NORGES HANDELSHØYSKOLE

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THE ECONOMIC IMPACT OF NORNED ON NORWAY – WHO BENEFITS?

A welfare analysis

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"This thesis was written as a part of the Master of Science in Economics and Business Administration at NHH. Neither the institution, the advisor, nor the sensors are - through the approval of this thesis - responsible for neither the theories and methods used, nor results and conclusions drawn in this work."

Preface

This master thesis is written as part of the Master of Science in Economics at the Norwegian School of Economics. The thesis represents 30 ECTS credits and corresponds to one semester of studies.

Our interest for cost-benefit analysis was sparked when we attained the course Economic Appraisal of Investment projects at NHH, and later we found that analyzing the Norwegian electricity market enabled us to satisfy some important requirements we had put on ourselves.

We would like to thank our supervisor Karl Rolf Pedersen for competent and patient guidance in the process leading to this thesis. We also want to thank Erling Norheim Faugstad in Statnett for helping us and providing us with data.

Finally, we want to thank the Norwegian School of Economics, the Student Association at NHH, and Bergen for five fantastic years.

Oslo, 16th of December 2011

Harald Martens Holm   Tor Westby Stålsett

Abstract

This thesis assesses the welfare effect of NorNed on the Norwegian society, and distributional issues are also addressed. In doing so we combine traditional welfare theory with theory on international trade and apply a cost-benefit methodology to systematically analyze the welfare effect.

To analyze the welfare effect we apply a standard partial equilibrium model on relevant data for the NorNed cable provided us by Statnett for a period from May 2008 to September 2011. The same data is used to calculate a NPV of the NorNed project.

We find that NorNed has increased Norwegian welfare in the magnitude of 992 million Norwegian kroner in the period. Norwegian consumers have lost 1 801 MNOK from the introduction of the cable, while Norwegian producers have gained 2 802 MNOK, respectively 703 MNOK for Statnett and 2 099 MNOK for Norwegian electricity producers. The NPV of the NorNed cable is calculated to be 6 000 MNOK over the entire lifetime of the cable.

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1.0 Introduction

1.1 Motivation

The idea for this master thesis started out as a question some years ago; how can economists argue that investing in an airport or railroad has a value equal to so and so much? It just did not make sense that something that intricate could be so precisely addressed.

In trying to answer the question, we attained the course "Economic Appraisal of Investment projects" arranged by Professor Karl Rolf Pedersen at the Department of Economics at the Norwegian School of Economics. The course provided us with the methodological expertise. Now we wanted to practice it.

In that sense, we approached our thesis knowing what most researchers decide later in the working process; the method. Next, we had to decide what project to appraise. We wanted our work to be of practical relevance and of academic interest.

The 10th of November 2008, Director of Federation of Norwegian Industries (Norsk Industri), Stein Lier Hansen said *"…in the years to come, the people of Norway will experience sky rocking electricity prices relative to what they are accustomed to."* and he continued *"In the future, we will export electricity to Europe without considering whether we have much or little water"* (Stavø 2009)

Three years later, in November 2011, the Norwegian municipality politician, Are Tomasgard, expressed his frustration over the fact that Norway had net export in a period where hydropower reservoirs were – in his view – empty, and concluded that *"..never has Norwegian electricity supply been as greedy as it is nowadays."* (NRK Brennpunkt 2011). This conclusion can only be interpreted as an allegation of Norwegian electricity producers charging an unreasonably high electricity price.

From these statements, we feel confident to say two things; firstly, serious misunderstandings of the fundamental drivers of trade are present in the Norwegian society, and secondly, knowledge regarding in what way a hydropower system works is limited. Most people can manage very well without knowing anything about these issues, but we find it alarming that people, who by the general public are perceived as reliable sources of information, makes such statements. In that sense, a study looking closer at these issues felt practically relevant.

Based on this, we wanted to learn more about the Norwegian electricity market, and how it is affected by trade in electricity. We found the NorNed cable an interesting case in that respect.

Making a master thesis academically interesting is an ambitious goal for a student. Most things have been thought of by someone before and limited time is available. But as we were doing research, we came up with an argument that seems to have been left behind in the appraisal of investments in the grid infrastructure. Whether the argument is academically interesting is for others to decide.

1.2 Research question

In trying to capture the essence of what we have just discussed, we formulated the following research question.

"Has the NorNed cable increased welfare in Norway, and if so, by how much? How is the welfare distributed within the society?"

1.3 Overview of the thesis

In chapter 2.0 we introduce some terminology and address important characteristics of the Norwegian and the Dutch electricity market. In chapter 3.0 we present welfare economics and theory on international trade, both of which will be used later in the analysis. Chapter 4.0 gives an introduction of the methodology we will be using in our analysis. Next, chapter 5.0 presents our initial data, and explains how we extended the initial data in order to make them applicable to our analysis. Chapter 6.0 is our analysis. Because this chapter is somewhat intricate, we offer a detailed overview of the structure of the whole chapter in chapter 6.1. In chapter 7.0 we conclude on the research question and in chapter 8.0 we discuss limitations and criticize our own work.

2.0 Background

2.1 Introduction

Electricity is generated in power plants in a process where turbines are transforming energy into electricity. The different generating technologies are numerous, but in this thesis thermal- and hydropower technologies are the relevant.

In a thermal power plant, the turbine is driven by steam. Steam is produced as water is being heated by burning of for instance gas, coal or a nuclear fusion. In a hydropower plant the kinetic energy of moving water drives the turbine.

Electricity cannot be stored. This means that supply has to meet demand continuously, and if it does not, consumers face black outs. Blackouts can have grave economic consequences to society.

In the world of physics, electricity is measured as power (kW or MW) and energy (kWh, MWh or TWh). Power is an instantaneous aggregate expressing the flow of electricity within a period of time. Energy expresses the integral of multiple periods with flow of power.

In this thesis, we term the market in which power is being traded, “electricity market” and the good being traded in this market “electricity”. Still, we will refer to plants producing electricity, as power plants.

What power measures, is called effect. Hence, the term effect capacity addresses the capacity of a power plant to deliver power. In similar manner, generation capacity addresses output capacity of the power plant in terms of energy.

In 1990 the Norwegian parliament passed the Energy Act (Energiloven) of 1990. This marked the beginning of a liberalization process driven by an urge to *“ensure that production, transformation, transmission, trading, distribution and use of energy are organized in a rational way for society, including common and private interests”* (Energiloven, 1990, § 1-2).

In the following we examine national characteristics of generation[1], transmission, trading and demand in Norway and the Netherlands respectively.

[1] We use generation as power production through the thesis.

2.2 The Norwegian market

Generation

In 1992, the state owned monopolist Statkraft was split into Statkraft SF[2] and Statnett SF[3]. As of that time, Statkraft SF was to focus on generation in a freely competitive electricity market. (Statkraft 2011)

Today, Statkraft SF is a major player in the Norwegian electricity market, both directly and indirectly; directly by owning the largest share of generation capacity, indirectly through cross ownership.[4] Statkraft has more than 200 competitors and close to all are owned by either national or local authorities, but managed according to commercial principles.

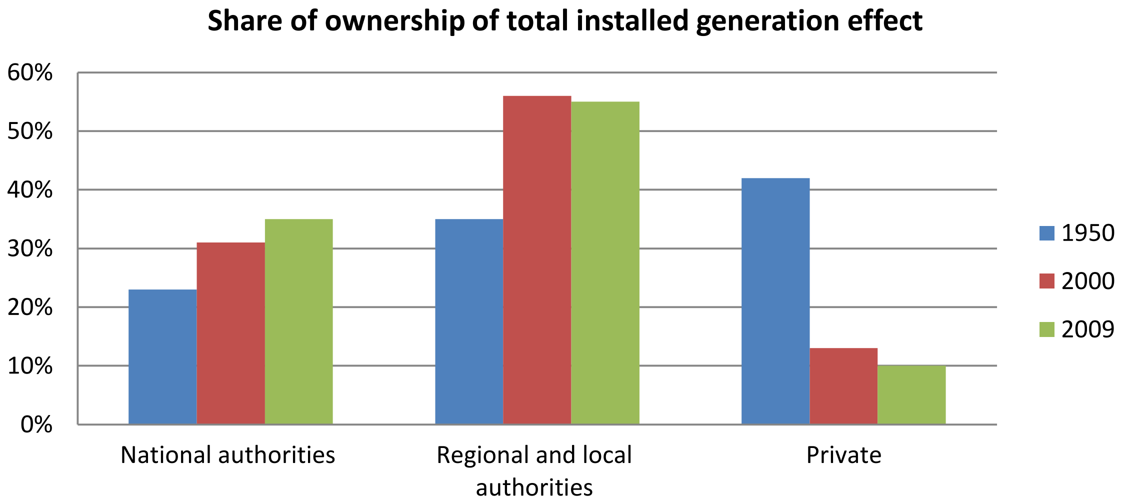


Figure 2-1 Generation ownership (EBL 2010) and (Kjærland 2009)

Figure 2-1 displays the share of generation effect held by different categories of owners. National authorities' share consists solely of Statkraft SF. Private refers to listed companies. It should be mentioned that Norwegian authorities have considerable equity interest in some of these[5].

[2] Before 1992 Statkraft had monopoly in operating the national grid system while at the same time owning a substantial share of generation capacity in Norway.

[3] SF stands for State owned Corporation (Statsforetak)

[4] For an in-depth analysis regarding the role of Statkraft SF in the Norwegian electricity market, see Singh & Skjeret (2006).

[5] In particular this is the case for Hafslund ASA and Norsk Hydro. Local authorities in the municipal of Oslo own 53.73 % of Hafslund ASA and national authorities owns 34.26 % of Norsk Hydro (Hafslund, 2011 and Norsk Hydro 2011). Norsk Hydro owns 2/3 of the 10 % of production capacity held by the "private" category (OED, 2009)

Norway is one of a kind when it comes to generation. Most of our electricity is generated by renewable resources, first and foremost hydropower. Because hydropower generation is dependent on precipitation, the total capacity of the system changes over time. According to NVE (2011), potential generation capacity of Norwegian hydropower is about 123 TWh in a year of normal precipitation.

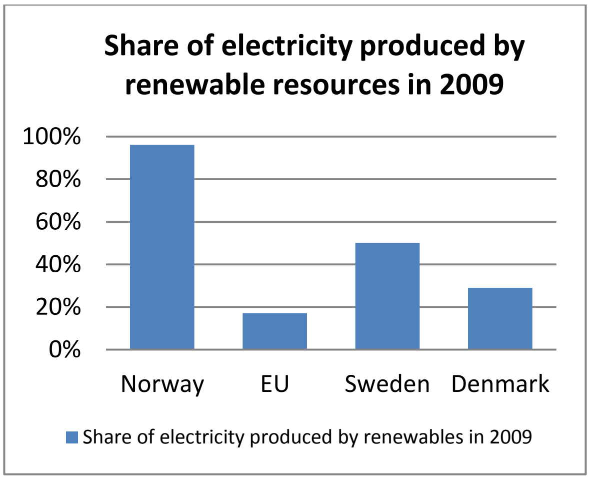


Figure 2-2 Share of renewable electricity generation

In 2009, total generation was 131 TWh in which 96 % (126 TWh) was produced by hydropower, 3.5 % by thermal power and less than 1 % by wind power. The same year, total effect capacity was about 26 500 MW. Of this, hydropower accounts for 25 000 MW, thermal close to 1000 MW and wind power less than 500 MW (SSB, 2011a and NVE, 2011a) It is evident that the Norwegian power system by and large is fueled by kinetic energy from water.

Planning of hydropower plant operations is somewhat laborious. This is due to the fact that the price of input – water – is not determined in any market. Førsund (2007) argues that the cost of letting water through the turbine now is not being able to run that water through the turbine later. In this perspective, a price on input can be assign, which is what the industry has done by introducing the term water value. The water value simply assigns a price on input based on prospects for future revenue, and thus recognizes the costs as defined by Førsund (2007). In planning of hydropower operations, maximizing the water value is the key objective.

A system dominated by hydropower has some advantages. First of all, electricity can be stored. Certainly not as electricity per se, but water being dammed and later run through turbines to produce electricity, essentially enables storing of electricity. It also makes generation flexible in the short run, meaning the system has flexible effect capacity, which is the second advantage.

The main disadvantage is that generation capacity is not predictable in the long run. The generation capacity of 123 TWh is based on a year with average precipitation. In presence of a dry year, or period, generation faces restrictions with accompanying consequences to price.

Demand

In general, there are hourly variations within a day, daily variations within a week and seasonally variations within a year around some average. This average has an increasing trend as economies grow. (Hannesson 2009)

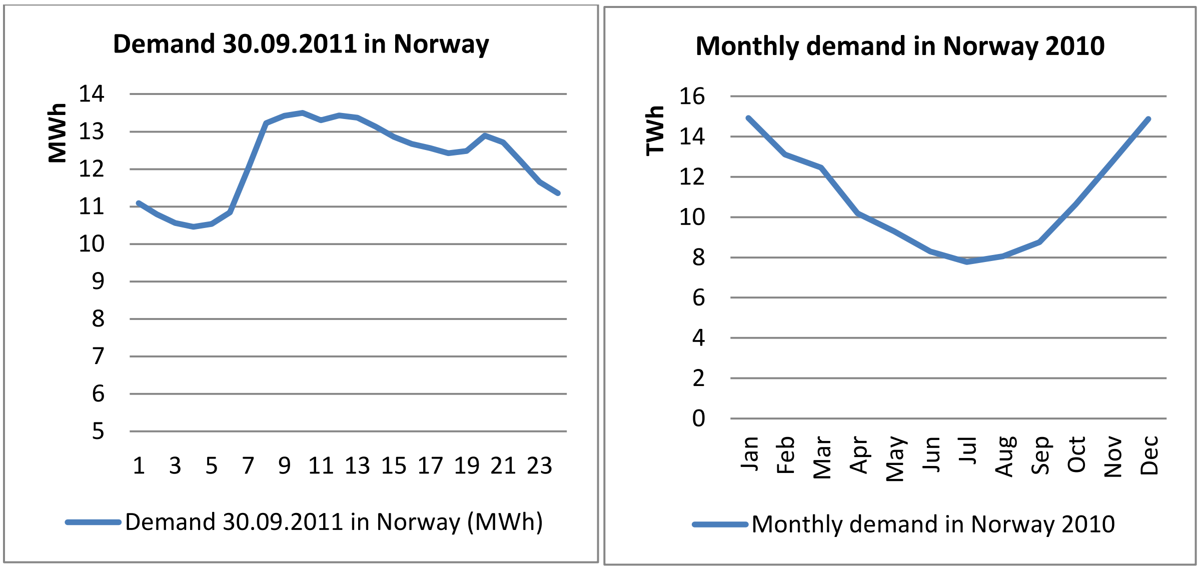


Figure 2-3 Electricity demand Norway (Nord Pool 2011c)

In Norway, electricity is used for indoor heating. Because of this, temperature has a significant effect on demand. This makes demand relatively stable within a day, but annual variations depending on seasons can be large.

It is evident from left side panel of figure 2-3 that demand is at its lowest during the night. As people get out of bed, demand increases sharply until around 10 AM from which it declines until around 4 PM, before it again starts increasing until 9 PM. It is also worth noticing that in the hour of maximum demand within the day, demand has increased by 29 % relative to the minimum level within the same day. This number is usually around 30 %, making 30.09 a typical day. (Statnett 2004a)

Transmission

Statnett SF went into business in 1992 as Norwegian transmission system operator (TSO). Due to special characteristics of the relationship between costs and output, transmission is regarded as a natural monopoly[6]. Hence, as Norwegian TSO, Statnett was granted monopoly in transmission operations.

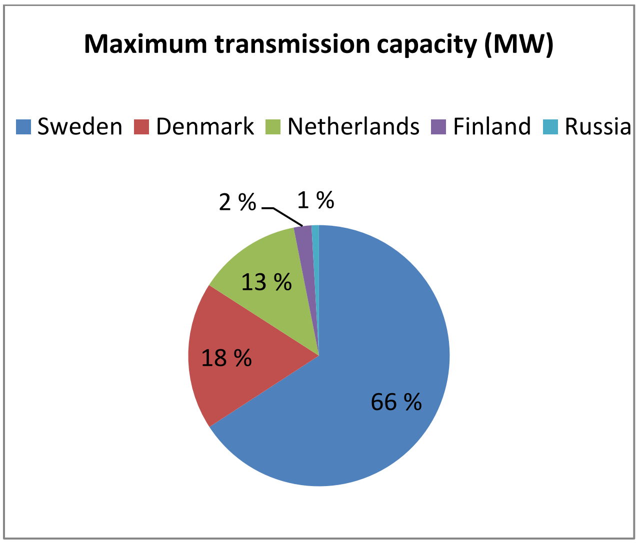
All state owned companies, including Statnett, are owned by the Ministry of Trade and Industry (NHD). To ensure appropriate operation of the monopoly, NHD has appointed the Norwegian Water Resources and Energy Directorate (NVE) supervisory body. (NVE 2011b) An important part of this mandate is to monitor revenue (tariffs) and costs from operations. (Wangesteen 2007)

The main sources of revenue for Statnett are bottleneck income and network tariff. Bottleneck incomes arise whenever transmission capacity is insufficient to satisfy demand. Then, the price mechanism is used to lower demand. The resulting difference between system price and area price renders bottleneck income. The network tariff is paid by every consumer and is based on her annual consumption of electricity. (Statnett 2008)

By and large, costs are maintenance and investments in necessary upgrading of the transmission network, including international interconnections. Today a total of 15 cables connect Norway to countries abroad, and a number of new connections are suggested or under construction.[7] Figure 2-4 summarize the existing connections.

[6] Wangensteen (2007) discuss the case of TSO and natural monopoly in detail in chapter 5.2 and 9.

[7] NORD.LINK is a project connecting Norway and Germany. This projects' application of license is being considered now and a final investment decision is to be made in 2013. NSI is a project connecting Norway and England. This project got its application declined in 2003, but Statnett and their British partner, National Grid, are still looking alternatives. SydVestlinken is a project connecting Vestfold in Norway to south Sweden, but the exact route and connection is not yet decided. Statnett are hoping for the connection to be up and running between 2018 and 2020. Skagerrak 4 connects Kristiansand in Norway to Tjele in Denmark with a transmission capacity of 700 MW. It will be ready to operate within 2014. (Statnett 2011a)



Interconnections to Norway		
Country	***# Cables***	***Maximum capacity (MW)***
Sweden	9	3600
Denmark	3	1000
Netherlands	1	700
Finland	1	120
Russia	1	50
Sum	***15***	***5470***

Figure 2-4 Transmission capacity and interconnections to Norway (Statnett 2011b)

Trading

In 1996, Nord Pool was established as the world's first multinational market maker for an electricity exchange. Today Nord Pool arranges market clearance in the Nordic market and arranges trading of three quarters of the total consumption in the Nordic market. The remaining consumption is sold at fixed price through long term contracts.[8] Nord Pool organizes several markets, but in this thesis, only the day-ahead market is considered. (NVE 2011) and (Nord Pool 2011a)

The process leading to market clearance in the day-ahead market is organized as follows. At any day, before noon, buyers and sellers report what quantities they are willing to buy and sell at what price, for every hour the upcoming day. Based on these reports, a system price clearing the market is generated by Nord Pool. This price functions as a reference price in the market when the same process, only this time at a regional- and not national level, is repeated to calculate area prices. Area prices differ from system prices because of bottlenecks in the grid. It is important to note that the system price is what producers are being paid for every MWh sold at Nord Pool, no matter what area they produce in or sell to. (Nord Pool 2011b)

[8] Nord Pool is owned 30 % by Statnett, 30 % by Svenska Kraftnät, 20 % by Fingrid Oyj and 20 % by Energinet.dk, all of which are transmission system operators in Norway, Sweden, Finland and Denmark respectively.

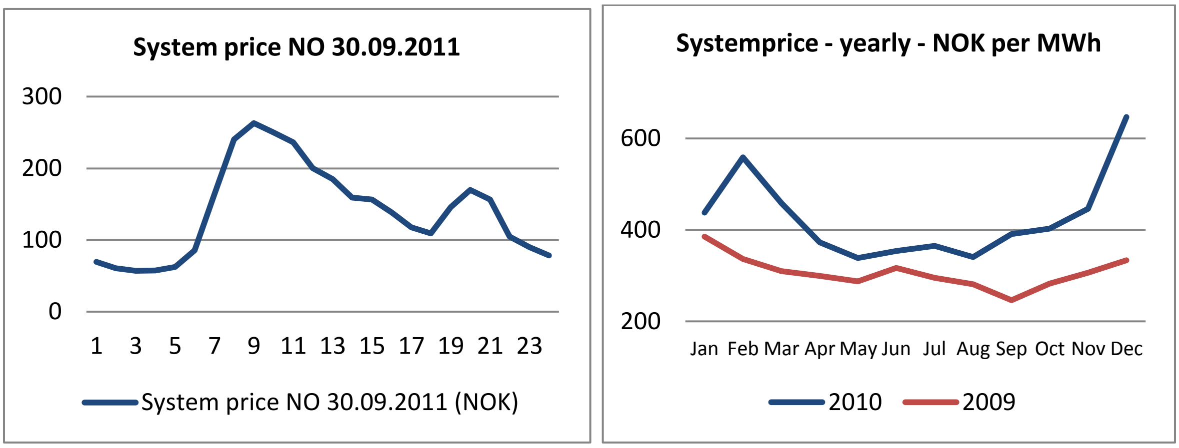


Figure 2-5 System prices at Nord Pool (Nord Pool 2011c)

The area price is a tool to manage the flow of electricity, which goes from areas with relatively low price to areas with relatively high price. This coordination process is managed by the TSO. Hence, revenue from this activity – the bottleneck income – goes to Statnett and is of no benefit to the producers of electricity. (Nord Pool 2011b)

The price coordination offered by Nord Pool has made Norwegian, Swedish, Finish and Danish electricity markets increasingly integrated. Still, due to bottlenecks in the grid, the individual countries are heavily dependent on their national abilities to generate electricity.

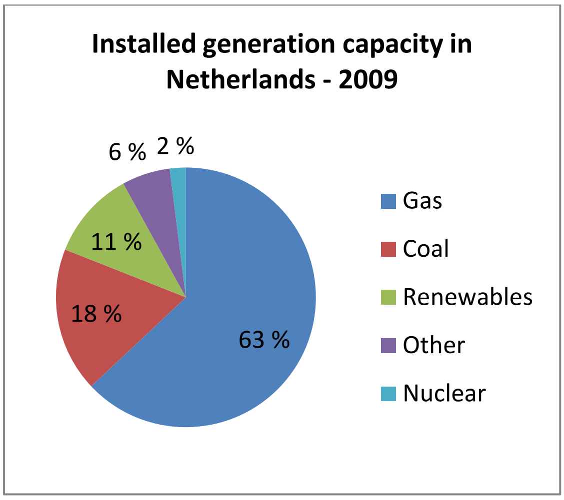
2.3 The Dutch market

The Energy Act of 1998

As member of the European Union, the Netherlands is subject to EU directives and regulations. In 1996 the Council of the European Union issued the Internal Electricity Market Directive in order to gradually integrate electricity markets in member states (The European Parliament, 1996). As a result the Netherlands adopted their Energy Act of 1998 (Overheid, 2011). The law took the same considerations as the Norwegian initiative with regards to generation, transmission and trading. (Wangensteen 2007)

Generation

Total generation capacity in the Dutch market is 120 TWh. Figure 2-6 displays the distribution of total generation capacity over different primary energy sources. Total effect capacity amounts to 25 300 MW. (Energie-Ned 2011)



Generation mix - TWh - 2009	
Gas	75.6
Coal	21.6
Renewables	13.2
Nuclear	7.2
Other	2.4
Total	120

Figure 2-6 Generation capacity and generation mix in the Netherlands in 2009 (RWE 2010)

From figure 2-6 it is evident that 83 % of generation capacity in the Netherlands comes from thermal sources, whereof coal and gas constitute 81 %. Coal and gas are both fossil fuels, which emits CO_2 as it is burnt.

Planning of operations at a thermal power plant is less abstract than in the case of a hydro power plant. The reason is that prices on input are explicitly stated in markets for coal, gas or other energy carriers.

Like any other system heavily dependent on one type of generation technology, the Dutch system has advantages and disadvantages.

The important advantage is that capacity is predictable in the long run. As long as fueling is provided, the power plants can produce according to installed capacity. Today, under normal conditions, the relevant types of primary energy sources are traded in the world market at a stable low cost; coal in particular. Moreover, the Netherlands is well known for their abundant reserves of natural gas.

The main disadvantage is a consequence of predictability; inflexibility in the short run. After start up, a plants' generation can be regulated by fueling. But, due to high start-up costs, producers need to consider the additional cost of a new start up when faced by the decision to shut down generation or not. This decision depends on present and future demand.

Demand

The previous chapter revealed that generation capacity in the Netherlands is close to that of Norway. Still, the Netherlands is four times as populated as Norway. One important explanation to this is that gas and district heating is used for indoor heating in the Netherlands. (Energie-Ned 2011) This means that demand is less dependent on temperature, and hence that seasonally variations are smaller.

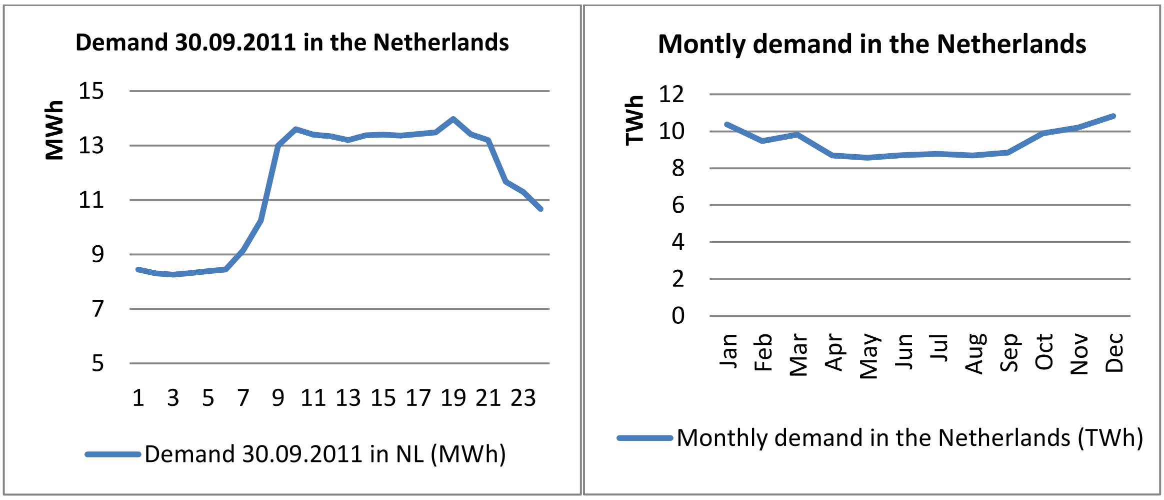


Figure 2-7 Electricity demand the Netherlands (IEA 2011)

Households account for 24 % of the Dutch electricity demand, the residual demand is constituted by different kinds of industries. Demand is at its lowest in the night and starts increasing as people get out of bed. From around 10 AM until 9 PM demand is relatively stable. The difference between maximum and minimum demand is close to 70 %. Econ Pöyry (2011) argues that this difference normally is in the magnitude of 100 %.

Transmission

The Energy Act of 1998 explicitly appointed the newly established company TenneT as a transmission system operator (TSO) in the Dutch market. At first, TenneT only operated the national transmission system, whereas some regions were operated by other companies. In 2003 TenneT became TSO monopolist. (TenneT 2011b)

There are many similarities with regards to how the electricity market is organized in Norway and the Netherlands. TenneT is owned by the Dutch Ministry of Finance and the supervisory body is the Office of Energy Regulation (TenneT 2011c). Moreover, TenneT collects revenue from bottleneck income and network tariffs in similar manner to Statnett. (TenneT 2011d)

Trading

Amsterdam Power Exchange was established as Dutch market maker for electricity and gas in 1999. Today it carries the name APX-ENDEX. In 2010, 31 % of total domestic electricity consumption was traded through APX-ENDEX. (Energie-Ned 2011)

Fundamentally, there are no differences with regard to how prices are obtained in the Dutch and the Norwegian market, but at APX-ENDEX sellers and buyers report quantities for every 15 minutes as oppose to every 60 minutes at Nord Pool. APX NL is the name of the price clearing the Dutch day-ahead market. Put another way, APX NL is the APX-ENDEX equivalent to the Nord Pool system price. (APX-ENDEX 2011a)

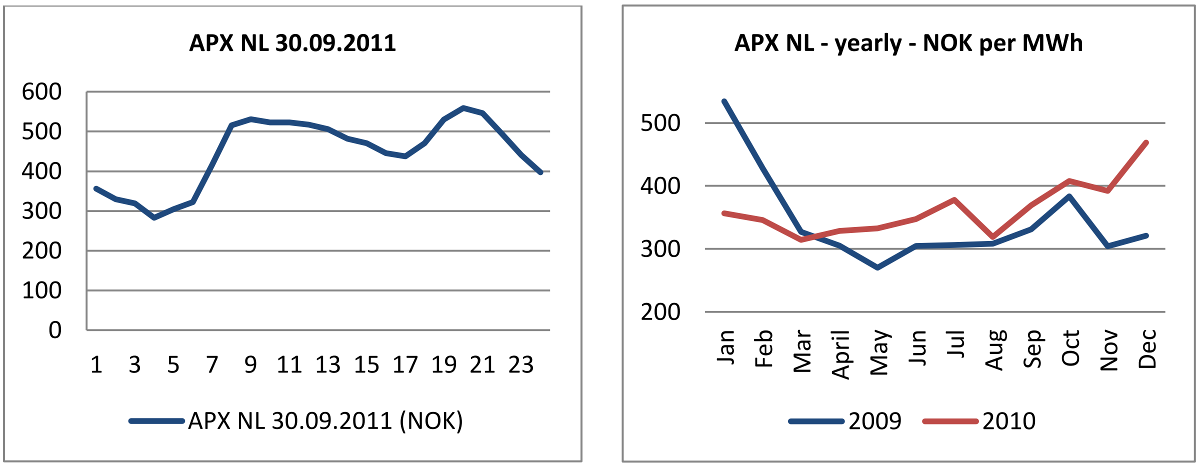


Figure 2-8 APX NL price at APX-ENDEX

It is evident from the left side panel of figure 2-8 that APX NL constitute a similar pattern to the Norwegian system price, put it is higher. In the right side panel we can see that prices seasonal variations over the year are smaller than I Norway.

2.4 Connecting the Norwegian and Dutch market

As of the 6th of May 2008 the Dutch and the Nordic market was connected by the world's longest subsea interconnection. The cable, called NorNed, was initiated in 1994 and given license to operate by different governmental entities during 2000 to 2003. From 2004 the project was undertaken by the two TSOs of Norway and the Netherlands in order to finalize the project and manage daily operations.

The NorNed cable enabled the countries to benefit from the differing variance patterns of the electricity price in the two markets.

3.0 Theory

3.1 Introduction

In the following chapter we present theory we find relevant to understand and analyze the trade taking place through the NorNed cable. We start out with exploring welfare economics in chapter 3.2. In doing so, we present some basic concepts of micro economics, market failure, the Pareto criterion and the Kaldor-Hicks. In chapter 3.3 we try to recap chapter 3.2 by linking the different theories. Chapter 3.4 explores theory on international trade and prepares the reader for what will be the red line through our analysis.

3.2 Welfare economics

Welfare economics date back to Arthur Pigou and his article "The Economics of Welfare" that was published in 1920. (Hicks 1975) In this article, Pigou wrote that *"the economic welfare of a community consists in the balance of satisfactions from the use of national dividend over the dissatisfaction involved in the making of it."* (Pigou 1920, p. 85)

Some economists opposed to the main arguments of Pigou (1920), and deliberate critique was aimed at his treatment of utility and welfare, which he equalized. During the 1930s, objections against Pigou's work gained support[9], but when Kaldor (1939) combined the work of Pigou (1920) and Pareto (1906), objections were forgone and the *Pareto criterion* made up the first cornerstone of welfare economics. (Ibid) The second cornerstone, the *Kaldor-Hicks criterion*, was originally two inverse arguments regarding compensation. Scitovsky (1941) analyzed these arguments separately and discovered flaws that could be omitted if both arguments were combined into one. The single argument is publicly known as the *Hicks-Kaldor criterion,* but it is also referred to as the Scitovsky criterion because of his contribution. We shall soon return to welfare economics and present the cornerstones in greater detail, but first some basic concepts of microeconomics need to be presented.

3.2.1 The freely competitive market

Within economic theory the freely competitive market plays an important illustrative role. This kind of market is an abstract creation because it makes simplifying assumptions about

[9] Objections against Pigou's work were primarily set forth by Roibbins (1932) and Myrdal (1929) and after a few years these objections enjoyed substantial support among economists.

reality. Still, the assumptions are justified in order to give analysts a chance to model and analyze changes in key parameters.

The basic assumptions of the freely competitive market can be derived from any introductory textbook of microeconomics, see Walter (2011). The assumptions are

1. Actors are rational
2. Actors face perfect information
3. Actors face diminishing returns
4. Actors maximize utility
5. There are many agents buying and selling
6. There are no barriers to entry or exit the market

Assuming rationality means that consumers prefer more over less consumption and producers more over less profit. Actors facing perfect information, means that everyone knows everything of relevance to the market action they are about to take. The third assumption is actually a hypothesis stating that as consumers increase consumption, their additional utility gained decreases. The same goes for producers with regards to profits. Fourth, consumers seek to maximize utility and producers seek to maximize profits. The last two assumptions need no additional comments.

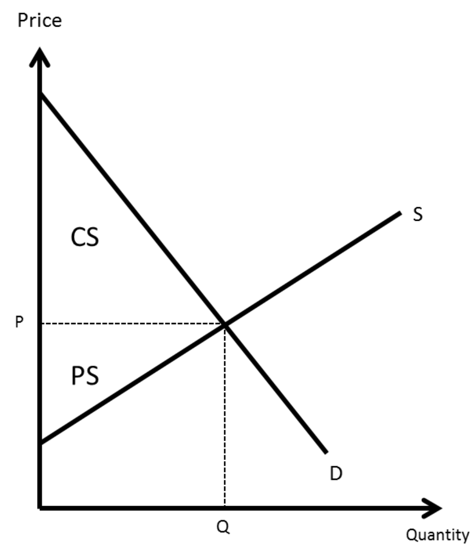


Figure 3-1 The freely competitive market

Along the demand curve (D) in figure 3-1, willingness to pay by consumers is expressed. The slope of the curve is determined by the marginal elasticity of demand, which is defined as consumers' percentage change in demand in response to a one-percent change in price.

Along the supply curve (S) in figure 3-1, the opportunity cost of production as faced by producers is expressed. The opportunity cost is the cost of not applying a resource in its best alternative application. In other words, it equals the value we could have realized by applying a given resource differently. The water value faced by a hydropower plant explicitly recognizes this concept.

At the point where no consumer is willing to pay to a producer what an additional unit costs, the market is in equilibrium. The equilibrium determines price and quantity in the market, which ultimately determines the producer and consumer surplus. The sum of the producer and consumer surplus is the social surplus.

The individual consumer surplus is defined as the difference between the maximum amount that a consumer is willing to pay for a good and the amount that the consumer actually pays. (Pindyck & Rubinfeld 2005) In figure 3-1 consumer surplus is the area marked CS, and this area is the sum of consumer surplus experienced by all independent consumers in that market.

The individual producer surplus is defined as the difference between the market price of a good and the marginal cost of production of that good. (Ibid) In figure 3-1 producer surplus is the area marked PS, which is the sum of producer surplus experienced independent producers in the market.

The equilibrium of a freely competitive market has one very important feature; it is a Pareto optimum[10]. The Pareto optimum is soon to be presented in greater detail. At this stage we emphasize that in the equilibrium of a freely competitive market, resources are being utilized in a way that maximizes the social surplus of the society[11] [12].

[10] This feature was discovered by Lerner (1934), Lange (1942) and Arrow (1951) and is publicly known as the first theorem of welfare economics.

[11] Maximizing the social surplus is the same as minimizing the efficiency loss. Efficiency loss is discussed in relation to figure 3-2.

[12] In the formulation "… in a rational way for society" from the Energy Act of 1990, "a rational way" reflects the wish to maximize social surplus. (Hope 2002) (Førsund 2007) (Wangensteen 2007)

3.2.2 Market failure

Due to market failures, very few markets are freely competitive. According to Boardman et al. (2011), market failures arise in the presence of monopoly, externalities, information asymmetries or public goods.

What is important about market failures is that whenever they are present, the market itself fails to allocate resources in a way that maximizes the social surplus, and hence the society loos social surplus as a consequence of it. Among the market failures mentioned above, only monopoly, externalities and public goods are of relevance to this thesis.

Figure 3-2 presents a monopoly where there is only one seller of a product. In that sense, it is the total opposite of a freely competitive market. Because of its unique position in the market, the monopolist is able to charge a monopoly price (P-M) that is higher than the price of a freely competitive market (P-F). This leads to efficiency loss equal to the triangle EL in the figure.

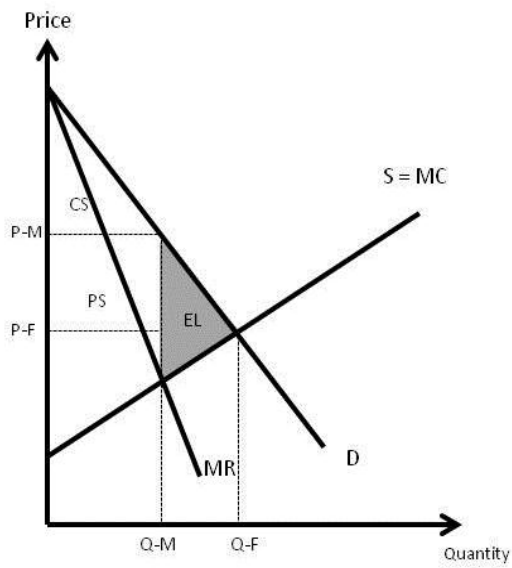


Figure 3-2 Monopoly and efficiency loss

Externalities are effects of production or consumption on third parties for which there is no market. (Boardman et al. 2011) In the case of externalities, the full cost or benefit of an activity is not reflected in the price of the good. An example is generation of electricity in a coal power plant; as electricity is generated CO_2 is emitted. CO_2 affects others than those consuming the electricity negatively.

Public goods are nonrivalrous and nonexcludable (Boardman et al. 2011). For a good to be nonrivalrous, one's consumption of the good cannot obstruct other people's consumption of that good. Nonexcludable means that it is impossible to effectively deny anyone consumption of the good. A good example of a public good is the air you breathe.

3.2.3 Pareto criterion

Returning to the cornerstones of welfare economics, our natural point of departure is the first cornerstone; the Pareto criterion. The Pareto criterion is concerned with resource allocation within a society. It is important to note that "resource" is very widely defined here, so wide as to include anything from which benefits can be produced.

The Pareto criterion states that if no alternative allocation of resources can make at least one person better off without making anyone else worse off, the initial allocation is Pareto optimal. In the presence of a Pareto optimum, economists sometimes claim the allocation to be Pareto efficient. (Boardman et al., 2011).

To understand what the Pareto optimum is all about, think of a society consisting of two individuals that are to share all resources available in the society. For simplicity, we assume that total benefits extracted from these resources can be expressed in monetary terms an amount to 100. In that case, our allocation problem can be displayed as in figure 3-3.

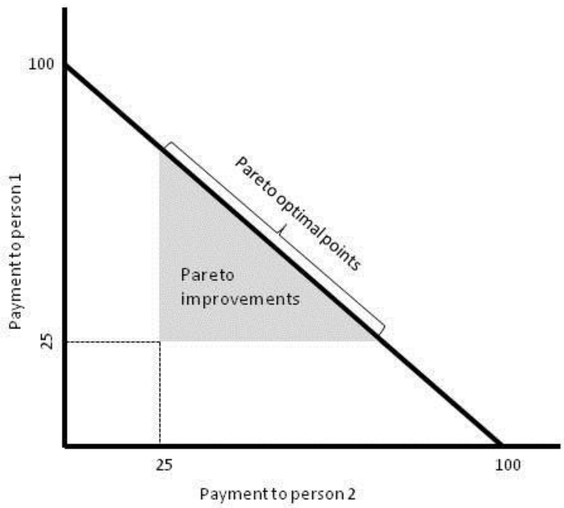


Figure 3-3 Pareto efficiency (Boardman et al. 2011)

The initial allocation is 25 units to each of the individuals. It is evident from the graph that the initial allocation cannot be Pareto optimal; it is possible to distribute money alternative ways that puts either of the individuals better off without putting the other one worse off, relative to status quo. As long as this is the case, we say that Pareto improvements are attainable. When we have reached a point where no further Pareto improvements are achievable, we have reached a Pareto optimum. This means that at all points inside the grey triangular area of figure 3-3 are associated with potential Pareto improvements, and only the points along the same triangle's hypotenuse can be Pareto optimums.

Reality is more complex than two individuals and a single pot of money. Still, the Pareto criterion serves as a decision criterion to any politician wanting to ensure efficient distribution of resources. The problem is that in real life every allocation has an alternative allocation, and almost all alternatives put at least one person worse off in order to put others better off. This means that in practice, the criterion cannot be used to determine whether an alternative is desirable over something else (Franco 2009). This brings us to the second cornerstone of welfare economics.

3.2.4 Kaldor-Hicks compensation criterion

The second cornerstone treats compensation as a way to determine desirability of an alternative. The Kaldor-Hicks criterion was originally two separate arguments regarding transfers of gains – or compensation – between winners and losers.

Kaldor (1939) suggests that an alternative should be considered desirable if the gainers to the alternative could compensate the losers for their loss, and still gain relative to the outset. Hicks (1939) made an inverse approach to the problem. He stated that status quo was desirable only if losers to the alternative could profitably sustain status quo by paying off the gainers to the alternative.

When these arguments are combined, they make up the Kaldor-Hicks compensation criterion, which states that an alternative is desirable if the beneficiaries of it are enriched enough to more than compensate the losers (Adler & Posner 1999). Franco (2009) emphasize that compensation need not actually occur for the alternative to be desirable. A potential to ensure that at least one person is made better off without anyone else being put worse off, is sufficient.

From this, it is evident that the Kaldor-Hicks criterion is less restrictive towards change compared to the Pareto criterion. Moreover, it enables us to state the desirability – in the perspective of an efficiency maximizing society – of an alternative to status quo.

3.3 A recap of welfare economics

The way we understand the quote of Pigou (1920) presented in the beginning of chapter 3.2, maximizing the social surplus of a society is the same as maximizing its welfare. In the perspective of a society, we believe this to be true because "satisfactions" coincide with "consumer surplus" and "dissatisfactions" to coincide with "producer surplus". This way, what we essentially do when maximizing social surplus is maximizing what Pigou would have called welfare. Ultimately, we then equalize welfare, utility and social surplus[13].

In this context, a Pareto improvement improves welfare, and if no further Pareto improvements are achievable, the welfare of a society is at a Pareto optimum. Moreover, if a Pareto improvement is achievable, the Kaldor-Hicks compensation criterion states that society should consider the change needed to realize it desirable because welfare can be transferred or redistributed between winners and losers within the society.

3.4 Theory of international trade

Theory about international trade is among the oldest of economic theories. From the 16th to the late 18th century, the subject was dominated by mercantilism, which was succeeded by Adam Smith, and later David Ricardo. Smith made use of his theory on absolute advantage to explain characteristics of international of trade, while Ricardo developed his theory of comparative advantage inspired by Smith.

Comparative advantage – the argument

Norman (1992) states that country A has a comparative advantage in producing good X relative to country B, if – in autarky – country A faces a lower opportunity cost in the production of good X than country B.

If a country produces all units being consumed in a market domestically, it is characterized by self-sufficiency. Autarky is a more theoretical term for self-sufficiency.

Ricardo (1817) argues that country A and B will gain from trade if either of them has a comparative advantage. This argument holds on the basis of lower opportunity cost enabling a more efficient allocation of resources, meaning that trade is a Pareto improvement to A and B together relative to autarky.

[13] As was pointed out in the beginning of chapter 3.2, Pigou equalized welfare and utility.

Autarky

In the following we try to recap some important characteristics of chapter 2.0 and put it in relation to opportunity cost.

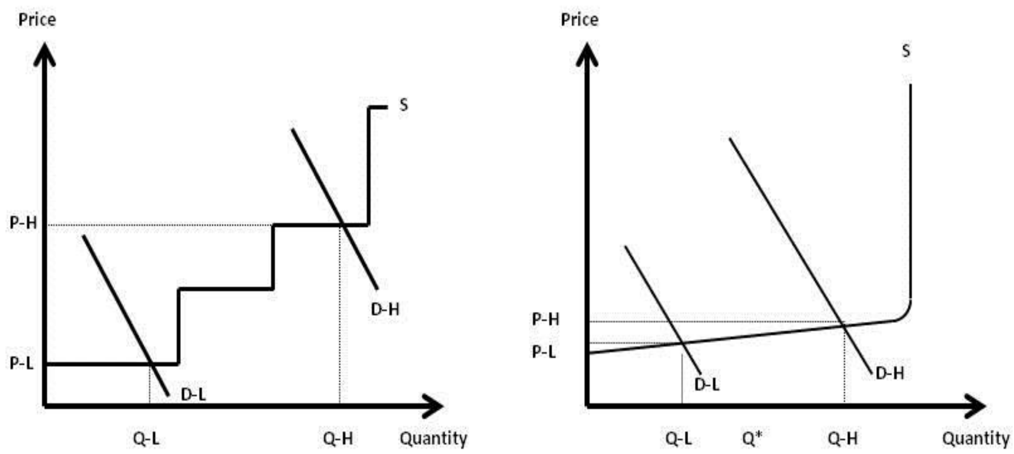


Figure 3-4 Different production technology, thermal (left side) and hydro (right side)

In figure 3-4 we have displayed two electricity markets. The left side panel displays a market in which thermal generation technology is dominant. The right side panel displays a market in which hydropower generation technology is dominant. In each of the markets we have included two demand curves D-H and D-L, representing high and low demand situations. In the two upcoming paragraphs we explain how these graphs are to be interpreted as autarkies.

The thermal character of the left side panel is recognized by the stepwise increase in opportunity cost due to high start-up costs associated with each power plant within the system. This requires a relatively sharp increase in WTP in order to increase supply marginally when demand is close to any of the steps. In consequence, the difference between prices observed in a high demand period and a low demand period is large.

The hydropower character of the right side panel is recognized by the slack increase in opportunity cost until the capacity limit of the system, from which point not even an infinite WTP cannot increase supply. The point where the supply curve intersects the price axis is determined by the cost of production, and the slope of the supply curve is dependent on the water value. [14] The cost structure of the system makes the difference between prices observed in a high demand period and a low demand period small.

When considering these markets as separate autarkies, it is evident that their respective opportunity cost differs, and they do so because of the unique ability to transform input into electricity in each of the markets.

It is evident that according to theory on comparative advantage, Pareto improvements to both markets together are attainable by introducing trade.

Introducing trade

In the previous paragraph we discussed characteristics of each of the markets separately. Now we will try developing this discussion into an example that enables us to explain what will happen when the markets becomes integrated by trade.

The example is partly based on Econ & Thema (2010) and figure 3-5 is a graphical illustration of the example. Assume two countries, A and B, that both are characterized by autarky at first, with production equal to SA-1 and SB-2, and prices PA-1 and PB-1. Assume that supply, SA and SA, is linear for the simplicity of the example. Total demand, XA + XB, in the example is constant and equal to the sum of demand within each country (which is also constant). Later, an interconnection with capacity β is built. As a result of trade, price in country A will rise to PA-2 when exporting to country B. The price in country B will decrease to PB-2 when importing from country A. We get a change in production, to SA-2 and SB-2 in each country.

[14] It is the water value that enables us to deduct a marginal cost function. Without water value, the cost of production would equal the average cost which is constant.

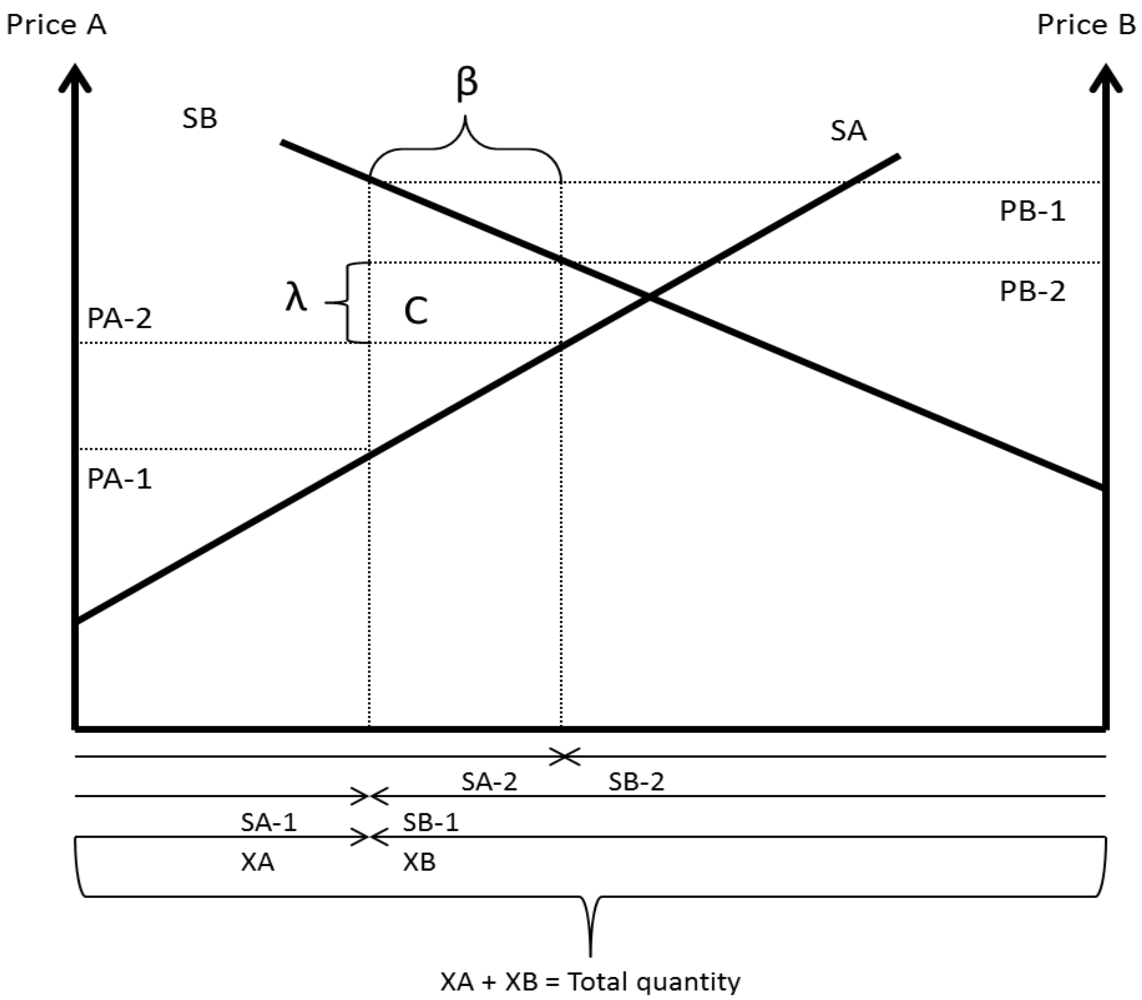


Figure 3-5 Trade of electricity between two nations. (Econ and Thema 2010)

The opportunity cost is equal to λ. It arises because WTP is higher in country B than in country A. The most important part of figure 3-5 is the rectangle C.

Rectangle C represents the bottleneck income that the operator of the interconnection enjoys. The value of rectangle C is equals λ multiplied by the quantity transferred through the interconnection, meaning SA-2 subtracted from SA-1 in this case.

The example helps us to nicely illustrate what bottleneck income is, but the interconnection also have effects within each of the countries that are more easily explained and understood by looking solely at one of the countries.

Figure 3-6 shows a refined version of figure 3-5 in the perspective of country A. It is refined in that a key assumption is changed; we now assume demand as being dependent on price. Hence, in figure 3-6, demand decreases as the price increases.

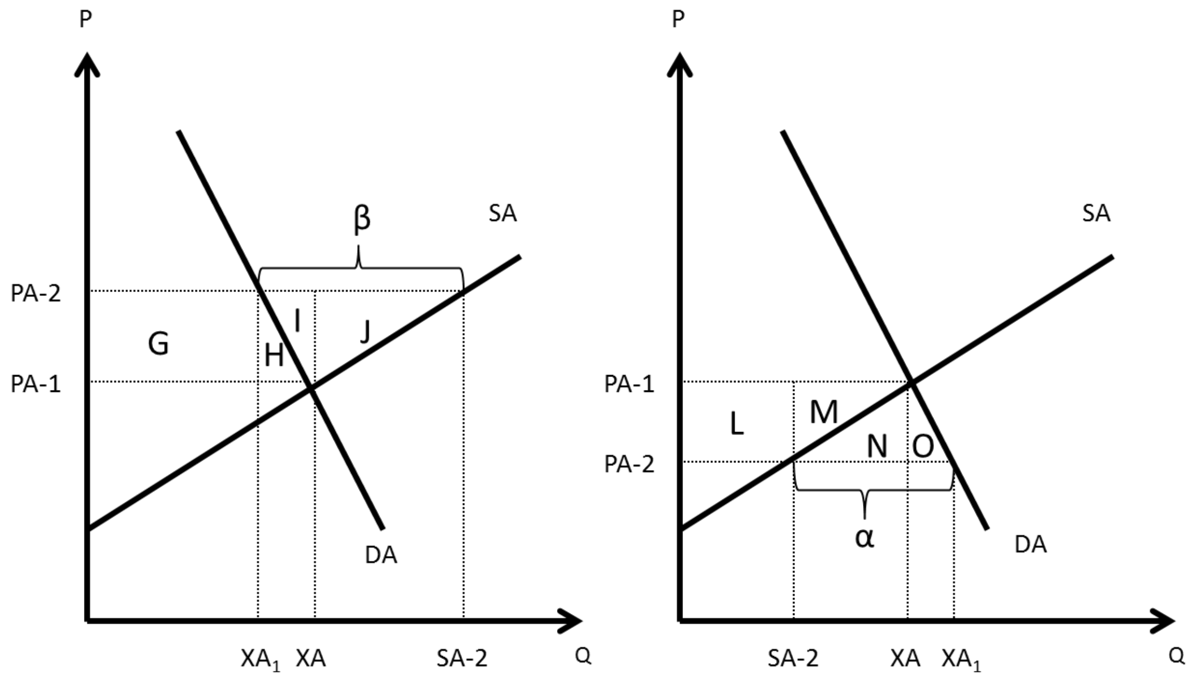


Figure 3-6 Trade with electricity, export (left side) and imports (right side)

In autarky, production and consumption in country A equals XA at price PA-1. In an export situation (left side of figure), domestic price increases to PA-2 as a result of higher price in the export market, decreasing domestic consumption from XA to XA_1. Electricity producers will produce a quantity equal to domestic consumption, XA_1, and the quantity exported, β, equal to SA-2. When imports (right side of figure), domestic price decrease to PA-2 as a result of lower prices in the import market, increasing domestic consumption from XA to XA_1. Electricity producers will produce SA-2, while consumers will consume domestic production, SA-2, and imports, α, equal to XA_1.

At this stage, we only want to focus on the areas I + J and N + O. The sums of these areas equal the net increase in social surplus due to trade, in the perspective of country A.

4.0 Methodology

4.1 Cost-benefit analysis

The framework we are about to present offers a method to systematically analyze and assess any projects contribution to the social surplus of a society. We ask the reader to bear in mind the discussion of chapter 3.3 regarding the link between social surplus, welfare and Pareto improvements when proceeding.

Today's practice

Today, governments in western economies has made the cost-benefit analysis an important input to the political decision making process. Especially projects, for example infrastructure investments or welfare programs, are subject to CBA. (Franco 2009). This is also the case for Norway, and the Norwegian Ministry of Finance published their latest handbook on CBAs in 2005. (NMF 2005)

The framework

Our main source for this chapter is Boardman et al. (2011), but NMF (2005) has also been used. We follow the structure of a CBA as it is outlined by Boardman et al. (2011), which to a large extent coincide with that of NMF.

We are going to start out with what usually is presented in the end. We do so because we want to establish some important terminology.

Classes of CBA

A CBA can be conducted at three different stages of a project. Assume t indicating a point in time on the timeline of the project starting at time t=0, and T indicating the end of the project. An ex ante analysis is conducted at t<0, an in medias res analysis is conducted at $0<t^m<T$ and an ex post analysis is conducted at t>T.

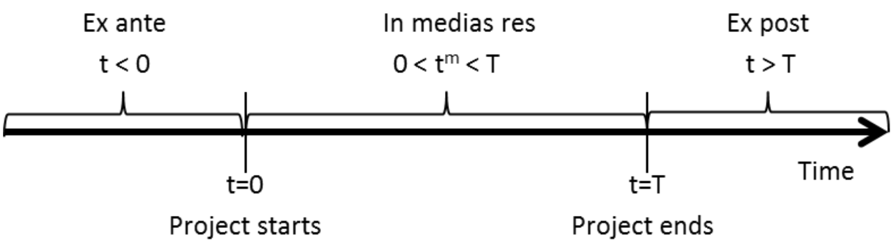


Figure 4-1 Classes of CBA (Boardman et al. 2011)

An ex ante analysis is aimed at helping the decision maker choose the alternative best fit to satisfy the purpose of the project. An ex post analysis is first and foremost conducted in order to learn more about the actual outcome of the project. Our focus is centered at in medias res because this is the analytical approaches we will be using later.

There is actually no difference in how the three classes of analysis are performed; they all fit into the general framework.

Proceeding to the general framework of CBA, we start out with the nine steps constituting all cost-benefit analysis, presented in table 4-1.

Major steps in Cost-benefit analysis	
Step 1	Specify the set of alternative projects
Step 2	Decide whose benefits and costs count
Step 3	Identify the impact categories, catalogue them and select measurement indicators
Step 4	Predict the impacts quantitatively over the life of the project
Step 5	Monetize all impacts
Step 6	Discount benefits and costs to obtain present values
Step 7	Compute the net present value of each alternative
Step 8	Perform sensitivity analysis
Step 9	Make a recommendation

Table 4-1 Major steps in CBA. (Boardman et al. 2011)

In step one, alternative projects are those seeking to replace status quo. Usually, one would need to know the objective of a project in order to specify viable alternatives. Because we will approach our research question by a medias res analysis of the NorNed project, there is only one obvious alternative; no NorNed project. It is important to notice the term counterfactual, which is the term of the displaced project. Hence, in our analysis we will be referring to the counterfactual as the (hypothetical) situation in which the NorNed interconnection had not been built.

The next step requires an identification of standing; whose benefits and costs are affected by this project? Some projects can have local, regional, national and global effects, so this step is not so much about identifying whose costs and benefits are affected as it is deciding whose costs and benefit count among those who are affected.

The third step requires the analyst to identify the different categories to which the project has an impact. The categories need to be put into separate catalogues, meaning costs and benefits. A typical example of a category within the benefit catalogue is revenue and a typical category within the cost catalogue is construction. Each of the categories consists of at least one impact that can be measured by identifying a measurement indicator. It is important to notice the criterion for treating something as an impact; there has to be a cause-effect relationship between a physical outcome of the project, and utility of people with standing. This criterion needs accurate treatment by the analyst.

Step number four is to estimate the impacts quantitatively over the life of the project. Because many projects lack reliable data, this step often turns out to be challenging. Analysts need to make assumptions and be ready to defend these. If impacts cannot be reasonably quantified, one should rather describe the impacts qualitatively.

The fifth step is to attach a monetary value to impacts. Hence, if an impact increases sales, the quantity should be multiplied by the price, and the monetary value is thus achieved. Not all impacts can be monetized, or are extremely demanding to monetize. Such impacts are not to be excluded from the analysis. Any impact satisfying the impact criterion should be included, and if it cannot be properly monetized a qualitative assessment of it should be offered.

In step six, future costs and benefits are discounted in order to express total value in present terms. There are two important reasons to discount future values. Firstly, the resources forgone in the project have an opportunity cost. Secondly, consumption has a time value, meaning that people in general prefer consuming today rather than tomorrow.

Consider a project that has a lifetime of n years, and that costs and benefits at time t are expressed by C_t and B_t respectively. In that case, the present value of costs and benefits in the project are expressed by equation 3.1 and 3.2 respectively.

Eq. (3.1) $$PV\ (C) = \sum_{t=0}^{n} \frac{C_t}{(1+s)^t}$$

Eq. (3.2) $$PV\ (B) = \sum_{t=0}^{n} \frac{B_t}{(1+s)^t}$$

In general, the discount rate for a CBA of a governmental project is set by the government, and will often differ depending on the classification of the project. The Norwegian Ministry of Finance has set the discount rate for projects financed by the government to 4 %, but explicitly states that individual adaptation to each project is necessary.

Step seven is to compute the net present value of the two alternatives. The net present value is found by subtracting equation 3.1 from equation 3.2, as shown in equation 3.3. Because we analyze net changes relative to the counterfactual, there is no need to calculate the actual value of the counterfactual.

Eq. (3.3) $$NPV = PV(B) - PV(C) = \sum_{t=0}^{n} \frac{B_t}{(1+s)^t} - \sum_{t=0}^{n} \frac{C_t}{(1+s)^t}$$

If the net present value turns of positive, it means that the project we are analyzing is a Pareto improvement to the welfare of the society. At least this will be true if all relevant impacts are monetized. If they are not, the conclusion is less certain.

The eighth step is to address the sensitivity of key output parameters to changes in key input parameters. Estimating the change in NPV as the discount rate changes is one example, and changes in NPV as demand for output from the project changes is another. In theory, there are no limits to what assumptions can be subject to a sensitivity analysis. This part of the analysis gives the opportunity to address weaknesses of the analysis.

The ninth, and last step, involves making a recommendation. In our case, the ninth step will be more of a conclusion than a recommendation.

Limitations

Boardman et al. (2011) states that in doing an in media res analysis, the most common error is the measurement error. Measurement errors can arise for two reasons. Firstly, we can measure the effect of something correctly, but incorrectly address causality. Alternatively, we can correctly address causality, but simply measure the effect wrong because of e.g. insufficient data.

5.0 Data

To conduct our analysis we have had to generate our own dataset out of some initial data provided us by Statnett. In the following, we first present the initial dataset provided by Statnett, after which we explain how and by what we have extended the initial data.

Initial data

Initially, Statnett provided us with a comprehensive set of data including prices, import and export through the cable in the format of an Excel-file upon our request. We were also granted access to a server containing hourly prices, demand and supply, by Nord Pool, which we used to verify our existing price series.

Extensions

Next, we had to compute some additional variables in order to conduct our analysis. What we are about to explain is most easily understood in the context of figure 3-6, which is why we included it here as well.

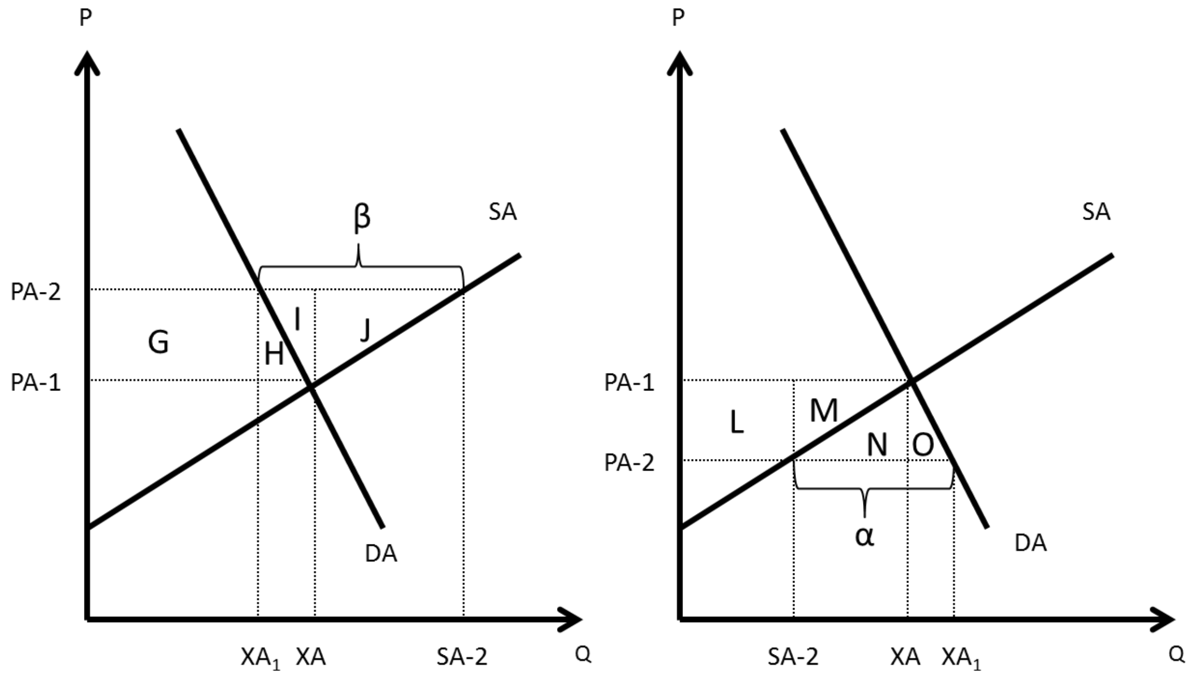


Figure 3-6 Trade with electricity, export (left side) and imports (right side)

Our data reveals PA-2, α or β and XA_1 hourly, but we do not know PA-1 and XA. Put another way, we have the facts, but we do not know what the world would look like if the cable had not been constructed.

In order to conduct our analysis, we need to know PA-1 and XA. This problem can be addressed in at least three ways.

Firstly, we can collect historical data on prices and quantities and assume that these have not changed as a consequence of the cable. Secondly, we can develop a model that simulates future prices and quantities. Thirdly, we can utilize results of empirical analysis conducted by others, in combination with theoretical knowledge, to calculate prices and quantities.

The first alternative is likely to correctly predict the variance of prices within periods – days, weeks, months and so on – around a given average. The problem is that this average is likely to be incorrect because effects of the project on the average are not accounted for. The second alternative enables us to more correctly address the average without sacrificing anything regarding the variance. On the other hand, this alternative is demanding with regard to time. The third alternative solves the time problem of the second alternative, but the obvious challenge is that such analysis might not exist, and if it does, ensuring consistency between these studies and our thesis might pose a second challenge.

However, such analysis does exist, so we chose the third alternative by utilizing the work of Stavø (2009) to first determine prices (PA-1), and then combine this information with the findings of Holmøy et al. (1998) regarding marginal elasticity of demand to calculate quantities (XA).

We chose to do so because developing a simulation model determining prices and quantities is too time consuming, and would in itself make up a decent thesis. This approach is criticized in chapter 8.0.

In the following we shall first give an in-depth presentation of Stavø (2009). We do so to make sure the reader can critically evaluate our choices so far, and later, our results and conclusions.

Empirical work by Stavø

Stavø (2009) investigates whether NorNed has affected the Norwegian system price in the period from May to December 2008.

She does so by first constructing an econometric model to simultaneously determine supply and demand in Norway. To this model, empirical data from 2002 to 2008 is applied in order to estimate relevant regression coefficients using a 2SLS method.

At the next stage, the coefficients are used to simulate future prices based on simulations of equilibrium in supply and demand. Simulations are made for three scenarios from May to December 2008 using exogenous data on the regression coefficients.

Only two of the three scenarios simulated by Stavø are of relevance to us. The first scenario leads to simulation of prices with NorNed whereas the second leads to simulation of prices without NorNed. The difference in prices in the first and second scenario forms the basis of her conclusions regarding the effect of NorNed on Norwegian prices.

According to Stavø (2009) prices have increased by 10 NOK per MW on average for the period as a whole. She also reports average changes for every second month of the period in addition to minimum and maximum price change. Table 5-1 summarizes her results.

Period	Average change in price per MW	Minimum change in price per MW	Maximum change in price per MW
May – June	10	-10	20
July – August	10	-30	20
September – October	10	-40	20
November – December	10	-40	20
Total	**10**	**-10**	**20**

Table 5-1 Changes in price with cable (Stavø 2009 p 46)

Unfortunately the periods January-February and March-April are not part of the study by Stavø. Hence, we have to assume aggregates for these months.

Because a freely competitive market is demand driven, and the fundamental drivers of demand for the periods November-December and January-February are concurrent, we assume the values of these periods to be the same. For the same reasons, we assume March-April to correspond with September-October.

We utilize the results from Stavø (2009) by applying the maximum and minimum deviation from prices in the different periods to our hourly data on export and import respectively, to calculate PA-1. Using maximum and minimum values can provoke measurement errors, and it would have been better[15] if we had the average deviation from prices from export and import periods respectively. This choice is criticized in chapter 8.0.

Finally, we want to point out an important weakness in Stavø (2009). The supply function in her simultaneous econometric model omits important explanatory variables. These are in example the price of (alternative) energy carriers like coal and gas, and also the price of CO_2 quotas. They are omitted due to lack of data.

Marginal elasticity of demand

Marginal elasticity of demand was defined in chapter 3.2.1. In the following we use this aggregate to calculate XA for every hour in our dataset.

In NOU (1998), researchers from Statistics Norway contributed by assessing the marginal elasticity of demand for electricity in Norway. Holmøy et al. (1998) concluded that the marginal elasticity of demand for electricity was -0.31, meaning that if the price increases by one percent, demand decreases by 0.31 %.

Now, we can utilize the fact that we know PA-2, PA-1, XA_1 and the slope of the DA curve to calculate XA by using the formula for elasticity

Eq. (5.1) $$el = \frac{\frac{\Delta Q}{Q}}{\frac{\Delta P}{P}} = \frac{\Delta Q}{\Delta P} * \frac{P}{Q}$$

See the complete deduction in appendix 1.

This way, the quantity, XA, is calculated hourly in our dataset, and the dataset is finally complete. Using the marginal elasticity of demand like we do here has one important limitation to our analysis. This limitation is discussed in chapter 8.0.

After having the initial dataset expanded, all variables needed to conduct our analysis are present. They are present in the form of time series with an hourly frequency starting at the

[15] Ideally we should have had hourly prices for every period/observation.

6th of May 2008, which was the first day of operational activity in the NorNed cable. The time series ends at 30th of September 2011. This gives us a total of 29 829 observations.

The dataset and calculations can be made available in the format of an Excel-file upon request.

6.0 Analysis

6.1 Introduction

In this chapter we do the in medias res analysis of the project. The project started 6th of May 2008, making this our starting point, t=0. We have chosen the 30th of September 2011 as the day in which we conduct the analysis, defined as $t=t^m$. The project lifetime is 40 years making T=40, ending the project in 2047.

We will use the nine steps presented in chapter 4.1 through the whole analysis. This chapter is organized as follows:

- *Chapter 6.2 - Step 1-3: Analysis framework*

  Gives the frame of the quantitative analysis; what is the alternative project, who is affected by our project, and what are the impacts from the cable.
- *Chapter 6.3 - Step 4-7: Case I – Net increase in social surplus*

  Assessing the net increase in social surplus of the cable from May 2008, t=0, to September 2011, $t=t^m$, and identifying the surplus for different groups.
- *Chapter 6.4 - Step 4-7: Case II – Net present value of NorNed*

  Assessing the NPV of the cable over entire project period, from t=0 to t=T.
- *Chapter 6.5 - Step 8: Sensitivity analysis*

  Analyzing the impacts of a change in certain parameters.
- *Chapter 6.6 - Step 9: Conclusion*

  Offers a conclusion of the in medias res analysis of NPV, but do not confuse this conclusion with the overall conclusion of the thesis.
- *Chapter 6.7 - Re-evaluating case I and II – subsidiary conclusion*

  After the analysis, we present two arguments of redistribution with potential impacts on our results from chapter 6.3 and 6.4.

When monetizing of impacts is possible, we have chosen to calculate costs and benefits in October 2011 value (real value) and present these in millions of Norwegian kroner (MNOK). We do not include taxes in the analysis[16].

[16] We do so because most producers are owned by Norwegian authorities, meaning that the profit of the producer is owned by the authorities, hence including taxes would only include transfers of existing national wealth.

6.2 Analysis framework

This chapter gives the framework of the analysis. Here, we explain our perspective and how we will go onwards with the historical and future assessment of the social surplus. We use CBA to identify the costs and benefits relevant for the project.

Step 1 – Specifying the set of alternatives

To conduct our analysis we have assumed the alternative to be no interconnection between Norway and the Netherlands. This way, the counterfactual case to which we shall analyze is the market as it exists today only without the cable.

Step 2 – Decide who has standing

Given our research question, only costs and benefits realized by the project affecting Norwegians count.

Step 3 – Identifying impact categories

Treating something as an impact requires a proven cause-effect relationship between a physical outcome of the project and the utility of people with standing. This requires us to attribute a ceteris paribus effect of different impacts of the NorNed cable to the utility of Norwegians.

Throughout the analysis we will make the same assumptions as Pigou (1920), meaning that we equalize utility, welfare and social surplus[17]. In that sense, the three terms have the same meaning in our analysis.

In the following we present the structure of our analysis. For practical reasons, we give a sequential representation of the structure, and ask readers wanting to see the bigger picture to see Appendix 2.

Benefit catalogue

The benefit catalogue consists of three categories; increase in social surplus (SS) from cable operations, increase in social surplus from domestic prices, and efficiency gains. The first two categories are monetized in the analysis, while the last category is a non-monetized effect.

Increase in social surplus from cable operations

Increase in social surplus from cable operations consists of gross increase to social surplus from TSO, and net increase in social surplus from agents. Surplus from TSO is a gross value

[17] See discussion in chapter 3.3 regarding this.

because of concurrent costs in the cost catalogue, while we assume no such agent costs resulting in a net increase from agents.

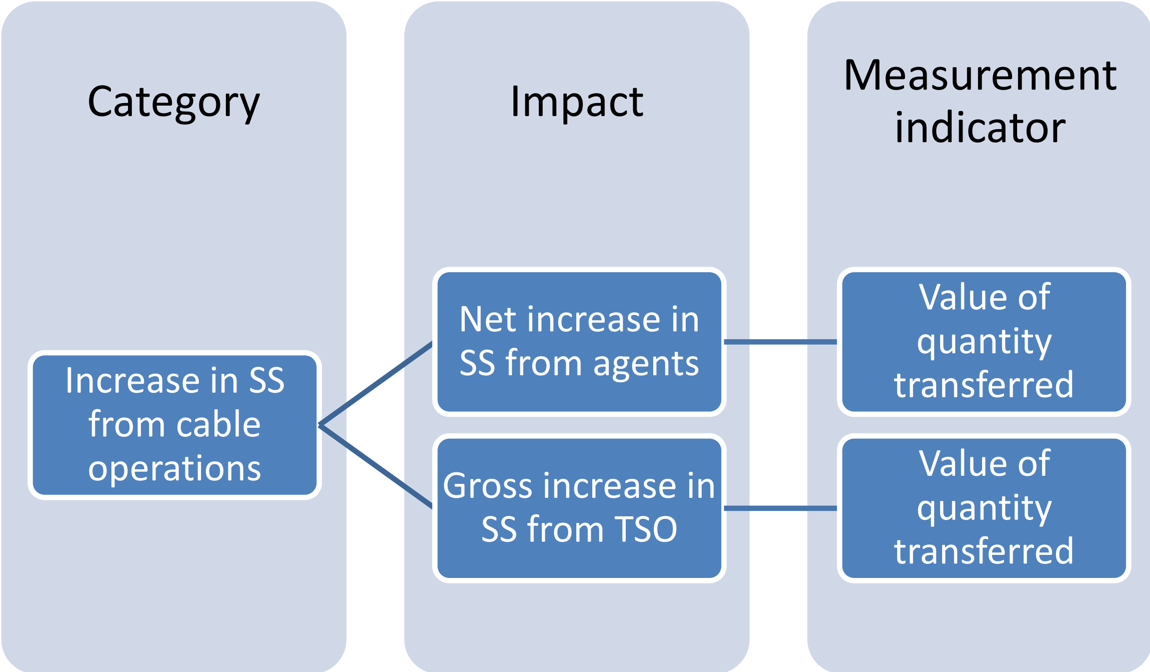


Figure 6-1 Increase in social surplus from cable operations

Net increase in social surplus from agents

Net increase in social surplus from agents is included due to peculiarities concerning the trading and transmission before and after 13th of January 2011. Before this date, transmission capacity was sold from TSOs to electricity producers through so-called explicit auctions, and the winner of the auction could use the cable capacity to realize an arbitrage. This way, a part of the bottleneck income was attributed to the TSO through an auction price, and the rest was attributed to the agent that bought the capacity. Statnett has informed us that the agents were Norwegian electricity producers when exporting, and Dutch electricity producers when importing. Of these, only Norwegian electricity producers have standing in our analysis, and this means that we only include revenue to agents when exporting. After the 13th of January, implicit auction was introduced. From that time onwards the bottleneck income was solely attributed to the TSOs, shared 50/50 between Statnett and TenneT.

Gross increase in social surplus from TSO

The TSOs in our case are Statnett and TenneT, and in the analysis only Statnett have standing. Gross increase in social surplus from TSO is here represented as Statnett's part of the bottleneck income before 13th of January 2011, and 50 % of the entire bottleneck income after this date.

Increase in social surplus from domestic price changes

Increase in social surplus from domestic price change consists of net increase in social surplus from electricity producers and net increase in social surplus from consumers.

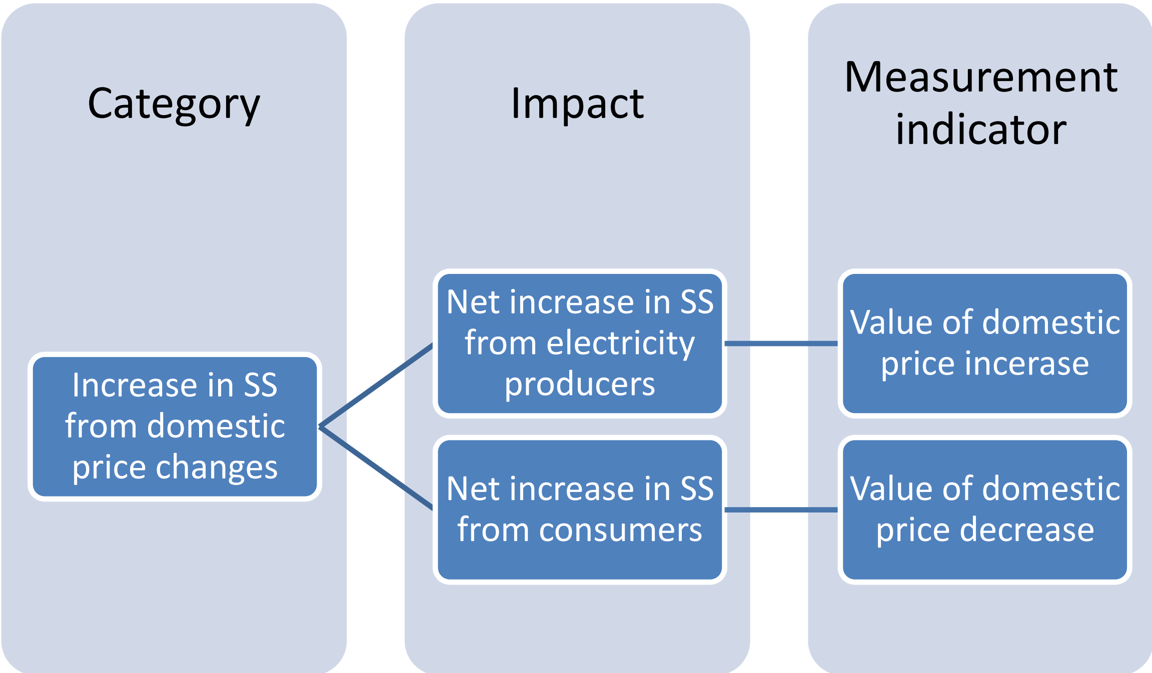


Figure 6-2 Increase in social surplus from domestic price changes

Net increase in social surplus from electricity producers

The increase in social surplus from electricity producers arise from increased domestic prices in Norway following an export situation. When the system price increases, it means that consumers have to pay a higher price for their total consumption, which again leads to higher revenue to the electricity producers. The price increase therefore also represents revenue foregone for Norwegian electricity consumers. The net difference is equal to the increase in social surplus from electricity producers.

Net increase in social surplus from consumers

The net increase in social surplus arises from decreased domestic prices in Norway following an import situation. Consumers experience lower prices and a higher quantity consumed. Here, we experience revenue foregone for Norwegian electricity producers. The net difference is equal to the increase in social surplus from consumers.

Efficiency gains

This is the non-monetized part of the analysis, and we will not allocate values directly to social surplus.

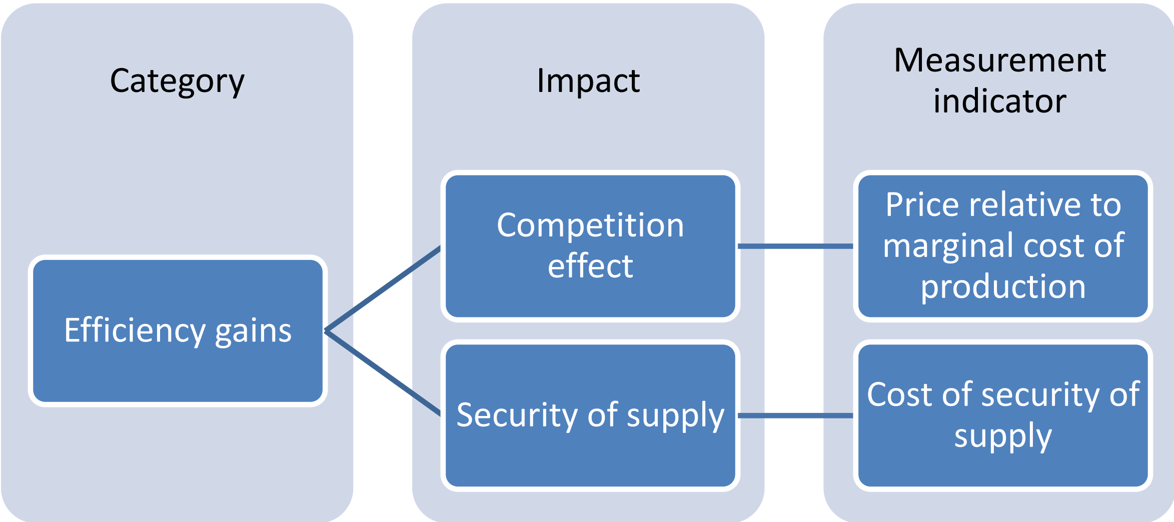


Figure 6-3 Efficiency gains

Non-competitive market is a source of market failure. This way, competition effects have relevance in our analysis because they potentially affect the efficiency of resource allocation in Norway. The measurement indicator for the competition effect is a highly theoretical aggregate, but in absence of anything better, price over marginal cost is chosen. We consider security of supply an impact in the efficiency category because the interconnection allows Norway to provide security of supply at a lower cost.

Cost catalogue

The cost catalogue consists of two categories; construction costs, and costs of operation.

Construction costs

Construction costs are provided us by Statnett. This is an accrued cost. This means that the impact is well defined and there is no need for a measurement indicator.

Costs of operation

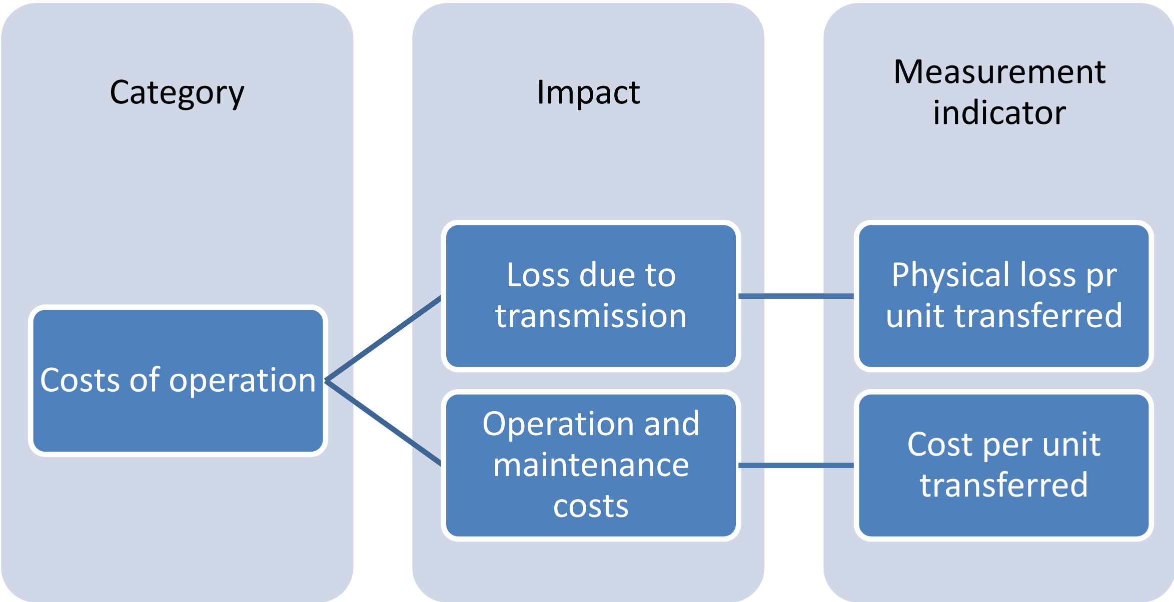


Figure 6-4 Costs of operation

Loss due to transmission

Due to physical laws, some electricity is lost when transferred. This also applies for NorNed, and Statnett calculate a loss of approximately 4 % when utilizing full transfer capacity. This loss has an opportunity cost equal to the price in the domestic market. However, we assume that the loss is included in the selling price of the exported electricity. Hence there is no effect of loss due to transmission in our analysis.

Operation and maintenance costs

We have requested Statnett to provide us these costs, but these numbers are not available to the public, and we have not succeeded in revealing them. However, a prediction is offered in Statnett's own ex ante analysis and we use these numbers. Operation and maintenance costs are put against the gross increase in social surplus from TSO, revealing the net increase in social surplus from TSO.

Presenting the social surplus

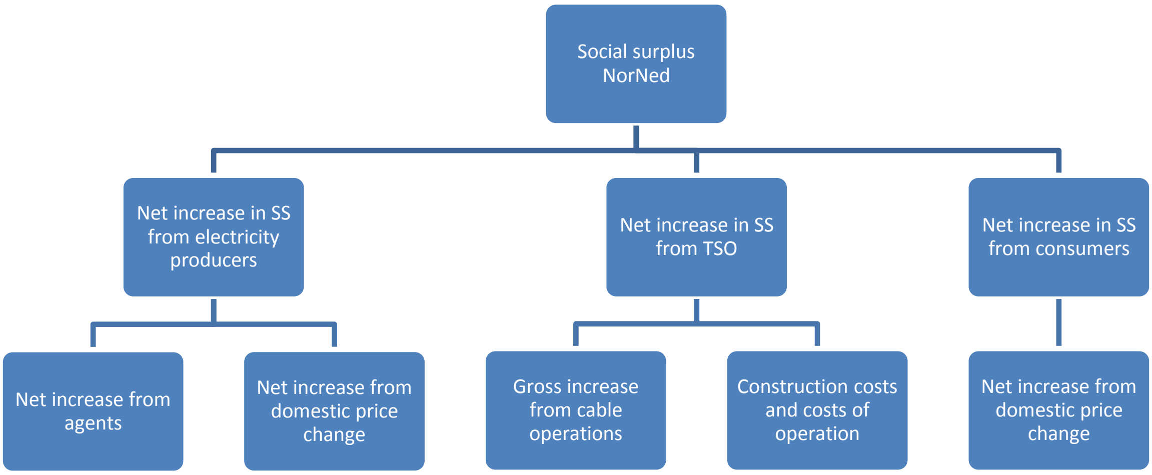


Figure 6-5 Increase in social surplus from groups with standing

In figure 6-5 above, we have rearranged the categories and impacts to display the contribution from different groups to the social surplus of the cable. Viewing the social surplus in the perspective offered by figure 6-5 enables us to identify the contribution to social surplus from different groups within the Norwegian society.

Efficiency gains are not included in figure 6-5 because the effect cannot be properly monetized and we can thus not appropriately identify the contribution to social surplus from this category. Still, we address efficiency gains qualitatively in our analysis.

6.3 Step 4 to Step 7: Case I - Net increase in social surplus

In this part, we identify the net increase in social surplus arising from NorNed up until time t^m. We look at the monetized and non-monetized costs and benefits. In the end, we will present the aggregated change in social surplus as a result of the cable, and attribute this to producer and consumer surplus.

Monetized benefits

Monetized benefits consist of increase in social surplus from cable operations and from domestic price change, shown in figure 6-1 and 6-2 respectively.

Increase in social surplus from cable operations

We now present the calculations corresponding to figure 6-1.

Net increase in social surplus from agents

The explicit auction system before the 13th of January generated a revenue to agents as a part of the bottleneck income. We remember that this revenue counts as part of the total revenue to Norwegian electricity producer due to this trading system. The total contribution to social surplus from agents is:

	2008	2009	2010	2011	TOTAL
Value	65	24	12	0	101

Table 6-1 Net increase in social surplus from agents (MNOK)

Gross increase in social surplus from TSO

We calculate the revenue to TSO as Statnett's part of the bottleneck income before 13th of January 2011, and Statnett's part of the entire bottleneck income after that date:

	2008	2009	2010	2011	TOTAL
Value	491	200	98	184	973

Table 6-2 Gross increase in social surplus from TSO (MNOK)

Increase in social surplus from domestic price change

We get two effects from the in domestic price change. In the following, we will analyze the net change in social surplus from consumers and electricity producers. In relation to figure 3-6, we are now determining the value of area I + J and N + O. We will analyze the other effect, which is a redistribution between consumers and electricity producers equal to area G + H and L + M from figure 3-6, in the end of this chapter. We now present the calculations corresponding to figure 6-2.

Net increase in social surplus from electricity producers

There are two domestic effects in the case of export. Firstly, the price on all units increases and secondly, as a consequence of the first, domestic consumption decreases. This is shown in the left side panel of figure 3-6. Domestic price increases from PA-1 to PA-2, which cuts consumption in country A from XA to XA_1. Export equals β and domestic production, covering XA_1 and β, equals SA-2.

This way, electricity producers loose on the lower domestic consumption, but gain the price increase on all XA_1 units in addition to the gain from exporting β. Consumers loose because they are paying more for all XA_1 units. Society as a whole gains if producers gain more than consumers loose, in which case the area I + J is greater than zero.

	2008	2009	2010	2011	TOTAL
Value	34	30	14	19	97

Table 6-3 Net increase in social surplus from electricity producers (MNOK)

Net increase in social surplus from consumers

There are two domestic effects in the case of import. Firstly, the price on all units decreases and secondly, as a consequence of the first, domestic consumption increase. This is shown in the right side panel of figure 3-6. Domestic price decreases from PA-1 to PA-2, which increases domestic consumption from XA to XA_1. Import equals α, domestic production equals SA-2.

This way, consumers gain the price decrease on all XA_1 units as well as increased consumption from imports. Producers loose because they produce less at a lower price. Society as a whole gains if consumers gains more than producers loose, in which case the area N + O is greater than zero.

	2008	2009	2010	2011	TOTAL
Value	6	20	36	29	91

Table 6-4 Net increase in social surplus from consumers (MNOK)

Total benefits

The value of the benefits catalogue, consisting of increase social surplus from cable operations and increase in social surplus from domestic price change, sums up to be 1 262 MNOK.

Monetized costs

Monetized costs consist of construction costs and costs of operation; the latter is shown in figure 6-4.

Construction costs

Construction costs amounts to a total of 4.6 bn. NOK (Statnett 2011f), half of which belongs to Statnett. We assume that this number is given in 2008-value because this was the commissioning year of the cable. The 2011-value of Statnett's construction cost is 2 439 MNOK. These are divided linearly over 40 years, starting in 2008. This generates a yearly cost of 61 MNOK.

Cost of operation

We now present the calculations corresponding to figure 6-4. Statnett will not reveal these numbers as they are not publicly available. Ex ante, these costs were estimated equal 17 MNOK per year (2004-value), and because we do not have access to any better estimate, operating and maintenance costs are set to 20 MNOK per year (2011-value) in our analysis.

These values were based on the "Skagerak-connection" which is a shorter cable. This value also includes unforeseen incidents. (Statnett 2004d) We find reason to believe that actual costs are higher than predicted ex ante by Statnett, especially considering the long down-periods of NorNed in both 2009 and 2010. However, we do not know the costs of these down periods. If deviations from predicted costs are to be revealed, these can be directly added/subtracted from our results given that they are expressed in 2011 values.

Total costs

The value of the cost catalogue is the sum of the construction cost and cost of operation, which sums up to be 81 MNOK for one year, 270 MNOK aggregated over the period.

	2008	**2009**	**2010**	**2011**	**TOTAL**
Construction costs	36	61	61	46	204
Cost of operation	11	20	20	15	66
Total costs	47	81	81	61	270

Table 6-5 Total costs (MNOK)[18]

[18] 2008 and 2011 not being fully operational years, allocated somewhat less yearly costs than 2009 and 2010

Non-monetized effects

Efficiency gains

We limit our analysis of efficiency gains to a theoretical discussion of what efficiency gains are likely to emerge, and how these theoretically speaking could have been measured.

Competition

From chapter 3.2.2 we remember an important source of market failure being non-competitive markets. If markets are not freely competitive, some of the social surplus is lost as producers exercise market power to increase market prices and business profits.

In addressing the competitive nature of the electricity market we need to consider both generation and distribution of electricity; the Norwegian market for electricity is competitive as long as distribution is unconstrained, but as distributions turns constrained, the competitive nature of the market might change. (Steen 2004)

Whenever distribution is constrained, the domestic market is divided into smaller regional markets where producers might exercise market power. The reason for this is that when distribution into the regional market is constrained, local producers can increase prices without fear of losing market shares to imports, as would be the case if distribution was unconstrained. Johnsen et al. (2000), Steen (2004) and Haug (2004) all investigates this problem using empirical data from Norway.

Steen (2004) finds that the Southern region is less competitive when bottlenecks are present. Still, he concludes that his result is not as economically significant as it is statistically significant. Hence, it should be considered a "word of warning" and not at present motive for policy changes. (Steen 2004)

In March 2009, the Southern region Steen analyzed in 2004 was divided into three price regions. The region NO2 consists of the southernmost part of Norway, which is also where NorNed enters Norway. According to Haug (2004), the risk of market power being exercised increases as the region becomes geographically smaller.

This way, the "word of warning" from 2004 was made current in March 2009, but the issue is yet to be researched in this new perspective. We believe that because NorNed, other things equal, has increased the import capacity to NO2, the danger of market power being exercised is reduced, or at least the maximum price local producers can charge is limited by the Dutch price for quantities transferable through NorNed.

Our suggestion of measurement indicator is based on the fact that price equals marginal cost in a freely competitive market. Hence, if price over marginal cost is larger than 1, society experience a efficiency loss.

Based on this, we find reason to believe that NorNed has affected the competitive nature of the Norwegian electricity market and thereby the utility of people with standing. But, it is beyond the scope of this thesis to conduct a more thorough analysis of this.

Security of supply

From chapter 3.2.2 we remember two important sources of market failure being externalities and the case of public goods. As either or both of them are present, social surplus is not maximized.

Because security of supply has the characteristics of a public good and production of it has positive externalities, the willingness to pay for it is lower than the cost of providing it. (Sandsmark 2011) This means that the optimal level of security of supply will not be provided solely by the market, and government intervention is needed to achieve a Pareto optimum.

Statnett is given the responsibility to provide security of supply by making sure that supply equals demand at all times, and to do so in a way that maximizes social surplus. Because NorNed, everything else equal, will ensure more stable prices in both markets, the least cost-efficient production units – those with the highest cost per unit – will not be used.

This way, security of supply is provided consumers at a lower cost with NorNed than what would have been the case without and the project should thus be considered a Pareto improvement to the Norwegian society.

We see that both reduced competition and increased security of supply are positive effects that might have occurred after the introduction of NorNed. This is likely to affect people with standing, but we cannot include them in our calculations as we lack explicit values for these effects.

Results – Net increase in social surplus

We have now identified, valued and discussed the monetized and non-monetized costs and benefits. As shown in figure 6-5, these can be attributed to the social surplus.

We now present the results corresponding to figure 6-5., calculating the net increase social surplus from the NorNed over the period:

Results (2011-values)					
	2008	**2009**	**2010**	**2011**	**Total**
Net increase in SS from electricity producers					
Net increase from agents (part of area C, figure 3-5)	*65*	*24*	*12*	*0*	*101*
Net increase from domestic price change (area I + J, figure 3-6)	*34*	*30*	*14*	*19*	*97*
Net increase in SS from electricity producers	99	54	26	19	198
Net increase in SS from TSO (Statnett)					
Gross increase from cable operations (part of C, figure 3-5)	*491*	*200*	*98*	*184*	*973*
Construction costs and costs of operation	*47*	*81*	*81*	*61*	*270*
Net increase in SS from Statnett	444	119	17	123	703
Net increase in SS from consumers					
Net increase from domestic price change (N + O, figure 3-6)	6	20	36	29	91
Net increase in SS from NorNed					
Increase social surplus	549	193	79	171	992

Table 6-6 Net increase in social surplus from NorNed, different groups (MNOK)

Net increase in social surplus from electricity producers

We see that Norwegian electricity producers profited well from the explicit auction system as agents before 13th of January 2011. They earned 101 MNOK on this system over this period. Parallel to this, electricity producers also gained 97 MNOK from increased domestic prices during export periods. Revenues are decreasing due to a decline in average auction price and a decline in quantity exported. In fact, 2010 was an extremely cold year in Norway, leading to a net import situation. In total, the net increase from electricity producers to social surplus was 198 MNOK.

Net increase in social surplus from Statnett

The net increase to social surplus from Statnett is equal to 703 MNOK. They face a decline in revenue due to a decline in price difference between the Netherlands and Norway from 2008-2011[19], as well as relatively higher auction prices compared to the price differences. The decline turns to an increase from 2010-2011 as the implicit auction system is more profitable for Statnett. If we take a more tabloid approach, we can say that Statnett have covered 37 % of the cable construction costs after only one tenth of project lifetime.[20]

Net increase in social surplus from consumers

The net increase in social surplus from consumers, which is the gain from extra consumption and lower prices under import, is 91 MNOK.

Net increase in social surplus from NorNed

The increase in social surplus from NorNed from May 2008 to September 2011, as experienced by the Norwegian society, is equal to 992 MNOK.

Redistribution between consumers and producers

In the following, we assess redistributions between producers and consumers. These effects are experienced by different groups in society, but they do not affect the net increase in social surplus because they are a mere redistribution within the society. We continue to focus on the three groups presented above, and analyse redistribution effects between these groups. Identifying the redistribution effects allows us to ultimately calculate the net surplus as experienced by the different groups, as well as producer and consumer surplus.

---

[19] From 2008-2009, the Dutch prices was almost halved, and the Norwegian prices faced a smaller decrease. From 2009-2010, the Norwegian prices increased substantially more than the Dutch. From 2010 to 2011, Dutch prices increased as Norwegian decreased. However, the relative price difference between the two decreased through the whole period, from 246 NOK in 2008 to 17 NOK so far in 2011.

[20] (973 – 66) / 2 439 = 37 %

Redistribution between electricity producers and consumers through domestic price change

We get an increase in domestic consumption when price decrease due to imports, and an increase in domestic production when price increase as a result of exports. This domestic effect hence leads to a transfer from consumers to electricity producers in the case of export, and from electricity producers to consumers in the case of import. The effect of export equals area G+H, and the effect of import equals area L+M in figure 3-6. These are the numbers for redistribution in the period:

	2008	**2009**	**2010**	**2011**	**TOTAL**
Transfer from consumers to electricity producers when exporting	1 376	1 453	740	694	4 263
Transfer from electricity producers to consumers when importing	182	500	903	777	2 362
Total	1 194	953	-163	-83	1 901

Table 6-7 Redistribution as a result of change in domestic price (MNOK)

We see that, during the first two years we had a net redistribution from consumers to electricity producers, while over the next two years we had a net redistribution from electricity producers to consumers. This is because we had a net import of electricity in 2010 and low net export in 2011. This, combined with a higher domestic price decrease when imports compared to price increase when exports, is both contributing to this result. However, the increase to electricity producers the first two years are much higher, making the total redistribution over the period equal to 1 901 MNOK from consumers to electricity producers.

Redistribution from TSO to consumers through grid tariff

Since the Norwegian TSO enjoys a monopoly on grid operations, Statnett's surplus is regulated by the Norwegian Water Resources and Energy Directorate (NVE). Statnett have to set their grid tariff on the basis of previous year's surplus. If they exceed the limit set by NVE, Statnett have to take this into consideration when they decide next year's grid tariff. In this way, surplus exceeding the limit set by NVE eventually contribute to lower grid tariff for consumers.

However, the reduction in grid tariff will not be equal to the exceeded surplus. This system is somewhat intricate and we are satisfied by pointing out the effect and conclude that the value of the consumer surplus is likely to be underestimated, while the value of surplus to Statnett is likely to be overestimated.

Results redistribution

We have seen a redistribution from consumers to electricity producers equal to 1 901 MNOK. We probably also have had a redistribution from Statnett to consumers through a decrease in grid tariff, but we do not know the value of this. We now combine this with the results from table 6-6, and look at the surplus for the three groups.

Norwegian electricity producers

We see from table 6-6 that the increase in social surplus from electricity producers is 198 MNOK. But we have to take redistribution into consideration as well to identify the surplus experienced by electricity producers. From table 6-7, we get that redistribution is 1 901 MNOK from consumers to electricity producers, meaning that Norwegian electricity producers experience a surplus from NorNed of 2 099 MNOK.

Statnett

From table 6-6, the increase in social surplus from Statnett equals 703 MNOK. The distribution effects from Statnett to consumers are unknown, and our only solution is to estimate that Statnett experience a surplus from NorNed of 703 MNOK.

Consumers

From table 6-6, the increase in social surplus from consumers equals 91 MNOK. However, we see from table 6-7 that consumers have faced a redistribution to electricity producers equal to 1 901 MNOK. The net effect on consumers is therefore -1 810 MNOK, making them worse off than they were before the cable was introduced.

Net producer and consumer surplus

Statnett and electricity producers represent Norwegian producers, so the net producer surplus for Norway is 2 802, while the net consumers surplus is equal to -1 810 MNOK, which again is equal to the social surplus of 992 MNOK from NorNed.

6.4 Step 4 to Step 7: Case II - Net Present Value of the NorNed project

Until now, we have looked at the first operating years of the cable and calculated values from historical prices and quantities. Now we analyze future revenue from time t^m to the end of the cable's life-period, time T. At the end of this chapter we aggregate the historic and future social surplus giving us the net present value of the whole project, from 2008 to 2047.

In the following we address the future prospects of trade between Norway and the Netherlands. As was discussed in chapter 3.4, regarding theory on comparative advantage, what essentially motivate trade, is differing opportunity costs. We assume markets as being freely competitive which means that the opportunity cost equals the price, hence the following discussion relates to prices in the two markets.

If the difference between prices is likely to increase, the future revenue from trade will exceed what have been realized thus far. If the difference between prices is likely to decrease, the future revenue from trade will be lower than what have been realized thus far.

Future price trends

Significant carbon reduction policies have been, and probably will continue to be, taking place in the European countries, especially if we take into account the recent positive development in Durban, late fall 2011. The most important driver for this is the EU 20-20-20 target and the even more ambitious goals for 2050[21]. In this process, politicians will try to internalize the negative externality from consumption of fossil fuels (CO_2 emissions) by making emitters pay. (European commission 2010) This will give rise to an increase in production costs in thermal power plants relative to plants fueled by energy not emitting CO_2, e.g. hydropower plants. This means that Dutch prices will increase more than Norwegian prices, which ultimately means that future revenue from the cable is likely to be higher than past revenue.

Another aspect of this argument is that Norwegian consumers will have to pay a higher price on domestic consumption as a result of the Dutch price increase. In that sense, the cost of CO_2 emissions benefits Norwegian electricity producers on the expense of Norwegian consumers.

[21] The EU strives for a reduction in CO_2-emissions, by 8 % in 2020 and 20 % in 2030 relative to 1990 levels.

A second argument is that projections are that renewables will account for 18.5 % of the generation mix in Europe in 2030[22]. (European commission 2010) By and large wind will fuel the new power plants. Because wind is intermittent, the need for flexible production technology, e.g. flexible hydropower technology, will increase. Again, Norwegian production technology gains comparative advantage relative to Dutch technology, but with a different fundamental driver than discussed in the previous paragraph. This means that future revenue is likely to be higher than past revenue.

On the other hand, we know that one of Statnett's future interconnection plans involves a NorNed 2-cable from Norway to the Netherlands. Constructing the second cable will affect the profitability of the first cable by lowering the price differences between the two markets, everything else equal. The magnitude of the effect is however hard to predict.

Conclusion

We will probably see an increase in price difference from an increase in production costs of thermal energy and differences in the energy mix, while a more integrated market can damper the increase in price difference. However, the impact on this is hard to predict and we assume that the average of the past four years reflects the future social surplus.

We will use the sensitivity analysis to analyze a possible increase in future social surplus, to see how this affects the NPV of NorNed.

NPV calculation

The annual social surplus for the period 2011-2047 is assumed to be equal to the average of the period from 2008 to 2011[23]. Based on this, the future annual social surplus is calculated to be 292 MNOK (real value).

The Norwegian Water Resources and Energy Directorate (NVE)'s guidance in social economic analysis of energy projects suggests 6 % discount rate for projects in the national grid. This is based on a risk free rate of 3.5 % and an additional risk premium of 2.5 %. (NVE, 2003) This is also the rate Statnett uses in their analysis of NorNed.

[22] An increase from 10 % compared to 2010

[23] 2008 and 2011 are not complete years, so these years are only included with the operating months (2008 from May to December, and 2011 from January to September).

However, the NMF (2005) suggests a risk-free rate of 2 %, leading to a new risk-adjusted rate of 4.5 %. This risk-adjusted rate is used in the NPV-calculations.

The net present value of the project with the assumptions above, hence the net increase in social surplus for Norway from NorNed over the entire project period, is calculated to be 6 000 MNOK.

6.5 Sensitivity analysis

Step 8 – Sensitivity analysis

Now we wish to discuss our assumptions and analyze what impact a change in these will have on our analysis. First we are going to analyze one effect relevant for both Case I and II, then we are going to analyze two effects only relevant for Case II.

Change in the counterfactual price

We have used Stavø (2009) to calculate the counterfactual prices in Norway, by taking the price increase and add/subtract these from the actual prices we see in the market. An alternative is to use her finding of the general price increase in Norway of 10 NOK per MWh.

	Social surplus (Case I)	NPV (Case I + II)
Δ Price = 10 NOK per MWh	883	5 315

Table 6-8 Sensitivity analysis of changes in domestic price differences (MNOK)

The results when we use the average price increase gives us 883 MNOK increased social surplus and a NPV of 5 315 MNOK compared to the original increase of 992 MNOK and 6 000 MNOK.

Using the average price increase of 10 NOK per MWh from Stavø (2009) enables us to more correctly calculate the period total, but it would have made it impossible to address the redistribution.

Change in future values of social surplus

Our discussion regarding future trends in chapter 6.4 revealed that we might have underestimated the future social surplus. Hence, we now analyze the effect of an annual increase in social surplus in two scenarios, 1 % and 2 % respectively.

A 1 % annual increase in social surplus from year 2012 leads to a new NPV equal to 6 761 MNOK. A 2 % annual increase in social surplus leads to a new NPV equal to 7 695 MNOK.

Both scenarios render a substantial increase in NPV compared to the initial value of 6 000 MNOK. It is evident that an inaccurate estimate for future social surplus can have a substantial effect on the NPV.

Change in the discount rate

In our analysis, we have used a discount rate of 4.5 %. In our sensitivity analysis, we wish to look at the NPV with the suggested rate from the Norwegian Water Resources and Energy Directorate (NVE) at 6 %.

The NPV of the project with a 6 % discount rate is 5 091 MNOK, compared to 6 000 MNOK with the original 4.5 % discount rate. This is because of a lower valuation of future social surplus when we increase the discount rate.

Marginal elasticity of demand

Ideally, we would prefer having the ability to address how changes in marginal elasticity of demand affected the results of our analysis. Unfortunately, this is not possible. The reason is that when changing the value of the marginal elasticity of demand in our calculations, we graphically rotate the demand curve around the point XA_1, PA-2, and not around the point XA, PA-1 which would be the correct method.

6.6 Recommendation/Conclusion

Step 9 – Conclusion

In the CBA framework, this section normally includes comparison between two alternative projects, choosing one over the other based on the NPV calculations. However the main purpose of our analysis is assessing the net increase in social surplus from the NorNed cable. This means that the ninth step of the CBA is of less relevance compared to the overall conclusion of this thesis presented in chapter 7.0.

Hence, we are satisfied by pointing out that the net present value for the Norwegian society from the NorNed cable is 6 000 MNOK over the whole project period.

We refer to the conclusion in chapter 7.0 for the conclusion to our research question.

6.7 Re-valuating case I and II - subsidiary conclusion

In the following section, we argue that revenue to electricity producers and revenue to agents are under-evaluated in our analysis. We argue that because the electricity producers are (mostly) owned by Norwegian authorities, and dividends paid by these companies thus replace tax as a source of finance of public spending, the actual value of these revenues are approximately 20 % higher than our calculations show.

Ownership

In addressing ownership, we need to consider what kinds of entities are included in the "producer" category. Whose profits does the "producer surplus" include? As explained under chapter 6.3, producer surplus consists of revenue to electricity producers, and to Statnett, in total 2 802 MNOK.

From chapter 2.2, we know that Statnett is solely owned by the Norwegian national authorities. In the case of electricity producers, we have researched the size of total production and the distribution of production over different categories of owners in 2010. Our findings and calculations are found in Appendix 3.

We found that among the fifteen largest companies, 53 % of total production was owned by national authorities, 6 % owned by regional authorities, 22 % owned by local authorities and 5 % was privately owned. This way, 86 % of total production in 2010 can be attributed to the fifteen largest companies.

Because we considered researching the ownership structure of the more than 200 remaining companies too time consuming, we assume the ownership structure of the fifteen largest companies being representative for all Norwegian electricity producers. This way, we assume the production explained thus far as being total production.

In that case, all categories of owners are attributed a larger slice of total production. The adjusted ownership distribution is 61 % to national authorities, 7 % to regional authorities, 25 % to local authorities and 7 % to private. This means that 93 % of the electricity producers are government owned.

Because Norwegian authorities at different levels are principal shareholders, they can dictate how much dividend should be paid to shareholders. Assuming that authorities face perfect information with regards to future returns on different investments or allocations, 93 % of the producer surplus can replace tax as a source of finance for public spending. [24]

Cost of finance

Financing public spending with taxes comes with a cost. This cost consists of two parts. The first part is the cost of administrating the system that ensures taxes are collected, the second part is the efficiency loss taxes inflict on the society. According to NMF (2005) the cost of finance in Norway is 20 %. This means that in order to finance 1 krone of public spending, the authorities have to collect 1.2 kroner in taxes.

Our argument

Because the dividend can replace – or crowd out – taxes krone by krone, we argue that the tax burden can be reduced by an amount even greater than producer surplus. Because the producer surplus comes at no cost, it can actually replace 1.2 times the tax reduction it inflicts. This way, the part of the producer surplus owned by the authorities has an additional value of 20 %. Alternatively, one could say that the producer surplus enables public spending, to the benefit of consumers, 1.2 times the value of the producer surplus.

In the perspective of this argument, we can calculate the added value of the producer surplus. To simplify the calculations we assume that the surplus from the cable is paid uncurtailed as dividend to shareholders.

Because Statnett is 100 % owned by the government, Statnett's entire surplus should be multiplied by 1.2. Their surplus will increase from 703 MNOK to 844 MNOK. With our assumption that 93 % of the electricity producers being owned by the government, 93 % of their surplus should also be multiplied by 1.2. Their surplus will increase from 2 099 to 2 590 MNOK[25].

This again leads to a social surplus as experienced by Norway equal to 1 624[26] MNOK (included consumer surplus) compared to 992 MNOK in our initial analysis increasing the social surplus by over 60 % compared to a situation where we do not take our 1.2 argument into account.

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[24] In particular, perfect information about the return on investment – or return on allocation – for all investment opportunities.

[25] 2 099 * 0.93 * 1.2 + 2 099 * 0.07

[26] 844 + 2 590 – 1 810

To our knowledge, project appraisals in the power industry do not take this argument into account and no similar argument has been put forth by scholars we have come across in working on this thesis.

Limitations

Firstly, managing and collecting the dividends probably comes at a cost. Hence the administration part of the cost of finance probably still exists[27], but we know nothing about the size of it. Secondly, authorities do not exhibit perfect information about the returns of different investments. How do we e.g. calculate the correct return on investments of a new teacher?

[27] Given that the producer surplus is earned in a freely competitive market, the administration cost is the only cost.

7.0 Conclusion

The basis of this thesis was the research question; *"Has the NorNed cable increased welfare in Norway, and if so, by how much? How is the welfare distributed within the society?"*

Our analysis shows that the NorNed cable has increased the Norwegian welfare by the amount of 992 MNOK during the period from the 6th of May 2008 until the 30th of September 2011. This answers the first and the second part of our research question.

In order to answer the third part of our research question, we have to divide the Norwegian society into groups. We identified three groups, electricity producers, TSO Statnett, and consumers, and attributed the increased welfare to the respective groups. In doing so, we identified a redistribution from consumers to electricity producers equal to 1 901 MNOK. There has also been redistribution from the TSO to consumers, but the magnitude of it is uncertain.

In that sense, the cable has made consumers 1 810 MNOK worse off. This way, consumers have transferred substantial parts of their welfare to electricity producers, gaining a total of 2 099 MNOK. Statnett's net surplus from cable operations is estimated to be 703 MNOK.

This creates a consumer surplus of -1 810, producer surplus of 2 802, and a social surplus equal to 992 MNOK. Meanwhile, we have pointed to the fact that the ownership structure of the electricity producers and the transmission system operator increases the value of social surplus by 60 %.

Because producers gain on the expense of consumers, the NorNed cable is no Pareto improvement to the Norwegian society, but on the grounds of the Kaldor-Hicks criterion, the cable should be considered desirable because it is possible for the producers to compensate the consumers for their loss, and still gain.

8.0 Critiques

In the following we point out some important limitations of this thesis. We start out with two limitations relating two concrete measurement errors as discussed in the limitations paragraph of chapter 4.0. Thereafter, we point out three more general limitations.

Firstly, in chapter 5.0 we discussed the deviation between the actual price and the price simulated by Stavø. These deviations are actually not as big a problem as it might seem. It would have been a problem if we assumed a price series simulated by Stavø to represent the counterfactual price, but that is not what we did. We used the difference between two price series that Stavø simulated, and subtracted this from the actual price. The relevant question in that case is whether the differences simulated by Stavø are valid. Because her simultaneous econometric model has fairly good explanatory power and other econometric challenges seems to have been dealt with well, we have no reason to conclude that validity is weak. In that sense, this measurement error is of the kind where we measure the right effect wrongly.

Secondly, in chapter 3.3, when discussing autarky, we said that the slope of the supply curve was dependent on the water value. This means that the supply curve changes in consequence of trade. To see this, consider the water value at given point in time. As water is being let through the turbine, less water is left in the reservoir, and because of the scarcity, the value of the remaining water increases.

If we label water value w, introducing trade will render a change in the right side panel of figure 3-4 as shown in figure 7-1 below. In words; the slope of the supply curve steepens in order to recognize the increase in water value following the potential to sell existing units at a higher price than what was possible under autarky.

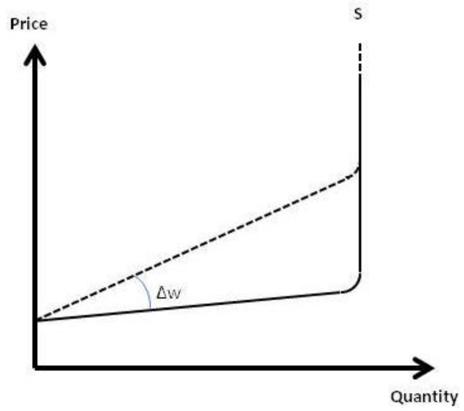

Figure 8-1 Changing supply curve in consequence of trade

In our calculations we have not taken this effect into consideration. We have done so because isolating the effect of the interconnection on the water value is beyond the scope of this thesis.

Thirdly, we have conducted our analysis using a partial equilibrium model of the economy in order to analyze a ceteris paribus effect of the NorNed cable. Ideally, we should have used a general equilibrium model. This would have enabled us to more properly assess the ceteris paribus effect of the NorNed cable on Norwegians. In particular, a general equilibrium model would have enabled us take into account that transfers through NorNed are likely to crowd out or replace transfers through other cables in Norway. If such replacing indeed takes place, we are likely to have overestimated the positive effect that NorNed has had.

However, applying a general equilibrium model would have required a lot more data, which would have been though within the limited amount of time available for this thesis.

Fourthly, we cannot rule out the possibility that relevant impacts of the NorNed cable may have been excluded from our analysis. We know of no method to reveal impacts in a more systematic way than we have done.

Last, but not least, there are impacts that have not been monetized. How to include such effects in a CBA in an objective and consistent way is a question missing a definite answer.

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Appendix 1 – Calculations to find the counterfactual consumption

We know that the price elasticity is negative, hence the quantity decrease when we increase price. We put (XA, PA-1) as a starting point, and (XA_1, PA-2) as the second point:

$$el = \frac{\frac{\Delta Q}{Q}}{\frac{\Delta P}{P}} = \frac{\Delta Q}{\Delta P} * \frac{P}{Q} = \frac{(XA_1 - XA)}{(PA2 - PA1)} * \frac{PA1}{XA}$$

We assume that PA-1 = (PA2-ε), where ε is Stavø's (2009) deviations when import and export:

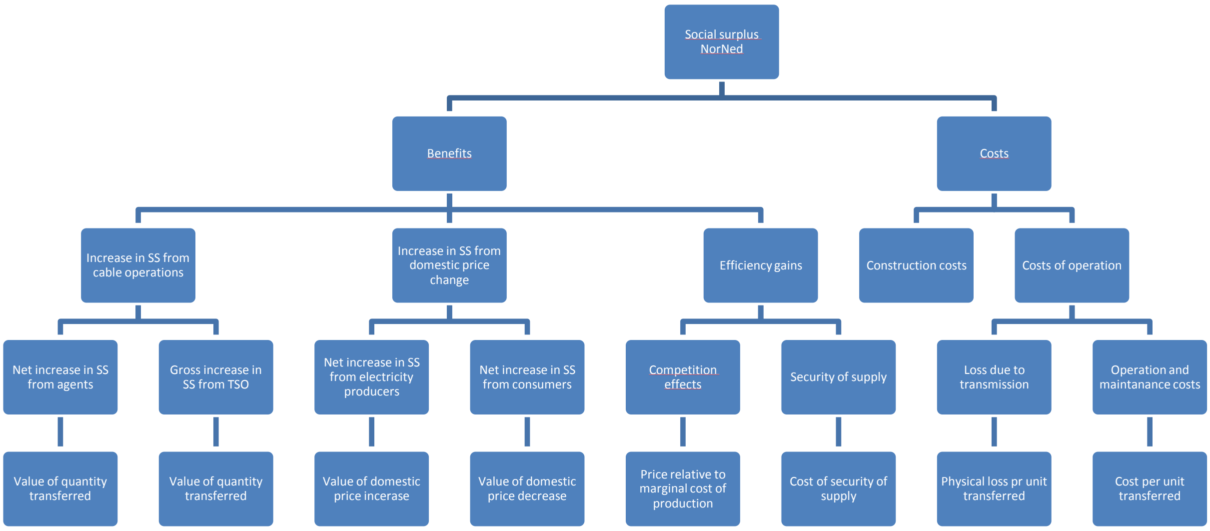
$$el = \frac{(XA_1 - XA)}{\left(PA2 - (PA2 - \varepsilon)\right)} * \frac{(PA2 - \varepsilon)}{XA} = \frac{(XA_1 - XA)}{XA} * \frac{(PA2 - \varepsilon)}{(\varepsilon)}$$

$$=> (XA_1 - \mathrm{XA}) * XA^{-1} = \frac{el}{\frac{(PA2 - \varepsilon)}{\varepsilon}} => \left(\frac{XA_1}{XA} - 1\right) = \frac{el * \varepsilon}{(PA2 - \varepsilon)}$$

$$=> \frac{XA_1}{XA} = 1 + \frac{el * \varepsilon}{(PA2 - \varepsilon)} =>$$

$$XA = \frac{XA_1}{1 + \frac{el * \varepsilon}{(PA2 - \varepsilon)}}$$

Appendix 2 Exhibit



Appendix 3 Ownership structure power companies in Norway

	Production 2010			Ownership 2010			
Company	MWh	GWh	TWh	Stat	County municipality	Municipality	Private actors
Statkraft		52 400	52,4	100 %			
E-CO Energi		9 183	9,2			100 %	
Norsk Hydro		8 144	8,1	49,9 %			50,1 %
Agder Energi		6 600	6,6	*45,5 %*		54,5 %	
Lyse Energi		5 271	5,3			100 %	
BKK		5 001	5,0	49,9 %		50,1 %	
Skagerak Energi		4 958	5,0	66,6 %		33,4 %	
Nord-Trønderlag Elektrisitetsverk		3 349	3,3		100 %		
Hafslund		3 041	3,0		1,4 %	55,3 %	43,4 %
Akershus Energi	2 252 367	2 252	2,3		100 %		
Trønderenergi		1 795	1,8			100 %	
Orkla		1 655	1,7	10,2 %			89,8 %
Østfold Energi		1 542	1,5		50 %	50 %	
Troms Kraft		1 160	1,2		60 %	40 %	
Vardar		576	0,6		100 %		
Total electricity production, 15 largest companies			106,9	65,4	7,7	26,9	6,9
Norway's total production			124,5				
15 largest companies' share of Norwegian production			85,9 %				

	2010		
Ownership	Total production (TWh)	Share of total	Share of total assumed 100%
State-owned	65,4	52,6 %	61,2 %
County municipality	7,7	6,2 %	7,2 %
Municipality owned	26,9	21,6 %	25,2 %
Private owned electricity production	6,9	5,5 %	6,4 %