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GLOBAL CHANGE AND ENERGY MARKETS – ANALYSIS THE EFFECTS OF NORDIC ELECTRICITY MARKET INTEGRATION ON ENVIRONMENTAL POLICY USING GTAP-E MODEL

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ABSTRACT: This study applies the GTAP-E model which incorporates carbon emissions from the combustion of fossil fuels and this provides for a mechanism to trade these emissions internationally. This facilitates an analysis of North European Energy production and energy markets while still consistently taking into account the effects of global trade and global abatement. We analyse the effects of energy market integration on the scope of national abatement policies in the countries on the Baltic Rim, and especially in Finland. Energy markets will influence emissions policies via technological opportunities for energy production and for energy trading. The costs of abatement will also depend on the degree of competitiveness of energy markets. Also the effects of the use of Kyoto mechanisms on competitiveness and efficiency in the North European markets are analysed. Energy market integration will itself depend on global and European abatement targets. The main finding of the study is that while emission trading clearly may lead to more cost-efficient and less costly abatement, the integration of energy markets can by itself lead to cost reductions of almost the same magnitude. Also, while the emission permit price is lower due to the electricity market integration there are both losers and winners within the Nordic group.

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TIIVISTELMÄ: Tässä tutkimuksessa hyödynnetään globaalia numeerisesti laskettavaa yleisen tasapainon mallia (GTAP-E), jossa on myös mukana CO2 päästöt. Mallissa CO2 päästöt syntyvät hiilen, öljyn ja liikennepolttoaineiden käytöstä tuotannossa tai loppukulutuksessa. Tutkimuksessa analysoidaan sekä Kioton sopimuksen mukaista että pelkän EU:n kattavan päästökaupan ja Pohjoismaiden sähkömarkkinoiden integroitumisen vuorovaikutuksia. Energiamarkkinoiden vapautuminen kilpailulle ja niiden osittainen integroituminen vaikuttaa päästökaupan kustannuksiin mm. fossiilisten polttoaineiden helpomman korvattavuuden kautta. Tutkimustulosten mukaan sähkömarkkinoiden integroituminen saattaa tuoda merkittäviä kustannussäästöjä hiilidioksidipäästöjen vähentämisessä, joskin Pohjoismaiden sisällä vaikutukset eivät ole kaikille aina suotuisat johtuen mm. vaihtosuhteiden muuttumisesta.

1 Introduction

The mitigation of global climate change relies on both economical and technological measures. While it is being currently debated, to what extent economical measures are to be global, the scope of national policy measures will nevertheless depend on the global economy via the externalities arising from global abatement policies. On the other hand, the scope of national policies is also restricted by the technological possibilities of domestic power generation and energy trade. Contrary to trade in products, energy trade is usually dependent on regional transfer capacities, and this is certainly the case for the energy goods presently regarded as the most important for abatement policies, namely, natural gas and electricity. Thus, while abatement is mandated at a global level, its scope will to a large extent depend on regional developments. This subproject studies the interactions between the integration of the North European energy markets and emission abatement policies.

European energy markets are to be liberalised in the near future. There is already a European Union directive liberalising the electricity markets, and a directive on fuels is under scrutiny. In addition, there is a European Council agreement on the liberalisation of the markets for natural gas. Energy trade between the Nordic countries, the Baltic countries, Russia, as well as Northern Central Europe is thus likely to be liberalised, and it is these emerging Baltic Rim energy markets we are focusing on in the current study.

The effects of integration on competitiveness should be beneficial to mitigation policies, insofar as they increase the efficiency of resource utilisation. However, the effects need not be beneficial in all sub-regions. Moreover, integration may make it more difficult for a particular country to apply its peculiar abatement policies. If possibilities for imports are abundant it will be more difficult to use economic measures to direct consumption of energy to less polluting sources, as national policies are bound, say, by the agreements on integration. Abatement investments will also be in competition with investments on transmission capacities to increase energy imports, and with investments to power generation capacity

To achieve the integration of North European energy markets, heavy investment in transmission capacity is necessary to facilitate trade in energy. Presently, Nordic electricity markets are integrated to the Baltic countries and to Central Europe only to a very limited degree, while the Nordic gas grid and gas pipelines from Russia to Central Europe are only at a planning stage.

In the Nordic countries, liberalisation and integration of electricity markets has already taken place. Nordic electricity markets thus highlight the interdependence of abatement policies and energy trade. Arguably, the integration of energy markets in the countries surrounding the Baltic Sea will have many of the consequences of common Nordic electricity markets on the region as a whole.

After de-regulation, competition in the Nordic electricity markets has increased, and the retail prices of electricity have consequently fallen. This effect is due to an increase in the number of competitors, and to increased possibilities for electricity trade between distributors and producers. Some of the traditional risks in electricity generation have also been reduced, notably the variability in generation costs due to yearly variability in hydropower generation. However, since electricity trade between Nordic countries largely stems from a need to complement hydro-power capacity with fossil fuel-based power in dry years, country-specific emission targets may have an adverse effect on electricity trade, insofar as these policies restrict fossil fuel-based generation capacity.

Further integration of the North European energy markets will have several effects. While electricity prices in Northern Central Europe are likely to fall, Nordic electricity prices are actually more likely to rise from their present, relatively low level, once free, regional electricity trade can be commenced. This, and the fact that especially the Nordic countries have committed to relatively stringent emission targets, will have important consequences to investment in power generation in the Baltic Rim countries. In particular, investment may be directed abroad. Many Nordic power companies are already active in the Baltic countries and it is possible that Finnish – and thereby Nordic - electricity markets will have an access to Baltic power in the future. Since emission targets are less stringent in the Baltic countries, imports of electricity may constitute a cheap substitute for domestically produced electricity, with adverse effects on emissions in the Baltic Sea region. There are also plans to increase the gas transmission capacity from Russia to Central Europe by a new pipeline through the Nordic countries. While some of these investments may facilitate domestic abatement, some of them clearly will not.

The two main issues to analysed in this study are:

- how does the Nordic energy market integration affect on the national abatement policies, and
- how does the introduction of an international CO2-permit market affect the results when electricity markets are integrating within Nordic countries.

However, before presenting the modelling framework and the results of the analyses, a short review of Nordic electricity markets is provided.

2 The Nordic electricity markets

Four Nordic countries (Denmark, Finland, Norway and Sweden) have deregulated their electricity markets. The Nordic market is becoming more and more integrated one the deregulation also freed cross-border electricity trade. A common market place, the Nordpool, forms the main trading place where a spot (and futures) market price for electricity is determined. Although bilateral contracts are still the most common way to sell electricity in the Nordic market the Norpool spot price forms a reference price for the contracts as well.

The Nordic countries have in fact had a long tradition of co-operation (Nordel co-operation has taken place since early 1960s) in making use of their different electricity generation structures. But this co-operation took place under regulated international trade arrangement (only the large state owned companies were allowed to import and export electricity).

2.1 Denmark

Denmark's electricity come from conventional thermal plants and combined heating and power (CHP) facilities. Denmark was one of the first countries to implement major support programmes for renewables and CHP generation. Environmental protection was a major objective, but security of supply was also a powerful influence. Among these policies was the national heat plan that gave the national and local governments the power to prescribe for certain parts of the country, the form of heating that citizens should use.

Today, Denmark has the highest share in the world, of electricity generated in CHP plants and one of the largest existing district-heating systems. In 2000, 12.6% of Danish electricity generation was from wind turbines, also the highest of any nation. Denmark is expected to come very close to meeting its CO_2 commitments, if all of its current abatement policies remain in place especially a national system of tradable CO_2 quotas for power plants.

Denmark is now a net energy exporter. In recent years, high prices have even led to increased exploration and new oil and gas finds in the North Sea. Estimated recoverable reserves of oil now stand at 260 Mtoe, which enables Denmark to sustain the current level of oil production for the next 14 years.

Denmark has liberalised its power market beyond the requirements of the European Union's 1996 Electricity Directive. Since 1 April 2000, customers consuming 10 GWh per year have been free to choose their supplier. On 1 January 2001 the threshold was lowered to 1 GWh. By 1 January 2003, all end consumers will be able to choose their supplier. A system of tradable CO_2 quotas for power plants was introduced on 1 January 2001. The IEA recommends that the government extend the quota system beyond 2003. Without this system, electricity exports could soar after 2003, and national CO_2 emissions could fall short of the Kyoto target by more than 19%.

Further adaptation to market conditions will be necessary. Denmark's grid operators currently must purchase power from these sources at fixed and above-market rates despite their higher costs, even if cheaper, fossil-fuel power stations have to be taken off the grid. Consequently, only 60% of the electricity market is governed by competitive price signals, which makes the electricity prices for residential customers among the highest in IEA Member countries.

2.2 Finland

Finland's electricity procurement is highly diversified. Total generation in 1994 was 62,18 TWh, of which 30 percent came from nuclear power, 20 percent from hydro power, 30 percent from co-generation (CHP) and 20 percent from conventional condensing power. Imports from Russia (5 TWh), Sweden (1.6 TWh) and Norway (0.002 TWh) amounted to 9 percent (6.602 TWh) of the total electricity procurement. Such a diverse pattern of generation has the obvious advantage of low dependence on a single exogenous factor, such as yearly precipitation level (as is the case in Norway, although in Norway there are large reservoir capacities that alleviate the problem). On the other hand, a fairly large share (over 20 percent) of Finnish generation uses imported coal and natural gas, and is therefore subject to possible cost shocks if the fuel prices rise considerably. Another distinctive feature of electricity procurement is the large share of co-generation of heat and electricity (CHP). In utilising and developing co-generation techniques Finland is among the world leaders. Current total generation capacity is about 14.9 GW. Total demand is forecast to reach 92 TWh by 2010. This is roughly equivalent to a 2 percent annual increase in consumption of electricity.

The total electricity demand is divided as follows: industry 55.1 percent, households 23.1 percent, agriculture 3.9 percent, service sector 11.2 percent, and public sector 6.7 percent . Transmission losses are about 4 percent of the total consumption.

The Finnish Electricity Market Act came into force in June 1995, first opening up the 500 kW customer market. The second and final phase of the market deregulation began on 1.1.1997 when all customers became entitled to choose their suppliers. Transmission and distribution of electricity is regulated by the new authority, The Electricity Market Authority, which is an independent expert body subordinate to the Ministry of Trade and Industry.

Finland's market reform model resembled that of the non-voluntary pool model, as a bilateral contract market and a pool, which was based on both demand and supply bidding, were active simultaneously. The pool, EL-EX, began operating in August 1996 and accounted initially for only about 5 percent of the country's total electricity trade in 1996. Despite its small share of trade the quoted spot prices provided a useful point of comparison for bilateral contracts. There has been fairly rapid convergence of the Finnish Pool with the Nordic electricity exchange, the Nord pool A.S.A. As of 3.6.1998 EL-EX started to operate as an official representative of the Norwegian-Swedish joint spot market Nord Pool A.S.A. In May 1998 the Swedish Svenska Kraftnät became a major owner of EL-EX with a 50 percent share. Currently Nord Pool includes Finland as a market place for electricity trading.

Deregulation followed a rapid rationalisation process among Finnish electricity companies. Some companies merged and the largest company IVO has increased its share of the retail market by buying distribution companies. IVO (currently Fortum) also bought the majority share of Sweden's Gullspång and formed a joint company, Birka Energi, with the Stockholm Energi. There have even been talks of a merger of the largest Swedish company Vattenfall and Fortum, which have not yet realised.

2.3 Norway

Nordic electricity market restructuring began with the introduction of the Norwegian Electricity Market Act in 1991, which initiated competing in generation and marketing of electricity in Norway. Statkraft, the dominant state-owned electricity company, was re-organised and simultaneously given a degree of independence; while it remained a state-owned company it is now run along commercial lines. Its vertical monopoly structure was split into separate companies: Statkraft SF which is now solely responsible for the generation and sales of electricity, and Statnett SF, which was established as the grid company (controlling 70 percent of the high voltage 132 kV lines) and also acts as the system operator. Transmission and distribution remain regulated by the Norwegian Water and Energy Administration (NVE).

A Statnett subsidiary, Statnett Marked, was established to administer the spot market for electricity trading. Statnett Marked formed the basis of a joint Norwegian-Swedish electricity pool, Nord Pool A.S.A, which began operating on 1.1.1996 at the time the Swedish electricity market was deregulated. NordPool is owned and operated on a 50-50 basis by the two grid companies Svenska Kraftn and Statnett SF. In 1997, the total volume of trade in the Nordpool spot (40.6), futures (42.6) and regulating markets (5.9) was 89.1 TWh, and the spot market trade represented about 20 percent of total Norwegian-Swedish electricity consumption. Statnett also runs a real-time market (the regulating market), using it to settle imbalances in real time.

As of 3.6.1998, the Finnish electricity exchange EL-EX began operating as the official representative of Nordpool in Finland. EL-EX products have since been merged with Nordpool's, and its ownership base broadened in May 1998 when the Swedish grid company Svenska Kraftn purchased a 50 percent share. EL-EX was merged with NordPool in 1998. Nordpool organises two markets, Elspot and Eltermin, the latter being the futures and forward market. Elspot is a day-ahead market in which a trading day is divided into 24 hourly markets. Market participants provide separate bids for these 24 hours and the market clears for each of these hours. Each participant provides a schedule of quantities and prices by 12 noon for delivery the following day. The clearing price is determined by 2:00 pm and final prices are determined. A generator can specify a range of prices and quantities with which it buys or sells on the spot market. In addition, a generator can have bilateral contracts on the sale of electricity. In practice there can be different price zones, and Nordpool arranges separate Elspot markets for each zone.

Norway's electricity generation is practically all hydro power; in 1994 total electricity generation was 113,5 TWh, of which 112.9 TWh (99.4 percent) was hydro generated. The 1994 generation level can be considered as an average yearly generation level. The system has large reservoir capacity, (about 80 TWh) which is able to store water for a number of years.

2.4 Sweden

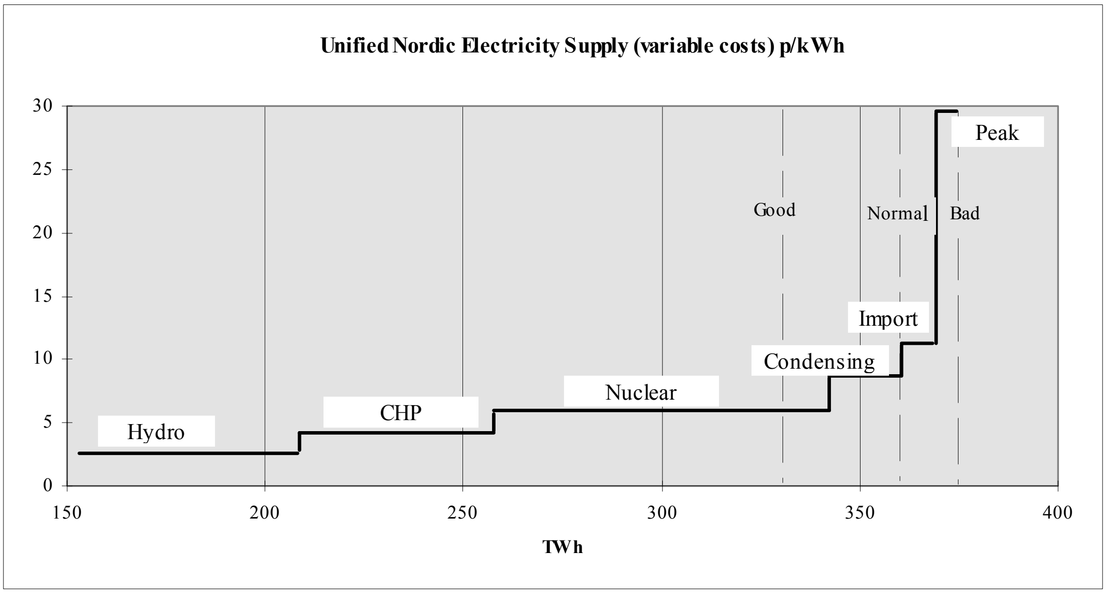
The deregulation of the Swedish electricity market commenced in 1991. The largest state owned company Vattenfall was re-organised into an independent generation company, a regional network company and several local network companies. All its operations in the national grid were transferred to a separate grid company, Svenska Kraftnät, which manages the national grid and is responsible for all international links.

Deregulation entailed fundamental changes: production and sale of electricity were completely separated from the transmission and distribution of electricity. The transmission of electricity on the grid was regulated by a new authority, the Grid Authority, which has since been replaced by the Swedish National Energy Administration. The total amount of electricity generated in 1994 was 137,65 TWh, 42 percent of which was hydro power, 51 percent nuclear power, and the remaining 7 percent fossil fuel based generation. Table 1.3 shows that the largest company, Vattenfall, dominates the market with over 50 percent market share. Vattenfall is the largest supplier of electricity in the Nordic market (units in TWh).

2.5 The Nordic electricity transmission system

On the whole the Nordic electricity generation is highly dependent on water supply (and hence climate) which brings additional uncertainty (despite the fact that hydro power is fairly easily adjustable) to the price variation.

The figure below shows the structure of the overall Nordic electricity supply in 1993.



Due to the climatic conditions hydropower generation can vary yearly as much as the total amount of electricity generation in Finland (70 TWh).

The national grid companies, i.e. the transmission system operators in the Nordic countries, co-operate within an organisational body called Nordel. This is why the Nordic electricity market area is also called Nordel area.
Nordel's tasks fall mainly into the following categories:

- System development and rules for network dimensioning;
- System operation, operational security, reliability of supply and exchange of information;
- Principles of transmission pricing and pricing of ancillary services;
- International co-operation;
- Maintaining and developing contacts with organisations and regulatory authorities in the power sector, particularly in the Nordic countries and Europe;
- Preparing and disseminating neutral information about the Nordic electricity system and market.

The national grids and their interconnections form the backbone of the Nordic electricity market.

Table 1 shows the capacities of the interconnections within the Nordel coutries.

Table 1. Existing interconnections between the Nordel countries.

Countries	Transmission capacity , **MW**	
Denmark - Norway	From Denmark **1040**	To Denmark **1040**
Denmark - Sweden	From Sweden **1775**	To Sweden **1700**
Finland - Norway	From Finland **100**	To Finland **70**
Finland - Sweden	From Sweden **2230**	To Sweden **1830**
Norway - Sweden	From Sweden **4055**	To Sweden **4755**

The utilisation of existing interconnections to areas outside the Nordic area is of considerable importance to the energy and power balance.

These links are as follows:
Finland-Russia.
Poland-Sweden.
Germany-Sweden.
Denmark-Germany

Table 2 describes the capacities of these interconnections as they exist to day.

Table 2. Existing interconnections between the Nordel countries and other countries

Countries	Transmission capacity , **MW**	
Denmark – Germany	From Nordel **1950**	To Nordel **1950**
Finland – Russia	From Nordel **60**	To Nordel **1160**
Norway – Russia	From Nordel **50**	To Nordel **50**
Sweden – Germany	From Nordel **600**	To Nordel **600**
Sweden – Poland	From Nordel **600**	To Nordel **600**

The total exchange of electricity within the Nordel area and between Nordel and other countries in 2001 was over 50 TWh corresponding to 13 % of the total electricity consumption. The Nordel area as a whole imported 1.4 % of the total consumption in 2001.

Other interconnections which may play an important role for the importation of energy to the Nordic electricity market area are:

An interconnection between Norway and the UK.
An interconnection between Finland and Estonia.
An interconnection between Norway and Holland.
The expansion of Kontek between Denmark East and Germany.
The further expansion of the interconnection between Finland and Russia.

The most critical cross sections (the most probably overloaded interconnections) within the Nordic electricity market area are found in the south, where the Swedish, Norwegian and Danish grids are interconnected. The pressure on these interconnections will be considerable in the future.

Since the beginning of the 1990s, the power and energy balances have weakened and the security of supply in the Nordel area has deteriorated. A dry year leads to considerable price increases. In the event of this trend continuing after 2005, the security of supply may become so vulnerable that steps should be taken to improve the power and energy balances and for the handling of shortage situations.

In so far as the consequences calculated for the supply are deemed to be unacceptable, a decision must be made as to whether measures should be taken by the individual countries or within the framework of Nordic co-operation to ensure the desired degree of self-sufficiency.

The table below indicates the capacities of the existing transmission interconnections within the Baltic Rim area. In addition to these, a decision has been made on 600 MW transmission line between Sweden and Poland.

Existing interconnections between the Nordel countries and other countries

Countries	Stations	Rated voltage kV	Transmission capacity MW		Total length of line km	Of which cable km
Denmark - Germany			From Nordel	To Nordel		
	Kassø - Audorf	2 x 400~	1400 1)	1400 1)	107	.
	Kassø - Flensburg	220~			40	.
	Ensted - Flensburg	220~			34	.
	Bjæverskov - Rostock	400=	600	600	166	166
Finland - Russia			From Nordel	To Nordel		
	Imatra - GES 10	110~	.	100	20	.
	Yllikkälä - Viborg	±85=	.	1000	.	.
	Nellimö - Kaitakoski	110~	60	60	20	.
Norway - Russia			From Nordel	To Nordel		
	Kirkenes - Boris Gleb	154~	50	50	10	.
Sweden - Germany			From Nordel	To Nordel		
	Västra Kärrstorp - Herrenwyk	450=	600 2)	600 2)	250	220

1) Transmission capacity varies between 1,200 and 1,500 MW, depending on operating conditions.
2) Owing to restrictions in the German network, transmission capacity is currently limited to 450 MW from Nordel and 400 MW to Nordel.

2.6 Nordic electricity markets and CO2 emissions

Amundsen et al. (1997) have analysed the interaction of Nordic electricity market liberalisation and integration on implementation of environmental policy with a partial equilibrium electricity market model. The Nordic electricity market accounts roughly 16 percent of the CO2-emissions in the Nordic countries (this is due to the large share of the hydro power). Norway is completely hydro-based, and Sweden has roughly 50-50 hydro-nuclear composition of its electricity generation. The level of CO2-emissions from the Nordic power production varies therefore considerably with level of hydro generation in these two countries. Denmark (almost totally coal-based generation) and Finland (with about 50 percent of CHP and coal-condensing generation) increase their coal-based generation whenever hydro capacity in Norway or Sweden fall, like it did in 1996.

The model the authors use is a multi-region (4 regions) partial equilibrium model, with price responsive demand (unlike in, say, MARKAL). Each region has a set of four possible technologies (hydro, gas, nuclear, coal). Power production is assumed to use three kind of inputs; primary input (natural gas, coal, uranium), capital (for new production capacity) and CO2 emissions for technologies that emit CO2 in the production process. CO2 emissions are modelled as a joint input with the primary input. In the long run capital can be substituted for primary input and emissions can be reduced via this substitution mechanism.

Two different emission reduction mechanisms were considered: a common Nordic market for emission permits and a national market for emission permits. Under both cases the authors evaluated welfare gains when the Nordic electricity market integration takes place.

Under a system of CO2-emission permits the electricity producers have to purchase rights to emit that corresponds their desirable output levels. Given the different electricity generation techniques within the Nordic area, one would expect, ex ante, that an integration of the power market would yield welfare gains from the increased flexibility in the production structure.

The authors considered a CO2-emission reduction policy, which restricts the level of the emission in year 2000 to level that prevailed in 1990. A comparison of the social welfare measure levels (sum of consumer and producer surplus) between autarky and free power trading regimes shows that the market integration bears considerable welfare gains (NOK 1.4 billion). If the policy is tightened to a 30 percent CO2-emission level reduction (instead of the zero level of the 1990 level) then the gain from integrated Nordic electricity market rises to 2.8 bn. NOK.

The more restrictive the emission restriction policy becomes the higher will the cost disadvantage of coal generation be. Opening of the electricity trade within the Nordic region means more substitution possibilities between generation techniques, given that there is an adequate transmission capacity available.

Next, the authors analyse welfare effects of introducing Nordic emission permit market. Existence of the emission permit market means that a country with high costs of emission reduction (say Norway) can purchase permits from country with lower marginal abatement cost (say Denmark). In equilibrium the marginal abatement costs will be equalised with different levels of emission reductions between the countries.

The results indicated that welfare gains from having emission permit trading within the Nordic area are modest, given the existence of the Nordic electricity market trading. Integration of the power market was more important factor than the type of the emission reduction mechanism.

The following permit prices (NOK per ton of CO_2) were obtained, given various combinations of free Nordic power and emission permit markets under EU target for emission reduction (1990 CO_2 levels by year 2000).

	National Markets	Free Nordic Trade	
		Power	Power and permits
Denmark	72.6	56.0	68.2
Finland	213.7	112.7	68.2
Norway	85.5	222.5	68.2
Sweden	25.2	0	68.2

3 Policy simulations with the GTAP-E model

Until now the interactions Nordic environmental policies and the power market analysis integration have focused on power markets alone with no consideration of how other sectors of production in the economies adjust to the policies implemented.

In this study, the Global Trade Policy analysis Project (GTAP) modelling framework is utilised. The GTAP-model is a multi-region, computable general equilibrium model, which takes into account both inter-sectoral and international adjustment for a policy. (For a detailed presentation of the model see Hertel (1997)).

3.1 GTAP model

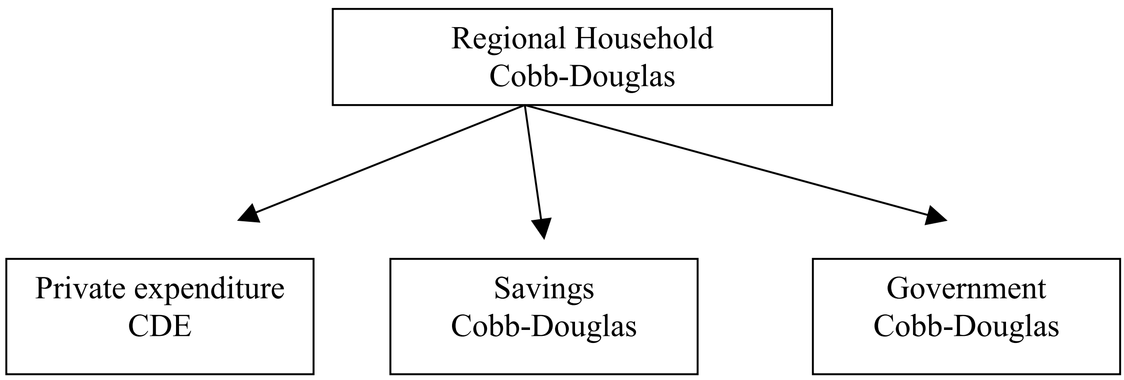
The standard GTAP-model is a multi-region, applied general equilibrium model, with perfect competition and constant returns to scale. Imports are differentiated by their source from domestic goods, that is, the Armington assumption is made on bilateral trade. The standard model has some salient features that distinguish it from other CGE models: a presentation of private household preferences with a non-homothetic constant-difference-of-elasticity (CDE) functional form, an explicit treatment of international trade and transport margins, and a global banking sector which intermediates between global savings and consumption.

Each industry is represented by a single homogeneous commodity. The basic model includes three factors of production: labour, capital, and land. Labour and capital are mobile across domestic sectors, while land is assumed to be used only in agricultural sectors. Capital is traded internationally like intermediate inputs, while labour and land are not mobile across borders.

The model gives users a wide range of closure options (choosing which variables are exogenous), including a selection of partial equilibrium closures which facilitate comparison of results to studies based on partial equilibrium assumptions.

Regional Household

In each region, there is a regional household whose Cobb-Douglas preferences are defined over composite private expenditures, composite public sector expenditures and savings. The regional household derives income from ownership and sales of primary

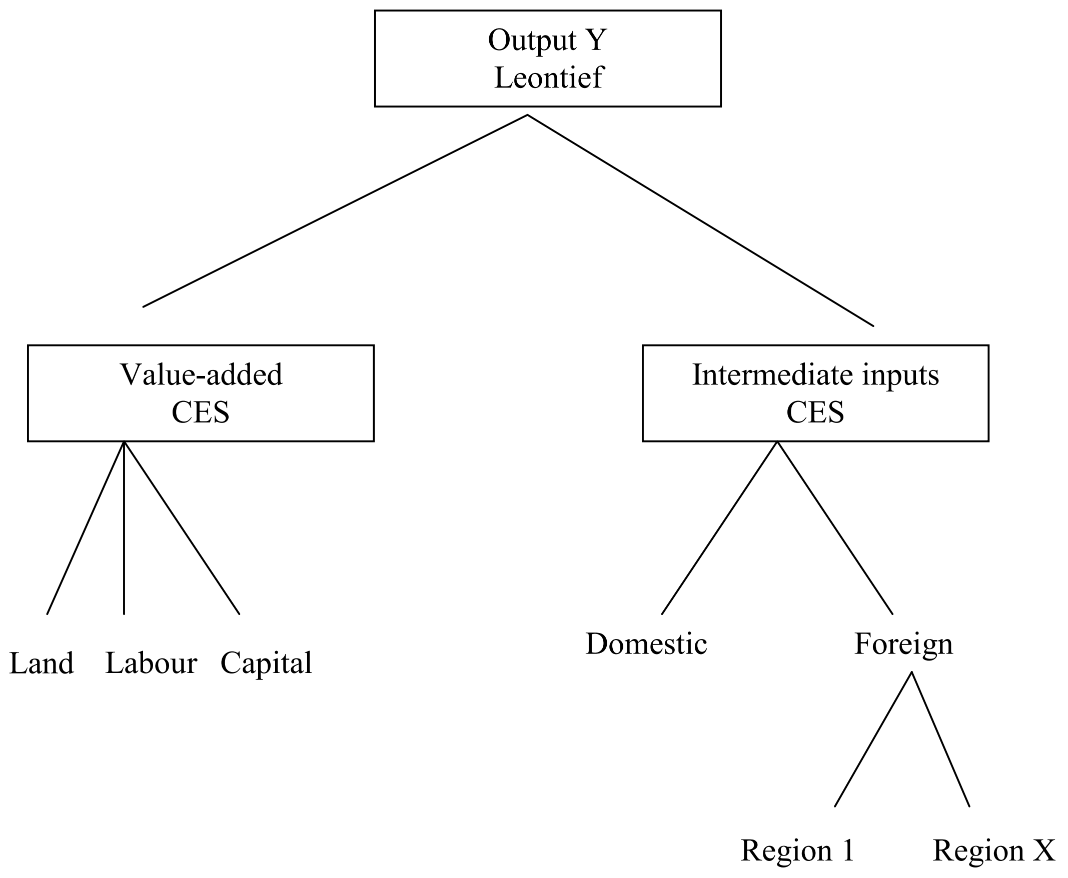


factors of production - capital, skilled and unskilled labour, land and natural resources. It turns out that the intertemporal, extended linear expenditure system could be derived from an equivalent, static maximisation problem, in which savings enters the utility function (Howe, 1975). This result provides a justification for the inclusion of savings in the regional utility function.

Private expenditures are governed by a Constant Difference of Elasticity (CDE) function which was first proposed by Hanoch (1975). The CDE function has the desirable property that the resulting preferences are non-homothetic and is more parsimonious in its parameter requirements than functional flexible forms. It can also be shown that the CES and the Cobb-Douglas are special cases of the CDE function. Government expenditures are governed by a Cobb-Douglas preference function. Finally, there is inter-industry demand whose technical specifications are described by the usual input-output matrix.

Production

Production is presented by a multi-level production function. The upper nest is a Leontief production function involving value added and intermediate inputs. Value added is produced through a Constant Elasticity of Substitution (CES) function of the three primary factors of production. Each intermediate input is in turn produced using domestic and imported components (the Armington assumption) with the technical process described by a CES function. Finally, imported components are a mix of imports from the other regions in the global model with the technical process again described by a CES function.



Households own all factor supplies - land, natural resources, capital, skilled and unskilled labour and sell their services to firms. In the GTAP model, sluggishness of some factors is allowed so that it is possible for factor prices not to be equalised within a region. Firms are supposed to sell output and purchase inputs (whether primary factors or intermediates) in competitive markets. Hence, firms make no economic profits.

Labour and capital are mobile across domestic sectors, while land is assumed to be used only in agricultural sectors. Capital is traded internationally like intermediate inputs, while labour and land are not mobile across borders.

The GTAP model allows for factor taxes, production and consumption taxes, export taxes and import tariffs which are in turn distinguished by production sector, by agent (regional household, firm, government) and by region.

Savings and Investment

Given the Cobb-Douglas assumption about preferences of the regional household, savings are a constant proportion of regional household income. The pool of savings is what becomes available for investments. There is a capital goods sector in each region, which produces the investment goods. The rate of return on capital goods is assumed to be inversely related to the stock of capital. The allocation of investment across regions and sectors is done in such a way that expected regional rates of return change by the same percentage. In the model, the pooling of savings and the global allocation of investment is done costlessly.

The GTAP model does not contain a financial sector. An investment is therefore represented by a unique investment good that is not form-specific, sector-specific, or region-specific. As such, the model framework has a limitation in the flow analysis of FDI. The model is strongly relevant, though, to general equilibrium analyses of an FDI-related increase in a region's capital stock, and of a technology spillover.

Macro Framework

In the GTAP model, private households and government are treated as a single decision-making economic agent called the regional household. Private households supply productive factors (land, labour, and capital) to producers, and obtains factor income in return. Government revenues come from household income taxes, producers' taxes, and taxes on international transactions (minus subsidies if they exist). Regional income is defined as the sum of private households' factor income and government revenues minus capital stock depreciation. Regional income in excess of regional expenditures is saved and used as investments by producers. Two global sectors complete the system. The global transportation sector provides services that account for the difference between FOB and CIF values for a particular commodity shipped along a specific route. The global banking sector is designed in such a way as to secure the global savings-investment consistency.

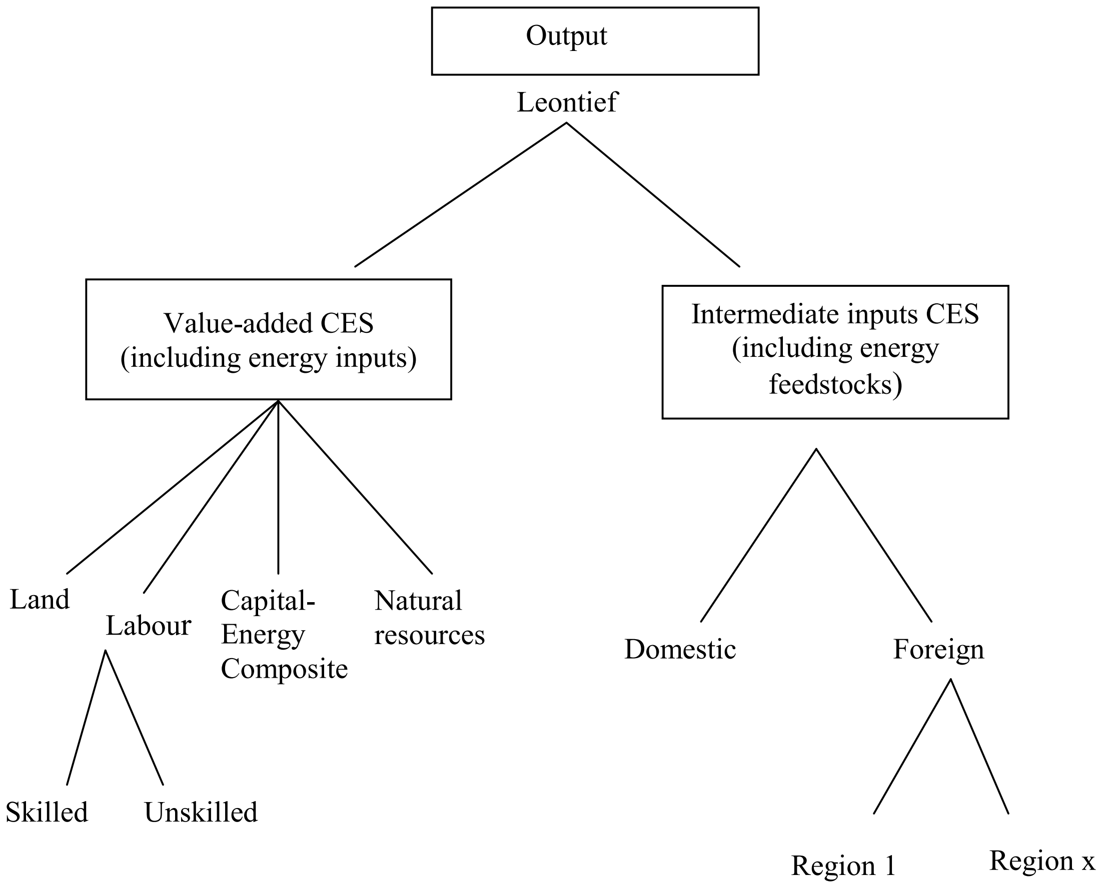
GTAP-E: introducing capital-energy substitutability to the GTAP model

GTAP-E model version extends the standard GTAP model to include possibility of substitution of energy inputs in production and in consumption. The important issue of capital-energy substitutability vs. complementarily is considered explicitly in this model. The substitutability is a widely debated issue in energy economics and econometric evidence seem to disagree on the sign of the elasticity. In the Australian based MAGABARE model technologies are 'bundled' with each having fixed share input structure (including the value added). At higher level, however, the different technologies are substitutable so K and E can be substituted with each other via the technology change. According to Borges and Goulder (1984) a 'sufficient' condition for K-E complementarity is that the elasticity of substitution between K and E within the K-E nest is a 'substantially smaller' value as compared to the elasticity of substitution between the KE composite and labour (or other factors). The following formula can be used to determine complementarity of K and E in outer nest in the nested CES production structure:

$$\sigma_{KE-outer} = [\sigma_{KE-inner}\sigma_{VA}]/S_{KE} + \sigma_{VA}$$

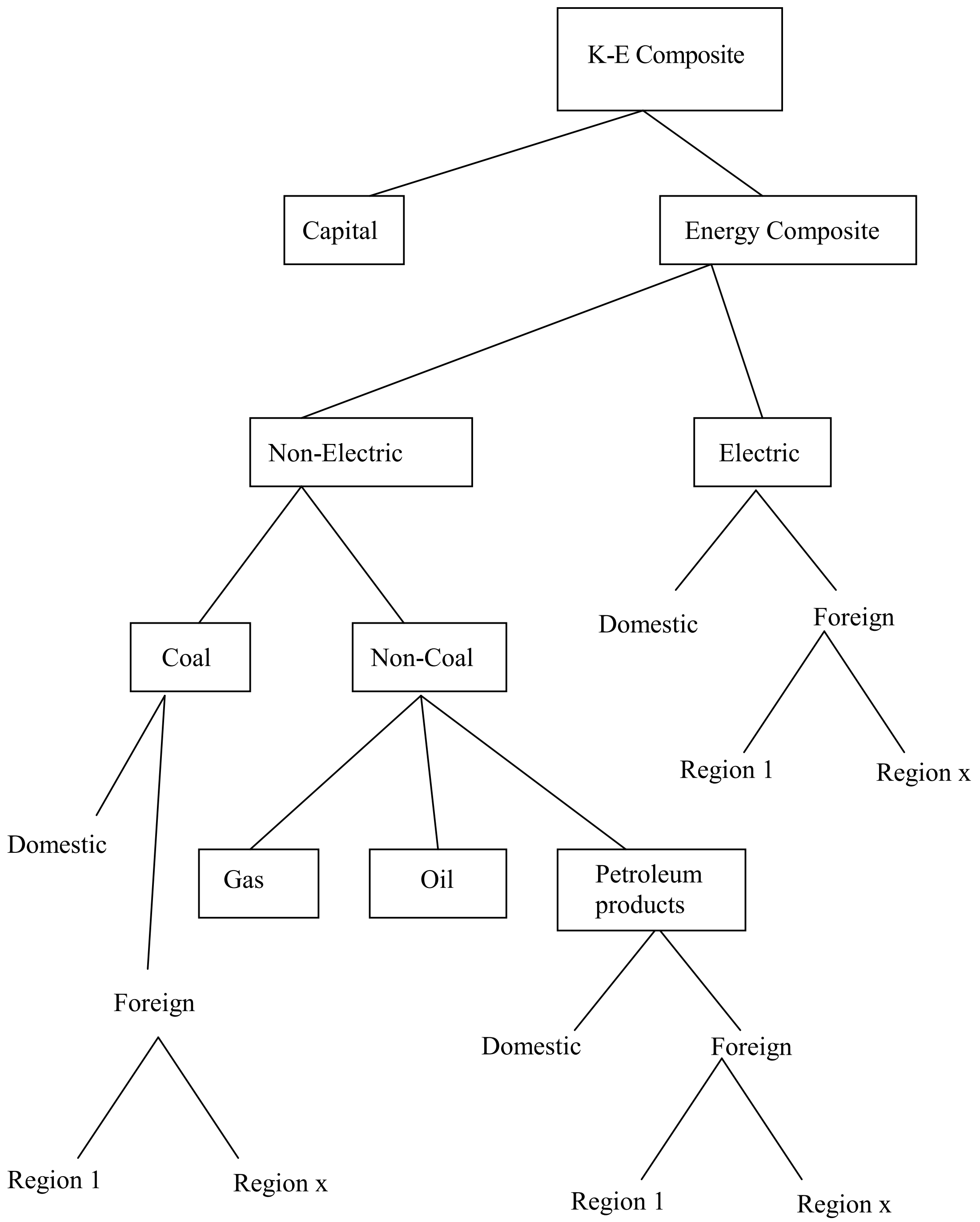
where S_{KE} is the share of the *KE*-composite in the outer (value-added) nest, and $\sigma_{KE-inner}$ and $\sigma_{KE-outer}$ denote the inner and outer substitution elasticities between K and E. In the GTAP-E the $\sigma_{KE-inner}$ is specified as 0.5 for most industries, that is, K and E are assumed to be substitutes. It turned out, however, that in most industries the $\sigma_{KE-outer}$ was negative, indicating K-E complementarity.

Production structure in GTAP-E



In the GTAP-E energy inputs are refined so that a primary energy can also be used (in addition as a source of energy input) for various industrial and household activities. Energy input is labelled as a 'feedstock' when the content of the energy input is simply transformed to become part of output commodity. In the GTAP4E (E to denote the energy data) database the feedstock (denoted as COL_F, OIL_F, GAS_F) are taken out of the energy composite and included in the intermediate input block.

Capital-Energy (K-E) Composite



Demand

In GTAP-E there are five energy commodities: coal, gas, oil, petroleum products and electricity. The energy commodities are separated from other commodities with CES-nested structure. Consumption in GTAP was divided into private consumption, government consumption and savings. Government consumption is assumed to follow the Cobb-Douglas utility function. The substitution elasticity between energy composite good and non-energy composite good is assumed to be 0.5 while in the inner-nest of the energy composite the substitution elasticity between different energy goods is assumed to be one.

Private consumption is assumed to follow the constant elasticity of difference (CDE) functional form and there the composite energy good is identical CES function of energy good as in the above case.

Aggregation of the database

For this project the standard GTAP-model had to be modified with energy-capital substitutability possibility. The GTAP-E model, due to Troung (1999), was chosen as a starting point as it includes fairly detailed fuels structure (see above). As this is not a standard model within the GTAP 'family' of models even a small modifications are more time consuming than models that used only the standard GTAP-database.

The first exercise was to re-aggregate the data, so that these two countries would be regions of their own. Because GTAP-E uses energy data (volume and value) the standard aggregation programs (which are built for the standard GTAP database) will not suffice. The data was therefore aggregated in two parts: first the standard GTAP-database and then the energy data. For the energy data an aggregation scheme was specified in a special editing program (viewHAR). After having aggregated the energy data to the same level as the GTAP-data the two databases were merged as one. The exercise required also re-calculation of certain parameter values so that the new data would be in 'balance' for the model.

The current version of the GTAP-E model uses the version 4 of the GTAP database - supplemented with the necessary energy data. The relevant data and description of its incorporation to the GTAP database can be found in the following web address:

http://www.agecon.purdue.edu/gtap/database/energy/status.htm

3.2 BAU-scenarios

The policy analyses compare the effects of policies to a baseline situation without policies. Especially in the case of climate policies, the baseline assumptions have a crucial impact on results, since the actual abatement tasks are based on baseline growth in emissions. Our analyses are based on widely used or official baselines, which are summarised in the following.

3.2.1 The economic and energy sector development in the EU

The EU baseline assumes fairly rapid economic growth by 2010, with the OECD growing at 3 per cent annually and the EU at 2.3 per cent. The community integration and liberalisation policies are assumed to continue, which could have a large impact on the energy markets. Climate policies are not assumed in the baseline.

In European Union Energy Outlook to 2020, the world economy is expected to grow by slightly more than 3% pa throughout the projection period. All OECD regions are projected to slow down to a growth rate close to 2%pa in the longer term while most non-OECD regions show average annual growth rates of close to 3.5%. Economic growth in the EU is expected to be just under 3% in the short run but it is assumed that the EU growth rate after 2000 will decelerate gradually and, in the period after 2010, will be limited to less than 1.8%.

The long established trend of restructuring of EU economies away from the primary and secondary sectors and towards services and high value added products (less material and energy intensive products) is assumed to continue, although the pace of change is expected to decelerate in the long run.

The baseline scenario is based on the assumption that EU policies currently in place will be continued. The baseline scenario does not include any policies that specifically address the climate change issue. Global primary energy consumption is likely to increase by an average annual growth rate of close to 2%over the outlook period and the energy intensity of the world economy is expected to decline by 1.4%pa in the period to 2010 and by slightly less than 1% after that.

The global energy system will continue to be dominated by fossil fuels over the next 25 years. The dependence on fossil fuels is likely to be close to 90%by 2020. Given the projections for growth in primary energy demand and the continued dominance of fossil fuels, global emissions are expected to grow quite rapidly. For the period 1990-2020,China and India will account for a very large proportion of the increase in CO2 emissions.

In view of the relative size of the increase in emissions from developing countries, it is clear that any action to reduce emissions from the EU alone will only have a limited impact on long run CO 2 concentrations. The baseline projects that global energy markets will remain well supplied at relatively modest cost throughout the projection period. Crude oil prices are projected to increase somewhat from recent levels in the period to 2020 but they will remain below their level of 1990.Gas prices in Europe are assumed to rise significantly faster in the longer term. The price of hard coal, imported in the EU, is expected to remain relatively stable.

3.2.2 EU baseline assumptions on energy:

Production of fossil primary energy within the EU is expected to decline in the period to 2020,after peaking in the period 2000-2005. The decline of EU indigenous solids and oil production is especially noticeable in the longer term. Renewable sources of energy are likely to receive a significant boost as a result of policy and technology progress.

Energy demand is expected to continue to grow throughout the outlook period even though at rates significantly smaller than in history. Thus, while significant economic growth can take place with only a small increase in energy use, there is no complete delinking between energy and the economy.

The growth rate in primary energy consumption is expected to continue to be close to 1% pa over the period to 2010 and then to decelerate to just 0.4 % pa until 2020. The implied energy intensity improvement is gradually expected to improve and to reach an annual rate of more than 1.5% pa by 2020. Structural change in the demand side mainly explains this change. The role of energy technology is also important.

The EU energy system remains dominated by fossil fuels over next 25 years. Indeed, the share of fossil fuels is projected to increase marginally over the projection period from its 1995 level of just under 80%.This is despite the significant pro-environmental policy assumptions adopted in the baseline. Individual fossil fuels become increasingly specialised: oil for transportation, and coal and gas for power generation.

Spurred by its very rapid penetration in new power generation plant and co-generation, gas is by far the fastest growing primary fuel. Its share in primary energy consumption is projected to increase further to 27%by 2010.The projection shows, however, stabilisation at that level beyond 2010.

The share of oil in primary consumption is projected to be relatively stable over the period to 2020 and its annual growth rate is projected to decelerate from 1%in the period to 2010 to 0.1%during 2010-20.

Nearly two thirds of overall energy requirements in the EU are expected to be imported by 2020,compared to less than half in 1995.Import dependency will increase for all fossil fuels. Perhaps the most significant change regarding energy security in the EU over the outlook period relates to the rising dependency on gas imports from regions that may not prove to be politically stable.

The rising share of fossil fuels will lead to an increase in the carbon intensity of the EU energy system. Together with the modest increase in energy demand, this will lead to an increase in CO_2 and other energy related emissions. The greater penetration of non-fossil fuels and renewable energies, beyond that projected in the baseline, may require additional policy measures in view of the relatively low prices of fossil fuels that are expected over the outlook period and the adverse changes in market structure. CO_2 emissions are projected to increase annually by 0.6% pa throughout the outlook period.

The transportation sector is by far the largest source of additional emissions in the period to 2010.Beyond 2010,it is the electricity and steam generation that is almost solely responsible for the increase in CO_2 emissions.

3.2.3 Finnish Climate Strategy baseline

The Finnish baseline scenario bases on a synthesis of the forecasts for economic growth by the major forecasting institutes and ministries. It also includes very technology-specific predictions for productivity growth and energy efficiency stemming from research institutions. The forecast for population growth, which points at an almost stagnant and ageing population, stems from Statistics Finland. World price forecasts stem from many sources, most importantly from the IEA.

The baseline scenario assumes that industrial production continues to grow at an average annual rate of 3.5 to 2010, the reference year for the impact evaluations. However, even the baseline predicts large differences between industry branches. Thus, the electronics industry is predicted to grow at an average annual rate of 8 per cent, lead by the IT branch. The traditional Finnish export industries, forest and basic metal industries, are expected to grow significantly more slowly, at 2.5 and 2 per cent annually, respectively. Reflecting growth in forest industries, forestry is also expected to grow fairly briskly, at 2 percent a year. Chemical industries are taken to grow slower still, at 1.7 per cent, largely because the demand for refined oil products is expected to be slow. Some of the more domestically oriented industries, however, are expected grow relatively briskly, as are services. Regional concentration, stimulating construction and related industries, as well as the ageing of the population explain this. Agricultural production, on the other hand, is expected to decrease.

For energy efficiency, very detailed forecasts are given by the ministries responsible for preparing the National climate strategy. On the average, energy efficiency is expected to improve by 2 per cent for fossil fuels, but again, there are important sectoral differences. The increase is expected to be especially high in the transport sector, reflecting the effect of the EU gas mileage target, whereas in the energy sector, increases to the already high average efficiency are much harder to come by with. The energy efficiency of housing is also expected to improve fast, but this effect is more pronounced for electricity and heat consumption than fossil fuels. Overall, energy efficiency in consumption can be said to have more room for improvements than power generation, which is reflected in the baseline as well.

Some of the most crucial assumptions for the baseline concern generation capacity. In the baseline, electricity consumption is forecast to grow from 80 TWh in 2000 to 90 TWh in 2010. How this increase is to be met on the production side obviously affects the scope for reductions very much. The baseline assumes that there is an increase in the use of almost all of the domestic sources that are available. This includes wind power and bioenergy, but these can not meet but a fraction of the demand growth (practically all potential hydropower sites are protected, and wind power, while growing very fast, starts from a low level). Imports of electricity from other Nordic countries and Russia are currently contributing over 10 TWh to the supply, but in the future, Swedish and Norwegian demand may not leave much room for exporting electricity. Imports are thus expected to decrease, and the gap is taken to be met by existing coal-fired condensing plants. While the consumption of fossil fuels is increasing in most sectors in the baseline, electricity generation provides the most important single reason why Finnish emissions are not expected to meet the Kyoto target in the baseline. The baseline emissions are forecast at 90 Mt. CO_2-equivalent for 2010, of which fossil fuels account for 70 Mt. The Finnish Kyoto target is 76,5 Mt CO_2-equivalent, with fossil fuels at 54 Mt.

3.3 Policy scenarios

The policy scenarios studied in this report aim at identifying the importance of energy market integration in the climate policy context. The scenarios compare abatement in Finland, the EU or Annex 1 with or without Nordic electricity market integration. The scenarios are:

FI-1: Imposing the Kyoto CO_2 emission reduction targets in Finland alone and assuming no CO_2 reduction policies in rest of the world

FI-2: Imposing the Kyoto CO_2 emission reduction targets in Finland alone and assuming no CO_2 reduction policies in rest of the world and assuming liberalised and integrated Nordic electricity markets

EU-1: Imposing the Kyoto CO_2 emission reduction targets in the EU-EFTA region assuming no CO_2 reduction policies in rest of the world

EU-2:Imposing the Kyoto CO_2 emission reduction targets in the EU-EFTA region assuming no CO_2 reduction policies in rest of the world and assuming liberalised and integrated Nordic electricity markets

Annex-1: Imposing the Kyoto CO_2 emission reduction targets in all Annex-1 countries (excluding the USA)

Annex-2: Imposing the Kyoto CO_2 emission reduction targets in all Annex-1 countries (excluding the USA) and assuming liberalised and integrated Nordic electricity markets

The initial CO_2 emission levels were calculated from the energy volume data that has been constructed for the GTAP-E application[1].

3.4 Results from the CO2 restriction policies

Unless otherwise indicated, all results are reported as percentage changes with respect to the BAU levels.

Table 1: CO2 permission price (USD per CO2 Mt)

Region	EU-1	EU-2	FI-1	FI-2	Annex-1	Annex-2
Finland	**14.5**	**10.9**	**20.0**	**14.1**	**5.28**	**5.27**
Sweden	**14.5**	**10.9**	**0.0**	**0.0**	**5.28**	**5.27**
Denmark	**14.5**	**10.9**	**0.0**	**0.0**	**5.28**	**5.27**
EEA	0.0	0.0	0.0	0.0	5.28	5.27
USA	0.0	0.0	0.0	0.0	0.00	0.00
Japan	0.0	0.0	0.0	0.0	5.28	5.27
EFTA	**14.5**	**10.9**	**0.0**	**0.0**	**5.28**	**5.27**
IVY-countries	0.0	0.0	0.0	0.0	5.28	5.27
Rest of EU	**14.5**	**10.9**	**0.0**	**0.0**	**5.28**	**5.27**
Rest of Annex1	0.0	0.0	0.0	0.0	5.28	5.27
ROW	0.0	0.0	0.0	0.0	0.00	0.00

The CO2 emission permit prices indicate that under the extreme case of Finland alone applying the Kyoto CO_2 emission reduction targets (FI-1), the emission permit price is 20 USD per CO2 Mt. When the permit trading is extended to the EU-EFTA area (scenario EU-1) the equilibrium permission price comes down to 14.5 USD per CO2 Mt.

The last two columns report CO2 emission permit prices for the Annex1 cases with (Annex1) and without the electricity market integration (Annex1+ele). As can be seen

[1] See http://www.agecon.purdue.edu/gtap/database/energy/status.htm - energy.vol

the effect of the Nordic electricity market integration is marginal on the emission permit market equilibrium. This is intuitive result given the scope of the permission trading in the Annex1 case.

When the Nordic electricity market scenario is implemented (via the increase Armington elasticity of electricity) the price of the emission permit price in the Finland alone scenario (FI-2) comes close to that of the EU-1, that is 14.1 USD, and in the EU-EFTA case to 10.9 USD per CO2 Mt.

The costs of abatement are given in Table 2, which shows the costs in terms of losses incurred by the regional households. It is easy to see that electricity market integration and emission trade lower abatement costs in general, but not necessarily in all of the EU countries. When most Annex-1 countries abate, the effect of regional energy market integration is positive, but pales in significance compared to the increased cost-efficiency large permit markets allow. Interestingly Finland and Denmark seem to be worse off in the case where the electricity markets have integrated. The reason for this result comes from worsening of their terms of trade (export price divided by import price). In the EU-2 scenario the terms of trade for Finland worsens by 0.5 and for Denmark nearly 1 percent. So, although the emission permit price is lower due to the electricity market integration there are both losers and winners within the Nordic group. An intuitive reasoning would suggest that the two coal-based electricity generating countries would gain from the Nordic electricity market integration, via the cost reduction, when adequate hydro-power is available. The above result suggests, however, that the export price changes may turn the overall gain from the electricity market integration, in face of the CO2 policy, for Finland and Denmark (which import a lot of electricity in a normal hydro-year) into negative.

Table 2: Equivalent variation (million USD)

	Annex-1	**Annex-2**	**EU-1**	**EU-2**	**FI-2**	**FI-1**
Finland	-110.25	-78.17	-342.95	-618.728	-685.59	-553.21
Sweden	-146.63	-149.86	-585.93	-389.258	84.34	-7.88
Denmark	-282.66	-365.07	-880.50	-1340.47	-1.27	-4.85
EEA	-747.51	-752.66	205.32	126.4999	-11.24	6.78
USA	357.18	355.14	673.44	594.2413	-22.88	-3.78
Japan	-910.18	-901.75	1817.50	1733.291	-36.82	-2.58
EFTA	-627.22	-491.26	-1526.84	-507.908	5.78	-17.28
IVY-countries	-2080.16	-2096.07	-199.77	-3.1422	188.59	-25.32
Rest of EU	-6577.67	-6646.93	-30563.23	-30338.3	-90.83	164.35
Rest of Annex1	-703.81	-703.60	-6.02	-15.4165	2.38	-0.50
ROW	-469.71	-472.86	141.81	63.63461	-24.95	-11.43

The Nordic electricity market accounts roughly 16 percent of the CO2-emissions in the Nordic countries (this is due to the large share of the hydro power). As was mentioned Norway is completely hydro-based, and Sweden has roughly 50-50 hydro-nuclear composition of its electricity generation. The level of CO2-emissions from the Nordic power production varies therefore considerably with level of hydro generation in these two countries. Denmark (almost totally coal-based generation) and Finland (with about 50 percent of CHP and coal-condensing generation) increase their coal-based generation whenever hydro capacity in Norway or Sweden fall, like it did in 1996.

In a normal hydro year free trading of Nordic electricity is likely to lead to situation where Norwegian and Swedish hydro power substitutes Finnish and Danish coal powered electricity generation (given that the cross border transmission capacities are sufficient). Table 2. reports industry output of electricity in different regions. It can be seen that Nordic electricity market integration (EU-2) indeed leads to drastic fall in industrial electricity generation in Finland and Denmark, while those in Norway and Sweden increases. This reflects the differences in the producing costs of electricity in the Nordic region.

Table 3: Industry output of electricity in region R

	EU-1	EU-2	FI-1	FI-2
Finland	-3.54	-96.77	-4.67	-35.69
Sweden	0.79	22.00	0.21	4.79
Denmark	-18.96	-102.58	0.04	0.53
EEA	2.32	-19.87	0.02	0.01
USA	0.04	0.07	0.00	0.00
Japan	-0.01	-0.01	0.00	0.00
EFTA	7.72	64.37	0.09	0.42
IVY-countries	0.60	28.73	0.42	9.59
Rest of EU	-3.98	-4.30	0.00	0.00
Rest of Annex1	0.09	0.11	0.00	0.00
ROW	0.03	0.16	0.00	0.00

When the CO2 emission permit trading is taking place only among the EU countries (Finland, Sweden, Denmark, rest of EU in the current model) equilibrium price is USD 12.03 per CO2 Mt. The price falls to USD 11.65 when the Nordic electricity market integration was assumed (EU-ele). The price falls due to the fact that electricity in the latter scenario moves more easily (with respect to the price differentials) within the Nordic area and hence emission reduction policy can be conducted within more ‘flexible’ energy system. Intuitively the result is what one would expect (especially during a normal water supply), given the structure of electricity generation (se above section) within the Nordic area. Given that the Swedish nuclear power plants are gradually run down the results would be slightly changed in the future, as Sweden would have to substitute its nuclear generation with something else. In this study the effects of abolishing Swedish nuclear capacity was not considered.

Table 4: Percentage change in CO2 level in electricity sector

	EU-1	EU-2
Finland	-23.2325	-69.8146
Sweden	-13.2908	-4.52017
Denmark	-27.9899	-76.3324
EFTA	-12.3014	-4.99367
Rest of EU	-27.1553	-23.9583

Table 4. indicates that the CO2 emissions are reduced considerably especially in Finnish and Danish electricity sectors, which reflects the increased imports from Sweden and Norway.

Table 5: GDP volume changes

	EU-1	EU-2	FI-1	FI-2
Finland	-0.31497	-0.50196	-0.46525	-0.43093
Sweden	-0.28141	-0.15534	-0.00268	0.00865
Denmark	-0.42745	-0.94336	0.00036	0.00012
EEA	0.02988	-0.56953	0.00103	-0.00143
USA	0.00173	0.00111	0.00005	0.00001
Japan	0.00649	0.00603	0.00014	0.00003
EFTA	-0.30741	-0.19528	-0.00106	-0.00044
IVY-countries	-0.00654	0.02634	-0.00053	0.00925
Rest of EU	-0.33637	-0.25103	0.0019	-0.00078
Rest of Annex1	0.01119	0.00901	0.00027	0.00032
ROW	0.01041	0.00934	0.00035	0.00011

In terms of GDP volume changes (table 5) the electricity market integration seems also benefit the rest of the EU. On the other hand Finland and Denmark face larger GDP drops in EU-1 than in EU-2 scenario. Closer look at sectoral output changes (tables 6 and 7) reveals that in EU-1 scenario nearly all sectors of production in Finland reduce output in the face of the EU-wide CO2 restriction policy. In the EU-2 scenario this is not the case, which partly reflects the greater tradability of cheaper electricity from Sweden and Norway, thus alleviating the cost shock that originates from the original CO2 policy. It must be emphasised, however, that this result is highly dependable on availability of hydro base power and also on the sufficiency of cross border transmission capacities.

Table 6: Industry output: EU-1

	FIN	SWE	DEN	EEA	USA	JPN	EFT	FSU	REU	RAN	ROW
COAL	-29.14	-49.33	-19.79	-1.54	-3.89	-5.61	13.23	-0.97	-19.59	-3.36	-2.70
OIL	-11.60	-10.49	-1.14	-2.24	0.04	-2.89	-0.11	-1.08	3.15	0.35	-0.82
GAS	68.09	-8.75	-18.10	0.33	-0.16	0.22	-16.55	-2.77	-9.40	0.19	-1.13
PetrChem	-6.53	-8.09	-5.67	0.16	0.38	0.18	-14.55	-0.79	-1.60	0.45	-0.15
Electricity	-3.54	0.79	-18.96	2.32	0.04	-0.01	7.72	0.60	-3.98	0.09	0.03
WOOD	-0.86	-0.18	0.20	-0.21	0.01	0.01	-0.31	0.10	-0.23	0.05	0.03
Transport	-0.24	-0.36	0.06	-0.01	0.02	0.00	-0.30	0.07	-0.30	0.01	0.00
IronSteel	-1.35	-1.48	0.27	1.90	0.49	-0.04	1.87	2.99	-2.11	0.33	0.44
Chem	-1.10	-0.59	1.16	0.48	0.18	0.00	0.06	0.96	-1.13	0.25	0.27
OthMet	0.38	-0.02	0.05	-0.27	-0.04	-0.15	-0.15	0.21	-0.15	0.02	0.03
AGRIC	-0.07	-0.13	0.08	-0.13	-0.01	-0.20	0.04	0.23	-0.01	0.02	0.04
SERVICE	-0.83	-0.34	-0.71	0.14	0.02	0.07	-0.37	0.02	-0.20	0.06	0.08
Dwelling	0.44	0.30	0.40	0.06	-0.01	0.14	0.02	-0.02	0.20	-0.02	-0.01
CGDS	-9.06	-2.09	-5.15	0.70	0.61	0.37	-1.13	0.31	-0.93	0.81	0.65

Table 7: Industry output: EU-2

	FIN	SWE	DEN	EEA	USA	JPN	EFT	FSU	REU	RAN	ROW
COAL	-49.62	-51.13	-21.79	-29.84	-4.48	-5.60	11.87	3.01	-15.69	-3.58	-3.00
OIL	-11.12	-8.11	-0.68	11.85	0.25	-2.42	-0.74	-2.53	2.49	0.51	-0.66
GAS	31.95	-6.75	-37.89	-21.31	-0.12	0.19	-12.91	-4.50	-7.03	0.25	-0.93
PetrChem	-5.59	-6.04	-6.48	-7.40	0.34	0.16	-11.83	-0.31	-1.16	0.41	-0.07
Electricity	-96.77	22.00	-102.58	-19.87	0.07	-0.01	64.37	28.73	-4.30	0.11	0.16
WOOD	3.39	-1.18	1.16	0.22	-0.01	0.00	-2.23	-0.57	-0.25	-0.01	-0.03
Transport	0.19	-0.47	0.71	0.16	0.01	0.00	-1.49	-0.11	-0.21	0.02	0.01
IronSteel	7.67	-1.92	3.62	-5.68	0.50	0.05	-2.59	1.05	-1.27	0.34	0.43
Chem	3.63	-1.17	2.71	-1.92	0.18	0.02	-3.45	-0.08	-0.71	0.26	0.25
OthMet	6.19	-1.36	2.21	0.51	-0.02	-0.11	-3.31	-0.83	-0.08	0.08	0.03
AGRIC	3.71	-1.10	2.03	0.78	0.02	-0.17	-2.27	-0.52	-0.06	0.06	0.02
SERVICE	-1.64	0.18	-0.71	-1.19	0.02	0.05	0.07	-0.01	-0.15	0.04	0.06
Dwelling	0.35	0.03	0.39	-0.13	-0.02	0.11	-0.16	-0.03	0.16	-0.03	-0.01
CGDS	-22.99	2.05	-5.65	-4.28	0.46	0.27	2.61	0.70	-0.77	0.61	0.49

Changes in value of regional exports of electricity are given in table 4 below. The percentage changes are very high for Swedish and Norwegian exports. These figures should be, however, be interpreted in qualitative manner. The initial trade flows were small so the changes in percentage terms seem to be very large.

Table 4: Value of regional exports of electricity

	EU-1	**EU-2**
Finland	**-19.06**	**-21.88**
Sweden	**23.29**	**855.58**
Denmark	**-47.55**	**96.51**
EEA	21.63	-66.26
USA	0.52	2.97
Japan	0.91	1.25
EFTA	**25.43**	**123.95**
IVY-countries	1.38	85.51
Rest of EU	-1.76	-23.27
Rest of Annex1	1.55	1.90
Rest of World	0.98	6.67

4 Conclusions

This report has studied the effects of energy market integration on the costs of climate policies. The main finding of the study is that while emission trading clearly may lead to more cost-efficient and less costly abatement, the integration of energy markets can by itself lead to cost reductions of almost the same magnitude.

It also turned out that while the emission permit price is lower due to the electricity market integration, there are both losers and winners within the Nordic group. An intuitive reasoning would suggest that the two coal-based electricity generating countries would gain from the Nordic electricity market integration, via the cost reduction, when adequate hydro-power is available. The above result suggests, however, that the export price changes may turn the overall gain from the electricity market integration, in face of the CO2 policy, for Finland and Denmark (which import a lot of electricity in a normal hydro-year) into negative.

Electricity market integration and emission trade are especially important if abatement targets are honored by only some of the Annex-1 –countries, whereas, if most Annex-1 countries abate, the effect of regional energy market integration is still positive, but makes only a small difference to the costs of abatement.

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Appendix

The Kyoto Mechanisms

International Emission Trading. Trade in emission permits between the countries which have committed themselves to limiting their emissions. Finland can thus purchase emission permits from a country which has a surplus of permits. It is not yet been decided if only governments will be able to use this mechanism, or if the private sector will also have access to it. Quota trading is to be a supplement to national measures.

Joint Implementation. Project-based transferral of emission permits between the countries that have committed themselves to limiting their emissions. Finland can thus receive credit for reductions resulting from a Finnish-financed project in another country which is committed to limiting its emissions. Joint Implementation projects must be a supplement to national measures.

Clean Development Mechanism. Also project-based transferral of emission permits to a country committed to limiting its emissions, though from a country which is not committed to limiting its emissions. In this case, Finland can receive credit for emission reductions from a Finnish financed project in a country without commitments. The projects can generate credits from 2000, and must be in accordance with the criteria for sustainable development in the countries where they are carried out. CDM projects must ensure additional reductions.

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