REPORT

Interaction Between the EU ETS and the Nordic Electricity Market: Setting the Scene

Markus Åhman, Dallas Burtraw & Karen Palmer

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Lars-Gunnar Lindfors
Scientific Director

Swedish Environmental Research Institute

Organization

IVL Swedish Environmental Research Institute Ltd.

Address

P.O. Box 21060
SE-100 31 Stockholm

Telephone

+46 (0)8-598 563 00

Report Summary

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Author

Markus Åhman, Dallas Burtraw & Karen Palmer

Title and subtitle of the report

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This paper builds a foundation for assessing which specific research questions are most important and where our efforts would add most value. In consideration of the interaction between emissions trading and the electricity market, several related but separate issues and research questions are relevant to analyse. To keep the questions as clearly defined and distinct as possible, we summarize the focus of further research in four areas that frame the discussion on the interaction between the EU ETS and the electricity market, and in broad terms the incentives for investment behaviour that are created.

- Understanding and managing uncertainty.
- Price interactions between the EU ETS and the Nordic power market.
- Incentives for investment created by various approaches to allowance allocation.
- How other climate related policies such as renewable support programs interact with the EU ETS and electricity markets.

Keyword

Electricity, emissions trading, EU ETS, climate change, liberalisation

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Summary (in Swedish)

Rapporten lägger en grund för forskning kring interaktionen mellan EU:s system för utsläppshandel (EU ETS) och den nordiska elmarknaden. Syftet är att öka förståelsen för hur EU ETS, genom elmarknaden, påverkar konsumenter och miljön. Rapporten diskuterar konceptuella aspekter av prisbildning och jämför förväntade resultat utifrån teoretiska modeller med empiriska data. En genomgång av litteraturen kring den nordiska elmarknaden och EU ETS visar på ett antal utestående forskningsfrågor, och vi kartlägger tillgängliga metoder för att analysera dessa frågor.

När man betraktar interaktionen mellan utsläppshandel och elmarknaden är det relevant att analysera flera relaterade men fristående frågor. Vi har grupperat dessa i fyra prioriterade områden:

- Förstå och hantera osäkerhet.
- Prisinteraktion mellan EU ETS och den nordiska elmarknaden.
- Påverkan på investeringsincitament från olika sätt att tilldela utsläppsrätter
- Hur andra klimatmål och –styrmedel, som exempelvis dom kring förnybara bränslen, interagerar med EU ETS och elmarknaden.

Rapporten identifierar viktiga frågor och var ytterligare forskning kan tillföra mest värde. I framtida prioritering av frågeställningar och av vilka metoder som är mest användbara bör man även bygga vidare på litteraturgenomgången och på den institutionella forskning som pågår. I vårt eget arbete inom Elforsks program Market design kommer vi också att fortsätta dialogen med företrädare från intressenter i näringslivet, myndigheter och i den politiska sfären..

Summary

This white paper sets the scene for research on the interaction between the electricity market and the European Emissions Trading Scheme (EU ETS). We look at conceptual aspects of price formation, and compare empirical evidence with theoretical expectations through a review of the literature on the functioning of the Nordic electricity market and the EU ETS. From this review a set of prioritised research questions emerges, and we then go on to map available methods to these research questions. This forms a foundation for research that explores different aspects of uncertainty, options for organising the EU ETS and analysis of how the EU ETS may affect price level and volatility in the allowance and electricity markets, as well as investment. Ultimately, the research project that this white paper is a product from, aims to improve the understanding of how the EU ETS, through the electricity market, will affect consumers and the environment.

In consideration of the interaction between emissions trading and the electricity market, several related but separate issues and research questions are relevant to analyse. To keep the questions as clearly defined and distinct as possible, we summarize the focus of further research in four areas that frame the discussion on the interaction between the EU ETS and the electricity market, and in broad terms the incentives for investment behaviour that are created.

- Understanding and managing uncertainty.
- Price interactions between the EU ETS and the Nordic power market.
- Incentives for investment created by various approaches to allowance allocation.
- How other climate related policies such as renewable support programs interact with the EU ETS and electricity markets.

This paper builds a foundation for assessing which specific research questions are most important and where our efforts would add most value. In making the final decision on which questions to address and what methodologies to apply we will draw on the literature review and on the coming institutional research. Furthermore, we will seek the input from stakeholders within and outside of the HOPE project.

Contents

1 Introduction

The electricity sector is key in greenhouse gas mitigation. It accounts for roughly one-third of carbon dioxide emissions in the industrialized countries and is expected to deliver two-thirds of the emission reductions in the first few decades of climate policy regimes (U.S. EIA 2006). Moreover, the electricity sector is the most important product market affected by Europe's Emissions Trading System (EU ETS), partly because the electricity sector is not exposed to direct competition from non-European countries and is therefore more able to abate emissions without carbon leakage. Since the launch of the EU ETS in January 2005, there have been substantial variations in the price of emissions allowances, contributing to the price volatility in the electricity market that Europe has experienced over the last years. The additional uncertainty introduced by the EU ETS has led some observers to question whether the system is the best means for bringing down greenhouse gas emissions from electricity generation in Europe.

This white paper sets the scene for a research exploring different aspects of uncertainty, options for organising the EU ETS and how that may affect price level and volatility on the allowance and electricity markets. We look at conceptual aspects of price formation, and discuss empirical evidence alongside theoretical expectations. Although the electricity sector is not exposed to direct competition from non-European countries, the Nordic power market is exposed to competition from electricity generators in other parts of the EU operating in different regulatory environments with respect to rules for recovery of costs and rules governing the implementation of the EU ETS. Moreover, electricity intensive production in the Nordic countries competes with production outside the region and it is sensitive to the relative changes in electricity prices. The influence of the EU ETS on prices and investment behaviour in the electricity sector depends crucially on the market structure of the sector. The European electricity markets are moving towards a higher degree of integration and price liberalization but the pace of that progress is affected by the design choices that are being made for the EU ETS.

The focus is held on the Nordic market; however, to understand the factors affecting the performance of the market we will need to keep a broader perspective in view. We will look at how the options for the design of the EU ETS and decisions of participating countries are affected by the semi-integrated and semi-liberalized European electricity market. We will also consider the potential effects of these options from a Nordic perspective and also from a broader European perspective. Any design that is proposed for the EU ETS would have to pass the scrutiny of all participating countries, which is why such an analysis is necessary in order to make the research relevant in the policy context of the EU. Although the basic mechanisms and dynamics of the Nordic electricity markets obviously are important for the analysis, the investigation of the fundamentals of the electricity market itself will be kept as brief as possible, primarily drawing on previous research.

2 Objectives and target groups

The objective of this white paper is to lay the foundation for research in the interaction between the EU ETS and the Nordic electricity market and how alternative ways to organise the EU ETS may affect price level and price dynamics. Specifically, it sets the scene for the research carried out in the HOPE project. The paper identifies pressing research questions, applicable theories, suitable methods and previous findings for the analyses in the context of the Nordic electricity market. This is done by discussing theories surrounding the electricity market and the general research problem and by reviewing the literature on the interaction between the EU ETS and the electricity market, examining the applicability and relevance of previous findings. For the sake of brevity and time constraints, the specific literature on the design of EU ETS itself is given less attention in this white paper. Instead, the authors refer to the numerous previous publications we have produced on the EU ETS.

The target groups of the research are policy makers involved in the design of Swedish and European energy policy, decision makers in industry wishing to gain a better understanding of how policy will affect their business, and the academic community.

3 Structure of the paper

The first section of the paper gives a brief introduction to how competitive markets function, going into some more depth and detail on the unique characteristics of electricity markets in general. It then takes a closer look at the Nordic electricity market, attempting to shed light on how closely it follows the assumptions underlying the theory of perfect markets. This will put the findings of previous research into context and provide a foundation for the choice of research questions and methodologies. The second section provides a discussion of 'price volatility' and how it is linked to different kinds of uncertainties. The third section of the paper gives an overview of the applied literature on the EU ETS and the electricity market, followed by two sections where prioritised research questions and methodologies are presented. The paper is closed by laying out priorities and methodologies for future research to be carried out by the research team.

4 Price formation in electricity markets

4.1 Overview of price formation in competitive markets

This section gives an overview of how competitive markets work and lays out some of the special features of electricity markets. It is not a description of the Nordic electricity market, which is more competitive than most other electricity markets. Rather, this section takes a general approach and provides a backdrop to the subsequent discussion on the specific characteristics of the Nordic electricity market.

In a fully competitive market, no producer can affect the price, and at the equilibrium between supply and demand the price will be equal to the marginal cost of production for producers and the marginal benefit of consumption to consumers. The short run marginal cost will depend on costs that vary in the short term (e g fuel costs), whereas the long run marginal costs will also include a scarcity rent that reflects the value of fixed resources (e.g. investment costs in a factory). However, wholesale markets for electricity have some specific characteristics that make them particularly prone to imperfections. If a producer can affect prices in order to increase its profits, for example by reducing production or dispatching out of merit order[1], the producer has market power. The fact that electricity cannot be stored, limited capacity for production and transmission and low elasticity in demand are all factors that may increase the risk of market power arising. This said, market power is not necessarily exercised even in cases where it would be possible for a producer to do so. Furthermore, many electricity markets are dominated by a relatively small number of large companies. This, in combination with high barriers to entry, co-owned generation capacity and a transparent price could also increase the potential for tacit collusion of firms. However, a transparent price obviously also makes it easier for consumers and external parts to follow the market.

It is important to make a distinction between wholesale electricity market, i e the purchase and sale of electricity from generators to resellers (retailers) and the retail market, where electricity is sold to consumers. Although retail prices are following the development of the wholesale market, the total cost to consumers also consists of distribution costs and taxes which may change not only prices but also the dynamics. Delivery of electricity services relies on transmission and distribution systems, which usually are thought of as natural monopolies and are provided through cost of service regulation. Nonetheless, the transmission system is a strategic asset and its control and the location of new investment affects the economic value of generation assets. Furthermore, few customers pay time-differentiated electricity prices, even though marginal generation costs and the opportunity cost of transmission services vary over time of day in many cases. Hence retail prices can be expected to depart more from the predictions of a simple competitive model than wholesale prices.

Often there is a difference between short run and long run market equilibrium, and this is an especially important feature in electricity markets. In short run equilibrium, capital costs and capacity are assumed to be fixed. A competitive market will ensure that existing capacity will be used most effectively. However, the capital stock may be smaller or larger than what is effective in the longer term given the demand for products. This shows the importance of low barriers to entry and exit. Profits made in a market should guide investors and shareholders in their decisions and aid the adjustment of the capital stock to the optimal size, although restrictions on technology types or location are commonplace in many electricity markets.

A competitive market will allow uncertainties to be managed and the cost of doing so to be reflected in the price of goods and services. For electricity, such uncertainties include weather, fuel prices, technology development and regulation. The financial market where derivatives like futures and forwards are traded plays an important role for allowing market players to hedge their risks. An efficient market for financial derivatives is characterised by high volume trading and different risk tolerance of market players,

Low barriers to entry are one of the most important features of a well functioning competitive market over the long term. As long as the scarcity rent is not high enough to cover the capital cost of a new facility, no investments will take place. Barriers to entry raise the capital cost of a new facility, thereby creating the opportunity for greater sustained collection of scarcity rent by incumbents.

A low cost to customers for choosing and switching suppliers is another important prerequisite for competition, as is full information among all market players. For example Wilson (2006), EMI (2006 and 2006c), Kim et al (2003), Giulietti et al (2005) provide good insights on the importance

[1] The merit order is the order in which different types of production facilities are used, and it is determined by the short run variable costs associated with the respective plants.

of search and switching costs for market efficiency. If consumers are locked into using only one supplier, it will decrease efficiency of the market. However, trying to create lock-in is a common strategy applied in many industries, for instance through loyalty schemes in the airline business and long term contracts in telecommunication. In fact, search and switching costs have been found to be a one of the most important determinants for market shares in some sectors. Interestingly, in many electricity markets it is difficult, expensive or even impossible for consumers to switch supplier, a fact that obviously has detrimental effects on competition especially with respect to the retail electricity market. Some markets where generation services are separated from transmission and distribution services can have a competitive wholesale market for generation services but a regulated retail market.

There is no single indicator that will capture whether a market is fully competitive or not. However, two common approaches to analyse electricity markets are: (i) to look at differences between market price (and bidding schedules) and simulated or estimated marginal costs for firms, and (ii) to look at the structural characteristics of the market, for instance in terms of market concentrations, turnover and transaction costs. For a comprehensive assessment of different measures of market concentration in the Nordic electricity market, see CERA (2002).

The market shares of the largest market actors give a quick measure of how concentrated the market is, which in turn gives an idea of the risk for market power. A related, more sophisticated measure of market concentration is the Herfindahl-Hirshman Index (HHI). HHI is simply the sum of the squares of the market shares of all market actors:

$$HHI = S_1^2 + S_2^2 + ...S_n^2$$

where S_i is the market share of each actor. A market with a high HHI is more concentrated, and a low HHI indicates low concentration. HHI can be calculated in different ways, for instance based on installed capacity or produced electricity and taking into account cross ownerships. A third indicator of market concentration is the Residual Supply Index, RSI. It is a measure of how much supply capacity remains should one or several market players be excluded from the market. The residual is compared to the total demand of the market. If the supply capacity of the remaining firms is not enough to meet the market demand, there is a higher risk of market power being exercised.

However, concentration measures only give an indication of the risk for market power. Electricity markets can, even at relatively low market concentrations, be susceptible to market power. For instance bottlenecks in the transmission grid, or differences in the flexibility of generation between firms, can give firms with a low market share ability to exercise market power at certain time periods or in certain geographical regions (Copenhagen Economics, 2002).

One way to limit producers' ability to exercise market power in wholesale electricity markets is to allow for active participation by the demand side. Economic experiments on the design of wholesale electricity markets have shown that allowing demand side bidding in an electricity auction will substantially reduce firms' ability to exercise market power and raise price (Rassenti et al. 2002).

A final note is that price elasticity is a critical factor for how markets work. In general, the price elasticity for electricity is low, especially in the short term (for an overview of recent studies, see Lijesen, 2007).

4.2 Reality check: characteristics of the Nordic electricity market

The previous section laid out some of the fundamentals of electricity markets. This section will shed some light on the basics of the Nordic electricity market and how it compares to a perfectly competitive market, thus laying the foundation for following discussion on research priorities and methodologies.

The primary argument for liberalising regulated markets is that competition increases efficiency, pushing down costs of generation, improving price formation and maximising the utility for clients. The strive toward a more efficient market was also the reason why generation and trading of electricity was opened to competition in the Nordic countries. It is clear that very few, if any, markets meet the criteria of a fully competitive market, but even a less-than-perfect market can offer significant efficiency advantages over a regulated one. The critical question then becomes how potential imperfections in the Nordic market may affect efficiency in general and price formation and volatility in particular, and what specific requirements potential imperfections put on an analysis of the interaction between the EU ETS and the electricity market.

4.2.1 Background

The Nordic electricity market has been transformed from a regulated market into its current more liberalised form in a gradual process that started in the early 1990s. Although many of the characteristics of a competitive market have been in place for some years, the integration, harmonisation and expansion of the market continues to this date. The primary objectives of liberalisation were to increase the efficiency in the use of capacity, to increase the freedom of choice for consumers and to create better conditions for a cost efficient energy supply. The dominant position of some utilities especially in localized markets was an area of concern and a common Nordic electricity market would significantly reduce their dominance and guarantee stronger competition. Norway was the first to gradually liberalise its market in 1990, Sweden and Finland did so in 1996, followed by Denmark. The generation and trade of electricity are now open to competition, while the transmission networks are still a regulated monopoly with government control.

Before the liberalisation, prices were largely determined by the returns (revenues) the Nordic governments required from their energy companies. Even though there existed privately-owned and municipally-owned energy companies, the state-owned firms dominated the market and in practice set a price cap on electricity. Each energy company had a regional exclusive franchise monopoly that made it possible for them to control the amount, timing and location of investments in generation. The prices for generation services were set based on average costs of generation plus a 'reasonable' return to the owners on invested capital. This meant that additional generation costs could always be recovered by an increase in the electricity price, which was based on average embedded cost of providing service. An important question in regulatory economics is whether such an approach to regulation creates an incentive and ability to over-invest in capital, because rate of return is guaranteed (Averch and Johnson (1962), Joskow (1974)). Empirical efforts to identify a bias toward over-investment in capital in regulated electricity markets have not been entirely successful. Nonetheless the theory is consistent with the situation in the Nordic area at the time of liberalisation, where there existed a significant surplus in capacity that resulted in an initial downturn in prices immediately after the liberalisation. Many industries with capacity to self-generate electricity sold this off, in part to focus on core competencies but probably also because electricity prices were low at the time. Since the market reform, installed capacity for electricity generation has declined, with the capacity reserve margin[2] dropping almost 20 percent between 1996 and 2000 before starting to increase again (EMI 2006a).

Since liberalisation the Nordic market has become increasingly integrated. A common exchange for electricity trade has been created (Nord Pool), the regulation of the electricity sector has been harmonised and the transmission capacity between the Nordic countries has been improved. This trend continues with increased transmission capacity remaining a priority, both among the Nordic countries and between the Nordic market and continental Europe. There already exist cables that connect the Nordic market to Russia, Estonia, Poland and Germany, and several new connections are planned for the coming years (***Table 4.1***).

The improved conditions for cross-regional and cross-border electricity trade tends to relieve scarcity in generation capacity because peaks in electricity demand tend to be less coincident over broader geographic areas. This enables short-run scarcity in generation supply to be smoothed out, and it has decreased the need for capacity and a number of high cost plants have been closed. However, the price levels on the spot market during the last 2-3 years suggest that there is room for investment in new capacity and many investments are taking place in the Nordic electricity market.

4.2.2 Market size and concentration

In 2005 approximately 390 TWh was consumed in the Nordic countries (EMI, 2006a). Of this, Sweden accounts for some forty percent, Norway thirty percent, Finland twenty percent and Denmark 10 percent. In Sweden, Finland and Norway industry has a large share of total consumption (between 40 and 50 percent) while the Danish industry accounts for below 30 % of annual consumption and instead the agricultural-, housing-, and service sectors have larger shares of total consumption. This is explained by different industry structures. For instance Denmark has a much lower share of energy intensive industries than Sweden. All the Nordic countries except Denmark have a high average electricity consumption per capita compared to other countries in the world.

More often than not, the Nordic countries are net importers of electricity (**Figure 1**). However, in wet, mild years like 2005, they can be self sufficient or even net exporters of electricity. Within the Nordic market, electricity trading is governed primarily by the level of the water reservoirs in Norway and Sweden, reflected in market prices. During the winter, when inflow is low and demand is high, Sweden and Norway generally act as net importers from Finland and Denmark, which have a larger proportion of thermal production. In the spring and summer the roles reverse, with Norway and Sweden acting as net exporters of electricity.

[2] The capacity reserve margin is a measure of how sensitive the system is to peaks in demand and equals the total generation capacity minus peak consumption divided by peak consumption.

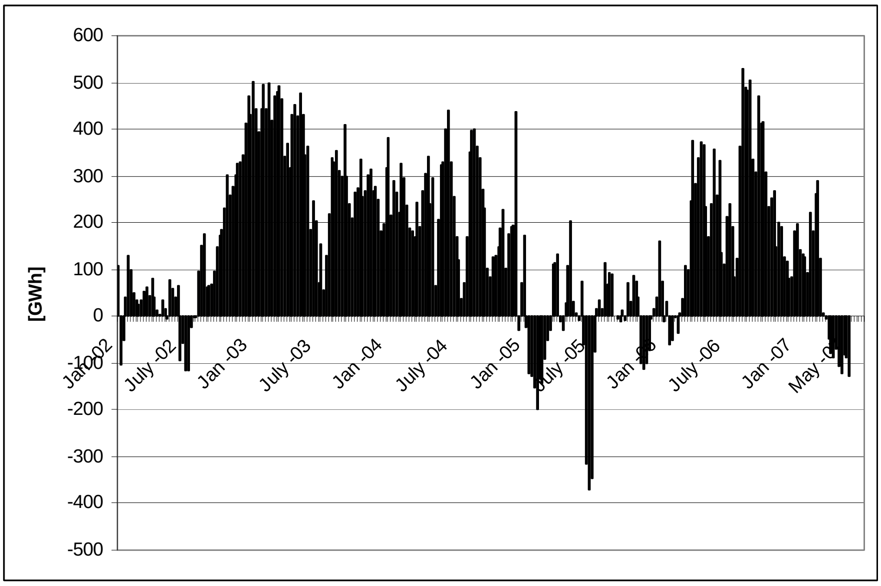

Figure 1. Net import of electricity to the Nordic market, 2002-2007. Source: Swedenergy.

Electricity production differs considerably among the Nordic countries. Norway uses almost exclusively hydropower for its generation, whereas Sweden and Finland use a combination of hydropower, nuclear power, CHP and conventional thermal power. Most of the hydropower capacity is located in the northern areas, whereas thermal power prevails in the south. Denmark relies mainly on CHP and conventional thermal power, but wind power is also providing a substantial part of the supply of electricity (Table ***4.1***).

Table 4.1. Electricity production [TWh], 2005.

	Denmark	**Finland**	**Norway**	**Sweden**
Electricity production, total	**34,4**	**67,9**	**138,0**	**154,7**
Thermal Power, total	**23,6**	**44,2**	**0,4**	**73,4**
- Nuclear		22,3		69,5
- Other thermal 1)	23,6	21,9	0,4	3,9
- coal	14,5	7,0		1,1
- oil	0,3	1,5		1,4
- peat		4,5		0,1
- natural gas	8,6	8,9	0,4	0,7
- other 2)	0,2			0,6
Renewable total	**10,8**	**23,7**	**137,6**	**81,3**
- hydro	0	13,6	136,5	72,1
- other renewable	10,8	10,1	1,1	9,2
- wind	6,6	0,2	0,5	0,9
- bio	2,9	8,9	0,3	7,4
- waste	1,3	1,0	0,3	0,9
- geothermal power				
Import(+) /export(-)	1,4	17,1	**-12,0**	**-7,4**

1) Fossil fuels, 2) West Denmark refinery gas.

When the process toward liberalisation was begun, the concentration of the market was one of the main problems that were discussed. Rightly or not, this is still often raised as an issue of concern. Currently the three main players - Vattenfall, Statkraft and Fortum - constitute approximately 50 % of the Nordic market. They are all vertically integrated companies, i.e. firms that are engaged in both generation and trading of electricity, which some observers find disturbing. The market concentration is greater in the retail market than in the wholesale market. Other issues that have been raised as problematic are the limited ability for consumers to make informed choices and the differing negotiation power between large and small consumers. At least in the popular debate, the intensity in the criticism of the electricity market seems to be correlated with the prices of electricity, with rising prices giving fuel to worries that electricity firms are exercising market power.

Against this backdrop a number of studies have been carried out to investigate the function of the Nordic electricity market, see for instance Energy Markets Inspectorate (EMI) 2006, Bergman, (2006), CERA (2002). Two studies (CERA (2002) and EMI (2006b)) have calculated HHI for the Nordic market and for price areas that occur when there are bottlenecks in the system. These calculations indicate that when the Nordic system works as one price area there is little risk of market power, but when there are bottlenecks, HHI rises to levels well above where market concentration can be problematic. EMI (2006b) concludes that the trend towards increasing market concentration could become problematic if it were allowed to continue. EMI also finds that entry barriers for new investments need to be lowered and that the flexibility of wholesale electricity clients needs to be increased, for instance by new contract forms between suppliers and clients.

In an interview study by EME Analys (2006) several firms in the market stated that they felt that the large producers of electricity have some control of the price by carefully managing how much hydro they let onto the market. The objective would be to make sure that fossil generation with high marginal production costs are always on the margin, thus increasing prices and thereby the revenues received for generation on hydro and other inframarginal generation units. Whether the large firms go as far as abusing their position seems unclear, although some interviewees were of that opinion. There seemed to be a higher trust in the financial market than in the physical spot market, although the volatility of the financial market suggests that it is still immature and that there are not enough actors willing to take on risk. Furthermore, there is a lack of financial instruments that can be used to hedge against very large price spikes.

In sum, the scientific literature gives little evidence of market power being exercised on the Nordic electricity market. Consequently, the baseline for our analyses will be the assumption that the market is competitive. However, since the public and policy debate on the electricity market is still dominated by the issue of potential market power, and since there may be situations where conditions for market power could potentially arise even in the Nordic market, we will pay attention to this issue when formulating the research questions and methods.

4.2.3 Trading and price formation

The price of electricity charged to consumers is made up of the wholesale generation price, network tariffs for transmission and distribution services, electricity certificates [3], the energy tax, VAT and other taxes and fees (Figure 2). Swedish combustion-based electricity also is subject to a sulphur tax and a nitrous oxide charge, but is exempt from energy- or carbon dioxide taxes. The Nordic electricity market is relatively well integrated and increasingly harmonised but regulation, taxes and

[3] Electricity generators who use renewable energy sources in the Swedish market are granted electricity certificates by the government, in proportion to the amount of electricity produced. The certificates can then be sold alongside the generated electricity. Most Swedish electricity consumers are obliged to hold a certain quota of electricity certificates in relation to their consumption. This quota obligation creates a market for electricity certificates and the idea is to increase the profitability of renewable energy. The energy intensive industry is exempt from the quota obligation.

fees still vary between countries, resulting in different prices to final consumers even among the Nordic countries Although the HOPE project is focussed on how the price of EUA is formed and particularly how it affects the electricity market, other policy instruments and market failures are important for determining the price of electricity the consumer actually pays. (Figure 2). However, the energy intensive industries are largely exempt from taxes and in most cases negotiate bilateral and long term agreements making them less exposed to short term volatility on the spot market. In addition, the long term agreements are almost always confidential, making it difficult to assess the effects on large industry consumers based on public market data.

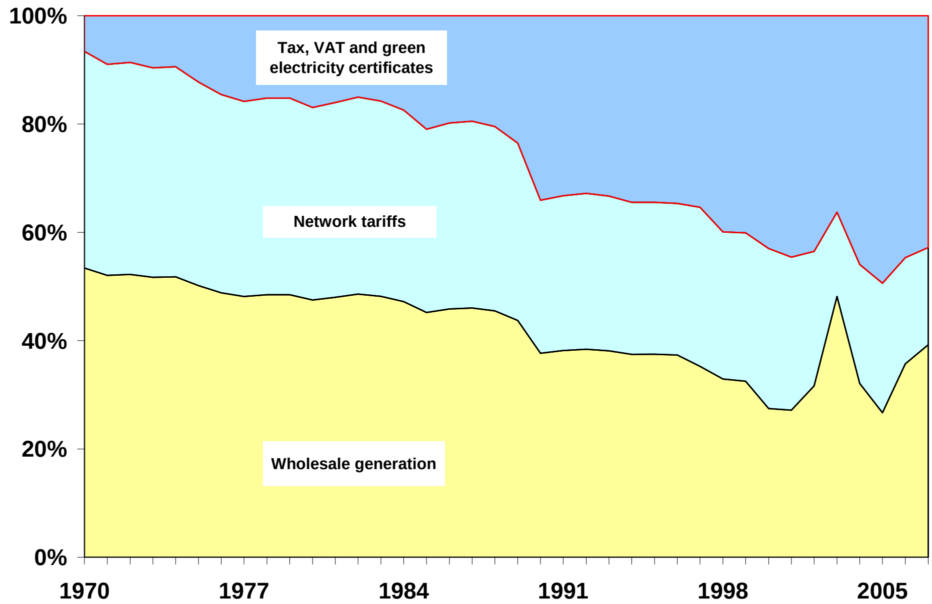

Figure 2. Development of components of Swedish retail electricity price 1970-2007, contract of 20 000 kWh/yr. Source Statistics Sweden (SCB) Swedenergy.

The two most important drivers of electricity demand are temperature and the state of the economy, while the supply system is highly dependent on a variety of factors, but among these probably the hydro power systems in Norway and Sweden is most important. The amount of hydro power available determines the need to use other energy sources. EMI (2006a) lists the other most important factors determining market price of electricity:

- Hydrological conditions.
- Capacity development.
- Interactions within the Nordic electricity market.
- Interactions with continental Europe.
- Fuel prices.
- Competition on the electricity market.
- The price of emission allowances.

Consequently dry, cold years (for instance 2003) give high average prices, while wet, mild years give lower prices. 2005 was a wet year, with 35 TWh more hydro than during a normal year, which may have reduced the impact of high international prices on fossil fuels and the introduction of the EU ETS on the Nordic electricity price.

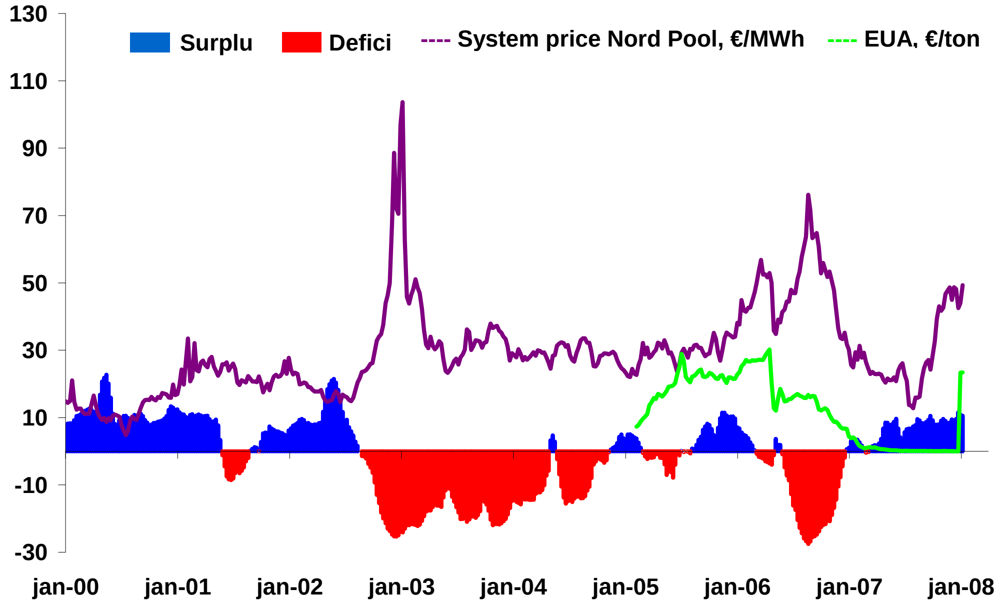

Figure 3. Nordic hydro storage balance, Nordic system electricity price, EUA prices. 2000-2007. Source: Swedenergy.

A specific characteristic of the Nordic electricity market is that the vast majority of the trading takes place at Nord Pool or in the OTC market with clearing of the contracts at Nord Pool clearing house. Nord Pool organises physical trading (the Elspot and Elbas markets) and financial trading (the Eltermin market) in electricity and also provides clearing services. A steadily increasing proportion of physical power trade takes place via Nord Pool, in 2006 more than 63.3 %. The spot price on Nord Pool also forms a reference for bilateral trade (EMI 2005). Hourly equilibrium prices are set one day in advance on the spot market, based on the sum of all buying and selling bids. The financial market enables traders to buy futures to protect their positions against variations in the spot prices for several years ahead. Nord Pool also organises trading of EU emission allowances (EAUs) and electricity certificates. An advantage of Nord Pool is that the transparency in prices lends credibility to the market and facilitates planning of investment and retirement and scheduled maintenance for generation capacity.

The order in which different types of production facility are used, the so called merit order, is determined by the variable cost associated with the respective plants. This means that the most expensive plant needed will set the market price, or in the case of flexible hydro power the alternative value of the stored energy. (Figure 4).

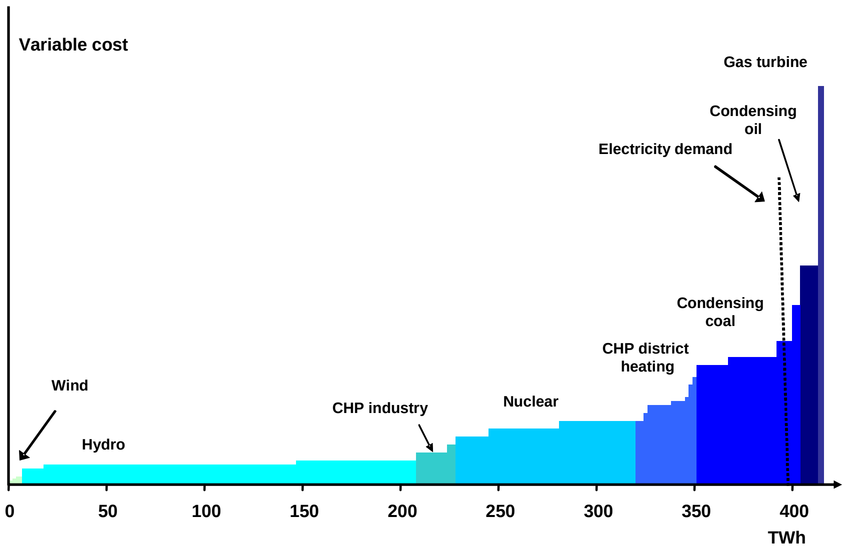

Figure 4. Schematic illustration of the merit order in the Nordic electricity market for a normal year. Source: Swedenergy.

The literature does not provide clear conclusions on what fuels and technologies are price setting. Bruce (2007), referring to contacts with Vattenfall estimates that coal condensing plants are price setting 70-75 % of the time on a yearly basis. Econ (2006) concludes that gas-fired power plants are not price setting in the Nordic market and changes in gas prices are not likely to change the merit order in the Nordic Market. This means that changes in gas prices have little direct effect on electricity prices. Instead, gas prices affect electricity prices indirectly, by affecting allowance prices which in turn do have an impact on the electricity market.

Demand for electricity is more volatile than many other markets, in part due to the difficulty in storing electricity. Since there is no way of buying electricity when prices are low and saving it for later, wholesale generation prices tend to fluctuate depending on time of day, and day of the week, depending on weather and season etc. Furthermore, demand elasticity is low whereas supply is more elastic since generators can adjust production according to price levels (albeit to varying degrees depending on fuel and technology). In practice, this means that hydro producers save water during the summer months, nights and weekends when demand and prices are lower, to be able to increase production during periods when the price is higher. This results in smaller differences in prices between summer and winter and between day and night than what would have been the case if water could not be stored (Econ, 2004).

In general the time dimension is very important for price formation. For instance, the shape of demand and supply curves may show different time variability in different markets. Further, electricity is traded in a number of different contracts and instruments with different time horizons. This makes it important to choose time resolution carefully when analysing correlations and casual relationships between markets.

Nordel (2004) makes the observation that the Nordic electricity market was designed on the assumption that consumers would respond when the price is high by reducing demand or potentially switching suppliers. If a sufficient part of the consumption is not shifted away from peak load hours in situations with scarcity, the market will not operate as intended in the short run.

That is, if the market is not flexible enough to allow for relatively quick demand response, it will lose efficiency.

Nordel concludes that although the Nordic market has clear and relatively transparent price signal, there is still a significant unexploited potential for increased demand response. Many of the large consumers of electricity, for instance steel- or paper industries, are heavily dependent on electricity and in the short term have limited possibility to reduce demand in other ways than production decrease. Fritz (2006) concludes that while there is not enough demand response in the Nordic electricity market today, it seems probable that there is a significant ability and interest among consumers to reduce their consumption if the economic incentives are high enough. However, most other consumers including virtually all commercial and residential customers do not see variation in electricity price over time of day (Nordel 2004).

In a paper accentuating the interdependence of generating capacity, price volatility and service reliability, Tishler et al (2007) concludes that in a competitive market, even if the installed capacity was designed to serve the projected demands, frequent surpluses and occasional full utilization inevitably would lead to price volatility. Figure shows the price development of the Nordic electricity price since the market was liberalised in 1996.

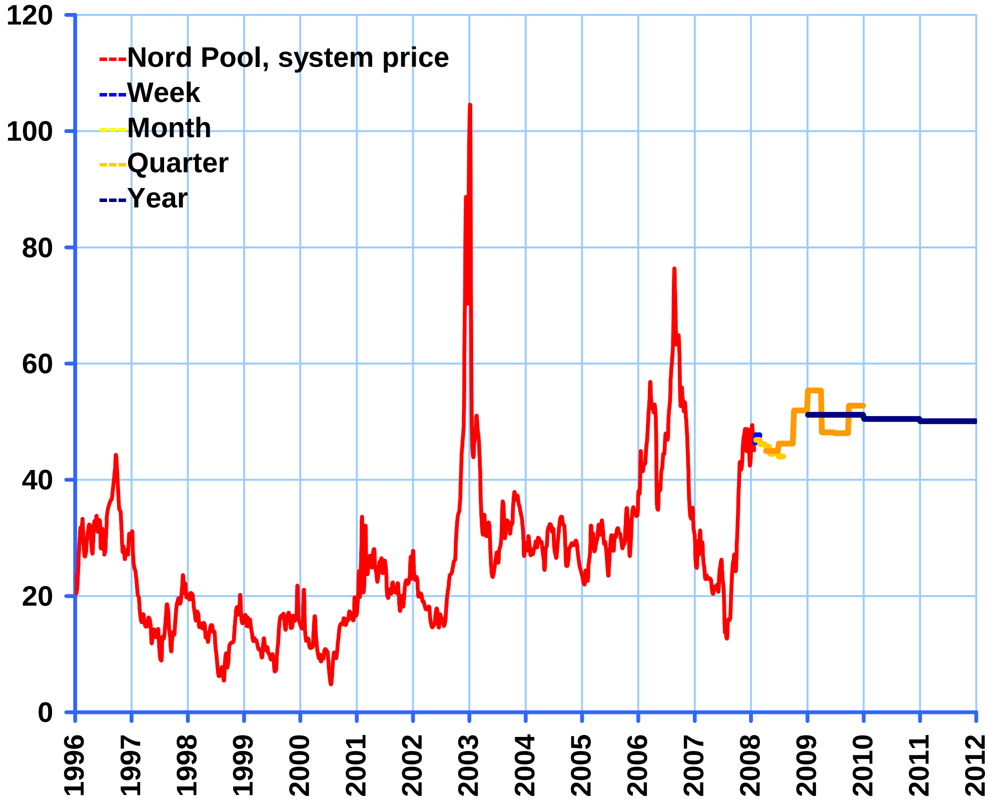

Figure 5 Nordic system electricity price. Source Swedenergy

4.2.4 Transmission capacity, bottlenecks and relevant market

There still exist transmission constraints in the Nordic market. To manage these bottlenecks the market is split[4] during parts of the year, resulting in sub-markets with different prices during periods with insufficient transmission capacity. Nord Pool's normal price areas are Sweden, Finland, Jutland/Funen (Denmark), Zealand (Denmark), Oslo, Tromsö and Trondheim (Norway). Often, two or more price areas are combined to form a larger sub-market, for instance Sweden often combines with Denmark and/or Finland. During the periods of one common Nordic price area (just over 30% of the time in 2005), the high concentration in the market poses a smaller risk to competition than when the market is split, and the Swedish Energy Agency (2004) even draws the conclusion that market splitting only has limited effects on competition.

Although there is transmission capacity to continental Europe (Table Table ***4.2***), Damsgaard (2007) shows that the price dynamics of the Nordic electricity prices differ considerably to that in Germany. In the Nordic market price variations, on an annual basis, are largely determined by hydrological conditions, whereas price variations in continental Europe are significantly greater over the day and between seasons due to the dominance of thermal generation. Damsgaard concludes that in this respect, there still exist "Nordic prices". Copenhagen Economics (2002a) go as far as concluding that the Nordic market can be regarded as isolated from competition and price formation standpoints. The impact on the market from imports from continental Europe, primarily Germany and Poland, is negligible (Copenhagen Economics, 2002b). However, this conclusion is questioned by other observers and analysts (for instance Jardfelt, 2007, Thorstensson, 2007).

Table 4.2. Transmission capacities to and from the Nordic electricity market.

Connection	**From Nordic countries [MW]**	**To Nordic countries [MW]**
Existing connections, 2005		
West Danmark - Germany	1350	950
East Danmark - Germany	600	600
Finland - Russia	.	1560
Norway - Russia	50	50
Sweden - Germany	600	600
Sweden - Poland	600	600
Finland - Estonia	350	350
Planned connections		
Norway - The Netherlands 2)	700	700
2) Planned to start operation in 2007		

[4] There are three principal way s to deal with bottlenecks in the Nordic system: market splitting, counter trading and limiting import/export. Market splitting is used when transmission constraints can be foreseen in the planning phase, resulting in different price levels among regions, thus signalling a need for increased generation capacity in deficit areas. Counter trading is applied when bottle necks occur in real time operation. This means that the system operator orders an increase in production in the deficit area and/or a reduction of production in the surplus area. The resulting costs of the trading falls on the system operator and provides a signal that the capacity of the grid needs to be increased. Limits of import/export means that the system operator limits the transmission capacity between his area and other price areas.

5 Reflections on uncertainty, flexibility and volatility

Risk and uncertainty[5] are not inherently bad things. By taking risks, investors can earn greater profits, although a high risk will mean that any investment will have to show a greater return in order to be attractive. In the economics literature the value associated with a wait-and-see strategy is called the *option value*. Uncertainty over prices in products or inputs will, on average, slow investments compared to a situation under certainty, and climate policy uncertainty is no exception to this. The greater the level of policy uncertainty, other things such as the expected value of important variables being held equal, the less effective climate change policies will be at providing incentives for investment in low-emitting technologies (see for example IEA (2007), Philibert (2006) and Laurikka (2006)). Furthermore, the closer in time a change in policy is the higher will the value of waiting be for a company. Thus in a period leading up to an expected change in policy there may be a slow down in investments.

However, there is an inherent trade-off between flexibility and certainty in any policy system. On the one hand, there are benefits of retaining options to adjust policies to changing priorities and external developments, for example in the international climate policy regime. On the other hand, there is a need to provide certainty to market actors. This is particularly relevant in the power sector, where investment cycles stretch over several decades.

In the EU ETS this tension between flexibility and certainty is brought to the surface. Rules and allocations of emission allowances are set for five years at a time (so-called trading periods), which according to critics does not provide enough certainty to market actors. Consequently, there have been calls to increase the length of the trading periods in order to reduce regulatory uncertainty and thereby stimulate investments. Less frequent revisions of the allocation would also reduce some of the distortions that updating of the allocation creates (for a discussion of this, see for instance Åhman et al, 2007). Another option would be to create a formal political commitment to prices above a certain level in order create incentives to make long term investments which today are considered too uncertain (Burtraw and Palmer, 2006). A guaranteed minimum price could be a solution in this direction. However, the volatility in prices of emission allowances (Figure **6**), and the uncertainty this creates for market actors, must be viewed in the light of other market factors. This begs the question whether there is a fundamental difference between political uncertainty and other market uncertainties, and if so, what can policy makers learn from this?

[5] 'Risk' and 'uncertainty' are not the same thing. In general, 'risk. implies that it is possible to quantify and assign a number to an 'uncertainty'. In that sense, dealing with uncertainty requires different and more complex strategies and tools than does dealing with risk.

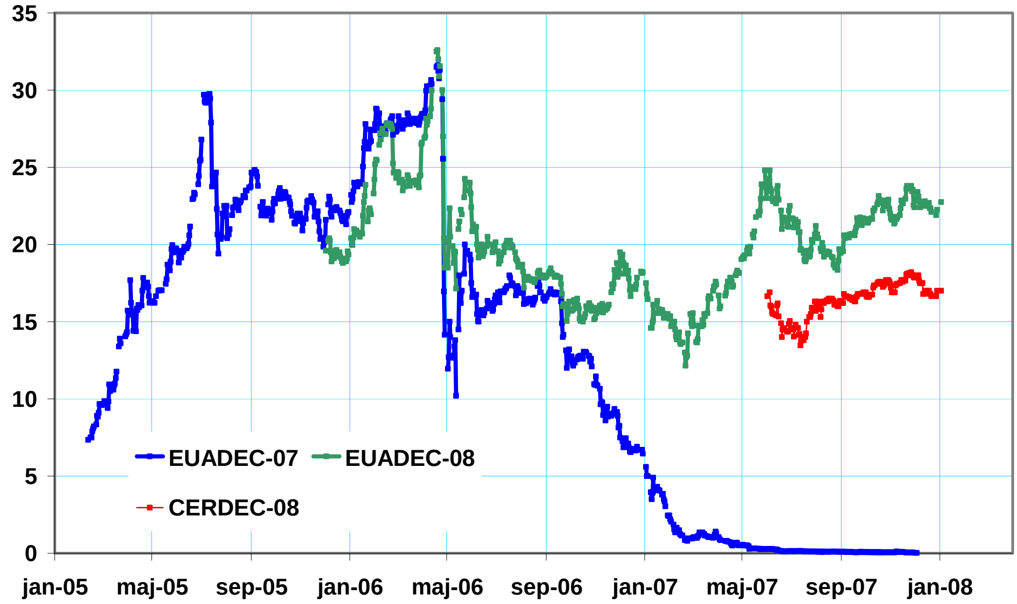

Figure 6. Prices of emission allowances (EUA) on Nord Pool. Source: EEX, Nord Pool, Swedenergy

In the debate around the EU ETS, critics have argued that an important difference between the uncertainty and risk associated with the trading system for emission allowances and other market risks, such as demand fluctuations, volatility in fuel prices and weather variations, is that variations in policy are much more difficult to predict or at least to model compared to other uncertainties. Whereas the market for emission allowances can be deemed "artificial", in the sense that there is no underlying physical commodity being traded, other market factors are directly connected to physical conditions that are easier to predict and manage. Hence political uncertainties, as opposed to many other uncertainties, are extremely difficult to hedge.

Since the price of emission allowances is heavily affected by political decisions, which are hard to predict, there will be a high uncertainty around the long term price development. It is also true that the demand for emission allowances is directly affected by the relative price of fuels, so that price volatility in fuel markets can be amplified in the allowance market. The history of the EU ETS also gives some support to this, with prices varying between over 30 €/ton to below 1 €/ton in under a year. Furthermore, there is still significant uncertainty over emissions for the period 2008-12, and even more so for the period after 2012 for which no formal decision on rules of the EU ETS is taken as yet. In sum, critics of the trading system argue that instead of creating incentives for long term investments based on expectations of higher future prices of carbon emissions, the EU ETS so far has only managed to stimulate changes in system operation based on short term marginal costs. This makes the trading scheme less effective in driving investment in low carbon technologies and perhaps even more so, in research and development of new technologies.

However, the literature does not give unambiguous evidence with respect to the effect of allowance price uncertainty on investment. For instance, Laurikka (2006a) points out the difficulties in drawing conclusions from both standard discounted cash flow analysis and from real options models. IEA (2007) concludes that it is unlikely that climate policy uncertainty would pose a serious threat to overall capacity levels in most electricity markets in the long run. If climate policy is set over sufficiently long time scales, the total risk will be dominated by fuel price risk, with climate policy contributing relatively little to the total risk profile of the investments. In contrast, Laurikka and Koljonen (2006), using an extended discounted cash flow model, show that uncertainty regarding the allocation of emission allowances is critical in a quantitative investment appraisal of fossil fuel-fired plants in Finland. Furthermore, they stress that the impact of emissions trading not only depends on the expected level of allowance prices, but also on their volatility and correlation to fuel prices. Furthermore, the results of Zhao (2003) suggest that emissions trading may in fact help maintain firms' investment incentive under uncertainty compared with a scenario with fixed emissions charges, because firms factor in a convenience yield for the value of holding allowances over and above the marginal cost of avoided abatement expenditures. This premium leads to additional investment in order to have a hedge against the uncertainty in the allowance market.

The period of 5-15 years into the future is key since that is the typical time over which a planned new power generation needs to recoup the majority of its investment. Using a real-options model, IEA (2007) shows that the price of carbon required to make an investment in a hypothetical carbon capture and storage (CCS) facility viable is 37 percent higher if policy is set only five years into the future compared to if policy is set for 15 years ahead. Åhman et al (2007) conjecture that, ideally, price visibility should always be kept at least 10 years into the future. These authors investigate options to manage the trade-off between the certainty and flexibility in the EU ETS by creating a so-called 10 Year-Rule for the allocation that could be one step towards providing such visibility.

In addition to the trading system there also exist other climate polices that both implicitly and explicitly are directed to the power market. Economists have long debated whether it is more efficient to use a stable price such as a tax to reduce emissions, or to specify the quantity of emissions to be reduced as is done in a cap and trade emissions trading scheme[6]. Philibert (2006) and Pizer (2002) provide a review of the literature on the subject.

However, a closer look at other market factors gives rise to an even more complex picture. For instance it is clear that the markets for oil and natural gas are not without failures. The OPEC has great influence over the supply, thus controlling the price of oil to a significant degree. It is furthermore clear that external events such as political turmoil and armed conflicts in the Middle East affect the oil price. Since oil and natural gas prices are heavily correlated any change in the supply of oil also affects gas prices. Furthermore, Russia has during the last few years shown that it is prepared to use its power over natural gas supplies to reach other political objectives, thus disrupting the energy system. Whether or not the action taken by Russia should be seen as a one-time event is unclear, but what is evident is that uncertainty about the supply of natural gas to the European power sector is not working in favour for investments in natural gas-fired power generation.

The combination of uncertainty that derives from fundamental "traditional" market parameters such as fuel prices (Figure 7), and uncertainty that stems from a newly created market such as the EU ETS, makes it even more important for achieving climate policy goals that other climate and energy policies also should be surrounded by stability and clearness. Other policies currently implemented in Europe that aim to help achieve carbon related goals include feed-in tariffs and tradable green certificates, which are often compared to emission trading in terms of their effectiveness of driving new investments in low carbon technology. If investors perceive climate policy measures as short-sighted and volatile the effect will be that lock-in to carbon emitting

[6] In a seminal paper Weitzman (1974) showed that a key factor in this decision is how uncertainty in abatement costs relates to uncertainty in negative impact on the environment from emissions. The basic conclusion by Weitzmann is that if cost uncertainty dominates environmental uncertainty a tax is preferable to a cap & trade system and vice versa.

technologies as a relatively less risky strategy than investment in new and in some cases unproven technologies..

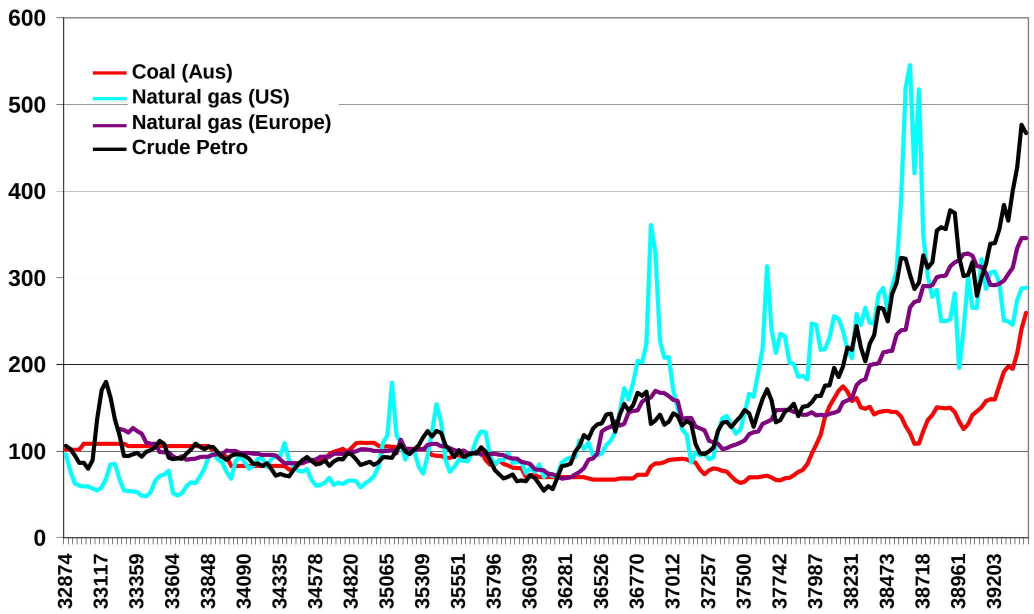

Figure 7. Indexed fuel prices. 1996 index=100, Source: World Bank, Swedenergy

Traditionally, the power sectors in Europe have been dominated by the combustion of fossil fuels for energy conversion and so far the introduction of renewables, besides hydropower, into the market has been relatively slow. Fluctuating energy and climate policies increase the uncertainty for investors, hence hampering green-field investments. It is also clear that the aforementioned uncertainty favours investments at existing installation – so-called brown-field investments – and that this propels the need for climate policies. An explicit objective of both the EU ETS and the green certificate system is to stimulate green field investments in relatively new technologies such as wind and solar power. However, if poorly designed these types of policies can also be counterproductive and make it even more difficult for investors to choose new technologies; thus maintaining the lock-in.

The efficiency gains of using emission trading as opposed to other types of regulation hinges on the ability of firms to capture gains from trade in the market. If markets are thin or transaction costs are high there will be less trade (Stavins 1995). Usual measures of liquidity include market activity and a lack of price dispersion. Even if there are plenty of trades, if there is significant price variation the lack of a single price will undermine efficient allocation of resources. Measures of price dispersion can be varied, for example the average percent absolute deviation of each transaction from the mean over some time period (Newell et al. 2005).

6 Effects on electricity prices of emissions trading

Since electricity prices are determined by marginal production based on fossil fuel, the price will be the same for all generated electricity, including that from nuclear, biomass and hydro. On the one hand, one of the objectives of the EU ETS is to make low carbon technologies more profitable. On the other hand, there is a significant transfer of wealth from consumers to generators.

A fundamental observation is that how the EU ETS affects price *levels* is related but not equal to how it affects price *dynamics*. We will focus on how different ways of organising the EU ETS will affect volatility, but with an eye on the long term effects of the EU ETS we will also look at how certain key aspects of the design of the EU ETS (e.g. allocation) may affect price levels in the electricity sector.

The subject can be divided in several sub-questions:
1. How does the introduction of a carbon price – regardless of how it is imposed - affect electricity price and price dynamics?
2. How does the carbon price affect the price of electricity to consumers?
3. How does the EU ETS affect price dynamics, e g by affecting the merit order or the level of uncertainty in the market?
4. How would an altered design of the EU ETS affect the electricity market and the ability to reach the environmental objectives?
    a. Allocation design effects on pass through rates
    b. Price regulations' effects on certainty and efficiency
    c. Does the design of the ETS affect price dynamics in other ways?

In the general resource economics literature, the function of markets, pricing of externalities and choices of suitable environmental policy instruments have been investigated thoroughly. Seminal contributions include Pigou (1920), Weitzmann (1974). It is beyond the scope of this paper to give a comprehensive overview of this extensive body of literature. Instead we will focus our efforts on the more applied work of later years.

Before the EU ETS was launched, for instance Reinaud (2003, 2004), Econ (2003, 2004), Ilex (2004), Bode (2006) and Shuttleworth et al (2005) assessed potential effects of the EU ETS in relation to the electricity market. A central question in this work has been the rate of "pass through".

The term "pass through" can be loosely defined as the level to which the carbon price is reflected in the electricity price. However, this definition is slightly ambiguous, as the effect on electricity price will depend not only on the carbon price and the average carbon intensity of electricity generation, but also on the merit order of capacity in the electricity system. For our purposes, pass through should be interpreted as the extent to which the increase in *marginal cost* of generation is reflected in the price of electricity. Even though the Nordic electricity system is dominated by hydro and nuclear power the carbon price will have a substantial impact on electricity prices since the *marginal* generation is often relatively carbon intensive. For example, if the marginal cost of generating 1 kWh of electricity increases by 1 euro cent due to the carbon price, a 100 % pass through rate would thus imply that the electricity price also increases by one cent. In a competitive market this price will apply to all electricity sold in the system, not just the last kWh. Thus pass through in this sense should not be confused with pass through of increased *average cost* of generation*,* a definition that is sometimes also used in the literature. Furthermore, in the literature numbers on pass through are sometimes given as a percentage of the cost increase for a given fuel or plant type that is reflected in the average price in a system during a given period (this notation is, for example, used by Econ 2004 and 2006) This notation does not, however, tell the reader whether the pass through rate, when it deviates from 100 %, can be explained by market players not passing through the full marginal cost of carbon, or by the mix of fuels and plant types in the system.

More recently, Sijm et al (2005, 2006), Hewicker et al (2005), Philibert (2006) and Bonacina and Gulli (2007), among others, have extended the work on the interaction between the EU ETS and the electricity market, in some cases attempting to include empirical evidence in the analysis. Besides the level of pass-through, the effect of market power on pass through has drawn increasing interest. However, there seems to be no conclusive evidence on this matter, with findings of both higher and lower pass-through in the event of market power represented in the literature.

Econ (2004) used a modelling approach, applying a power market model (Econ Classic) of the Nordic electricity market to the problem of pass through rates. They forecasted significant, but not 100% pass-through rates that decrease over time. Their modelling indicated short term pass-through of approximately 70 % of the marginal cost increase for coal condensing, while in the longer term (10 year perspective) the pass-through would decrease to around 50%. The reason pass-through rates decline is that a price of carbon stimulates investments in low emitting capacity, thus reducing the time of year when coal condensing plants are price setting. Econ also concluded in their 2004 report that pass-through rates were likely to be lower in the Nordic market than in continental Europe. In a more recent report (ECON, 2006), results from an extended power market model finds higher pass-through rates, above 80 % of the increase of marginal costs for coal fired plants.

Literature that uses empirical evidence includes EME Analys (2006) and Sijm et al (2005, 2006, 2006b). EME Analys interviewed 10 firms active on the electricity market in the winter of 2005/2006 on issues of competition and price formation. All interviewees stated that the EU ETS was the most important driver for the increase in electricity prices during the second half of 2005. Many interviewees expressed little trust and concern over the functioning of the EU ETS. They pointed to other environmental policy instruments, like the NOx charge and the system with electricity certificates, which have not had the same dramatic effects on electricity prices. Among the factors mentioned as particularly problematic with the EU ETS were:

- Lack of fundamental information of supply and demand for emission allowances.
- The political influence of the price is extremely high since the regulation of the market is evolving and is a very politicised process.
- Market players can affect the price of allowances, and thus affect the price of electricity, by taking relatively small positions on the allowance market.
- The lack of banking provisions between 2007 and 2008.
- National considerations have influenced the allocation of allowances.

Sijm et al (2005, 2006) analysed pass through rates of CO2 costs, also including empirical data from the EU ETS. They use a range of methodologies, including interviews with stakeholders, empirical and statistical analyses, theoretical explorations and modelling. The focus is on the German and Dutch electricity markets, and the studies conclude that there is a significant correlation of the price of CO2 and the price of electricity. In the Netherlands the pass through rates are found to be between 39-55 percent, and in Germany 42-73 %, based on regression analyses. Modelling work using the COMPETES model showed pass through rates between 60 and 80 % depending on the country, market structure, demand elasticity and CO2 price considered.

An important observation in IEA (2007), which takes a more general approach, is that a high pass through rate can actually act as a buffer against uncertainty in carbon prices. This is because fuel prices and carbon prices are correlated to some extent. For example, if gas prices are low, then this will drive carbon prices down also, thus to some extent cancelling out the positive effect on gas generators.

To many electricity consumers in industry, the indirect effects of increased electricity price are more important than the direct costs of allowances. This is true in particular for the sectors that are subject to global competition, making it highly relevant in the discussion on competitiveness of European industry. The aluminium industry has been found to be perhaps the most severely affected by the EU ETS, and that sector is in fact not part of the scheme itself. Consequently, there have been suggestions to introduce policies that protect industries that have little or no possibility to pass on carbon costs to their clients, from rising electricity prices. However, one of the central pillars of the trading scheme is to include the cost of CO2 into energy prices, so exclusion of energy intensive industries from this would work against the original objectives of the scheme. Furthermore, the manner in which the allocation of emission allowances is done has an impact on competitiveness, investment incentives and costs incurred in industry. There is a growing literature on this subject; for recent analyses of competitiveness effects of the EU ETS on energy intensive sectors like steel, pulp and paper and aluminium, see for instance Demailly & Quiron (2007), Smale et al (2006) and Brännlund and Lundgren (2007). In the electricity sector in particular, the manner of allocation affects investment incentives and strategic behaviour of firms, see for example Åhman et al 2007, Åhman & Holmgren (2006), Neuhoff et al (2007). A related literature has examined this set of issues of different types of allocation on investment decisions in the US and EU context, see for example Burtraw et al. (2002), Parry (2005), Palmer & Burtraw (2006), Palmer et al (2006), Åhman, et al. (2006), Åhman, M, Holmgren, K. (2007), Harstad and Eskeland (2006), Fischer and Fox (2007b).

7 Prioritised research questions

The preceding sections have given an overview of the basic mechanism of the Nordic electricity market and of the recent literature on the general research questions relevant for the interaction between the EU ETS and the electricity market. We then provide an overview of the focus for the HOPE project by framing four general questions. Building on this, a number of specific research questions that need to be analysed further have been identified. Future work, in the HOPE project and by others, should focus their efforts on these questions. The questions are listed by category.

Understanding Uncertainty

1. **How does uncertainty affect incentives for investment and operation of the electricity system?** Some major sources of uncertainty include climate policy, natural gas price, technological change, hydro power availability, demand. Many of these factors are correlated.

2. **What are the effects of uncertainty over various aspects of program design for climate policy in particular**? Some of these aspects include the level of stringency, the initial

distribution of emission allowances, treatment of new and retiring sources, banking and administrative adjustments. What is the trade-off between the expected value and variance of carbon allowance price and decisions about investment?

Managing Uncertainty

3. **How can the regulatory uncertainty in the trading scheme be reduced?** This would include potential to centralise more of the decisions to the EU level, making them less prone to alterations due to political changes at the Member State level. Another option would be to increase the length of the trading periods. This would reduce regulatory uncertainty, which may have positive impacts on investments.
4. **What options exist to reduce price volatility in the EU ETS?** Measures that would limit future price variability would also reduce risk premium. Better banking and borrowing provisions would increase the flexibility over time. How would these options influence the potential to reach environmental targets?
5. **How can a more level playing field be achieved in the implementation of the EU ETS?** Companies will be more willing to invest, even under uncertainty, as long as they can establish a competitive advantage over other players in the market. This requires that policy makers establish clear rules and that companies can be confident that these rules will be applied consistently to all market players. In the context of the EU ETS, this applies for example to treatment of new entrants and of plants that are closed.
6. **How can firms better manage regulatory uncertainty?** Increased self-generation or formation of strategic partnerships among energy intensive firms are two strategies that are expected to become more common. Increased transmission may help mitigate increasing variability in hydro resources that may result from climate change, and help to mitigate the cost of policy. How will these efforts affect price formation and the effectiveness of climate policy?

Compliance Cost Pass Through

7. **What impact do EU ETS compliance costs have on retail electricity prices?**
8. **How does the pass-through rate vary with the portfolio of generation capacity in various markets?** How is it affected by the degree and nature of market liberalization in various member states?
9. **What opportunities do firms have to manipulate the utilization of capacity in order to affect short run variable costs and electricity price?** Is manipulation possible for example through increased use of emitting facilities at specific times of day in local markets?

Allocation

10. **To what extent does the initial distribution of allowances affect the incentive to locate investment?** Does allocation affect the marginal incentive for generation in different ways among member states that are linked on the transmission grid?
11. **Does variation in allocation method lead to variation in electricity price among member states and in the pass through of CO_2 cost to electricity**

Interaction with Other Policies

12. **How do other policies to mitigate greenhouse gas emissions in the Nordic countries affect the price of ETS emission allowances and how those prices are passed through to electricity prices?**

8 Methodology

At least four basic approaches can be used to analyse the interaction between the electricity market and the EU ETS:

- Analysis using a micro-economic toolkit
- Modelling
- Experiments
- Institutional research

In this section we provide an overview of these four different approaches and their relevance for the HOPE project. In section 8.5 we map each of the research questions identified above to the particular method or methods that could be used to address it.

8.1 Analysis using a microeconomic toolkit

Microeconomic theory is a useful tool for understanding how markets work, for characterizing market equilibria, for characterizing market failures and ways to correct them and for revealing how market outcomes and the behaviour of firms and consumers are affected by interventions in the market place. Economic theory can also reveal how the ability to exercise market power can affect electricity price determination. Writing down a theoretical model is a good way to formalize one's thinking about a particular economic question and, even when a theory model does not provide a precise answer, it can indicate what variables the answer depends on, providing an indication of where to look for the answer. For example, past research has shown that how taxes on inputs to production are passed through in the prices of final goods will depend on the functional forms of the demand and supply functions, including the price responsiveness of both (Palmer and Burtraw (2004), Fischer and Fox (2007a), Parry 2005).

A downside of a theoretical approach in the case of electricity is that it will necessarily involve simplifications in representing both the supply and demand sides of the market. Conceptual models are always a simplification of the real world, but in the case of electricity the simplifications can be even more dramatic. Electricity markets are characterized by long-lived capital and policies such as emissions taxes or renewable portfolio standards will change the shape of the supply curve as generators shift in the dispatch order. With multiple types of generators this type of effect is difficult to characterize within a conceptual model. Also, electricity demand varies greatly between peak and off peak time periods and this type of detail is not easy to capture in a conceptual model. To the extent that these features of electricity markets are important to understanding the relationship between the EU ETS and electricity markets, there may be limits to what can be learned from conceptual modelling.

8.2 Simulation Modelling

Another approach that could be used to tackle the issues raised by the HOPE project would be to use a model of the Nordic electricity market and its interactions with the wider European electricity markets in neighbouring countries. Simulation modelling provides a way to introduce technological and institutional realism about the electricity sector into analysis that may be difficult to capture in a conceptual model. For example, conceptual models typically assume that supply curves for goods are smooth and continuous; however, the electricity sector has long-lived capital and a variety of technologies with different fuels and capital intensities are used to generate the product. Electricity is not storable, so supply and demand must equal at each point in time. Electricity markets may also be segmented due to transmission constraints between locations and the severity of these constraints may vary over time.

However, modelling approaches also have several drawbacks. Models have substantial data requirements usually needing data on heat rates, fuel and operating and maintenance costs and a whole host of constraints. For the Nordic market, data on hydro including variability in precipitation, storage capability and environmental constraints are also key. To the extent that there is an existing model parameterized for the Nordic market that would meet our needs, these data requirements may have already been met substantially. Perhaps an even greater limitation is the fact that models require numerous assumptions about features and institutions of the electricity market, regulations, fuel prices, etc. that can have a substantial effect on the findings of the analysis. Thus, it is key that model users are aware of all of the key assumptions that went into setting up the model and how important they are in determining the results. When the influence of a particular assumption is believed to be critical, it is important to consider alternative parameterizations and how they might affect the results of the analysis.

Another issue for the project is that most of the models of the electricity sector are proprietary to consulting firms and other profit making ventures. This means that the underlying model code may not be available for modification, which could limit the types of questions that could be considered. Also, use of a proprietary model could limit the credibility of the research with academic audiences.

Using a Nordic sector electricity model will require some investment in learning how to use and, if possible, manipulate existing models or developing our own model based on existing algorithms at RFF. It is difficult to know up front which approach poses more of a challenge, but it is certain that there would a non-trivial learning curve in either case. The appendix reviews the different electricity sector models potentially available for use in this project and their key salient features.

8.3 Experiments

Experimental economics is the use of experimental approaches to evaluate economic theories. Traditionally most experimental economists have conducted their experiments in an economics laboratory. This laboratory generally comprises a group of human participants at a set of computers that are linked together with specialized software that allows the participants to be presented with a set of carefully designed decision tasks where the incentives, choices, information, and other characteristics are carefully controlled. By allowing one factor to vary while holding all other factors constant in the laboratory, experimentalists can test theoretical predictions about how that "treatment variable" affects outcomes. Due to their availability and suitability, college students are frequently used as experimental participants in economics laboratories.

Laboratory experiments tend to focus on what makes markets work, rules for exchange, and the behaviour of economic agents under different market or exchange mechanisms. With these lab experiments, it is possible to estimate or predict reactions to changes in economic rules. For example, laboratory experiments could help determine how market participants react to different approaches to allocating emission allowances.

8.4 Institutional research

An approach that could help to inform the other approaches identified above or to develop insights about key aspects of certain questions related to this project is research on existing institutions and technological features of the Nordic electricity market. Questions about institutional features such as how regulation works, both those applied to the electricity markets and a particular countries implementation of the ETS and related policies, such as policies to promote renewables. Institutional research would involve gathering and organizing this information on policies for the Nordic countries and their trading partners to develop a sense of the context within which the industry operates.

Another form of institutional research involves gathering data and facts related to the actual configuration of the regional electricity markets. Information about transmission capability both within the Nordic market and between the Nordic market and its trading partners is key to understanding how the electricity market will be affected by the evolution of the EU ETS. We have already started some of this research as displayed in the discussion of the characteristics of the Nordic electricity market above. More of this type of institutional research would be necessary for informing all three of the other approaches described above: in order to develop conceptual models that are relevant to the Nordic market, to parameterize simulation models for the Nordic electricity sector, and to design experiments with some contextual relevance.

8.5 Mapping Questions and Potential Research Methods in HOPE

The preceding discussion identifies four different research methods that could be used to address the research questions raised in this project. Which research method is most appropriate depends on the research questions raised.

Question	Methods
1. **How does uncertainty affect incentives for investment and operation of the electricity system?**	**Economic theory**: Review literature and develop a conceptual model that incorporates price setting considerations in electricity sector in Nordic market and utility responses to uncertainty. Payoffs may be asymmetric. Can important differences be identified between the operation of individual installations and the operation of a portfolio of installations managed by a firm? **Modelling**: Modify and apply an electricity market model that can explicitly capture the effects of uncertainty on firm behaviour. A substitute might be the use of the delta method

	to use results from multiple deterministic scenarios analysis to represent what might happen under uncertainty. A third approach is option theory modelled at the level of individual installations.
2. **What are the effects of uncertainty over various aspects of program design for climate policy in particular**?	**Economic theory: C**onceptual review of prices versus quantities literature in environmental economics. Extend the analytical approach laid out in Palmer and Burtraw (2007). **Modelling**: (See 1 above)
3. **How can the regulatory uncertainty in the trading scheme be reduced?**	**Economic Theory:** Changes in the trading period can be characterized over time leading to different risk profiles in an economic model. Uncertainty can also be modelled explicitly with specific functional form assumptions. **Institutional Research:** The analysis would benefit from a strong understanding of what is the direction of policy for the EU. What is the status and momentum for further market liberalization?
4. **What options exist to reduce price volatility in the EU ETS?**	**Economic Theory:** A safety valve instrument that might introduce additional allowances if prices spike above a specified level is unpopular among EU policymakers. However, offsets provide an effective safety valve by introducing additional allowances into the market. Allowing banking and borrowing may also reduce volatility as it increases the flexibility in time. **Experiments:** The introduction of a reservation price in an auction is supported by economic theory and is considered a good feature of auction design. This type of feature can provide assurance for innovators and investors. Experiments can illustrate the change in behaviour of investors in the presence of a reservation price.
5. **How can a more level playing field be achieved in the implementation of the EU ETS?**	**Institutional Research:** Interviews with regulated entities under the EU ETS can help identify which aspects of the regulatory program produce the greatest uncertainty about future outcomes.
6. **How can firms better manage regulatory uncertainty?**	**Economic Theory:** Individual investments can be modelled using option theory that accounts for characterizations of uncertainty. **Simulation Modelling:** The value of

	investments by various entities including transmission companies can be explored under various characterizations of uncertainty.
7. **How do EU ETS compliance costs affect retail electricity prices?** 8. **How does the pass-through rate vary with the portfolio of generation capacity in various markets?** How is it affected by the degree and nature of market liberalization in various member states?	**Economic theory:** Economic theory will provide different answers depending on the nature of the model. A constant returns-to-scale model with a competitive market will show that pass through rates hinge on relative demand and supply elasticities upstream and downstream in the product chain. The electricity sector has important fixed capital, so pass through rates hinge on the portfolio of technology, as well as market structure and the ability of generators to influence prices. If prices are determined by a regulator, the pass-through will reflect the original cost of allowance acquisition on average. **Experiments**: The determination of electricity prices should reflect opportunity cost. This has been shown in abstract ways previously (Plott 1984). Experiments in a context specific to the Nordic electricity market may help regulators and others appreciate the way that market prices are determined. They can help reveal the degree to which prices are determined on the basis of original cost versus opportunity cost. **Modelling**: These questions have been looked at before using models for various parts of the European electricity market. Several extensions to the previous work are possible including examination of imperfectly linked markets for fuel and electricity among neighbouring countries. The question of market power requires a model that allows for examination of strategic behaviour.
9. **What opportunities do firms have to manipulate the utilization of capacity in order to affect short run variable costs and electricity price?**	**Economic Theory:** The conceptual opportunity to manipulate factor markets in order to raise rival's costs or to affect product price is established in the strategic literature on industrial organization. The specific aspects of the electricity industry could be usefully modelled using analytical methods to illustrate the stability of such strategies. **Simulation Modelling:** What is the potential magnitude of payoff of manipulating factor markets? Does this strategy require coordination among a cartel? **Institutional Research:** How stable is a cartel likely to be in the electricity industry? What type

	of coordination mechanisms could support cartel behaviour?
10. **To what extent does the initial distribution of allowances affect the incentive to locate investment?**	**Economic theory:** Economic theory coupled with empirical data can show the importance of allocation decisions when allocation provides an incentive for new investment (Åhman and Holmgren, 2007). Similar approaches and analytical methods can be used to examine the incentives associated with alternative methods, and the strategic aspect of decisions in different countries within a larger "allocation game." **Experiments**: Experiments can serve a pedagogical purpose for this question to illustrate how strategic behaviour will respond to differences in policy. There does not seem to be a fundamental research question in this case that could be informed by experiments. **Modelling**: An electricity sector market model could be used to contrast a situation in which the Nordic market is an island to one in which it transmission flows in and out of the market, or goods and services trade and the location of production hinges on factor prices including electricity.
11. **Does variation in allocation method lead to variation in electricity price among member states?**	**Economic theory:** If allocation is not an auction or lump sum, but is tied to behaviour such that it creates incentives, it can lead to a variation in electricity price. Moreover, allocation may affect electricity prices if different countries have different degrees of (a) regulation, (b) existing portfolios of generation technology into which new investment is added or dispatch is planned. The change in electricity price may be a key aspect of an "allocation game" from the stand point of national interest. **Experiments**: The "Acid Rain Game" (Mäler and DeZeeuw (1998)) was a seminal illustration of strategic issues associated with Europe's policies to reduce acidification. Similar ideas could be explored in an experimental setting. **Modelling**: An electricity sector market model would be useful to measure the potential magnitude of this effect.
12. **How do other policies to mitigate CO2-emissions in the Nordic countries affect the price of ETS emission allowances and how those prices are passed through to electricity prices?**	**Economic Theory:** The introduction of multiple constraints is likely to affect the shadow price (allowance price) of the cap on emission allowances. However, the incidence of different types of policies varies according to specific characteristics of the industry. For instance, an intensity target or renewable portfolio standard

	is likely to have less of an effect on electricity price even though social cost is greater per ton of carbon reduced. A subset of producers is likely to benefit and a subset are likely to be harmed by such policies. **Modelling**: If we can adjust one of the Nordic electricity sector market models to represent the renewables policies in different countries, we could look at the interaction between these two policies and see how changing the renewable policy affects allowance prices and electricity prices. However, to really look at this need to have separate linked model of other demands for EUAs as electricity is not the only game.

9 Conclusions and next steps

In consideration of the interaction between emissions trading and the electricity market, several related but separate issues and research questions are relevant to analyse. To keep the questions as clearly defined and distinct as possible, we summarize the focus of further research in the HOPE project in four areas that frame the discussion on the interaction between the EU ETS and the electricity market, and in broad terms the incentives for investment behaviour that are created.

- Understanding and managing uncertainty

As we have noted in the review above, most of the literature suggests that uncertainty in the implementation of climate policy undermines the incentives for investments that would help achieve the policy goals.

- Price interactions between the EU ETS and the Nordic power market.

The EU ETS leads to changes in revenues and changes in costs. On net have profits for some firms or for the industry as a whole increased under the program? How has the incidence of cost been shared by electricity producers and consumers?

- What incentives for investment are created by various approaches to allowance allocation?

Only lump sum distribution of allowances or an auction provide entirely neutral incentives affecting the choice of technology for new investments. All other approaches alter the slope of the playing field, often in ways that are not anticipated.

- How do climate related policies such as renewable support programs interact with the EU ETS and electricity markets?

Many supplemental policies are explicitly intended to promote specific technologies. These policies are especially justified when there are market failures with respect to specific technologies.

In previous sections we listed a number of more detailed research questions and map available research methods with each question. When assessing for which research questions we would add most value and in making the final decision on what methodologies to apply, we will draw on the literature review and on the coming institutional research. Furthermore, we will seek the input from stakeholders within and outside of the HOPE project.

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Appendix

Overview of Available Models for the HOPE project

The following is a sample of models that may be useful for the project. The first group of models was identified in the inventory of models of the Nordic electricity markets that was included in the first phase of the Nordic Energy Perspectives project. Two of the models listed may be likely candidates for modelling as part of the HOPE project – the PoMo model, which proprietary that can be used for short term system dispatch, and the Balmorel model, which is a public domain model and incorporates capacity investment. Subsequently we also consider LIBEMOD, a model from Statistics Norway and the University of Oslo and some other models owned by consulting firms including the ECON suite of models and VTT-EMM.

PoMo** and **DoS: PoMo (short for Power Model) is an electricity market model that covers Sweden, Finland and Norway. The model focuses on wholesale electricity spot transactions. It is an optimization model that minimizes the future costs of meeting a given level of electricity demand. The model assumes that electricity markets are perfectly competitive. The model runs over a four year time horizon and divides demand into 52 week-long time steps. The model has a sophisticated treatment of hydro dispatch each week and has the ability to explicitly consider fuel price volatility. Because the parameters of the model are estimated statistically, the model can be used to calculate a distribution of future electricity spot prices. It includes costs of CO_2 allowances and other taxes. Investment in new capacity is exogenous in the model. (Unger et al. 2006). PoMo includes biomass in the form of waste fuels, industrial by-products and wood chips and refined biomass. It is unclear from the documentation we reviewed whether wind turbines are represented or not.

DoS is a complementary model to PoMo that predicts electricity demand which is exogenously input into PoMo. The model appears to have detail regarding electricity demand by industry and type of end-use, which helps inform load shape predictions. The model uses econometric estimates of derived electricity demand as a function of electricity price for electricity intensive industries. For other industries and households, demand is calculated using assumed own-price elasticities. The model also includes the heating sector.

PoMo would not enable an investigation into questions about the nature of investment, except as a separate check on the projected utilization of new facilities. It could be used to look at allowance cost pass through in wholesale electricity rates. Also, because prices are stochastic there is somewhat formal treatment of uncertainty.

Balmorel: This model was developed by a group of researchers from several institutions to analyze electricity and district heat energy markets in the Baltic countries, including Norway, Sweden, Denmark, Finland, and Germany. It is maintained by Hans Ravn of RAM-lose edb. The model has open source code that is available along with examples of data sets on the web (www.balmorel.com). The model is implemented in GAMS. It combines engineering economics elements with econometric elements. Demand is dependent on electricity price and supply of electricity and district heat depend on technical parameters and fuel costs. Transmission constraints between regions are represented and the model has the ability to model environmental taxes or caps on emissions. The model allows for both exogenous and endogenous investment in both new production technologies and transmission links.

The HOPE project would need to supplement the model with additional supply data., which is a downside. In the first phase of the Nordic Energy Perspectives project, the model was run using data for Denmark, Finland, Norway and Sweden (Unger et al. 2006).

This model appears well suited to looking at questions related to how the cost of complying with the ETS affects investment. Presumably one would have to handle uncertainty issue with a scenario approach. If we have the source code, we might also be able to use it to look at the relationship between policies to promote renewables, end-use efficiency and other technology policies and the ETS.

There are several other models that have various strengths.

ECON Classic and ECON Carbon Market: ECON Classic is a partial equilibrium model of the electricity markets in the EU, including all the Nordic countries. This is an optimization model that maximizes the sum of producer and consumer surplus in each year. It assumes that electricity markets are perfectly competitive, although exogenous mark-ups can be included. The model divides demand into five sectors (households, service, industry, industry electric boilers and district heat). Annual load is divided into 65 time steps. The model is usually used for 15-20 year forecasts. Investments are endogenous except for renewables and nuclear. Fuel prices are exogenous. ECON Classic also has a component for electricity certificates.

ECON Carbon Market is an extension of ECON Classic and includes emissions from all sectors covered by the EU ETS. In the model, emission from generation from heat and power generation and from production in EU ETS industries are matched with the cap, i.e. the total emissions must be lower than the total amount of allowances. The carbon price is determined by requiring supply to equal demand for allowances, via endogenous abatement in the ETS sectors. Geographically, the model covers EU-27 plus Norway and Switzerland.

ECON BID is focussed on price structure and variability, and it was developed with the purpose of improving the analyses of transmission investments, where profitability is more dependent on variability than on absolute levels. The model has an hourly resolution, also making it suitable for analyses of wind power.

These models are owned by ECON, the Norwegian consulting firm.

VTT-EMM: This model is an optimization model that minimizes the cost of meeting electricity demand. The model includes the four Nordic countries, but does not include any transmission constraints among them and thus there is a single electricity price in the region. Several features of the market are exogenous including imports and exports with neighbouring regions, electricity demand and new investments. The model is owned by VTT Technical Research Center, a contract research organization in Finland.

LIBEMOD: This model characterizes a set of markets for energy goods including coal, natural gas, oil, electricity and biomass. Natural gas and electricity are traded in Western European markets, and oil and coal are traded in world markets. Electricity also is produced by reservoir hydro, pumped hydro, nuclear, waste power and wind power. Fuel prices are determined annually, while there are seasonal and time-of-day markets for electricity. The model includes 17 countries in Western European.

Electricity producers in LIBEMOD face a number of costs including fuel costs, start-up and maintenance costs and investment costs. In addition, there are technical constraints such as limits on the use of reservoir hydro. Transfers of water between seasons cannot exceed the reservoir capacity.

LIEBEMOD allows alternative assumptions about market structure in electricity and gas markets, both for domestic markets (domestic production of electricity as well as domestic transport and distribution of electricity and gas) and for international markets (transportation of electricity and gas across Western European countries). For each market, market structure can represent perfect competition or empirical imperfections or mixed characteristics. The model determines all prices and quantities in the energy markets, as well as emissions of CO_2. The model can be used to address a variety of policy cases including climate policy (Aune et al. 2004a; 2004b). LIBEMOD was developed jointly by the Frisch Center of Department of Economics, University of Oslo and Statistics Norway.

Two other models have capabilities that could be useful in addressing the questions in HOPE but they are not configured for the Nordic power market.

COMPETES: This model was developed by the Energy Research Center Netherlands (ECN) and simulates electricity market operations using complementarity theory. COMPETES (COmprehensive Market Power in Electricity Transmission and Energy Simulator) covers electricity markets throughout Europe with transmission linkages between countries. The model does not include capacity planning and retirement; it covers dispatch organized by three seasons and four time blocks. It simulates strategic behaviour of large producers on the wholesale market under different market structure scenarios (varying from perfect competition to oligopolistic and monopolistic market conditions) This strategic behaviour is based on the theory of Cournot and Conjectured Supply Functions (CSF) on electric power networks.

Haiku: This model was developed by Resources for the Future and is configured for the continental US electricity market. The model solves for system operation over three seasons and four time blocks and long run generation capacity investment and retirement in twenty regions, with power transfers between regions constrained by transmission capability. Gas and coal market prices are endogenous, as is electricity demand. A wide variety of environmental policies and approaches are configured in the model including allowance trading and technology support programs including tradable renewable credits. The model offers a choice in the characterization of market structure as either competitive or regulated cost of service.