NORGES HANDELSHØYSKOLE

Bergen/ Québec City, Spring 2010

Future Potential for Hydro-Québec

and the Québec Electricity Market

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Master Thesis in Economics and Business Administration –

Major in Business Analysis and Performance Management (BUS)

Executive summary

The purpose of this thesis is to investigate what a restructuring of the Québec electricity market could mean for Hydro-Québec and the Province of Québec. The thesis is divided into four main sections. Section one describes the drivers of electricity markets and we get an introduction to the situation in Québec. The environmental aspect of energy is also explained. Section two describes the electricity market in Norway and the Nordic countries, which works as a benchmark in this thesis. Section three shows how a restructured market in Québec could be designed, which impact this would have on electricity prices and hence what potential there is for Hydro-Québec. The last section summarizes the thesis, which shows that revenues from electricity sales can experience a significant increase if there is political will.

Preface

I was lucky enough to spend my time doing this paper at Université Laval, Québec City, Canada. First, I want to say thanks to Professor Sophie D'Amours, Catherine Levesque and everyone at For@c Research Consortium which made this stay possible. My supervisor Professor Mikael Rönnqvist has been to a great help with professional advices. He also holds a great stake in making this semester abroad possible and I must thank him for his positive attitude to the whole project. I want to say thanks to my family for always letting me take my own decisions and supporting me. The one I must show my greatest gratitude regarding this thesis is Marie-lin, which was the main motivation factor for me to follow in the footsteps of the Vikings and cross the Atlantic. The semester was A-W-E-S-O-M-E! A natural follow-up is to tell the whole Hamel family how much I appreciate the way I have been welcomed. Je me souviens. I also want to thank Professor Alban D'Amours and Professor Jean-Thomas Bernard for very useful discussions and help.

This thesis was written as a finalizing work of my studies at NHH with a major in Business Analysis and Performance Management. After a discussion with Sophie D'Amours last fall I figured out that the Québec electricity market and its future possibilities would be interesting to investigate. The topic could maybe have had a basis in a more "straight on" Business Analysis and Performance Management theory approach, but I believe it represents a very good summary of my studies. I consider the topic to be a typical consultancy task, which is very likely to be met later in professional life. At times it was challenging. I had to learn one industry and two markets from scratch. I wanted to describe the situation in Québec and how the Norwegian market design was built up thorough, to make this thesis valuable for readers from both Québec and Norway. Now as the work is complete, I must say I have learned a lot both of the electricity industry and how to do research in general.

The thesis may contain several assumptions, but I have tried to make the best use of the information available. Some aspects could always have been given more attention, but I feel that I have been able to show an interesting view of the Québec electricity market. The views in this thesis are my own and I feel proud and satisfied after giving my very best.

Québec City, 15th of June 2010

Atle Nedbu Teig

Statements

- I have chosen to take the approach of using the plural form *we* throughout the thesis.
- All currency values are in Canadian Dollars (CAD), if not otherwise stated.
- For simplicity is one U.S. Dollar (USD) set to have the same value as one CAD. With the basis of the last year's currency rates, this is a reasonable assumption.
- One CAD is set to be 6 Norwegian Kroner (NOK).
- One CAD is set to be 0.75 Euro (EUR).
- One Euro is set to be 8 NOK.
- British Thermal Unit (BTU) is a traditional energy unit.
  Often seen as one million BTU (mmBTU).
- If not otherwise stated is weight measured in metric standards.
- kWh = 10^3 Watt hours
- TWh = 10^12 Watt hours
- Tables and figures are given chronological numbers on a chapter basis.
- Only headings level one (main sections) and two (sections) are listed in the table of content.
- Text is following English (U.S.) grammar standards, while Norwegian standards are used in Excel tables and figures.
- Internet references are not shown with the date of application in the footnotes. Please see reference list.

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“I shall make electricity so cheap

that only the rich can afford to burn candles”

Thomas A. Edison

1.0 Introduction and Background

1.1 Introduction

Canada is a country in North-America that consists of ten provinces and three territories. In size, Canada is the second largest country in the world with an area of almost 10 million km^2. The country is known for having a rich access to a variety of natural resources. Most of the 33 million inhabitants of the country live in the provinces, which are bordering the United States of America. Québec is the largest province and French is the official language. French settlements have been living in the province for more than 400 years and today 7.7 million people live in Québec, which is often considered to be a characteristic province that still is highly influenced by the French culture. Political towards the international arena the different parts of Canada stand united together. Internally the provinces and territories have a strong political and economical independence. As a consequence, electricity markets are under provincial control.

Hydro-Québec generates, transmits and distributes electricity in the province of Québec. Almost all of the electricity generated in the province comes from hydro electricity. Hydro-Québec is owned by the Québec government and has monopoly on the regulated Québec electricity market. Electricity has traditionally been, and is still considered to be priced at a low level. 165 TWh per year, which is roughly Québec's yearly need and consumption of electricity, are guaranteed supplied at a low price through a law called *Act respecting the Regie de l'energie*. The law is more commonly known as the *The Heritage Pool.* The price of electricity shall according to this law only reflect the average cost of generating, transmitting and distributing the electricity plus a reasonable rate of return. This is called the cost-of-service basis. This measure gives Québec some of the lowest electricity prices in North-America.

1.2 Motivation of the thesis

The last two decades we have seen electricity markets all over the world being deregulated and restructured. In Canada the provinces of Alberta and Ontario have restructured their electricity market. The province of Québec still has a regulated electricity market under governmental control. A restructuring of the Québec electricity market is a hot topic in Québec today and the intensity of this discussion is expected to grow in the future.

We start this thesis by looking into factors that determines supply and demand in electricity markets. Knowledge about the market is essential when we investigate how the inhabitants of Québec would react to a restructured electricity market where the market sets the electricity price. Several factors influence the supply and demand of electricity and a general presentation of these variables will help us understand the demand situation in Québec. We will look into how a markets with or without market power handles the supply of electricity. Natural resources are key determinants when deciding at which cost electricity can be supplied. Together with governmental guidance it determines most of the supply conditions. With this as background knowledge, we will examine the motivation behind changing the Heritage Pool policy that restricts Hydro-Québec as an energy supplier.

In the light of climate change, which is a great problem of discussion in the 21st century, we find it natural to see how generators of hydroelectricity can take advantage of the greenhouse gas emission regulations. We give an introduction to the reasons behind the climate change, so we understand why emission reductions must be targeted. One way to reduce greenhouse emissions is to make the polluter pay. This might sound as an easy incentive form, but in reality it is a very hard task to allocate the costs of a global problem. We will see how policies today handle these issues. The climate change section is naturally followed up by a theoretical presentation of economic theory models relevant for taxation and cap & trade.

The nature of the electricity markets in Québec and Norway makes these two markets very interesting to compare. These two electricity markets have disposal of the same natural resource able to create electricity. 99 percent of the electricity being generated in Norway is produced from hydroelectric power plants, while the province of Québec generates 96 percent[1] of their energy from hydropower. On a world basis only about 16 percent are produced from hydroelectric power plants[2]. Norway chose to restructure its electricity market 20 years ago and therefore represent an opposite market design than the one in Québec. Having these two markets with similar resources, but different market design, is valuable for this thesis. We initially believe the Nordic electricity market with Norway as a key role player can be a very good benchmark for Québec.

The purpose of this thesis is to use the theoretical background and knowledge of other electricity markets, to develop a new market design for the Québec and see how profitable it could be for Hydro-Québec. We start this thesis supposing that the Québec electricity market has a great restructuring potential. We initially suppose that Hydro-Québec and the province of Québec miss out on large revenues from domestic sales, export and efficiency losses by regulating the industry the way it is done today. A goal of a restructured electricity market is to make the consumers in Québec more energy efficient and hence make more electricity available for exports. We will try to see how environmental taxes and quotas can affect the price of electricity and see if this has a revenue potential for Québec as a producer of hydroelectricity.

[1] Statistics Canada, Electric Power Statistics Jan 03, 2003
[2] IEA, Electricity/Heat in the World in 2007

1.3 Background electricity

Electricity is a source of energy and a key ingredient in the world as we know it. Today's society is dependent on electricity to cover daily needs as heating and making food. For the world to continue the technical and economical growth experienced the last centuries, availability of electricity supply is essential. We can define electricity as a bundled commodity of energy and transportation. This commodity has some specific characters that make the industry particular. Electricity cannot be stored and it therefore needs to be consumed at the same time as being produced. The demand varies great from time a day, week, and year. One unit of electricity is measured in watts, but it is not possible to physically trace this unit back to the producer or give the unit different attributes. That makes electricity a homogenous product.

The net electrical output from an electric generator at a given time is measured in Megawatts (MW) and is referred to as *power*. Consumption of electricity is measured in Watt hours and is most commonly seen as kilowatt hour (kWh) which describes the amount of *energy* consumed. KWh is used as a billing unit that quantifies energy deliveries from generators to end consumers.

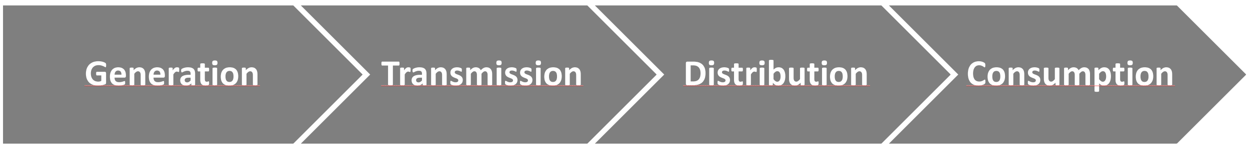


Figure 1.1 Market chain

Figure 1.1 shows how the electricity market is shaped in its simplest form. Electricity is generated through several kinds of production technologies. These technologies have very different characteristics when it comes to flexibility, production costs and emission of greenhouse gases. From the production site, the electricity is transported through a transmission grid to the customers. To make the electricity usable for consumption, the electricity is transformed in the distribution network before being delivered. These basic features and economic characteristics of the industry make the design foundation of the electricity market, and is useful background knowledge for the further work of this thesis.

1.4 Supply and demand in electricity markets

1.4.1 Elasticity basics

Above we defined electricity as a commodity which demand varies great in due to day, week and year. In this section we will look into factors that affect demand and supply, and hence price of electricity. To be able to separate and analyze electricity consumption, customers are often divided into classification groups. A useful and broadly used approach is to divide customers into sectors as household, service/commercial industry and heavy/energy intensive industry. Sectors are useful when we try to determine elasticities for different customer groups.

Elasticities measure the percentage change in one variable as a consequence of a one percent change in another variable. An analysis of elasticities is a sensitivity analysis. Elasticities are often used when we discuss changes in prices. We are interested in finding out how much a one percent increase in price will influence the quantity demanded and hence if the price change is profitable.

$$E_p = (\%\Delta Q / \%\Delta P)$$

As an example, a store sells 1000 lawn mowers each year. If the price next year rises with one percent from 500 dollars to 505 dollars and price elasticity is -1.5, the store will next year sell 985 units. Total revenues will decrease from 500,000 to 497,425. Revenues decrease because the reduction in demand is larger relative to the price increase. We say that demand is elastic since it is greater than 1. An explanation can be that other stores in the area have kept last year's price. When there are no close substitutes, we can experience another outcome with an inelastic demand, where elasticity is less than 1.

Other elasticities we often observe are income elasticity and cross-price elasticity between different goods. Elasticities also occur for the supply side, where the supply is influenced by factors as raw material input prices, wages, taxes and interest rates. Elasticities are often calculated for a certain point on the demand or supply curve. This has its limitations as elasticities tend to change, dependent of the position on the curves. Alternatively arc elasticities are used, where elasticities are measured over a certain range of prices.

Following we will try to explain the drivers in electricity markets by using examples and data relevant for Québec. We believe such an approach with including Québec data and relevant examples in the theoretical presentation, gives a greater understanding of both the theory and the underlying situation of the Québec electricity market.

1.4.2 Income elasticity [3]

The general economical activity level (GDP) of a country seems to be a major demand driver of electricity.

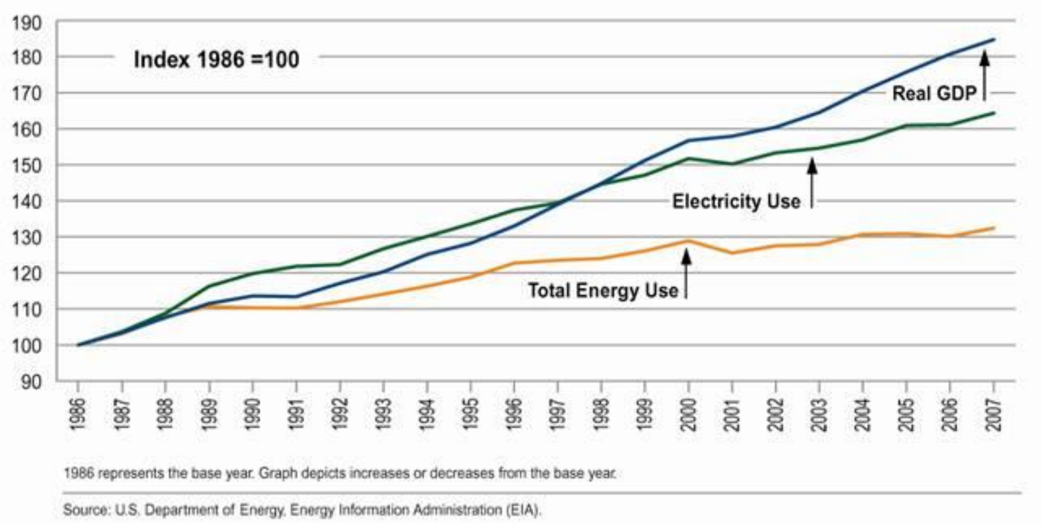


Figure 1.2 [4] Income elasticity

The figure above is almost similar to a figure in Wangensteens book Power System Economics – the Nordic Electricity Market. The figure shows the correlation between electricity, real GDP which represents income and the total energy use in the Unites States. U.S. data gives us an estimate for the situation in Québec and Canada, and the U.S. electricity market will play an important role later in this paper. Unlike Wangensteens chart of 12 traditional EU states, the real GDF grows more than the electricity use. Income elasticity for electricity in the USA is therefore under 1 according to this chart. A possible explanation is that USA is in a post industrial stage and that electricity consumption is less responsive to changes in income. We see that business cycles affects energy and electricity use as well. The downturn in the economy around year 2000, lead to a smaller demand of

[3] Section 1.4.2 and 1.4.3 are based on Wangensteen, Power System Economics – the Nordic Electricity Market, CH 3, 2007

[4] Democratic Policy Committee, The Case for a 21st Century Electricity Transmission System

total energy and electricity. In this U.S. example, higher oil prices lead to higher prices of both electricity and other energy products. We will get back to how prices of energy products correlate. The most important we can learn from figure 1.2 is that economic conditions play a role in determining the demand for electricity.

1.4.3 Price elasticity

A demand driver with high relevancy in this thesis is price elasticity. A possible restructuring of the Québec electricity market would have a direct impact on the prices, and is therefore a factor we must examine. As most other commodities, electric consumption is dependent on price. But consumers are also highly dependent on electricity. We can therefore state that the elasticity of demand for electricity is inelastic in the short run. For many purposes is it hard to substitute electricity as a source of energy. The only way to avoid higher electricity bills in the short run is to reduce consumption. In the longer run consumers are more adaptable and able to substitute their energy needs to other energy sources or lower their consumption with permanent solutions as for example better housing isolation.

The consumption and elasticity of electricity is comparable to those which implies for gasoline. It takes time for people to change their consumption pattern considerably. If the price suddenly rises sharply for gasoline, it will in the short term induce less immediate consumption. People will reduce their driving. But this is possible to reduce only by a certain amount. In the long run consumers will change the type of cars, to smaller and more fuel efficient vehicles. We have seen evidence of this during the last ten years. The car park has changed radically due to higher fuel prices and more focus on environmental friendliness.

The same is reasonable to assume for electricity. If the price goes up considerably, the price sensitive consumers will consume less. But it is hard to go through with other measures in the short run. In the longer run, the consumer will be more price elastic. Measures as more energy efficient buildings and usage of other sources of energy take time to implement. These measures must also be proven to be economical efficient. A consumer therefore needs to analyze the market for some time to make sure the actions taken are profitable.

It is behind of the scope of this thesis to make an analyze of different elasticities in the Québec electricity market. Such analyzes would demand great insight into statistical methods, and time and efforts had to be placed in a large survey. We therefore take advantage of previous analyzes made by researchers within the field. What is both fascinating and confusing, is that these results tend to differ quite much. This can be expected, because when deciding price elasticities you must exclude all other factors. The regulated price experienced in Québec, also makes it hard to perform a real life research based on dynamic prices.

Wangensteen presents us the following results from Canadian studies of price elasticity on electricity.

Study	Sector	Price elasticity	
		Short term	Long term
National Energy Board Canada 1989	Household	-0.16	-0.73
	Service	-0.13	-0.46
	Industry	-0.11	-0.45
Energy, Mines & Resources Canada 1990	Household	-0.14	-1.10
	Service	-0.06	-0.36
	Industry	-0.09	-0.49

Table 1.1 Price elasticity I

This study clearly highlights the fact that demand is more elastic in the long run that the short run. We recognize that households seem to be more price sensitive than service and industries. Disadvantages with these studies are that they are twenty years old and based on data from all over Canada.

Arsenault et al. have made a research on the Québec demand for energy. This study investigates total energy demand and focuses not only on electricity. Unfortunately, it exist very few studies made on pure electricity demand in Québec, so we choose to include this study due to the fact that electricity stands for about half of the final energy use in Québec and it can give us a relevant comparison. The study by Arsenault et al. compares its own results with three other studies. We will present two of them, as the third one is not directly comparable due to statistical specifications.

Study	Sector	Price elasticity	
		Short term	Long term
Arsenault and others	Household	-0.28	-0.68
	Service	-0.33	-0.59
	Industry	-0.16	-0.35
IFSDM	Household	-0.12	-0.40
	Service	-0.42	-1.06
	Industry	-0.15	-0.48
CANREM	Household	-0.12	-0.49
	Service	-0.28	-0.62
	Industry	-0.07	-0.21

Table 1.2 [5] Price elasticity II

Longva, Olsen and Strøm performed a similar research in Norway 1988 right before the deregulation found place. The motivation is to show the connection between economic growth and the energy sector and they therefore examined long term electricity price elasticities.

Sector	Primary industries	Energy intensive industries	Other manufacturing industries	Service industries	Households	Total economy
Price elasticities	-0.40	-0.70	-0.60	-0.69	-0.53	-0.55

Table 1.3 [6] Price elasticity III

Based on the results of these studies we can support out initial thoughts that the demand for electricity is inelastic. A one percent rise in the price of electricity will reduce consumption by less than one percent. Different sectors seem to have different levels of

[5] Arsenault et al., A total energy demand modell for Québec, 2005
[6] Longva, Olsen and Strøm, Total elasticities of energy demand, 1988

elasticity and all sectors have inelastic demand. Subsidizing or regulating electricity prices to an artificial low level therefore seems to be economically inefficient.

1.4.4 Weather conditions

A very important factor influencing the demand for electricity is weather conditions with temperature and precipitation as the most important variables. The temperature affects the demand for electricity in two ways. In areas with cold winter conditions we recognize a large demand during winter. We say that we have a peak demand during winter. These conditions apply for both Norway and Canada. Another peak demand period can be observed during summer, in areas where it gets warmer than the comfort temperature. Electricity is needed to run air condition units. Certain areas in both USA and Canada can experience such peaks during summer due to warm temperatures. Temperatures are most relevant for households and commercial/service industry. Electricity demand varies great for the time of the day. For households there are two peak periods, one in the morning when people wake up and start their day, and one in the evening when they get back from work and perform daily activities as cooking and showering. The tertiary sector of the industry fills up the demand between the two household peaks, demand is greatest during normal work hours. For energy intensive industries it is more difficult to exemplify. Energy use can vary from a constant need through 24 hour a day, 7 days a week, to peaks during nights if production is located in an area or country where electricity is cheaper during low demand hours. Where hydro power counts for a large share of the total production, the precipitation has a great influence on the price. Capacities from thermal plants are constant. If we experience a year with low precipitation, it means that more expensive production methods must be used. With an oversupply of water, turbines at hydro plants run constantly and we may experience a water overflow. Prices will then be lower. In figure 1.4 this can be explained by adjusting the horizontal arrow representing hydro power available.

1.4.5 Volatility of the US currency

Raw materials are priced in US dollars. For countries that import raw materials for use in electricity generation, a weak dollar is an advantage as the input factor is cheaper. In for example Europe, this can lead to better conditions for German coal plants which again lead to lower prices. For Québec and Canada as a electricity exporter to USA., a weaker dollar means that the U.S. have less purchasing power and that the exporter needs to reduce its prices to not be out shifted by cheaper U.S. power suppliers. During the last five years from January 2005 we have experienced large fluctuations in the exchange rate, with a USD/CAN minimum of 0.90 compared to a maximum of 1.30. A strong Canadian Dollar against the USD is not an advantage for exports to the south and the variation can lead to differences in electricity demand from the U.S.

1.4.6 Fossil fuel prices

As for other commodities, the prices of fossil fuels are determined from supply and demand and vary on the basis of many factors. The prices are closely connected to the world economy. Political situations can strongly influence the price levels. Political instability in the Middle East has shown us the last century how the oil price can be affected. Last subsection showed how raw material prices are influenced by USD changes. Oil itself is not the most important price indicator for electricity, but tends to correlate with prices of coal and natural gas. Much more electricity is generated from coal and gas. The two main price determinants are the marginal cost of the coal or gas and transportation costs. Coal is mainly transported by ships or railways, while gas is transported in either pipelines or special liquid natural gas (LNG) ships. Freight rates in shipping can vary much and can affect the price levels. Forecasting future freight rates is an art of its own. Most natural gas imports to the U.S. come from Canada by pipeline, and coal mostly comes from Colombia, which represents a short haul route with less price variation. Shipping rates are therefore not a larger topic in this thesis.

Gas is a more expensive electricity generation method than coal, but has several advantages compared to coal based generation. A main advantage is that it is considered to be a much cleaner form of energy, with lower emissions. In areas that are rich of one of the resources, transportation costs will naturally also be lower. Long term contracts of supply are more to be found in the natural gas market than for oil and coal. High infrastructure investments for pipelines makes suppliers secure a certain price level for the gas delivered. Price contracts have therefore often been tied to the developments of the oil price. Recently spot markets for natural gas are developing, and the natural gas price is expected to be more independent. The New York Mercantile Exchange is the world's leading commodity exchange and the Henry Hub represents the pricing point for spot and future prices of natural gas deliveries. The following figure shows the development of the natural gas delivered for electric generation in the U.S.

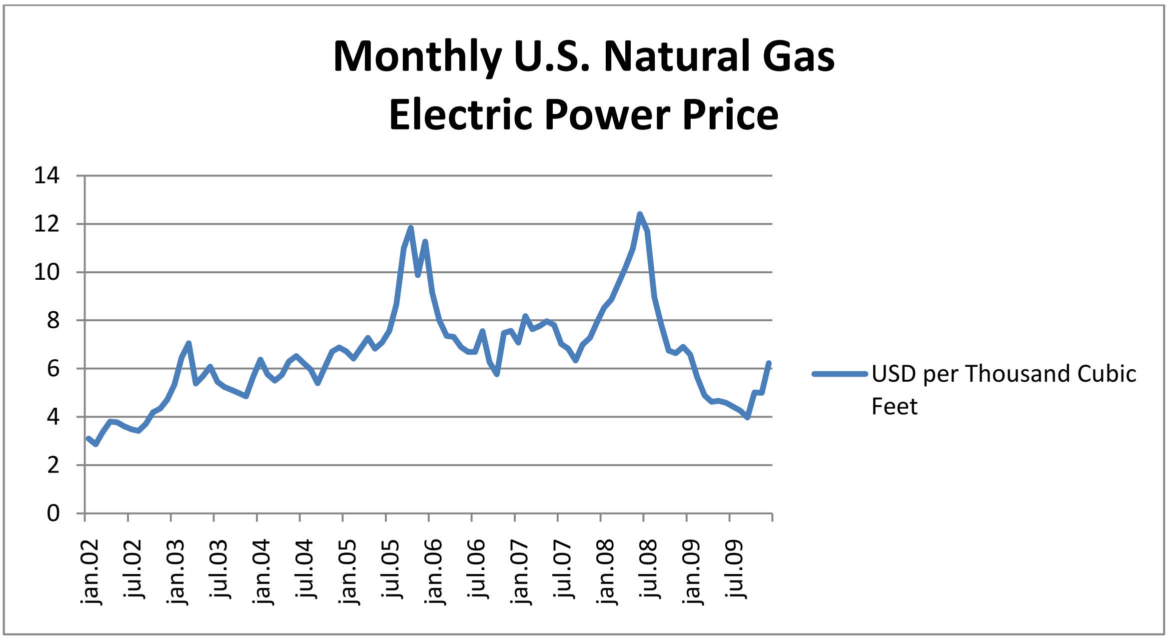


Figure 1.3 [7] Natural gas prices for electric generation

The relative large price changes tell us that in the U.S. the price is quite independent and varies by supply and demand factors. This is a very interesting finding when we later are about to see that natural gas is the price setter in the north eastern parts of the USA.

1.4.7 Cross-price elasticities

A 1989 study from Hydro-Québec shows that 80 percent of the households in Québec use electricity as their unique source of energy[8]. This number has been increasing since then and today electricity dominates the market. The residential demand in Québec is therefore less influenced by price changes of other energy sources than areas with multiple sources of energy available. Over 10,000 households convert from oil to electric heating in Québec every year[9]. For larger customers it is natural to believe that more choices of energy sources are possible. The price of other energy sources should therefore still be considered as a

[7] Data based on numbers from EIA, Monthly U.S. Natural Gas Electric Power Price
One standard cubic foot ≈ 1030 BTU
[8] Bernard, Bolduc and Belanger, Québec Residental Electricity Demand: A microeconometric Approach, 1996
[9] Hydro-Québec, Strategic Plan 2009-2013, 2009

current factor. Unfortunately, there is little research done on cross price elacticities within Québec. An old study of residential energy demand from 1987, gives an insight to some of the research that has been done.

	Electricity	Oil	Gas
Price electricity	-0.59	0.35	-0.27
Price oil	0.37	-0.76	0.05
Price gas	-0.03	0.01	-1.39

Table 1.4 [10] Cross-price elasticity

These results show the own and cross price elasticities of electricity, oil and gas with constant income for the Québec residential demand. Unfortunately the cross price elasticities are quite different from other studies[11]. This makes it hard to determine something concrete. We especially question the numbers between electricity and gas. They are both negative and is a result contrary to expectation. Bernard thinks that gas and electricity moves closely, and says that not much weight should be given the data above[12]. Residential consumers have not often the possibility to change between energy sources. To install a natural gas driven generator for an individual residential demand requires investments costs. Especially in Québec where it has been very cheap to install and use electric ovens, it is reasonable to expect low cross elasticities numbers. For large electricity users, we could expect more willingness to substitute between energy sources in the long run. Considering electric generation, we would expect that the lowest cost generating method would always be preferred. In reality, this is not the case, because many more aspects play a role. The environmental aspect is one of them. We will see this later in this thesis.

1.4.8 Developments in an open market

In an open market with no market power, a producer will operate as a price taker in the market. An open market assumes product homogeneity, free entry and exit barriers, transparency and full information. There are no governmental regulations or subsidies. The

[10] Bernard, Lemieux and Thivierge, Residental Energy Demand, 1987
[11] Bernard, Bolduc and Belanger, and Wangensteen
[12] Meeting with Bernard, Université Laval, 2010

supply conditions in such an area depend largely on the production technologies available to produce electricity. A coal plant using a coal fired steam turbine has quite different cost characteristics than a hydroelectric producer or a windmill farm. The cost structure differs much with respect to fixed costs, variable costs, unit commitments requirements and ramping, start and stopping costs[13]. The supply curve with different production technologies is often referred to as merit order loading or industry cost curve. The producers with the lowest marginal cost per unit will get to sell their products first until their capacity is used. The numbers of suppliers continues to grow up the ladder until the industry cost curve hits the demand, as a profit maximizing company will continue producing until price reaches marginal cost of that additional unit. This can be showed in the following figure of the most common technologies and their short run marginal cost curve.

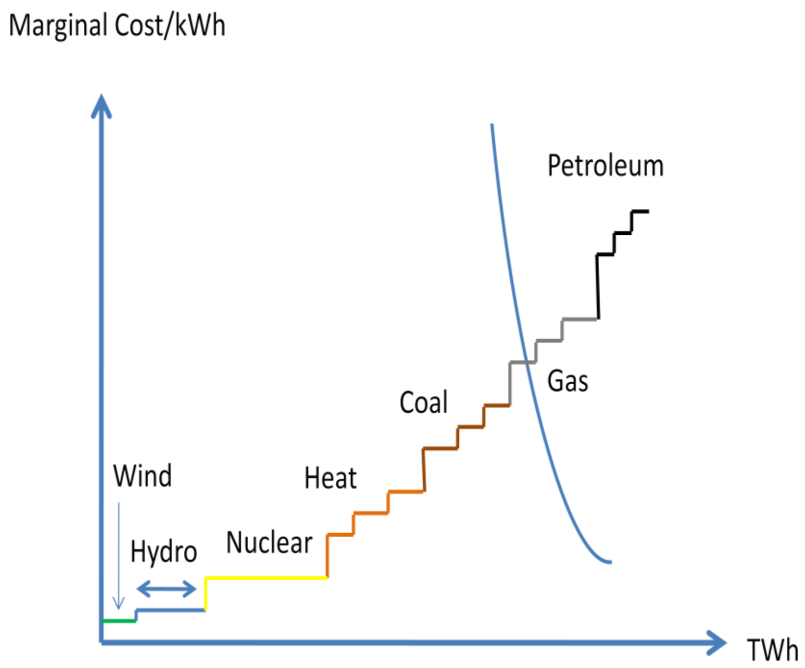


Figure 1.4 Merit order curve

We will recognize this curve in markets where capacity already is available. The market price is decided by demand and the least cost efficient supplier. We then understand that in an open market with different production technologies, marginal production cost has a large influence on the supply curve. Since demand varies throughout the day, more expensive production methods must produce electricity in peak hours. This can typically lead to higher

[13]Rud, ENE 424 Lecture 2, 2010

prices during the day and cheap prices during night. Since the start and stop up costs in thermal production are considerable, it may be better to let the plants run during nighttime and let consumers buy electricity cheap. We have this situation in for example Germany, which is largely dependent on thermal power production.

We distinguish between two types of hydro plants, run-of-river power plants and reservoir dams. The first type must use the resource when it is available, but the latter can decide whether to let the water be stored or to make electricity. Unlike fossil fuel technologies, fuel does not make up the operational or variable cost for a hydropower. Since the marginal cost of producing one more kWh is almost zero for hydropower, the operational cost consists of the alternative value of the water if the plant has storage capacity. This is often referred to as water value or marginal opportunity cost and represents the foregone income of production in a later period. This value depends on the marginal cost of the alternative production technology, inflow of water, transmission capacity and demand in future periods. In periods with too high water inflow, water must be spilled and the marginal opportunity cost is low. On the other side, a scarcity will arise if there is little water in the reservoirs and marginal opportunity cost will therefore be higher. Hydropower can therefore at certain times be located at a higher or lower marginal cost than in figure 1.4. But on average hydropower reveals great opportunities for profits in markets where the marginal cost of the most expensive production method sets the price, especially if those production methods imply start up and ramping costs. To start and stop a hydro power plant is a simple and fast process with very low costs. These peculiar characteristics give producers of hydro power an exclusive opportunity to produce electricity during peak hours to a high price, and let other production methods cover the base load demand to lower prices.

In the long run the market price must cover new investments in production capacity. The LRMC supply curve will therefore look different than the one in figure 1.4. For hydropower producers the largest costs are the fixed cost is the capital cost of investment in plant, property and equipment (PPE). The easiest accessible hydropower sites were built first and new sites are more expensive to build. Other renewable energy sources are also expensive to built, but can be cheap in use as seen with wind. This explains why natural gas and coal plant are that popular to build and holds a great share of the current production capacity, as the investments costs are lower. We will discuss financing renewable energy more in section

3.7, but the main focus in this thesis will be the fact that Hydro-Quebec's current capacity is already present and that they are able to produce electricity at a lower cost than generators of electricity based on fossil fuel sources as showed in figure 1.4.

1.4.9 Market Power

In reality we seldom have perfect markets where every participant is a price taker and price equals marginal cost. The electricity market is no exception and varying levels of market power can be expected depending on the market conditions. This market power can either be created by law or under the fact the leading market participants have been able to become too big within its area. Traditionally the electricity markets have been a regulated industry, and hence the governments have had control of the tariffs. In deregulated or restructured markets capacity limits of the transmission grid leads to the opportunity for a company to gain market power. Market power can lead to an oligopoly or monopoly situation. The price of electricity can therefore differ quite much from a theoretical open market price. It could therefore be interesting to examine how the electricity market in Québec would respond under price or quantity competition. This thesis will have the approach that a restructured market will try to achieve a perfect market without market power. This is a very rough assumption, but it is an approach which is taken for many theoretical presentations of a variety of industries. Considering that the Nordic market is chasing a closer integration with the European continent to enhance competition and develop the market, we believe this is a reasonable approach to make for a restructured electricity market.

The next section describes the Québec electricity market, which experiences market power in terms of a governmental regulated market. But unlike monopolistic or oligopolistic theory, they do not choose to price where marginal revenue equals marginal costs. The electricity in Québec is offered at very low rates, under what in a theoretical situation would have been the market equilibrium.

1.5 The Québec market

In the early days of the electricity supplies in Québec it was left to private actors. Dissatisfaction with high prices and poor management led to an expropriation of the company holding an almost monopoly position, the Montreal Light, Heat and Power Company. It was turned into a crown corporation in 1944, which created the basis of the Hydro-Québec we know today. Led by the liberal government elected in 1960, the whole electricity industry in the province was nationalized in 1963 and Hydro-Québec got the sole right to acquire the rest of the market. The electricity industry was now a monopoly under governmental control. Its mission was to trigger the industrial development and ensure uniform and fair rates to all residential customers.

The next decades increasing energy needs led to a large building activity. The La Grande installations, which are among the worlds largest, were planned and built in this period. The regulatory framework had a small change in 1981, where Hydro-Québec became a joint-stock business with the government of Québec as the only owner. In the 1990's electricity markets around the world experienced changes, and Hydro-Québec's response to the changing business environment, was in 1997 to create an agency named *Regie de l'energie* that is responsible for electricity transmission and distribution. The main motivation for this small restructuring was to get access to the opened wholesale electricity markets in the USA, where Hydro-Québec from now on could sell excess capacity at market prices. The process led to a divesture of Hydro-Québec into the Hydro-Québec we know today, with different departments that have separate business responsibilities.

- **Hydro-Québec Production**
- Generates power for the Québec market. Supplies Hydro-Québec Distribution with 165 TWh/year through the Heritage Pool and sell the surplus on wholesale markets. The department has the responsibility to balance electricity capacity in the transmission grid and is also active in arbitraging and purchase/sale transactions.
- **Hydro-Québec TransEnergie**

  Operator of the transmission grid in the province of Québec and responsible for interconnections with U.S. Northeast, Ontario and the Canadian Atlantic provinces.
- **Hydro-Québec Distribution**

  Monopoly supplier of electricity in Québec. Receives 165 TWh per year from Hydro-Québec Generation and purchases the rest on tendering markets.
- **Hydro-Québec Equipment**

  Designs, builds and maintains generation and transmission facilities.

The province of Québec has access to rich hydropower resources that have been explored during the last century. This asset makes the Québec supply situation special, where 96 percent of the energy comes from hydroelectric sources. The basis of the Québec electricity market is that Hydro-Québec Production must provide Hydro-Québec Distribution with 165 TWh per year at the low rate of 2.79 cent per hour. This is determined in the law called *Act respecting the Regie de l'energie* known as *The Heritage Pool.* The market is under governmental control where Regie de l'energie has the role as a monopolistic energy board. The board's mission is to satisfy the energy needs of Québec through sustainable development both economically, socially and environmentally. Under the act mentioned, Regie has exclusive jurisdiction to set rates in Québec. The Heritage Pool rate is set to cover the average costs of production plus a reasonable rate of return. For electricity demand above 165 TWh per year, Hydro-Québec Distribution buys capacity by a tender call process. This means that small individual providers bid for the contracts. Typical suppliers would be investors of a windmill farm or a solar energy installation. Prices paid by Hydro-Québec Distribution are often higher than the price it sells the electricity for. Price paid per kWh can be around 10 cents per kWh for wind energy and even higher for solar energy due to the high investment costs the new capacity requires. So far the tender calls cover a small amount of the total capacity, but the cost must be carried by Hydro-Québec and reduces the company's profit.

1.5.1 The retail market

When Hydro-Québec is setting prices to their end customers, the same rate setting policy as the Heritage Pool applies. Rates to end-customers are supposed to be fair and only cover the additional average costs in transmission and distribution plus a reasonable rate of return for these divisions. Unlike the Heritage Pool price, the rates are examined every year and adjusted if the forecasted additional revenue does not cover the forecasted costs of supplying electricity and satisfying the customers demand. Therefore we can claim that the customers actually pay for the expensive tender call supplies mentioned in the very end of the last subsection. In table 1.5 the most common rates for *energy* in Québec are be presented. Additional *power* charges will apply for capacity access, and increase the total electricity bill.

Energy sectors	Energy conditions	
Households and farms Rate D	First 30 kwH/day 5.45 ¢/kWh	Remainder of consumption 7.51 ¢/kwh
Small commercial Rate G	First 15,090 kWh/year 8.82 ¢/kWh	Remainder of consumption 4.85 ¢/kWh
Medium commercial Rate M	First 210,000 kWh/year 4.51 ¢/kWh	Remainder of consumption 3.19 ¢/kWh
Large commercial Rate L	Flat rate 2.99 ¢/kWh	Special long-term conditions appears in some industries

Table 1.5 [14] Retail prices

Average annual consumption for individual households and farms is about 17,000 kWh per year. This gives an average price of approximately 6.2 cents/kWh. The rates in Québec are among the lowest in North America. Every year Hydro-Québec carry out a survey, that compares electricity prices in major North American cities for seven customer groups. Montreal, which is the biggest city in the province, is the city where rates to residential customers are the lowest in the whole survey[15]. Among all other customer groups is Montreal always among the lowest-rate cities. If we compare with cities around Montreal located in the north-east of the continent, Québec's position as low cost electricity supplier sticks out even more. Only in the category *medium-power customers* is Québec then marginally beaten. In general, low prices can be found in areas with rich access to natural resources.

1.5.2 Motivation for restructuring

The supply situation in Québec creates a remarkable situation where Hydro-Québec as an energy producer is quite limited in its choices in regards of production planning and market influence. The situation can be shown in the following simplified figure. Please notice that scales and measures are not fully applicable, and only meant for an illustration purpose.

[14] Hydro-Québec, Rates and Bills
[15] Hydro-Québec, Comparison of Electricity Prices in Major North American Cities, 2009

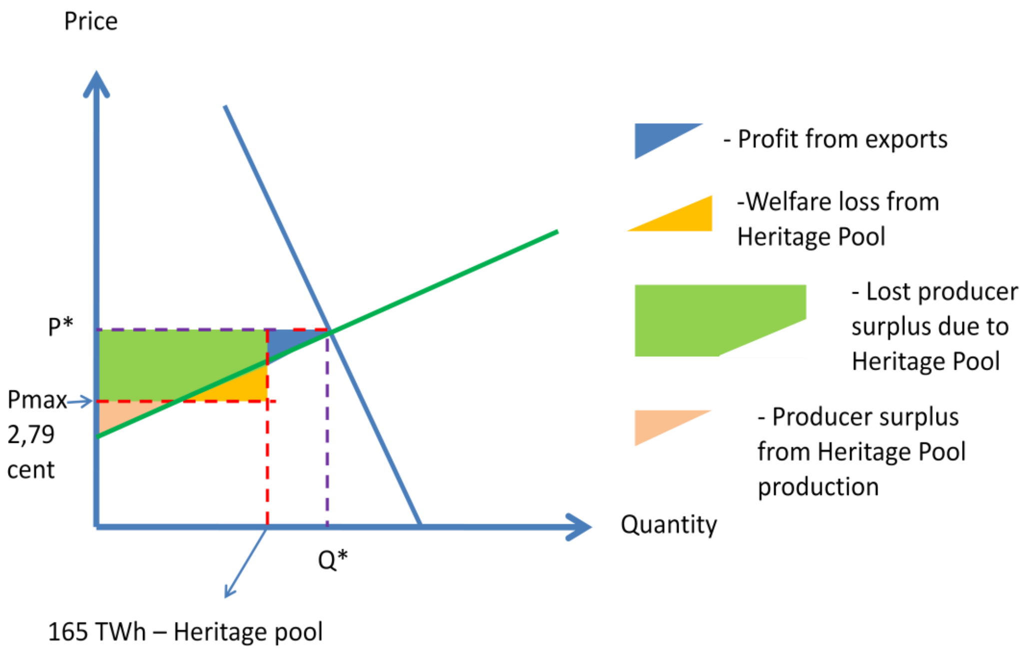


Figure 1.5 Market situation

As we see from this figure, the governmental regulations on supply restrict Hydro-Québec to sell electricity at market price. For a large part of its total capacity, Hydro-Québec must sell the electricity for less than the market price. We know from microeconomics that such restrictions or subventions would create welfare losses. The blue area describes the profit Hydro-Québec earns from export sales today. The pink area represents profit from domestic sales under the heritage pool. The green area shows producer surplus given to consumers due to the Heritage Pool requirements. If a market price was applied, this would lie above the 2.79 cent per kWh and Hydro-Québec and its owners, the provincial government, would keep of the surplus. The new producer surplus could be used of many public purposes and benefitted the population of Québec, instead of being given as subsidized electricity. This is one motivation to see why Québec should restructure its electricity market.

The yellow area represents the power Hydro-Québec must sell as a part of the 165 TWh Heritage Pool, where marginal opportunity cost of the energy is above the set price of 2.79 cent. Even though the marginal cost of production is very low, it is correct to assume that marginal opportunity cost at some point exceeds 2.79 cent. This was explained earlier on, where the term "water value" also was presented. The Heritage Pool therefore creates a welfare loss that would not be present if the market let supply and demand decide the price of electricity. A market price for electricity would imply an efficiency improvement in consumption, which could be exported. Export sales are very important for the company's income and profit. This is the second motivation to see how Québec can restructure its electricity marked, and will follow us further in this thesis.

A third motivation is the environmental issues the world is facing today. Hydro-Québec as a producer of CO2 free electricity, can gain from environmental policies. This is closely connected to the two previous motivation factors, surplus allocation and energy efficiency since a price on greenhouse gas emissions possible would affect the electricity price. In the next section we will give an overview of the climate change, before we in later sections will try to figure out how this can turn into a business opportunity for Hydro-Québec.

1.6 Climate change

1.6.1 Historic changes in the climate on earth

Changes in our global climate are something that is a part of the natural cycles of the earth. Researchers claim that the earth experienced its last ice age about 9000 years ago. The temperatures also vary between ice ages. We are now in a period where we have experienced the temperatures to be rising the last 300-400 years, from what we call the little ice age around year 1600. But since the industrial revolution, us as humans have made an impact on the environment never seen before. Our intelligence has made us able to create a society where we explore the resources of our planet. This has lead to record high emissions of climate gases and affection on the average temperature. The final consequences are yet undetermined, but in general researchers have the opinion that the temperatures on earth will continue to rise due to the human activity.

1.6.2 Reasons for the recent climate change

We often hear about the greenhouse effect and tend to automatically think of it as something negative. That the greenhouse effect is actually crucial for our existence is a fact we seldom consider. It is estimated that temperatures on earth would have been around 30 Celsius lower without the greenhouse effect[16]. But due to our activity, the concentration of greenhouse gases in the atmosphere has increased significantly the last 200 years. CO2

[16] Cicero, Faktaark 2: Hva er drivhuseffekten?

carbon dioxide, CH4 methane and N2O Nitrous oxide are the three largest contributors to emissions.

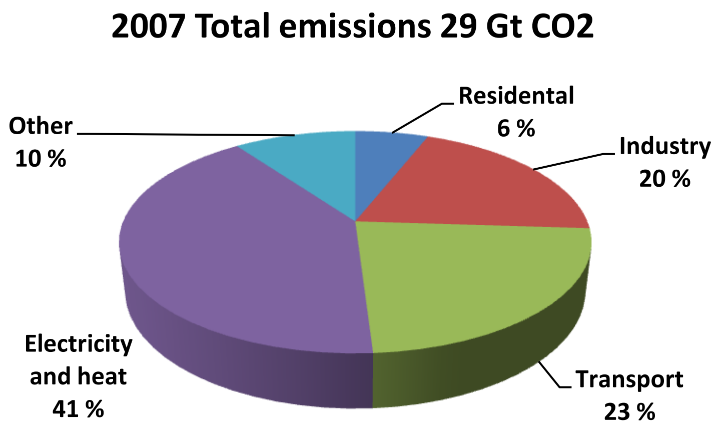


Figure 1.6 [17] Total emissions

The figure above presents the annual greenhouse gas emissions by sector. The electricity and heat sector has a great impact on the environment and is the sector that contributes the most to CO2 emissions. 41 percent of the total CO2 emissions are directly related to electricity and heat, while the total energy sector directly and indirectly actually must answer for 94 percent of the total CO2 emissions. For all greenhouse gas emissions, energy counts for 83 percent of the emissions. The two generating methods that pollute the most are electricity production from coal and natural gas plants. Plants efficiency level can vary significantly between countries and plants.

1.6.3 Consequences of climate change

As a result of the human imposed emissions argued for above, both temperatures and CO2 concentration in the atmosphere have increased the last 200 years. The following image shows this recent development.

[17] IEA, CO2 emissions from fuel combustion Highlights 2009 edition, 2009

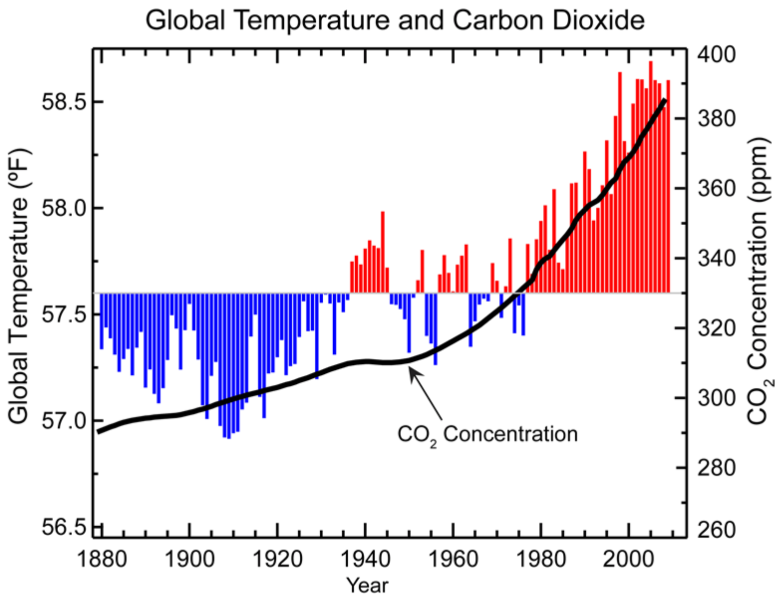


Figure 1.7 [18] Temperatures and CO2

The CO2 concentration in the atmosphere has rose by 36% within this time frame and is expected to double in about 50 years time if business as usual continues[19]. If we convert the temperature changes into Celsius, we see that the last decade has deviated from the global average temperature by about 0.55°C. This might not seem much, but 2°C more than the pre-industrial revolution level is believed to change the environment considerable. There is a great discussion of how much the temperature will rise the next 100 years, but researchers usually end up in an interval between 1°C and 6°C[20]. Uncertainty characterizes much of the climate discussion, as the situation today is never experienced before. Most researchers today recognize that the recent development has happened as a consequence from human activity, but to estimate the direct impact it will have on the future is extremely difficult as we are uncertain of the exact effects of the higher emissions. We also don't know level of emissions we will discharge in the future, but there is now an international understanding that emissions need to be reduced to avoid undesired consequences.

1.6.4 Climate change in Québec

Québec is the province in Canada that has increased their greenhouse gases the least between 1990 and today. Emissions are about four percent higher, which is considered to be

[18]NOAA, Global Climate Change Indicator
[19] Norwegian Climate and Pollution Agency, Miljøstatus I Norge – Klimagasser
[20]CICERO, Faktaark 3: Samfunnsutvikling og framtidens klima

quite good due to the population and GDP growth experienced the last 20 years. Transportation and the tertiary sector including commercial businesses counts for much of the increase. Last November, the provincial government announced that Québec would reduce its emissions with 20 percent below 1990 levels by 2020. Québec's plans for emission reductions are mostly regarding the transportation sector, by promoting public transportation and electric vehicles. Unlike other Canadian provinces and U.S. states, the electricity generation sector is almost free of greenhouse gas emissions and is therefore not directly affected by CO2 reduction plans. The province's only major gas power plant was closed in 2008 due to dissatisfaction of the emissions from the plant.

1.6.5 What is done to fight climate change?

The climate change problem developed into a really hot topic during the 1980's. In 1992 the Earth Summit meeting in Rio de Janeiro agreed on the United Nations Framework Convention on Climate Change, a deal which sets focus on stabilizing the greenhouse gas concentration in our atmosphere. The convention was non-binding and provided no mandatory limits of maximum emission levels. It recognized that the industrialized countries stand for most of the emissions, and that these countries need to reduce their emissions. Developing countries on the other hand, which are in a position to be negatively influenced the most by climate change, must be allowed to increase their emissions to be able to experience economical and social development. The work following the treaty from 1992, lead to the Kyoto Protocol which was established in Kyoto, Japan in 1997.

1.6.6 The Kyoto Protocol [21]

The Kyoto Protocol filled in the missing gaps of the 1992 Climate Convention and was meant to be in force from 2008 to 2012. Individual emission targets were set to each country, averaging a 5.2 percent reduction in the emissions from industrialized countries by the end of the period. Europe was supposed to reduce its emissions by 8 percent. The base year was set to be 1990. The protocol was not valid until enough countries making up 55 percent of the worlds greenhouse gas emissions accepted and signed the deal. When major emitters as Canada and Russia finally recognized the protocol, it became valid in 2004. The Kyoto

[21] Store Norske Leksikon, Klimakonvensjonen

Protocol suggests three different flexible mechanisms for countries to control their greenhouse gas emissions. The mechanisms are tools to help a country to reduce their emissions at ease.

Before using any flexible mechanisms, the first choice a country has is to reduce their emissions domestically by introducing restrictions. It can be very hard to know the marginal production and abatement cost for a single emitter, and it can even be economically inefficient to make the reductions domestically. The three mechanisms suggested by the Kyoto Protocol are therefore meant to help the government to reach their emission goals, so that reductions will be accomplished in an efficient way.

The first flexible mechanism is called *Joint Implementation*. This mechanism allows a country to reduce their own emission by investing in projects in other countries which needs to reduce their emissions. The host country will benefit from foreign investments and technology.

The second option is the *Clean Development Mechanism.* This method has been nicknamed the green mechanism, as it allows industrialized countries to invest in emission reducing technologies in developing countries without any reducing obligations. This also leads to a sustainable development by transferring capital and technology to the developed countries and was a necessarily premise for the developing countries to accept the Kyoto Protocol.

The last mechanism is called *Emission Trading.* In our case this is also the most interesting one. The theoretical purpose of this mechanism is that a limited amount of quotas is released on the market within a country or a group of countries. This way the government can control the amount of emissions, and the lower the limit is set, the bigger pressure is on reducing emissions. This will in theory lead to a higher price on the quotas which can be traded among companies to make the reductions cost-efficient. As a consequence of the Kyoto Protocol, the European Union (EU) and the European Economic Area (EEA) created the Emission Trading Scheme, which can be seen as a pioneer project in reducing emission by using market forces. Before looking into the ETS in detail, we believe it is useful to see how these market forces works in theory and we will in the next section explain how theoretical models handles emission reductions.

1.7 Economic theory models relevant for taxation and cap & trade [22]

We have seen how greenhouse gas emissions have an impact on the environment. We can claim that a market failure has appeared regarding emissions, since the world has emitted more than what is sustainable for our planet. This is one of the largest examples that a competitive market can be economically inefficient, because it is unable to inform the consumers of the real costs they are exposed to. A negative externality has lead to market failure, because the real costs or benefits are not shown in the market price. By definition, an externality is an action by either a producer or consumer which affects other market participants, but is not accounted for in the market price. Pollution is such a form of negative externality. The typical feature of a negative externality is that the polluter will choose to locate itself on a higher activity level which imposes more negative consequences than what is socio-economic efficient. We say the incentives of individual actors differ from the interest of the general public. This can be illustrated by the following figures which assume that participants are price takers in the market.

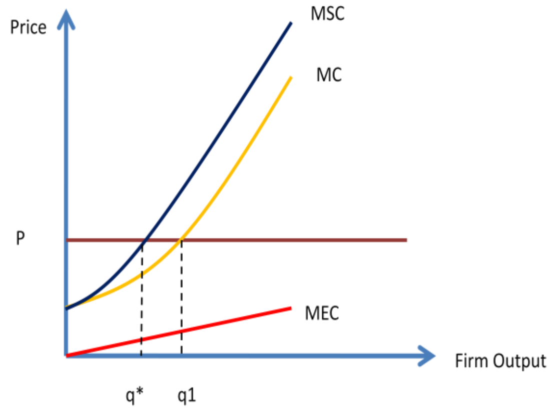


Figure 1.8a Individual

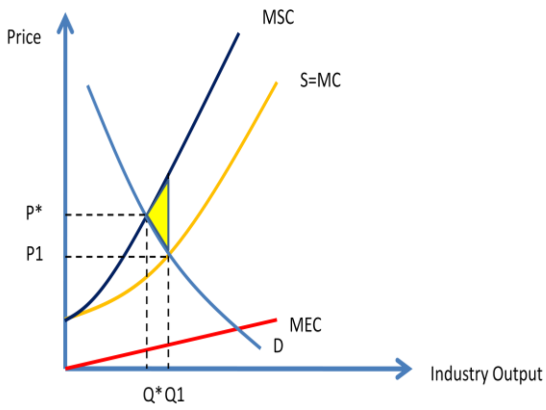


Figure 1.8b Industry

In the example to the left, the individual polluter choose to position where P=MC. Since we have negative externalities, Marginal Social Cost (MSC) of the emissions will be higher than Marginal Cost (MC), and we get a difference called Marginal Economic Cost (MEC). For the industry curves on the right, we see that the efficient output Q* is lower than the actual Q1, and the present price P1 is lower than P* would have been in a regulated market where

[22] This section is based on Pindyck & Rubinfeld, Microeconomics 6th ed, 2005

companies would adapt at Q*. We clearly see the environmental inefficiency of a negative externality, illustrated by the yellow triangle representing the cost of society.

1.7.1 Local vs. global pollution

Due to the recognition of environmental danger and the impact pollution causes, movements of politicians and other interest groups tries to reduce these negative externalities. We can separate between pollution that has a local and global impact. A local impact means that the consequences only arise within a certain area, while a global problem affects everyone. An example of local pollution and waste that is relatively easy to measure is the waste from a specific household. In Switzerland you need to buy specific bags at the super market, to be able to get your household waste picked up by the municipality's garbage trucks every week. Each bag is taxed with a small amount which is meant to cover handling and environmental costs of the waste. On a global basis you have more market participants and problems as how to measure, allocate and regulate arises. An obvious problem is the free passenger problem, which means that by standing outside the regulations you would get a competitive advantage at producing emission intensive products. An individual actor has no incentives to reduce its emissions. The Kyoto Protocol was designed in hope to deal with this problem and reduce greenhouse emissions on a global basis. In general we can say local regulations are easier to shape and execute than global regulations. But we have examples of global agreements, which have succeeded. During the eighties researchers figured out the negative impact CFC-gases had on the ozone layer in the atmosphere, and in 1989 the Montreal convention was signed in order to stop the emissions of these gases. Due to the fact that the CFC-gases take years to decompose, we can first now report of a decrease in CFC emissions, and 20 years after the Montreal convention we can declare it as a success[23].

1.7.2 Efficient reduction level

We assume that every company makes their output and hence emissions decisions independently in order to position themselves where they maximize profits. This follows the arguments above. This assumption can also be transferred to an industry or a country's

[23] Klima og forskningsdirektoratet, Mer klimagasser i atmosfæren

economy in our example. If governments want companies or countries to reduce pollution and negative externalities, they can implement measures as for example taxes and quotas linked to the emissions. Market forces will then lead to a cost efficient reduction. At the same time there is a limit of how much a country shall reduce their emissions before it gets socio-economical inefficient. If a country so far has introduced few or no ways of reducing their emissions, it will be easier and less costly to reduce their emissions by one pollution unit. But when the emission reductions increases, the costs of reductions will also increase. It can even be efficient to clean less, if they are placed to the left of point E* in the next figure. Here the abatement costs will be higher than the social cost saved from the cleaning.

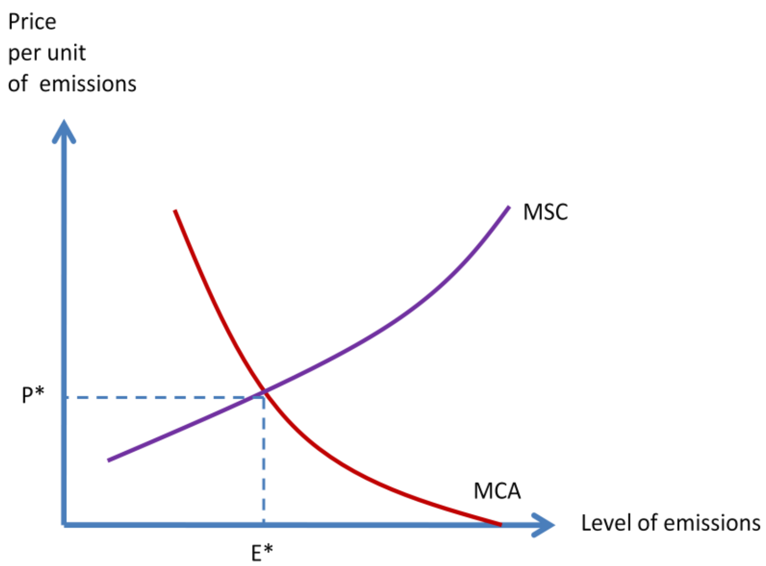
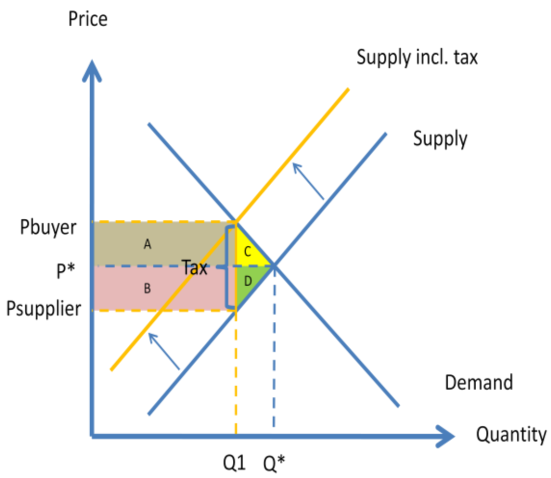


Figure 1.9 MCA and MSC curves

As this figure illustrates, it can be socio-economical efficient to make a country that has negative externalities reduce their emissions. We assume that in an unregulated market, the country will locate itself where Marginal Cost of Abatement (MCA) meets the x-axis. The socio-economic equilibrium is found at point E* where MSC meets MCA. To make this happen, the regulating authorities must make companies position at point E*. The Kyoto Protocol in our case, has decided that a 5.2 percent reduction to 1990 level by 2012 is point E* for this period. We claimed that taxes or quotas could be appropriate measures to reach that goal, so we will now present the theoretical framework behind this.

1.7.3 Tax versus cap

If a company, industry or whole economy wants to reach a desired emission level, an emission standard can be introduced. This puts a maximum limit of how much the company can pollute. In the model above this would implicate that the maximum level of emissions would be limited to E*. The other solution would be to introduce an emission tax per pollution unit. When introducing a fee, the polluter would choose to reduce emissions as long as the marginal cost of abatement is smaller than the fee. If this fee is set similar to the value of P* in our model, we will achieve the same result as if an emission quota of E* is put through.



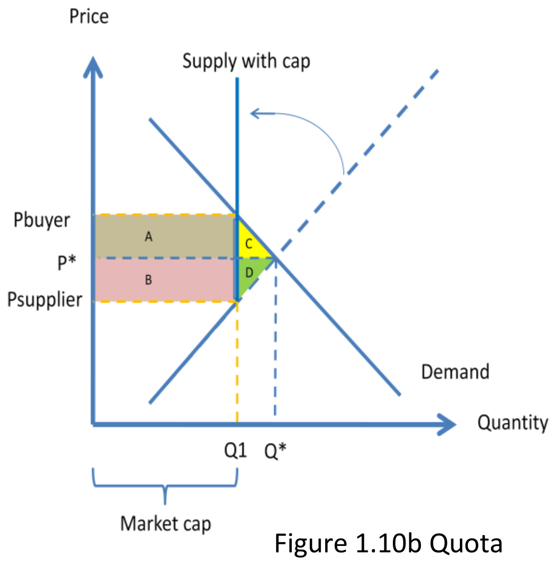


Figure 1.10a Tax

Figure 1.10b Quota

The two figures above show us that using either taxes or quotas will give us the same result. Pindyck & Rubinfeld takes basis in a simple supply and demand cross when explaining the impact of a tax or quota. We suppose we are in a competitive market where price is equal to marginal cost and the government imposes a tax of *t* dollars per pollution unit. This means that the price the buyer pays must be *t* dollars more than the price the seller receives. In the figure 1.10a above, the starting point is in position Q* and P*. We are in the market equilibrium and supply is the same as demand. When the tax is imposed, the seller must raise its price equal to the size of the tax, not to incur a deficit as big as the tax. The supply curve will therefore shift to the left and we get a new equilibrium in the economy at quantity Q1. P buyer is the new price paid by the buyers. This is equal to the price sellers receive, plus the tax. In this example with equal elasticity the tax burden is shared equally between seller and buyer. The price is changed for both supplier and buyer, where the buyer must pay more and seller receives less. We see that the tax results in a change in consumer surplus ΔCS=-A-C and producer surplus ΔPS=-B-D. The new governmental tax revenue is A+B so in total the tax gives a deadweight loss to the producer and consumer similar to C+D.

The effects shown under taxes can also be achieved by using quotas. The regulating authorities simply introduce a supply restriction. The maximum quota limit must be set equal to point Q1 in figure 1.10b. At quantity Q1 the new supply curve will appear as vertical, because it is no longer allowed to supply more than the quota limit. Who that gains the profit from this policy, depends on how the government allocates the quotas. If they are given out, companies get the gain, opposite to an auction where the profit would belong to the government as under taxation.

The reasoning above seems convincing and no matter what policy chosen, the outcome will be equal. But in a real world this is not the fact. This is due to uncertainty of the location and varying gradient of the abatement and social cost curves in figure 1.9, the outcome may differ quite a lot. New technology development and different marginal costs between companies makes it hard to determine the abatement cost curve. The marginal social cost curve can be difficult to determine due to individual preferences.

The valuable advantage by choosing a quota approach is that the final limit of emissions can be determined. This is why this is the chosen policy of the Kyoto Protocol. But if quotas are to be handed out in an efficient way, it would demand full information of the abatement cost curves of every nation and emitting company within the country. This is an impossible task. Therefore the quotas have been made tradable. This solves the problem that the regulating authorities no longer need detailed information about each individual emitter. Under this system each company are allocated a certain allowance available for emissions. If they need more, they must buy them from other firm that holds a transferable quota. A company will sell their quota at a price similar to its alternative value. Alternatively an auction finds place and the companies need to buy the emission quotas from this market. Government will then get the quota income. The total numbers of quotas are chosen to reach the desired maximum level of emissions. The regulated free market will by itself allocate the quotas among the firms and the abating efforts will be done by those participants who can do them the cheapest way. The regulating and market based policy have merged and created a combined instrument.

1.7.4 Who has to pay for the quotas?

Now as we have examined how governments can reduce emissions by applying either an tax or cap and trade system, the next step will be to investigate who that will carry the costs. In figures 1.10a and 1.10b above, tax or quota costs are equally shared between buyer and supplier. The curves elasticities are relatively equal to each other. This does not necessarily have to be the case. The cost allocation depends on the elasticity of the supply and demand functions. If demand is relatively inelastic and supply relatively elastic, most of the tax burden must be carried by the buyers. Naturally, if the situation is the other way around, the sellers must cover the tax burden. We can summarize this in a "pass-through" formula where we see how much of the tax burden the buyers must carry.

Pass-through fraction for buyers = Es / (Es-Ed)

The effect can be studied in this figure, where demand is inelastic relative to the supply curve. We clearly see that buyers must cover most of the quota cost.

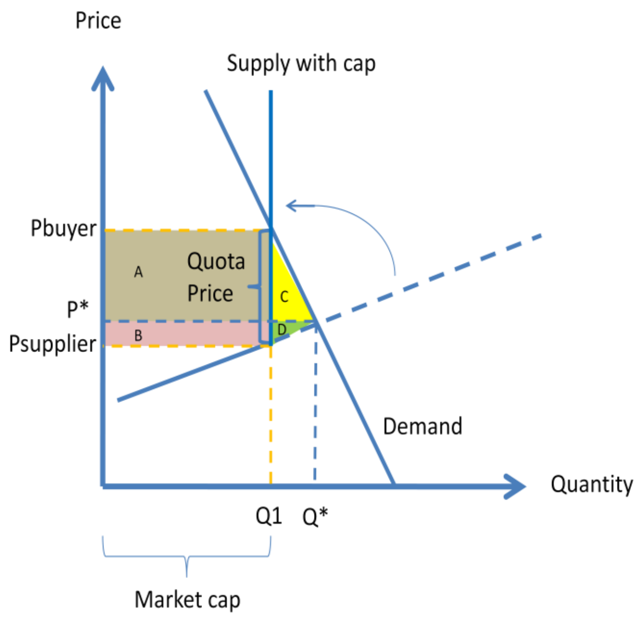


Figure 1.11 Inelastic demand and quota

This figure fits well together with the situation for electricity. As reported, the demand for electricity is inelastic. This would mean that the consumers would have to carry the majority of the cost occurring due to the imposed quotas. As we can see in the figure above, the quota price will largely be transferred to the consumers. A small part will be covered by producers, as we recognize a small decline in quantity supplied. This occurs because at the new price inclusive quota cost the demand will not satisfy the production cost of all previous producers. We keep in mind that some thermal plants keep production going even though price is lower than marginal costs because of ramping, start and stop costs. This is of course still relevant, and can lead to that the producers cover more of the quota cost. If the state of the market is oligopolistic, we might see that producers carry an even larger part of the quota costs due to political pressure.

In areas with extensive supply of hydropower, the time where generators with quota needs will be price setters, is of interest. The market price will then be affected by the quota price. If the marginal opportunity cost of the water is high, we might have a situation where hydropower is more valuable than the marginal cost of thermal production plus the CO2 quota, known as marginal opportunity cost of the water resources. We can experience this typically in years with low precipitation. With oversupply of water hydropower can also be the price setter, but now prices will be lower than the fossil fuel cost and hence not affected by CO2 quotas. The cost of energy production from fossil energy sources will vary in regards to raw material input and efficiency of the power plant. Plant efficiency decides the carbon intensity and tells us the CO2 emitted per kWh electricity. Further this decides how many quotas that are needed and hence the cost of electricity. Gjesdal concludes that most of the quota costs will be carried by the end-consumers[24]. His findings fit well with the theoretical presentation in this section. In general we will experience higher electricity prices with CO2 allowances, which must be paid by the end-consumers.

[24] Gjesdal, Price effects of CO2 Quotas on the Nordic Electricity Market, 2008

2.0 Norway – A Similar Case

2.1 Power market in Norway before restructuring [25]

Traditionally power markets around the world were organized as privately owned utilities with public regulation or the utilities were owned either centralized by the government or decentralized by the state, counties and municipalities. The latter was the case in Scandinavia and the Norwegian market before the restructuring of the electricity market starting in 1990. The situation led to monopolies in the area where the utility had the concession to operate, and consumers had to buy electricity from the supplier available in the area.

The production characteristics in Norway were the same then as now, almost all electricity production came from hydropower. The industry was fragmented, the production sector consisted of almost 70 electricity generators and there were around 230 network owners in the system. It was some vertical integration among these firms, where examples were to be found especially at regional and local level. About 85 perfect of the network firms were publicly owned. Statkraft, a public owned company, accounted for approximately one third of the total generation of around 108 TWh in 1991. Statkraft also controlled 70% of the transmission grid and had the sole responsibility for electricity imports and exports.

On the demand side about 90 percent of the power was sold on bilateral long term contracts, with energy intensive industry demanding about one-third of the energy need. Power producers who had the concession for the actual area negotiated non-standarized "over the counter" contracts with their customers. If the demand exceeded capacity, producers had to buy power from other concession areas. Due to this market design, the electricity market could be characterized as inflexible and non-transparent, and the authorities had to monitor the prices and set a maximum price. The Statkraft price was therefore set as a base price and was regulated once a year.

The remaining 10 percent of the annual power production was not sold through bilateral long term contracts. Due to the characteristics of hydropower, both over and undersupply of occasional power can occur in the market. Therefore a market for spot transactions, called

[25] The first three sections are mainly based on Bye & Hope, Deregulation of Electricity Markets – The Norwegian Experience, 2005

Samkjøringen, was already established in 1972 to handle this short term market and keep the transmission grid frequency on the desired level at 50 Hertz. This would later figure as a pre-ancestor for the later market design.

2.2 Motivation for restructuring

In a regulated market inefficiencies are likely to occur. Prior to the restructuring, the market worked as a cost reimbursement system and incentives for being cost efficient were low. The Statkraft base price was set to match long run marginal cost, but the market price did not reflect the investment level of new capacity. Production and capacity investments were covered by either direct or indirect subsidies from the government. When capacity and actual supply differ, inefficiencies in production arise. Before the restructuring, water was spilled in a normal year due to overcapacity. Inefficiencies in production were therefore a motivation factor to restructure.

On consumer level, prices differed widely among customer groups. Energy intensive industry paid prices as low as one third of households[26]. If we look on the electricity revenue aspect on its own, this policy reduces the social welfare. Important to take into consideration is the widespread district policy in Norway that wants to keep local communities sustainable by offering profitable economical conditions. Then the question of a differentiated price will turn more complicated. But the net loss accrued from the price discrimination in distribution, was estimated to be around 3.7 and 4.5 Billion NOK per year according to several studies done by Bye, Strøm and Johnsen[27]. Also in the transmission grid, researchers believe inefficiencies occurred because of the lack of competition. With this as a background politicians decided to restructure the electricity market to make participants economical rational by introducing a market based exchange system in the hope of making the electricity industry more economical efficient.

2.3 How the new market was designed

Bye and Hope writes in their article that a fully market based power system must contain the following five design elements to be complete.

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[26] Bye & Strøm, Kraftpriser og kraftforbruk, 1987
[27] Bye & Hope, Deregulation of Electricity Markets – The Norwegian Experience, 2005

- Market for trade in electricity
- A financial market where power derivatives in order to handle risk.
- A short-term market for production capacity and balancing supply and demand
- Market for investing in new capacity
- Markets for trade in emission derivatives.

In the Nordic market we find four out of these five elements, which now will be presented. A market for investing in new capacity is still absent.

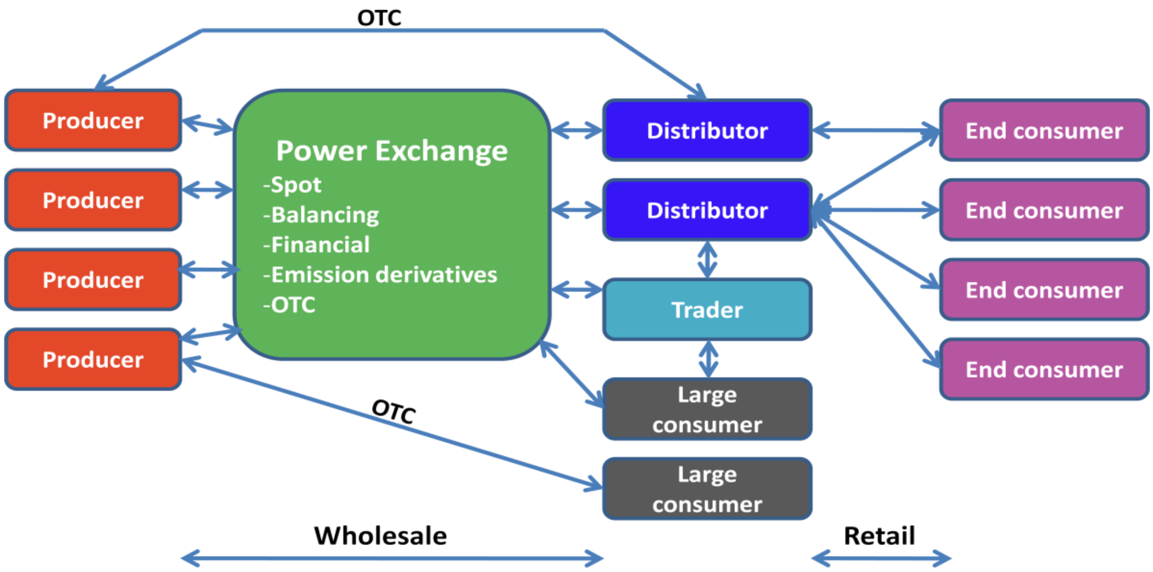


Figure 2.1 [28] Wholesale and retail market

Rud identifies two main markets in the electric industry and separates into the wholesale and retail market. This figure shows the design of the electricity industry in Norway. Trade in the wholesale market can find place either through the power exchange or through a bilateral trade between the participants going on over the counter (OTC). At the exchange we have both the physical and financial market. These market deserves to be elaborated more to give a broader understanding of how the industry was restructured.

2.4 The wholesale market

The Nordic wholesale market is organized as a power exchange, called Nord Pool, which handles physical and financial trade in power contracts within the Nordic countries. Nord

[28] Rud, ENE 424, 2010

Pool offers the largest and most liquid market place for physical and financial power contracts in Europe. Nord Pool is the central counter party in all trades, and creates a secure market where producers, distributors, brokers or large companies can buy and sell power. Nord Pool Spot which handles the physical market covers more than 70% of the physical trade done in the Nordic market for electricity. In 2009 Nord Pool Spot had an annual turnover of 285.5 TWh which in monetary values is equivalent to about 10.7 billion Euros[29].

2.4.1 The physical markets

2.4.1.1 Elspot

On the elspot market hourly contracts for physical delivery in the next day's 24 hours period are traded. This is called the day-ahead-market, and participants are obliged to buy and sell the agreed contracts. The Nord Pool aggregates the purchase bids to a demand curve and the sale offers to a supply curve, and comes up with an equilibrium price. This specific price is called the hourly spot price, or sometimes also the system price, and appears where the two curves intersect. It is important to mention that this spot price does not consider bottlenecks in the congestion grid.

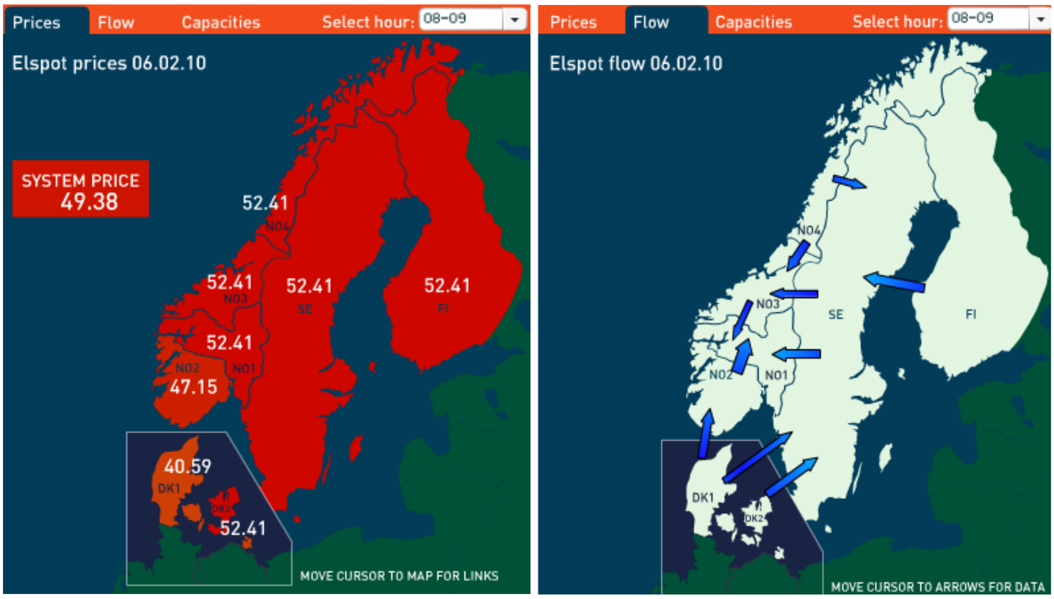


Figure 2.2 [30] Spot price 06.02.10

[29] Nord Pool, Key Figures
[30] Nord Pool Spot, Elspot Capacities

As we can see from this image gathered from Nord Pool, the system price in the Nord Pool area is 49.38 between 08.00 and 09.00 on the 6st of February 2010. But in six out of total eight areas the price is higher and in NO2 and DK1 the price is lower. In these two areas we recognize an excess supply, more than the capacity in the grid can handle and transport to the six other regions.

2.4.1.2 Regulating power market

The regulating power market is a balancing market and its main purpose is to correct for supply and demand differences that occur because of transmission constrains between different price areas. As we saw in figure 2.2, we might have a situation with either excess supply or excess demand in one area. Then a special price will be set in those areas influenced by the bottlenecks. Relatively to the spot price the price will be set down in the area with excess supply and up where we experience excess demand. This measure is taken to make sure the congestion grid will not be overloaded. The Transmission System Operator (TSO) Statnett is responsible to regulate this upward or downward capacity change. The TSO chooses which producer or consumer that must change its supply or demand from the same bids and offers that creates the market equilibrium given in the spot price. The participant with the lowest price offer for the volume change needed is chosen. Naturally this problem at hand is only relevant for participants with a considerable size in the market.

2.4.1.2 Elbas

Elbas is a compliment to the spot market and an alternative to the regulating power market. In the Elbas market the participants continuously can perform cross boarder intra-day trading. Trade can be made until one hour of delivery, and this feature is meant to balance the supply and demand in the market. All the trade on the elbas market is meant to utilize the cross boarder capacity and reduce the regulating power market performed by the TSO's.[31] This has proven to economically efficient for all participants.

[31] Nord Pool Spot, The Elbas Market

2.4.2 The financial markets

The financial market is an instrument to trade price securing contracts. These are demanded in the market for the purpose to hedge and manage risks connected to changes in the market price for electricity. The risk can be illustrated in the simple, following figure where buyer holds a long spot position in the asset. +p and –p illustrates possible future profit or loss at time T, while p0 is the price today.

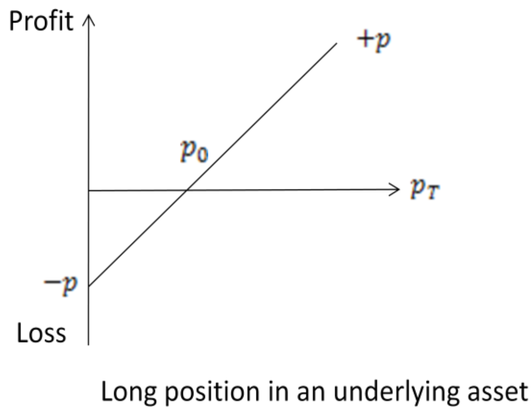


Figure 2.3 [32] Financial contracts

There are four types of derivatives traded on Nord Pool that are designed to reduce risk. These are futures, forward, options and contracts for difference (CDF)[33]. A future contract is a standardized contract that sets a price for a given quantity at a certain time in the future. A forward contract has many of the same qualities, but is non-standardized. What that differs futures and forwards from an option contract, is that by options you must pay a fee upfront and you get a right, but not an obligation to exercise the contract. Finally, CDFs enables participants to hedge against price area risks. The reference price for the derivatives is the spot price. For all the derivative contracts, there is no physical delivery of electricity, they are pure financial instruments.

[32] Figure based on Gjerde & Sættem, BED 030, 2007
[33] Nord Pool, Product Specification

The physical and financial markets can be summarized in this figure.

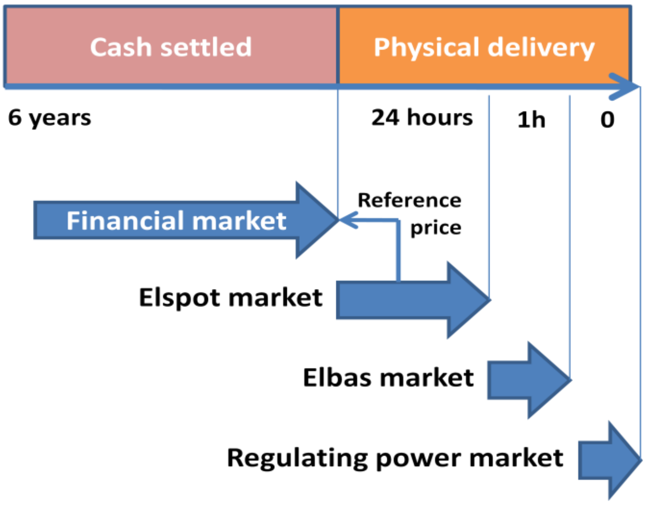


Figure 2.4 [34] Physical and financial markets

2.4.3 Emission derivatives

A separate market at Nord Pool is the emission derivatives market. Nord Pool provides trading, clearing and delivery of European Union emission allowances (EUAs) and certified emission reduction s (CERs) for the whole Kyoto period. This will be explained closer in section 2.7 about the European Trading Scheme.

Nord Pool also offers a clearing service which settles the contracts made over the counter (OTC) in the bilateral market. This reduces the risk for the trading parties. According to Nord Pool's own statement that the spot price is the reference price for the bilateral market, we can say that the transparency of the power exchange strongly affects the prices on OTC's, so that the wholesale market can be seen as one both on and off the power exchange.

2.5 The retail market

The largest end users have the possibility to buy electricity directly in the wholesale market at the power exchange, but talking about the retail market we focus on those who buy electricity from a distributor. We have learned that the Nordic wholesale market is integrated. For the retail markets this is not the case, the retail markets are still divided into

[34] Nord Pool Spot AS, Welcome to Nord Pool Spot

domestically markets. This is due to technical, regulatory and commercial barriers[35]. A consumer can choose among more than a hundred suppliers domestically. Some deliver their services in certain areas only, but the availability of suppliers is still large enough that we can state that the market is competitive. The retail market design allows companies that do not have their own production to compete in the retail market. They are intermediaries in the supply chain. Around 50,000 customers change supplier each quarter[36]. This is about 2.5 percent of the households. The price paid by end users is dependent on how efficient both the wholesale and retail market is. Important to remember is that the price the end consumer pays, is not only the spot price. The electricity price is finally put together by distributor charges, network charges, a special electricity tax and the value added tax of 25 percent. The last couple of years the wholesale price has made up around 40-45 percent of the total price paid by consumers, while network charge and taxes in total have respectively made up around one fourth and one third of the total price[37].

In general, household customers can now choose among three different contracts types. Electricity distributors take the advantage of price differentiation methods and differences in peoples risk willingness. The most common contracts are as following.

- Spot contracts: Price follows the Nord Pool's spot price, plus a margin. Contract may have a max or min limit, and price may be calculated as daily or monthly average.
- Standard variable: Price varies according to the spot price on Nord Pool, but price changes must be given with a two week notice. Prices are in general a bit higher than spot, due to higher risk for the distributors.
- Set prices: Prices are normally set on a one year time basis and represents on average the highest price due to distributor risks.

Around 10 percent chose set prices in 2007, and the remaining 90 percent were split equally between spot and standard variable contracts[38]. Since the deregulation found place, a technical revolution has found place in terms of information access. Now, price information

[35] NCA, Capacity for Competition, 2007
[36] Verdens Gang, Rekordhøye strømpriser – denne uken dobles prisen: Ikke velg feil priskontrakt på strøm, 2010
[37] Statistics Norway SSB, Priser på elektrisk kraft, 1.kvartal 2010 Økte strømpriser
[38] Norwegian Water Resources and Energy Directorate NVE, Kontraktstyper og markedsutvikling

from each supplier can be easily found on the Internet and process of changing supplier is very simple. This makes the switching costs very low, and due to the transparent market it is hard to charge a price higher than the market price. Restrictions in the transmission grid and extensive market power should be the only reasons why market power would occur.

2.6 Results of the restructuring

2.6.1 Prices and consumption

One of the main motivations to restructure was the fact that prices did not decide the production capacity. After the restructuring new investments in capacity did not occur and excess capacity was now released into the market, instead of being spilled to keep prices artificially high. As a result prices dropped close to short run marginal cost, and together with the efficiency gain from the new accrued competition between suppliers, electricity got cheaper for the consumers and approached the new spot price. This could happen as the direct control over generating utilities was abandoned and end-users could now participate in the spot market.

The price gap between customer groups has declined since the restructuring, and for the industry sector this means higher prices. This problem has raised great concerns in rural areas where local communities heavily rely on corner stone energy intensive industries that run the economy. If we look at the welfare loss from electricity directly, the restructuring seems as economically efficient and goes in line with economical theory. But in Norway with a spread population, where district politics is an important theme at every political election, other preferences may be more valuable than economically correct allocation of energy resources. The government therefore decided to keep on providing energy intensive sectors with favorable conditions from the state owned Statkraft. Prices are as low as 0.05 – 0.20 NOK/kWh, and in 2006 such contracts counted for as much as 16.9 TWh/year. Last year Statkrafts estimated loss was around one billion NOK due to sales of cheap industry power[39]. The last contracts will run out in 2011, and an extension of these contracts is questionable because of European Union competition regulations[40].

[39] Statkraft, Annual Report, 2009

[40] Nordic Competition Authorities, Capacity for Competition, 2007

In the longer run after the restructuring, prices were expected to rise. The economical development experienced during the 1990's and 2000 demanded a steady growth in electricity consumption and the previous available capacity was now utilized. In the long run it is natural for the electricity prices to be close to the long run marginal cost, as demand will continue to grow, new investments must be made and financed by higher electricity prices. In addition the restructuring opened up new export opportunities where excess capacity could be sold. Investments were made in transmission capacity and excess capacity was now sold to foreign markets. If domestic electricity demand continues to grow, Norway will be in a state where more efficient utilization of existing plants must be encouraged and possibilities for new investments in capacity created, to keep Norway's position as a net exporter of electricity in a normal year.

The figure 2.5 shows the development of the wholesale electricity price from 1996 to 2008.

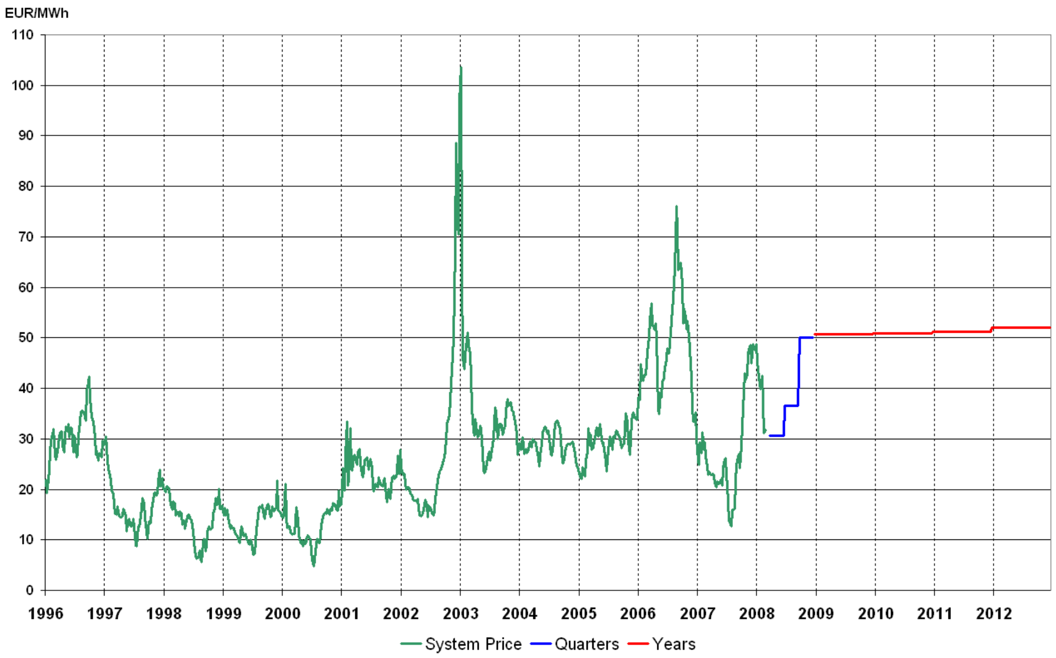


Figure 2.5 [41] Wholesale prices 1996-2008

Figure 2.6 shows the last years development in detail.

[41] Nord Pool Spot AS, Welcome to Nord Pool Spot

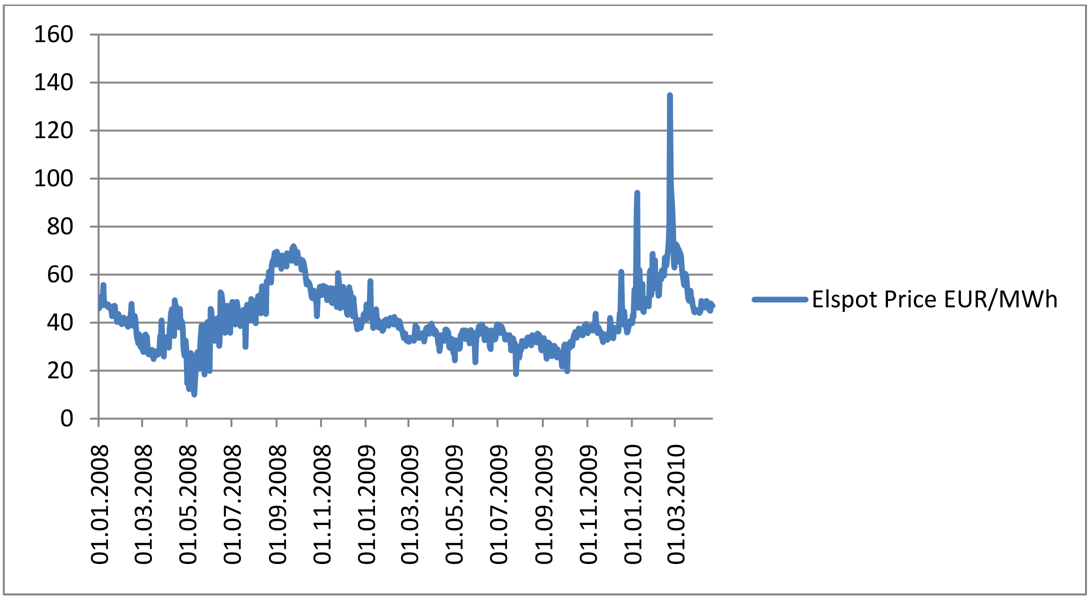


Figure 2.6 [42] Wholesale prices Nord Pool 2008-2010

During the 1990's wholesale prices were still low. Wholesale prices held a level between 0.10 and 0.20 NOK per kWh from the restructuring in 1993 until the beginning of the 21st century, except some short peak periods as the one in the beginning of figure 2.5. Little precipitation in 1996 pressed the prices upwards. The very high prices experienced at the turn of the year 2002/2003 was due to cold weather and unusual little precipitation in the fall, which led to low water levels in the reservoirs. In 2006 a combination of a low water level together with all time high prices of fossil fuels and the introduction of CO2 quotas pressed the price upwards. Overall it seems as the spot price has more doubled since the restructuring, which is only confirmed if we closely study the last two years prices as well. The extreme peak in February 2010 was due to extreme cold weather, closed nuclear plants in Sweden and trouble with the transmission grid. We also recognize that prices vary during seasons due to factors mentioned previous in this thesis.

[42] Nord Pool Spot, System price

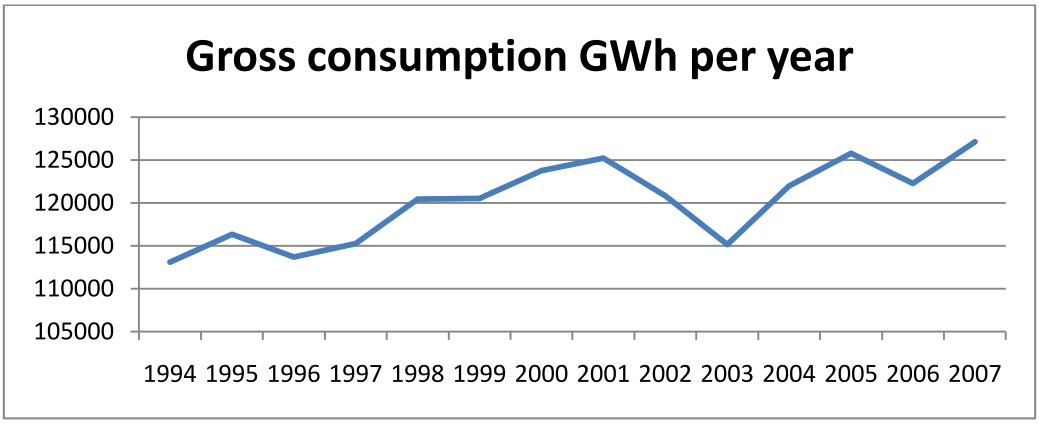


Figure 2.7 [43] Gross consumption Norway 1994-2007

The yearly consumption has not been much affected by the increase in price. Statistics Norway provides the necessarily data to make the graph of the gross consumption since 1994. The declines in 1996, 2001 and 2006 can partly be assigned to the higher prices. But it is reasonable to believe that other factors as weather conditions, the IT bubble and the 9/11 attacks influence on the general economy have more to say.

2.6.2 Market concentration

The power industry has traditionally had a strong position in the Nordic countries and the inhabitants have felt a certain and proud identity to the industry and its participating companies. Power companies were owned by either the government on a national, regional or municipal level. The social democratic party has had the leading political position the last century. This made a privatization of the companies not politically feasible and the restructuring happened without changes in ownership structures. The kept ownership structure is why we consequently use the expression restructuring instead of deregulation. But this does not exclude the fact that many companies were split vertically, now with a producing and distributing division. The large amount of companies regardless of their ownership structure was thought to be enough to secure a well functioning market. Since the restructuring we have seen some horizontal integration among companies, where large companies have acquired smaller ones. Cross ownership of companies and joint ownership of production plants have also developed to a significant extensiveness. In the Norwegian market Statkraft holds a 30.2 percent direct generation capacity. When the indirect

[43]Statistics Norway SSB, Electricity Statistics 2008 Table 8

ownerships are taken into account, this number increases to 42.4 percent and the Herfindahl Hirschman Index[44] reaches the value of 1997[45]. A concentration of 1800 or more is considered to be a highly concentrated marketplace. The competition authorities are therefore monitoring price developments carefully, so Statkraft can not exercise market power. The creation of a greater market by including the other Nordic countries was a key step to decrease market concentration, and the concentration on the overall Nordic market today is considered to be quite low[46]. But still, usage of market power is sometimes detected even without bottlenecks in the grid. It must therefore be monitored and enforced by the competition authorities to secure fair prices.

2.7 The European Trading Scheme ETS

The ETS was introduced in subsection 1.6.6 as the European solution to one of the flexible mechanism in the Kyoto Protocol. It is now time to explain the ETS more in detail and show what impact it has on prices and Norway as a producer of hydro electric power. The ETS is the EU's response to help member states reach the emission obligations in the Kyoto Protocol. Currently only emissions of CO_2 gases are included in the scheme, but plans to include additional greenhouse gases are under consideration. When designing the market for greenhouse gas emissions reductions, the European Union decided to make use of the cap and trade technique. As we have seen in the theoretical part, a main advantage with this approach is the fact that total emission level can be decided. In this way the EU wants to reduce greenhouse gas emissions in an efficient and cost effective way. The possibility to trade the allowances makes the emission cuts to be achieved at the least cost. The scheme currently covers more than 10,000 installations with a net heat of 20 MW or more in the energy and industrial sectors that counts for more than half of the CO_2 emissions and 40 percent of the total greenhouse gas emissions[47]. The sectors currently under influence by the scheme are power stations and other combustion plants, oil refineries, coke ovens, iron and steel plants, cement factories, glass, lime, brick, ceramic, pulp, paper and board producers. The following allowance contracts are available today.

[44] The Herfindahl Hirschman Index (HHI) is an indicator of market concentration of firms and hence competition.
[45] Nordic Competition Authorities, Capacity for Competition, 2007
[46] Bergman, European Electricity Market Integration the Nordic Experience, 2003
[47] European Union, Memo/08/35, 2008,

- European Union Emission Allowances (EUA) products can be found as future, option or newly introduced also spot contracts. EUA's purpose is to trade EU emission allowances in standardized contracts.
- Certified Emission Reduction (CER) can be traded in the same three contracts forms as EUA's. CER's has been introduced as a consequence of the CDM mechanism which is mentioned in subsection 1.6.6. Its mission is to serve the market as cost-efficient, cleared and standardized contract for trade in emission reductions in developing countries[48].

2.7.1 What factors have an impact on the quota price?

Støyva[49] reports in his thesis that the same factors that have influence on electricity price will also be of current interest when the price of CO2 allowances is determined. Weather conditions will affect electricity demand and precipitation, wind and solar days determines how much power that can be created from quota independent technologies. Economic activity and price elasticity will affect the amount of electricity demanded. Prices of fossil fuels will determine the order of production technologies and hence the amount of quotas needed. Coal for example produces more than twice the amount of emissions per kWh compared to natural gas.

The quota system is a new installation and as most other markets it needs time to develop. Unavailability of accurate market data can influence the price. Uncertainty has been a strong price driver since the beginning of the quota regime. Rules and regulations, how quotas are allocated and how they work are typical problematic issues that have been raised. How much of the emission reductions that must be done domestically is a good example on such a problem. In the second period this is limited to 90 percent[50]. The Kyoto Protocol is only valid until 2012, and its future development is under continuous questioning. An abandoning will lead to less investment in green technology and higher prices on quotas in the present period.

[48] European Climate Exchange, CER products
[49] Støyva, CO2-kvotenes innvirkning på den nordiske kraftprisen, NHH, 2005
[50] IESC, EU ETS – An Introduction

2.7.2 The first ETS period 2005 – 2007

The first period was meant as a test period where the market should be built, designed and developed in a way to facilitate for the following periods. The necessarily infrastructure had to be organized so a dynamic market for CO2 allowances could be created. In the first period quotas were given out on the basis of historical emission levels. Reduction of emissions was quite low, and since the quota price is dependent on the scarcity of emissions available, it was not a surprise that the quota prices were close to zero in the end of the period. The development of the price can be seen in the figure under.

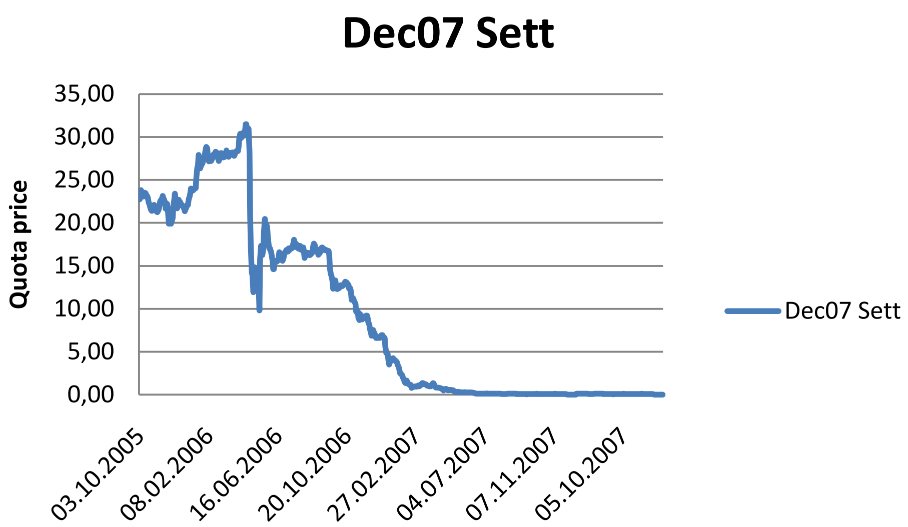


Figure 2.8 [51] Quota price first ETS period

The figure shows the development in the EUR future contract with settlement in the last month of the first period. We chose this contract out of simplicity. Contracts with settlement in December 2005 and 2006 could also have been used, since a "banking and borrowing" policy within the period existed. This means that quotas could be used at the time preferred within a trading period. This might create incentives for strategic purchasing and stocking of allowances. In general, prices with shorter settlement date will be priced a bit lower due to lower time risk. This is also the case for CO2 quotas, but the price with settlement in December 2007 represents the price quite well. The difference is normally around 0.50 Euro,

[51] Figure based on data from European Climate Exchange, ECX Historical Data

but it naturally increases closer to settlement date due to more information and reduced risk. We see that prices started off around 20-25 Euros per metric ton CO2 allowance. The availability of accurate market data were in the start-up phase missing and led to a price increase. When verified emission data were released in 2006, it led to a drop in prices because the market anticipated an over allocation of quotas. Around the beginning of 2007, the market anticipated an oversupply of quotas. Together with the fact that quotas from the first period could not be banked and transferred to the next period, it made the dramatic price drop occur. This criterion was changed when the scheme went into its second period.

2.7.3 The second ETS period 2008-2012

We are currently in the middle of the second ETS period, also known as the Kyoto period. In this period countries must fulfill the emission targets planned by the Protocol. A similar uncertainty experienced in the first period can also be recognized in the second. But unlike period one, have the prices kept a certain level. Prices seem to have stabilized at around 15 Euro per ton and it seems as a stabile market has been created. We are still more than two and a half years from the end of the period, but the market seems confident that the current quota regime manages to regulate the market in an adequate way. Scarcity of quotas has increased from a total of 2.15 billion tons available in the first period, to 2.08 billion tons in period two[52]. We can expect some price changes in the end of the period, as information on supply and demand will be clearer. But quotas from period two can now be "banked" and used in period three. This is expected to reduce the dramatic price drop seen in 2007.

[52] EU, Emission Trading: 2007 verified emissions from EU ETS businesses

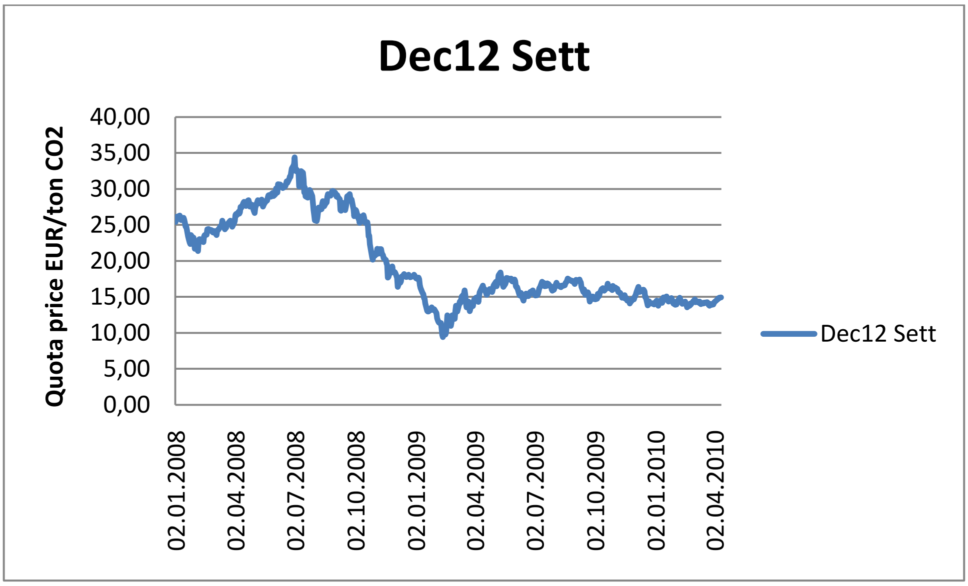


Figure 2.9 [53] Quota price second ETS period

2.7.4 The next ETS period 2013 – 2020

There are great possibilities and a strong hope that the EU will continue its emission trading scheme. Despite some teething problems, the scheme has proven to be efficient.

"No one talks about under-performance in Europe since 2005 because of the carbon price. Changes have occurred in certain industries, but the notion that the carbon price would wreck the overall economy is clearly disproved for the European system, which for a long time had a high price compared to what was expected."
A. Denny Ellerman MIT Energy Initiative[54]

To be able to reach its goal of 21 percent reduction within 2020 compared to 1990 levels, the system must be continued and improved to help the EU reach the goal cost efficiently. The emission decrease will follow a linear line each year to reach the target of a maximum emission level of 1.72 billion ton per year in 2020. Previous quotas have been given out for free. From 2012 a much larger share must be auctioned, which means they must be bought by those who need them. Airlines and producers of aluminum and ammonia will be new entrants in this period. This is expected to lead to more pressure on the price.

[53] Figure based on data from the European Climate Exchange, ECX Historical Data
[54] MIT Energy Initiative, Carbon emissions trading in Europe: Lessons to be learned

2.7.5 Impact on electricity price in Norway

In period one all quotas were given out for free. In period two only 10 percent were auctioned. In the next period EU wants to start by auctioning out 60 percent in 2013 and then increase this percentage the following years. The power sector must buy the required allowances on auctions. Due to the inelastic demand, the power sector has been able to pass on the increased cost of the CO2 allowances to their customers. The power sector is not threatened by comparative advantages from other part of the world in terms of electricity production. Due to the physical characteristics of electricity transmission we experience geographical markets. The EU expects end-consumer electricity prices to rise around 10 to 15 percent by 2020 compared to business as usual without CO2 quotas. The price and volatility of fossil fuels is likely to have a much greater impact on prices. Some may fear that since electricity producers now must participate in quota auctions, it will make the prices on electricity higher. The EU believes this is not the case, as producers already pass on most of their quota costs to their customers due to alternative value the quotas represents. Therefore a free allocation or not, should not make a difference, except eliminating windfall profits for some electricity producers that manages to reduce emission targets cheaper than the quota cost.

For Norway as a producer of hydro electricity, the introduction of quotas means that the alternative value of the water increases since the most expensive power that enters the system decides the price. Production costs will stay the same, as hydropower emit close to zero CO2 emissions. Hydropower generators experience a windfall profit. Since the owners of hydropower production companies in Norway are mostly owned by the government in some way, this profit will gain the public. Simultaneously, foreign producers are not always price setters in the Norwegian market. When Norwegian producers have excess capacity of power, CO2 quotas will not affect the price. This will happen in wet period where hydropower is price setter because of limitations in transmission capacity for exports. Prices will be lower than marginal cost of the most expensive production method plus the CO2 quota. In dry periods, the alternative value of the water will be higher because of the limited import capacity, and we will experience higher prices than foreign prices since hydropower now is the most expensive production method due to the marginal opportunity cost.

Støyva tries to figure out CO2 quotas impact on the Nordic electricity price. In his theoretical part, he claims that 42 percent of the quota price is transferable to the Nordic market. The empirical analysis finds a somewhat higher impact, but this turns out that these results are hard to prove statistically. Støyva makes several key assumptions when finding these numbers that may influence the outcome. We find it reasonable to assume a somewhat higher number than 42 percent. According to analyst Lasse Torgersen in ECON Pöyry, the price effect in Norway will be about 0.10 NOK in a normal year, while the quotas have made it 0.14-0.15 NOK more expensive to produce one kWh from a coal plant[55]. We therefore roughly assume that the price in the Norway will be influenced by the European market with coal as the price setting production method and the CO2 quota price, about 60 to 70 percent of the time, where the price sometimes could even be higher than in Europe because of the future marginal opportunity cost. Hence will the price be lower than the European price 30-40 percent of the time because of oversupply and restrictions in the transmission grid. With a generation of about 130 TWh/year, 0.10 NOK per kWh means an income from CO2 quotas of approximately 13 Billion NOK per year for Norwegian electricity generators and their owners.

[55] Verdens Gang, Lasse Torgersen, CO2 kvoter gir strømsjokk – Høyere strømpris rett i statskassen, 2007

3.0 Future Potential for Hydro-Québec and the Province

We have until now focused on a theoretical approach of the electricity industry, we have been introduced to the Québec electricity market and seen the motivations for restructuring, discussed strength and weaknesses of environmental regulations and we have given an insight into the experience of the Norwegian restructuring. We strongly believe this gives a necessarily understanding and knowledge, when we now look into the possibilities for the province of Québec to restructure its own electricity market.

3.1 Restructuring the market in Québec

A restructuring of the electricity market in Québec to a situation where the electricity price is decided by the market, would remove the efficiency loss described in figure 1.5. Prices would reflect marginal opportunity cost of electricity and it would lead to a more efficient use of the resources. Hydro-Québec would regain the surplus that today is given to the consumers and its profit would go to the company's owner which is the government. This sounds easy in its simplicity, but several obstacles are in the way of restructuring the electricity market in Québec. We will now discuss how we would recommend designing a restructured market and which consequences this would mean for Hydro-Québec and the inhabitants of the province.

Clark and Leach discusses the potential for an electricity market restructuring in Québec[56]. Their two main focuses lie on an alteration of the production sector and which political issues this would imply. Unlike other regulatory regimes, the main goal of a restructuring in Québec is not necessarily higher efficiency on the production level. It is rather an efficient use of electricity by consumers, which have access to the cheapest electricity prices in North America[57]. The Heritage Pool policy is the reason for these low prices and it leads to great profit redistributions from the producer Hydro-Québec to its customers, in form of the cheap electricity prices.

A deregulation of the industry with a following subdivision of the producing plants, would not lead to increased competition to any great extend. If we take a look at the Hydro-

[56] Clark and Leach, Potential for Electricity Market Restructuring in Québec, 2007
[57] Hydro-Québec, Comparison of Electricity Prices in Major North American Cities, 2009

Québec facilities, they are few and utilities a small amount of watersheds. La Grande is the largest river system with 14,354 MW installed capacity. This counts for 32.4 percent of the total capacity in Québec. The total capacity of Québec's generating fleet is 36,810 MW, but if we count in power purchase agreements with small private suppliers and the Atlantic provinces total capacity amounts to 44,192 MW. To illustrate the Québec situation we present a map over Hydro-Québec's major facilities.

Figure 3.1 [58] Map Quebec

[58] Hydro-Québec, Annual Report 2009

Generation is fairly concentrated and the small amount of river systems and producing installations makes a restructuring complicated. If Hydro-Québec would hold the same ownership position as today, Clark and Leach estimates the HHI to be 6140. This indicated a very high market concentration. Alternatively, a deregulation could find place and the assets that are in Hydro-Québec's ownership today, would be fully divested and sold to individual companies. Such a fully divesture of all assets would give an HHI index of 618. This measure would lead to a highly competitive market, but is hard to carry out because of the technical challenge. Multiple plants per river system namely complicate the possible divesture process. The dependency on the same water flow could possibly create conflicts of interest between plants and lead to an inefficient use of resources. To divest only in separate river system levels is to prefer, but this measure would not be enough to prevent a strong market concentration in Québec. As we saw, the operator of the La Grande river system would have about 1/3 of the market. We understand that a divesture of the Québec electricity market is very hard to go through with in a technical perspective.

3.1.1 Politics

Political will is probably a bigger obstacle that must be passed before a restructuring can find place. Strong traditions and identity feelings describes the Québec electricity market. A deregulation where Hydro-Québec is divested and sold from the government to private actors seems unlikely also from a political view. As noted earlier, Hydro-Québec has strong traditions and it is associated with the Québecois movement which is important for many Québecers. Researchers have shown that Québecers prefer to keep the rates low instead of being benefitted with tax-reliefs that would exceed the higher electricity price[59]. It seems as the residents of Québec do not understand that a restructuring can lead to economic rents that will benefit them and they strongly want to keep the current ownership structure of Hydro-Québec. This thesis will therefore not suggest a sale or divesture of Hydro-Québec. Such a restructuring would probably be too hard to accomplish both technically and politically.

[59] Clark and Leach, Potential for Electricity Market Restructuring in Québec, 2007

3.1.2 How can a restructured market be designed?

In this section we can make use of all the knowledge we have learned about the Norwegian restructuring and how the Nordic market is designed. Québec and Norway have an equal starting point with rich access to water resources. Norway early chose to restructure its electricity industry, while Québec has chosen to keep a more conservative line. We believe Québec can learn much from the Nordic system. Nord Pool being the first multinational power exchange was an early innovator of taking advantage of different countries electricity characteristics. If we have a look at the map over the restructured electricity markets in the USA, we detect that geographically a similar market could be created in the north east corner of the continent. Knowing that Québec's western neighbor province Ontario also is restructured, we can see the contours of a possible electricity pool.

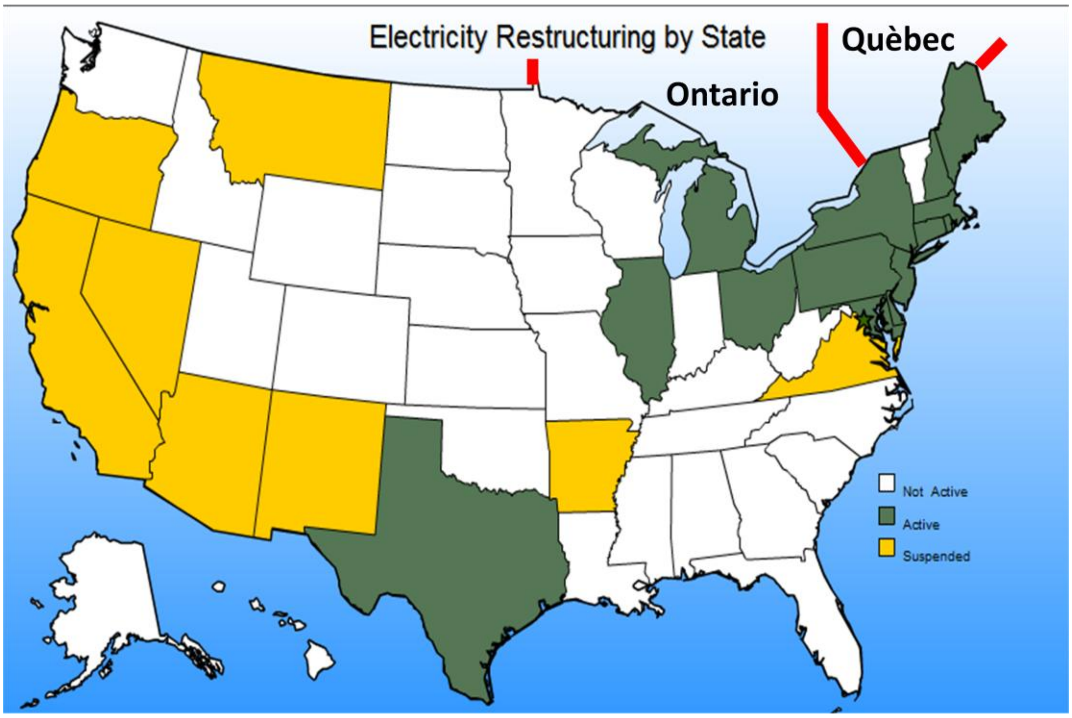


Figure 3.2 [60] Map restructured markets USA

Maine, New Hampshire, Massachusetts, Connecticut, Rhode Island, New Jersey, Delaware, Maryland, Pennsylvania, New York, Ohio, Michigan and Illinois are all states that have restructured their electricity market. The restructured markets in USA are already known

[60] EIA, Status of Electricity Restructuring by State

with power pools where wholesale electricity is traded. Currently there are three main pools known as independent system operators, serving the suggested integrated area. The New England[61] area and New York both have their own pool, while the PJM pool[62] operates the wholesale electricity markets in all or parts of 13 other states. As a start it would be natural with Québec to integrate with Ontario, New York and the New England pool, since these areas have boarder lines to Québec and already transmission interconnectors. Ontario, New York and New England also make up the majority of electricity exports from Québec today. As we have discussed before, the problem is initially not that Hydro-Québec would exercise market power to hold the electricity prices high, but actually to keep them high enough so they would reflect the marginal opportunity cost. This solution could make Québec still able to keep the ownership of its crown company and at the same time reduce Hydro-Québec's market power so an integrated wholesale market would determine the market price. This market price would lead to higher prices in Québec. With only these three areas integrated, Hydro-Québec would hold about a quarter of the generating capacity. A further integration only including the restructured states of the PJM pool would decrease market concentration considerably, encourage efficiency and let the different areas take advantage of different production technologies and demand patterns. Hydro-Québec's market share could then potentially be as low as twelve percent.

The Nordic market is an example of how efficient the creation of a power pool exchange can be without having to split up the major producing and governmental owned company in each country. In the Nordic countries such a divesture would probably have created political unrest, but instead they now have a well functioning market where the price is decided from supply and demand. But this market design comes with a price, a transmission grid with the desired capacity must be on hand. If there is not enough capacity for electricity to flow from low price to high price areas, the market will not be fully efficient, bottlenecks will influence the price too much and companies will be able to exercise market power. This is of course a problem Québec would have to handle, especially since Hydro-Québec would be the sole generator of a certain size in Québec. With an energy board like Regie de l'energie or some

[61] Maine, New Hampshire, Massachusetts, Connecticut, Rhode Island and Vermont are known as the New England region

[62] The PJM Pool is a regional transmission organization serving all or parts of 13 states plus District of Columbia, where New Jersey, Delaware, Maryland, Pennsylvania, Ohio, Michigan and Illinois have restructured electricity markets.

kind of competition authorities still controlling and monitoring the prices and market situations this problem could be solvable in Québec. What makes this concern smaller in Québec's case is that Québec unlike other markets does not struggle with a company exerting market power and charging the customers high prices, because of the governmental ownership which gives a certain control. As we have claimed, the problem is quite opposite, namely too low prices, which do not give incentives to energy efficiency. The problem would be more of a concern in the participating U.S. states where private actors control the grid and would try to gain market power to influence the price to their own advantage. A research by Wolak[63] reports that a credible regulatory mechanism must monitor a restructured market. The Nordic competition authorities have this responsibility together with the national energy agencies, which role is to actively promote the legal and institutional framework and conditions necessarily for developing the Nordic and European electricity market. This condition must be satisfied in a Northeast American-Canadian power exchange as well. We can imagine the role of Regie de l'energie to develop in this direction, together with for example parts of the U.S. Department of Energy.

Today Québec has 17 interconnections with the neighboring areas. Recently a new interconnection to Ontario with a capacity of 1250 MW was taken in use. This line enables Hydro-Québec to export more power to Ontario and also use the neighboring province's transmission system to export more energy to New York and the US Mid-West.

MW	Churchill	New Brunswick	Ontario	New England	New York	Total
Import mode	5150	770	1970	1970	1100	10960
Export mode	0	1100	2545	2275	2125	8045

Table 3.1 [64] Interconnections

The total interconnection capacity has the size of about one fifth of the total generation capacity in Québec. For a future integration of the wholesale markets this is a great start where the infrastructure base is already in place. Discussions are ongoing in regard of building a new transmission line to New Hampshire as well. This line is estimated to get the capacity of 1200 MW and will increase Québec's ability to export electricity. The situation in

[63] Wolak, Designing Competitive Wholesale Markets for Latin American Countries, 2003
[64] Hydro-Québec, Our system at a glance, and Hydro-Québec Strategic Plan 2009-2013

Norway is quite similar. Norway holds a transmission capacity of around 5500 MW to its neighboring countries and it is sufficient to create an integrated market. Considering that Norway's maximum producing capacity is around 25,000 MW we see that the underlying conditions are quite the same. Norway also works on improving transmission capacities as it believes investments in the grid will lead to a greater economic rent and better exploration of the resources.

The transmission grid in the USA is in private possession. This makes it very hard to get an overview of capacities and would complicate the process of creating an integrated market. The way grid capacity is purchased in the USA is a constrictor for this market design. In the Nordic market the transmission capacity is done by implicit auctioning where the capacity allowances is included in the auctions of electricity in the market. This automatically makes electricity flow from surplus areas with a low price to areas with a demand and higher prices. Unless a bottleneck occurs, this system leads to one unique system price. The system in USA is based on explicit auctioning. This means that transmission capacity is auctioned separately from the electricity. Since these two goods now are traded separately, non-transparency of information can lead to inefficient usage of the transmission grid and hence efficiency losses. An example of this poor market design is that the electricity was flowing from high price to low price areas in the connection between Western Denmark and Germany 24 percent of the time in 2006 due to explicit auctioning[65]. Investigating the U.S. transmission grid closer is out of scope for this thesis. Information is very hard to access. We can only assume that transmission operators are interested in making profits and that an integrated market would solve the transparency problem efficiently with or without regulatory help. As an insight, Wangensteens book claims that the transmission grid is a natural monopoly and it should be operated by a single transmission system operator under regulatory surveillance to reach economic efficiency. This is due to the physical characteristics of the grid. It is crucial for an integrated wholesale market that no owners of the transmission grid are able to deny access to the transmission grid from competitive generators.

As argued for when discussing the Nordic restructuring, a complete power pool has some criteria it must fulfill.

[65] Nordic Competition Authorities, Capacity for Competition, 2007

- An exchange must be organized to able trade in electricity. If the political will is there and they work against the technical barriers, there is no other barrier that should make this criterion impossible.
- Derivatives for hedging must be available to allow participants to treat their risk willingness. This option should naturally follow an integrated exchange.
- A market for short-term production capacity trade where supply and demand is balanced. Different transmission grid designs may create problems, but this is crucial for the exchange to work efficiently.

The first two criterions will naturally be a part of an integrated power exchange in the north-east corner. The TSO's handles the third function and the TSO's must allow all firms access where the market determines the price. If the U.S. grid is to be kept in private possession, a better market transparency must be encouraged. Norway and the Nordic market fulfill these criterions and should be seen as a benchmark of how the integrated market should be built in the northeastern part of America. The last two criterions listed in section 2.3; trade in emission derivatives and a market for investing in new capacity, will be discussed later in section 3.3 and 3.7.

3.2 Price developments in an integrated market

What price on electricity could we expect from an integrated wholesale market? This is one of the most interesting questions we need to ask ourselves when discussing the proposal of creating an integrated market. This price would determine how much Hydro-Québec could improve their financial performance. If there is no market power or bottlenecks in the transmission grid, we would experience one uniform spot price for the whole area, just as in the Nordic market. But as we have discussed, the same problems experienced with bottlenecks in the Nordic region arises in our north east USA/Canada case.

The last three years electricity exports from Québec have increased rapidly. From being stable around 15 TWh per year, Hydro-Québec sold 23.4 TWh to exports the last year and is a very important contributor to Hydro-Québec's net income. The numbers from 2009 shows that net exports totaled $1,258 million for 18.5 TWh, which gives a unit contribution of 6.8¢/kWh. Less generating, procurement and transmission costs net exports gave a net income of $672 million in 2009.

Electricity sales outside Québec

	All export sales			Québec production			
	Revenue MCAD	TWh	Per unit CAD	Net Export MCAD	TWh	Per unit CAD	Net income MCAD
2005	1464	15,3	0,096	830	6,7	0,124	n/a
2006	1149	14,5	0,079	814	7,0	0,116	564
2007	1483	17,5	0,085	1104	10,7	0,103	733
2008	1897	21,1	0,090	1484	15,2	0,098	977
2009	1495	23	0,065	1258	18,5	0,068	672

Table 3.2 [66] Electricity sales outside Québec

The difference between revenue and net export numbers are due to correction being made from Hydro-Québec's own imports, which the province either consumes itself or works as an intermediate. This is the case for electricity supplied form Churchill Falls, Labrador, which is northeast of Quebec. We see a trend of higher sales and net income until 2008, but falling average prices per unit of the electricity coming from Québec's own drawdown[67]. An explanation is that the more Hydro-Québec exports, the lower the average price of exported electricity will be, because it no longer sells power only during the very peak periods with the highest prices. If they continue to increase exports, we can assume this trend to continue towards the marginal production cost method that sets the price in the export market. The dramatic fall in price and from 9.8¢ in 2008 to 6.8¢ in 2009 is explained by the more difficult market conditions in 2009, compared to the booming years before. This naturally affected the net income considerably. Together with the financial crisis prices on fossil fuels fell and an economic downturn made demand in general smaller than the years before. But still, the importance of export is crucial for Hydro-Québec's result and is shown in the figure collected from the 2009 annual report.

[66] Numbers taken from Hydro-Québec's annual reports 2005-2009
[67] The lowering of a reservoir

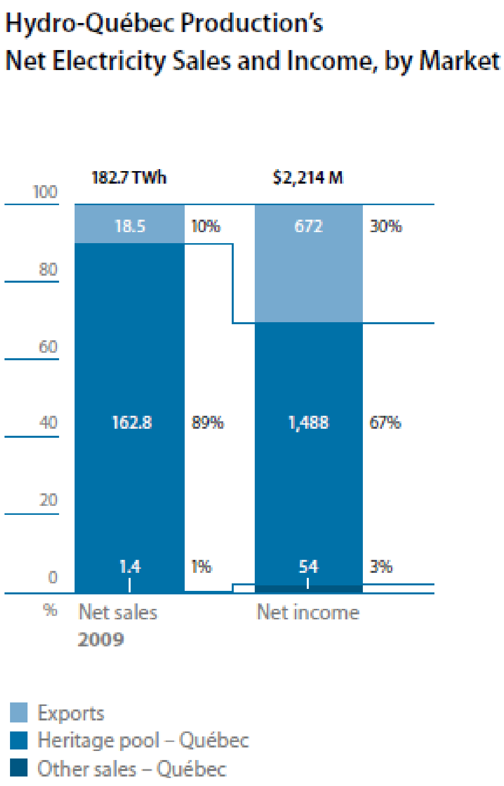
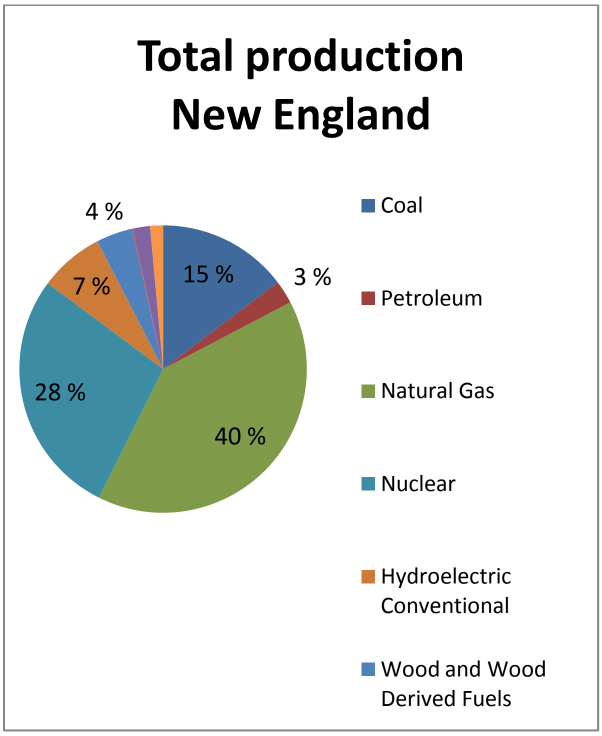


Figure 3.3 [68] Net electricity sales and income

Exports only counted for 10 percent of net sales volume, but counted for 30 percent of the Hydro-Québec Production division's net income. For the whole Hydro-Québec group, this makes up 22 percent of the net income. To increase exports is already one of Hydro-Québec Production's main business objectives for the future. In the 2009-2013 Strategic Plan, Hydro-Québec pursues that exports to Ontario and New England/New York are to be expanded. Building new transmission lines and accessing the private lines in the U.S. are central for enabling this strategy.

We have throughout this thesis said that the marginal opportunity cost of production should decide the price of electricity in an integrated market. For Québec it is therefore highly relevant to make an analysis of the production in New England, New York, Ontario and Pennsylvania. The first figure below show how the most utilized production methods are distributed in New England alone and the second shows the relevant U.S. areas together with Ontario.

[68] Hydro-Québec Annual Report 2009



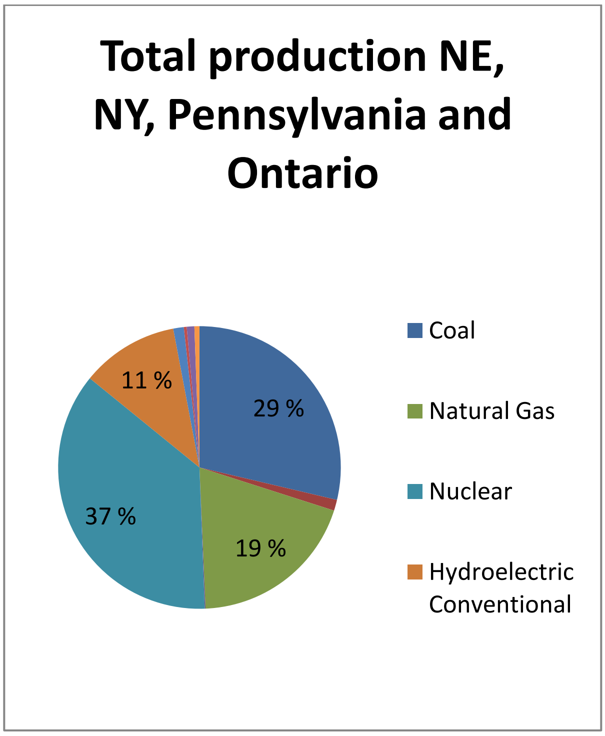


Figure 3.4a Production New England

Figure 3.4b [69] Total production

As in most other electricity markets coal, natural gas and nuclear dominate the supply situation. Hydropower is used wherever available and the use of petroleum based plants cover a small amount of total production to fill demand in peak hours. For us, it is very interesting to see which production method that sets the market price in the area. This can theoretically give us an estimated spot price in a future integrated market. To be able to calculate this price, we need to have knowledge of prices of fossil fuels and efficiency of generation methods. If we remember the merit load curve, it shows that production from natural gas is the marginal source of electricity. The curve in figure 1.4 is transferable to the market northeast in the U.S. today. For the last 15-20 years, natural gas has been the marginal source of electricity in the northeast. During these years, no new nuclear or coal facilities has been built in New England. This situation has developed since natural gas was cheap during the 1990's and since natural gas is known as a relatively clean and efficient energy source compared to coal. The nuclear technology has its own environmental problems. From figure 1.3 we identify two peaks in the price of natural gas during the 2000

[69] Number are gathered from EIA, Net Generation by State by Type of Producer by Energy Source (EIA-906) and Ontario Power Authority, Supply Mix Advice Report, 2005

decade. The price is now back on a medium level, and it is expected to stay fairly low due to new technology development of shale gas.

In the following tables we have done estimates on the future electricity generation price from gas in the northeast of USA, based on price data from the U.S. Energy Information Administration and efficiency levels are gathered from the U.S. National Petroleum Council. We chose to make three scenarios, which represents a low, medium and high price development of the input fuel. This approach will later also be taken for coal. These estimates are very useful, and will be the base for further calculations in this thesis.

Gas Scenarios Northeast of USA	Natural Gas Electric Power Price USD/mmBTU		
Gas USD per kWh	Low 4 USD	Medium 7 USD	High 10 USD
NGCC 52% efficiency 6500 BTU/kWh	0,026	0,046	0,065
CT 34% efficiency 10000 BTU/kWh	0,040	0,070	0,100

*NGCC - Natural Gas Combined Cycle[70]
*CT - Combustion Turbine

Table 3.3 71 Gas scenarios

The scenarios fit well with the highs and lows of natural gas price seen the last 15 years. The price per mmBTU has varied from just above 2 USD to almost 10 USD per mmBTU. When discussing natural gas, we divide into conventional and unconventional gas types. Conventional gas as we know it primarily consists of methane. Conventional gas is fairly easy and economically profitable to extract. Unconventional gas is defined as gases that are expensive and hard to extract. New technologies influence these qualifications, and what is unprofitable today can be profitable tomorrow. The last couple of years the exploration of shale gas has experienced a rapid growth due to developments in the technology. The northeast of the U.S. is an area with especially large deposits and some of these reservoirs cost less or the same to explore as conventional natural gas. This supports our estimates and makes it reasonable to believe that access to gas for electricity generation will remain at the same level for the near future and dominate the power supply in the northeast of the U.S.

[70] NGCC uses a gas turbine to generate electricity and the waste heat creates steam that runs another turbine so overall efficiency is increased compared to combustion turbines which extracts energy from gas only.
[71] National Petroleum Council, Electric Generation Efficiency, 2007 and EIA Natural Gas overview

Coal prices used for electricity generation vary quite much from state to state and plant to plant. Some plants have old contracts, which enable them to buy coal very cheap. This can especially be seen in the mid-western states of USA, where cost can be as low as 1.50 USD/mmBTU. In the northeast of USA where we have our focus, prices tend to be higher than the U.S. average. The reason for that is that more of the procurement happens on the spot market, where a market price applies. Coal production is more expensive on the east coast of USA, where coal is mainly produced from underground mines. This is naturally more expensive to extract than surface mines. High transportation costs from other supply areas, makes the price on the north-east cost easily as high as 3 to 4 USD/mmBTU. Much of New Jersey's demand is actually based on imported coal, which raises the price and gives New Jersey some of the highest coal prices in USA. As for natural gas, we have chosen to make three scenarios with a low, medium and high price. The price levels are chosen on the basis of U.S. Energy Information Administration (EIA) historical data and outlook for the future.

Coal Scenarios Northeast of USA	Coal Electric Power Price USD/mmBTU		
Coal USD per kWh	Low 2,5 USD	Medium 3,5 USD	High 4,5 USD
High efficiency 44% - 7700 BTU/kWh	0,019	0,027	0,035
Low efficiency 37% - 9275 BTU/kWh	0,023	0,032	0,042

Table 3.4 [72] Coal scenarios

Recent numbers released from EIA support the numbers in the scenario analysis. Average cost of coal delivered for electricity generation in New England January 2010 was 3.32 USD/mmBTU. This is up four percent from 3.19 January last year, while the same price for natural gas was 7.87 and 8.48 USD/mmBTU respectively[73]. The figure under shows us the average fuel cost price for the entire USA for 1997-2008. This also supports both our low and high price scenarios. Even though the low price has not been seen in over ten years and the high price represents the most recent peak that ended with the financial crisis, it shows that the numbers we have chosen describe the scenarios to their extreme points.

[72] National Petroleum Council, Electric Generation Efficiency, 2007 and EIA, Coal overview
[73] EIA, Receipts, Average Cost and Quality of Fossil Fuels Table 4.13.A. and 4.10.A.

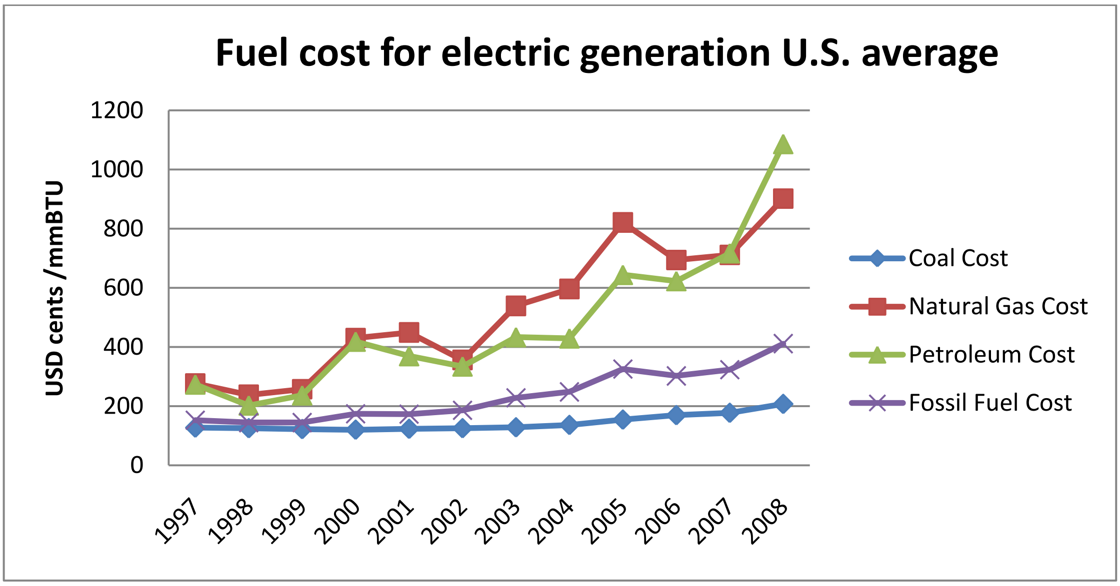


Figure 3.5 [74] Fuel cost

The marginal cost prices correlate well with the wholesale prices on the NEPOOL which is the electricity exchange in the New England area. Below is the wholesale prices shown for the last decade.

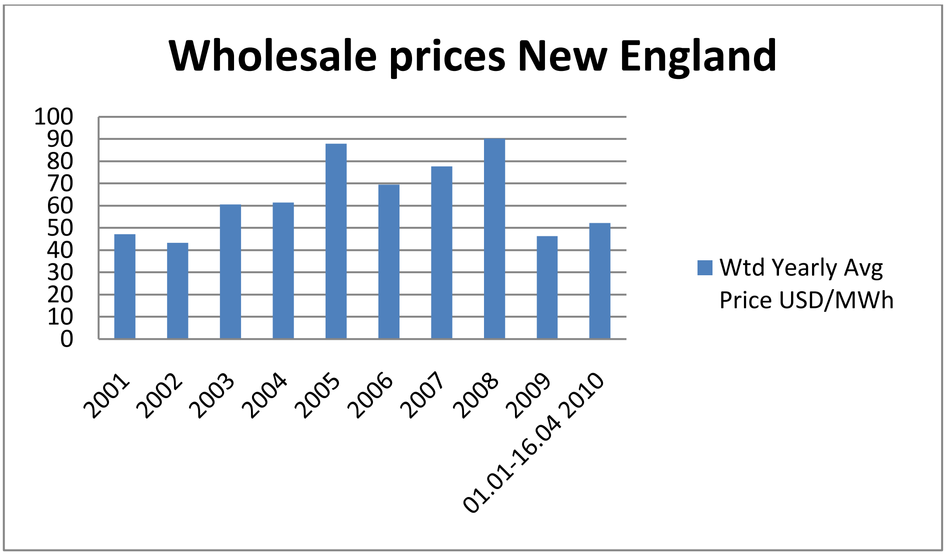


Figure 3.6 [75] Wholesale prices

We want to compare wholesale prices to the price on natural gas since it is the price setter. We therefore compare this chart to the graph showing developments in the price of natural gas delivered for electric generation in figure 1.3. We recognize that they seem to correlate

[74] EIA, figure data from ES 4 Fuel cost for electricity generation
[75] EIA, Wholesale Market Data NEPOOL wholesale prices 2001-2010

and follow the same trend. Figure 3.6 show that a rising trend in wholesale prices appeared the last decade, with 2005 as an exceptional year due to high fossil fuel prices. Economic situation, falling demand, drop in fossil fuel prices and new technologies prices led to the drop in 2009. On NEPOOL in January 2010 the average wholesale price was 6.60 USD cents per kWh[76]. As a comparison, the average cost of natural gas delivered for electricity generation was 7.87 USD USD/mmBTU, which gives a production cost of 5.12 cents at our NGCC plant. This still fits well with our scenarios when we know that not all plants for the moment have an efficiency level as low as 6500BTU/kWh, combustion turbines with lower efficiency will be used during certain hours with peak demand and that wholesale prices in reality are somewhat higher than the absolute marginal cost.

3.2.1 Theoretical wholesale prices

If we compare the wholesale prices in New England the last five years to the price Hydro-Québec receives for electricity sales outside Québec in table 3.2, we see that the price Hydro-Québec receives is somewhat higher. This can indicate that Hydro-Québec sells electricity in peak hours where the price is higher, as we anticipated in theory subsection 1.4.8 where we discussed advantageous characteristics of hydropower production. But in the same table (3.2) we just saw that the more Hydro-Québec exports, the lower gets the average price received per kWh from their own production. For the simplicity for further calculations though, we assume that the price Hydro-Québec will receive in an integrated wholesale market, is similar to the average wholesale price. To compensate for this assumption, we have chosen to make the wholesale average price estimates somewhat higher, so we can better display Hydro-Québec's income potential. We also assume that these wholesale prices are not including a price of CO_2 allowances. We can do this because of the uncertainty of the estimates and the current small size of the RGGI allowance price, which will be elaborated as an own topic in the next section. The following table gives an estimation of how the wholesale price received by Hydro-Québec would look like under the three scenarios where natural gas is price setter.

[76] EIA, NEPOOL wholesale prices 2010

Gas Scenarios Northeast of USA	Natural Gas Electric Power Price USD/mmBTU		
Average Wholesale Prices	Low 4 USD	Medium 7 USD	High 10 USD
USD per kWh	0,030	0,060	0,080

Table 3.5 Average wholesale prices gas based

As we have seen, many factors can influence average wholesale prices of electricity. One possibility behind the numbers we have reached above is that by high fossil fuel prices the economy is strong and creates a high demand for electricity. Hence more expensive production methods must be taken into use. The opposite is the case when demand is low and we can experience lower prices. This situation we have experienced the last two years.

We need to assume theoretical wholesale prices for coal as well. The efficiency range between plants is smaller for coal. Since coal is a cheaper production method than natural gas, the least efficient coal plants should be turned off after all natural gas plants in low demand periods if we only look at the fossil fuel cost aspect. Therefore the least efficient plant should reflect the coal average wholesale price. But on the other side, since there is much focus on making the coal technology cleaner, we assume that wholesale prices on NEPOOL in the time to come would converge towards the most efficient technology. We therefore ended up with the following three scenarios for the average wholesale price, if coal was price setter.

Coal scenarios Northeast of USA	Coal Electric Power Price USD/mmBTU		
Average Wholesale Prices	Low 2,5 USD	Medium 3,5 USD	High 4,5 USD
USD per kWh	0,020	0,029	0,038

Table 3.6 Average wholesale prices coal based

Many unclear factors have the ability to influence fossil fuel prices in the future. When determining the three scenarios we have chosen to base our prices on a relative short time frame. If we were about to predict the future 30-40 years ahead, uncertainty grows. We believe fossil fuel prices will increase together with its scarcity. Predictions from EIA estimate the prices of coal and natural gas to rise in size of 30 to 50 percent within 2030 from 2010 levels[77]. This will naturally have a significant impact on the electricity prices.

We remember from 2.7.5 that in Norway, coal is the price setter around 60-70 % of the time. Based on the interconnection capacity, such numbers would also be reasonable to expect for natural gas from USA in Québec. This means that Hydro-Québec would offer lower prices in Québec 30 to 40 percent of the time, since supply of water is larger than the capacity in the transmission grid. But similar to Norway, when there is undersupply, transmission restrictions will sometimes lead a higher area price than the spot price in the market, due to the fact that the marginal opportunity cost is higher. Québec customers would need to pay the higher price during these times. Subsection 3.1.2 discussed how Hydro-Québec in such bottleneck periods could exercise market power, but also suggested a solution to the problem. The domestic market would maybe not be as competition oriented as in Norway, but this is the price to pay for keeping Hydro-Québec in its present form. For the previous and following calculations we will for simplicity assume that the excess price paid by Québec customers in undersupply periods equal the lower price paid in oversupply periods. By doing this, we can assume the same price in each scenario. Despite the uncertainty, we have created some suitable estimates that we believe adequately represent the situation for Hydro-Québec today.

3.3 Revenues from an integrated market with emission trading schemes

Today there is no trading scheme like the ETS in place in North-America. As one of few industrialized countries, USA has not yet accepted the Kyoto Protocol. For the moment there is doubt if a new climate deal will come in place for the period after 2012 when the Kyoto Protocol expires. Much responsibility lies on the participants attending the climate summit meeting in Mexico later this year. Uncertainty arises if USA this time will accept a prospective new protocol. USA is critical to emission cuts they would have to go through with, compared to other large nations and especially the world's largest polluter China. But chances are that we will see a change in direction from the U.S. regarding their environmental politics. It seems as President Barack Obama is more concerned about climate challenge than his predecessors. In a speech Obama held when he was the President

[77] EIA, Annual Energy Outlook, 2008

Elect, he said that the U.S. would develop strong annual targets on emission reductions, in order to reduce emissions to 1990 levels by 2020 and an additional 80 percent within 2050. In the same speech he supports a 15 billion USD per year investments in renewable energy technologies. This is supposed to reduce emissions coming from the second largest polluter, and boost the green industry in USA[78]. Last year the U.S. Congress established a bill that will make major electric suppliers raise its renewable energy share to at least 20 percent within 2020. The bill is called the American Clean Energy and Security Act of 2009 and can be seen as a cap and trade regulation. For the moment the act is only considering the electric industry, and is yet to be accepted by the Senate. A possible acceptance is positive for Hydro-Québec which sees a possible growth in both exports and market prices. This change in policy direction from the U.S., gives hope that a new climate deal also will include USA and create a market similar to the ETS where polluting industries must pay for their emissions in North-America as well. A global problem needs a global solution.

Although a domestic initiative on emission allowances are not taken in the U.S., positive movements have been made in some regions. Québec is a partner in the Western Climate Initiative which mission is to reduce greenhouse gases. Western states of the U.S. and five Canadian provinces are participating. One effort is to introduce a cap and trade program. The program is still under construction and is not yet valid. For Québec as an electricity producer, it is more interesting to look to the east where they have interconnections for exporting electricity. The Northeastern and Mid-Atlantic States have created something called the Regional Greenhouse Gas Initiative (RGGI) which is the first mandatory and market based initiative in the U.S. to reduce greenhouse gases. The first compliance period is 2009-2011. The RGGI covers fossil fuel fired power plants with a capacity of 25 MW or more, which in total affects about 225 facilities region-wide. Its main target is to reduce CO2 emissions from the power industry by 10 percent from 2009 levels by 2018. This effort, together with an optimistic view of a new climate deal where the U.S. hopefully will participate, makes us believe that there can be economic benefits for Hydro-Québec in the same way as the ETS has led to higher energy prices in Europe. As we have seen earlier, this extra cost for the marginal producer of electricity which is based on fossil fuels, will increase the market price of electricity and make producers of hydroelectricity earn windfall profits.

[78] change.cov, A new chapter on climate change

Figure 3.7 [79] Clearing prices RGGI

Figure 3.7 shows the development in the RGGI CO2 allowance price. The price seems to stabilize on a price of as low as 2 USD/Short Ton, which turned into EUR and metric tons means a price of 1.65 EUR/Ton. This is only about 1/10 of the prices experienced in the EU and ETS today. We need to ask ourselves why the difference is that large. One major reason is that the reduction demand is only 10 percent of 2009 levels compared to 20 percent of 1990 levels in the ETS program. The marginal cost of emission reductions is much cheaper in the first parts of the marginal cost of abatement curve as seen in figure 1.9 due to the exponential shape of the curve. Offsets are also possible to a certain extend in the RGGI market, which means power producers can reduce their emissions in other sectors than the power industry. This helps keeping the MCA curve low at the beginning. It is reasonable to claim that too many allowances have been released on the market and the abatement cost of emission reductions seems to have been overestimated. We may see some price volatility in the end of the first period in 2011, due to the continuously quota auctions. But RGGI learned from the largest ETS mistake, and allowed banking of allowances to future periods. This will reduce price volatility and avoid bottom prices. Another reason is that much of the electricity production in the New England area now comes from natural gas plants. Since coal emits more CO2 than gas per kWh, reductions can be made when shifting production method from coal to natural gas. We have seen in New England during the last 15-20 years

[79] RGGI, Auction Results

that coal plants have been replaced by natural gas plants. Natural gas has been a preferred method as it demands a low capital cost, has a short approval and construction period and has high energy efficiency with the modern technology. New natural gas plants have emissions about 35 percent lower than a traditional natural gas plant with a combustion turbine. Nuclear generation has not been popular since some incidents in the 1970's and 80's. These factors together with the economic downtimes experienced since 2008 makes the RGGI CO2 allowance price that low. Since demand has lowered, the need for allowances has decreased as well.

With the price of CO2 allowances in New England today, the cap and trade program would not lead to substantial income for a hydroelectricity generator, the impact on the electricity price will be marginal. But there are reasons to believe that the price of CO2 allowances will increase in the time to come. If USA shall reach future climate goals, a well functioning carbon market is an absolute necessity. Point Carbon, an environment analyst company, estimates that a nationwide cap and trade program will result in a carbon price of around 13 USD/Ton in 2012 with an increase to 16.50 USD in 2020 as a result of fewer allowances available in the market[80]. McKinsey assumes a somewhat higher price of 16 Euro/Ton in the U.S. and explains the price difference with the EU as different offset policies[81]. If the criterions from the suggested American Clean Energy and Security Act of 2009 are accepted we will see this scenario, but offset regulations will be somewhat less strict than what the ETS must fulfill. The price is therefore anticipated to be a bit lower than in the EU.

Since we want to estimate the future revenue potential from CO2 allowances for Hydro-Québec, we find it natural to follow the same approach as before by making three scenarios for the price of CO2 emissions. We base our estimates on the knowledge we have from RGGI and ETS prices today together with the future estimates we have seen above.

[80] Point Carbon, A new chapter on climate change
[81] McKinsey & Co, A new look at carbon offsets

CO2 Allowances Scenarios	Low Price USD	Medium Price USD	High Price USD
USD per metric Ton	2,00	15,00	40,00

Table 3.7 CO2 allowances prices

Behind these estimates there are several assumptions. In the lower price, business as usual is assumed and prices are the same as in the RGGI program today. If the Clean Energy and Security Act is accepted, it is reasonable to believe that a price of 15 USD can occur immediately. The Act suggests a minimum price of 10 USD and combined with analysis shown above, we assume 15 USD to be a good medium price estimate. A price of 40 USD in the high price scenario is based on expectations of the ETS prices in the future together with historical prices seen in the ETS. The scenarios may be inexact, but they will be able to give us an understanding of how Hydro-Québec may benefit from CO2 quota prices in the time to come. We therefore need to calculate how much the price of emission allowances will influence the price per kWh.

Step one is to find out how much CO2 is emitted per kWh for each production method. A study from the US Department of Energy from 1999 states that the New England average is 879 gram CO2/kWh for coal and 551 gram CO2/kWh for natural gas[82]. During the last ten years much focus has been directed to lower these limits. Recent numbers from the International Energy Agency (IEA) and EIA makes us believe that these location specific numbers are lower today[83]. On basis of these three studies we have created estimates where we assume emissions to be 375 gram CO2/kWh for natural gas and 800 gram CO2/kWh for coal. We now interpret these results in the previous table.

CO2 Allowances Scenarios	Low Price USD	Medium Price USD	High Price USD
USD per metric Ton	2,00	15,00	40,00
CO2 tax/kWh Coal	0,00160	0,01200	0,03200
CO2 tax/kWh Gas	0,00075	0,00563	0,01500

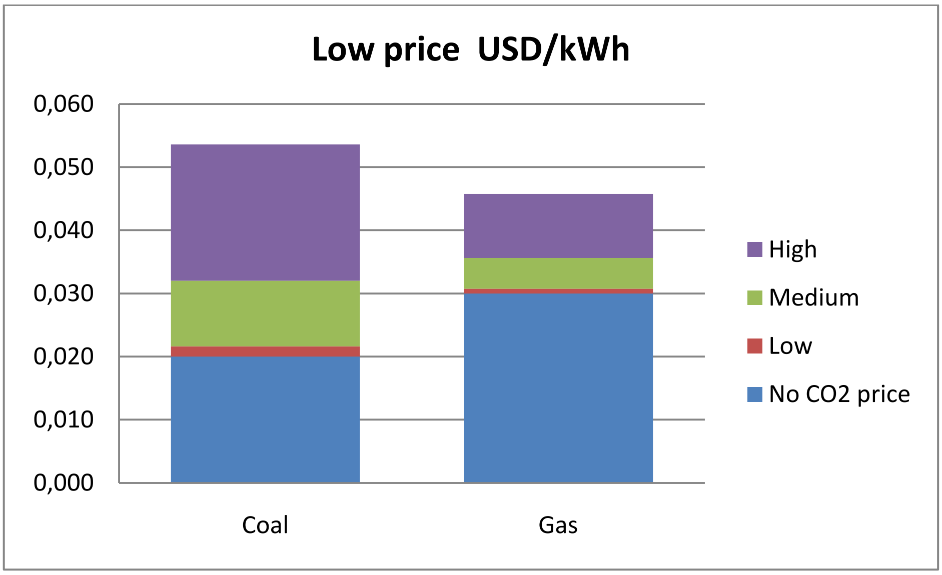
Table 3.8 CO2 allowance scenarios

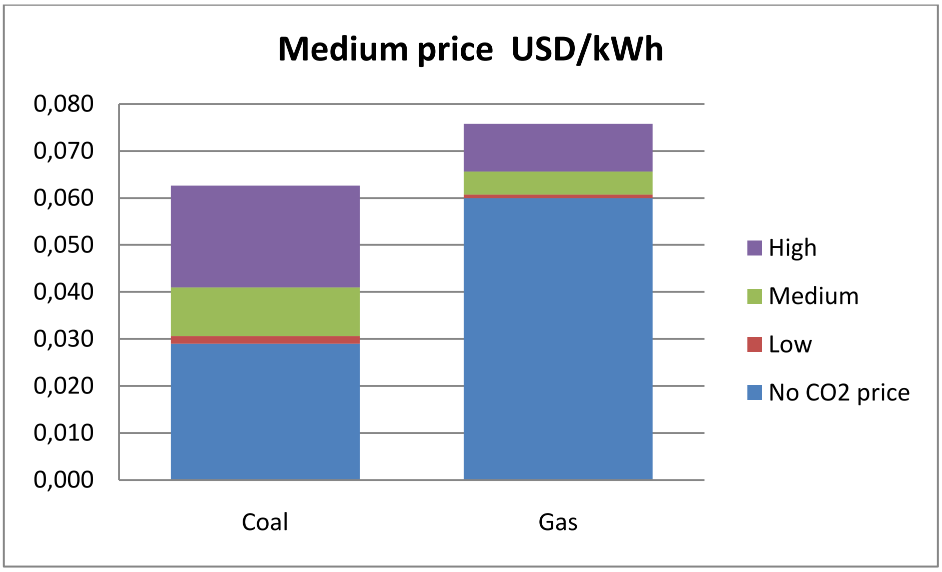
[82] U.S. Dep of Energy, Carbon Dioxide Emissions from Generation of Electric Power in the United States, 2000
[83] IEA CO2 emissions form fuel combustions 2009 Highlights
and EIA, Voluntary reporting of greenhouse gases program fuel and energy source codes and emission coefficients

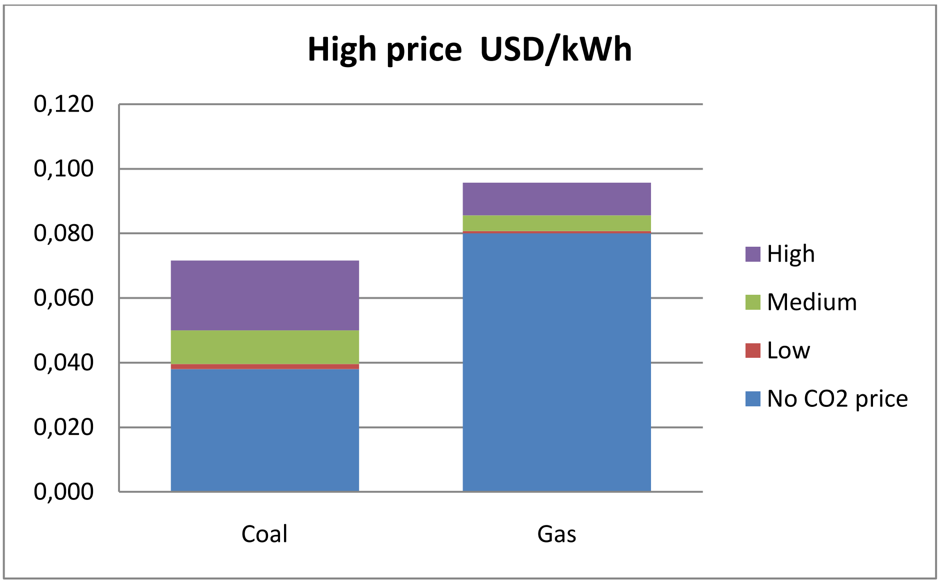
What does this table show us? Most importantly it shows that a low allowance price will hardly affect the electricity price at all. It also shows that the price increase of producing coal will be more expensive relatively to producing from natural gas. Since natural gas is price setter in the northeastern part of USA today, it is therefore interesting to research whether coal ever will turn out to be a more expensive production method.

For the following figures, we base our calculation on the average wholesale prices. Some may argue that it would be better to focus on the natural gas and coal scenario prices, which are somewhat lower and tells us the marginal cost of generation. But in an integrated wholesale market, the wholesale price is the one interesting for a market participant. The wholesale represents better the price Hydro-Québec can expect on a power exchange. If we compare the last year's wholesale prices to the average export price received by Hydro-Québec, it confirms our reasoning. The following figures present the low, medium and high average wholesale price scenarios with four different scenarios for the CO2 allowance price. This gives us average wholesale prices including the price of CO2 allowances. The figures assume that the fossil fuel scenario is the same for both natural gas and coal in each scenario.

Figure 3.8 Low medium and high average wholesale prices with four CO2 scenarios.


Low price USD/kWh
0,060
0,050
0,040
0,030
0,020
0,010
0,000
Coal
Gas
High
Medium
Low
No CO2 price


Medium price USD/kWh
0,080
0,070
0,060
0,050
0,040
0,030
0,020
0,010
0,000
Coal
Gas
High
Medium
Low
No CO2 price


High price USD/kWh
0,120
0,100
0,080
0,060
0,040
0,020
0,000
Coal
Gas
High
Medium
Low
No CO2 price

As we see from these figures, natural gas will still be the price setter in almost all scenarios. Coal will only take over as a price setter with low fossil fuel and high CO2 allowance prices. The price of natural gas is too high relative to coal, for coal to be a more expensive generation method. These figures do not include the fact that price levels of coal and natural gas may be different. A medium price of coal and low price of natural gas could easily occur, and coal would then be price setter in the market at medium and high CO2 quota prices. It would be too comprehensive to make figures of all scenarios, but all scenarios are summarized in the following table.

Average Wholesale Prices with CO2 Allowance Scenarios USD per kWh		Fossil fuel prices					
		Low		Medium		High	
		Coal	Gas	Coal	Gas	Coal	Gas
CO2 allowance price	No CO2 price	0,0200	0,0300	0,0290	0,0600	0,0380	0,0800
	Low	0,0216	0,0308	0,0306	0,0608	0,0396	0,0808
	Medium	0,0320	0,0356	0,0410	0,0656	0,0500	0,0856
	High	0,0520	0,0450	0,0610	0,0750	0,0700	0,0950

Table 3.9 Average wholesale prices with CO2 allowance scenarios

If a medium or high price on both CO2 allowances and fossil fuel occurs, the situation for Hydro-Québec will turn very favorable. The table shows how much the average wholesale price inclusive CO2 allowance per kWh will be in each scenario. Since the most expensive electricity offered decides the market price, hydropower will sell their supply at the same price and producers will experience windfall profits. We have seen in earlier sections that the end consumers in an open market are the ones ending up with the bill for the increased prices due to the introduction of CO2 allowances. Hydro-Québec would therefore earn more on export sales, and the surplus redistribution from domestic customers would become even larger if Québec abandoned the Heritage Pool policy. Since Hydro-Québec is owned by the provincial government, this can be turned into something positive for the inhabitants of Québec. The extra income surplus redistribution will namely be redistributed to the province either as dividends or company taxes.

3.4 Energy efficiency

Higher prices in the province of Québec would mean higher revenues for Hydro-Québec. The surplus would be transferred from the customer to Hydro-Québec and its owner, the province of Québec. This would be a change in consumer to producer surplus. Regarding energy efficiency, the yellow triangle in figure 1.5 represents the welfare loss due to today's market design. It is very hard to determine what a change in the price from being regulated to being decided from a market, would have to say on the consumption of electricity in Québec. In subsection 1.4.3 we saw some numbers from studies that have been done. These studies vary significantly, and the results are only valid within a certain range. If we assume that electricity prices would double, these numbers would make less sense. Elasticities are only valid for smaller intervals where they can be considered as linear. When changes in price are as large as the one experienced in our case, we can no longer assume that demand will follow a linear curve. In a discussion with Professor Jean-Thomas Bernard, we discussed different scenarios regarding energy efficiency in Québec[84]. We choose to base our upcoming efficiency scenarios on this knowledge, together with knowledge from the elasticity studies.

Hydro-Québec is central in the province's work to reduce energy consumption and improve energy efficiency. The Hydro-Québec incentives should have been highlighted well in this thesis. For residential consumers a row of measures are taken to reduce electricity consumption. We can recognize several efforts also being present in Norway. The focus lies on making residential customers aware of their energy use and get them to consume energy wisely in their homes. Campaigns for investing in new refrigerators, efficient lighting bulbs, swimming pool timers and energy efficient windows and doors are extracts from efforts taken. Supporting subventions are offered to new houses installing geothermal energy. For business customers other measures apply, as for example programs for building optimization and improvement of industrial systems. In total Hydro-Québec has a goal of reaching 11 TWh in improved energy efficiency by 2015. This is our efficiency scenario number one, which we call *business as usual*.

Scenario number two takes into account measures suggested throughout this thesis. An integrated market for electricity is able to be established in the region and the price for electricity will increase as it is decided by the market. In this scenario though, only residential households plus small and medium businesses are affected. The power intensive industry is not included. Around 100 TWh per year will be affected by a price increase. The

[84] Meeting with Bernard, Université Laval, 2010

government still controls prices offered to large power users in the industry. The paper & pulp together with the large aluminum industry represents the large power classification. We call this scenario the *regulated restructuring.*

The third and last scenario is the *total restructuring* scenario. In this scenario all market participants must pay the market price for the electricity demanded. What separates this scenario from scenario number two is that around 60 TWh of power intensive industry is affected. Around 270 Hydro-Québec customers fall into this classification. The aluminum industry in Québec demands around 50 TWh yearly. Together with the paper and pulp industry we make an estimate that around 60 TWh belongs to industries that are heavily subsidized by the provincial government. This is approximately one third of the Québec's electricity demand. Table 1.5 showed that these actors today pay a flat rate of 2.99 cents per kWh for the *energy* consumed. If we hold the additional *power* capacity charges outside, which also covers transmission and distribution charge for this customer group, the price per kWh is just above the heritage pool price of 2.79 cents. The low electricity prices for this customer group have been an intentional choice by the politicians in Québec to attract these industries and secure jobs for the people. The politicians saw a possibility to take advantage of the hydro resources. Bernard is one of the most known critics against this policy. Since new power plants now are so costly to exploit, a price based on average cost of production leads to the fact that new development of supply sources are heavily subsidized by the government. Bernard and Belanger estimate that a position at a new developed aluminum plant is supported by an indirect subsidy in the range of 255,351 and 729,653 dollars per permanent job per year[85]. Their calculations say that Québec would be much better off exporting the electricity at market price than selling it cheap to energy intensive industry.

Our assumption in the *total restructuring* scenario of a single market price for the whole energy intensive industry in Québec may not be very likely for the moment. The industries have a traditional strong position within the province, and the labor unions have a strong political influence. Facilitating for industry is an important part of the province's district population policy. A more reasonable assumption could be that electricity prices for heavy users could be rising together with the amount demanded. For example the first 30 TWh could be cheap and then the price could be increasing. But allocation problems would then

[85] Belanger and Bernard, Cout Economique de l'electricite vendue aux nouvelles alumineries, 2008

arise. Who gets the first 30 TWh? Is it equally divided? Will the existing participants get access to this pool first? This will lead to entry problems for new plants and a distortion of competition. To avoid these complicated issues and to be able to show the case to its extreme, we choose to assume that all market participants must pay the market price in our third scenario.

3.5 Income calculations

We have so far in this thesis made scenarios of both future fossil fuel prices and CO2 scenarios. These were merged into average wholesale prices with CO2 allowances scenarios in table 3.9. We will choose three out of these scenarios for further use in the calculations of possible revenues for Hydro-Québec and the province. These scenarios should represent a low income, medium income and high income possibility for Hydro-Québec. This will represent a broad and relevant analysis of our scenarios. We assume that electricity consumption saved in Québec can be exported to the U.S. at market price.

- The first scenario chosen is average wholesale prices and a low price on CO2 allowances. CO2 prices in the RGGI are at this level today and low average wholesale prices have been seen and can occur again. The expected average wholesale price inclusive CO2 allowances will therefore be as low as 3.08 cents/kWh.
- The second marginal cost scenario is maybe the most likely to happen in the time to come. This scenario expects a medium allowance and wholesale price, which means a wholesale price inclusive CO2 quota of 6.56 cents/kWh.
- To show the extreme case, a high price on both variables is chosen in the third scenario. As of now, a high CO2 price may seem unlikely, but it shows an interesting result. High wholesale prices have been seen recently, and can easily happen in the future. Price is as high as 9.50 cents/kWh.

In contrary to oil deposits, hydro power resources are infinite. It is a part of the natural circular movement and will create income for Québec continuously. The NPV rows therefore represent the value of the water and hydro dam assets. We assume a required return of 7.5 percent. The inflation rate is set at 2 percent on the basis of Canadian inflation numbers from the last 20 years.

Scenario *business as usual* is quite easy to calculate. The efficiency gains from efforts to reduce domestic demand can be assumed exported to higher prices.

Please note that the numbers in square brackets are in cents. Ex. (3.08 cents - 2.79 cents).

1) Business as usual	Low	Medium	High
Efficiency Calculations	11 TWh x (3,08-2,79)	11 Twh x (6,56-2,79)	11 TWh x (9,50-2,79)
Result	$ 31,9 Million/year	$ 414,7 Million/year	$ 738,1 Million/year
NPV	$ 0,58 Billion	$ 7,54 Billion	$ 13,42 Billion

Table 3.10 1) Business as usual

Even a relatively small effort to reduce domestic consumption can have large consequences. Depending on the market price, Québec can estimate new income from exports in the range of 31.9 million to as much as 738 million per year. Remembering that 2009 exports were 23 TWh and it brought in 1.495 Million that counted for as much as 22 % of the net income for the Hydro-Québec group, we clearly see the business improvement potential if fossil fuel prices stay on a decent level.

Scenario *regulated restructuring* builds on the first scenario and includes the 11 TWh Hydro-Québec efficiency efforts, but now residential customers will have to pay market price on their electricity consumption. A price increase will naturally lead to less demand, and the reductions in domestic electricity use can be exported. Bernard estimates the long term elasticity to be around -0.4 to -0.5, but believes this number can be underestimated[86]. Some of the estimates from section 1.4.3 are also in this interval. We claim that as long as the electricity is cheaper or the same price as the closest substitute, natural gas for residential use, we will see small amounts of energy type substitution. A substitution will demand costly investments in equipment. Since fuel prices are the same or most probably higher for private actors than large electric utilities, it will not be profitable. Reduction in demand will therefore come from energy efficiency and savings alone. Just as for marginal abatement cost of emissions, the first energy reductions will be the easiest ones to make. Before looking into scenario 2, we therefore need to estimate some reductions of consumption based on our low, medium and high wholesale price scenarios.

[86] Meeting with Bernard, Université Laval, 2010

We saw in subsection 1.5.1 that the average price by households and farmers was 6.2 cents/kWh. If we assume that the same average transmission and distribution cost of about 3.4 cents (6.2 minus 2.79 cents from the Heritage Pool) applies, we can use elasticity estimates to find out the reductions. We assume that these costs will stay the same and occur in every case for all sectors. This may be a rough assumption, especially for medium business customers. But because of the overall relative large elasticity uncertainty, we assume an elasticity of -0.4 for all 100 TWh to ease our calculations.

Consumption reductions	New end-consumer price			Price increase	Elasticity assumption	Reduction		Adjustment
Low	6.20+(3.08-2.79)	=	6,49	5 %	0,4	2 %	→	2 %
Medium	6.20+(6.56-2.79)	=	9,97	61 %	0,4	24 %	→	20 %
High	6.20+(9.50-2.79)	=	12,91	108 %	0,4	43 %	→	35 %

Table 3.11 Consumption reductions

We choose to adjust the reduction to somewhat lower levels in the medium and high case as we believe the reductions will be harder and more costly to accomplish. The numbers are used to see whether a transformation of consumer to producer surplus or efficiency improvement finds place. We implement our adjusted reduction numbers in our energy efficiency scenarios.

2) Regulated restructuring	Low	Medium	High
Efficiency Calculations	100 TWh x 2%	100 TWh x 20%	100 Twh x 35%
Export Sales Cal.	2 TWh x (3,08-2,79)	20 TWh x (6,56-2,79)	35 TWh x (9,50-2,79)
Domestic Sales Cal.	98 TWh x (3,08-2,79)	80 TWh x (6,56-2,79)	65 TWh x (9,50-2,79)
Result Export	$ 5,8 Million	$ 754 Million	$ 2348,5 Million
Result Domestic	$ 284,2 Million	$ 3 016 Million	$ 4361,5 Million
From 1)	$ 31,9 Million	$ 414,7 Million	$ 738,1 Million
Total	$ 321,1 Million/year	$ 4184,7 Million/year	$ 7448,1 Million/year
NPV	$ 5,8 Billion	$ 76,1 Billion	$ 135,4 Billion

Table 3.12 2) Regulated restructuring

The energy reduction in Québec is exported to the U.S. and represents the efficiency improvement. The Result Domestic represents the change from consumer to producer surplus. The surplus has clearly gone from the people to the government. Since Hydro-Québec is owned by the province, this will benefit the inhabitants of Québec. The lowest price scenario will barely have any impact, but we recognize that the numbers are significant for the medium and high wholesale price scenarios. We believe our most likely scenario for the future is somewhere in excess of the medium scenario. This makes a net present value of approximately 75-85 billion dollars for the regulated restructuring. If we add this amount with the net income around 3 billion per year that Hydro-Québec generates today, we get a market value of the company around 130-140 billion. This correlates well with other estimates that have been made[87].

Total restructuring will lead to the most radical changes. With this market design, the energy intensive industries in Québec would lose their competitive advantage with medium or high average wholesale prices. They would then probably find other locations to produce their goods. The following calculations do not include the economic contribution the industries create in Québec. A complete research would include contributions as for example, company and employee taxes, the industries business with other Québec companies and the general economic activity the industries create in their area. Alcoa only, a large aluminum company which has 3600 employees and nine aluminum plants in Québec, estimates their total economic generation in Québec to be around 1.5 Billion per year[88]. Unfortunately, a complete research is out of scope for this thesis. We are satisfied with showing the value of Hydro-Québec's hydropower assets. But we keep in mind that Bernard and Belanger states that every new job in the aluminum industry is heavily subsidized. The solution is probably somewhere in between.

Large industrial users pay 2.99 cents for their electricity. Only 20 cents of the price is supposed to cover transmission and distribution cost. The additional is covered by the *power* cost. It is therefore relevant to make three average wholesale scenarios with the Heritage Pool price also in this scenario.

3) Total restructuring	Low	Medium	High
Efficiency Calculations	60 TWh x (3,08-2,79)	60 TWh x (6,56-2,79)	60 TWh x (9,50-2,79)
Result	$ 174 Million	$ 2262 Million	$ 4026 Million
From 1) and 2)	$ 321,9 Million	$ 4184,7 Million	$ 7448,1 Million
Total	$ 495,9 Million/year	$ 6446,7 Million/year	$ 11474,1 Million/year
NPV	$ 9,0 Billion	$ 117,2 Billion	$ 208,6 Billion

Table 3.13 3) Total restructuring

[87] Montreal Gazette, Privatize Hydro-Québec
[88] Alcoa, Annual Report, 2008

This table illustrates the most extreme scenario of them all. With high fossil fuel and CO2 quota prices, the electricity sales will bring in an additional 11.4 billion per year. We do not believe this is a very realistic scenario in the near future, and we do neither necessarily support efforts that will make the energy intensive industry leave the province. But we believe sound price setting can help secure future energy supply and trigger energy efficiency for both residential and industrial users. How price sensitive the consumers will be also depends greatly on the general economic development of Québec. As we have seen in the case Norway, even though wholesale prices have more than doubled, consumption has increased since the restructuring, thanks to a strong growth in the national economy over the last 20 years. To what extend the plan of electrification of the transportation sector to save on emissions will succeeds, will certainly affect the future domestic demand in Québec. We believe a market price would better reflect such variables, and therefore lead to a more dynamic market for electricity.

The calculations above have their limitations. Many assumptions are made for us to reach the numbers above. Changes in these assumptions can lead to different outcomes. For example, our calculations do not include the cost of expanding the transmission grid. This should have been included when investigating the profitability of the project. A 1250 MW interconnection can easily amount 500 million. The unavailable transmission grid information in the U.S. makes it a tough assignment. We have chosen to exclude such calculations due to the complexity and inaccuracy it would lead to. Large cost must be expected when implementing the whole restructuring process. *Power* charges should possibly also have been taken height for in the calculations, but lack of data access makes this difficult. Although this analysis has its weaknesses, we believe it highlights the situation well by showing different possible revenue scenarios for Hydro-Québec. The exact numbers are not the most important, but to make an understanding of the future possibilities for the Québec electricity market.

3.6 Allocation of rent

If a restructuring found place, the big political issue in Québec would be how to allocate the new income from higher electricity prices. In a society where low electricity prices are preferred to a market price with following tax reductions, that actually could make inhabitants better off is declined, finding a rule of allocation is extremely challenging. The efficiency improvement can in theory make all participants better off. Such a rule is of course not likely to be found, but a rule that makes the majority of voters better off should be targeted. What creates the most resistance against higher electricity prices is the argument that it would lead to an unfair social cost. The low income groups would be more affected than high income groups. Since electricity among many is seen as a basic, human right in Québec, redistribution must preferably ensure that low income groups are not worse off. Several redistribution policies have been launched regarding redistribution. To use the new profits on public expenses as health, infrastructure and education is a good option. Some suggest paying out dividends from Hydro-Québec directly to the inhabitants of Québec and some even an extreme version where Hydro-Québec is divested and the ownership given to the inhabitants. As stated, tax reductions seem not to be a preferred option. We believe Québec can see to Norway also to solve this issue. In the same way as hydropower is a natural fortune in both Québec and Norway, Norway also has very large amounts of offshore oil and gas. Through the last 40 years, this has created an enormous income for the government. In 1990 a governmental sovereign fund was established to administer the fortune. Its target is to keep or increase the value of the original oil fortune as it is transferred to monetary values. The whole idea is that future generations shall enjoy the fortune just as much as the generations today, while the yearly profits can be used in the state budget. In 2006 Québec established a Generations Fund to pay down the public debt of Québec. The idea is similar, future generations should not have to pay for today's fun. We support this idea, and believe this is an acceptable way to manage income from higher electricity prices. Professor Alban D'Amours, former deputy minister of revenue and energy, and president of the public debate panel on energy ahead of the creation of *Regie de l'energie* in 1997, support these thoughts and states that larger income from higher prices should be invested in a long term plan that will benefit future generations[89]. Even though renewable water and fossil fuel resources may not be the best direct comparison, the case of the sovereign fund shows that people are willing to make a sacrifice when their children and future generations are affected. This can be the solution to make Québecers accept a higher price for their electricity.

[89] Meeting with D'Amours, Québec City, 2010

3.7 Financing new capacity in renewable energy for the future

We have now seen how profitable the current electricity capacity can be for the province of Québec. So before ending this thesis, we will explain some of the new trends that exist for creating new capacity in markets today. This capacity can then be used to cover future growth in domestic demand or to be exported. With the low rates experienced today, we have seen that the provincial government must subsidize new generating facilities. The hydropower sites that were easiest to build were utilized first and Bernard estimates the cost of new hydropower facilities in Québec to be in the range of 10¢/kWh[90]. The cost of generating is increasing and the price of electricity should reflect this change. This is what we have argued for throughout this thesis, by saying that electricity prices should reflect the marginal opportunity cost. If the market would decide, the new capacity would be from fossil fuel plants. This is the case since new large scale hydropower sites are expensive to build and wind and solar also demands relative large investments costs per kWh. But since governments wants to increase the percentage of renewable energy they are now supporting renewable energy projects with financial funds. Instead of subsidizing these projects there is a new instrument in the industry that can be used. This instrument will make the market pay and cover the costs for the higher investments cost of renewable energy. Some governments have already taken this instrument in practice. If we remember back to section 2.3, we saw that a market for investments in new production capacities was missing in the restructured Norwegian market. As of today, the Norwegian government is working on a green certificate policy that has been present in Sweden for some time. Green certificates are supposed to encourage investments in clean and renewable energy. Sweden has a target of increasing their production capacity with as much as 17 TWh within 2016 with the help of this policy. New producers of renewable energy are given these green certificates equal to the amount of energy they produce. Governments can then create a regulatory policy which forces distributors of electricity to buy a certain percentage from these suppliers. This will create a price of the limited certificates that the producers hold, and help finance the renewable energy that has a higher long run marginal cost than fossil fuel production. In a functioning wholesale market this would be easy to implement by imposing distributors to buy a certain percent from holders of green certificates. From the

[90] Bernard, New Energy Policy, 2007

commercial and industrial sector we could also assume that a volunteer, individual demand for green certificates could arise. It would be an excellent opportunity for a company to show corporate social responsibility by supporting the green, renewable industry. Deutsche Bahn, the German railway company, is a good example of this. On their website they promote that they offer a CO2 free transportation method as they buy their electricity from green sources[91]. For Québec we believe such green certificates could help the province finance small run-of-river hydro plants, geo-thermal heating, solar and windmill projects. Today the Hydro- Québec mostly agrees long term contracts with small individual producers of electricity through the tender calls process. Instead a subvention of these projects, they should let the market finance these projects by purchasing green certificates. For the development of large hydro sites it is more questionable if green certificates can be used to finance new capacity. There are discussions if large dams are to be considered as environmental friendly due to the impact on the natural river flow. No matter the outcome of these discussions, the development of wind and solar energy in Québec has a great development potential and could take advantage of this policy.

In theory green certificates would work as the CO2 quotas we have discussed in detail earlier. The government sets a cap of how much development that is desired and the certificate price is decided in the market. Alternatively, feed-in tariffs can be used to stimulate renewable production. Especially in Germany this has been a popular measure. Private persons are inspired to invest in small producing units as solar panels on their roofs. If they have surplus in production, this surplus is fed into the grid and the government pays a price for this electricity. In this case, the government decides the price, while the market decides the quantity. As the green certificates were comparable to cap and trade, feed-in tariffs are equal to a taxing policy. These possible efforts and future developments are closely linked to an introduction of smart readers which dynamically measures the energy consumption. For the moment smart readers are considered to be too expensive for the Québec market. Figure 3.9 shows how the electricity price would be influenced by green certificates. The price would be higher and as a consequence more sound capacity could be developed.

[91] Deutsche Bahn, CO2-frei ZUG fahren und Güter transportieren

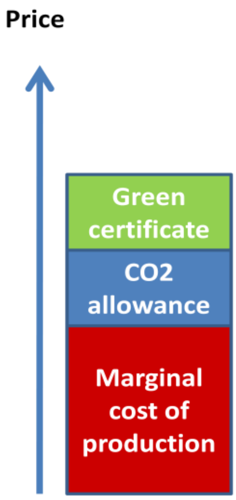


Figure 3.9 Price with CO2 and green certificate

As a matter of fact, the income from CO2 allowances can also be used for investing in green renewable technologies. The RGGI uses the income from CO2 allowances mainly for two purposes. The first is to reduce CO2 emissions and the second is to support a green economy by investing in energy efficiency and renewable energy. We believe that a green certificate policy is useful and would help developing the future capacity needs, secure future electricity supply and decreasing the dependency on fossil fuel in electricity generation. This will also be of current interest for Québec as the province is using more and more of its capacity itself and development needs in new capacity both for domestic usage and exports are present. Green certificates would enable other producers than Hydro-Québec to access the Québec generation market, with the government still having control over a sound environmental development of electric generation, by setting the criterions for certificate allocation. It could also stimulate the development of a new industry where a green and renewable industry is in focus, which would contribute to the Québec economy. When fully developed, we could even experience that the new capacity will lead to a price decrease, as more capacity is available in the market. This depends on how strong the future demand growth will be compared to the capacity offered. We have not had a greater focus on green certificates in this thesis, as we believe the initial problem of the heritage pool must be overcome before this measure could be relevant. But it is indeed an interesting topic for a future research project.

3.8 Problems

In this thesis we have mostly argued for the positive aspects of an integrated market for electricity. We have seen that the price for the end-consumers will increase and they will believe this is negative. But for the economy as a whole, a restructuring is efficient. It is a question of resource allocation if end-consumers will benefit from a restructuring or not. But is it really so that a market price is the perfect solution? C.-K. Woo, Lloyd and Tischler have looked into the restructurings in Alberta, California, Norway and the UK[92]. The case of Norway is considered as a reform success and we have therefore argued for the implementation of a Norwegian market model for a restructuring in Québec. But they also find some negative aspects about the Norwegian restructuring.

The main problem working against the ideas of this thesis are is the limitations in the transmission grid. Throughout this thesis, restrictions in the transmission grid have been seen as a treat to a common market price, and they also see this as one negative aspect of the Norwegian reform. Québec has fairly good interconnections with its neighbor areas, but a single generator in Québec would probably still lead to market power. We are remembering that in Norway there are many generators offering their supply. Limitations in the U.S. transmission grid are also problematic. Expanding the grid in the New England and New York area is very expensive. Around the large cities there is no free land for new grids. This is why New York and Boston experiences the highest residential electricity prices around 25 cents/kWh, even though other cities within the same state pay a much lower price. A better grid will improve efficiency, but the governments need to keep in mind that there is also a limit of how economical efficient a grid update can be. To make an estimation of how much would have to be invested in the grid to make a unified system price is a very hard assignment. It is behind the scope of this thesis, but definitely an interesting problem of discussion and it should be an interesting topic for further research. In this thesis we have assumed that the limitations transmission grid would not make an integrated market impossible, and we have found our motivation for this assumption by looking to the Nordic market.

[92] C.-K. Woo, Lloyd and Tischler, Electricity market reform failures: UK, Norway, Alberta and California, 2003

Woo, Lloyd and Tischler also state that the investment level in new capacity has gone down. We find this natural since Norway had excess capacity before the restructuring, as the case is for Québec today. When prices increase to marginal cost of new generation, we will see expansion in the generation capacity in a market where supply and demand decides the price. Green certificates and CO2 allowances can stimulate green and renewable generation and the overall capacity. This can also help to ease market entry by other generators, which is a problem in regions with hydro based production due to scarcity of rivers. Small scale hydro, windmill, bio-fuels and solar energy are therefore methods of current interest. In general, Woo, Lloyd and Tischler are supporters of the Norwegian market design and consider the many participants on the supply and demand side as positive. This is hard to achieve in Québec, an integrated market in the northeast of the continent is therefore a suggested solution to this problem. For the three other restructured markets, they identify more market failures. Some major critics are the facts that there are too few buyers and sellers in the market, too high price volatility and the market transparency is too small. As a consequence, availability and efficiency of hedging instruments are not the same as at Nord Pool. The hydropower from Québec can stabilize the market price, so less volatility occurs and the market becomes more predictable. We therefore suggest Québec and the other participating states and provinces to adopt the design of Nord Pool which we have thorough presented in this thesis.

4.0 Concluding remarks

4.1 Outlook for the future

Since we started the work on this thesis, some movement has happened in terms of raising the electricity price in Québec. In the end of March the Québec government announced their provincial budget, where the raise of the Heritage Pool price starting in 2014 was the most controversial change. The finance minister announced that the Heritage Pool price would increase with one cent per kWh within 2018 from 2.79 to 3.79 cents/kWh[93]. Low income groups will be protected through a special solidarity tax. The income from this effort is actually meant to be placed in the Generations Fund to help pay down Québec's public debt. The gross debt is currently around 150 billion dollars. It seems as politicians are slowly realizing that new sources of electricity supply are costly. This eventually had to lead to an upward pressure on the prices, as argued for in this thesis. For the time being there are no immediate plans to fully integrate the electricity markets in northeast USA and east Canada. The general economic situation in the world is a negative driver of a restructuring. If the world economy is able to recover and the extensive climate goals are about to reached, the possibility of a restructuring in the future may still have a chance.

4.2 Conclusion

Due to the characteristics of the Norwegian electricity market, it may not be that easy to implement a Nordic market design in other regions. We believe that in this thesis, we have been able to show that the Québec electricity market has a great starting point and is able to learn from the market restructuring in Norway 20 years ago. We believe a restructuring would improve the economic efficiency and benefit current and future generations of Québecers. Our estimates vary between almost zero to around 200 Billion dependent on the outcome of fossil fuel prices, CO2 prices and which restructuring scenario that is chosen. Most likely a restructuring of the Québec electricity market would mean around a 100 billion dollar income for Hydro-Québec and its owner. It is up to the politicians to have the courage to make an unpopular political decision, whether or not Québec can benefit more from their valuable assets and increase the province's income and welfare.

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Democratic Policy Committee

- The Case for a 21st Century Electricity Transmission System
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