to Q1 2009. We see a sharp decline in new investments from the third quarter of 2008 which continued through the first quarter of 2009. From the second quarter of 2009 however (not included in this chart), the numbers have started to increase again.

7.1.2 Electricity prices

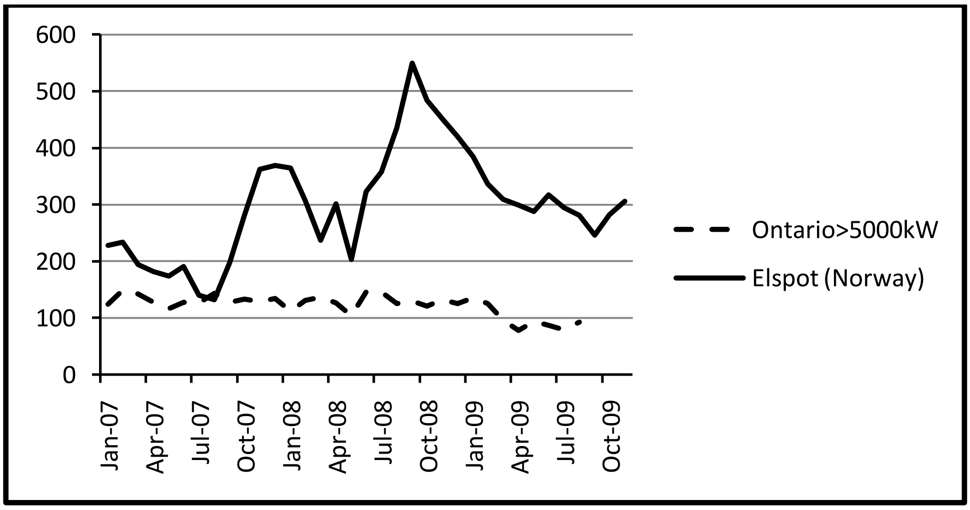
Following the financial crisis of 2008, electricity prices declined sharply in all markets in step with i.e. the falling oil prices. Because the Canadian energy markets are still characterized by large monopolistic utility companies, the observed effects were smaller for the Canadian market as a whole. The province of Ontario experienced sharper falls in the electricity prices due to the reformed provincial electricity market there. However, as can be seen from the charts 7.3 and 7.4, the volatility of the Nordic (and thus Norwegian) energy market has been much greater during the whole period, probably due to a more effective competition in the Nordic markets. Because of the price guarantee from the Ontario government, this affected the profitability of the Norwegian RE investments more than similar projects in Canada (Ontario). The data is summarized in appendix 2, 3 & 4.

CHART 7.3: ELECTRICITY PRICE INDEXES FOR ONTARIO AND CANADA



NOTE: Monthly electric power selling prices, indexed (1997=100), source: Statistics Canada

CHART 7.4: ELECTRICITY PRICES FOR NORWAY



NOTE: Elspot prices on Nord Pool Spot (NOK/MWh), source: Nord Pool Spot

7.1.3 Reasons for the sharp decline in the value of renewable energy stocks

It is clear that the RE sector has been affected by the economic crisis. The costs of clean energy have seen unnatural heights over the past few years, mainly due to supply-chain bottlenecks and soaring commodity prices. An investment surge had just started to ease this situation when the credit crunch arrived to put the squeeze on demand. Because of the high level of debt financing, this reduced supply of liquidity hit the RE sector harder than other sectors. When unexpected events like a recession hit the economy, investors tend to become more risk averse. In an effort to diversify their portfolio, the more risky investments are left behind.

The observed investor behaviour does not confirm the increased willingness to invest that standard economic theory would predict and we have to find a way of modeling the observed behaviour. A loss of risk appetite among the investors started to manifest in September 2008. This included the banks and financial institutions that up to that point had provided debt financing for RE investments. Sharp increases in borrowing spreads offset by the rapid reductions of official interest rates in the winter of 08/09 illustrate this new investment environment. As project financing was hard to obtain, projects with a lower risk profile were prioritized, leaving the high-risk RE sector lacking investors. There are three reasons why the RE sector was hit so hard (NEF 2009):

1. Oil and gas prices collapsing by 70%: RE stocks are after all energy stocks and therefore bound to suffer when the oil and gas prices see such a rapid decline.
2. Flight to quality: investors were getting rid of stocks with any sort of technological or executional risk in favour of longer established businesses.
3. Credit crunch: investors penalized companies with high capital requirements, even the more established asset-based companies, because the RE sector is high-growth and therefore capital hungry.

The first is straight forward to measure as oil and gas prices are quoted on the commodities market. It is however not a candidate for explaining the lack of investment in the long run, because the fossil fuel depletion is expected to keep pushing the prices up again. The effect of reduced commodity prices in general would have a positive effect on investments by making the initial investment cost lower as discussed in the previous chapter. The two latter however, seem to hold more potential for explaining the investor behaviour. They both relate to risk, directly in the case of the investors who suddenly became risk averse and moved their money to more secure investments, and indirectly through the credit crunch, making it necessary to prioritize between projects, thus penalizing the high-risk investments.

The market data supports the hypothesis of a reduction in the investment level for RE energy. This means that there must be something the simple investment analysis does not account for. In the next chapter the discussion will move on to the reasons behind the observed falling investment trend.

7.2. Why the renewable energy sector was hit so hard: the importance of risk

It is difficult to assign any direct causality between the fluctuations in the interest rate and the following drop in RE investments. However, other factors that affect the investment levels might work through these interest rates. One such possible relationship to the nominal interest rate is that of risk.

7.2.1 Understanding the concept of risk

In the context of this thesis risk will be defined as "the chance of an event occurring which would cause actual project circumstances to differ from those assumed when forecasting project benefit and costs" (State of Victoria, Australia, Department of Treasury and Finance 2001, p 16). Mandri-Perrot (2009) suggests that risk can be assigned into one out of the three categories presented below according to its source: Changes in the business environment that might "adversely affect operating profits as well as the value of assets" (Mandri-Perrot 2009 p 103) give rise to *political and macroeconomic risk*. Possible changes in interest rates, inflation rates or exchange rates are examples of sources of this type of risk. The risk that the sector in which the company is operating might be affected by economic or other factors more than other sectors is the *sector risk*. The *project risk* is the risk related to financing, design, construction, and operation and maintenance of a project. So called counterparty risk – specific risks arising from counterparties not being able to meet their responsibilities is included in the project risk. When discussing risk, *real* or actual risk is sometimes distinguished from the *perceived* risk.

7.2.2 Financial risk

Remember from chapter 5 how the β is a financial measure of the market risk associated with a specific stock or industry. The average market portfolio is assumed to have a β of 1. A β higher than 1 means that the underlying industry is more risk exposed than the market as a whole, while a β less than one indicates that the industry is generally less exposed to risk than the average industry. If the nominal risk free interest rate is known, we can use the difference between a stocks β and the expected return on the market to quantify the price of risk on a specific stock. The CAPM assumes that there are two types of risk: systemic risk and unique risk[29]. Unique risk arises from exposure to a specific project and can be eliminated through diversification. Systemic risk is the risk of a portfolio after all unique risk has been diversified away. Systemic risk consists of two forms: market risk and event risk. There are four subcomponents of market risk: equity risk, interest rate risk, currency risk and commodity risk. Event risk involves an unexpected and sudden shock that can arise from any general type of risk. Such risk is very difficult to predict. It is the unique risk of a project we are interested in here.

Table 7.1 presents the betas of selected energy indices on the Canadian and Norwegian stock markets[30]. The betas of the Canadian indices S&P/TSX Capped Energy index and S&P/TSX Capped Utilities index are calculated relative to the Toronto S&P 500, the Oslo energy index and utilities index relative to the Oslo Benchmark index. Both utility indexes show beta values lower than 1 which confirms that utilities in general are less risky investments. The Canadian energy index show the expected beta higher than one, indicating that energy investments generally include a higher risk than the market in general. The Oslo Energy index however, has a beta lower than 1. This is probably due to the structure of the Norwegian Energy sector. As explained in chapter 3.2, Norwegian energy investors are either utility companies or companies with roots and experience from the petroleum sector, which in general would involve a lower investment risk. The development of the Canadian oil sands in Alberta is likely to impose additional risk on the Canadian energy sector as a whole, reflected in the higher beta of the Capped Energy Index.

Table 7.2 displays the stock betas of selected global energy indices, calculated relative to the US S&P500 Composite. The stock beta displayed is the beta of the equity, thus are the betas of table 7.2 not directly comparable to the beta used to calculated the discount rate used in the

[29] Unique risk is sometimes referred to as firm-specific risk.
[30] Source: www.finance.yahoo.com

DCF analysis which is the beat of the total assets. The indexes included are the Wilderhill New Energy Global Innovation Index (NEX), the First Trust Global Wind Energy Index (FAN), the Market Vectors Global Alternative Energy Index (GEX), and the AMEX Oil Index (XOI). The betas presented in the table confirm that the renewable energy stocks in general are more risky than the market as a whole. The Amex Oil Index has a lower beta (0.828) which indicates that petroleum investments in general are less risky.

TABLE 7.1: BETAS STOCK INDICES

	OSLO (OSE)	B:	TORONTO (TSE)	B:
MARKET:	OSEBX	1	GSPTSE	1
ENERGY:	OSE10GI	0,887	SPTTEN	1,253
UTILITIES:	OSE5510GI	0,772	GSPTTUT	0,391

TABLE 7.2: GLOBAL STOCK INDICES

INDEX:		B:
S&P 500	GSPC	1
AMEX OIL	XOI	0,828
WILDERHILL NEW ENERGY GLOBAL INNOVATION	NEX	1,682
VECTORS GLOBAL ALTERNATIVE ENERGY	GEX	1,897
FIRST TRUST GLOBAL WIND ENERGY	FAN	1,642

7.2.3 Sources of risk

The first section of this paper established that RE projects are more risk exposed than most other projects. So far, the discussion has focused on describing the risk that can be observed through financial data and market indicators and not on what initially causes this additional risk. RE projects have several characteristics that contribute to this risk exposure. First and foremost, there is uncertainty connected to the use and application of technology. The solar PV generator analysed in chapter 5 is an example of that. The relatively new technology of photovoltaics is still only partly mature. That gives rise to technological risk, as the efficiency and application of the technology is still uncertain. Wind power and hydropower technologies are mature technologies and are not exposed to the risk related to immature technologies.

Many RE technologies are of an intermittent nature. Solar, wind and small-scale hydro are variable energy sources and the electricity generation depends upon external factors. Thus, they might not be able to create power at the time of demand. Unless paired with some mechanism for storing the electricity in periods with lower demand, this represents an uncertainty. Small-scale hydro and wind turbines are also subject to the risk of prolonged breakdowns due to offsite monitoring and long response time. The long lead times and high up-front costs also represent risk associated with investing in wind power or hydropower.

There is also a considerable amount of financial risk related to investing in RE projects. Due to the fact that such projects are often smaller than other energy generation projects, but have higher initial investment costs. Fossil-fuelled technologies, especially gas-fired technologies have lower initial investments and higher fuel costs. This causes RE technologies to appear more expensive in the near term and somewhat riskier in the long run, even at equal or slightly lower total lifetime costs. Investors and creditors require compensation in the form of higher risk premiums for what they perceive as a higher risk exposure. The small size of many RE projects makes it difficult to raise fund in the public markets, leaving debt financing as the only realistic financing alternative. With less equity available, the debt ratio increases and the company's financial strength will be reduced. RE investments can experience difficulties finding financing in a competitive environment. A higher discount rate assigns less importance to future cash flows. An obvious concern is that the high discount rates of a competitive market will favour low capital/ high operating cost alternatives over renewable options.

In most parts of Canada, electric utilities are still in a period of transition from a regulated monopoly structure to a competitive environment, but the precise outcome of that evolution or even the pace of the change is uncertain. In the meantime, the safest strategy for investors is to minimize the capital outlays by deferring new, long-term investments, or, if necessary, chose the new investments with the lowest up-front costs. Similar developments followed the financial crisis of 2008. Politicians demanded changes to the financial industry, but as long as the new regulations have been introduced, investors will delay capital intensive investments into the future.

Also, characteristics of global energy markets may affect the priorities of investors. Investors can reduce their risk exposure by limiting their investments to resources whose costs tend to follow the fluctuations in the market price of electricity. There is reason to believe that the marginal electricity generators in general will be fuelled by natural gas or oil and that the market price of electricity therefore will track the gas prices. Investing in a gas-fired unit would appear less risky than a RE investment as the costs of a RE generator are predominantly fixed and thus relatively independent of future market electricity prices.

In addition to the technology and market related uncertainties, RE investments are also affected by political risk. The unsettlement regarding climate regulations is likely to continue also through the next few decades. This situation has led to a confusing situation for the companies in the Norwegian energy sector. Support mechanisms and political incentives for RE have gained variable political support over the past decade. The government promotes and promises one day, but then changes its mind the next day and take it all back. One example is the plans of a common market for so-called green certificates with Norway. In 2003 it was a clear understanding all-party agreement that green certificates were the road to take. Since then, however, the negotiations with Sweden have collapsed, for so to be continued again in the fall of 2007. In September 2009 the Swedish minister for Enterprise and Energy and the Norwegian minister for Petroleum and Energy signed an agreement on the establishment of a joint market-based system for green certificates by 2012 (Bjartnes 2009). The previous postponements of such a market do, however, cause the energy industry to react with suspiciousness. And industry surveys give reason to predict that private investors will take a cautious approach and minimize new investments until more clearness about future RE support and policies has been achieved.

7.2.4. The consequences of risk on investment behaviour

An important assumption made in this thesis is that the main goal of investors is to maximize their own profits. In the overheated world economy before the economic slowdown, investors experienced artificial high interest rates, making it necessary to increase the risk substantially in order to achieve additional returns. The hunt for the additional profit, high energy prices, as well as a general (over) optimistic investment climate lead the investors into markets characterized by newer and more experimental technologies such as renewable energy. For these investments, a higher risk exposure could mean prospects of higher returns. The developments after the crisis have been the opposite; all markets have experienced a “flight to quality” as investors have moved their money into more secure markets. The market risk may not necessarily be substantially higher than before the crisis, but the uncertainty of the future development makes investors *perceive* the risk as higher than before the crisis. Credit spreads are measures of risk premiums in the credit market and can be used to illustrate the increased risk aversion of the banks and financial institutions that lead to the credit squeeze in the fall of 2008. Garcia and Yang (2009) examine default and liquidity risk –the main components of the corporate bond spread– for Canadian firms that issue bonds in the U.S. market, focusing in particular on their evolution during the credit crisis. They find that, during this period, the liquidity component increased more for speculative-grade bonds than it did for investment-grade bonds, consistent with a "flight-to-quality" phenomenon.

The data discussed in this chapter suggests that RE projects are high risk projects and that this might be a reason why such projects are struggling to find financing during a recession. To say something more about the exact consequences of this, it is necessary to find a way of representing the risk in the models. The DCF model used in chapter 5 is a static model, and can therefore not be used to analyse the dynamics of an industry. However, the framework does highlight the important characteristics of RE energy projects. The next chapter will discuss two ways of modelling risk. First, how risk is in fact incorporated in the model from chapter 5 through financial risk premiums included in the debt interest rate. After that, the effects of changes in the critical parameters of the DCF analysis will be studied in a sensitivity analysis (SA). This allows for an investigation of the isolated effect of a change in one model parameter on the total profitability of the investment. Real options theory might offer a better explanation to why the RE investments have fallen. The last part of chapter 8 includes a discussion of evidence from real options theory.

CHAPTER 8: MODELLING RISK

The results from the previous chapters established that changes in investor attitude towards risk led to reduced liquidity and a higher price on debt financing in financial markets. This chapter will study how we can account for this risk within the model from chapter 5. Another approach to the importance of risk is introduced in the last part of the chapter, which includes a discussion of how evidence from real options theory can help to support the hypothesis.

8.1 Risk premiums on project financing

Different forms of risk are accounted for in the DCF model by splitting the relevant debt interest rate (r_D) into three parts: the real interest rate, which is the nominal business prime adjusted for inflation, as well as a credit premium (R_c) and a project specific risk premium (R_p). The idea is that the institution providing the debt will consider both these forms of risk when establishing the offered interest rate. Also, there is a high degree of risk incorporated in the price on equity through the beta and the market risk premium in particular. This illustrates how an investment in a traditional energy technology might receive a lower interest rate on the debt compared to a riskier investment in a RE technology.

8.2 Sensitivity analysis

Sensitivity analysis (SA) is a "systematical procedure for estimating the effects on the outcome of a study of the chosen methods and data"[31]. A SA can be executed to test the robustness of a study or to decide what source of uncertainty weights more on the study's conclusions. Therefore, the SA can be an important element of judgment for the corroboration or refutation of a scientific hypothesis. This is of particular importance when both the model parameters and the available data are affected by uncertainties. SA can also be a useful tool to direct the research priorities by focusing on the parameters that mostly determine the uncertainty of the model. A typical SA involves varying one parameter ceteris paribus; assuming all other inputs constant. The disadvantage of a one-way analysis is that it measures the influence of only one variable at the time and that it assumes independence

[31] ISO14041. Environmental management—life cycle assessment—goal and scope definition and inventory analysis. 1999.

among the input variables. Nonetheless, there are situations when such dependencies exist among the input parameters that could possibly affect the results of the SA.

The calculated net present values in chapter 5 are based on long-term predictions. As the lifetimes of the RE investments studied in this thesis are of 20 years and more, the relevant cash flows are subject to great uncertainty. This uncertainty suggests the use of SA to study how the variation (uncertainty) in the net present values can be apportioned, qualitatively or quantitatively, to different sources of variation in the input of a model.

The SA will investigate the sensitivity of the NPV to a change in some of the parameters that are considered critical to the result of the analysis. Further, the changes of individual parameters that affect the NPV will be discussed using star diagrams. The star diagrams display the changes in the NPV when the input parameters are changed ceteris paribus, allowing us to study the effect of certain changes to the base case. A star diagram should therefore show the most important and most uncertain variables of the cash flow. The sensitivity is calculated as a sensitivity factor, f_s, or a "slope":

$$sensitivity\ factor\ for\ variable\ i = f_s^i = \frac{\Delta NPV}{\Delta input\ variable\ i}$$

The sensitivity factor describes the magnitude of the change in NPV relative to the change in the specific parameter.

The long lifetime introduces more risk to the project, changes in the lifetime parameter T of the projects does however have almost no influence on the calculated NPV, mainly because of the relatively low annual cash flows compared to the size of the initial investments, but also due to the choice of depreciation method. If the annual cash flows would be of different magnitudes, the effect of changing T could be different. Because of the low percentage of the total cost, the O&M costs are not very important for the overall profitability.

For the projects considered here, the most uncertain parameters are: initial capital investment, sales price, tax rate, and debt interest rate. The profitability of each investment is also strongly dependent on the technical specifications and the efficiency of the technology. If the generator runs at a higher efficiency than the capacity factor used in the NPV calculations, this will affect the overall profitability positively. However, the effect of a 25% increase in the overall efficiency would give exactly the same increase in profits as an increase in the sales price by the same magnitude. The reason for this is that the capacity factor dictates the quantity produced, and since the revenues are given by price multiplied by quantity, the effect would be the same. The sensitivity of the NPV of changes in the capacity factor is therefore not calculated, but implicitly observed through the price sensitivity.

Based on uncertainty intervals of +/- 25%, the assumed price paths from the base case example have been adjusted. Using 5%, 10%, 15%, 20%, and 25% changes in each of the four parameters respectively, the different present values for each project has been calculated.

The Canadian solar PV project has been treated slightly differently from the other investment in the SA. The sales price has been changed within a range of -25% to +100%. This has been done to capture a price increase in the same magnitude as that following the introduction of the FIT program from C$0.42 to C$0.802 (91%).

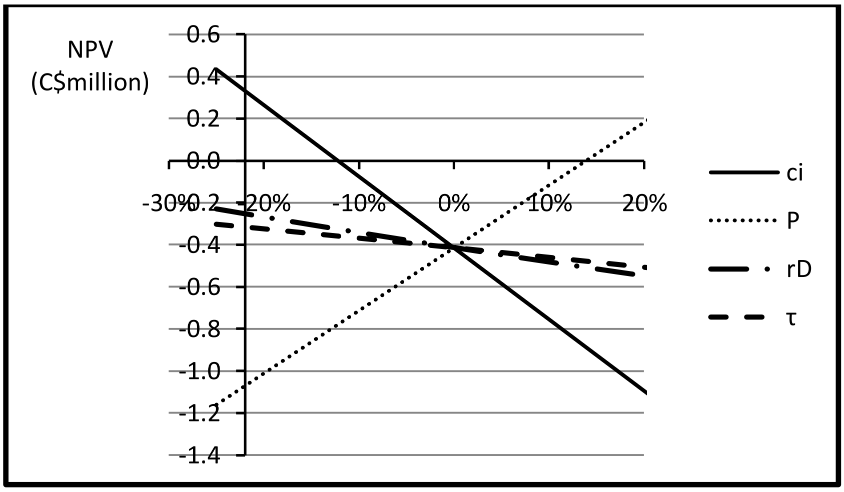
Because a SA studies changes to the NPV by changing the numerator of the present value some authors chose to include only the cost of time in the relevant discount rate. The argument is that including a risk premium would mean to account for risk twice, both by using a risk adjusted discount rate as well as using the dispersion of possible present values as a rough estimate of the risk related to the investment (Gjærum and Bøhren 2003). Because of the high degree of uncertainty in all parameters studied in this thesis however, a risk adjusted discount rate will be used in the SA. Using a risk free discount rate could undervalue the uncertainty incorporated in the other factors of the analysis other than the one parameter studied. Because a changed attitude towards risk would explain the development in RE investments following the crisis, the risk factor has to be included in the following analysis. This allows for a more realistic analysis of the factors that are considered most important to the profitability of the investment projects. The discount rates used are therefore the same as in chapter 5. Thus, the aim of the following SA is to identify the parameters of higher importance to the profitability of RE investments, but not to quantify the uncertainty related to each parameter.

8.2.1 Canada

Wind power

Chart 8.1 displays the effects of a change in each of the three model parameters on the value of the project NPV if all other parameters are held unchanged (ceteris paribus). As expected, the sales price, P, shows a strong and positive relation to the present value as higher P will increase the annual cash flow. The sensitivity of NPV to changes in P is 7.2. The three other parameters represent costs and show the expected negative relationship to the NPV. This analysis confirms that changes in the sales price or the investment cost are of greater importance to the project's profitability than changes in the debt interest or tax rates. The slope of the investment cost ci which has a gradient of –8.2. The model used in chapter 5 assumes a linear relationship between the two parameters in chart 8.1 and the project NPV. This is not the case for the debt interest rate and the tax rate. The two lines look almost straight, they are however slightly convex and the effects of increases in either of them would give a negative and declining response in the NPV. Given the parameters in the base case scenario, a change in the sales price will affect the project NPV the most: every one percent increase in the sales price triggers a 7.2% increase in the projected NPV.

CHART 8.1: WIND POWER IN CANADA
EFFECTS OF CHANGES TO THE INPUT PARAMETERS



NOTE: The chart displays the changes in total net present value of the investment due to changes to investment cost per unit (ci), sales price (P), debt interest (rD) or tax rate (τ)

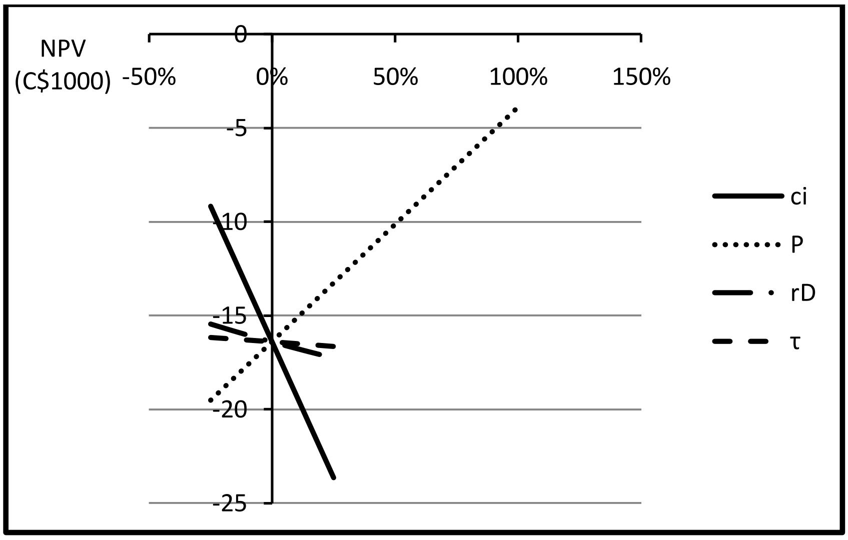
Solar PV electricity

The ceteris paribus effects of a change to the investment cost ci and the sales price P on the project NPV are displayed in chart 8.2.

According to the analysis, the price per Watt peak of installed capacity (ci) is of higher importance to the project NPV. With a sensitivity factor of -1.8, a 1% decrease in ci will give approximately a 2% increase in the NPV. Again, the relationship between ci and NPV is linear and negative, while the sales price P shows a positive relation to the project present value. The uncertainty interval of the sales price is increased up to a 100% change in the price. This is to capture the effect of a change of the same magnitude as the increase following the introduction of the FIT program. A 100% increase gets close to making the NPV positive. The NPV is less sensitive to changes in any of the parameters compared to the wind project, mainly due to the low revenues of the solar PV project. Especially the sensitivity to changes in the tax rate is very low, only -0.06. The sensitivity factors are summarized in table 8.1.

Chart 8.2 also shows the results of changes to the debt interest rate r_D or the tax rate. As discussed in the previous chapter r_D relates exponentially to NPV, with a decreasing marginal return of increases in the two rates.

CHART 8.2: SOLAR POWER IN CANADA
EFFECTS OF CHANGES TO THE INPUT PARAMETERS

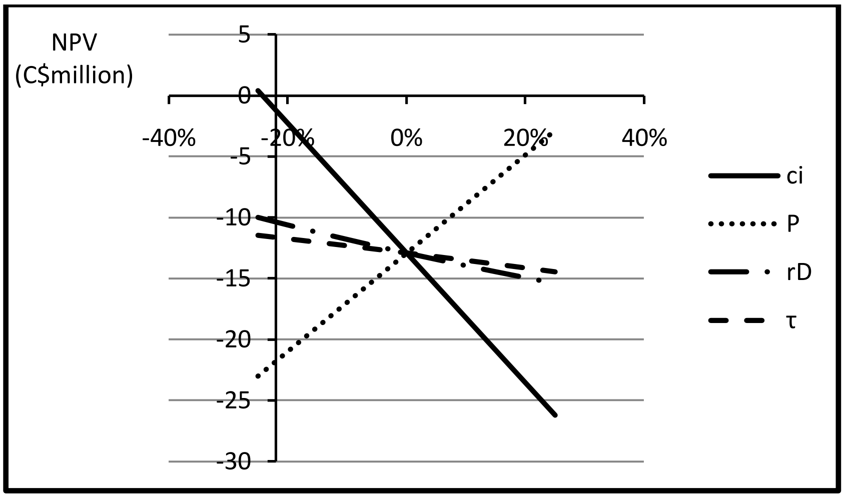


NOTE: The chart displays the changes in total net present value of the investment due to changes to investment cost per unit (ci), sales price (P), debt interest (rD) or tax rate (τ)

Small hydro power plant

Chart 8.3 presents the results from the SA of the parameters ci, P, r_D and τ. Again, the investment cost ci is of higher importance to the project profitability with a sensitivity factor of -4.1. The sensitivity of the NPV to changes to the sales price is also high (3.1). Under the Ontario feed-in tariff and standard offer programs the uncertainty in sales prices is removed through the offering of long term contracts. Thus, the investment cost ci seems to hold a greater potential for influencing the NPV, through either technological improvements, increased investment support through various policy measures, or through lower commodity prices. The tax sensitivity factor is low (-0.46), but much higher than for the solar investment. The sensitivity of NPV to changes in the debt interest rate is -0.81.

CHART 8.3: HYDROPOWER IN CANADA
EFFECTS OF CHANGES TO THE INPUT PARAMETERS



NOTE: The chart displays the changes in total net present value of the investment due to changes to investment cost per unit (ci), sales price (P), debt interest (rD) or tax rate (τ)

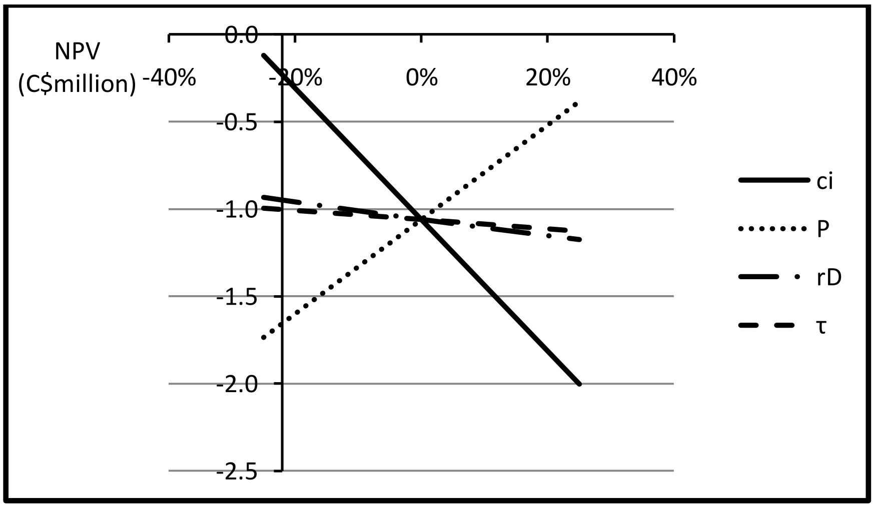
Table 8.1 sums up the results of the sensitivity analyses for renewable energy technologies and presents the calculated sensitivity factors for each technology and parameter. The signs and shapes of the calculated sensitivity graphs seem plausible in proportion to the expectations, confirming that the analyses seem to have been executed correctly and according to the underlying model. A change in the initial investment, measured by the price per unit of installed capacity ci is more influential in a wind power project than in a wind or small hydro project. The solar PV investment stands out, as the calculated NPV is less sensitive to changes in the underlying parameters than what is the case for the two other investments. With its relatively low level of installed capacity, this investment requires significantly less capital than the wind and water projects. The NPV of the wind power project is much more sensitive to changes in any of the parameters studied here. The high sensitivity to changes in P also means that higher or more stable winds that would result in a higher efficiency of the turbine than what is assumed by the capacity factor used in the example would show an increase in the profitability corresponding to that of a price increase.

8.2.2 Norway

Onshore wind power

Chart 8.4 displays the effects of a change in the model parameters on the value of the project NPV (ceteris paribus). With sensitivity factors of -3.6, and 2.6 for the investment cost ci and the sales price P respectively, the present value of this investment is sensitive to changes in the underlying model parameters included in this sensitivity analysis. Any decrease in the investment cost will trigger a more than three times as large increase in the NPV. The NPV is also very sensitive to changes in the sales price P. This is important to the prospects of investing in renewable energy in Norway, because the profitability of the investment depends on the development in the Nordic electricity prices. The sensitivity factor of the debt interest is -2.4. Also here the sensitivity to changes in the tax rate is low (-0.64).

CHART 8.4: ONSHORE WIND POWER IN NORWAY
EFFECTS OF CHANGES TO THE INPUT PARAMETERS



NOTE: The chart displays the changes in total net present value of the investment due to changes to investment cost per unit (ci), sales price (P), debt interest (rD) or tax rate (τ)

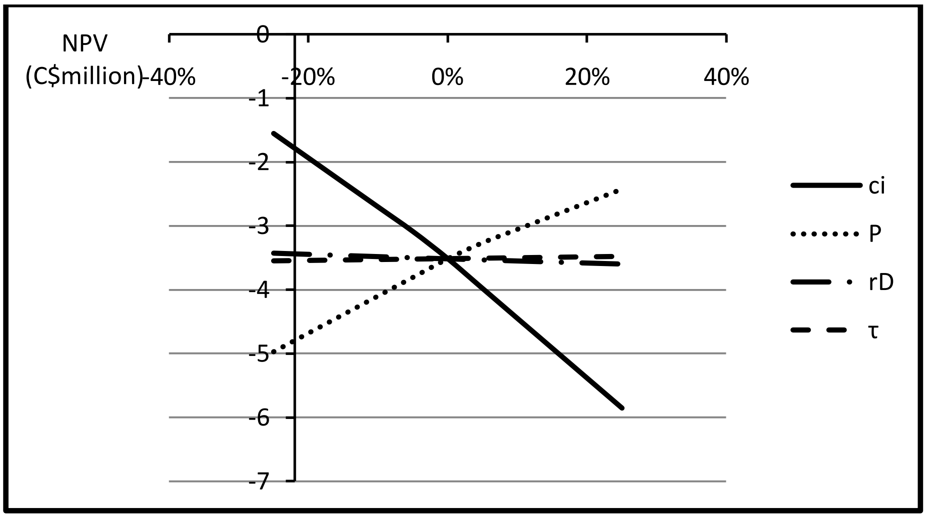
Offshore wind power

Chart 8.5 displays the relationship between the NPV of the offshore wind investment and the ci, and P parameters. The sensitivity factors are summarized in table 8.1.

The electricity price P relates positively to the NPV, as a 1% increase in the electricity price would increase the NPV by 1.6 times as much. A decrease in ci by 1%, for example due to a decrease in the market price of steel, would give approximately a 2.6% increase in the NPV.

This investment project was in chapter 5 the only project that showed a negative taxable income after the depreciation had been deducted from the profits. As argued earlier, the resulting negative tax was set to zero due to the impossibility of postponing taxes for ever. The same is done here. The tax is set to zero for the cash flows that resulted in a negative taxable income, represented by a break in each of the lines in the chart below. As can be seen from the chart, the NPV is little sensitive to changes in the debt interest or the tax rate. The sensitivity factors are -0.09 and -0.04 for debt interest and tax rate, respectively.

CHART 8.5: OFFSHORE WIND POWER IN NORWAY
EFFECTS OF CHANGES TO THE INPUT PARAMETERS



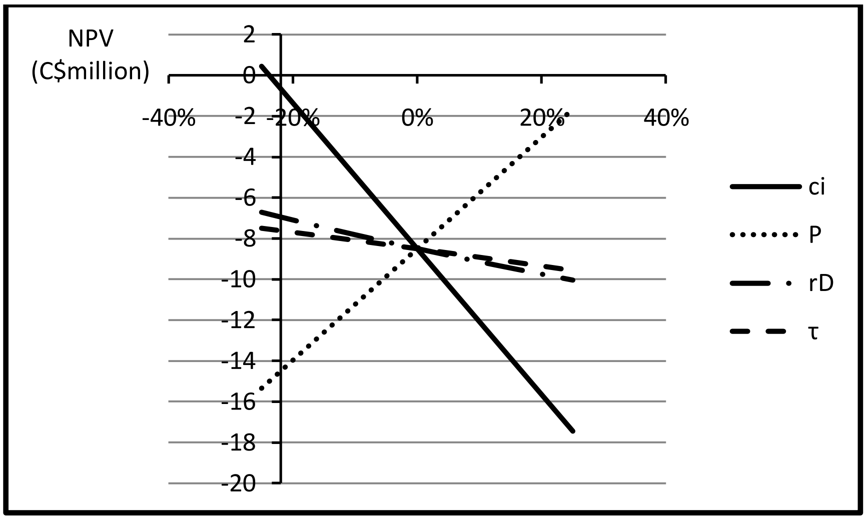
NOTE: The chart displays the changes in total net present value of the investment due to changes to investment cost per unit (ci), sales price (P), debt interest (rD) or tax rate (τ)

Small hydropower plant

The results of the sensitivity analysis for the small-scale hydropower plant in Norway are summarized in chart 8.12. Again, the investment cost has the highest influence on the NPV with a sensitivity factor of -4.2, represented by the steeper slope in the chart below. Hence is the NPV more sensitive to changes in ci than to changes in either of the other parameters studied here. The sales price also shows a high sensitivity factor (3.2).

The chart shows that a 1 % change in the debt interest rate would give an almost corresponding change in the NPV as the sensitivity factor of the debt interest is -0.8. The sensitivity of NPV to changes in the tax rate is also negative and with a decreasing marginal return, but significantly lower than the other sensitivity factors.

CHART 8.6: HYDROPOWER IN NORWAY
EFFECTS OF CHANGES TO THE INPUT PARAMETERS



NOTE: The chart displays the changes in total net present value of the investment due to changes to investment cost per unit (ci), sales price (P), debt interest (rD) or tax rate (τ)

The sensitivity factors for the three Norwegian investments are displayed in table 8.1.

8.2.3 Results

The sensitivity analyses show that in general the most critical parameter for the profitability of RE investments in Canada and Norway is the investment cost. This is not surprising considering the magnitude of these initial investments. The exception is wind power in Canada, where the NPV seems more dependent on the electricity price. The difference between the Norwegian and Canadian onshore wind power projects is puzzling, but may be due to different capacities. Also, we know from chapter 5 that the investment cost per unit of installed capacity is slightly lower in Canada than in Norway which makes the relative importance of the investment cost lower for Canada than for Norway.

All of the RE investments studied here are also highly dependent on the electricity price. It should be noted, however, that the RESOP and FIT programs in Ontario have contributed to eliminate the price risk for RE investors in the province. Long term contract prices would mean that the relevant sales price is known at the time of the investment and over the economic life time of the investment. This is particularly important in periods of high volatility in world energy prices. As explained before, the NPV is also very sensitive to the efficiency of the generator, and the sensitivity factor of the capacity factor will be exactly the same as the factor for the sales price.

The analyses show a moderate sensitivity to changes in the debt interest rate. Due to the magnitude of the investment, it would be expected that variations in the price on debt have a strong affect on the projects' profitability. However, this effect is partly absorbed through the discount rate due to the use of weighted average cost of capital as shown in chapter 5.

TABLE 8.1: SENSITIVITY ANALYSIS - RESULTS

Canada	Onshore wind	Solar PV	Small hydro
P	7.19	0.77	3.12
ci	-8.19	-1.77	-4.12
rD	-1.67	-0.22	-0.81
τ	-1.12	-0.06	-0.46
Norway	**Onshore wind**	**Offshore wind**	**Small hydro**
P	2.55	1.66	3.21
ci	-3.55	-2.66	-4.21
rD	-0.45	-0.09	-0.76
τ	-0.25	-0.04	-0.49

NOTE: Values for the debt interest rate, r_D, are stated for a 100% increase in the parameter

In the previous calculations, the discount rate from the DCF analyses of chapter 5 has been considered the most relevant discount rate. It should be noted, that that may mean to account for specific risks twice, and that the uncertainty of the investment may be overstated. The SA has been executed to identify parameters sensitive or important to the results DCF analyses and the aim has been to say something about the importance of one parameter relative to the others, not to measure the exact effect of such a change. This can also help understanding how the project profitability changes in different circumstances or scenarios. The results predict that changes in energy prices in most cases will be of higher importance than a change to the investment cost. The high sensitivity factors also show that there is a high degree of uncertainty related to RE investments and that the predictions from the investment analyses are far from robust. This is expected, because the profitability of RE projects is highly dependent on project specific factors.

Uncertainty does run both ways and high uncertainty of the results from chapter 5 also indicates the possibility of obtaining better results in a case where the investment is chosen. Small changes in the input parameters can offset large changes in NPV that may actually make the investment profitable. In order to take such a high risk however, both creditors and investors require compensation in form of higher returns. Because the creditors have priority, the effect of higher uncertainty is higher for the price on equity than for the price on debt.

8.3 Real options theory

In classic theory, a firm will invest if the estimated discounted cash flow from the project exceeds the investment cost, that is, if the NPV of the project is positive. Real options theory challenges this by noting that the opportunity to invest has value of its own and that this value will be lost when the investment is made due to irreversibility and the investor's ability to delay the investment decision.

If a firm has the opportunity to invest today in an irreversible project with stochastic value X at investment cost C_i and the project cannot be delayed, it will do so if the estimated net present value of the investment is a positive number:

$$NPV = X - C_i \geq 0$$

If it is possible to delay the investment decision for one year however, this flexibility must be taken into account. Since the project is irreversible, the flexibility is lost when the investment is made. In this case, the investment has two costs: the normal investment cost and the value of the option to invest in one year from now *C(X).*

Using results from derivatives theory[32] it is possible to show that the firm will invest today if and only if:

$$NPV = X - C_i - C(X) \geq 0$$

Where *C(X)* is the value of delaying the investment decision. This means that the impact of uncertainty has changed. Before the only impact of uncertainty was through convexity of the

[32] See Black & Scholes (1973) for the exact formula for the value of an option, and Bjerksund & Ekern (1990) for a more thorough presentation of the results and implications.

profit function, returns to scale or discount rate due to risk aversion, now it has a direct and positive impact on the value of the option of delaying the investment, as can be seen from the equation above. This has an important implication for our renewable energy case: with higher uncertainty, the firm will require a higher project value in order to invest today. This means that increased uncertainty today can lead to investments being delayed into the future if the investors are considering the option value *C(X)*. Depending on how long investments can be delayed for, option value considerations could lead higher uncertainty to cause temporary or permanently lower investment levels. Thus, options theory can contribute to explain the observed negative relationship between investments and uncertainty. This would be of particular importance in cases of large changes to the investment environment such as what happened during the second half of 2008. The breakdown of financial institutions gave rise to a high insecurity about the future structure of financial markets. The crack in the financial sector caused large effects on the world economy as a whole. This has contributed to expectations of change in financial sectors all over the world. As long as the future structure of credit and financial markets are uncertain, investors may decide to delay the investment decision for a while until the future development seem more certain. This additional uncertainty can be interpreted as an upward shift in overall risk levels, and a following increased risk aversion that would agree with the results from the real options theory.

However, the results do not intuitively explain periods of higher risk taking such as the one experienced prior to the financial crisis. Why would investors invest in uncertain and risky projects at all? Sarkar (2000) finds that the probability to invest increases with uncertainty when uncertainty is low, and decreases when uncertainty is high. The credit spreads of chapter 6 indicated increased uncertainty in financial markets. The increased credit spreads indicate a shift from low uncertainty and high risk taking to a much higher uncertainty and lower risk taking. Sarkar's findings support the existence of a flight to quality phenomenon leading to lower RE investment levels.

CHAPTER 9: CONCLUDING REMARKS

9.1 Summary

The aim of this thesis has been to assess the effects of the world economic crisis on investments in renewable energy technology. During the financial crisis of 2008, the energy prices fell significantly in all markets and that reduced the profitability of all RE projects. The profitability fell less in Canada than in Norway because of the price guarantee from the government. In addition, the total cost of financing has increased due to higher equity requirements and larger risk premiums. In sum, this effect is greater than the lower risk free interest rate. The sensitivity analysis indicated that electricity prices and the investment cost have a great impact on the profitability of the projects discussed in this paper. High sensitivity factors imply that the investments are subjects of high uncertainty. Targeted political incentives such as a feed-in tariff and investment support help reduce the investment risk. However, characteristics of the particular project will dictate the effectiveness of such measures.

Several key factors have been discovered that the standard cash flow analysis does not intuitively account for. When energy prices and interest rates fell rapidly in the second half of 2008, the potential investors wanted to invest, but did not have access to credit due to reduced liquidity in debt financing markets, also known as a credit crunch. The low liquidity increases the price of debt financing, cancelling out t lower investment costs through higher interest rates. When liquidity is low and the perceived risk is high, investors are forced to prioritize. Which projects end up finding financing depends on a number of factors, including the core business and strategic planning of the company, the investor's risk tolerance, the portfolio of the potential investing company as well as its profits from other operations.

A temporary fall in short-term interest rates does not have a strong affect on very long interests such as the ones relevant for the investments studied in this thesis. However, because it is possible to fix interest rates for a long period of time, it can in fact have an effect that the model used in this thesis does not account for. With correct timing, the debt interests could be fixed on a historically low level in the fall of 2008. The implication would have been a lower price on debt and reduced financial risk due to a fixed interest rate.

The market data indicated a significant reduction in all RE investments, and this reduction is larger than for the market as a whole. Higher levels of risk combined with a development towards more risk diverse investors as the main driver behind this decline in RE investments and thereby find support for the hypothesis introduced in chapter 1. However, this risk affects different investor groups differently. Real options theory offers an explanation to the observed reductions in RE investments. When investors have the opportunity to delay the investment decision, the value of this option should be included when calculating a project's NPV. A higher risk will therefore make the investor to delay the decision until the uncertainty of the markets is reduced. The initial risk level determines whether or not a higher risk leads to higher risk taking or not. In a low risk environment, a higher uncertainty will trigger a hunt for additional returns just as we observed in the years directly prior to the crisis. Investors perceived the general level of risk as low, thereby taking higher and higher risk in their investment decisions. The financial and economic crisis of 2008 changed the understanding of the market uncertainty. All of a sudden the market was perceived as high risk, causing investors to delay their investments until they could get a clearer picture of what future development would be like.

9.2 Limitations and topics in need for further study

The main objective of this thesis has been to study the link between a global economic crisis and investments in renewable energy technologies. The results and conclusions are, however, very general. Since small changes to the input parameters may lead to considerable different results of the investment analysis, further research targeting each technology and investor group is necessary to better understand the complex dynamics at work. Tax exemptions are a commonly used policy measure to increase the incentive to invest in renewable energy technology. The analyses are made only taking a 28% income tax and the deduction of interest payments into account. A further study should take the tax dimension fully into consideration. The analyses in this thesis indicated a very low profitability of small-scale hydropower projects. This results stands in sharp contrast to the current level of development of this technology in both Canada and Norway. The reasons for this deviation should be more closely evaluated.

9.3 Conclusion

In summary, a significant decline in RE investments from the third quarter of 2008 and onwards is due to higher levels of uncertainty in financial markets and more risk-averse investors. The RE sector has been affected more than other sectors due to the technological and economical characteristics of such projects. In particular, the typical cost structure of a RE investment affects the estimated profitability when the risk exposure is high. Political incentives targeting the two parameters that are of higher importance to the economic viability: investment cost and sales price; are expected to have impact on investment activities. Furthermore, differences in unique risk between projects exist due to project specifics such as investor type, market, technology, and size.

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APPENDIX

Appendix 1: Empirical capacity factors for wind power in Norway (2004-2008)

TABLE 5.8: CAPACITY FACTORS

Year	Capacity factor
2004	**21,5%**
2005	**26,8%**
2006	**25,7%**
2007	**28,9%**
2008	**25,7%**
Average	**25,7%**

NOTES: Based on NVE 2009

Appendix 2: Electricity Selling prices for Canada

Table 329-0050
Electric power selling price indexes (non-residential), monthly (index, 1997=100)

Survey or program details:
Electric Power Selling Price Indexes for Non-residential Customers - **2325**

Year	January	February	March	April	May	June	July	August	September	October	November	December
2000	99.9	99.9	99.9	99.2	99.4	99.4	99.4	99.5	99.6	99.7	99.7	99.7
2001	102.0	102.0	102.0	102.0	102.0	105.1	108.0	108.0	107.9	107.8	107.8	107.8
2002	105.9	105.8	109.0	109.0	105.6	109.5	121.5	125.4	132.6	116.2	116.5	118.3
2003	124.2	133.4	133.2	124.5	118.3	118.1	121.5	123.7	119.7	121.6	118.1	118.5
2004	123.9	121.6	117.4	120.0	123.2	121.8	122.7	122.0	124.5	123.5	124.7	124.3
2005	126.3	122.7	127.0	129.2	126.0	132.5	137.4	141.8	143.2	137.6	130.7	139.4
2006	134.1	131.9	132.1	128.2	131.1	129.9	135.1	135.3	127.9	131.7	134.1	131.7
2007	129.2	130.1	131.5	127.8	124.2	128.6	130.7	137.5	134.3	133.0	131.3	133.0
2008	126.9	130.5	131.9	132.3	127.1	137.0	140.5	135.8	133.3	132.2	136.2	137.1
2009	136.6	136.1	126.4	119.6	124.5	122.3	122.5	124.9				

Source: Statistics Canada. *Table 329-0050 - Electric power selling price indexes (non-residential), monthly (index, 1997=100)*, CANSIM (database).

<http://cansim2.statcan.gc.ca/cgi-win/cnsmcgi.exe?Lang=E&CNSM-Fi=CII/CII_1-eng.htm>

(accessed: December 12, 2009)

Appendix 3: Electricity selling prices Ontario

Electric power selling price indexes Ontario

Legend:
v3834009 Table 329-0050: Electric power selling price indexes (non-residential); Ontario; Electric power selling price over 5000kw (index, 1997=100) [P7007]

v3834022 Table 329-0050: Electric power selling price indexes (non-residential); Ontario; Electric power selling price under 5000kw (index, 1997=100) [P7020]

Monthly	v3834009	v3834022
Aug 2006	142.5	170.1
Sep 2006	108.7	149.6
Oct 2006	117.1	155.3
Nov 2006	133.6	164.0
Dec 2006	117.1	153.7
Jan 2007	124.5	135.3
Feb 2007	149.3	140.4
Mar 2007	142.6	148.3
Apr 2007	127.5	139.0
May 2007	116.1	131.4
Jun 2007	127.8	138.1
Jul 2007	126.5	137.4
Aug 2007	143.6	146.8
Sep 2007	127.1	138.3
Oct 2007	133.3	141.6
Nov 2007	128.7	137.2
Dec 2007	134.3	140.2
Jan 2008	112.2	130.7
Feb 2008	131.2	142.1
Mar 2008	137.1	145.5
Apr 2008	126.4	139.4
May 2008	103.8	124.6
Jun 2008	146.0	150.9
Jul 2008	146.0	150.9
Aug 2008	125.9	140.2
Sep 2008	129.7	142.4
Oct 2008	121.2	137.6
Nov 2008	131.8	147.8
Dec 2008	125.1	142.9
Jan 2009	135.8	149.3
Feb 2009	125.6	143.5
Mar 2009	96.1	125.9
Apr 2009	78.3	113.4
May 2009	93.5	126.7
Jun 2009	86.6	121.7
Jul 2009	79.0	116.1
Aug 2009	92.4	126.5

Source: Statistics Canada

Appendix 4: Electricity prices Norway

System price (Elspot prices at Nord Pool Spot (NOK/MWh)

Month	Elspot Price
07 Jan	228,15
07 Feb	233,21
07 Mar	193,67
07 Apr	182,16
07 May	174
07 Jun	190,95
07 Jul	140,11
07 Aug	131,86
07 Sep	197,62
07 Oct	281,49
07 Nov	362,71
07 Dec	368,95
08 Jan	364,38
08 Feb	306,94
08 Mar	236,55
08 Apr	301,55
08 May	203,16
08 Jun	323,26
08 Jul	357,58
08 Aug	435,59
08 Sep	549,44
08 Oct	483,85
08 Nov	451,08
08 Dec	419,62
09 Jan	384,96
09 Feb	336,04
09 Mar	309,63
09 Apr	299,53
09 May	287,39
09 Jun	316,65
09 Jul	294,9
09 Aug	280,87
09 Sep	246,53
09 Oct	282,5
09 Nov	306,23
09 Dec	-

Data updated: 12. Dec. 2009, 13:10 Time is CET (GMT +1)
Source:
http://www.nordpoolspot.com/reports/systemprice/Post.aspx

APPENDIX 5: HISTORICAL INTEREST RATES NORWAY

Norwegian Inter Bank Offered Rate

Nominell rente. Yearly average of daily data

	Tom/next	1 uke	2 uker	1 mnd	2 mnd	3 mnd	6 mnd	9 mnd	12 mnd
2008	5,86	5,9	5,93	6,01	6,13	6,23	6,31	6,25	6,24
2007	4,76	4,68	4,75	4,79	4,87	4,96	5,11	5,23	5,34
2006	3,11	2,99	3,03	3,02	3,05	3,1	3,24	3,39	3,53
2005	2,25	2,14	2,17	2,15	2,18	2,22	2,32	2,45	2,57
2004	2,17	2,06	2,07	2,03	2,01	2	2,01	2,08	2,18
2003	4,53	4,39	4,37	4,28	4,16	4,08	3,95	3,91	3,95
2002	6,99	6,9	6,9	6,9	6,91	6,92	6,91	6,91	6,92
2001	7,31	7,24	7,26	7,24	7,22	7,23	7,16	7,12	7,09
2000	6,6	6,59	6,6	6,6	6,66	6,75	6,87	6,98	7,08
1999	6,93	6,87	6,84	6,71	6,59	6,52	6,28	6,12	6,02
1998	5,89	5,92	5,98	5,93	5,87	5,83	5,76	5,7	5,67
1997	3,66	3,63	3,65	3,59	3,67	3,74	3,92	4,04	4,16
1996	5,06	4,98	4,99	4,87	4,88	4,9	4,99	5,05	5,11
1995	5,58	5,53	5,54	5,42	5,43	5,48	5,64	5,75	5,86
1994	5,54	5,52	5,56	5,63	5,76	5,87	6,05	6,19	6,33
1993	7,62	7,58	7,55	7,41	7,3	7,21	7,03	6,93	6,87
1992	13,78	19,4	15,16	13,78	12,38	11,87	11,24	10,66	10,83
1991	10,59	10,53	10,57	10,58	10,59	10,57	10,56	ND	10,55
1990	11,44	11,41	11,45	11,44	11,49	11,53	11,61	ND	11,62
1989	11,29	11,28	11,3	11,31	11,37	11,37	11,38	ND	11,33
1988	13,2	13,2	13,26	13,28	13,44	13,5	13,59	ND	13,65
1987	14,28	14,38	14,55	14,63	15,03	14,71	14,72	ND	14,8
1986	14,96	14,81	NA	14,64	NA	14,39	14,35	ND	14,32

Source: http://www.norges-bank.no/templates/article____55486.aspx

Appendix 6: Historical interest rates Canada

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1969	7,00	7,00	7,50	7,50	7,50	8,00	8,50	8,50	8,50	8,50	8,50	8,50
1970	8,50	8,50	8,50	8,50	8,50	8,50	8,00	8,00	8,00	8,00	7,50	7,50
1971	7,00	7,00	6,50	6,50	6,50	6,50	6,50	6,50	6,50	6,25	6,00	6,00
1972	6,00	6,00	6,00	6,00	6,00	6,00	6,00	6,00	6,00	6,00	6,00	6,00
1973	6,00	6,00	6,00	6,50	7,00	7,75	7,75	8,25	9,00	9,00	9,00	9,50
1974	9,50	9,50	9,50	10,5	11,0	11,0	11,5	11,5	11,5	11,5	11,0	11,0
1975	10,5	9,50	9,00	9,00	9,00	9,00	9,00	9,00	9,75	9,75	9,75	9,75
1976	9,75	9,75	10,25	10,25	10,25	10,25	10,25	10,25	10,25	10,25	9,75	9,25
1977	9,25	8,75	8,75	8,75	8,75	8,25	8,25	8,25	8,25	8,25	8,25	8,25
1978	8,25	8,25	8,75	9,25	9,25	9,25	9,25	9,75	10,25	11,00	11,50	11,50
1979	12,00	12,00	12,00	12,00	12,00	12,00	12,50	12,50	13,00	14,75	15,00	15,00
1980	15,00	15,00	15,75	16,75	13,75	13,25	12,25	12,25	12,25	12,75	13,75	18,25
1981	18,25	18,25	17,75	18,25	19,50	20,00	21,00	22,75	21,25	20,00	17,25	17,25
1982	16,50	16,50	17,00	17,00	17,00	18,25	17,25	16,00	15,00	13,75	13,00	12,50
1983	12,00	11,50	11,50	11,00	11,00	11,00	11,00	11,00	11,00	11,00	11,00	11,00
1984	11,00	11,00	11,50	11,50	12,00	12,50	13,50	13,00	13,00	12,50	12,00	11,25
1985	11,00	11,50	11,75	10,75	10,50	10,50	10,50	10,25	10,25	10,00	10,00	10,00
1986	11,00	13,00	12,00	11,25	10,25	10,25	9,75	9,75	9,75	9,75	9,75	9,75
1987	9,25	9,25	8,75	9,25	9,50	9,50	9,50	10,00	10,00	9,75	9,75	9,75
1988	9,75	9,75	9,75	10,25	10,25	10,75	10,75	11,25	11,75	11,75	11,75	12,25
1989	12,25	12,75	13,50	13,50	13,50	13,50	13,50	13,50	13,50	13,50	13,50	13,50
1990	13,50	14,25	14,25	14,75	14,75	14,75	14,75	14,25	13,75	13,75	13,25	12,75
1991	12,25	11,25	11,25	10,75	9,75	9,75	9,75	9,75	9,50	8,75	8,50	8,00
1992	7,50	7,50	8,25	7,75	7,50	7,00	6,75	6,50	6,25	7,75	9,75	7,25
1993	6,75	6,50	6,00	6,00	6,00	6,00	5,75	5,75	5,75	5,75	5,50	5,50
1994	5,50	5,50	6,25	6,75	6,75	8,00	7,50	7,25	7,00	7,00	7,00	8,00
1995	9,25	9,50	9,75	9,75	9,25	8,75	8,25	8,00	8,00	8,00	7,75	7,50
1996	7,25	7,00	6,75	6,50	6,50	6,50	6,25	5,75	5,75	5,00	4,75	4,75
1997	4,75	4,75	4,75	4,75	4,75	4,75	4,75	4,75	4,75	5,25	5,50	6,00
1998	6,00	6,50	6,50	6,50	6,50	6,50	6,50	6,50	7,25	7,00	6,75	6,75
1999	6,75	6,75	6,75	6,50	6,25	6,25	6,25	6,25	6,25	6,25	6,50	6,50
2000	6,50	6,75	7,00	7,00	7,50	7,50	7,50	7,50	7,50	7,50	7,50	7,50
2001	7,25	7,25	6,75	6,50	6,25	6,25	6,00	5,75	5,25	4,50	4,00	4,00
2002	3,75	3,75	3,75	4,00	4,00	4,25	4,50	4,50	4,50	4,50	4,50	4,50
2003	4,50	4,50	4,75	5,00	5,00	5,00	4,75	4,75	4,50	4,50	4,50	4,50
2004	4,25	4,25	4,00	3,75	3,75	3,75	3,75	3,75	4,00	4,25	4,25	4,25
2005	4,25	4,25	4,25	4,25	4,25	4,25	4,25	4,25	4,50	4,75	4,75	5,00
2006	5,25	5,25	5,50	5,75	6,00	6,00	6,00	6,00	6,00	6,00	6,00	6,00
2007	6,00	6,00	6,00	6,00	6,00	6,00	6,25	6,25	6,25	6,25	6,25	6,00
2008	5,75	5,75	5,25	4,75	4,75	4,75	4,75	4,75	4,75	4,00	4,00	3,50

source: http://www.bankofcanada.ca/pdf/annual_page49_page50_page51.pdf