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Road transport emissions in the EU Emission Trading System

TemaNord 2007:536

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Content

Preface

In June 2006 COWI was commissioned by the Climate Change Working Group of the Nordic Council of Ministers to analyse the effects of including road transport emissions in the EU Emission Trading System.

The objective of the study is to analyse whether the EU Emission Trading System can be made more cost-effective by including road transport emissions in the trading system.

The Climate Change Policy Working Group does not necessarily share the views and conclusions of the report, but looks at it as a contribution to our knowledge about the EU Emission Trading Scheme and the effect on the electricity price in the Nordic electricity market.

Oslo, March 2007
Jon Dahl Engebretsen
Chairman of the Climate Change Working Group

Summary

The CO_2 emission from the Nordic transport sector has grown by 18% since 1990 (with road transport as the main source), compared to an 8% growth in emissions from other sectors. Most analyses and experience conclude that in the transport sector emission reductions are relatively costly to implement compared to other energy intensive sectors. Fuel for road transport is heavily taxed in the Nordic countries, but the willingness to pay for transportation is high in industry and at consumers' level. Reducing emissions by reducing transport demand, e.g. through increased taxation, therefore often is estimated to cause relatively large welfare losses. Technical solutions as introducing bio fuels, electric cars etc. are currently also relatively expensive compared to emission reduction measures in the power and energy intensive industries.

The growth in and importance of the transport sector emissions, combined with the relatively high emission abatement costs in the sector, indicate that benefits could be gained by including transport sector in the EU CO_2 emission trading system.

The emission trading system imposes a cap on the total emission from the firms included in the system. Within this cap the system allows the involved firms to trade emission allowances. This enables those firms with low marginal emission abatement costs (MACs) to make more reduction than needed by themselves and to sell the surplus emission reductions with a profit to those firms with high marginal emission abatement costs. Through the emission trading between firms with low and high MACs the total costs of meeting the cap is lowered.

Including road transport in the emission trading system offers an opportunity to harvest such benefits from trading. The reason for this is that the road transport sector with its high MACs can purchase emission allowances from the sectors currently included in the EU Emission trading system at lower costs.

This report has analysed the effects of including road transport CO_2 emissions in the EU Emission trading system. As road transport have high MACs this sector will become at net buyer of allowances and thus affect the existing trading system. The effects in focus are the impacts on the allowance price of this inclusion as well as the secondary effects on the electricity and heat generation sector and the energy-intensive industry in the Nordic countries.

Furthermore, the report also analyses the somewhat wider question of how reduction requirements may be distributed between sectors already included in the emission trading system today (the so-called Emission Trading Sectors) and the Non Emission Trading Sectors. As the targets of

the Kyoto Protocol and the European Burden Sharing Agreement are binding for the participating countries, there is a one-to-one relationship between reductions in the two sectors: Reductions which are not undertaken in the emission trading sectors must be made in the non-trading sectors and vice versa.

The reason for conducting this analysis is to clarify the various and complex effects of including the road transport emissions in the Emission trading system. Such effects include:

- The inclusion of road transport will tend to increase the allowance price, as the demand for allowances will increase. Thereby the production costs of energy-intensive firms and other firms will increase.
- Governments may allocate a larger number of allowances allocated to accommodate some of the increased demand. This will tend to restrict the increase in the allowance price.
- However, increasing the supply of allowances to the Emission trading sectors will also increase the need for reductions in the remaining Non-trading sectors. Depending on the specific allocation this may imply that the Non-trading sector reduction costs per tonne increases to the detriment of consumers, Emission trading sectors and Non-trading sector firms.
- Thus, the allocating authorities are confronted with the very important task of finding the right balance between reductions in the trading and non-trading sectors.

The effects on road traffic of including this sector in the Emission trading system are largely ignored in the presentation. This reflects that the road transport sector is expected to buy allowances from other Emission trading sectors, and that road transport is fairly inelastic to the increased costs that this imposes on the sector. The results of the CGE model supports this point, i.e. that the reductions in road transport CO_2 emissions are limited when included in the EU Emission trading system. The bulk of emission reductions are made in the other Emission trading sectors at lower costs.

This analysis thus focus on the balancing between trading and non-trading sector reductions, while at the same time describing the impacts on emission-intensive sectors and other sectors in the Nordic countries. The results are based on extensive numerical modelling of the European Allowance market, using a top-down macroeconomic Computable General Equilibrium model, as well as a bottom-up energy system model describing in great detail the Nordic energy system.

The analysis of the allowance market is scenario-based. Five scenarios are defined, consisting of two pair of scenarios and one stand-alone scenario. Each of the pairs consists of two variants, one in which road transport is outside the emission trading system and one where road transport is included. The stand-alone scenario is a least cost emission reduction scenario.

The scenarios are based on three allocation schemes, which systematically describe a set of hypotetical, yet realistic principles by which the European allocating authorities balance the reduction requirements between the trading and non-trading sectors. The two of schemes take systematically into account whether the road transport emissions are included in the Emission trading system or not, the third implicitly assumes all sectors are included. This is needed in order to make the results from the scenarios comparable with each other.

The scenario including road transport in the first of the scenario pairs assumes that *only the* CO_2 *emission growth from road transport since 1990* is included in the Emission trading system, and that no additional allowances are allocated to the Emission trading system. The scenario including road transport in the other pair assumes that *all of road transport* CO_2 *emissions* are included in the Emission trading system, and that governments allocates additional allowances, similar to the allocation of allowances to the other Emission trading sectors. The last scenario is a least cost allocation of allowances, ensuring the same marginal reduction costs in the both the Emission trading sectors and the Non-trading sectors.

Key findings

The analysis is made under assumption that the Nordic countries, as well as all EU member states, must meet certain emission reduction commitments by 2015, and that this can happen in situations when road transport is either outside or included in the emission trading system. The overall finding is that including the road transport sector in the trading system will provide significant benefits to the Nordic countries, as well as other EU member states, by reducing the overall CO_2 abatement costs compared to the situation when road transport is not included. The size of this cost reduction depends on how road transport specifically is included in the Emission trading system and differs between countries depending on the climate policy of each individual country. In particular the balancing of reductions to be made within and outside the Emission Trading Sectors is of great importance. A wrongfooted balance might require that reductions with high unit costs are carried out, while reductions with low unit costs are not, e.g. the transport sector might be required to make reductions, which could be carried out more cheaply in the energy sector.

The more detailed findings concerning the allowance market and the impacts on different firms/sectors, particularly the energy sector, by including road transport are presented below.

Finding regarding the allowance market

- As road transport is a relatively fast growing source of emissions, therefore including it partially or fully in the Emission trading system (and without compensating fully the emission trading sectors with more allowances) will tend to move reductions from the non-trading sectors to the trading sectors. This will tend to increase the allowance price.
- The scenarios analysed show that the allowance prices are markedly lower than the Non-trading sectors marginal reduction costs. This indicates that overall economic efficiency can be enhanced when the Emission trading sectors bears a larger burden of reduction than the Non-trading sectors. This lowers the total costs of all reductions.
- Including road transport emissions in the Emission trading system offer economic benefits for almost all countries in all scenarios, but also higher allowance prices. If there is a severe mismatch in a country between the country's trading and non-trading sector reduction requirements, further adjustments of the balance between these reduction requirements are needed in order to offset the detrimental effects of the higher allowance prices.
- The analysis suggest that most Western European countries can benefit strongly from including road transport emissions in the Emission trading system, mainly as this will ensure a better balance between the trading and the non-trading sectors reduction burden. This would cause the allowance price to increase significantly.
- As reductions in the road transport sector are rather expensive, it is important that the road transport emission reduction requirements are balanced against the much more efficient reduction potential of e.g. the electricity sector.
- The numerical analyses in this study show that *the reduction costs can increase four-folds* with an unbalanced reduction requirement between ETSe and NETSe.
- By including the road sector emissions in the Emission trading system, the balance between road transport and especially electricity and heat sector emission reductions are left to the market forces. This offer opportunity for a more efficient and less costly emission reduction for the combined Emission trading sectors and road transport sector. *The analysis indicate that the GDP loss to EU member states caused by meeting overall emission reduction commitments in 2015 may be reduced to a third or even a fourth if road transport is included, depending on the specific design and allocation of allowances.*

Findings regarding impacts on firms

- The competitive pressure on the energy intensive (and other) industries comes from markets with little or no emission costs and regulation, i.e. outside EU. The export and import patterns of Nordic energy intensive industries suggest that the competitive pressure from outside EU is somewhat smaller than on other industrial sectors.
- Both electricity and transport are important goods to the Nordic firms (and consumers). Competitiveness in terms of the costs of exporting firms is influenced both by the price of goods produced by firms included in the ETSy (e.g. electricity) as well as firms outside the ETSy (e.g. transport). Therefore, striking the right balance between reductions in the ETSe and NETSe will help reducing the climate costs of exporting and other firms.
- The analysis indicates that the most cost-effective climate policy will tend to emphasise reductions in the most energy-intensive industries. This result seems reasonable, partly because these sectors have relatively more fuel substitution possibilities (at least relative to sectors with very low fuel use, e.g. the service sectors), and partly because a contraction of output from these sectors will result in more emission reductions compared to other sectors, which have lower emission intensities.
- With the most efficient allocation of reductions between the trading and the non-trading sectors, the Nordic electricity price will increase by 10% in 2015, compared to a situation with zero allowance costs. In the longer term this price effect will diminish as carbon intensive generation capacity is replaced by less carbon intensive generation capacity. It is outside the scope of this study to investigate these longer term effects.
- The Nordic energy system responds to the increased allowance price by a shift in production technologies from in particular coal towards wood and waste. By 2015, however, this effect is rather limited, as the allowance price will not influence (much) on the structure of the power system as investment plans cannot easily be altered within this time horizon. In a longer perspective, the effect on production technologies and fuel use will be higher, and for instance a high allowance price may also increase the share of wind power, hydro, nuclear or other low-carbon technologies in the system.
- While the total amount of transmitted electricity is largely unchanged, the production of power shows a slight tendency for moving northwards from the coal plants in Denmark to Finland, as the existing capacity’s potential for wood and waste firing is larger in Finland. This may change when capacities are adjusted in the long term.

- The electricity and heat sector reduces its emissions by between 3.4% and 8.9%, depending on the allocation scheme and reduction burden of the Emission trading sectors.

Reservations

The conclusions from the allowance market analysis are based on assumptions about the future allocation policy of the countries participating in the allowance market in 2015. While the overall figures for the total reduction requirement of the emission trading and the non-trading sectors on average are fairly reliable assumptions for future allocations and reductions, the assumptions on individual countries may be skewed. It has not been possible to obtain all the necessary information needed to present a completely systematised approach for assessing the reduction requirements in the trading and non-trading sectors in each of the analysed countries. The consequence is that the overall results regarding the allowance market and all the countries participating in the Emission trading system are more precise than the simulation results regarding specific countries, e.g. the non-trading sector MACs for each of the Nordic countries. As always, the models are more useful for creating insights rather than forecasts of specific figures.

1. Background

The UN Convention on Climate Change and its Kyoto Protocol sets up targets for the emission of greenhouse gases from industrialised countries, including the Nordic countries and EU member states.

As an important means to reach the emission reduction obligations the EU has established a European CO_2 Emission Trading System (ETSy). The system includes the 11,500 installations within the energy sector (power and heating) and within other energy intensive industries as cement, metal, glass and pulp and paper. The CO_2 emission from industries covered amounts to 45% of total EU CO_2 emissions. For these industries the ETSy provides an overall cap for the annual emissions of CO_2, and allows the individual industries to trade the allowances amongst themselves to minimize emission reduction costs. This means that the total emission of CO_2 from the sectors covered by the EU ETSy is fixed by the cap, but how the emission is distributed between the member states, sectors and 11,500 installations is determined by the allowance trading.

The main reason behind establishing an emission trading scheme like the EU ETSy is that it can help to reduce the overall emission reduction costs to society. The idea is that industries with high CO_2 emission reduction costs may purchase emission allowances from companies with lower reduction costs. Companies with low emission reduction costs could on their side sell some of their allowances and instead invest in low cost emission reductions within their company. This would help to utilise the full potential for low costs emission reductions and reduce the overall costs compared to a situation when all companies should reduce emissions.

The allowances are allocated (distributed) to the individual installation by the governments of the member states, mainly for free. However, through trade of the allowances a price is attached to the allowances. This price is in principle reflecting the costs associated to reducing emissions, as this will be the lower limit to the seller of the allowance (or she would be better off keeping the allowance for herself) and the upper limit to the buyer (or he would be better off making the reduction himself). Looking across installations, sectors and EU member states the large number of actors and transctions in principle will cause the allowance price to reach the marginal reduction cost for all of the sectors involved in the trading system. If the system is efficient with low transaction costs, the market price of the allowances will be independent on the fact that they are allocated for free. Trading will take place, and the allowances will be purchased and sold by those that benefit the most. The main effect of the allocation system is the distribution of income between the installations.

Emission reductions are also needed in other sectors to enable the EU member states to meet their obligations, for instance within the transport sector. There are only few uniform EU measures implemented to ensure emission reductions in these sectors (e.g. the targets for emissions per kilometre), whilte further measures needed to ensure these reductions are currently the responsibility of the individual governments

The EU ETSy is open for expansion, both in terms of other GHG gases than CO_2 and in terms of including new sectors. As the transport sector is the main emitter of GHG outside the sectors EU ETSy it is worth while to consider if including the sector in the ETSy is an attractive option.

The historic and present CO_2 emission in the Nordic countries, and in particularly from the transport sector, is presented in table 1-A below.

Table 1-A. Historic and present CO_2 combustion emission in the Nordic countries

Million t. CO_2	1990			2005		
	Transport	Other	Total	Transport	Other	Total
Sweden	20,7	29,7	50,4	25,1	27,5	52,6
Norway	12,0	16,7	28,7	14,4	20,6	35,0
Finland	12,5	40,6	53,1	13,5	52,3	65,8
Denmark	11,8	39,7	51,5	14,5	36,4	50,9
Total	57,0	126,7	183,7	67,5	136,8	204,3

Source: European Energy and Transport. Trends to 2030 – update 2005.

The CO_2 emission from road transport is the main part of total transport sector CO_2 emission, ranging from approximately 65% in Norway and 75% in Denmark to approximately 85% in Sweden and Finland.

Within the EU ETSy the CO_2 allowances are allocated by the governments of the individual member states. The allowances are mainly provided free of charge, even though up to 10% can be sold by governments to the industry. The EU ETSy has been in operation since 2005, and large volumes of alloances have been traded on the allowance marked. The price level has fluctuated considerably, and the present price of 1EUR/ton CO_2 is a fairly low price, probably reflecting a generous allocation of allowances. The forward price for allowances to delivery in 2008–12 (the commitment period) is currently in the range of 17–20 EUR/ton CO_2.

Including road transport in the EU ETSy will enable the sector to buy allowances at considerably less costs to the sector than if emission reductions were undertaken within the sector. Almost all studies show that emission reductions undertaken within the road transport sector generally are relatively costly (COWI 2004a). One way to reduce CO_2 emission from road transport could be to reduce road transport consumption, e.g. through higher fuel taxation. Road transport fuels are however already relatively heavely taxed, and this indicates that the willingness to pay for transport is high, compared to many other goods. The social costs of reducing transport consumption based on a willingness to pay concept therefore are relatively high.

Also technological solutions for CO_2 reduction from road transport exist, e.g. to use biofuels istead of gasoline and diesel. These measures are however also relatively costly, and face marginal CO_2 abatement costs starting at above 40 EUR/t CO_2 and rapidly increasing (COWI 2007).

The road transport sector as a sector with relatively high CO_2 reduction costs therefore could benefit joining the ETSy, as this would allow the road transport sector to trade allowances with sectors with relatively low reduction costs. It is therefore likely that total Kyoto compliance costs for the Nordic countries could be reduced if the EU ETSy was expanded also to include road transport, as this would allow the road transport sector to purchase allowances from sectors with lower marginal abatement costs. The specific advantage, however, depends on the National Allocation Plans and the split of the reduction burden between the ETSy sectors and the other sectors.

It should be underlined, that the emission trading system will have as an important effect that some countries will be net importers of allowances, and others become net exporters. This means that the net importing countries will undertake less real emission reduction within their country than needed to meet their commitments, and instead import allowances from other countries. Opposite, those countries becoming net exporters will in effect undertake more emission reduction within their country than needed to meet their obligations, and instead export part of these reductions in the form of allowances. To maintain national targets for specific branches or sectors is therefore in contradiction with the aims and functioning of the ETS.

As mentioned road transport is heavily taxed in the Nordic countries. This taxation is taken into account in the model simulation. However the specific taxation data may for each country not be fully up to date as it depends on the information provided in the GTAP database and the baseyear selected for this information.

2. Study methodology

The objective of this study is to analyse whether the inclusion of road transport emissions[1] into the European Emission Trading System (ETSy) will increase the economic efficiency of European climate change mitigation.[2]

It is generally acknowledged that the road transport does not react very strongly to changes in road transport usage prices. Rather, many of the most important effects of including road sector emissions in the ETSy are likely to be found outside the road transport sector.

The sectors included in the ETSy (such as the electricity and heat generation sectors, the so-called Emission Trading Sectors, or ETSe) are in particular suceptible to the impacts of including the road sector emissions. Such an inclusion could have important impacts on the demand and supply of emission allowances. This could cause significant changes in the allowance price, in the use and trade in allowances, and in turn also the price of electricity and heat and other important characteristics of the energy systems in the Nordic and other European countries.

The exact extent of these changes, especially concerning the supply of allowances, depends heavily on the principles of allocation used by the European emission allocating authorities. Therefore, this study presents a scenario-based analysis, which investigates the impact of including road sector emissions in the ETSy, depending on exactly how the allocation of allowances is made.

However, the analyses presented here will also consider effects not alleviated by the ETSy. In case strong reduction requirements are placed with the road transport sector (when it is not included in the ETSy), the costs of transport are likely to increase. As transportation as well as energy are important inputs to the economic activity, unbalanced reduction requirements on either sector can have adverse effects on the economic performance. *The most important output of this study is a description of when and how including the road transport sector in the ETSy can improve this balance in terms of economic efficiency.*

In addition, the study will also analyse the exact effects of allowance price changes on the Nordic energy system using the MARKAL like bottom-up energy system model Balmorel.

[1] It is assumed that the emission costs are paid by the importing or distributing firms and passed directly on to the consumers of road transport fuel, also known as the so-called upstream approach.

[2] It does not make sense to evaluate the economic efficiency of the ETSy alone of such an inclusion, as the ETSy is a market, which in absence of imperfections, does always facilitate the most efficient allocation of allowances and reductions.

2.1. Three allocation schemes and five scenarios

The attention of this study is the focused allocation of allowances to the ETSe firms and the residual emission possibilities in the non-Emission Trading Sectors (NETSe). In *five scenarios* the study investigates the effects of including the road sector emissions in the ETSy using *three different allocation schemes.*

The scenarios all describe the year 2015. This year is meant to describe the mid point of the third ETSy trading period. This period has been selected for the simulations, as it is unlikely that the necessary legal work within the EU to allow the road sector emission into the ETSy can be completed earlier. It is assumed that the overall emission targets for 2013–17 are the same as for 2008–12, i.e. the Kyoto targets are unaltered.

The *first* allocation scheme (called NAP) is an extension of the NAPs 2008–12 to 2015 by using the same absolute caps on emissions in the ETSe and NETSe as in 2008–12. Two more general allocation schemes are also investigated. The *second* allocation scheme (called Same Relative Reduction, SRR) is quite simple to calculate as it assumes same reduction percent in both ETSe and NETSe. This allocation principle, however, suffers from poor economic efficiency as reduction costs normally are significantly lower in the energy intensive ETSe than in transport and other sectors in NETSe, and the ETSe therfor should take a larger share of reductions to minimize overall costs.

The *third* scheme (called Efficient Allocation of Reductions, EAR) is – by theoretical construction – economically efficient (meaning that the required overall reductions are reached at the least costs). Unfortunately, it is not easy to describe or determine very precise guidelines for how to administratively implement this principle, besides that the expected marginal abatement cost of all sectors should be equal to the expected allowance price, e.g. as if all sectors were included in the ETSY. The three allocation types are described below:

- *Extension of NAP 2008–12 (NAP)*: The absolute amount of allowances allocated annually in the period 2008–12 is replicated for the period 2013–17. The Kyoto targets are left unchanged and therefore, the permitted emissions from the NETSe are the same as in 2008–12. Including the part of the road transport sector's emissions exceeding the 1990 level thus amounts to requiring the ETSe to undetake the reductions equivalent to the transport sector's extra emissions since 1990. This is equivalent to including road transport emissions in the ETSy by allocating the sector allowances equivalent to its 1990 emissions, although (the probably neglicible) emission reductions in the road transport sector cannot be sold into the ETSy.
- *Same Relative Reduction (SRR)*: Using this scheme, both the sectors included in the ETSy and the sectors outside are required to perform

the same percentage reduction relative to some baseline. An example of the SRR scheme is given in box 2-A.

- *Efficient Allocation Reduction (EAR):* This scheme is based on economic welfare theory, which states that the reductions are allocated most efficiently when the ETSy allowance price is equal to the marginal abatement cost for the NETS in all countries. In principle this corresponds to assuming that all sectors are included in the ETSy.

In this analysis, the numerical simulations of the NAP scheme are based on data from the published allocation plans for 2008–12 as at the beginning of October 2006, while the EAR scheme allocations are the results of the simulations rather than inputs. A hypotetical example of how an SRR scheme allocation is made is provided in Box 2-A:

Box 2-A: An example of the SRR scheme

Consider a hypothetical example where a country's Kyoto cap is 45 Mt. The emission trading sectors have baseline emissions of 30 Mt and the non-trading sectors have baseline emissions of 20 Mt. As the total emissions are 50 Mt, this leads to a total national reduction requirement of 5 Mt, or 10%, to reach the cap of 45 Mt.

With the SRR principle both sectors must reduce their emissions by 10%. Therefore, the number of allowances allocated to the ETSe is 27 Mt. The remaining NETSe emissions are 18 Mt, meaning that the national authorities must somehow bring about 2 Mt of reductions from sectors not covered by the ETSy or from state purchase of Kyoto allowances (from JI or CDM projects or in the form of AAUs).

To simplify the analysis we present five scenarios, which illustrate the effects on the allowance price when the three schemes for allocation described above are used to determine the amout of allowances allocated to the road transport sector. The five scenarios are illustrated in table 2-A:

Table 2-A: Overview of analysed scenarios

Road transport not in ETSy	Road transport in ETSy
NAP: This scenario describes the most likely development in the EU allowance market if the NAPs for 2008–12 are continued in 2013–17 (with the representative mid year of 2015).	**NAP-t:** This scenario is the same as **NAP**, except that the growth in road transport emissions since 1990 are included in the ETSy. The road transport sector is assumed to purchase allowances from ETSe firms corresponding to its emission growth since 1990. This increases the demand for and price on allowances as the amount of allowance allocated to ETSe is the same as in the **NAP** scenario.
SRR: With the same relative reduction for the ETSe and NETSe, the reduction requirement in per cent is the same in both ETSe. I.e. if the required reduction is 10% for the country, both the ETSe and NETSe must reduce emissions by 10%. (The allowances may be bought from or sold to other countries and therefore a 10% emission reduction may not specifically take place in the country's ETSe after trading)	**SRR-t:** This is as the **SSR** scenario, but the road transport sector is fully included and allocated allowances corresponding to the same relative share as for other ETSe's. When the relative reduction requirement in per cent is the same in the ETSe and NETSe, including road transport emissions into the ETSy does not change the overall relative reduction requirement in the ETSe or NETSe. However, as transport emissions in general are relatively expensive to abate, it is likely that the ETSy allowance price will increase.
EAR: With the Efficient Allocation of Reductions scheme the reductions are distributed such that the cost of the marginal reduction in all sectors is the same as the allowance price in all countries.	

It can be noted that in the EAR scenario it does not matter whether the road transport emissions are included or excluded from the ETSy. In any case, the reduction requirement of the NETSe and ETSe is assigned such that the marginal reductions in the ETSe and NETSe have the same cost.

In the EAR scenario, the allocations to the ETSe and the resulting reduction requirement for the NETSe are outputs of the model, not inputs to it. This scenario is primarily illustrative, as it shows the 'optimal' allocation of the reduction burden between ETSe and NETSe. This 'optimal' allocation is of course strongly dependent on the used model and the underlying database. Thus it is only suggestive regarding whether the other allocations between ETSe and NETSe can be improved. It illustrates, however, very well the scope for excessive costs of climate action in case the balance between ETSe and NETSe reductions becomes wrongfooted.

2.2. Analysis methodology

As the preceeding sections show, the effects on the allowance price of including road transport emissions into the ETSy depend on complex dependencies between marginal abatement costs of the different sectors, their share of emissions, and the allocations decided by the policy makers.

Furthermore, when the effect on the allowance price is found, the consequences for the electricity and heat prices and other effects on the Nordic energy system are also determined through equally complex interdependencies in the energy systems.

This study therefore splits the quantitative analyses in two parts using quite different numerical simulation techniques:

- A top-down *Computable General Equilibrium (CGE) model* is used for determining the effects on the *allowance price* of including the road transport emissions in the ETSy. This model takes account of both substitution of fuels, industrial and consumer demand towards less CO_2-intensive production and consumption, while it also accounts for the economic income effects of international transfers of money in return for reductions made abroad; and
- A bottom-up *Energy System Optimisation model*, which accounts for the Nordic energy system, especially concerning *electricity and heat prices* and demand, the composition of fuels, international electricity trade, CHP and other important characteristics of the system.

The CGE model analysis of the effects on the allowance price is presented in chapter 3 of this report. The bottom-up model analysis of the impacts on the Nordic energy system is found in chapter 4. Finally, this study also presents a legal analysis of the requirement for including the road transport emissions in the ETSy. This analysis is presented in chapter 5.

3. Allowance market effects

This chapter describes the numerical simulation analyses of the effect of including road sector emissions in the ETSy. For the reasons described in chapter 2, these effects are to a large extent determined by the amount of allowances allocated to the road transport sector if included in the ETSy.

The results of the allowance market analysis are presented in five stages. First, the reduction requirements for the ETSe and NETSe sectors are described for each of the five scenarios analysed. These reduction requirements drive the changes in allowance prices, which are presented next. Then the model results of the changes in the electricity and transport prices are presented. Finally, the model results of the effects on income, consumption and activity (in terms of GDP) are presented.

The CGE model used for these analyses is a multi-sector, multi-region top-down model called GTAP-ECAT. This model is an extension of the GTAP model[3] where the firms' and consumers' energy use has been extended such that substitution between different fuels is possible. The model also contains several regional and international markets for CO_2, which are used for modelling the European Emission Trading System. The reader is refered to appendix B for a brief overview of the model, the baseline scenario data and references to further documentation on the model.

An important limitation of most climate/energy CGE models is that they do not describe the 'world' in terms of specific technologies and reduction actions. Rather, they rely on an elaborate system of top-down nested consumption and production functions. In these the shares of different fossil and green fuels (as well as other goods) are substituted with each other in response to changes in relative prices. While this of course is a serious simplification of demand and supply (in particular OF?the energy system when the subject of the model simulations are emission reductions), it nevertheless allows a treatment of all economic sectors, and thereby assessments of important macro economic effects on consumption, international trade and so on – effects that are also of great interest when evaluating climate policy.

At this point it is also worth mentioning an important limitation in the interpretation of the results. The model handles only CO_2 emissions from combustion of fossil fuels. These are only a part of the total GHG emissions. The focal point of the analysis is the distribution of reductions between the ETSe and the NETSe. The results of how large reductions the

[3] The GTAP model is a world trade model with an extensive database covering the world split into 87 regions and 57 economic sectors. See https://www.gtap.agecon.purdue.edu/

ETSe and NETSe should make only apply to the ETSe and NETSe combustion CO_2.

3.1. ETSe and NETSe reduction requirements

The impacts of the different allocation schemes are influenced by the relative sizes of the ETSe, NETSe and road transport sector emissions. The magnitudes of these emissions are illustrated in table 3-A for the Nordic countries, the Western and Eastern EU Member States.

Table 3-A: Baseline emissions of CO_2, combustion of fossil fuels, 2015 (Mt)

	Nordic countries	Western EU	Eastern EU
a) Total emissions (b+c)	228	3,326	683
b) '– of which ETSe	81	1,190	369
c) '– of which NETSe	146	2,136	314
d) ' + hereof road transport	54	838	97
e) Gross Kyoto Target	183	2,894	845
f) Gap (e – a)	45	432	-162
Required reduction (f / a)	-20%	-13%	24%

Source: Own projection of GTAP 6.0 database based on 'European Energy and Transport – Trends to 2030 (update 2005)', DG-TREN (PRIMES).

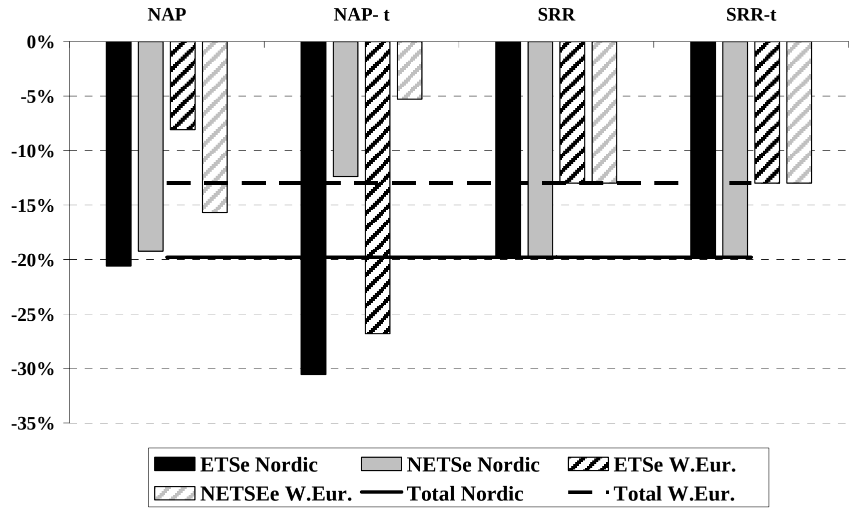
Note: The total emission figures are not in concordance with UNFCCC data because of differences in definitions and sector classification. ETSe emission figures rest on own classification of the ETSe sector, which may differ from national definitions. The 'Combustion gross Kyoto Target' is calculated on the basis of the assumption that combustion CO_2 emissions will be reduced in same proportion as other emissions, e.g. process CO_2, methane etc. In particular, the transport emission figures in this table have a different definition than those in table 1-A (which are somewhat higher).

The baseline projections in Table 3-A is based on the hypothetical assumption that no action to reduce emissions are taken from the base year and onwards.

This assumption results in significant increases in the emissions from the Nordic countries from 2005 to 2015. With this baseline both the Nordic and the Western EU countries face substantial reductions of around 13% to 20% in 2015 in order to bring these baseline emissions to the level of the Kyoto obligations. In Eastern EU the emissions are lower than their Kyoto obligations.

In four of the five scenarios the reduction requirements for the ETSe and NETSe are constructed by the NAP and the SRR scheme and used as input into the model. These reduction requirements tell *a priori* a lot about how the model results may look like. The reduction requirements for the Nordic countries and for EU25 plus Norway in these four scenarios are illustrated in figure 3-A.

Figure 3-A: Reduction requirements for the ETSe, NETSe and total in the Nordic countries and Western Europe, by scenario (% reduction of 'do-nothing' baseline 2015)



Source: Calculations with GTAP-ECAT.

Note: The reduction requirement is calculated assuming that the energy sector will reduce its emissions in the same proportions as other emission sources.

The first general remark to be made is that the average Nordic reduction requirement of app. 20% in total is larger than the average European reduction requirement of 13%.[4] This indicates that the Nordic countries are likely to be net importers of allowances, at least in situations where the Nordic ETSe firms are required to make reductions that are not much smaller in relative terms than the other European ETSe firms.

The second observation is that there is the NAPs of the Nordic countries seem to assign reductions to the ETSe and NETSe of approximately the same relative percentages (i.e. around 20%). On the contrary, the remaining Western European NAPs seem to rely more on NETSe reductions. However, in the NAP-t scenario (where extra road transport emissions since 1990 are included) this balance is markedly different. Compared to the NAP scenario the ETSe reductions are significantly larger: in the Nordic countries the ETSe reductions are 10 percentage points larger, while the Western European countries have ETSe reductions which are app. 18 percentage point larger.

By requiring that road transport acquires all additional emissions since 1990, 264 Mt of allowances are acquired by the road transport sector

[4] This is a result of the baseline projection (from '*European Energy & Transport – Trends to 2030*'), in which the Nordic CO_2 emissions increase more from 2001 to 2015 than the emissions in the remaining EU countries.

from the ETSy.[5] This brings the ETSy reduction from 5% of the baseline emissions to 21% of the baseline emissions. This markedly increases the demand for allowances without increasing the supply, and therefore, a rather significant increase in the allowance price can be expected going from the NAP to the NAP-t scenario.

Conclusion 3-1: The increase in European road transport emissions since 1990 is at 264 Mt very significant. If these allowances must be bought from the ETSy without any increase in the total number of allocated allowances the ETSy contribution (incl. road transport) to the climate change abatement increase from a 5% reduction to a 21% reduction.

The third observation to make concerns the SRR scheme. This scheme assigns the Same Relative Reduction to both the ETSe and NETSe regardless of whether road transport is included in the ETSy or not. The reduction assigned is the overall reduction required to reach the country's Kyoto target. So, in the SRR and SRR-t scenarios the economic effects of including road transport in the ETSy are rooted solely in the difference in the marginal reduction costs of the ETSe, the NETSe and the road transport emissions.

3.2. Allowance prices and NETSe Marginal Abatement Costs

The allowance price in the ETSy will in principle determine the marginal abatement costs of the sectors covered by the emission trading system in all member states, as they will be able to trade allowances or make emission reductions until their marginal costs reach the allowance price. Opporsite to this, the marginal costs of the NETSe will differ across EU member states as these sectors can not trade emission allowances across borders.

With the described allocation schemes, the ETSe sectors in all countries are assigned allowances which are traded in the ETSy. In each country, the number of allowances subtracted from the total energy sector reduction requirement leaves a limited amount of allowed emissions to the remaining NETSe emission sources. The model simulations depart from the assumption that the resulting reductions in the NETSe emissions are made from an efficient least cost principle.

This country-by-country least cost NETSe reduction principle implies that there will be a NETSe Marginal Abatement Cost (MAC) in each country.[6] Together with the ETSy allowance price this NETSe MAC is an

[5] The road transport sector is, in the setup of this scenario, not allocated any allowances, as the sector's reductions are not traded in the ETSy. For all practical purposes this is equivalent to the road transport sector joining the ETSy and being allocated a number of allowances equivalent to its 1990 emissions.

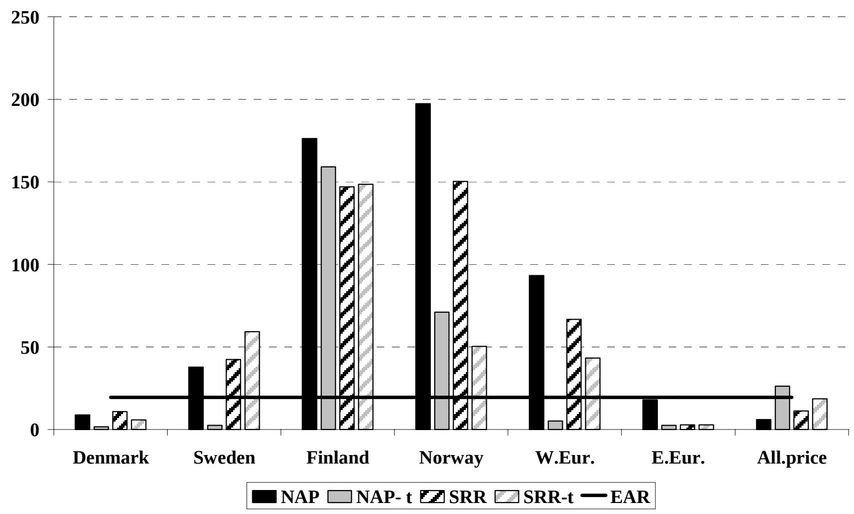
[6] The NETSe MAC can be interpreted as the national CO_2 tax necessary to achieve a given reduction.

output of the model in each scenario, as well as the database, and the assumptions regarding the NAPs, the chosen distinction between ETSe and NETSe etc.

The difference between the NETSe MAC and the allowance price describes the extent to which the allocating authorities have been able to strike a balance between, on the one hand, the expected allowance price and, on the other hand, the available reductions in the NETSe sector and their costs.[7]

Large differences between the NETSe MACs and the allowance price indicate that the balance between ETSe and NETSe reduction requirements can be improved. Hereby the cost of reductions will be diminished. The allowance price and the NETSe MAC for the modelled EU regions and countries are shown in figure 3-B below. The allowance prices are indicates by the bars on the righthand side of the axis of the figure.

Figure 3-B: Allowance prices and NETSe MACs in the five scenarios (Euro/tonne CO_2)



Source: Simulations with GTAP-ECAT.
Note: In the Efficient Allocation of Reductions (EAR) scenario all the NETSe MACs are by definition equal to the allowance price, which is illustrated by a line instead of bars.

From the figure it can be seen that in most countries (and in particular in the NAP scenario), the NETSe MAC is larger than the allowance price. This indicates that the NETSe reduction requirements in the analysed scenarios are in general too strict. Conversely, the ETSe allocations are too generous (this conclusion is, however, also subject to the reservations mentioned in footnote 7). The only exception seems to be Denmark,

[7] It is assumed that the emissions from fossil fuel combustion will be reduced in the same proportion as other sources. If in some country relatively more cost-efficient reductions can be made through another source, the reduction requirement and the MACs will be lower. As the ETSy allowance price is not likely to be affected by one country's actions, this will improve the balance bewteen the country's NETSe MAC and the allowance price.

where the ETSe allocation is quite strict.[8] With optimal allocation in EU an allowance price of approximately 20 EUR/tCO_2 is estimated.

For the countries with low NETSe MACs two explenations are available: (1) The country may have very low costs in these sectors, or (2) the required reductions in the NETSe are small compared to the potential reductions. For example, the low Danish NETSe MACs are mainly caused by the relatively strict Danish ETSe allocation, and the consequently less strict reduction requirement on the NETSe.[9]

Conclusion 3-2: The scenarios analysed show that the modelled allowance prices are markedly lower than the NETSe MACs in many EU countries. This indicates that the overall economic efficiency is enhanced when the ETSe bears a proportionally larger burden of reduction than the NETSe. Requiring the ETSe firms to undertake more reductions may thus yield significant economic benefits. A few countries have low NETSe MACs, and this is typically a consequence of relatively small NETSe reduction requirements.

It is also noteworthy that the NETSe MACs genereally fall when road transport emissions are included in the ETSy (this goes for all countries NAP-t and for all except Finland and Sweden in the SRR-t, where it is almost unchanged). This indicates that road transport is less sensitive to the cost of CO_2 emission than other NETSe emissions. Including some or all road transport emissions in the ETSy therefore shifts economic reduction burden to the more emission intensive ETSe, which tend to improve the economic efficiency of the reductions (see box 3-A).

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[8] This is beneficial to Denmark when the ETSy allowance price is low (as it is in most scenarios), because Denmark in this case can buy cheap reductions from other EU countries and avoid making expensive NETSe reductions.

[9] Because the model's definition of ETSe is not perfect, it cannot necesarily be argued from this model result that the Danish allocation to ETSe is too small.

Box 3-A: Economic reduction potential and emission intensity

An important relationship exists between the emission intensity of a sector and its reduction cost. An example will easily illustrate this. In the table below the emissions, Gross Value Added (GVA) and emission intensity of the Danish food sector and electricity and heat sector is shown.

	Emissions ($Mt\ CO_2$)	GVA (bn DKK)	Emis. Intensity ($DKK / tonne\ CO_2$)
Food	1.7	32.6	19,200
Electricity and Heat	28.4	24.6	866

Note: Gross Value Added (GVA) is a measure for the economic value of the production. It is calculated as the sum of wages and profits from the production.
Source: www.statistikbanken.dk

If the only way of reducing emissions were to abandon production in the sector, abating one tonne of CO_2 in the food sector would lead to a loss of 19,200 DKK of value added. If the reduction were to happen in the electricity and heat sector, the corresponding loss would be only 866 DKK, all else equal.

Not even considering fuel substition this example shows why emission intensive production in many cases offers economically attractive reduction potentials.

Besides fuel substitution other factors of importance for the economic costs of reduction are the good substitution possibilities, i.e. can the purchasers of the emission intensive goods easily shift their demand towards less emission intensive goods.

Conclusion 3-3: Including road transport emissions in the ETSy tends to lower (or leave unchanged) the relatively high NETSe MACs. Not only does this mean that reductions in the remaining NETSe become cheaper, but also that expensive road transport emission reductions are replaced with cheaper ETSe reductions.

3.3. Trade in allowances and reduction costs

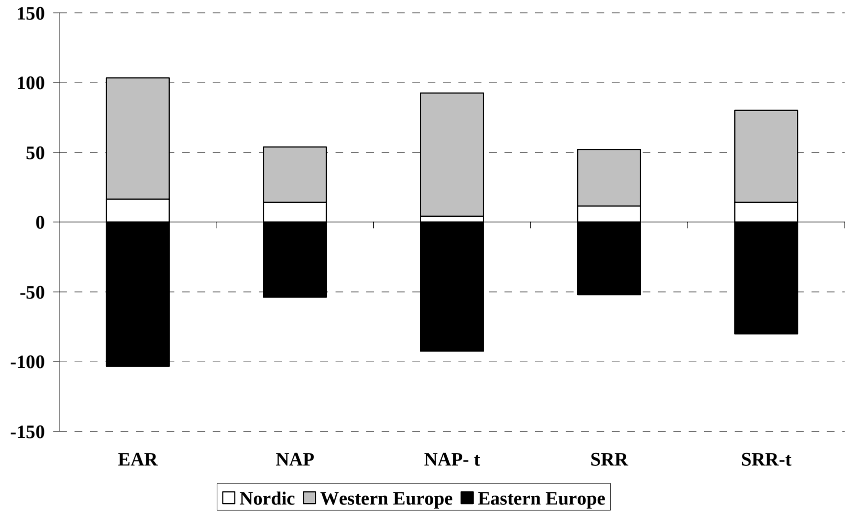
The location of the reductions by sector and geography is determined by the difference between the marginal abatement costs in the ETSe in the different European regions. This, in turn, depends on the emission intensity, substitution possibilities, but also on the reduction requirements in the different regions. In particular Eastern Europe must *a priori* be expected to be net exporters of allowances for all these three reasons:

- Income and production is relatively lower, so forgoing productive activity (with energy use and emissions) is relatively cheaper here

- There is a number of other ‘cheap’ options, like improved production efficiency and fuel substitution.
- The Eastern European need for reductions is small, as the baseline emissions in general are lower than the Kyoto targets

While the direction of the flow is determined by these factors, its magnitude is determined by the market volume and the allowance price. A higher allowance price and a higher market volume lead to larger flows of allowances. The market volume is larger when the road sector emissions are included (the EAR, NAP-t and SRR-t). In these scenarios the allowance price also tends to be higher. This impact can be seen in figure 3-C.

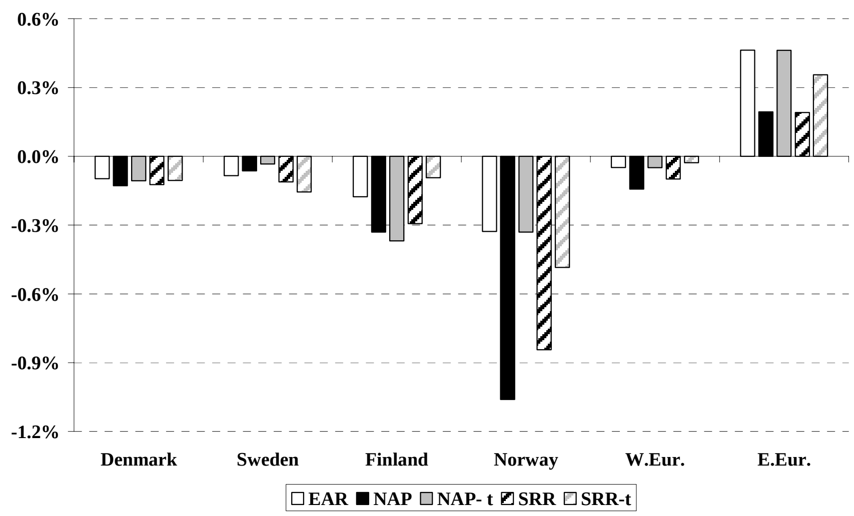
Figure 3-C: Net import of allowances by region (Mt)



Source: Calculations with GTAP-ECAT.

Of further interest it can be mentioned that Finland and Norway import most of the allowances to the Nordic region (between 3 and 9 Mt each, depending on the scenario), while Denmark and Sweden have a somewhat smaller import (between 0 and 3 Mt, depending on the scenario).

Figure 3-D: Cost of emission reductions (% of GDP)



Source: Simulations with GTAP-ECAT.

The figure shows that the economic efficiency is improved (i.e. smaller reduction cost) in all countries by including the road transport emissions in the ETSy in the NAP-t scenario. The only exception is Finland, where the reduction cost increases slightly (and not significantly different from 'no change').

The reason for this is that the 1) in the simulations Finland is a relatively large importer of allowances, and 2) the allowance price increases from app. 5 to 25 €/t when transport is included in ETSy, and 3) this increase is larger than the reduction of the Finnish NETSe MAC obtained by including the transport sector (please see figure 3-B). The negative effect of the increase in the price of the imported allowances is larger than the positive effects of a better balanced reduction requirement. As can be seen Finland is much better of in the EAR scenario. This shows that also Finland can reduce reduction costs by including road transport emissions in the ETSy.

The same story goes for Sweden in the SRR and SRR-t scenario. Here, Swedens NETSe MAC also increases slightly, and as the allowance price also increases, Sweden is worse off. Again, a stricter allocation to the ETSe would remedy this effect, as it seems that the Swedish non road transport NETSe emissions are even harder to reduce than the road transport emissions.[10]

While the EAR scenario is 'optimal' in the sense that it gives the lowest possible *European* reduction costs, some single countries may be better off in other scenarios. This is so because net exporters of allowances typically benefit from higher allowance prices, while net importers benefit from lower allowance prices. Other factors, e.g. fuel substitution possibilities, also play an important role for the total cost of reduction.

Conclusion 3-4: Including road transport emissions in the ETSy tends to yield moderate to strong economic benefits for almost all countries in all scenarios, even though the allowance price increases significantly. If there in this case is a severe mismatch between a country's ETSe and NETSe reduction requirements, further adjustments of the balance between ETSe and NETSe reductions in that country are required in order to offset the detrimental effect on that country of the other countries actions.

3.4. Electricity and transport prices

Over half of Europe's combustion CO_2 emissions originate from electricity and heat generation (33%) and road transport (20%). Therefore, the main economic impacts pass through these two sectors, by adding the allowance price to the costs of these sectors. The more emission-intensive the sector is, the larger is the impact on the sectors costs. This has two effects:

[10] Again, results concerning single countries may be influenced by inadequate coverage of the GTAP database concerning the countries NETSe energy consumption or other economic parameters.

- *Fuel substitution,* where the sector's firms try to substitute their fuel for other fuels, e.g. coal for natural gas, or for electricity
- *Output contraction*, where the purchasers of the sectors' goods gradually substitutes these for less emission-intensive goods or imports from countries with little or no emission costs and/or regulation.

The demands for transport and electricity are known to be rather insensitive to the price of these goods, so the reduction potential of output contraction in these sectors is rather limited. In order to make a discernible effect on the sectors' output and emissions, the sectors' output prices need to rise considerably.

The fuel substitution possibilities of the electricity sector are rather good compared to road transport.[11] This is a main reason that reductions in the electricity and heat sector are relatively cheaper than in the road transport sector.

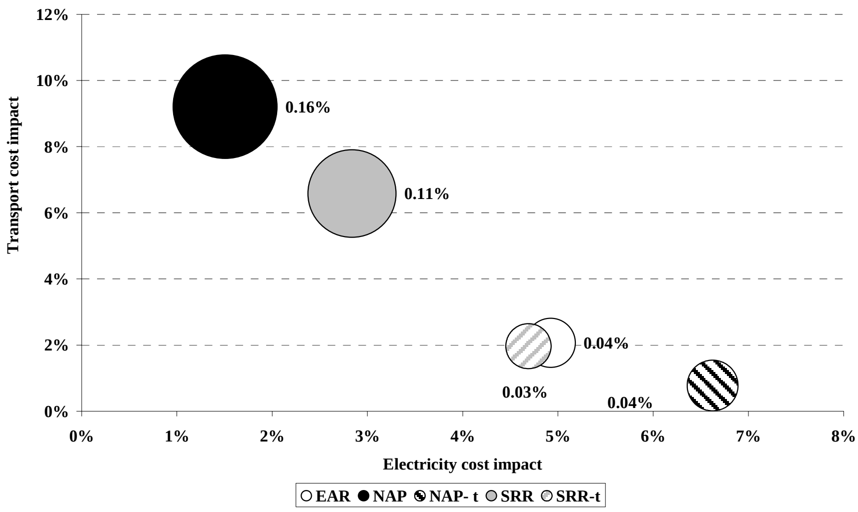
This indicates that a balanced approach is needed when reduction requirements are assigned for the NETSe and ETSe, and when moving road transport into the ETSy. In particular, it is important that road transport is not required to undertake disproportionally large reductions, exactly because the reduction costs in this sector are significantly larger than in the electricity and heat sector. This is illustrated in figure 3-E, which shows the effect on transport and electricity prices combined with the impact on the GDP of meeting the emission reduction commitments in the five scenarios analysed.

The figure very clearly shows that placing too heavy a burden on the transport sector has a large negative impact on the reduction costs through a large increase in the price of road transport. Shifting a significant share of the reduction burden towards the ETSe – where the cheaper substitution possibilities are much more abundant – reduces the costs of reduction in terms of the GDP to a quarter of the most expensive option evaluated.

It is in particular interesting that the SRR scenario (where the percentage reduction requirement of NETSe and ETSe are the same) results in the second most expensive reduction costs. This shows that reductions are much more easily accomplished in the electricity and heat sector, i.e. the needed price increase in the transport sector is much larger than in the electricity and heat sector, even though the required reductions percentages are the same.

[11] Depending on international fuel prices and the allowance price, the fuel mix in electricity and heat generation can change relatively easily compated to the road transport fuel mix, in the short term change through shifts in international trade in electricity, and in the long term through phasing out of carbon intensive technologies.

Figure 3-E: EU25 + Norway Costs (% of GDP) compared to transport and electricity cost impact (% of transport total costs and electricity total costs)



Source: Simulations with GTAP-ECAT.

Note: The areas of the circles indicate the GDP loss. The cost impacts on the two sectors (transport and electricity, respectively) does not include General Equilibrium effects from e.g. the labour market, and should thus be interpreted as a first order cost impact of the allowance price in the two sectors.

Conclusion 3-5: As reductions in the road transport sector are rather expensive, it is important that the road transport emission reduction requirements are balanced against the much more efficient reduction potential of e.g. the electricity sector. *The numerical analysis shows that the reduction costs can increase four-folds with an unbalanced reduction requirement between ETSe and NETSe.*

Including road transport emissions in the ETSy implies that the balance of reductions between the electricity and the road transport sector is adjusted momentaneously by the market forces rather than by national authorities, which have to make their judgements years in advance. Thus, the scope for limited foresight, misjudgement and errors by the national authorities is considerably reduced.

Conclusion 3-6: By including the road sector emissions in the ETSy, the balance between road transport and ETSe emission reductions is left to the market forces. This allows for more efficient and less costly reduction efforts for the combined ETSe and transport sector emissions. For the analysed allocation schemes the GDP loss has been reduced to one quarter when including transport sector in the ETSy compared to the situation when transport is not included.

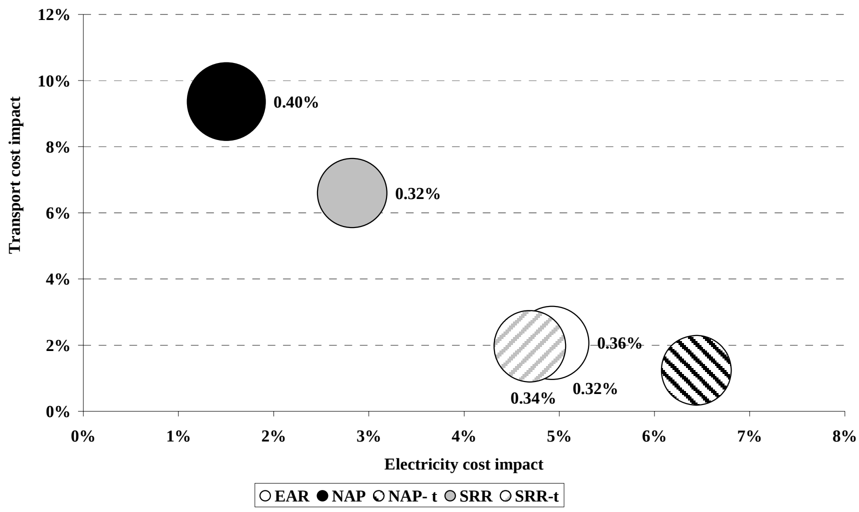
3.5. Effects on international competitiveness

It can be argued that the competition on the international market is stronger than on the domestic market, and that the allocation of allowances should consider the effects on the competitiveness of exporting firms, in particular concerning markets that span countries with no or little GHG emission regulation.

However, both electricity and road transport are essential inputs in all firms, so if either the price of electricity or of road transport increases disproportionally, this will have an excessively large effect on the output price of the firms. In fact, all firms use a variety of inputs from both NETSe and ETSe firms.

In order to make decisions that considers social welfare, rather than the interests of special sectors it is essential that the reduction requirements are balanced such that the abatement cost of the ETSe (the allowance price) and NETSe (the national MAC) are roughly equal. Figure 3-F shows the impact on all exporting firms' costs in the five scenarios together with the reduction costs of the ETSe and NETSe.

Figure 3-F: EU25 + Norway emission cost transfer to all exporting firms' costs (% of production value)



Source: Calculations with GTAP-ECAT.

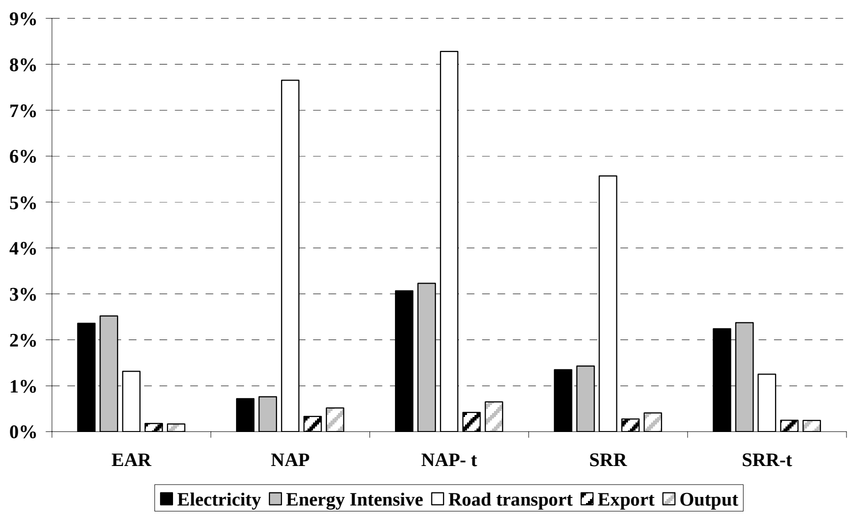
Note: The areas of the circles indicate the magnitude of the export cost impact. The cost impact does not include General Equilibrium effects from e.g. the labour market, and should thus be interpreted as a first order cost impact on exporting firms of all allowance costs.

The figure shows that the impact on the exporting firms' costs are somewhat mixed. This indicates that exporting firms rely both on energy intensive goods (from firms included in the ETSy) as well as goods from other firms. Note in particular that the exporting firms' costs are more sensitive to the cost of transport than the cost of electricity.

Conclusion 3-7: Both electricity and transport are important goods to the Nordic firms (and consumers). Competitiveness in terms of the costs of exporting firms is influenced both by the price of goods produced by firms included in the ETSy (e.g. electricity) as well as firms outside the ETSy (e.g. transport). Therefore, striking the right balance between reductions in the ETSe and NETSe will help reducing the climate costs of exporting and other firms.

Comparing between the different major energy consuming sectors as well as indicators for overall output and exports, the balancing dilemma is quite evident. In the economically inefficient NAP and SRR scenarios, the road transport price increases are multiples of the general output and export price increases, c.f. figure 3-G. As was seen from figure 3-F this is detrimental to the costs of all exporting firms, as this is more sensivtive to the cost of transport than the cost of electricity.

Figure 3-G: Cost impact by sector and scenario, Nordic countries (%)



Source: Simulation with GTAP-ECAT.

Note: The cost impact does not include General Equilibrium effects from e.g. the labour market, and should thus be interpreted as a first order cost impact on exporting firms of all allowance costs. For Energy-Intensive Industries (all ETSe except electricity and heat), the cost impact also includes the cost impact from electricity.

The cost impact on energy-intensive industries (which also includes the cost impact from electricity) is roughly the same as the impact on the electricity sector, as energy related costs amounts to a large share of total costs in these industries. This indicates that the emission intensity in the energy intensive industries is not that different from the electricity and heat sector.[12]

[12] Note that this analysis does not take process emissions into account.

Conclusion 3-8: The differences in the cost impacts between the scenarios indicate that the cost-effective climate policy will tend to emphasise that the most energy-intensive industries (including electricity and heat generation) will have to bear the largest burdens. This result seems reasonable, because a contraction of output from these sectors will result in more emission reductions compared to other sectors.

3.6. Competition effects in the energy intensive industries

This chapter has argued that the most cost-efficient emission reductions are found in the most emission intensive sectors. All else equal (i.e. not considering fuel substitution) an output contraction of e.g. 1 million Euros in an emission intensive sector yields more emission reductions than the same contraction in a less emission intensive sector. When considering fuel substitution possibilites (which may differ between electricity and heat, energy intensive industries, and road transport) the scope for emission reductions increases further.

In any case some reductions must be undertaken, and to the extent fuel substitution is not sufficient to attain the necessary reductions, output contraction of the most energy intensive production (whether it be electricity and heat, or energy intensive industries) is the most economically efficient answer.

From figure 3-G it can be seen that the the Nordic energy intensive industries' output cost impact of increasing allowance and electricity prices is between app. 1% and 3%.

It is however, not only the energy intensive industries in the Nordic countries which costs are influenced by the allowance price. Also the industries of all other EU countries must pay extra for emissions and electricity. The competitive effects on the energy intensive industries (as well as any other economic sector) are therefore limited to the import and export markets concerning countries outside EU. A large part of assessing the competitive effects of the cost impacts thus depend on the shares of export and imports, inside and outside the EU. These are shown in table 3-A.

Table 3-A: Shares of demand, output and international trade for selected goods, 2001 (%)

	Agriculture	Energy Int. Industries	Other industries	Service
Share of demand	2%	6%	23%	52%
Share of output	2%	7%	22%	51%
Import share of demand	25%	27%	47%	8%
Export share of output	18%	42%	48%	10%
Share of exports not to EU	26%	21%	38%	53%
Share of imports not from EU	38%	19%	23%	51%
Export 'exposure'	5%	9%	18%	5%
Import 'exposure'	10%	5%	11%	4%

Source: The GTAP 6.0 database. Note: The rows for demand and output does not sum to 100% as a number of smaller sectors are not shown. The import and export exposure is calculated as the product of the export/import share and the share 'not to EU'.

As can be seen from the table, only around 20% of energy intensive imports and exports have origin/destination outside EU. This means that 80% of the Nordic import and export of energy intensive goods are subject to app. the same cost impacts as in the Nordic countries.[13] To a large extent this blunts the competitive impact of the allowance price on the Nordic energy intensive industries. Further, only 27% of the Nordic demand for energy intensive goods is covered by imports, and only 42% of the Nordic energy intensive output is exported.

Multiplying these two shares gives an 'exposure', i.e. the share of the exports and imports destined to and originating from countries outside EU with no allowance costs. From the table it can be seen that 9% of energy intensive export goes to, and 5% of imports come from countries without allowance costs. From table 3-A it is also noteworthy that energy intensive goods have only app. half the exposure of goods from other industries, and an exposure not very different from services and agriculture. These figures thus suggest that energy intensive industries are less exposed to competition than other industrial sectors, and that increasing prices for transportation thus can be a more serious threat to industrial exports.

A final thought on this issue is intensity of international competition within energy intensive goods. Some energy intensive goods are highly *homogeneous* (the goods from different producers have app. the same qualities), meaning that the origin of the good is of little importance for the buyer – what matters is almost only the price. The competition for this type of goods is often very intense. Other, so-called *heterogeneous* goods, are much less exposed to competition, as their qualities differs

[13] This depends on the energy and emission intensity of energy intensive industries in other countries. Therefore, if the Nordic countries' energy intensive industries are relatively more energy and emission efficient than their European competitors, increases in the allowance price may be a competitive advantage to Nordic energy intensive industries. Whether this is actually the case (or merely a theoretical possibility) is outside the scope of this project.

both among producers, and often also by countries of origin, driven by local customs and preferences.

Both homogeneous (e.g. certain qualities of paper, intermediates for steel and cement) heterogenous (e.g. special quailties of metals etc) goods are found among energy intensive goods. Also high transport costs may limit the scope for strong international competition. Thus a part of the energy intensive goods produced in the Nordic countries are highly exposed to international competition, while another part is not.

A project much more detailed than the present study is needed for a thorough description of which energy intensive sectors that are intensely exposed to competition from outside EU, and which sectors that are not. In any case, however, the figures presented in table 3-A suggests that there is a large component of localised preferences for energy intensive goods. Therefore, the extent of intense international price competition may be viewed as somewhat limited. If this is the case, the adverse competitive effects on the Nordic energy intensive sectors caused by an increasing allowance price may be small.

Conclusion 3-9: The competitive pressure on the energy intensive (and other) industries comes from markets with little or no emission costs and regulation, i.e. outside EU. The export and import patterns of Nordic energy intensive industries suggest that the competitive pressure from outside EU is somewhat smaller than on other industrial sectors.

4. Energy system effects

As the allowance price represents a variable cost on heat and electricity production, a change in the allowance price will have some effects on the energy system. First of all, a change in the allowance price will have an effect on the heat and electricity prices. Furthermore, it will influence the production patterns as a change in the allowance price most likely will change the merit order of heat and power producers. For instance, an allowance price above a certain level will make biomass and/or gas more competitive than coal. Therefore, a change in the allowance price will shift production from some production units to others, which will also influence on the fuel consumption, and which may also influence on the import and export patterns.

In a longer perspective, the shift in merit order will not only influence on the dispatch among existing producers, but also on investments in new production units.

4.1. General approach

The model simulations analysing the energy system effects are carried out for the Nordic power system in year 2015 and with different allowance prices on CO_2. It is a basic assumption that the electricity and heat markets are well-functioning markets with full competition between power producers. Thereby, the electricity and heat prices equal the marginal production costs in the system. The model simulations are carried out for a normal year with respect to rainfall.

The model used is the Balmorel model (www.balmorel.com), which is a technical/economic partial equilibrium model. The model simulates the electricity and heat markets, taking into account:

- the electricity and heat demand;
- the technical and economic characteristics for each kind of production unit, e.g. capacities, fuel efficiencies, operation and maintenance costs, and fuel prices;
- the environmental taxes and quotas;
- the transmission capacities between regions and countries.

As output, the model comes up with production and transmission patterns on a total cost-minimizing basis. The model also comes up with estimates of electricity and heat prices assuming liberalised and well functioning markets with full competition among power producers.

The specific model version used for this scope of work contains the electricity and CHP system in the Nordic countries (Denmark, Finland, Norway and Sweden). These countries are integrated in a common electricity market and hydro-power accounts for approximately half of the electricity generation. The transmission grid in the Nordic countries as well as the main power producers are shown in Figure 4-A below.

Figure 4-A: The transmission grid in the Nordic Countries

Power trade with the Continent is included in the model by an assumed electricity price in each time segment to which there can be either import or export. It is assumed that the price level on the Continent will correspond more or less to the price level in the Nordic countries in a normal year with respect to rainfall, and therefore the net exchange between the Nordic countries and the Continent (on an annually basis) will be close to zero. This assumption is used for all allowance prices. In other words, it is assumed that if the prices increase in the Nordic countries due to an increased allowance price on CO_2, the prices will also increase on the Continent, and the net exchange between the Nordic countries and the Continent will still be close to zero in a normal year.

For further details on the Balmorel model, see Appendix D.

4.2. Selected main assumptions

In this section, some of the main assumptions for the analysis are presented. The assumptions are mainly based on Elkraft System (2005). However, some assumptions, e.g. on fuel prices, have been updated compared to this study.

Table 4-B below shows the *electricity demand, heat demand* and the *installed capacity* in the Nordic countries in 2005. The heat demand included in the model is only the demand for district heating (DH). Depending on the composition of power plants, fuel prices etc, the model optimizes whether heat should be produced at heat-only boilers (HOB) or at combined heat and power plants (CHP).

Table 4-B: Capacities and demand, 2005

	Denmark	Finland	Norway	Sweden	Total
Electricity demand, TWh	35.7	86.6	129.9	150.0	402.2
DH demand, TWh	34.8	34.0	1.6	33.5	103.9
Installed capacity, MW	13,585	16,410	27,945	32,132	90,072
– hydro power	0	2,981	27,607	15,129	45,717
– nuclear	0	2,656	0	8,822	11,478
– natural gas	2,858	2,002	0	591	5,451
– coal	5,593	3,649	0	1,000	10,242
– peat	0	2,272	0	560	2,832
– oil	1,113	1,608	188	4,590	7,499
– waste	299	0	20	138	457
– biomass	566	1,202	30	903	2,701
– wind	3,156	40	100	309	3,695

In 2015, it is assumed that the total electricity demand has increased to 433.6 TWh and the total heat demand to 109.2 TWh. The decommissioned capacity from 2005 to 2015 has been assumed to 6,008 MW and the capacity at new plants to 6,040 MW, meaning that the total capacity in the model is more or less the same in 2015 as in 2005 (and meaning that the capacity balance is tighter in 2015 due to a higher demand). The investments in new plants include among others the establishment of a new nuclear power plant in Finland (1,600 MW) and an upgrade of the Swedish nuclear power plants (550 MW). In addition to this, around

3,000 MW of new wind power is established in the Nordic countries, and 760 MW new gas- and coal-based capacity is established in Sweden and Finland.

The analyses are carried out assuming the same decommissioning and investment plans for all companies regardless allowance prices. By using the same expansion plan for all allowance prices, the production system does not adapt to the allowance price. On the one hand, this may seem to be a somewhat pessimistic assumption, or a rough simplification. On the other hand, there are only limited possibilities for the production system to adapt to an altered allowance price until 2015. The time frame of establishing new production units (planning, decision, tendering, construction etc) is simply too short, considering that the plans for including the transport sector in the ETSy are yet on a very early stage.

Furthermore, the analyses are carried out assuming the same electricity and heat demand for all allowance prices. The estimated effects on prices may therefore be conservative. In the real energy market, increased prices (e.g. as a consequence of an increased allowance price) may result in a decreased demand, which will counteract the price increase. However, the price elasticity on electricity and heat, in particular in the short term, is rather small, and therefore the effect from price elasticity, if taken into consideration, would probably not influence much on the results.

The table below shows the *fuel prices* used for the analyses. The prices do not include taxes.

Table 4-C: Fuel prices, USD(05)/boe

	Coal	Nuclear	Gas	Fuel oil	Light oil	Peat	Straw	Wood chips	Waste
2015	13.3	5.0	35.5	46.4	60.5	29.8	20.7	34.0	0.0

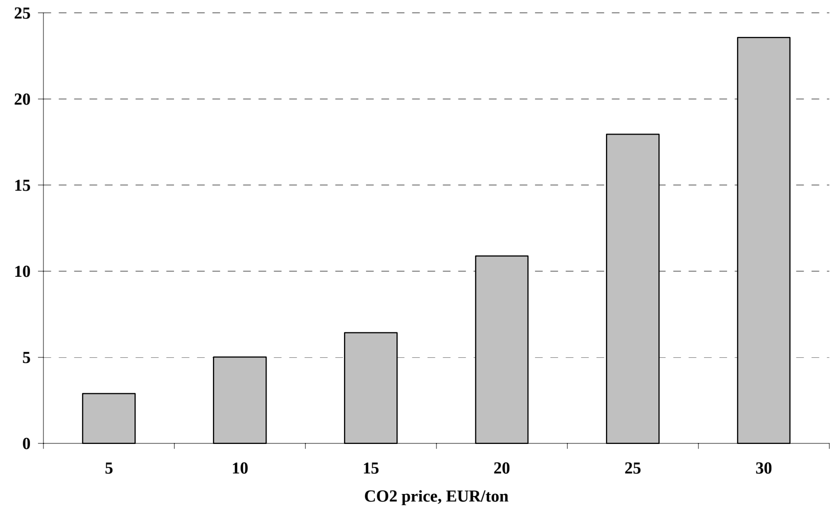
Source: PRIMES (2006), table 1-6. Note: boe means barrels of oil equivalent. It is assumed that 7.33 boe is equal to one tonne of oil equivalent.

The analyses are carried out for the *allowance prices:* 0, 5, 10, 20, 25 and 30 EUR/tonne CO_2.

4.3. Electricity and heat prices

Figure 4-A below shows the increase in electricity price for each allowance price compared to the situation without any allowance price.

Figure 4-A: Increase in electricity price (%) as a consequence of an allowance price on CO_2a



Source: Simulations with Balmorel. Note: The baseline electricity price (i.e. where the allowance price is zero) is 48 Euro/MWh.

It appears that the electricity price increases by 3–24% depending on the allowance price. In terms of the scenarios described in chapter 2, the following conclusions can be drawn:

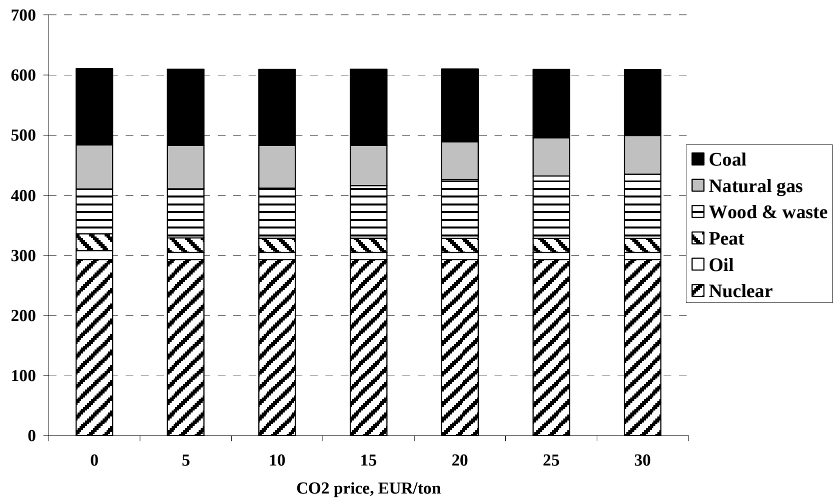
Conclusion 4-1: With the most efficient allocation of reductions between the ETSe and NETSe, the Nordic electricity price will increase by 10% compared to a situation without emission restrictions. In the scenario where the ETSe reduces least, the electricity price increase is 3%. Including the road transport sector using the given allocation schemes causes electricity price increases of 2% to 7%, depending on how strict reduction targets the ETSe is subjected to.

When it comes to heat prices, these can both increase and decrease following an increase in the allowance price. In most situations the heat price goes up. But if the heat is produced at a combined heating and power plant (CHP) with a high power-to-heating ratio and/or based on clean fuels with respect to CO_2, the plant may benefit so much from increased electricity prices in the market that the heat price corresponding to the marginal heat production cost actually goes down (even though the plant may have some additional CO_2 costs). In the situation with an allowance price of 30 EUR/tonne, the heat price on average increases by 33% compared to the situation without any allowance price. In one area, however, the heat price decreases by 76% as a consequence of the allowance price.

4.4. Fossil fuel mix

Figure 4-B below shows the total fuel use and the fuel mix depending on the allowance price:

Figure 4-B: Total fuel use and fuel mix in TWh depending on the allowance price



Source: Simulations with Balmorel.

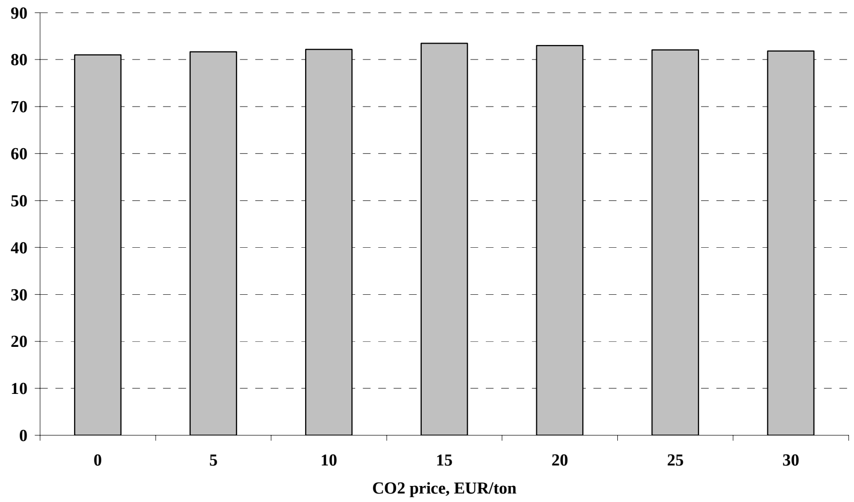
It appears how for instance the coal consumption decreases and the wood & waste consumption increases when the allowance price increases. In a longer perspective, where the allowance price will not only influence on the power dispatch among existing units, but also on the structure of the power system (i.e. investments in new production units), the effect on the fuel mix as well as on the total fuel consumption will be even more distinct.

Conclusion 4-2: The Nordic energy system responds to the increased allowance price by a shift in production technologies from in particular coal towards wood and waste. By 2015, however, this effect is rather limited, in part because of the assumption that the allowance price will not influence (much) on the structure of the power system within this time horizon, because more time is needed to complete investments in less emission intensive generation capacity. In a longer perspective, the effect on production technologies and fuel use will be higher, and for instance a high allowance price may also increase the share of wind power, bio mass and natural gas in the system.

4.5 Transmission requirements

The change in allowance prices leads to some changes in the production patterns, which may also lead to some changes in the transmission patterns among countries. Figure 4-C below shows the total power transmission on the cross border connections, including also the links to the Continent and Russia, depending on the allowance price.

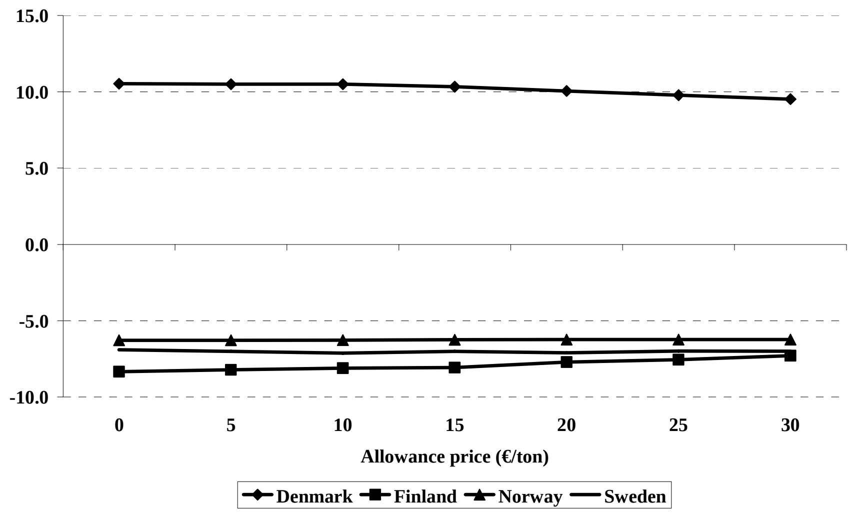
Figure 4-C: Power transmission in TWh on cross border connections (including also links to the Continent and Russia) depending on the allowance price



It appears, however, that the total amount of power transmission at the cross border connections is not much influenced by the allowance price.

The increasing allowance price does, however, slightly change the inter-Nordic pattern of production. The relatively large Danish export of electricity of 10.5 TWh/year decreases by 1 TWh per year, while the Finnish net import is decreased by the same amount. In other words, the simulations suggest that the production of power will tend to move northwards towards the Finnish potential for wood and waste.

Figure 4-D: Net power export depending on the allowance price (TWh)



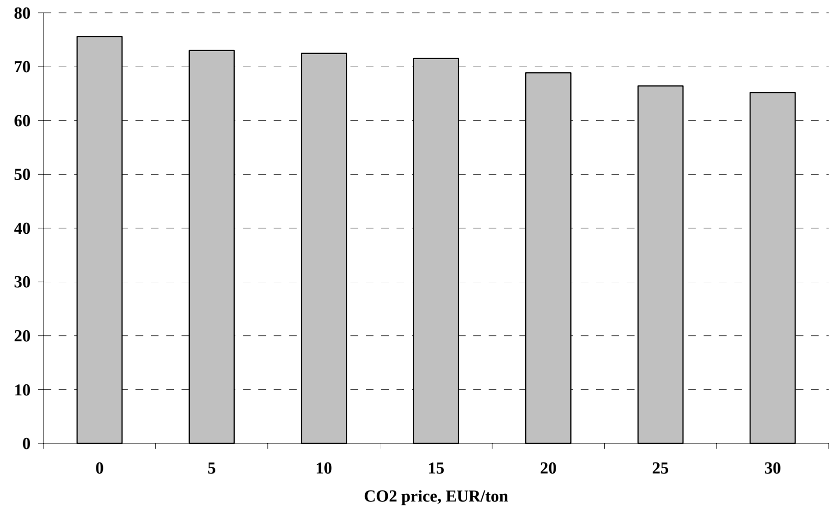
In a longer perspective, if the potential of establishing new renewable energy sources (or other technologies with low CO_2-emissions) is higher in some countries than in others, increased allowance prices may have a larger impact on the power transmission than indicated in the figures above.

Conclusion 4-3: While the total amount of transmitted electricity is largely unchanged, the production of power shows a slight tendency for moving northwards from the coal plants in Denmark to those in Finland, as the existing capacity's potential for wood and waste firing is larger in Finland. This result is valid for the short term, where new investments and decommissioning have not yet changed composition of capacity and the fuel mix much. This may change when capacities are adjusted in the longer term.

4.6 Emissions

As increased allowance prices create an increased incentive to produce heat and electricity using technologies with low CO_2 emissions, increased allowance prices result in lower CO_2 emissions. Figure 4-D below shows the total CO_2 emission from power and CHP production in the Nordic countries in 2015 depending on the allowance price.

Figure 4-D: Nordic energy system CO_2 emission in Mt depending on the allowance price



It appears from the figure that the CO_2 emission decreases from approximately 76 Mt to 65 Mt, corresponding to a decrease of 14%, when the allowance price goes from 0 EUR/tonne to 30 EUR/tonne. This is due to the change in production patterns towards technologies with lower CO_2 emissions.

In many cases, technologies with lower CO_2 emissions also have lower emissions of SO_2 and NO_x. For instance, gas technologies, which have lower CO_2 emissions than coal technologies, have no emissions of SO_2, and the NO_x emissions from gas technologies are in general also lower than those from coal technologies. In the simulations carried out for 2015, the SO_2 emission decreases from 125,000 tonne to 77,000 tonne, and the NO_x emission decreases form 235,000 tonne to 221,000 tonne by introducing an allowance price of 30 EUR/tonne compared to no allowance price.

Conclusion 4-4: The Nordic electricity and heat sector reduces its emissions by between 3.4% and 8.9% compared to a situation with an allowance price at zero, depending on the allocation scheme and reduction burden of the ETSe. On a longer time horizon where the composition of capacities can adjust to the altered allowance prices, the reductions in emissions will be larger.

5. Legal analysis

5.1. Status

Inclusion of road transport into the EU ETS will require a number of amendments of Directive 2003/87/EC to take into account the specific features of road transport. Currently, the EU ETS covers only CO_2 emissions from power stations and energy-intensive industries.

Article 30 of Directive 2003/87/EC allows the European Commission to review the Directive in the light of developments in the international context, based on a Commission report on the application of the Directive accompanied by proposals as appropriate. Part of this concerns the possibility of including other sectors, inter alia the transport sector, in order to improve the economic efficiency of the scheme.

By mid-October 2006, the Commission is just about to launch the review of the scheme, focusing on the scope as well as on how to make it more simple and predictable. Most recently, it has been communicated that the Commission will carry out consultation through the remainder of 2006 and that the Commission will then propose amendments to the Directive in 2007.

The Commission review of the Directive will focus on scope, further harmonisation and predictability, compliance and enforcement as well as the link to 3rd countries. The ETS is being reviewed also in the light of the development within the UNFCCC and the Kyoto Protocol, not least the decisions of the Nairobi COP meeting in November.The following list thus provides an overview of the Articles of the Directive, which will have to be amended to include road transport, taking as a starting point that the existing regulation will basically remain with updates as needed.

Logically, such a list cannot be seen isolated from the other part of the Commission review process and initiatives, which now start to materialise. Thus, if more sectors are to be included in the EU ETS besides the already proposed aviation, this may in the end have to fundamentally restructure the architecture of the scheme. The following walk-through should thus be seen as a supplement to this debate rather than provide definite answers.

In case the EU review process may conclude that road transport should not be included as a new sector into the ETS for all Member States as a whole, Article 24 allows individual or a pool of EU Member States to move unilaterally forward. This is based on the condition that the inclusion of such activities are approved beforehand by the Commission according to the procure in Article 23(2) of the directive, taking into consideration the particular effects on the internal market, potential distortion of the competition, the environmental integrity of the scheme and the realibility of the planned monitoring and reporting system.

Also various alternatives such as a national or regional emission trading scheme or other supplementary mechanisms may be further explored (voluntary agreements, fuel taxes and other mechanisms providing direct incentives on consumers to reduce fuel use), bearing in mind that the EU ETS does not hinder Member States in maintaining or establishing such schemes.

One might want to relate the new European trading scheme for air transport emissions (a new proposal has just been published) to the road transport emissions. Here, it is worth noting that most of the air transport emissions concerns international flights,. Thus it is quite natural that European air transport emissions most efficiently should be regulated centrally (i.e. the allocations etc. are made from Brussels), to avoid race-to-the-bottom policies.

However, most road transport emissions concerns national transport as well as a number of central abatement policies (i.e. public transport) also have a strong national policy component. Therefore, it may be relevant to address road transport emissions through national regulation, rather than centralised European regulation.

5.2. Review of the Directive

The following is an article-by-article review of Directive 2003/87/EC as amended, listing the provisions which need to be revised and explaining how each article needs to be adjusted to take into account the special features of road transport. No definite formulations are provided, as this is considered premature at the given stage of the EU ETS review. However, all major provisions, which need to be reformulated, have been addressed.

Preamble

To add a paragraph explaining the need for inclusion of road transport that the C02 emissions account for about one fifth of the GHG emissions in the EU, the specific features of road transport as well as the potential for reductions.

Article 2 – Scope

Add 'Road transport' to the categories of acitivities provided in Annex I, in order to ensure consistency in the application of all articles referring to Annex I, notably Articles 2(1), 3,4,14(1), 28 and 30.

Article 3 – Definitions

Revise the following definitions:

(b) ‘emissions’, since these will no longer be from a stationary source (installations) only;
(e) ‘installations’, since these will no longer be only from stationary technical units, but should also cover mobile sources;
(f) ‘operator’, since this is no longer limited to operators controlling stationary sources (installations);
(h) ‘new entrants’ – modification of the wording, since these are no longer limited to installations.

Article 4 – Greenhouse gas emission permits
Revise deadlines for issuing permits according to Articles 5 and 6, depending on the final deadlines for the revision of the Directive and its transposition.

Article 5 – Application for permits
Revise the wording, since this is no longer limited only to stationary installations.

Article 6 – Conditions and contents of permit
Revise the wording due to the new wording of Article 3 on the definitions of emissions, installation and operator, as well as changes in the definition of what the permit may cover.

Article 7 – Changes relating to the installations
Revise the wording due to revised definitions in Article 3 of ‘installations’ and ‘operators’.

Article 9 – NAP
Revise the wording of Article 9 para. 1 according to the final EU approach on this in the revision of the Directive. Annex III on the allocation criteria should be revised accordingly.

Article 10 – Method of allocation
Revise the wording in terms of the final decision on the method for allocation in the transport sector (including road tansport); inter alia whether allocations should take place through grandfathering or auctioning (for the time after 2012).

Article 11 – Allocation and issuing of allowances
Revise the wording in order to be consistent with the proposed new definitions under Article 3.

Article 12 – Transfer, surrender and cancellation of allowances
Revise the wording in order to be consistent with the proposed new definitions under Article 3.

Article 14 – Guidelines for monitoring and reporting of emissions
Set a deadline for the revision of the MRGs to include potential new sectors, including road transport. Review the wording of Article 14(3), since the provision no longer should be dealing with installations only.

The Guidelines as set out in Annex IV will have to be revised to take sufficiently into consideration the transport sector and the revised list of the Annex I activities.

Article 22 allows for amendments to Annex III for the period 2008–2012, based on the procedure in Article 23(2), except for the criteria (1), (5) and (7). Article 24 furthermore allows the Commission to adopt monitoring and reporting guidelines for activities not listed in the existing Annex I.

Article 15 – Verification
Revise Annex V in order to include road transport as an activity in Annex I and ensure that road transport emissions are subject to verification. The wording of the annex will need to be revised, since it no longer deals with installations only.

Article 19 – Registries
In order to ensure that there are no transfers incompatible with Article 19(3), revise EU Regulation 2004/2216/EC Article 2 in order for the Regulation to be consistent with the revised definitions of Directive 2003/87/EC.

Revise the Regulation in order to provide for the relevant procedures in the Registries system for the use of the allowances in subsequent periods.

Annexes
The following changes should apply to the annexes when including road transport in the EU ETS:

Annex I – Categories of activities
With reference to Article 2, revise the categories of activities in Annex I.

Annex III – Criteria for NAP
With reference to Articles 9, 22 and 30, the criteria should be adjusted to cope with road transport as a new sector in the EU ETS. Also, specific guidance for the road transport should be developed as further guidance instruments.

Annex IV – Monitoring and reporting guidelines
With reference to Article 14(1), revise the MRGs to include road transport, depending on the final choice of set-up in the ETS.

Annex V– Criteria for verification
With reference to Article 15, ensure that all emissions listed in the revised Annex I are subject to verification. Adopt methodology so that it is not only related to stationary sources, and in relation to the site of installations.

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Resumé (summary in Danish)

CO_2 emissionen fra den nordiske transport sector er vokset med 18 % siden 1990 (med vejtransport som den primære kilde), sammenlignet med en 8 % vækst i emissioner fra andre sektorer. Dette tyder på at der er behov for at anvende nye virkemidler hvis transporsektoren skal bidrage ti reduction af emissionerne. De fleste analyser peger imidlertid på at omkostningerne ved reduktioner i transportsektoren er relativt dyre, sammenlignet med omkostningerne i de energiintensive sektorer. Brændstof til vejtransport er relativt højt beskattet i de nordiske lande, og betalingsviljen hos forbrugere og industri er høj. Det er derfor ofte forbundet med store velfærdstab at reducere transportforbruget, f.eks. gennem øgede afgifter. Tekniske løsninger, f.eks. anvendelse af bio-brændstoffer, elektriske biler mv., er ligeledes relativt dyre med de nuværende teknologier, sammenlignet med CO_2 reduktioner i de energiintensive industrier.

Væksten i og betydningen af transportsektorens emissioner, kombineret med de relativt høje reduktionsomkostninger i transportsektoren, peger på at der kan opnås fordele ved at inkludere sektoren I EUs kvotehandelssystem.

Kvotesystemet er et »cap-and-trade« system, hvor der pålægges loft over den samlede emission fra de kvotebelagte virksomheder. Inden for dette loft kan virksomhederne handle udsliptilladelser med hinanden. Dette tillader virksomheder med høje reduktionsomkostninger at købe udslipstilladelser fra virksomheder der har levere reduktionsomkostninger, virksomheder der således med fordel kan lave yderligere reduktioner og sælge de tilhørende emissionstilladelser på markedet. Gennem denne handel med emissionstilladelser mellem virksomheder med høje og med lave reduktionsomkostninger kan de samlede omkostninger ved at overholde emissionsloftet minimeres.

At inddrage vejtransport i kvotesystemet udgør en mulighed for at opnå sådanne fordele gennem handel. Vejtransporten med dens høje reductionsomkostningern kan købe udslipstilladelser fra de nuværende kvotevirksomheder til lavere omkostniner.

Denne rapport vurderer effekterne af at inkludere vejtransport i EUs kvotesystem. På grund af de relativt høje reduktionsomkostninger forventes transportsektoren at blive netto køber af kvoter, og dermed påvirke det samlede kvotesystem, dels gennem kvoteprisen, dels gennem gennem el- og varme sektoren og andre energiintensive sektorer.

Endvidere analyseres fordelingen af reduktionsforpligtigelsen mellem de nuværende kvotesektorer og de øvrige ikke-kvote-sektorer. Da de nationale forpligtigelser er bindende er der en klar sammenhæng mellem

reduktionerne i de to grupper af sektorer: Reduktioner som ikke gennemføres i kvotesektorerne skal gennemføres i de ikke-kvotebelagte sektorer.

Formålet med denne analyse er at belyse de forskellige og ofte komplekse effecter af at inkludere vejtransport i kvotesystemet, herunder:

- Inkludering af vejtransport tenderer til at at øge kvoteprisen da efterspørgslen after kvoter vil øges. Derved vil kvotevirksomhedernes omkostninger øges.
- Regeringerne kan allokere supplerende kvoter for at imødekomme den forøgede efterspørgsel. Dette vil dæmpe tendensen til stigende kvotepriser.
- Imidlertid vil øget allokering af kvoter øge kravet om reduktioner fra de ikke-kvotebelagte sektorer. Dette vil påføre de ikke-kvotebelagte sektorer øgede og stigende omkostninger.
- De allokerende myndigheder er således konfronteret med den centrale opgave at identificere den rette balance mellem reduktioner i hhv. de kvotebelagte sektorer og de ikke-kvotebelagte sektorer.

Effekten på vejtrafikken ved at inkludere den i kvotesystemet er stort set ignoreret i analyses. Dette afspejler at vejtransporten forventes at købe kvoter fra de andre sektorer, og at vejtransport er relativt inelastisk over for prisen på transport, herunder prisstigninger på grund af kvotekøb. Resultaterne af modelberegningerne understøtte dette synspunkt, altså at de faktiske reduktioner i vejtransporten ved at inkludere den i kvotesystemet er begrænsede. Hovedparten af reduktionerne opnås gennem køb af kvoter og dermed reduktioner i andre sektorer.

Analysen fokuserer derfor på balancen mellem reduktioner i hhv. kvotesektorerne og ikke-kvotesektorerne samt på beskrivelse af effekterne på de energiintensive og andre sektorer i de nordiske lande. Resultaterne er baset på modelberegninger af det europæiske kvotemarked i en generel makroøkonomisk ligevægtsmodel samt en detaljeret bottom-up model af det nordiske energisystem.

Analysen af kvotemarkedet er scenarie-baseret. Der er definere fem scenarier, bestående af 2 par scenarier samt et enkeltstående scenarie. Hver af parene består af to varianter, en uden inddragelse af vejtransport I kvotesystemet og en med inddragelse af vejtransporten. Det enkeltstående scenarie er et minimumsomkostnings-scenarie.

Scenarierne er baseret på tre forskellige allokeringsprincipper som på systematisk vis beskriver et sæt hypotetiske, med realistiske, principper som EU landenes myndigheder benytter til at finde balancen mellem de kvotebelagte sektorer og de ikke-kvotebelagte sektorer. De to af principperne tager systematisk I betragtning om vejtransporten er inkluderet I kvotesystemet eller ej. Dette er nødvendigt for at sikre sammenligneligheden mellem scenarierne.

I transport-inkluderings scenariet af det første scenarie-par antages at *kun væksten i vejtransportens CO_2 emission siden 1990* medtages i kvotesystemet, og at der ikke allokeres ekstra kvoter til kvotesystemet. I transport-inkluderings scenariet i det andet scenariet-par er antaget at *al CO_2 emission fra vejtransport* medtages i kvotesystemet, og at der tildeles yderligere kvoter til systemet, svarende til tildelingen i andre kvotesektorer. Det sidste scenarie er et minimumsomkostnings-scenarie, som sikrer samme marginale reduktionsomkostninger både i kvote-sektorerne og i sektorerne uden for kvotesystemet.

Centrale resultater

Analysen er udført under antagelse af at de nordiske lande, og EU medlemslandene, skal imødekomme nærmere angivne reduktionsmålsætninger i 2015. Dette kan enten opnås med vejtransport uden for kvotesystemet eller med vejtransport medtaget i kvotesystemet. Den overordnede, generelle konklusion på dette studie er, at det vil give betydelige økonomiske fordele hvis EU inkluderer vejtransporten i kvotesystemet. Dette gælder både for de nordiske lande og for EU medlemslandene generelt, idet de samlede omkostninger ved at nå reduktionsmålene er betydeligt lavere end hvis vejtransport ikke er medtaget. Hvor store omkostningsreduktioner der er tale om afhænger af hvordan vejtransport inkluderes i kvotesystemet og varierer mellem landene, afhængig af den faktiske klimapolitik i hvert enkelt land.

De mere detaljerede konklusioner om kvotemarkedet og om effekterne på virksomheder og sektorer, specielt energisektoren, ved at inddrage vejtransporten er beskrevet i det følgende.

Resultater for kvotemarkedet

- Da vejtransport er en relativt hurtigvoksende udslipskilde, vil hel eller delvis inkludering i kvotesystemet (og uden at kompensere fuldstændigt med øget kvotetildeling) vil reduktionerne ofte blive flyttet fra vejtransporten til kvotevirksomhederne. Dette vil øge kvoteprisen.
- De analyserede scenarier viser, at de modellerede kvotepriser er markant lavere end de gennemsnitlige reduktionsomkostninger i sektorerne uden for kvotesystemet. Dette indikerer at den samlede økonomiske efficiens kan forbedres når kvotesektorerne bærer en relativt større reduktionsbyrde end sektorerne uden for kvotesystemet.
- Ved at inddrage vejtransportemissioner i kvotesystemet kan der opnås økonomiske fordele i næsten alle lande omfattet af scenarierne, men samtidig også højere kvotepris. Hvis der er en alvorlig ubalance mellem et lands reduktionskrav til hhv. kvotesektorerne og sektorerne uden for kvotesystemet er der brug for at justere byrdefordelingen

mellem kvote og ikke-kvote sektorerne for at modvirke de negative effekter som de højere europæiske kvotepriser medfører.

- Simuleringerne på kvotemarkedsmodellen tyder på, at de fleste vesteuropæiske lande vil have stor fordel af at inddrage vejtransporten i kvotesystemet selv om kvoteprisen vil stige betydeligt, da dette typisk vil medføre en bedre balance mellem reduktionerne i hhv. kvotesektorerne og de ikke-kvotebelagte sektorer.
- Eftersom reduktioner i vejtransportsektoren er forholdsvis dyre, er det vigtigt for den økonomiske efficiens, at reduktionskravene for vejtransportsektoren balanceres med det væsentligt bedre reduktionspotentiale i fx elektricitetssektoren.
- Ved at inddrage vejsektoremissioner i kvotesystemet overlades balancen mellem emissionsreduktion i vejtransport- og især elektricitets- og varmesektoren til markedet. Dette giver mulighed en mere efficient og mindre omkostningskrævende reduktionsindsats for kvotesektorerne og vejtransporten set under et. Analysen indikerer, at BNP tabet ved at opnå reduktionsmålene i 2015 reduceres til en tredjedel, eller endda en fjerdel, ved at inddrage vejtransporten i kvotesystemet. Hvor stor omkostningsreduktion der opnås afhænger af hvordan vejtransporten konkret inddrages.

Resultater vedrørende konsekvenser for sektorer og virksomheder

- Konkurrencedygtighed hvad angår eksportvirksomheder påvirkes af priserne på varer produceret af firmaer både inden og uden for kvotesystemet. Derfor afhænger konsekvenserne for eksportvirksomheders omkostninger af en række forskellige priser, herunder både kvotepriserne og elpriser, men også priser på andre produkter som direkte eller indirekte påvirkes af reduktionsomkostninger.
- Forskellene i omkostningseffekter mellem scenarierne viser, at den mest omkostningseffektive klimapolitik fremhæver reduktionerne i de mest energiintensive industrier. Dette giver mening, dels fordi disse sektorer har forholdsvis flere muligheder for at substituere brændstoffer, og dels fordi en reduktion af output fra disse sektorer vil resultere i flere emissionsreduktioner end andre sektorer, som har lavere emissionsintensitet.
- Med den mest effektive reduktionsallokering mellem kvote og ikke-kvote sektorer vil de nordiske elpriser stige med 10 % i forhold til en situation uden emissionsbegrænsninger. I det scenarie hvor emissionerne fra kvotesektorerne mindskes mindst stiger elpriserne med 3 %. Inddragelse af vejtransportsektoren ved hjælp af de givne allokeringsordninger vil medføre en 2–7 % stigning i elpriserne, afhængigt af hvor strenge reduktionsmål der pålægges kvotesektorerne.

- Det nordiske energisystem reagerer på den øgede kvotepris med et skift i produktionsteknologi fra især kul til træ og affald. I 2015 vil denne effekt dog være mere begrænset, idet kvoteprisen ikke (i betydeligt omfang) vil påvirke energiforsyningssystemets struktur inden for denne tidsramme. På længere sigt vil effekten på produktionsteknologi og brændstofanvendelse være større, og fx kan en høj kvotepris også øge andelen af vindkraft i systemet.
- Mens det samlede omfang af el-transmission stort set er uændret, viser kraftproduktionen en tendens til at flytte sig mod nord, fra kulanlæggene i Danmark mod Finland, da der er større kapacitetspotentiale for træ- og affaldsfyring i Finland. Dette kan ændre sig når elkapaciteten justeres på længere sigt.
- Elektricitets- og varmesektoren reducerer sine emissioner med 3,4 %–8,9 %, afhængigt af kvotesystemets allokeringordning og reduktionsbyrden for de kvotebelagte sektorer.

Forbehold
Konklusionerne fra kvotemarkedsanalysen, der er præsenteret her, er baseret på en række antagelser om den fremtidige allokeringspolitik i de lande, der deltager i kvotemarkedet i 2015. De samlede tal for de totale reduktionskrav i ETSe og NETSe i gennemsnit repræsenterer rimelige antagelser om fremtidige allokeringer og reduktioner. Derimod kan antagelserne om specifikke lande være mindre robuste, da det ikke har været muligt at få al nødvendig information til vurdering af reduktionskravene i kvotesektorerne og de ikke-kvotebelagte sektorer i hvert af de analyserede lande. Dette betyder, at de samlede resultater for kvotemarkedet og de lande der deltager i kvotesystemet er mere præcise end simuleringsresultaterne for de enkelte lande, fx kvotesektorernes marginale reduktionsomkostninger for de enkelte nordiske lande.

Appendices

A. Abbrevations and word explanations

CO_2e	CO_2 equivalent (by GWP factors)
ETSe	**Emission Trading Sectors:** Sectors participating in the *EU Emission Trading System*: Electricity & Heat, Paper, pulp & printing, cement, steel and aluminium
ETSy	**EU Emission Trading System**
GTAP	**Global Trade Analysis Project**, see www. gtap.org
Mt	Mega tonne
Mtoe	Million tonnes of oil equivalent
NETSe	**Non-Emission Trading Sectors:** Sector not included in the ETSy

B. GTAP-ECAT model documentation

A general equilibrium model has been developed by COWI on behalf of the Danish Environmental Protection Agency for this specific aim. It is named GTAP-ECAT (GTAP European Carbon Allowance Trading) and is based on the existing and highly recognised GTAP (Global Trade Analysis Project) model, which is a multi-country, multi-sector static general equilibrium model, developed and maintained by a substantial international network of universities and research units.

For the present purpose, the world economy has been divided into 13 regions and 11 commercial sectors. In this process, special attention has been given to the EU and the Nordic countries and to sectors by energy intensity.

Compared to the standard GTAP model[14], the GTAP-ECAT model handles energy demand in production and final demand at a more detailed level, allowing for more detailed formulation of substitution possibilities between energy goods and the technological progress, and including an estimation of the resulting carbon emissions. This formulation is based on an energy version of the GTAP model, called GTAP-E.[15]

Furthermore, the GTAP-ECAT includes a detailed treatment of carbon allowance trading within the ETSe. This is done in the following way:

- CO_2 is added to the model as a scarce resource for which its users pay an economic cost. The emissions of CO_2 are directly proportional to the use of fossil fuels. The allowed emission of CO_2 is scarce due to the Kyoto target.
- Regarding emission reductions, the economy is divided into two parts:

[14] See Hertel (1997).
[15] See Burniaux and Truong (2002).

a) The ETSe (emission trading sectors, consisting of electricity & heat generation, refineries, iron & steel, cement and paper, pulp and printing)
b) The NETSe (the remaining sectors, public consumption and the private households). The ETSe are allowed to trade emission allowances within international 'bubbles' (e.g. EU27), while reductions within the NETSe are determined on a national basis, assuming that the needed NETSe reductions are carried out in a cost-effective way within each region.

- A certain share of the emission allowed by the Kyoto target is allocated to the ETS as allowances. An equilibrium requirement between supply and ETS demand within the EU forms the EU allowance price. The number of allowances allocated to the ETS and the Kyoto target together determines the maximum residual NETS emission. Thus, the number of ETS emission allowances is an important determinant of the marginal abatement cost in each of the NETS.
- There is also trade of international emission rights, such as ERUs from JI projects, CERs from CDM projects and AAUs (governments only). Their price and quantities are specified exogenously and help to reduce the reduction requirements in the ETS and NETS. All traded credits are countered by emission reductions in their region of origin, although this is also treated exogenously.

Further documentation about the GTAP-ECAT model can be found in COWI (2004a) and COWI (2006a). In these references as well as in COWI (2004b) and COWI (2006b) examples illustrating the uses of GTAP-ECAT can also be found.

The GTAP database

The data foundation of the simulations is the GTAP database[16] is very comprehensive and generally accepted as being of high quality, as it has been tested by numerous research studies and institutions throughout the years.

A relatively new feature is an energy database, which is based on IEA statistics. This database covers sector-specific use and trade in crude oil, solid fossil fuels, natural gas, distributed gas, refined oil products and electricity. Unfortunately, the IEA data is not sufficient to construct a complete energy balance; only gross inland and final consumption can be approximated in a reasonable manner.

The simulation results presented in the present report are based on 2001 figures, which is the base year of the newest version of the GTAP database (version 6.0). When constructing a database for CGE use, it is

[16] See Dimaran (2006).

necessary to make various adjustments to the data compared to their official sources for technical reasons. Table B-1 shows that the GTAP database energy figures are rather close to those of World Energy Outlook 2004, although this publication has 2002 as its base year.[17]

Table B-1: GTAP 2001 and WEO 2004 total primary energy supply (mtoe)

	GTAP v6.0			WEO 2002
	EU15	EU10	EU25	EU25
Solid fuels	215	92	307	303
Refined oil	590	50	640	648
Natural and distributed gas	349	40	389	389

Source: The GTAP 6.0 database and World Energy Outlook 2004 pp. 466.

Note: The table excludes energy use in the refining sector, which combusts 40 mtoe oil and 3 mtoe gas.

Emissions and reductions

The close correspondence between GTAP and WEO energy use does, however, not necessarily mean that the emissions of CO_2 in the two data sources are close to one another. This is due to the fact that some energy goods are not combusted, but are instead used as process input. This particularly concerns the refineries sector, where some of the GTAP energy flows cover so-called feedstock. Feedstock is intermediate inputs into further refining, and is thus not combusted.[18] Also in the chemical-rubber-plastics sector, some refined oil products are not used for combustion, but as process input.[19] Finally, the emissions presented in WEO 2004 do not include emissions from international bunkers.[20] Table B-1 shows that the differences between the two data sources are not overwhelming.

[17] As there is no WEO publication with data from 2001, the WEO figures for 2002 are available on the IEA website.

[18] The feedstock data for GTAP 6.0 database has unfortunately not been released yet. COWI has prepared its own temporary feedstock data for this project. This has been documented in a working note.

[19] Comparing emission data from UNFCCC and GTAP emissions, it has been roughly assumed that 80% of all refined oil products in the chemical-rubber-plastic sector are used as feedstock in industrialised countries, whereas the ratio for developing countries is only 60%.

[20] This concerns emissions from international aviation and marine transport. Data on these emissions was obtained from UNFCCC. http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/2761.php

Table B-2: EU25 emissions according to WEO 2004 and GTAP v6.0 (Mt CO_2)

	GTAP emission coefficients	GTAP emissions 2001	WEO emissions 2002
Solid fuels	3.88 Mt / mtoe	1,191	1,170
Oil, uncorrected	3.07 Mt / mtoe	2,125	-
– of which bunkers	-	198	-
– of which CRP process	-	185	-
Oil, corrected	3.07 Mt / mtoe	1,742	1,677
Gas	2.23 Mt / mtoe	872	884
Total (corrected) emissions	-	3,805	3,731

Note: The emissions from refinery combustion are 123 Mt from oil sources and 7 Mt from gas sources.

Note: The data on oil combustion emissions are not directly comparable to the energy use in table B-1, as this table deals only with refined oil (in order to compare with WEO), while the table above deals with the combustion of both crude and refined oil.

The EU25 emissions calculated from the GTAP database were 3,805 Mt CO_2 in 2001, while the WEO 2004 emissions for 2002 were 3,731 Mt CO_2. Besides the difference in the year covered, the methodological issues regarding feedstock, bunkers etc also influence the exact size of the emissions. Neither the GTAP energy database nor WEO 2004 is documented in sufficient detail to resolve these issues. The project group's e-mail questions to the IEA have not been answered. The GTAP EU15 emissions are 3,206 Mt, while the EU10 emissions are 599 Mt.

It is quite apparent that the reductions needed to meet the Kyoto target (the emission gap) are very sensitive to the methodology used for calculating emissions. However, what is important to the economic assessment of allowance prices and other economic effects is not so much the *absolute* size as the *relative* size of the reduction, i.e. the reduction measured in per cent.

The most feasible and robust way to determine a reliable emission gap is by using:

- a percentage-based reduction need relative to 2001
- the GTAP 2001 emissions for calculating an absolute Kyoto target for use in the model simulations.

The data on the EU25 2001 relative reduction needs are taken from UNFCCC's homepage. The reduction requirement used and reported here concerns emissions of all GHGs, excluding land use changes and forestry (LUCF).

Non-CO_2 reductions

Furthermore, and more importantly, the model applied for this project is a combustion CO_2 model. Thus, applying the relative reduction presented above is equivalent to an implicit assumption that reductions in emissions from combustion of CO_2, other CO_2 emissions and non-CO_2 GHG emissions are made in the same proportions. Obviously, this does not need to be true, especially if EU25 non-CO_2 reductions are significantly cheaper and more easily available than CO_2 reductions. It is very difficult to assess whether this is the case. There seems to be a general consensus that in particular in developing countries, non-CO_2 reductions are rather cheap and relatively abundant. However, not considering JI and CDM, it becomes important whether this is also the case for EU15 and EU10.

A study[21] of the effects of including non-CO_2 emission reductions in the reduction efforts shows that even for the EU15 countries there may be important effects of including non-CO_2 emissions in the reduction efforts. Generally speaking, the reduction requirements for CO_2 became smaller, in the range of 1 to 4 percentage points, with an average of 2.2% points.[22] In relative terms, this amounted to between 10% and 50% of the needed CO_2 reductions. This means that the regional MACs fell by approximately the same ratio.

Thus, to investigate the impact of using the potential for non-CO_2 reductions as a substitute for CO_2 reductions, sensitivity analyses will be carried out by adjusting the relative reduction needs presented above.

A final matter relating to the CO_2/non-CO_2 issue is the extent to which EU10 have abundant non-CO_2 reductions and the fact that these reductions cannot enter into the EU ETS directly, but will have to be traded as JI credits (or possibly as AAUs).

ETSe sectors in GTAP

The sectors assumed to participate in the EU-ETS are the following: Electricity and heat, iron and steel, non-metallic minerals (essentially cement industry), paper-pulp-printing and refineries. These sectors are defined according to NACE classifications and other sector classifications specific to the individual EU countries. All emissions in these GTAP sectors are assumed to be eligible to participate in emission trading in the EU-ETS.

In the actual ETSy, only large boilers and combustion plants are covered by the emission trading scheme. Furthermore, large combustion plants in other sectors may be included in the ETSy. There is unfortunately not a reasonable way to adjust the GTAP database and model to reflect these facts in a way where the resources spent for this purpose is proportional to the gain. Therefore, the number of allowances allocated for ETSe firms in the model simulations must be based on the ETSe

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[21] See Kets and Verweij (2005): 'Non-CO_2 Greenhouse gases', CPB Discussion Paper No. 44, April 2005. The study looks at national reduction efforts without a pan-EU CO_2 allowance market.

[22] This is from a somewhat higher reduction requirement, which has a weighted average of 9.4% for EU15. The effects of a 5.8% reduction target should be 40% lower, i.e. 1.3% less CO_2 reduction requirements.

emissions as they appear in the database, rather than on absolute figures from emission statistics external to the GTAP database.

C. GTAP-ECAT Baseline

The GTAP-ECAT baseline is a projection of the GTAP 6.0 database, which describes the world economy in 2001. The simulations reflect a hypothetical situation in 2015, and thus the economic activities, energy use and CO_2 emissions from 2001 must be projected to 2015. The base of the projection is the projection in PRIMES (2006).

Economic activity

The projection's economic activity in terms of real GDP grows by 2% per year in the Western European countries, while the Eastern European countries (including Russia) are assumed to grow by 4.5%. The remaining industrialised countries have a real growth of between 2.3 to 2.8%. This growth is realised through a combination of an endogenous increase in the capital stock and an exogenously specified increase in Total Factor Productivity (TFP) of half the assumed GDP growth. The ratio between capital and labour income is roughly sustained for all countries.

Energy

The prices of oil and gas were quite low in 2001, and therefore a strong growth in the energy prices is assumed in the projection (resting on the assumptions from PRIMES (2006). The assumed energy prices are shown in table C-1:

Table C-1: European fossil energy prices (€/barrel of oil equivalent)

	2000	2015
Coal	8.40	13.30
Crude oil	31.30	46.35
Natural gas	16.80	35.35

Source: PRIMES (2006), table 1.6.

Note: The 2015 price is a simple average of 2010 and 2020.

While the production of fossil energy increases in a few European countries, the overall trend for the region's fossil energy is declining. However, the Norwegian production of both oil and gas is expected to increase, and this will outweigh some of the fall in the supply of other European countries.

Table C-2: European fossil energy supply (mtoe)

	2000	2020	% change
Coal	204	133	-35%
Crude oil	329	207	-37%
Natural gas	236	229	-3%

Source: PRIMES (2006), appendix B, sum of table 'EU25' and 'Norway'.

Note: The 2015 price is a simple average of 2010 and 2020.

CO_2 emissions

The projection of the energy emissions is also based on PRIMES (2006). A small number of adjustmenst has been made to make the GTAP emission data for 2001 match the UNFCCC data on emissions from the energy sector. It is assumed that the emissions from the combustion of fossil fuels must be reduced in the same proportions as the emissions from the non-combustion emissions. Based on this assumption, a 'Kyoto target' for the energy sector can be calculated, using the 1990 UNFCCC fossil fuel energy combustion emissions and the agreed reduction requirements. For EU25 plus Norway this leaves an emission gap of 477 Mt out of a 2015 emission of 4,237 Mt. This amounts to an average reduction requirement of 11.3%

Table C-3: Combustiton CO_2 emissions and reduction targets and requirements (Mt)

	Denmark	Sweden	Finland	Norway	W.Eur.	E.Eur.
2001 Emission	54	51	63	38	3,175	614
1990 Emission	52	54	56	29	3,150	918
Reduction req.	-21.0%	4.0%	0%	1.0%	-8.1%	-8.0%
Kyoto Target	41	56	56	30	2,894	845
2015 Emission	51	62	73	42	3,326	683
Gap (Mt)	9	6	17	12	432	-162
Gap (%)	18%	10%	24%	29%	13%	-24%

Source: Data from UNFCCC and own calculations.

D. Balmorel model documentation

The Balmorel model is a partial equilibrium model, which describes an interconnected international electricity and combined heat-and-power system. The model was developed around year 2000 for means provided by, among others, the Danish Energy Research Programme as part of an international cooperation. The purpose of the model developed was to provide a model capable of illuminating the international relationship in the area around the Baltic Sea.

The model simulates the electricity and heat markets in the countries represented. The dispatch between production units is found on the basis of among others:

- the heat and electricity demand;
- technical and economic characteristics for each kind of production unit;
- e.g. capacities, fuel efficiencies, operation and maintenance costs and fuel
- prices;
- environmental taxes and quotas;
- the possibilities of transmission of electricity between regions and countries.

The electricity and heat supply system is represented by a number of technologies, e.g. condensing units, extraction CHP units, backpressure CHP units, heat pumps, heat storages and various renewable sources including wind and hydro-power. Each unit further has geographically distinct technical, economic and environmental specifications. The operation of the units is subject to constraints like energy limitations, emission constraints and others. Revision schedules, derating and other modifications may be set for individual units and time periods.

The model has a geographical division, which allows for a description of an electricity transmission system. Thus, the electricity supply is specified in a number of nodes that are connected by transmission lines characterised by capacity, loss and cost. This allows for the identification of bottlenecks in the transmission system. Within the region an electricity demand node is defined.

In connection with the transport of electricity between the electricity supply nodes and the electricity demand nodes there are associated losses and costs. This represents an electricity distribution network.

The heat demand is represented in a number of nodes. Within each area there is both a supply and a demand node that are connected through a heat distribution network, which, as for electricity, is simply represented by a loss and a cost. The model operates with a division of time at three levels. A year is subdivided into a number of seasons, which in turn are subdivided. The time division within the year is flexible and should be chosen according to the specific purpose of the analysis.

The model permits the inclusion of both exogenous (user-defined) and endogenous (found in the model) investments in production technologies and transmission links, and an arbitrary combination of this.

As output, the model computes among others production patterns (existing and new units), including transmission patterns on a total cost-minimising basis. The model also computes among others estimates on electricity and heat prices, assuming liberalised and well functioning electricity markets with full competition among power producers as well as total fuel use and emissions.

The model is a generic model in the sense that general principles in modelling have been applied, and the implementation is done in a high-level modelling system (GAMS). The model is immediately available at www.balmorel.com. together with examples of data sets.

The specific version of the model that will be used for this scope of work contains the electricity and CHP system in the Nordic countries (Denmark, Finland, Norway and Sweden). These countries are integrated in a common electricity market and hydro-power production accounts for approximately half of the electricity generation. The countries are subdivided into ten price areas with limited transmission capacities between the areas. The areas are:

- Eastern and Western Denmark (2 price areas)
- Finland (1 price area)
- Northern, Central and Southern Norway and Oslo area (4 price areas)
- Northern, Central and Southern Sweden (3 price areas)

The heat demand included in the model is only the demand for district heating (DH). Depending on the composition of power plants, fuel prices etc. the model optimises whether heat should be produced at heat-only boilers (HOB) or at combined heat and power plants (CHP).