

The Green Lantern in the Energy Sector?

No, A Green Transformation will not come for Free

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Abstract

During the last decade, several influential organizations have emphasized the importance of green investments. Furthermore, many advocates have claimed that green investments would be beneficial both for the labor market but also for the economy. These statements are both misleading and hazardous since they provide a biased picture of the reality. There is no doubt that our societies need to turn more environmental friendly or “green”. However, this shift will not be costless. This thesis compares the cost effectiveness in Danish subsidies to the wind sector with investments in the oil sector. This is analyzed using economic theories such as opportunity cost and externality. The Porter Hypothesis, which argues that green regulations and subsidies leads to investments and a stronger economy, is also applied and tested. The results illustrate that green subsidies leads to more investments but unlikely to an improved economy. Furthermore, it is concluded that Danish investments in wind power are cost ineffective and that green jobs are relatively ineffective. Additionally the results show that, with a climate change adjusted cost for oil, the oil sector still remains more cost effective. This thesis argues that we need to turn our economy green but we must be willing to pay for it.

Key words: Green Investments, Green Jobs, Green Economy, Opportunity Cost, Externality, The Porter Hypothesis, Wind Power

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1 Introduction

Just a few years ago the concepts of “green investment” and “green job” were hardly ever discussed. But similar ideas have been valid ever since the late 1980s, when the Brundtland Report popularized the concept of *sustainable development*, and the discussion of how we shall combine our economy with a limited and a fragile earth became central. In later years, similar concepts such as green growth and green economy have received more attention and the discussion today is more centered on economic growth. Environmental threats, such as the climate change, are forcing companies and countries to become more “green”. This has led to many powerful organizations are proclaiming for green investments, green jobs and green growth. Several of these also declare that green investments will boost, and even be favorable for, the economy. This thesis tries to give a nuanced picture of the cost of turning green and the cost of green jobs. It is important that essential decisions, that might determine our future, are based on relevant facts.

“Green jobs are the jobs of the future – not just because they pay well and can’t be outsourced and not just because they’ll help strengthen our economy and lift up our middle class. But because they’ll help reduce our dependence on foreign oil, and save this planet for our children.”

(Barack Obama, 2008)

President Obama and several other leading proponents overlook the importance of opportunity costs. The opportunity cost is the value of the best alternative that gets neglected in favor of the chosen one. Investing green is seldom the best alternative from an economic perspective. This thesis illustrates the importance of opportunity cost by analyzing and comparing the wind power sector with the oil sector in Denmark. Wind power is often seen as a typical green investment that generates a lot of jobs, but it requires a lot of government subsidies. These

subsidies are in this thesis contrasted to investments in Denmark's most important energy sector, their domestic oil production. Oil as an alternative illustrates the cost of green investments in Denmark.

Ideas saying that green subsidies and regulations will boost innovations and the economy are often based on *the Porter Hypothesis*, which states precisely that. Results in this thesis support the part of the hypothesis saying that green subsidies trigger innovations. However, it does not support the part stating it also is beneficial for the economy. Green energy sources are environmentally preferable since they cause less damage to the environment than oil, but they are not economically viable. This analysis illustrates through basic calculations, even after accounting for the negative externality of oil, investments in oil are still more cost effective. Investing in oil and other finite resources are not a sustainable way but they are highlighting the true cost of a green transformation. This thesis emphasizes that we cannot build a green economy on false grounds. We must be prepared to pay for it.

1.1 Research questions

This thesis aims to illustrate the cost of investing in green energy sources. Industrialized societies have for a long time period exploited the earth's limited environment. In recent decades, the understanding of this problem has improved, primarily led to an increased demand for greener growth, greener industries and a greener labor market. "Greener" basically means more environmental friendly than earlier. This global shift might have a decisive impact on our way of life and our economies. The debate of green transformation and green economy is very broad and complex, but this thesis will put its major focus on green investments and green jobs. Comparing the cost effectiveness in the wind power and the oil sector provides a clear picture of green investments. Furthermore, the analysis calculates how effective a job in the wind power sector relatively is. Finally, the analysis includes the threat of global warming and incorporates it as an externality of oil. Thus, the thesis tries to answer the following research questions:

- How does the wind power industry differ from the oil industry in terms of cost effectiveness?
- How effective is a green job in the wind power industry compared to a job in the oil industry?
- How does the cost effectiveness of energy derived from climate change adjusted oil differ from wind power energy?

These three questions will be analyzed separately in the analysis. By answering these three questions, this thesis provides a good picture of the cost of investing in green energy. However, this thesis is not skeptical against green investments, rather against how they are approached and promoted. Green investments are necessary but we must have an unbiased view and we must invest in the best green alternatives. Otherwise, the green transformation risk losing pace quite promptly.

1.2 Structure

In the following, firstly the current discussion of green investments and green jobs and its origin will be presented. It is crucial for the reader to understand the current debate of cost effectiveness in green investments and the shift towards a green economy. Following that, the theories of opportunity costs and externalities are shortly presented. The principal contents of the Porter Hypothesis, stating that environmental regulations and taxes triggers innovation will also be presented. After these theories, a description of how the analysis is conducted will be presented. That will hopefully provide the reader with a greater understanding of the procedure but also increase the intersubjectivity in this report. Essential for the analysis is to understand the energy situation in Denmark and especially the wind and the oil sector; this is presented in part five. After that in chapter six, the main analysis is conducted. The analysis is divided in three sectors. First, a calculation of cost effectiveness in the two sectors is presented. After that, a calculation,

which focuses on labor efficiency, is given. Finally, in the analysis, a calculation that incorporates a climate change adjusted price for oil is presented. After the analysis, in chapter 7, a discussion is held. Chapter 7 also contains a brief conclusion and some suggestions for further research on the subject.

2 Green Investments & Green Jobs

The concepts of green investment and green job are frequently used, but their overall impact is much disputed. This section describes the most essential definitions and writings on the subject. Since the discussion of green economy is very broad and complex, this thesis will only be focusing on green investments and green jobs. Green investments and green jobs are concepts, which forms a part of the broader discussion. One existing problem in many studies on green investments is that they are funded by organizations with a clear agenda. It is easy to understand that some actors might want to find a result showing that we can have a healthy environment, economic growth and a low unemployment, all at once. Even though the ideas with green investments, green economy and green jobs permeates the current debate, the research on the subject is inadequate.

Gürcan Gülen (2011) argues that many authors neglect the occurrence of an opportunity cost. The author reflects upon the fact that every dollar invested in green technologies is no longer available for other kinds of investments. This is of course a significant statement; green investments must be compared to its alternatives. Furthermore, Gülen (2011) concludes that many reports on green jobs do not take account of old jobs turning green. The author argues that greening an existing job is not a new job and that reports that account these jobs as new, will get a biased result. Alex Bowen (2012), on the other hand, argues that different countries have different preconditions and for example countries that use a lot of fossil fuel in their economies will have a very hard time with their green transformation. The opportunity cost is an essential concept but it differs from case to case.

The most principal work on green jobs is the report "*Green Jobs: Towards decent work in a sustainable, low-carbon world*" which is funded by UNEP, ILO, IOE and ITUC Green Jobs Initiative (Renner, 2008). In the report, green jobs are defined as "*work in agricultural, manufacturing, research and development (R&D), administrative, and service activities that contribute substantially to*

preserving or restoring environmental quality". This is a very broad definition that contains an extensive set of jobs. Furthermore, they urge government on all levels to invest in "sustainable economic activities" to faster reach a sustainable society (Ibid, 2008).

There are several reports showing a positive result from green investments. Robert Pollin et al. (2009) show, through an input-output model, that green investments are more than three times more effective in creating jobs than fossil-fuel investments in the US. Lehr and Lutz (2011), on the other hand, estimate in their report net effects of large investments in green energy in Germany. Their results are showing that net effects from green investments are positive and that renewable energy has a large potential. Samuel Frankhauser et al. (2008) argue that the climate change will change our whole economic system. The authors state that the largest positive effects will turn out in the long run since green investments will lead to new innovations and improved technology.

Reports that emphasize the importance of the opportunity cost are generally more skeptical. Gordon Hughes (2011) argues that if the green investments are taken from other kinds of investments then the immediate job effect will be zero and the medium and long-term effect will be negative. Gabriel Álvarez et al. (2010) estimate economic impacts of green investments and their ability to create jobs. They look at subsidies steered to renewable energy sources in Spain. Their result showed that for every green job in the renewable energy sector, it requires capital that could create more than two jobs in the private sector. It is evident that studies on green jobs and green investments have various and contradictory results. However, it is not possible to find one true answer since green investments might have different outcomes in different contexts.

3 Theory

This part introduces essential theories and will hopefully increase the understanding both of energy economics but also of the results in this thesis. First, the concept of *opportunity cost* is introduced. The idea of opportunity cost is central of economics and for the argumentation in this thesis. Another key concept in energy economics is *externality*. When comparing different energy alternatives it is crucial to look at the externality cost. An externality occurs when the social cost of producing a product is larger then just the company's cost. Finally, *the Porter Hypothesis* is presented, which states that environmental regulations and taxes leads to more innovations that according to the hypothesis also can turn out to be favorable for the economy.

3.1 Opportunity Cost

The concept of opportunity cost refers to the fact that when resources are used in one investment, they cannot be used in another investment as well; the opportunity is forgone. The opportunity cost is the value of the best alternative that is been neglected. If you, as an investor, have one million dollars and two possible investments that cost exactly one million dollars each, it is only possible to invest in one of them and the opportunity cost is the value of the investment that gets rejected. From an economic point of view, we should always pick the alternative that optimizes our utility. This thesis focuses on two contrasting energy sectors, which are different in most ways, but both produce energy and are therefore comparable.

The opportunity cost should always be considered. Stephan A. Spiller (2011) states in the article *Opportunity Cost Consideration* that the idea of opportunity cost is a foundation to the subject of economics. He argues that we always should consider the alternative in every decision. The author also writes that consumers

consider opportunity costs more often when they have limited funds. Furthermore, Spiller argues that the idea of an alternative is not always considerable since the consumer has divided their investments in separate categories, which makes it harder to choose the best alternative. Tietenberg & Lewis (2009, p. 21) state that a shift between two alternatives is rarely costless. It is of course not costless to reallocate a countries energy production to another energy source. However, it is of course possible in a longer run to steer production in another direction and to consider the opportunity cost illustrates the cost effectiveness in the chosen sector.

Hughes (2011) argues that when many green industries are being promoted as labor intense they should be treated as a cost rather than a benefit. The author states that if 100 hours of labor produces the same amount as 50 hours of labor in another sector, then should the labor in the more labor intense sector be treated as a cost. Furthermore, Hughes (2011) states that if we want to find the true opportunity cost we must incorporate both an employment cost and the costs of externalities and calculate the net benefits. The author means that just looking at the amount of new jobs will provide a biased result, because we miss the cost of labor. When accounting for the gains of an investment it should be natural to include all relevant cost and not just the ones that is preferable for ones purpose. Hughes statement is relevant for this study since the wind power industry is labor intense while the oil industry is responsible for several negative externalities.

3.2 Externalities

Tietenberg & Lewis write (2009, p. 71), “*an externality exists whenever the welfare of some agent, either a firm or a household, depends not only on his or her activities, but also on activities under the control of some other agent*”. Environmental damages that are caused by companies or the government are in economics treated as externalities. As for example, greenhouse gases that triggers global warming is an externality. Furthermore Tietenberg & Lewis (2009, 71-72) conclude that an externality occurs when the social cost of a production is larger than the private cost.

An externality can be both positive and negative. A positive externality for house owners can be when a large company settles in town, which eventually leads to higher house prices. Negative externalities are more common and can for example be emissions of carbon dioxide, which harms our environment. This thesis focuses on a negative externality of oil, since it is the most significant externality when discussing energy use. The Porter Hypothesis that will be presented next, can be seen as a hypothesis of a positive externality.

3.3 The Porter Hypothesis

Michael Porter and Claas Van der Linde (1995) write that the Porter Hypothesis states that well-designed environmental regulations and taxes can trigger green innovations. They mean that the environmental innovations might even offset the costs of shifting towards a green economy. For example, if the government places a high tax on gasoline, then these taxes might trigger innovations in greener alternatives. This since the relative price of green substitutes has decreased. Porter and Van der Linde (1995) also state that companies generally invest in innovations in the same directions as its competitors, they mean that this could be fixed with environmental regulations. Porter and Van der Linde argue that regulations that trigger green investments might even be beneficial for the region.

Studies have supported one part of the hypothesis. Stefan Ambec et al. (2011) conclude, in the article *The Porter Hypothesis at 20*, that the Porter Hypothesis has gained a lot of popularity because it states that environmental regulations might not be harmful for the economy and for the economic growth. This idea is of course very appealing. Furthermore, Ambec et al. (2011) conclude in the article, which recapitulates several existing reports on the Porter Hypothesis, that the weak version of the hypothesis (that regulations leads to more innovations) are empirically established but the stronger version of the hypothesis (regulation leads to enhanced business performances) has received a more mixed result. Hughes (2011, p. 28) is more skeptical and argues that one major problem with the argument, stating that green technology increases all the time and therefore will be relatively effective in the future, is that so does other kinds of technologies.

4 Method & Data

A lot of inspiration for the method used in this thesis has been derived from Álvarez et al. (2010) and their calculations on labor effects of wind power investments in Spain. In that report, the authors look at how much subsidies that are needed in creation of a green job contrasted to a job in the private market. The authors also look at the cost effectiveness in green investments and compare that to the cost effectiveness in the private market. This thesis compares the government subsidies to wind energy with private investments in the oil sector. The strength with this method is its simplicity; it makes it powerful. Another strength with this method is the possibility for the reader to recalculate and check the results.

The first part the analysis focuses on government subsidies to wind power and compares that data with data for total investments in the oil industry. By contrasting government costs with investments in the oil sector, it illustrates a clear alternative to these wind power investments. The data for subsidies and investments are divided by the amount of output energy that each sector produces¹. This calculation offers a comparable number for how much energy produced per million invested Danish crowns (DKK). The next part of the analysis concentrates at the efficiency of a worker. This part includes different measure of direct and indirect jobs in the wind power and the oil industry. The two sectors are very different and what a job in these two sectors consists of differ to a great extent. It is therefore quite problematic to compare these two job sectors. This is solved through presenting a couple of different definitions and limitations of what a job in the wind power sector is. These different figures are

¹ $\frac{\text{Production}}{\text{Investments}} = \text{Output per Invested DKK}$

compared with the production in each sector and the result provides us with a number of how productive one worker in each sector is².

The last part of the analysis encounters the fact that oil is harmful to the environment and that it contributes to climate change. This part of the analysis takes position in a figure that Anderson et al. stipulate in their paper *Automobile Fuel Economy Standard: Impact, Efficiency, and Alternatives* (Anderson et al, 2010). It is argued that it is needed at least \$0.65 per gallon of gasoline to neutralize the negative externality of greenhouse gases. This number is of course an approximation and shall be seen as an approximation and not as a truth, but it allows us to estimate environmental effects. This number is transformed into a cost in Danish crowns per liter, simply by transform it to liters and exchange it to Danish crowns. It is also converted to oil trough another simple calculation. These figures are then multiplied with the annual amount of oil that is produced since the beginning of the 1970s. This cost per year is then added upon the investment costs for oil since if the companies were obligated to pay this environmental cost it would probably be seen as an investment. This new cost for extracting oil is then compared with the wind sector in the same way as in the first part of the analysis³.

The statistics that the analysis rests upon is gathered from solid Danish energy sources. Most of the data is collected from The Danish Energy Agency (DEA). The DEA is an agency under the Danish Ministry of Climate, Energy and Building. Among other things, they provide a lot of statistics. It is a trustful source since it is a part of the Danish government and their job is to provide unbiased data for development, progression and other related issues on the Danish energy sector. The labor statistics in the analysis is gathered from reports contributed by the Danish Wind Power Industry (WPI) and Arentsen & Åril (which have analyzed the importance of the Danish oil sector). The labor statistics is unfortunately very limited. Data for the oil sector shows the average amount of labor in the oil and gas sector in 2008 to 2010. This also implies that the calculation on efficiency in green jobs is compared to jobs in both the oil and gas

² $\frac{\text{Production}}{\text{Amount of Workers}} = \text{Output per Worker}$

³ $\frac{\text{Production}}{\text{Actual Investments+Envrionmental Costs}} = \text{Output per Invested DKK}$

sector during this limited period. However, it gives a good idea of how the current situation in green jobs looks like.

Data for production of wind power and oil is retrieved from the DEA. In 2012, the DEA published data for energy production in the file *Danish Energy Statistics: Energy Statistics 2011*. The data file consists among other things of data for annual production of oil and wind power from 1972 to 2011. One good thing with this data is that production of oil and wind power is given in the same unit. The unit is terajoule, which is the same as one trillion joules. The DEA also have data for production of wind power in kilowatt-hours and oil in m³. I have checked the results with that data (where it was needed to convert oil to kilowatt hours through a formula) and received an almost identical result. The analysis is also based on two files that present costs and subsidies for the oil and wind power sector. The wind power in Denmark is subsidized through the PSO (subsidies to the wind power sector) support. The DEA has presented a short but comprehensive file on expenditure in wind power. This data stretches from 2005 to 2008, which limits the time span for this part of the analysis. The data for investments in oil is also given by the DEA, which divides the cost between investments, research and drift.

5 The Energy Situation

Investments in green energy are crucial to achieve a green transformation. This is only logical since the biggest threat to our way of living is the greenhouse gases and the global warming, which to a big extent derives from our energy consumption. Greenhouse gases have multiple origins but our extended use of polluted energy is commonly seen as the biggest culprit. The Nordic country of Denmark has placed a lot of resources in the wind industry. Denmark has also succeeded in developing a lot of firms in the cleantech sector. A cleantech company focuses on sustainable alternatives and most commonly on sustainable energy sources such as wind power. Denmark is today a prominent country within the cleantech business. Although, Denmark has also during a long time invested a lot of resources in domestic oil and gas extraction.

The OPEC-crisis in 1973 was a tipping point, which made a majority of the Danish people and politicians willing to strive for an independency of foreign oil. In the report, *Energy Policy in Denmark*, it is concluded that Denmark has since then invested in several diversified energy sources. The idea has been to combine investments in environmental friendly and sustainable energy sources with extraction of domestic oil and gas. The mission has been successful since Denmark has gone from being a big importer of foreign oil to now being more then self-sufficient (See Lidegaard, 2012). Hereafter, first the Danish wind power sector will be presented. Thereafter, a description of the Danish cleantech industry and its growing importance is given. Finally in this sector, an introduction to the Danish oil production is provided. This is given to enhance the understanding of these sectors and the Danish energy situation.

5.1 Wind Power

Wind power is a vital part in the Danish commitment to create green jobs and to their mission to reach a sustainable society. According to the DEA, the wind sector did employ approximately 25000 people in 2010 and stood for a total of 48 billion Danish crowns in exports. In the same report it is stated that among other factors, the OPEC-crisis and funding for wind turbines has led to a high development of wind power in Denmark. This development in wind capacity is due to both more windmills but also to a more advanced technology. It is also remarked that the ideas and encouragement in the Brundtland Report influenced and accelerated the development of wind power (DEA, 2011, p. 15-16). The Danish parliament did in 2012 agree on a very ambitious energy deal. This agreement contained a goal, which stated that by 2020 should 50 percent of all Denmark's energy consumption should come solely from wind power (See Lidegaard, 2012, p. 6-7).

The support to Danish wind power stretches far back in time. The DEA writes that financial support for electricity produced by windmills has existed since the beginning of 1970s. Furthermore, the DEA concludes that in the formation of the wind power industry, windmills were supported both by installation grants but also through production subsidies (DEA, 2009, p. 26). Preben Mægaard (2009) writes that the progressive investments in windmills were abolished in 2001 when the liberal-conservative government took over. Although, there have been some major investments since Mægaards article. However, new wind turbines are not produced in the same pace as earlier. The support has changed both in terms of magnitude and in design.

The DEA writes that even though the sector was liberalized in 1999, the owners of the windmills were guaranteed a settlement price. This support (PSO) is available for other green energy as well. It was agreed in 2004 that a wind owners should receive 0,10 Danish crowns per KWH on top of the current market price. However, the production subsidy depends on the wind turbine connection time and its size. The agency remarks that those windmills that were build after the energy agreement in 2008 receives 0,273 Danish crowns per KWH but only until

for 22 000 load hours (DEA, 2009, p. 26). Between 2005 and 2008, the payment of PSO to the wind owners was approximately 5,04 billion Danish crowns.

5.2 Cleantech

Cleantech companies are defined as those focusing on sustainable energy and materials. It is companies that develop more efficient way to use energy (See DEA-Cleantech, 2010). Basically, cleantech companies are those who work towards a more sustainable energy use. Denmark is in the frontier of cleantech development and it is often argued that cleantech will contribute to economic growth. The majority of Danish cleantech companies works with green or sustainable energy and streamlines our energy use (DEA- Cleantech, 2010, p. 9).

Cleantech companies are becoming an essential part of the Danish economy. According to the report *Our Green Economy*, which is published by the Danish government, there are approximately 720 cleantech companies in Denmark. The same report states that these have a turnover of a total of €43 billion. It is also concluded “*Green companies have been nurtured by strong environmental and energy policies creating markets for green products – and by clear targets stimulating investments*” (Sølvndal et al., 2012, p. 12). According to a report on Danish green technology, it is concluded that green energy technology is now bigger than other sorts of energy technology. It is also stated that energy technologies stands for the largest part of the Danish total export relatively to other countries in EU15. In 2012 the total export of green technology stood for 32,5 billion Danish crowns alone (DEA-Energy, 2013).

5.3 Oil

Denmark is perhaps not commonly perceived as an oil drilling country. This is partially an incorrect understanding since Denmark has in fact extracted domestic oil since the 1970s. As concluded earlier, the Danish government has strived for an independency of foreign oil since the OPEC-crisis in the seventies and a

domestic oil production was a main part to accomplish that task. However, the Danish production and oil reserves are not close to being as vast as those in bigger oil drilling countries such as Norway. But the oil production in Denmark is and has been essential for the Danish economy. The oil and gas sector represent approximately three percent of Denmark's gross value added which makes it one of the biggest sectors and it constitutes fully nine percent of the Danish export (See Arentsen & Åril, 2012). The Danish oil production has a positive effect on the Danish economy and labor market. The DEA writes that together with sustainable alternatives has oil and gas production contributed to that Denmark is the only net exporter of energy in the European Union. The Danish society also receives several benefits because of huge tax revenues but also because of the labor the oil sector constitutes (Larsen, 2013, p. 50-52). Oil is harmful for the ecosystem but has been valuable for the Danish financial system.

6 Analysis

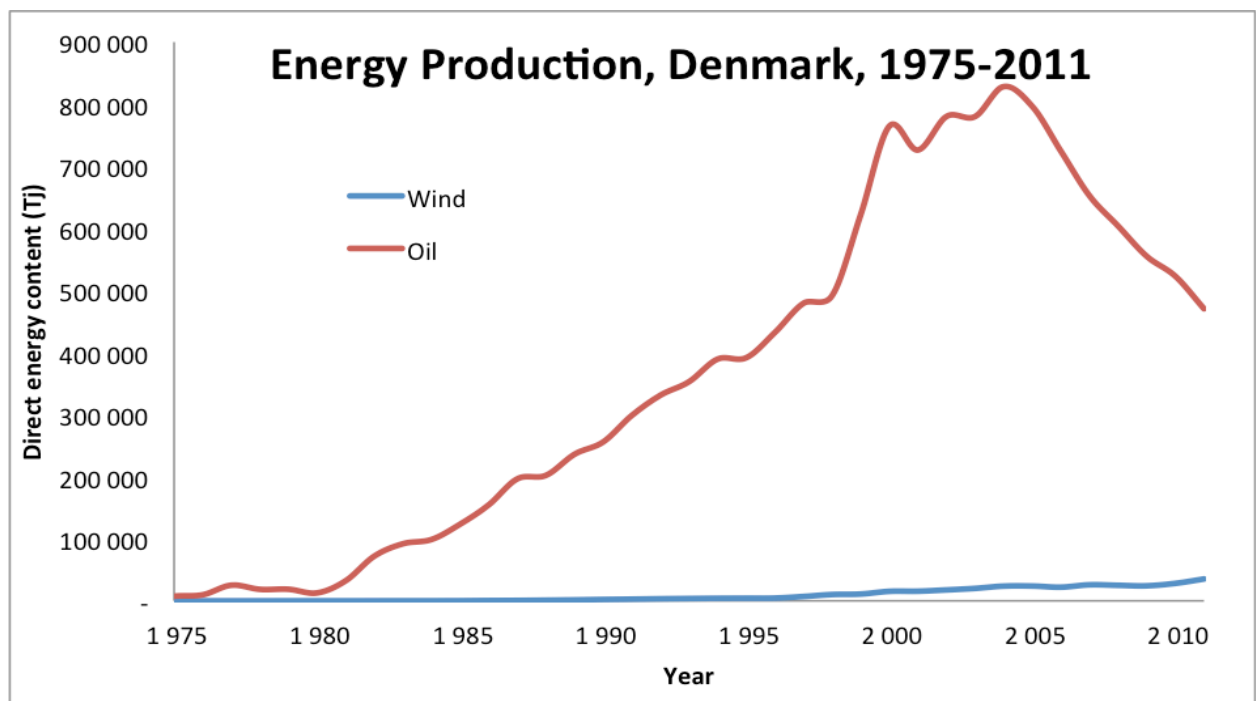
This analysis aims to illustrate the cost effectiveness of green energy investments. Wind power is often perceived as a typical green investment, which is good, both for the environment but also for the labor market. Both the wind power industry and the oil industry are vital parts of the Danish energy production but also of the Danish economy. As concluded earlier, Denmark is investing a lot of capital in green energy sources and especially in wind power. It is therefore very interesting to look at the opportunity costs for these subsidies. The oil production illustrates, in this analysis, the opportunity cost for these wind power investments. It would be possible to use gas or coal production instead of oil, but oil is Denmark's most important energy source and thereby the most natural alternative. The purpose of the analysis is to describe the cost effectiveness of green energy subsidizes and the efficiency of green jobs.

The analysis is divided into three major parts. First, the analysis describes how much energy that is produced per million invested Danish crowns. Wind power and oil are two of the biggest energy producing industries but this analysis assumes that they are the only two energy-producing sources. This thesis does neither take account of the fact that it is possible to use oil for other things nor that oil is a finite resource. The second part of the analysis illustrates the efficiency of green jobs by describing how much energy one worker in the two sectors produces in average. Finally, the negative externality of oil and its effects on the climate change is integrated into the calculation. These three steps provide a broad understanding of the cost effectiveness in Danish wind power subsidies.

6.1 Cost Effectiveness

Both wind power and oil are essential sectors for the Danish economy, but their cost effectiveness differs significantly. The Danish oil industry contributes with

the biggest part of the Danish energy production. The wind power industry is gaining market shares but remains trivial. These events are illustrated in Graph 1, which also shows that the oil production has declined rapidly during the last couple of years. Graph 1 also illustrates a stable development in the wind power production. Although, Denmark is one of the countries that produce the most wind energy per citizen, the sector has a long way before competing in terms of output with ancient energy sources such as oil.



(Graph 1, DEA-Data, 2012)

The data for the development of investments in wind power is hard to interpret since the production has been subsidized in several different ways since the 1970s. Therefore, the data for subsidies to wind power do only include the PSO⁴ contribution, which extends from 2005 to 2008. PSO is the government's cost for wind power, but like most of the government's money, it comes from the citizens. The Danish citizens pay a PSO tariff through their electricity bill and the money are steered to the wind energy producers. One obvious alternative is to cut this PSO tariff, which would imply that the inhabitants would have more money in their pockets. This PSO tariff could of course also be spend on other alternatives.

⁴ Contribution to windmill-owners through taxes, See chapter 5.1

It is important to emphasize that the PSO tariff does not stand for the total cost of wind power but for the government cost. The calculation in table 1 compares the total cost of producing oil with the government's cost for wind power

Table 1 shows the amount of terajoule produced per million invested Danish crowns in the wind, respectively in the oil sector. The figures in table 1 also show that the oil sector is much larger than the wind sector, both in terms of investments but also in terms of output. Although, the more interesting numbers in table 1 show how much output the two sectors generated per million invested Danish crowns. The wind power sector produces approximately 19,15 terajoule of energy per million invested Danish crowns. This is not close to the oil sector, which produces 69,26 terajoules per million invested Danish crowns. In this calculation, the oil sector is approximately 362 percent more cost effective than the wind power sector. This can also be illustrated by stating that for every million Danish crowns the Danish government spends on subsidies for wind energy, they chooses to produce only 27,64 percent of what they could produce for the same amount of money in the oil sector. The table illustrates the cost of green investments in wind power.

| Year | Investments in Oil, Million DKK | Subsidies to Wind, Million DKK | Output (Tj) Oil | Output (Tj) Wind | Amount (Tj) per Invested Million DKK (Oil) | Amount (Tj) per Invested Million DKK (Wind) |
|---------|---------------------------------|--------------------------------|-----------------|------------------|--|---|
| 2005 | 7 956,00 | 1 668,00 | 796 223,69 | 23 810,40 | 100,08 | 14,27 |
| 2006 | 10 189,00 | 1 076,00 | 724 062,38 | 21 988,65 | 71,06 | 20,44 |
| 2007 | 10 653,00 | 1 631,00 | 652 260,51 | 25 816,32 | 61,23 | 15,83 |
| 2008 | 11 281,00 | 667,00 | 603 525,08 | 24 940,08 | 53,50 | 37,39 |
| Average | 10 019,75 | 1 260,50 | 694 017,91 | 24 138,86 | 69,26 | 19,15 |

(Table 1, DEA-Data, 2012: DEA-Data-Oil, 2012: DEA-Data-PSO, 2009)

Table 1 describes the opportunity cost in output per invested Danish crown. Spiller (2011) argues that we always should encounter the opportunity cost and that decision makers sometimes are blinded by the fact that they often place resources in different budgets. Table 1 illustrates the alternative, for producing 19,15 terajoule per million invested Danish crowns, is the possibility to produce 69,26 terajoules instead. But it is of course, as Tietenberg & Lewis conclude, not costless to change it's production (2009, p. 21). Although, it is easy to see that if

the Danish government wanted to produce as much output per invested capital as possible, it would be disadvantageous to invest in wind energy. For every million Danish crowns the government invests in wind power they lose approximately 50 terajoules of output. The value of the opportunity is greater than the value of the chosen investments.

Roughly 50 terajoules can be seen as the loss, per million Danish crowns, of investing in green energy sources. Oil is a finite resource and it is harmful for the environment, but it is much cheaper than wind power. Just as the results in report by Álvarez et al (2010) does this calculation show that green investments are expensive for the economy. The investments in Danish oil are approximately eight times as large as the PSO support to Danish wind power. But the average output from the oil sector is almost 29 times as big as the output from wind power. It is evident that the amount and the efficiency of wind power have to increase rapidly if it shall be possible to face out the domestic oil dependence. The transition to a sustainable energy production does not come for free. It is probably inescapable for countries, regions and cities to invest in green technology and green energy because of the climate change and other environmental threats. But the argument from several politicians, which states that green transformation is a blessing in disguise for our economies, is incorrect. Even though, if the pace in green energy technology would exceed the pace of other technologies and green energy would become more efficient than oil, it would take a long time to repay these losses in cost effectiveness and in output.

6.2 Efficiency in Green Jobs

Jobs in the wind industry are generally defined as green since they have an insignificant negative impact on the environment (See for example UNEP et al. 2008). Advocates of green jobs proclaim that green jobs are those that work for a greener world and for a greener use of energy. The wind sector is very labor intensive and is often promoted as a job-creating sector. This section, of the analysis, will analyze how efficient green jobs in the wind sector are relatively to jobs in the oil and gas sector. There are many things that differentiate a job in the

wind energy sector from a job in the oil and gas sector. However, they both strive for the same output, energy.

It is accurate that the wind sector is very labor intensive. The amount of labor in the wind industry is well over 20 000 in average during the 2000s and as many as 28 400 in 2008. However, a big part of those numbers are according to the wind power industry accounted as indirect jobs. Indirect jobs are jobs that are created as a side effect of the wind energy production such as subcontractors. Approximately 45 percent of the amount of the total amount of labor is located in the “production” while 16 percent is in the sector “drift and service”. Other sectors that are included in the total figure are for example development of new products (13%) and sales and marketing (5%) (See WPI, 2012). The fact that around 25 000 people work in the wind power industry is of course positive for the labor market. But if it shall be positive for the economy at whole, it implies that these jobs are competitive in terms of output.

In table 2, the oil and gas sector is merged; this had to be done since the only good labor data available describes the two sectors as one. This implies that table 2 compares the wind power industry with the oil and gas industry. The comparison is done for the period of 2008 to 2010, which makes it up to date. This period was used since the best approximation of labor in the oil and gas industry is for this period only. However, it would have been interesting to look at longer time series since it would then be possible to state something about the development. Comparing these three years will give a trustworthy result of how the job efficiency looks like right now. It is of course easy to speculate that the differences between the two sectors was even larger in earlier periods since the wind industry has made big technological improvements during the last decades.

The amount of workers in table 2 is based on those who work with producing energy. In the oil and gas sector, this refers to those who directly produce oil and gas (1700) and those who indirectly work with engineering and architecture related to the oil production (4795) (See Arentsen & Åril, 2012). “Engineers” were included since it makes it more comparable with the wind sector. This since, in the oil and gas sector engineers and architects are an essential part of the production. In the wind power industry are those 45 percent that work in the “production” sector included in the calculation (See WPI, 2012).

| Year | Workers in Production Wind | Workers in Production Oil & Gas | Output Wind | Output Gas & Oil | Output per Worker Wind | Output per Worker Oil & Gas |
|----------------|----------------------------|---------------------------------|------------------|-------------------|------------------------|-----------------------------|
| 2008 | 12 780 | 6 495 | 24 940,08 | 980 962,04 | 1,95 | 151,03 |
| 2009 | 11 115 | 6 495 | 24 193,80 | 869 736,32 | 2,18 | 133,91 |
| 2010 | 11 250 | 6 495 | 28 113,92 | 830 223,19 | 2,50 | 127,82 |
| Average | 11 715 | 6 495 | 25 749,27 | 893 640,52 | 2,20 | 137,59 |

(Table 2, Production jobs, amount of terajoule energy produced per worker, DEA-Data, 2012, WPI, 2012, p.8, Arentsen & Åril, 2012)

The result shows a big difference in output efficiency. One worker in the wind energy sector produces roughly 2,20 terajoule of energy per year while one worker in the oil sector produces approximately 137,59 terajoule per year. In average, the amount of workers is almost twice as many in the wind sector as in the oil sector. As concluded in table 1, the output of wind energy is only a fraction of the output in the oil sector. Table 2 shows that a worker in the oil sector produces in average more then 62 times as much as a worker in the wind power sector. This is due to the fact that the wind power industry demands more workers than the oil and gas industry but produces only a fraction of what the oil sector does.

It can be argued that the sector “drift and service” in the wind industry is a significant part of the primarily production. This since the “drift and service” segment are not available for the oil and gas sector, but is probably included in production. Table 3 is identical to table 2 but it also includes the sector “drift and service” for the wind power industry. This means that the pile of workers in the wind sector gets bigger. Table 3 probably provides a more accurate picture of labor efficiency. The two sectors are far from identical and the labor figures are not presented in the same manner. Therefore, this sector is presenting two different alternatives, which hopefully enhances the understanding of the sectors and their efficiency. One worker in the wind industry does in the new calculation produces in average 1,62 terajoules per year while they in the oil industry produce in average 137,59 terajoules per worker. With ”drift and service” included, one worker in the oil sector now produces roughly 85 times as much as a worker in the wind power sector does.

| Year | Workers in production Wind | Workers in production Oil | Output Wind | Output Gas & Oil | Output per worker Wind | Output per worker Oil & Gas |
|---------|----------------------------|---------------------------|-------------|------------------|------------------------|-----------------------------|
| 2008 | 17 324 | 6 495 | 24 940,08 | 980 962,04 | 1,44 | 151,03 |
| 2009 | 15 067 | 6 495 | 24 193,80 | 869 736,32 | 1,61 | 133,91 |
| 2010 | 15 250 | 6 495 | 28 113,92 | 830 223,19 | 1,84 | 127,82 |
| Average | 15 880,33 | 6 495 | 25 749,27 | 893 640,52 | 1,62 | 137,59 |

(Table 3, Production and service jobs, amount of terajoule energy produced per worker, DEA-Data, 2012, WPI, 2012, p.8, Arentsen & Åril, 2012)

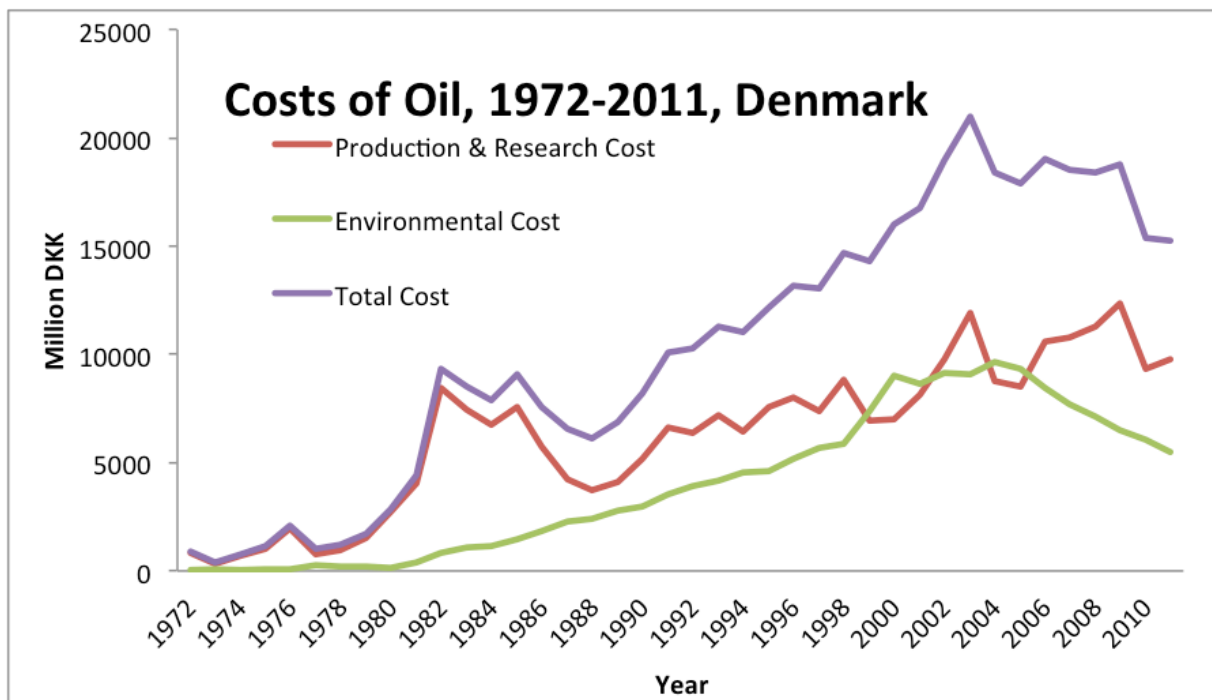
These two calculations show that a worker in the wind power sector produces a negligible part, compared to a worker in the oil sector. It shall of course be stressed that oil production is more capital intensive. However, these findings together with the results in table 1, showing how much energy produced per invested million Danish crowns, illustrates that the wind power industry is far from competitive. Green jobs in the wind sector should be seen as a cost rather than a benefit for the economy. As Hughes (2011) concludes, it is not positive for the economy if 100 people do the work 50 people could have done. In this case 62 to 85 people achieves the same as **one** person in the wind power sector does.

6.3 Climate Change Adjusted Oil

There is one obvious reason for choosing wind power instead of oil; wind power is environmentally friendly. The earlier calculations have not been totally satisfying, since they did not include any externality cost. Tietenberg & Lewis (2009, p. 71-72) mean that an externality occurs when the social cost is bigger than the private cost of producing. However, the negative externality of using oil is very hard to estimate, since oil affects several dimensions of our eco-system. Oil was, in 2011, the biggest source of carbon dioxide pollutions in Denmark (See DEA-Data, 2011, p. 38). When considering the opportunity cost, optimally every externality should be included. Including every externality is however not possible since there are numerous of externalities and it might be impossible to estimate the cost of these. This part of the analysis includes the biggest externality of oil, its contribution to the climate change. But in the end there is also a

hypothetical estimation of the total negative externality of oil. Adding on a climate change adjusted cost for oil affects oil as an opportunity cost for wind power since it affects the cost effectiveness of the oil production.

The estimate for the externality is based on Anderson et al (2010) who argue that the environmental cost per gallon of gas should be at least 0,65 USD, to mitigate with greenhouse gases. This estimate excludes other externalities like a decreased wild life and damages of oil spills. Although, it is interesting since global warming may be our planets biggest threat and oil is an essential factor in that equation. 0,65 USD per gallon equals, in 2005 prices, approximately 0,93 Danish crowns per liter of gasoline. The output of oil was then transferred into gasoline and multiplied with 0,93, which provided an estimate for the cost of the externality. This cost was then added on top of the original investments in oil, this is illustrated in graph 2.



(Graph 2, Costs for Oil, (In 2005 prices) Larsen, 2012, Environmental cost based on Anderson et al, 2010, CPI figures based figures from World Development Indicators)

It can be argued that one liter of gasoline affects the global warming less today because of technological improvements, but on the other hand, the concentration of carbon dioxide was lower for a couple of decades ago. This implies that the forests, which were healthier, had a bigger opportunity to deal with the lower amount of carbon dioxide. This calculation will assume that the effect of oil is

constant. It is probably impossible to find a true cost for offsetting the negative effect of oil since there is million of aspects that can be considered and the total cost probably vary in different regions and times. However, Anderson et al. number is an estimate that cannot be seen as the true figure but just as an approximation. Graph 2 describes the development in different cost related to the oil industry. The environmental cost was even larger than the total investments cost at two times.

Table 4 is showing that the cost effectiveness in the two sectors is more even after including the environmental cost. However, the cost effectiveness still differs a lot. A number for the climate change adjusted oil allows us also to make comparison with the wind industry. This comparison is in some matter fairer since none of the alternatives has a negative effect on the climate change. In earlier tables the comparisons have used the actual investments and costs. This calculation includes the original investments but also an environmental cost as an additional investment. This is logical since if companies were obligated to pay \$0,65 per gallon of gas, they would account it as an investment. Anyhow, the climate change adjusted oil is still more cost effective than wind energy. It is evident that with the environmental cost included, the total cost in the oil sector is approximately 18,46 billion Danish crowns in average. While the cost for wind power is approximately 1,26 billion Danish crowns in average. After including the externality for climate change, the oil industry produces 37,59 terajoules per million invested Danish crowns. The wind power industry produces the same as in table 1, 19,15 terajoules per million invested Danish crowns.

| Year | Investments in Oil (With Environmental costs), Million | PSO to Wind, Million | Output Oil (Tj) | Output Wind (Tj) | Amount of (Tj) per invested Million (Oil) | Amount of (Tj) per invested million (Wind) |
|---------|--|----------------------|-----------------|------------------|---|--|
| 2005 | 17 869,76 | 1 668,00 | 796 223,69 | 23 810,40 | 44,56 | 14,27 |
| 2006 | 19 054,73 | 1 076,00 | 724 062,38 | 21 988,65 | 38,00 | 20,44 |
| 2007 | 18 521,11 | 1 631,00 | 652 260,51 | 25 816,32 | 35,22 | 15,83 |
| 2008 | 18 404,10 | 667,00 | 603 525,08 | 24 940,08 | 32,79 | 37,39 |
| Average | 18 462,42 | 1 260,50 | 694 017,91 | 24 138,86 | 37,59 | 19,15 |

(Table 4, comparison between wind power subsidies and environmentally fixed oil costs, DEA-Data, 2012: DEA-Data, 2013: DEA-Data-Oil, 2012: DEA-Data-PSO, 2009: World Development Indicator)

Table 4 shows that if we take account for the climate change externalities, the gap between oil and wind power is much smaller. However, it is evident that even when the oil sector pays for cost of offsetting the negative externality; oil is still more effective. Oil is 96,29 percent more effective in terms of output per invested Danish crowns. If we just worry about the energy output and the externality of climate change, the best option is oil during this time period. Even after mitigating with the biggest externality, oil is still much more cost effective than wind energy.

It is very hard to estimate a cost for the true externality of oil. But if we suppose that the total environmental cost of oil is twice as big as the number Anderson et al. presented the result still shows that oil is more cost effective. A hypothetical estimation for the full environmental cost is present in table 5. The total cost has increased from roughly ten billion Danish crowns (in table 1) to more than 26 billion Danish crowns. However, the oil production in Denmark remains slightly more cost effective even after doubling this original number. In table 5, the oil industry produces 26,07 terajoules per million invested Danish crowns. Oil production is still 36,13 percent more cost effective than the wind energy production.

| Year | Investments in Oil (With Environmental costs), Million | PSO to Wind, Million | Output Oil (Tj) | Output Wind (Tj) | Amount of (Tj) per invested Million (Oil) | Amount of (Tj) per invested million (Wind) |
|---------|--|----------------------|-----------------|------------------|---|--|
| 2005 | 27205,51 | 1668,00 | 796223,69 | 23810,40 | 29,27 | 14,27 |
| 2006 | 27520,60 | 1076,00 | 724062,38 | 21988,65 | 26,31 | 20,44 |
| 2007 | 26235,21 | 1631,00 | 652260,51 | 25816,32 | 24,86 | 15,83 |
| 2008 | 25515,69 | 667,00 | 603525,08 | 24940,08 | 23,65 | 37,39 |
| Average | 26619,25 | 1260,50 | 694017,91 | 24138,86 | 26,07 | 19,15 |

(Table 5, comparison between green subsidies and environmentally fixed oil costs, DEA-Data, 2012: DEA-Data, 2013: DEA-Data-Oil, 2012: DEA-Data-PSO, 2009: World Development Indicators)

7 Discussion

The analysis showed that, in the case of Denmark, the wind energy investments are relatively cost ineffective. The value of the opportunity is greater than the value of the chosen wind energy investments. Through all calculations, oil has been more cost effective than wind power. This result is valid even after incorporating the cost for climate change adjusted oil. Furthermore, calculations have showed that one worker in the oil and gas sector produces somewhere around 62-85 times as much as one worker in the wind sector does solely. Although, It is obvious that Danish subsidies to green energy have triggered several green businesses and innovations. However, it is very unlikely that these subsidies are economic advantageous since these green investments are relatively cost ineffective. It might be hazardous to talk about green investments as a trigger for economic growth since essential decisions like this should be built on solid grounds, otherwise risks green investments not to be justifiable in the future.

The idea that green investments will boost the economy and lead to an increased amount of labor is common (See for example: OECD 2011: UNEP et al. 2008: Pollin et al, 2009). This thesis has showed that wind power investments are cost ineffective compared to its alternatives. Several reports concluding that green investments will generate many new jobs do not emphasize the importance of the opportunity cost (See for example: Pollin & Garrett-Peltier, 2009: CAP, 2009, Arik & Penn, 2011). Of course, green investments will create many jobs, but so will other kinds of investments as well. It is critical to include the opportunity costs in a calculation of cost effectiveness. The Danish government could save more than two thirds of investments spent on wind energy. This additional money could instead be invested in either green alternatives such as planting woods, rescuing the wild life or developing green and efficient energy sources, or in other job creating alternatives.

Green job is a disputed concept. In the second part of the analysis, efficiency in green jobs was measured and contrasted with jobs in the gas and oil sector. One

explanation to why the oil sector is more efficient is basically that the sector is more capital intensive. Calculations showed that it takes 62 to 85 persons in the wind power sector to achieve the same amount of output as one person in the gas and oil sector does. The low production per worker, together with the fact that energy from wind power costs three times as much as energy from the oil sector, provides a clear picture of the inefficiency in wind sector jobs. It is often stated that green energy sources are good for the labor market since they are more labor intensive (See for example: UNEP et al, 2008). This statement, that the wind power sector is labor intensive, is of course true. But this should rather be seen as a cost for the economy due to the fact that green jobs are expensive for the economy.

This analysis also shed some light on the complexity of energy economics. Hughes (2011) argues the real opportunity cost should include every environmental externality. In the first and second part of the analysis this was intentionally ignored. It was done since the purpose was to emphasize the economic cost of green investments. Although, investing all economic funds in oil would be foolish since the social cost would then be much larger in the future. Therefore, a true cost of energy sources should include all their externalities. A problem with complex externalities such as oil is that it is hard to estimate a certain number. One existing estimate is Anderson et al.'s estimate stating that it takes at least \$0.65 to counterbalance the climate change effect that a gallon of gasoline has. This estimate is not the truth but just an estimate. However, it makes it possible to incorporate the externality into the calculation on cost effectiveness.

The result, when including an estimate for the externality, showed that oil is still much more cost effective. With climate change adjusted oil, the result showed that oil is almost twice as cost effective than wind energy. The calculation in table 5 tries to estimate the full externality of oil and the result reveals that oil still remains more effective. However, the distinction is not very big in table 5. If we estimated the full environmental cost to three times as big as Anderson et al.'s number instead, we would find wind power to be more cost effective. This was not done since greenhouse gases are the main externality of oil and it is more likely that it represents half of the externality than one third. This implies that it would be better to extract oil and invest the additional billions of Danish crowns into other environmental friendly measures than investing the money in the wind

power sector. It is evident that the wind industry is far from being truly competitive in terms of cost effectiveness.

The government subsidies to wind power is not just capital that supports that industry, it is also capital that no longer can be used in another sector. As underlined several times in this report, the opportunity cost is significant. Spiller (2011) argues that one reason for not considering the opportunity cost is since people and governments divide their capital into different budgets. The support for wind power is earmarked to green energy and therefore is ancient energy sources, as an alternative, not on the table. This is obviously not an efficient way of decision-making. This thesis showed that oil would be more cost effective even after paying for these negative externalities. However, oil is not a sustainable energy source but there are other cheap energy sources that also would free resources, which could be use in other environmental matters. If a green transformation shall be possible, we must steer our green investments towards those investments that benefits the environment and the economy the most. It is not effective to place investments in projects solely because they are green.

The results in this thesis support the weak view of the Porter Hypothesis, but not the strong view. The weak view of the Porter Hypothesis states that environmental innovations are triggered by environmental regulations and taxes (2011, p. 16-17). The fact that Denmark has developed a lot of innovative cleantech companies supports this view. The fact that the export of green energy technologies is a relatively large part of the Danish export supports this hypothesis (See: DEA-Energy, 2013). However, the strong view of the Porter Hypothesis stated that these regulations will be economic beneficial for the country. Even though Denmark exports green technologies for 32,5 billion Danish crowns per year do these exports have an opportunity cost. If the subsidies and regulations had not been implemented, a lot of these companies would still produce ideas and services that could be exported. This together with the low cost effectiveness in the wind sector, point towards that environmental regulation is expensive for the economy.

7.1 Conclusion

Ideas saying that investments in green energy sources will be good for the economy and create many jobs are naive. The brown economy needs to turn into a green economy but we must be prepared to pay for it. Otherwise, the society will end up with several problems. Firstly, people will only take care of the planet as long as they believe it is possible to make money out of it. Secondly, our green transformation will not go as fast as it needs to go. This since people hope that it will come for free, or even be economic beneficial. Finally, these green investments will probably backlash in the future if people believe that they will be a boost for the economy. It will also be harder to implement future investments in green energy and green technology if we build today's investments on false grounds.

This thesis has showed through basic calculations that the wind power industry in Denmark is very cost ineffective compared to the oil sector. It would be cost ineffective even if we compared it to other brown sources such as natural gas or coal as well. This thesis also stated that workers in the wind power sector are very inefficient and should be treated as a cost rather than a benefit for the economy. Furthermore, this thesis included climate change adjusted oil and compared the cost for oil with wind power subsidies and showed that oil is still much more cost effective. Finally, the results in this thesis support the weak part of the Porter Hypothesis, saying that environmental regulations will trigger innovations. However, the results do not support the hard part of the hypothesis, saying that it will be beneficial for the economy.

7.2 Future Research

The current research on green jobs and green investments is insufficient. A global transition towards a greener world is unavoidable but how it will affect our way of life is still very much unknown. There is a need for unbiased research on this subject. How does a green transformation and green investments affect our societies is questions that we need good answers to. Furthermore, it is essential

that we look at the real cost of green investments and their opportunity cost, and tries to include as many variables as possible. Including the opportunity cost is an essential aspect that cannot be dismissed. It is also important that we study how we shall approach green investments. How can we create incentives for a green transition without promising good economic returns of green investments?

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