CE Delft
Solutions for environment, economy and technology

Oude Delft 180
2611 HH Delft
The Netherlands
tel: +31 15 2 150 150
fax: +31 15 2 150 151
e-mail: ce@ce.nl
website: www.ce.nl
KvK 27251086

Price effects of incorporation of transportation into EU ETS

Report

Delft, September, 2007

Author(s): M.J. (Martijn) Blom
B.E. (Bettina) Kampman
D. (Dagmar) Nelissen

In cooperation with: Ecofys BV (E. (Ernst) Worell and W. (Wina) Graus)

Publication Data

Bibliographical data:
M.J. (Martijn) Blom, B.E. (Bettina) Kampman, D. (Dagmar) Nelissen
Price effects of incorporation of transportation into EU ETS
Delft, CE, 2007

Transport / Carbon dioxide / Emissions / EC / Tradable pollution rights / Price / Competition / Effects / Analysis

Publication number: 07.4553.37

CE-publications are available from www.ce.nl

Commissioned by: VROM-Raad
Further information on this study can be obtained from the contact person Bettina Kampman, 0031 (0) 15 2150 150

CE Delft

Solutions for environment, economy and technology

CE Delft is an independent research and consultancy organisation specialised in developing structural and innovative solutions to environmental problems. CE Delfts solutions are characterised in being politically feasible, technologically sound, economically prudent and socially equitable.

For the latest information on CE check out our website: www.ce.nl.

This report is printed on 100% recycled paper.

Contents

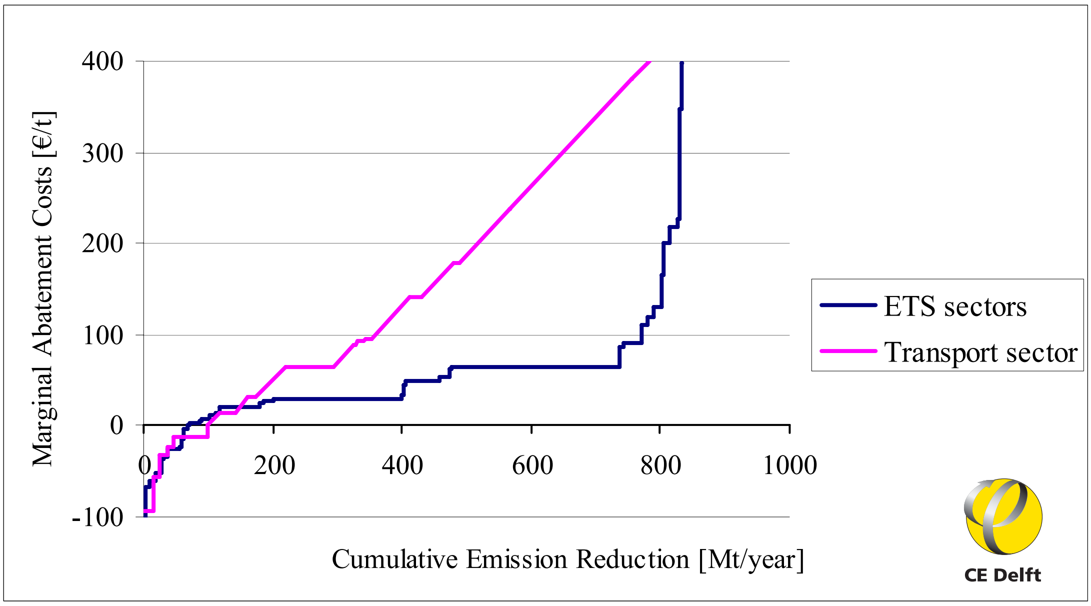
Executive Summary

Carbon dioxide (CO_2) emissions from transport are steadily increasing, even though various CO_2 mitigation policy measures have been implemented in recent years. A potential new policy measure for CO_2 mitigation in the transport sector is CO_2 emission trading. In this report the consequences of including the European transport sector in the EU Emission Trading Scheme (ETS) were assessed. The report was commissioned by the VROM Council (VROM-Raad), also on behalf of the Dutch Energy Council (AER) and the Council for Transport and Public Works (Raad voor Verkeer en Waterstaat).

First, the effect of integrating transport in the current EU ETS on the price of tradable EU allowances (EUa) was determined, under different reduction scenarios[1]. Second, an indication was given of the effects of this CO_2 price increase on competitiveness of the European industry and electricity sector. The study was based on existing data and literature, and on a relatively simple calculation model. Therefore, we consider the results to be rather rough estimates, providing a first approximate assessment of the effects.

Figure 1 shows the cost curves that were derived for both the transportation and the EU ETS sectors. The scope of the diagram corresponds to an abatement level in the range of 0-30%.

Figure 1 Marginal cost curves for transport (road transport and aviation) and ETS for 2020



1 Due to data limitations, the analysis of the transport sector was limited to road transport and aviation.

The effects of inclusion of transport in the EU ETS on the EUa price were calculated for two different scenarios:
- 22% emission reduction in 2020 (compared to 1990), with 50% CDM/JI[2];
- 28% emission reduction in 2020 (compared to 1990), without CDM/JI.

Based on this analysis, we conclude the following:
- Our findings regarding abatement costs are in line with findings in other literature: CO_2 abatement is more expensive in the transport sector than in the current ETS sectors. However, we also conclude that: there is a significant potential of ‘no regret’ abatement measures in both sectors, with higher economical benefit than costs. Up to 180 Mton CO_2 reduction (per sector), there are no large differences between abatement costs. At higher reduction levels, abatement costs in the transport sectors become significantly higher than in the ETS sectors. The curves seem to converge again at about 800 Mton reduction.
- In the first scenario, inclusion of the transport sector in the EU ETS leads to an increase of the EUa price from € 50 to € 65 per tonne CO_2. In the second scenario, the target can not be reached by the EU ETS sector alone, according to the cost curve used. When transport is included, the target is achievable, albeit at high EUa price: € 480 per tonne CO_2. However, we expect that at these high reduction levels, the uncertainties in the data increase significantly.
- The calculations show that the EUa price is very sensitive to the availability of (low cost) CDM and JI.
- As long as the EUa price increase is limited as in the first scenario, the overall effects on competitiveness are expected to be small. However, this by no means excludes significant effects on a sector or firm level.
- As an alternative, a separate emission trading system could be set up for the (surface) transport sectors. At higher abatement levels (where the cost curves of the various sectors diverge), this system can be expected to lead to implementation of less cost effective CO_2 abatement measures. However, it would have the advantage that the emissions of the sector can be capped without the risk of affecting the ETS sectors (by increasing the price of the EUa’s). Negative effects on competitiveness can thus be avoided.

The current study provides a first insight into the effects on EUa price that can be expected if the transport sector is included in the EU ETS. In our opinion, these results give sufficient ground to conclude that this policy option might be a viable option for the future. However, as this was only a rough analysis, we provide a number of recommendations for further research into this topic.

[2] Clean Development Mechanisms and Joint Implementation.

Summary

Background
Carbon dioxide (CO_2) emissions from transport are steadily increasing, even though various CO_2 mitigation policy measures have been implemented in recent years. A potential new policy measure for CO_2 mitigation in the transport sector is CO_2 emission trading. Emission trading is a market based instrument that aims to achieve emission reductions in the most cost effective manner.

The political momentum for this type of measure in the transport sector appears to be increasing, due to the recent introduction of the EU emission trading scheme (EU ETS) for stationary sources and the call for effective CO_2 emission reduction policy in the transport sector, as many other sectors manage to reduce their emissions. Although the European Commission is considering inclusion of aviation and maritime transport under the EU ETS, including the other transport modes has not yet been discussed on EU level.

It can be expected that including transport in the EU ETS will have substantial impacts on the demand and supply of emission rights and consequently on the sectors already trading (ETS sectors). In this report a rough assessment of these consequences is derived, using existing data and literature, and a relatively simple calculation model.

The report was commissioned by the VROM Council (VROM-Raad), also on behalf of the Dutch Energy Council (Algemene Energie Raad/AER) and the Council for Transport and Public Works (Raad voor Verkeer en Waterstaat).

Trade off: efficiency and competitiveness
An emission trading system has the advantage of ensuring that emissions are reduced where costs are lowest. This advantage generally increases with increasing scope of the trading system. Extending the EU ETS with the transport sector, or with a part of the sector, is thus likely to improve at least the short term cost effectiveness of CO_2 mitigation.

On the other hand, an integrated approach could have major drawbacks. If the abatement cost of transportation would be considerably higher than those of current EU ETS sectors, the allowance price in the EU ETS will increase due to the transport sector buying allowances from industry and increasing the demand. This might have significant impacts on the industry as the prices of electricity and carbon intensive products will increase. Some sectors (cement, aluminium, paper etc.) currently included in the EU ETS are vulnerable to higher energy prices and hence create a major risk of ‘carbon leakage’ due to relocation of activities.

Designing options
Our point of departure for analyzing the effects of incorporating the transport sector into the EU ETS is a common *cap and trade system* where transport emissions are capped at the same reduction percentage as the industry. This situation is compared with the situation where only the current EU ETS sectors are trading and no additional climate policy in the transport sector is assumed. Including the transport sector in the EU ETS means *de facto* a significant intensification of the climate policy of the transport sector. We further assume that the trading entity will be the fuel suppliers (upstream). Compared to a downstream scheme the upstream trading option can limit transaction costs of implementing the system, whilst still make full use of the reduction potential of transport users. The emission allowances are grandfathered to both the industry and transportation. Of all allocation options grandfathering of the tradable EU allowances (EUa) can be seen as potentially least harmful for the industry. Note that even though different allocation options can have a significant (financial) impact on the parties involved, (once only) allocation does not affect the price of emission allowances.

Approach
The effects on competitiveness are determined using a two step approach:
- First, the EUa price increase of integration in a common scheme compared to the current scheme under different reduction scenarios is determined.
- Second, a global indication of the effects of this CO_2 price increase on competitiveness of the European industry and electricity sector.

The first step has been conducted on the basis of establishing an integrated cost curve in relation to different reduction scenarios. The second step is based on a quick scan of literature on economic effects of climate policies.

Methodology
For the purpose of the first part of the analysis we have constructed a calculation model based on the abatement cost for different reduction levels. Within the model the price of an EU ETS allowance is determined by the cost of avoiding the last unit of emission in order to achieve a certain emission constraint. Each sector within the model will then chose an abatement level with a corresponding marginal price of abatement costs.

The basis of the calculations are cost curves for each sector, derived from data on the potential and costs of the abatement measures available in that sector. From the curves of the individual sectors, the cost curve of the aggregated EU ETS system can be constructed. The marginal abatement cost for the EU ETS sectors (in this report referred to as industry including the power supply and energy intensive sector) are based on the *Genesis database* (Ecofys)*.* The transport cost curve is derived from the sector analysis of transport in *Green4sure* (CE Delft) with regard to technical measures. As for the costs of non technical measures to reduce vehicle kilometres, we have conducted an additional analysis assessing the provisional *opportunity costs of* reducing mobility[3].

It is assumed in this study that the whole transport sector is included in the EU ETS. The main modes of interest are then the road sector, maritime shipping and aviation. However, due to lack of data, maritime shipping was subsequently left out of our calculations. The CO_2 contribution of railways (diesel) and inland shipping is considered too small to have a substantial effect on allowance prices. For reasons of efficiency we have left it outside the scope of the study[4].

Further assumptions
We have made the following assumptions regarding the cost curves:

- A national cost perspective: this means that costs and savings are calculated on the base of prices excluding VAT and taxes. The only exception is the calculation of the cost curve for non technical measures, where end user costs were used.
- Discount rate of 4%: The discount rate is the interest rate used to determine present values of future costs and benefits (savings).
- Definition of costs and reduction: for the industry only measures have been selected that can be taken by the trading entities**.** This means that measures taken by end users are not in the cost curve for industry. Reduction potentials are based on fuel savings (direct emission), indirect savings of end users are not taken into consideration. As mentioned before, for transport we have also included non technical measures.
- Base year: the base year of the study is 2004/2005. This baseline assumes that policies that were implemented in 2004/2005 will continue.
- PRIMES data were used as the baseline in both sectors.
- For the cost curve of road transport we used an oil price of € 35 per barrel.

Consequences of these assumptions
In general these assumptions will lead to a fairly conservative estimate of the cost of abatement in both the transport sector and industry, meaning that the cost effectiveness of implemented measures in practice will be more favourable than presented here. Also the oil price of € 35 per barrel can be seen as a fairly conservative estimate. One exception is that a higher discount rate can lead to less favourable cost effectiveness ratios.
This effect will probably be higher in the transport sector, since the current CO_2 incentives of taxes and duties are higher then for industry. Higher energy prices will mean that investments will be paid back in a shorter time, leading to more favourable cost saving ratios. The overall implication is that estimates of the price effects on the base of these assumptions will tend to be at the high end of the spectrum.
We explicitly mention that we have not been able to check all detailed assumptions regarding the individual cost data of the different sectors in this study (aviation, road transport, industry and electricity).

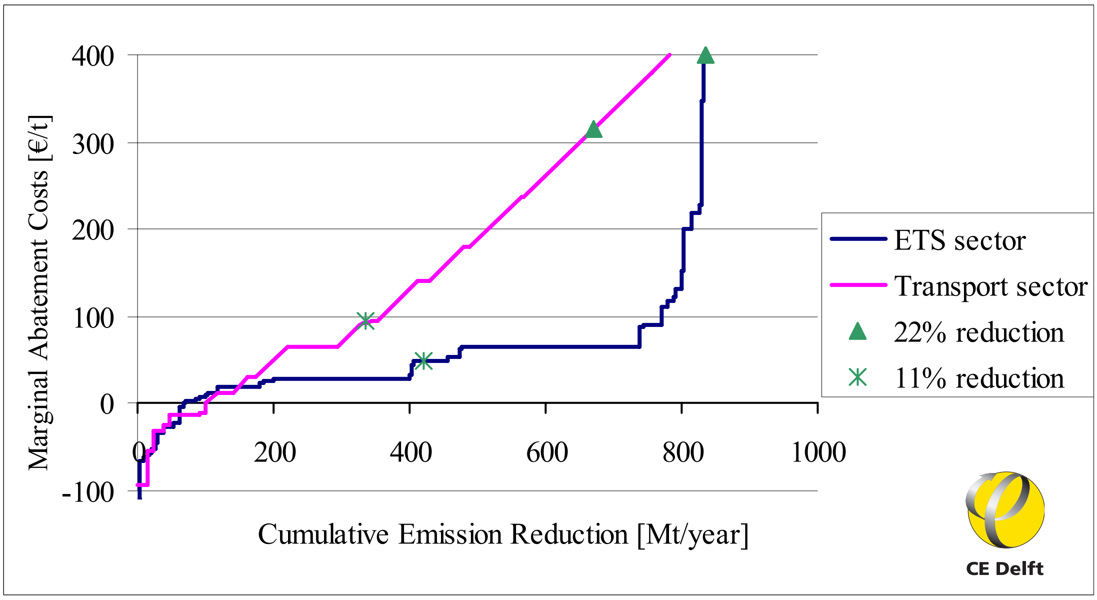
---

[3] Due to lack of data, end user effects in the current EU ETS sectors (similar to these non-technical measures in transport) were not included in our model.
[4] Electric rail transport is already included in the EU ETS, via the electricity producers.

The cost curves

Figure 2 shows the cost curves for both transportation and ETS sectors. The scope of the diagram corresponds to an abatement level in the range of 0-30%.

Figure 2 Marginal cost curve for transport (road transport and aviation) and the ETS sectors for 2020



The following conclusions can be drawn:

– The cost curves are in line with findings in other literature: CO_2 abatement measures are more expensive in the transport sector than in the current EU ETS sectors. However, we also conclude that:
  - There is a significant potential of 'no regret' abatement measures, about 100 Mton in both the EU ETS and transport sectors. These measures have higher economical benefit than costs. There can however exist barriers that will prevent the measures from being taken, in particular in the transport sector.
  - Up to 180 Mton CO_2 reduction (per sector), there are no large differences between abatement costs of these sectors. At higher reduction levels, abatement costs in the transport sectors become significantly higher than in the EU ETS sectors. The curves seem to converge at about 800 Mton reduction. At this point, abatement costs in the EU ETS sectors rise steeply.
  - In the EU ETS sectors, the abatement potential is largely dependent on a limited number of reduction measures with very significant potential. If one or more of these options are withdrawn or limited for some reason (public acceptance, technical obstacles, etc.), this will increase the EUa price. In the transport sector, the abatement potential is much more equally distributed between a larger number of measures.

Price effects

The effect of inclusion of transport in the EU ETS on the EUa price were calculated for two different scenarios:

- 22% emission reduction in 2020 (compared to 1990), with 50% CDM/JI[5];
- 28% emission reduction in 2020 (compared to 1990), without CDM/JI.

The results were as follows:

- In the first scenario, inclusion of the transport sector in the EU ETS leads to an increase of the EUa price from € 50 to € 65 per tonne CO_2. These results seem to be relatively robust. Note that since 50% CDM/JI is allowed in this scenario, and the CDM/JI abatement options are relatively cheap (less than € 50/tonne CO_2), the intra European emissions of the sectors included in the EU ETS will in fact be reduced by half of the target, i.e. by 11%. The data in Figure 2 show that this significantly reduces the abatement costs in these sectors, and thus the EUa price.
- In the second scenario, without any CDM/JI allowed, the target of 28% reduction can not be reached if the transport sector is not included in the EU ETS, according to the cost curve used. When transport is included, the target is achievable in our model, albeit at high EUa price: € 480 per tonne CO_2. However, we expect that at these high reduction levels, the uncertainties in the data increase significantly.
- The calculations show that the EUa price is very sensitive to the availability of (low cost) CDM and JI. The price will go up if less CDM/JI becomes available.
- The uncertainties involved in these calculations increase with the stringency of the CO_2 reduction. In general, we would expect the cost curves to be on the conservative side, overestimating costs of measures and underestimating the reduction potential. Some abatement measures (e.g. measures in the electricity using sectors and in maritime transport) could not be included in the calculations due to lack of data. Furthermore, learning effects and innovation are probably underestimated. This is the main reason why the cost curves of the EU ETS sectors could not reach the target in the second scenario unless transport was included. In reality, this kind of very stringent climate policies could be expected to lead to new solutions in industry and society that fall outside the scope of current models and databases.

Effects on competitiveness of the EU industry

This analysis is based on the assumption of changes in marginal CO_2 prices, since in economic theory production decisions are based on the individual companies marginal costs for the last unit produced. It can be argued that as a consequence of higher CO_2 prices, the current ETS sectors can sell more allowances against higher prices. This will ultimately lead to capital transfers between the transport sector to the industry. However, these transfers are not considered in this type of analysis, which requires an average cost approach in stead of marginal costs.

Since we conclude that in the first scenario, inclusion of transport in the EU ETS has an upward impact on EUa price, one can expect effects on competitiveness

[5] Clean Development Mechanisms and Joint Implementation.

of the sectors involved. However, as long as the EUa price increase is limited (as it is here), the overall effects are expected to be small.
This conclusion by no means excludes significant effects on a sector or firm level. CO_2 intensive sectors will face a competitive disadvantage compared to less CO_2 intensive sectors, and firms that trade goods on a global market will face loss of competitiveness. Sectors that have been identified to be vulnerable are aluminium, paper and pulp, steel and cement production.
We do not feel confident enough about the cost curves at high reduction levels to draw definitive conclusions about the impact on competitiveness in the second scenario.

Policy recommendations
The current study provides a first insight into the effects on EUa price that can be expected if the transport sector is included in the ETS. However, this study can by no means answer all the questions regarding this topic. Integration of transport under ETS may significantly increase the efficiency of achieving the overall abatement targets in the EU. These efficiency gains should be weighted against the potential negative effects. Against the background of the signalled uncertainties we conclude that these first results give good reasons to focus further research on the costs and benefits of the integration option within one scheme.

Research recommendations
We suggest the following in order to improve the analysis:
- Costs curves of the various sectors involved and of the CDM/JI options available in the future are crucial to the results of the calculations. However, data (especially in public literature) are scarce, and in some cases (namely maritime transport) lacking completely. Further research should, in particular, be carried out to determine potential and (end user) costs of abatement options in the various transport sectors and of end users of electricity.
- We have only briefly analysed the potential effect on competitiveness of the EU industry in this study. Also, we have not yet assessed the effects of different EUa allocation options. Both issues deserve more attention. We specifically recommend to further look into (allocation) options that may protect those branches of industry that are susceptible to global competition.
- The potential benefits of combining this policy with other climate policies in transport, such as fuel efficiency regulations and climate neutral fuels policies should be investigated further.
- As an alternative, a separate emission trading system could be set up for the (surface) transport sectors. At higher abatement levels (where the cost curves of the various sectors diverge), this system can be expected to lead to implementation of less cost effective CO_2 abatement measures. However, it would have the advantage that the emissions of the sector can be capped without the risk of affecting the ETS sectors (by increasing the price of the EUa´s). Negative effects on competitiveness can thus be avoided.

1 Introduction

1.1 Background

Carbon dioxide (CO_2) emissions from transport are steadily increasing, even though various CO_2 mitigation policy measures have been implemented in recent years. Policy measures implemented to date that have a direct or indirect impact on CO_2 emissions from transport include; voluntary agreements, investment in research and development, regulations, differentiated vehicle taxes, fuel taxes and infrastructure charges. A potential new policy measure for the transport sector is CO_2 emission trading. Emission trading is a market based instrument that aims to achieve emission reductions in the most cost effective manner.

The political momentum for this type of measure in the transport sector appears to be increasing, due to the recent introduction of the EU emission trading scheme (EU ETS) for stationary sources, i.e. the industry and electricity generation sectors, and the call for effective CO_2 emission reduction policy in the transport sector, as many other sectors manage to reduce their emissions. In addition, the European Commission has concluded that emission trading is a potentially attractive policy to deal with the climate impact of aviation[6]. The Commission is also considering the inclusion of maritime transport in the EU ETS as a means to implement climate policy for the maritime sector, but no decision has yet been taken up till now. Including the other transport modes such as road and rail transport in the EU ETS has not yet been discussed on EU level.

It can be expected that including transport in the EU ETS will have substantial impacts on the demand and supply of emission rights and consequently on the sectors already trading (ETS sectors) in the EU ETS. In this report, CE Delft assesses the consequences of including the European transport sector in the EU ETS. The report was commissioned by the VROM Council (VROM-Raad), also on behalf of the Energy Council (Algemene Energie Raad/AER) and the Transport Council (Raad voor Verkeer en Waterstaat).

1.2 Trade off efficiency and competitiveness

The goal of a system of tradable EU allowances (EUa) is to comply with the given emission limitations at lowest possible cost to the European economy, and thus to keep the unavoidable loss of general prosperity as low as possible. An emission trading system has the advantage of ensuring that emissions are reduced where costs are lowest. This advantage generally increases with increasing scope of the trading system. Limiting the system to the transport sector only, or to a part of the sector, will thus reduce at least the short term cost effectiveness of the measure. However, setting up a separate emission trading

---

6 On December 20, 2006 the European Commission published a legal proposal for the inclusion of aviation in the EU ETS which has been sent to the Council and the Parliament under the co-decision procedure. The European Parliaments Environment Committee and the Transport and Tourism Committee have discussed the proposal, alongside the Environment Council which discussed the response of Member States.

system for transport with a relatively tight emission target may be more effective to reduce CO_2 emissions in the transport sector itself, as the sector does not have the opportunity to purchase allowances from other sectors. Although it stimulates the sector to develop technologies itself that reduce CO_2 emissions, a closed system is considered a less cost effective option (see CE, 2005).

On the other hand an integrated approach could have major drawbacks. When the abatement costs of transportation are considerably higher than the abatement costs of current ETS sectors, the allowance price in the ETS will increase due to the transport sector buying allowances from industry and increasing the demand. This might impact the European industry as price of electricity and carbon intensive products will increase. Some sectors (cement, aluminium, paper, etc.) currently included in the EU ETS are vulnerable to higher energy prices and hence face a major risk of 'carbon leakage' due to relocation of activities. In a worst case scenario this might cause the European industry to close plants, relocate new plants outside the European Union and/or to postpone new investments.

The negative trade off between efficiency and competitiveness of the current EU ETS sectors is foremost depending on the abatement costs for different levels of reductions in both the transport and industry sectors and the allowed room for CDM/JI credits within ETS. Therefore the analysis in this study will focus on the marginal abatement curves (MAC curves) of both sectors against the background of different policy scenarios.

1.3 Objective and scope

The main objective of this study can be formulated as follows:

What are the effects on ETS allowance price and impacts on competitiveness of inclusion of the transport sector in the current EU ETS?

The cost curves we have developed refer to the abatement costs for the *European* industry and transport covered by the EU-25. Any conclusions to be drawn in this study on the competitiveness of the industry should thus be interpreted against a *European setting*. The effects are calculated for the year 2020.

The objective is investigated by use of a simple calculation model using the marginal abatement costs for the industry and relevant transport sectors. The marginal abatement cost for the ETS sectors (in this report sometimes referred to as industry including the power supply and energy intensive sector) are based on the *Genesis database* (Ecofys). The transport cost curve is derived from the sector analysis of transport in *Green4sure* with regard to technical measures. As for non technical measures we have conducted an additional analysis assessing the provisional *opportunity costs* (welfare losses) for reducing transport volume.

It is assumed in this study that the whole transport sector is included in the EU ETS. The main modes of interest are then the road sector, maritime shipping and aviation. The CO_2 contribution of railways (diesel) is considered too small to have a substantial effect on allowance prices. For reasons of efficiency we have left it outside the scope of the study[7].

1.4 Design options of emission trading

A comprehensive overview of design options for emission trading schemes for transport can be found in (CE, 2006).

Principally, the following types of emission trading schemes can be distinguished:
- **Cap & trade (C&T) systems**, setting emission ceilings in combination with tradable emission rights, and
- **Baseline & credit (B&C) systems**, setting a baseline emission standard in combination with bankable/tradable emission credits. In this type of scheme absolute CO_2 emissions are not regulated directly, only the relative emissions, such as for example CO_2 emissions per vehicle kilometre.

A baseline & credit system is currently under investigation by the European Commission, as a potential measure to reduce the (average) specific CO_2 emissions of new cars. The EU ETS system is a cap & trade system. An important reason to consider a C&T system for the transport sector as well is the need to limit the sector's increasing emissions. Another argument is that an integrated cap and trade system will further increase the effectiveness of reductions in both the transport and EU ETS sectors[8].

For these reasons we will assume a C&T system when analyzing the effect of incorporating the transport sector into the ETS.

Subsequently, various specific parameters have to be determined in order to establish the boundaries of the trading system :
- **Geographical scope**: national or EU.
- **Trading entity** (the party that is required to hand in emission allowances): end users (vehicle owners), filling stations, fuel companies, refineries.
- **Closed or open**: closed scheme (no linkage to EU ETS) or open scheme (linked to or embedded in EU ETS).

7 Note that the CO_2 emissions of electric railway transport are already included in the current EU ETS.

8 A *B&C system* for transport can be difficult to link to the current EU ETS and there exist no methodologies and institutions for setting baselines.

Geographical scope
The scope of a trading system can either be a national or a European system. A national system will refer to a Dutch system. Full integration of the transport sector within the EU ETS, automatically means covering all the countries under ETS and hence European cost curves as point of departure.
In this study, the analysis of the costs curves refers to the EU-25. Romania and Bulgaria have been left outside the scope of the study because of a lack of relevant data.

Closed or open
The issue of whether an emission trading scheme for the transport sector should be an open or closed scheme relates to the potential linkage to the EU ETS (or other emission trading schemes). We distinguish three possibilities:
- An open scheme: inclusion in the EU ETS.
- A semi open scheme: linkage to the EU ETS.
- A closed (fully separate) scheme: no linkage to the EU ETS.

An *open scheme* would mean that transport (or one or more transport modes) would be included in the EU ETS. A *semi open scheme* implies that the transport sector is not embedded in the EU ETS, but some sort of linkage would exist: credits under the transport scheme can be traded with credits under the EU ETS. One possibility for linking the transport sector to the EU ETS is by making use of project mechanisms, analogous to the Kyoto project mechanisms of joint implementation (JI) and clean development mechanism (CDM). Emission credits could then become available to EU ETS trading sectors by emission reduction projects in the transport sector. A *closed (fully separate) scheme* means that the transport sector is not connected at all to the EU ETS. Credits under the transport emission scheme can only be traded within the transport trading scheme itself.

Point of departure of this study is a fully integrated cap and trade emission trading system where the transport sector is included. The rationale for the first option is that cost effectiveness of an integrated system is optimal, making use of all potential reduction options in both sectors. The analysis of effects of integration gives us full insight in the price mechanism and consequences for industry.

Trading entity
The trading entity refers to the party that is required to hand in emission allowances. Many parties can in theory be eligible to do so, depending on their position in the product chain (upstream, middle stream, downstream). For example, in the road sector we can distinguish:
- **Downstream**: vehicle drivers (end users).
- **Middle stream**: filling stations.
- **Upstream**: fuel suppliers.
- **Far upstream**: oil refineries.

We assume in this study that the trading entity will be the fuel suppliers (upstream). This choice is economically justified. The option can limit transaction costs of implementing the system, but still makes use of the reduction potential of transport users (see CE, 2005).

Allocation

Before emission trading with a cap & trade scheme can be started, initial emission allowances have to be allocated to the trading entities. There are several methods to do this, which may or may not inflict direct costs on the trading entities. So far, in the EU ETS and in emission trading schemes in the US (PEW, 2003), this allocation has been done by 'grandfathering', where allowances are distributed without charge to the entities. This type of allocation usually has the most support from industry. An alternative would be to auction the credits (possibly returning the revenue to the parties involved), or to distribute the credits based on future emission prognoses.

For the aviation industry, CE Delft (2005a) identified auctioning as the most favourable option, because auctioning could circumvent potential unfair treatment related to 'early action' and newcomers to the market. It could also prevent entities from making windfall profits by passing on the costs of freely distributed allowances to end consumers.

We assume that the allowances are grandfathered to both the industry and the transportation sector. Of all allocation options grandfathering of the EUa's can be seen as potentially least harmful for the industry. We will further investigate the impacts of allocation on the industry in a qualitative manner in paragraph 3.5. It should be noted that the price of the EUa's does not depend on the type of allocation used.

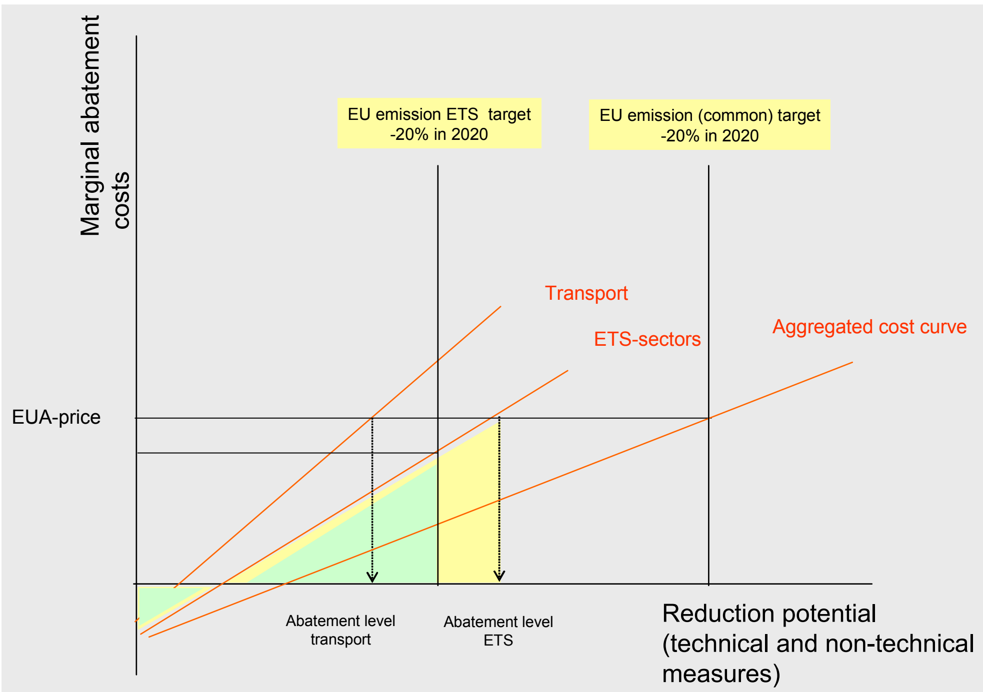
1.5 Consequences of different designs

Emission trading schemes directed at end users (vehicle drivers) will in general lead to higher transaction costs and may be difficult to implement, compared to schemes aimed at fuel suppliers or car manufacturers. C&T schemes directed at end users have the advantage that the trading entity itself has direct access to a large number of emission reduction measures. Filling stations and fuel suppliers only have limited access to direct emission reduction measures (they can increase their sales of biofuels). However, they will stimulate CO_2 reduction when they transfer the cost of emission allowances to the end users by increasing fuel prices. The non technical measures that end users have at their disposal, in reaction to higher prices, can be in part implemented immediately. Examples are substituting to low carbon transport alternatives and reducing the demand for transport for example by efficient logistics. Other behavioural measures to cut down the amount of traffic have a longer time frame, e.g. spatial planning policy measures, (re)location decisions, reducing commuter traffic. At least, a part of the behavioural reduction measures has a very indirect implementation mechanism and as a long time frame.

1.6 Methodology in a bird's eye view

For the purpose of the analysis we have constructed a calculation model based on the abatement costs for different reduction levels, in the sectors relevant for this study: the sectors currently included in the EU ETS (industry and energy), CDM/JI projects[9] and the transport sector. The curves are expressed as marginal abatement curves (MAC). They show different levels of reductions relating to different marginal costs. Using the MAC curves for the individual sectors as a basis, different aggregated MAC curves are constructed for different scenarios. Within the model the price of an EU ETS allowance is then determined by avoiding the last unit of emission in order to achieve a certain emission constraint. Each sector within the model will chose an abatement level with a corresponding marginal price of abatement costs.

Figure 3 Cost curves for transport, ETS sectors and the aggregated cost curve (schematic)



In Figure 3 the situation with and without incorporation of the transport sector into ETS is illustrated. Individual MAC curves are (schematically) shown for both the transport sector and the EU ETS sectors. Using the EU ETS curve in the graph, one can now determine the EUa price for any given abatement level, for the (reference) case that transport is not included in the EU ETS. When transport is included in the EU ETS, the equilibrium EUa price at given abatement level can be derived from the aggregated cost curve.

9 Projects under the Clean Development Mechanism and Joint Implementation.

How this equilibrium EUa price will be reached, can be seen as follows. Any initial grandfathering of allowances that does not correspond to equality of marginal abatement costs among economic sectors, encourages allowance trading between these sectors. Sectors with relatively high abatement costs, i.e. higher than the market price of an allowance, will buy additional allowances, whereas sectors with relatively low marginal abatement costs will sell their surplus of allowances. Equilibrium is reached when the marginal abatement costs of each participating sector is equal to the market price of the emission allowance.

In the situation assumed here, the transport MAC curve is higher than that of the EU ETS sectors, meaning that the costs of achieving a given abatement level (expressed either in Mton CO_2 or in % CO_2 reduction) is higher in the transport sector than in the EU ETS sectors. Reducing a given percentage of CO_2 emissions in the EU ETS sectors only will then lead to a lower EUa price and lower abatement price level, compared to achieving the same percentage in the aggregated scenario.

The graph also allows the comparison of *total* abatement costs for the EU ETS sectors, in both scenarios. The yellow shaded part under de MAC of the EU ETS sectors gives the total abatement costs for industry (€/ton x emission reduction), in case of an aggregated ETS system. This situation can be compared with the situation where trade is restricted to industry and there are no additional policy instruments for transport. Total abatement costs in the EU ETS sectors are then determined by the green shaded triangle. Clearly, total abatement costs in these sectors are higher in the aggregated case, due to the assumption that the marginal cost curve for industry is below the one for transport. However, note that this does not imply that the ETS sectors are also faced with these higher costs, since they will be able to sell emission allowances to the transport sector at the higher price.

The methodology is discussed further in the next chapter.

2 Methodology

2.1 Introduction

In the following, the calculation methodology will be explained in more detail. First of all, the baseline scenario (‘what will happen without any new policy?’) is derived, and the different policy scenarios that will be assessed are shown. To this end, assumptions regarding joint implementation and the clean development mechanism (JI and CDM) are discussed as well. The next step is the construction of the cost curves for the various sectors under investigation. These curves tell us what the cost and potential of various CO_2 abatement options are in these sectors.

2.2 Baseline and Policy Scenarios

2.2.1 Overall development of emissions

GHG emissions reductions are defined as percentage reductions below baseline emissions in 2020 or 2030. Therefore, when constructing a cost curve it is crucial tot define a reference case: the situation without policy support for the technical option investigated. Ideally a cost curve should be updated regularly when for example emission trading will mean that a part of the reduction potential will be used in order to realize the target.

In the table below we present the emission scenario that is used as baseline for the cost aggregated curve (i.e. for the scenarios in which both the current EU ETS sectors and the transport sector are included in the EU ETS). These data clearly show that even though the total emissions of the transport sector are less than those of the current EU ETS sectors, inclusion of transport in the trading system would imply a significant increase of emissions (and thus allowances) under the system.

As will be discussed in section 2.2.3, we will look at two different CO_2 reduction targets: reducing 22% or 28% of CO_2 emission in 2020, compared to the levels of 1990. These targets mean about **1,340 Mton** respectively **1,500 Mton** reduction. Additionally, it is assumed that CO_2 emission of aviation have to be stabilized compared to 2005. This amounts to an extra **174 Mton** emission reduction.

Table 1 Overview of the development of CO_2 emission (Mton) in the baseline scenario for **the aggregated cost curve**, EUR 25

Sector	1990	2000	2005	2010	2020
Energy supply	1,294	1,382	1,477	1,573	1,763
Industry	657	561	573	584	600
Transport (road)	792	970	1,022	1,075	1,116
Aviation (1)	114	174	228	281	401
Total	**2,743**	**2,913**	**3,072**	**3,231**	**3,479**
Reduction target -22% in 2020 compared to 1990 (excl. aviation)					**1,339**
Reduction target -28% in 2020 compared to 1990 (excl. aviation)					**1,504**
Reduction target aviation, 0% in 2020 compared to 2005					**174**

(1) = All arriving and departing flights.

The baseline for the EU ETS cost curve (i.e. for the scenarios in which transport is not included in the EU ETS) is given in Table 2. Targeted reduction is then about **850** and **950 Mton** respectively (assuming the same reduction targets as before, of 22% or 28% of CO_2 emission in 2020, compared to the levels of 1990).

Table 2 Overview of the development of CO_2 emission (Mton) in the baseline scenario for **the ETS cost curve**, EUR 25

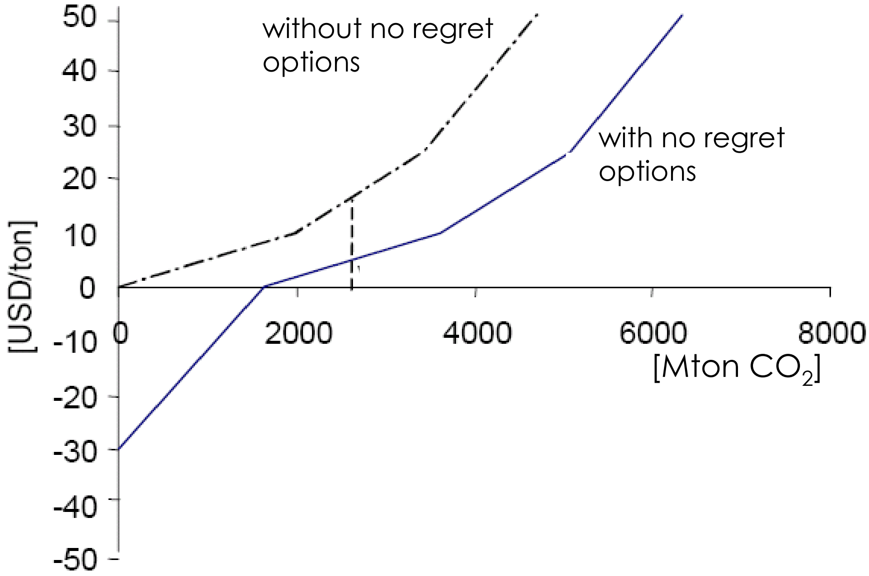
Sector	1990	2000	2010	2020
Energy supply	1,294	1,382	1573	1,763
Industry	657	561	584	600
Total	**1,951**	**1,943**	**2,157**	**2,363**
Reduction target -22% in 2020 compared to 1990				**841**
Reduction target -28% in 2020 compared to 1990				**958**

2.2.2 CDM and JI

Access to credits from joint implementation (JI) and the clean development mechanism (CDM) may limit the costs of any shortages in allowances. CDM and JI can be used by firms covered by the ETS and governments. Credits earned via CDM and JI can be converted into emission allowances under the ETS via the linking Directive (2004/101/EC). Member states can thus reduce domestic pressure to abate emissions. The negative economic effects of the Kyoto commitments can be minimized if the optimal policy mix between domestic reductions and reductions abroad is chosen. The available amount (and price) of CDM/JI credits allowed within the EU ETS will be primarily determined by the individual Member States via the National Allocation Plan and depends on national political choices. Secondly, the potential and price of CDM/JI credits depends on the supply of these technical options in developing countries.

On the base of supply and demand (from Kyoto parties) ECN (ECN, 2000) presents an analysis of the equilibrium price of a GHG emission reduction unit assuming a fully transparent global market for GHG reduction units. This world wide cost curve is presented in Figure 4, both with and without no regret options. These are options with negative costs, i.e. options that yield net benefits. No regret options are allowed within the system of JI/CDM when additionality can be proved. This is the reason why we used the 'no regret' version of the cost curve. This can be seen as a somewhat optimistic assumption.

Figure 4 World wide cost curve of GHG reduction options (Annex 1 and Non Annex 1)



ECN's analysis focused on the Kyoto target (2,8 Gigaton GHG). The current emission target for 2020 means of course a significantly higher demand for CDM credits. Demand for JI/CDM credits will drive up prices of credits and hence influence the allowance price on the EU ETS market. One must realize that Europe will not be the only demanding party for CDM credits. For the purpose of our analysis we have assumed that Europe might claim a part of the CDM credits proportional to it's share in worldwide GHG emissions (about 12%), which will be a fairly conservative presumption. Additionally it is supposed that the amount of credits within ETS will be limited to 50% of the target for 2020, corresponding with the Dutch policy statement on a fifty-fifty distribution of domestic reductions home and reductions abroad. On the base of these two assumptions a cost curve for CDM and JI measures available within ETS can be constructed.

This cost curve will hold for the first baseline scenario (see Table 3 in the following paragraph). The second baseline scenario does not allow for any trading opportunities between EU ETS actors and CDM and JI projects.

2.2.3 Overview scenarios

In Table 3 we present an overview of the different baselines and policy scenarios that are used in this study.

In the first scenarios, we assume that the emission budget (cap) is reduced by 2% a year, in the years between 2012 and 2020. This amounts to a reduction of 22% in 2020, compared to 1990. We furthermore assume that sufficient (cheap) CDM/JI measures are available to the EU ETS market to achieve 50% of the reduction target.

The second scenarios assume more stringent climate policies worldwide. In this case, the EU might opt for a more severe 2,8% emission reduction per year between 2012 and 2020. Emissions in 2020 are then 28% lower than in 1990. Furthermore, since climate policies are assumed to be much more ambitious on a global scale in these scenarios, CDM and JI will cease to exist - the countries were these project are implemented will then need to use these mitigation options themselves in order to achieve their own climate targets.

Table 3 Different scenarios for targeted emission reductions and corresponding cost curves

Name	Descriptions
Baseline scenario (1)	– Only current ETS sectors, no significant extensions/opt-ins. – Emission budget is reduced with **2% a year**, meaning **15% less emission in 2020 compared to 2012** (22% compared to 1990). – No agreement on a new international climate policy framework: 50% of total reduction available from JI/CDM credits in order to avoid loss of competitiveness of the European industry.
Policy scenario (1)	– Incorporation of the complete transport sector into a common ETS framework. – Same reduction targets as in baseline scenario (1).
Baseline scenario (2)	– Only current ETS sectors, no significant extensions/opt-ins. – Emission budget is reduced with **2.8% a year**, meaning **20% less emission in 2020 compared to 2012** (28% compared to 1990). – Due to an agreement on a international climate policy and binding constraints for developing counties there are no JI/CDM credits available.
Policy scenario (2)	– Incorporation of the complete transport sector into a common ETS framework. – Same reduction targets as in baseline scenario (2).

2.3 Important assumptions and considerations

When constructing the cost curves for the various sectors (shown in the following paragraphs), we have made the following assumptions:

- **A national cost perspective**: this means that costs and savings are calculated on the base of prices excluding VAT and taxes. The only exception is the calculation of the cost curve for non technical measures, where end user costs were used.
- **Discount rate of 4%**: the discount rate is the interest rate used to determine present values of future costs and benefits (savings).

- **Definition of costs and reduction:** for the industry only measures have been selected that can be taken **by the trading entities.** This means that measures taken by end users are not in the cost curve for industry. Reduction potentials are based on fuel savings (direct emission), indirect savings of end users are not taken into consideration. For transport we have also selected non technical measures that can be implemented by end users since these measures will contribute significantly to total reductions in this sector.
- **Base year:** the base year of the study is 2004/2005. This baseline assumes that policies that were implemented in 2004/2005 will continue. PRIMES was used for the calculations of the baseline in both sectors.

Albeit these common points of departure, one should take into account when interpreting the results that definitions and methodologies (time frame of savings, energy prices used, the extent of presumed penetration in Europe, economic and demographic growth level, etc.) for the costs and savings in both sectors will certainly not perfectly match. Within the scope of the analysis we did not check these detailed, but not seldom crucial, assumptions.

Secondly, an analysis like this should, in fact, be conducted from the cost perspective from end users. Consumers and producers will asses costs and benefits of reduction compared to buying allowances from a private perspective, not a national one. This means that a private discount rate and energy prices including taxes and VAT should be used. However, within the context of this analysis it is not realistic to apply a general factor to correct for the level of energy prices including VAT in relation to base energy prices in both sectors, since different investment decisions have different cost saving ratios. Energy prices can have a profound influence on cost saving rations when for example cost effectiveness approaches zero.

It is important to realize that levels of energy taxes and VAT are considerably higher in transport compared to those in the EU ETS sectors. For industry the most important EU wide incentive for CO_2 reduction is the cost of emission allowances. These have ranged from € 4-33 per ton during the current trading period. For transportation fuel taxes in the EU 15 Member States range from € 150-323 per ton emitted CO_2 for gasoline and € 94-288 per ton emitted CO_2 for diesel (with the majority of countries closer to the upper value of the range). From the perspective of a consumer or investor an investment in energy efficient transport will thus have a shorter pay back time period. This means that the current cost effectiveness findings can be viewed as overestimating the cost of measures in transportation more than for industry.

Another important notion the reader should bear in mind is that cost curves are derived from a static point of view and do not take into account that price induced volume reductions will take place throughout the whole economy. A dynamic analysis can be pursued within the context of a general or partial equilibrium model like for example Primes.

Finally, estimates of the costs of environmental policy that were made in advance of the policy's introduction ('ex ante') are often substantially higher than estimates made when the policy has been operational for some time ('ex post') (IVM, 2006). Several factors can be responsible for this gap, and to some extent the differences are inevitable. In many cases, the ex ante estimates were about twice as large as the ex post results, but in some cases the differences were either much larger or there was hardly any difference at all.

These considerations lead to the probable presumption that the cost curves presented here are more likely to form an upper limit than a lower limit.

2.4 Cost curve for the current EU ETS sectors

2.4.1 Sectors

Given the overall project goal, the focus of this study is on those industrial sectors that are separately distinguished in the Annex of the EU ETS directive:
- Iron and steel.
- Cement.
- Glass.
- Ceramics.
- Pulp and paper.
- Refineries.
- Electricity generation.

Sectors that are not individually listed in the Annex of the EU ETS directive, but that are included in the EU ETS because they operate combustion installations with a capacity over 20 MW (e.g. the chemical industry) are not included in the analysis.

2.4.2 Baseline construction

In PRIMES (the baseline scenario used for the analysis), final energy use data for iron and steel industry, the non metallic industry (for cement, glass, ceramics and other minerals) and the pulp and paper industry are included as well as the share of the various technologies (e.g. primary and secondary steel) in this final energy use. We apply these shares uniformly to all types of final energy use. By dividing the final energy use by the production, specific energy use values per technology can be calculated (e.g. GJ per tonne of primary glass and GJ per tonne of pulp).

Multiplication of the final energy use with emission factors yields an estimate for the CO_2 emissions of the sector. We distinguish fuel related emissions and indirect emissions related to the production of electricity and combined heat and power (CHP) heat. Emission factors for the fuels used are based on the emission factors of fuels used in the main sectors distinguished in PRIMES (iron and steel, non metallic minerals, paper and pulp). These main sector emissions factors are applied to the fuel use of all technologies in the sector (e.g. both for primary and secondary steel). The primary energy use and indirect emissions from the use of electricity are calculated based on conversion efficiencies and an emission factor from PRIMES based on the total production of electricity, including both industrial auto producers and public electricity generation and including both conventional and renewable electricity production. For CHP heat, a generation efficiency of 90% is assumed to calculate primary energy use. The emission factor for CHP heat is based on the fuel input used by industrial car producers as given in PRIMES. For primary energy use and indirect emissions from electricity and CHP heat, no distinction is made between the various sectors.

For cement, primary glass and primary steel production, also process emissions are calculated based on own estimates. For cement production, we assumed a value of 0.39 ton CO_2 per ton cement based on a clinker content of 75% and emissions per ton clinker of 0.52 ton CO_2. For primary glass, specific process emissions of 0.15 ton CO_2 per ton primary glass are assumed and for primary steel production, specific process emissions (from the use of limestone) of 0.13 ton per ton iron.

For refineries, no PRIMES data are available and energy use and emissions for refineries are therefore based on a specific energy use of 3 GJ per tonne of oil processed and specific CO_2 emissions of 220 kg CO_2 per tonne of oil processed.

Based on this specific energy use for the base year 2005, a frozen energy efficiency is used to construct the CO_2 emission development using the growth rates for the individual technologies. The specific final energy use levels (fuels, heat and electricity) are kept constant to the base year as well as the emission factors for fuels, electricity and heat.

2.4.3 Construction of the cost curve

A bottom up method is used to determine the potential for energy efficiency improvement. The base year for the assessment is 2005. Thus, data for the year 2005 are used as reference. As future target year 2020 is chosen. Only measures that have a high probability of being commercially available before 2012 are included.

Between 2005 and 2020, the industrial production is expected to grow. The net growth is the result of both an increase in capacity by new plants or expansion of the capacity of existing plants and - by decrease in capacity - by plants that are taken out of operation. New plants normally operate with an energy efficiency that is better than that of the old capacity. We assume the specific CO_2 emissions of the new plants up to 2020 to be 90% of 2005 levels. We also assume that the net growth will be totally met by new capacity. On the one hand, this is an overestimate of the contribution of new capacity because part of the growth will be met by expanding existing capacity. On the other hand, this is an underestimate because part of the existing capacity, generally less efficient than the average, will be taken out of operation in the period 2005-2020.

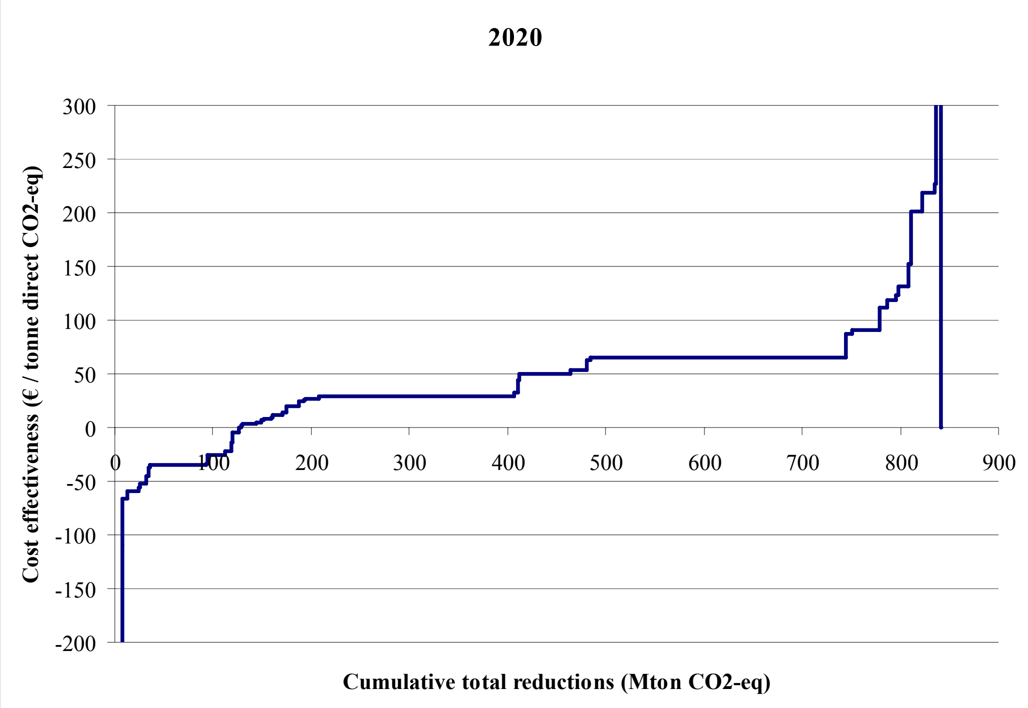
The additional investment costs and operation and maintenance costs for new capacity are assumed to be zero. The following procedure is followed to determine the potential for CO_2 emission reduction per sector:

1 Per sector, options are identified for the reduction of the fuel or electricity demand.
2 Per sector and per country, the 2005 specific direct (fuel related) and indirect (electricity and CHP heat) CO_2 emissions are calculated based on the PRIMES model.
3 Per option the technical potential for savings on fuel and electricity demand is determined, expressed in GJ fuel or electricity saved per unit of activity.
4 Per option, the 2005 degree of implementation of each option is determined, expressed in % of the production of the unit activity of the sector. Within the scope of this project, we keep the implementation degrees constant for all years and for all countries in the base year.
5 Per option, the maximum percentage of technical implementation up to 2020 is determined.
6 The potential savings on CO_2 emission for the option can be determined by multiplying the potential savings of fuel and electricity by the CO_2 emission factors of fuel use and electricity use for the sectors and by multiplying with the share of the capacity to which the option applies (using the implementation rates in base year and year analysed).

The following procedure is followed to determine the cost parameters per option. Per option the specific investment costs and specific annual operation and maintenance (O&M) costs are determined, expressed in €/unit of activity/year (investments) and in €/unit of activity (O&M costs). The figures are obtained from literature and expert consultation.

- Per option the benefits from saved energy purchase costs are determined based on specific energy prices.
- Using a pre set discount rate (4%) and an economic lifetime for each option, the annualised specific investment costs are calculated.
- The total annual specific costs for efficiency improvement are obtained by adding the specific annualised investment costs and the specific O&M costs and subtracting the saved energy purchase costs and CO_2 benefits.

Figure 5 Cost curve for measures that reduce CO_2 emissions in the current EU ETS sectors, EU-25, 2020



In appendix A list of available abatement measures in the ETS sector is presented.

2.5 Cost curve for the transport sector

As explained in chapter 1, relevant sub sectors included in transportation are:
- Road transport, including cars, motorcycles, trucks and busses.
- Aviation.
- Maritime transport.

2.5.1 Baseline construction for road transport

Baseline emissions of road transport in the EU in 2020 are taken from (EC, 2006). This report provides the baseline emissions of all sectors, including transport, for the EU and its member states. It distinguishes between passenger and goods transport. This baseline assumes that policies that were implemented in 2004, or that were being implemented by the end of 2004, will continue. PRIMES was used for the calculations in that study. The resulting baseline emissions for the EU-25 are shown in Table 4.

Table 4 Baseline CO_2 emissions for road transport in the EU-25 (in Mton)

	1990	2000	2010	2020
Private cars and motorcycles	479.5	561.7	584.5	567.5
Trucks	286.0	383.3	465.9	526.9
Busses	27.2	24.9	24.1	21.1
Trucks and busses	313.2	408.2	490.1	548.0
Total baseline road transport	**792.7**	**969.9**	**1,074.6**	**1,115.5**

2.5.2 Cost curve for technical measures in road transport

Two different types of cost curves were derived for road transport, one for the, mainly technical, measures that reduce emissions per kilometre (including fuel efficient vehicle improvements, biofuels, eco driving), one for the measures that reduce the kilometres driven (see next section).

The cost and potential of the technical measures that can be used to reduce the CO_2 emissions per kilometre[10] have been estimated using the following approach.

The cost and potential of the individual measures were estimated recently by CE Delft for Green4Sure, for the Dutch situation in 2030 (CE, 2007). This analysis was based on recent literature, using learning curve theory to predict future cost trends for new technologies. The measures considered in this study are listed in the text box below[11].

10 Without reducing the vehicle kilometres driven.

11 Note that hydrogen and fuel cell technologies are not included in this list, as it was not expected that these would have a significant market share in 2030.

Technical measures considered in Green4Sure

In (CE, 2007), the following technical CO_2 mitigation measures were considered for 2030:
For passenger cars and light duty trucks:
- Improved internal combustion engines.
- Lightweight materials + aerodynamics.
- Full hybrid drive.
- Tyre Pressure Monitoring System.
- Low rolling resistance tyres.
- Efficient air conditioning.
- Low viscosity lubricants.
- Eco driving (with gear shift indicator GSI).
- up to 10% biofuels (2nd generation).

For heavy duty trucks:
- 44 ton trucks.
- 60 ton trucks.
- More efficient engines.
- Low rolling resistance tyres.
- Low emission air conditioning.
- Improved aerodynamics.
- Long distant trucks.
- Lightweight construction.
- Eco driving.
- Up to 10% biofuels (2nd generation).
- Logistical optimisation (mainly implementing IT solutions).

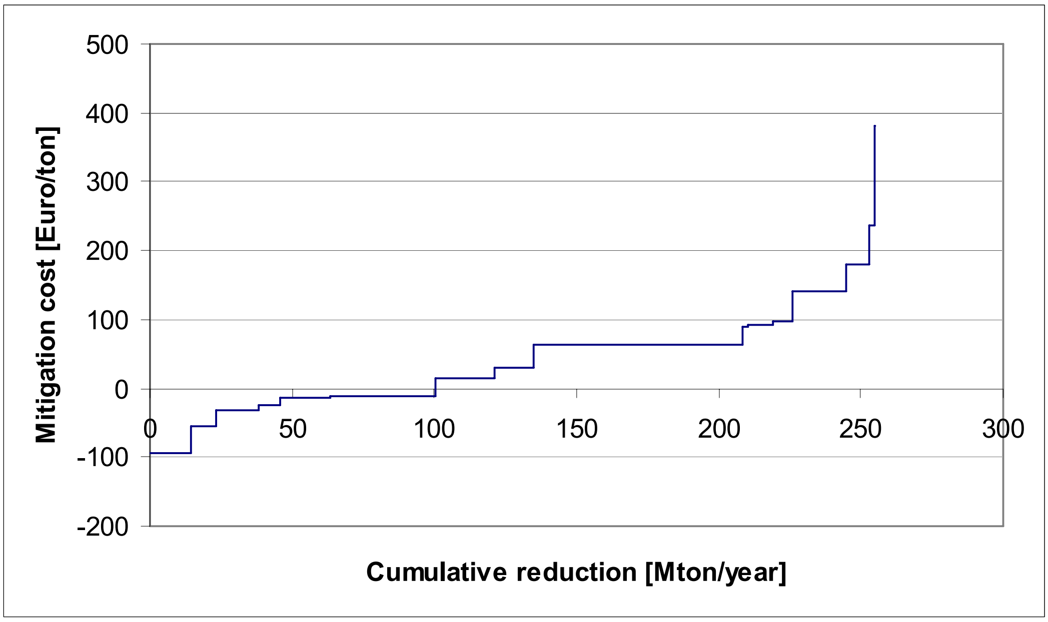
Data on costs and potential of these measures, market penetration assumed, etc. can be found in (CE, 2007).

Costs and potential of these measures were first estimated per vehicle. In Green4Sure, this was combined with estimates regarding market implementation rates of the various technologies, and baseline fleet emissions for the Netherlands, resulting in the costs curve for the Netherlands. In this study, the calculations have been adapted as follows:
- The baseline fleet emissions of the EU road transport sector were taken as the reference case (see EC, 2006).
- The year of focus was adapted to 2020. New assumptions regarding the implementation of the technologies were made[12].
- In Green4Sure, a baseline scenario was taken that assumed much more stringent fuel efficiency standards than in the PRIMES baseline. The potential and costs of fuel efficiency measures were adapted to account for this difference.
- The oil price was taken to be € 35/bbl (a discussion on the impact of oil price is given in paragraph 3.7).

The result is shown in Figure 6.

[12] Incl. modifying the assumption that the biofuels would be second generation. This could be the case in 2030, but does not seem to be realistic for 2020.

Figure 6 Cost curve for measures that reduce specific emission factors (CO_2 per km) in road transport, EU-25, 2020



2.5.3 Cost curve for non technical measures in road transport

In addition, an estimate regarding cost and potential of the non technical measures, i.e. the measures that lead to a kilometre reduction, was derived. As is well known from economic theory and empirical research (Goodwin, 2004), both passenger and good transport will react to the fuel price increase induced by inclusion of transport in the EU ETS. People will choose more fuel efficient cars or drive more fuel efficiently (i.e. implement some of the options listed in the text box), for example. But some will also consider taking the bicycle or public transport more often, visit their family or friends less, or even move houses to reduce their commuting distance. In goods transport, hauliers will try to improve the load factor of their trucks, companies might adapt their logistics to the new cost situation.

Unfortunately, data on costs and potential of these mitigation options are hardly available. However, literature provides price elasticities that give the effect of a fuel cost increase on the vehicle kilometres driven, which is the effect we want to model here. Based on an extensive literature review, (Goodwin, 2004) estimates this price elasticity to be -0.3 (long term elasticity, after 3 to 5 years[13]). This means that if the fuel costs increase by 10%, the vehicle kilometres will reduce with approximately 3%, both for passenger cars and heavy duty vehicles. In this study, we have chosen to use a price elasticity of -0.2, as a reasonable but somewhat conservative estimate.

[13] Elasticities are provided both for the short term (within 1 year) and the long term (usually about 3-5 years). The latter are generally much higher, since people and companies often need some time to react. In our study, we use the long term price elasticities.

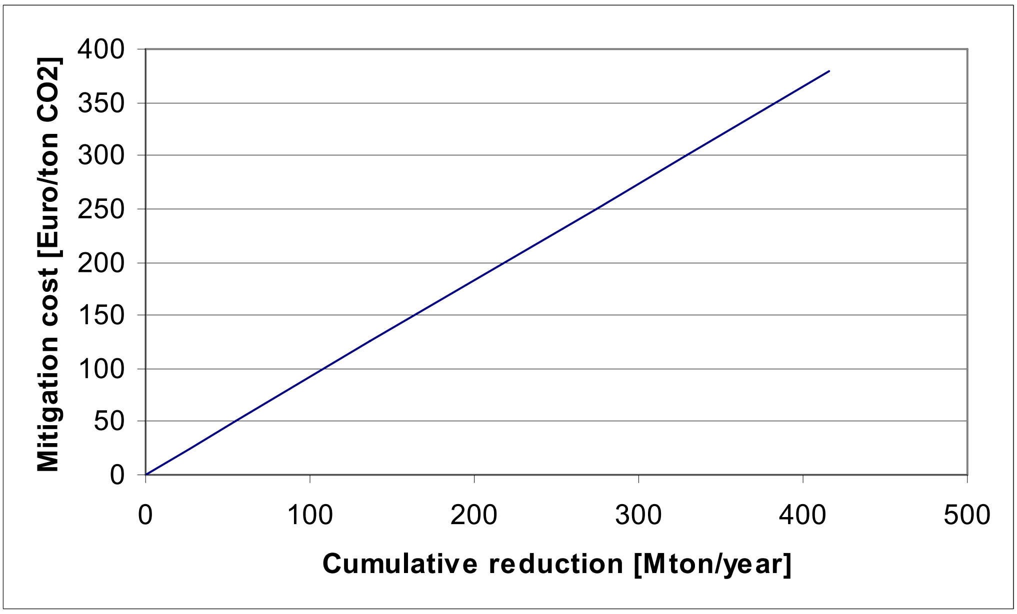
We can thus estimate the vehicle reduction at a certain EUa price, assuming that this price will be transferred to the fuel buyers as an equally high fuel price increase. Reducing kilometres induces costs to the vehicle owners - either direct, financial costs (changes to logistics, for example), or other welfare cost (less visits to family and friends, for example). We don't know these costs exactly, but we do know that these costs will be lower than the EUa price, because otherwise the vehicle owners would not take these measures. Using the 'rule of half'[14], we assume that the average costs of measures implemented in this case, is half the EUa price (see text box).

Example

If the EUa price is € 50 per tonne CO_2, we assume that this cost is added to the fuel price, leading to a fuel price increase of about € 0.13 per litre. This currently represents a fuel cost increase (for consumers, i.e. incl. fuel taxes) of 12,3% for diesel, and 8,3% for petrol. Using the price elasticity of -0,2, we estimate that diesel vehicle km's will then reduce by 2,5%, and petrol vehicle km's by 1,7%. This amounts to a total of about 50 Mton CO_2 per year (using the PRIMES baseline shown earlier, for the EU-25 in 2020). The average cost of the measures taken to achieve these kilometre reductions is approximately half of the price increase, i.e. € 25 per ton CO_2. This gives us a point in the cost curve of kilometre reduction measures: 50 Mton CO_2 reduction, at € 25/ton CO_2.

The resulting cost curves for these types of measures are shown in Figure 7.

Figure 7 Cost curve for the measures in the road transport sector that reduce vehicle km's driven, EU-25, 2020



[14] The **rule of one-half** estimates the change in consumers' surplus (or welfare loss) for small changes in price with a constant demand curve.

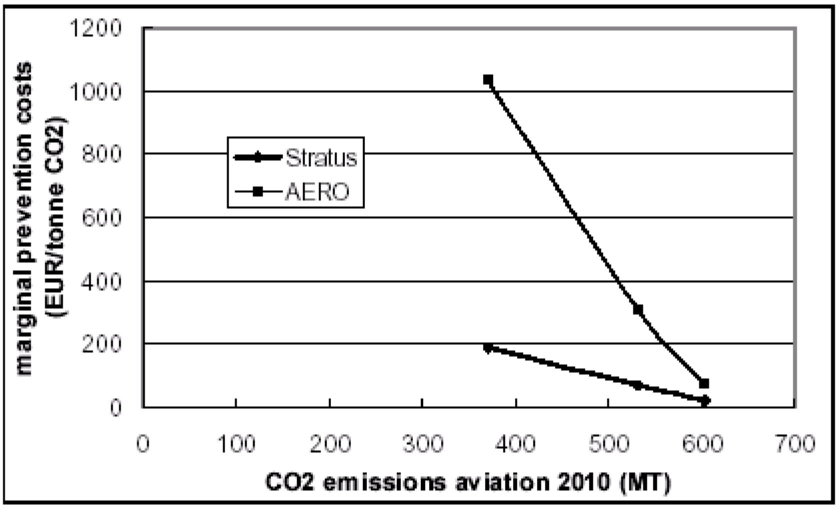
Note that this is only a first order estimate. In reality, price elasticities found in literature are only valid for relatively limited price increases. However, no information was found about how the elasticity might develop at increasing prices and reduction levels.

2.5.4 Aviation

The costs of reducing greenhouse gas emissions in the aviation sector are generally considered to be higher than in most other sectors. Reasons often cited for this are that the high share of fuel costs in direct operating costs of aircraft already provides a strong incentive to take measures to reduce fuel burn and thus CO_2 emissions. However, there are no comprehensive studies into the costs and potentials of reducing greenhouse gas emissions in aviation. Therefore, marginal abatement cost curves do not exist.

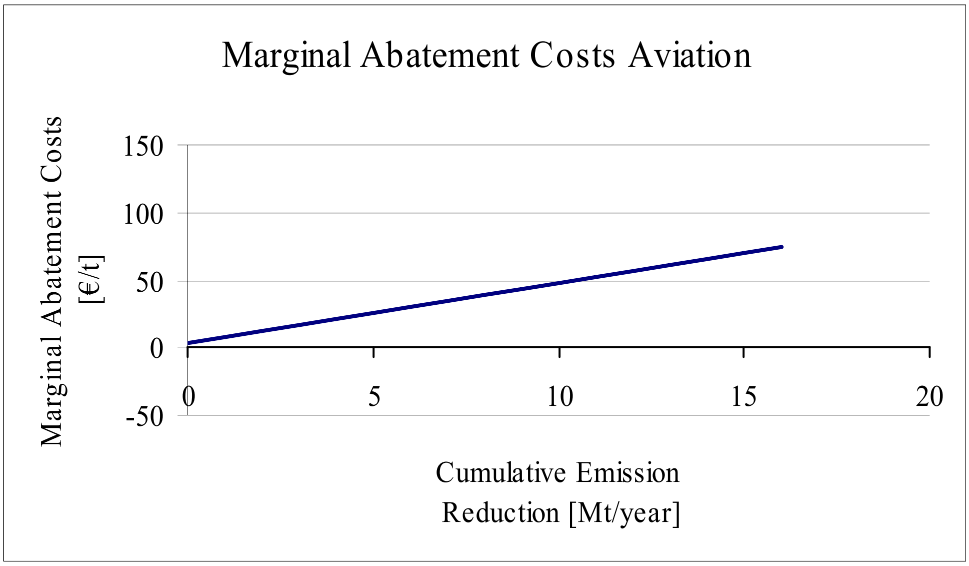
Figure 8, below, is taken from CE et al., 2002. It shows the marginal costs of different models for reducing CO_2 emissions in 2010. The marginal costs for reducing emissions 5% below the 1990 level were estimated to be around € 200 for the US fleet and over € 1,000 for the EU fleet. However, since both calculations used different models and made different assumptions, they are not directly comparable. It is clear from the picture, however, that the costs for emission reductions in the aviation sector could be high. These data for 2010 are used for our analysis for 2020.

Figure 8 Marginal prevention costs in aviation sector for year 2010 under a 'closed' CO_2 trading system, or kerosene charge, following from Stratus and AERO models



We have translated the above curve for the EU fleet (AERO) into a cost curve for the purpose of our analysis, as shown in Figure 9. We explicitly mention here that this curve is based on extrapolation of a line through only two 'observations' and should thus be interpreted with caution.

Figure 9 Cost curve used in this analysis for the aviation sector, EU-25



2.5.5 Maritime transport

Since fuel costs are very low in maritime transport, it can be expected that so far only CO_2 abatement measures are being implemented that are relatively cheap, compared to the measures in, for example, road transport. However, we have not found any concrete data on costs of abatement measures in maritime shipping. We have therefore not included this sector in the calculations[15].

2.6 Construction of the aggregated cost curve

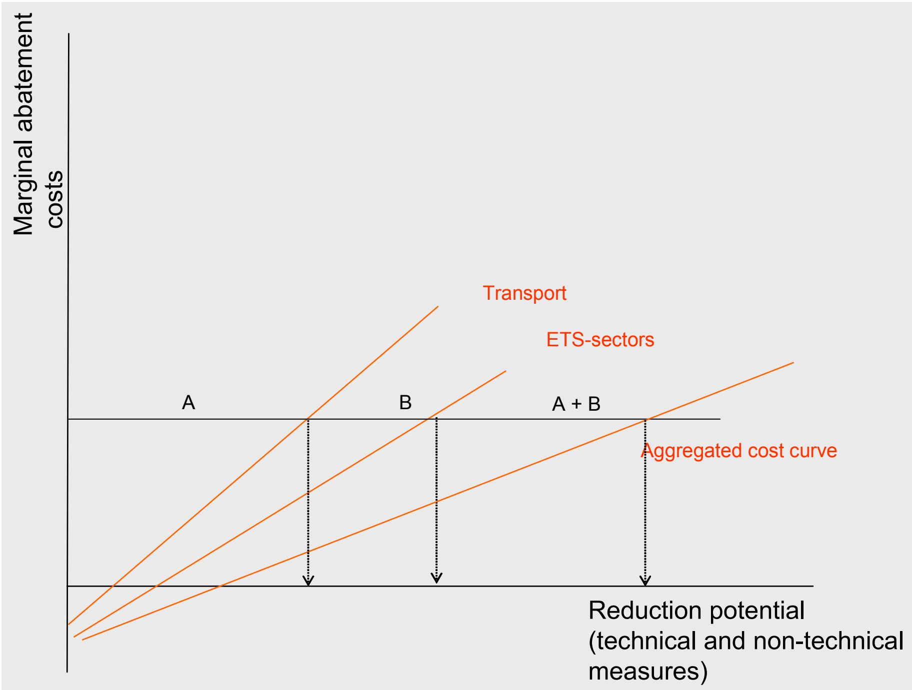
Now that the cost curves for the individual sectors are known, the aggregated cost curve for the extended EU ETS trading system (in which the transport sector is added to the current EU ETS sectors) can be derived. This curve should reflect potential and cost of all abatement measures of the various sectors, that were captured in the cost curves derived in the previous paragraphs.

This aggregated curve can thus be constructed by adding the abatement potential of the various sectors at any given cost level. Thus, the horizontal summation of the various curves gives the aggregated cost curve. Figure 3 gives an illustration of this principle. At a given abatement cost level, the total reduction potential is then the sum of the potential in the transport sector (A) plus that of the EU ETS sectors (B). Additionally, this summation principle has been used for aggregation of technical and non technical measures[16].
The result of this exercise is shown in the next chapter.

15 Note that maritime emissions are not included in the PRIMES baseline calculations either.

16 It should be noted that there is a strong interaction between both type of measures. Reducing the transport volume will decrease the potential for technical measures, and vice versa. A static analysis cannot deal with this type of interaction.

Figure 10 Construction of an aggregated cost curve



3 Results

3.1 Introduction

This chapter starts with the comparison of the resulting cost curves of transport and ETS sectors in paragraph 3.2. Subsequently, the results of the calculations are shown for the different scenarios are shown, in paragraph 3.3 and 3.4. Table 5 presents the structure of these sections.

Table 5 Overview of scenarios

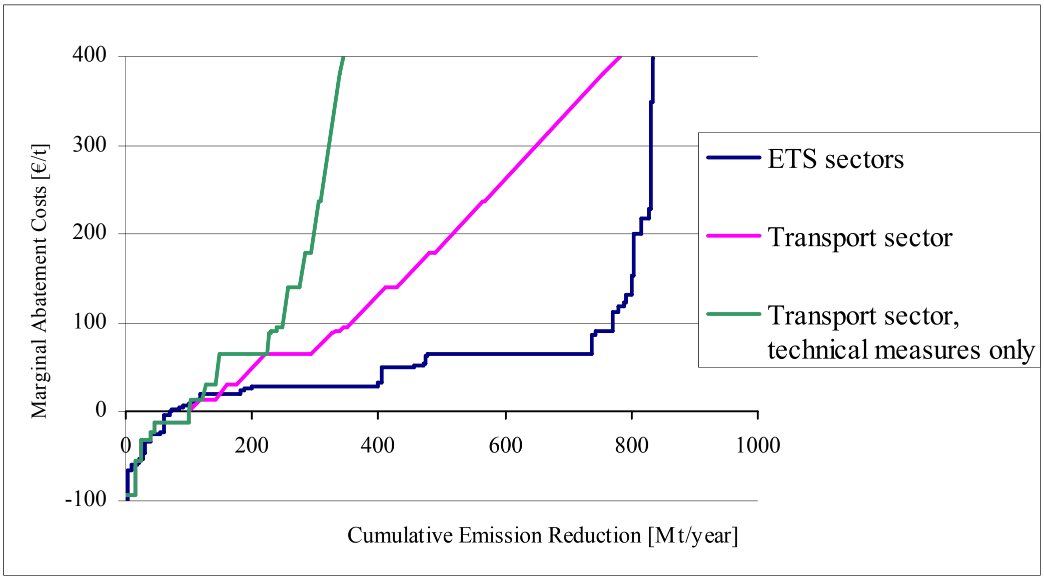
Paragraph	Section	Name	Descriptions
3.3	3.3.1	**Baseline scenario (1)**	– Only current ETS sectors. – Emissions are reduced with 22% compared to 1990. – 50% of total reduction available from JI/CDM credits.
	3.3.2	Policy scenario (1)	– Incorporation of the complete transport sector into a common ETS framework. – Same reduction targets as in baseline (1).
3.4	3.4.1	**Baseline scenario (2)**	– Only current ETS sectors. – Emissions are reduced with 28% compared to 1990. – No JI/CDM credits available.
	3.4.2	Policy scenario (2)	– Incorporation of the complete transport sector into a common ETS framework. – Same reduction targets as in baseline (2)

3.2 Comparison of the cost curves

Figure 11 shows the cost curves for both transportation and ETS sectors, for an abatement level in the range of 0-30%. For illustration purposes, the curve for the technical measures in the transport sector is included as well. Note that the total transport curve (indicated in pink), which includes both technical and non technical measures, was used in the calculations.

For a large part of the scope of the diagram, we see the cost curve for transport lying above the cost curve for ETS. This result can be viewed to be in line with the general findings from literature (Bates et al., 2006; CE, 2007; IVL, 2006). IVL (2006) pursued their analysis of the impacts of different options of GHG emission trading on the transport and industry sectors on the base of the crucial assumption that for any reduction level, at least down to 25% reduction volumes, the marginal cost for transportation are always higher than for industry.

Figure 11 Marginal cost curve for transport (road and aviation) and ETS sectors for 2020, JI/CDM is excluded



The diagram however shows some new insights which are relevant for our overall conclusions. First of all there is a significant and comparable potential of 'no regret' abatement measures in both sectors. In both sectors, around 70 to 100 Mton of abatement measures are available against negative costs. Up to 250 Mton of reduction there are no large differences between abatement cost levels in both sectors. It must be considered that measures that have negative costs should always be implemented when actors are assumed to be rational.

Many energy efficiency measures will pay for themselves over their lifetime through reduced energy costs. Evidently in the current situation there are non economic barriers like for example institutional, behavioural and social barriers that prevent these cost effective measures to be taken. Barriers that may limit or slow the penetration of apparently cost effective technologies include: lack of information, subsidies or regulated prices that may hold energy prices artificially low, differences in incentives between builders and users of energy equipment, consumer preference for other equipment attributes instead of efficiency, etc, etc. Even business management tends to give energy efficiency a low priority in decision making.

The question here is whether the extent in which these cost effective measures are implemented in both sectors differ. This is probably the case. As current CO_2 incentives in transport are considered to be larger, one has to come to the conclusion that these barriers in transport are more persistent and influence the demand and supply for efficient transport means in a more fundamental manner.

Incorporating transportation into the EU ETS might well generate a sufficient *financial* incentive to overcome the costs of technical and behavioural reduction measures in transportation, but it is certainly not guaranteed that all cheapest measures and even negative cost measures will be taken. The implication could be that at the margin the last transport *actor* will be confronted with higher marginal costs (than suggested here) since some cost effective measures were not taken (due to various barriers mentioned above).

Secondly, we see both cost curves rapidly converging in the end of the diagram when marginal abatement costs of industry rise steeply from € 100 per ton up to € 400[17]. An important part of industrial emissions are associated with chemical processes such as cement production, steel production and mineral oil refining. In this range of reduction (30-50%), options can have profound impacts on the production process with corresponding high costs. Also the ambition of these reduction levels means that measures will influence sectors that operate in small margins of profitability or in situation of overcapacity.

Thirdly, especially in the ETS sectors the cost curve shows that the overall potential is quite sensitive to a large potential of a limited number of measures. In the table below we present the top 3 of largest technical potential and the costs of measures from both sectors.

Table 6 Overview of measures with highest reduction potential in 2020

Sector	Measure	Potential 2020 (Mton/year)	Costs (€/ton)
ETS	New capacity by natural gas fired cycles.	260	65
	Replacement of existing capacity by natural gas fired cycles.	198	29
	CO_2 removal.	47	50
Transport	Improved internal combustion engines (base).	74	65
	Eco driving: – Trucks. – Passenger cars (incl. gear shift indicator).	 28 14	 -12 31
	Lightweight construction and aerodynamics road vehicles.	21	13

Table 6 shows that the ETS curve is strongly dependent on a large reduction potential of a small amount of options, which seems logical from the large scale of operation and capital intensive character of the energy sector and the energy intensive industry. The replacement and new capacity of natural fired gas combined cycles and CO_2 removal within the energy sector contribute all together to more than 50% of total potential in industry. The implementation of these kind of measures is not only depending on future CO_2 prices, but is to an increasing extent interwoven with political choices on national energy security and fuel mix considerations. Currently the energy sector seems to have a strong preference for coal fired production facilities (Tennet, 2007; CE, 2007), which makes at least a part of the potential of new gas fired utilities redundant. The development of an integrated CO_2 capture and storage (CCS) to a stable and feasible technology in

[17] It should be noted that for higher levels of reduction, the uncertainty increases significantly.

2020 is however at this moment far from being certain. At this moment components of CCS are in various stages of development. Complete CCS systems can be assembled from existing technologies that are mature or economically feasible under specific conditions, although the state of development of the overall system may be less than some of its separate components (IPCC, 2005).

The abatement potential of the transport sector is far more equally distributed over the reduction measures. In particular a variety of non technical measures can be implemented by a large number of actors within the sector[18].

Regarding technical enhancements, the efficiency of conventional gasoline and diesel vehicles can be improved by a number of promising technologies, including hybrid vehicles and advanced diesel engines[19]. New materials and more compact engines lead to lighter and more fuel efficient vehicles. Efficiency gains are also possible in vehicle appliances, especially air conditioning. Some practical measures, such as ensuring that tyres are correctly inflated, can make a surprisingly significant difference.

The consequence of this sensitivity of the cost curve to some important measures within industry is that withdrawal of these measures for whatever reasons (acceptance, technical obstacles, and institutional barriers) will have a principal upward influence on the EU ETS sector curve and the resulting EUa price.

Benchmarking the cost curve

The finding that marginal abatement costs for transport are above the costs of industry can be further supported by studying European tax levels (IVL, 2006). Tax levels create incentives for abatement measures with marginal costs lower than the tax levels. Under perfect market conditions including perfect information and no capital constraints we would expect that the level of abatement costs reflect tax levels. For industry the most import EU wide incentive is the cost of emission allowances. These have ranged from € 4-33 per ton during the trading period. For transportation fuel taxes in the EU-15 Member States range from € 150-323 per ton emitted CO_2 for gasoline and € 94-288 per ton emitted CO_2 for diesel. This information shows that tax levels for transportation are an order of magnitude higher than for industry throughout the EU. This supports the diagram showing higher reduction cost for transport than industry.

18 Although the measures that save transport volumes are clustered here as one type of reduction measure with different reduction levels relating to different CO_2 prices.

19 Turbochargers, fuel injection and advanced electronic methods of engine control can help cut fuel consumption.

3.3 Scenario 22% reduction with CDM

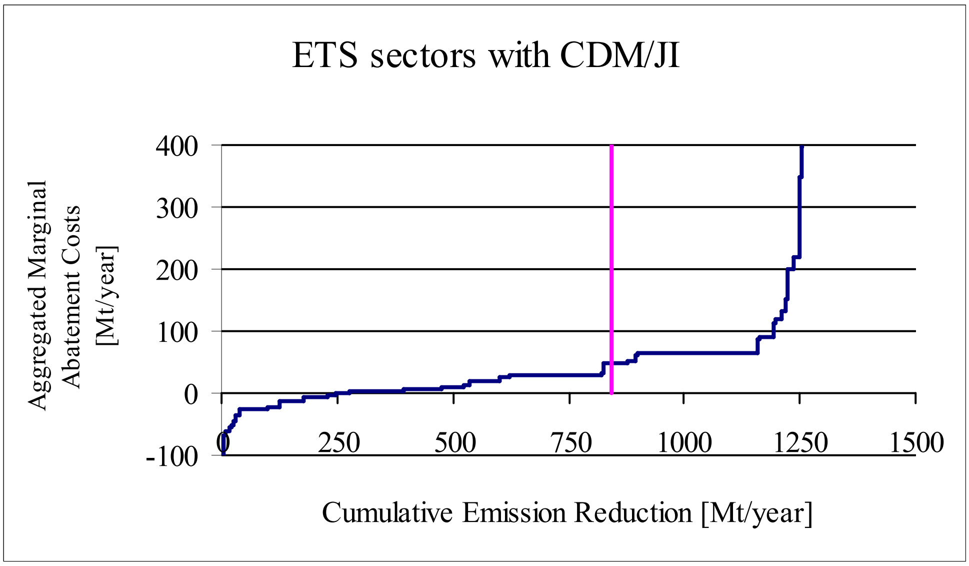
3.3.1 Baseline scenario 1

In this case only the current ETS sectors are trading within EU ETS. Emissions of industry are capped to 78% of 1990 level. The transport sector is not regulated through an ETS.

The marginal abatement cost curve of the EU ETS sectors is shown in Figure 12. The curve includes reduction options converted from CDM and JI covering up to 50% of the targeted absolute reduction (420 Mton). The cap is presented in the same diagram by the vertical line, representing 841 Mton reduction.

The respective allowance price resulting from the reduction target of -22% corresponds roughly with € 50 per ton. The targeted level of abatement does not correspond to a steep part of the cost curve. A 10% rise of the targeted level of avoided emission within Europe will imply a EUa price increase of 30% (€ 65/ton).

Figure 12 Marginal cost curve for ETS sectors for 2020, JI/CDM is included, the vertical line indicates 22% reduction compared to 1990

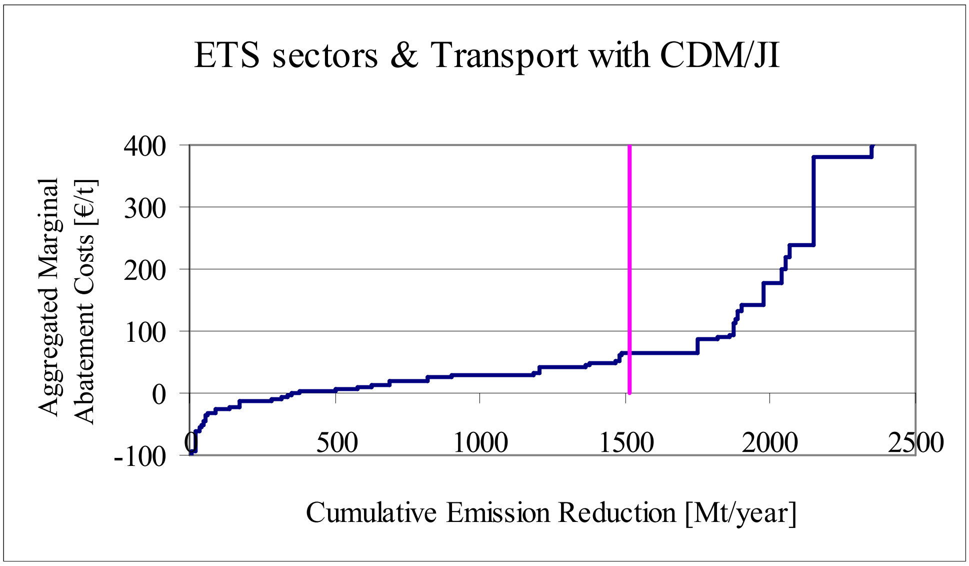


3.3.2 Policy option 1

Contrary to the baseline scenario 1, the transport sector will be included into a fully integrated ETS system. For both sectors, the 22% reduction compared to 1990 means 1,515 Mton. It should be noted that this *de facto* means a considerable higher amount of CDM/JI credits will be in circulation within ETS in relation to the baseline scenario (about 300 Mton extra). The resulting cost curve is shown in Figure 13.

The equilibrium allowance price resulting from the reduction target of -22% equals € 65 per ton, again positioned in a relative flat part of the aggregated cost curve.
These results are quite sensitive to the assumptions regarding CDM/JI availability: when the absolute amount of CDM/JI credits is maintained at the level of the baseline scenario 1 (420 Mton), the price will rise up to about € 90 per ton.

Figure 13 Marginal cost curve for the ETS sectors and transportation for 2020, CDM/JI is included, the vertical line indicates 22% reduction compared to 1990



3.3.3 Comparison

From our analysis it appears that incorporation of the transport sector in a fully integrated emission trading system will have limited effects on the CO_2 prices (€ 50 and € 65 per ton respectively) when the CDM/JI credits are allowed to cover 50% of total emission reductions within the system. When the absolute amount of CDM/JI credits is held constant at level of the baseline, a rise from € 65 to € 90 per ton can be expected.

In general this conclusion appears to be fairly robust in relation to a variation of the targeted reductions of around plus or minus 10% to 15%, since the slope of the curve is relatively flat within the range considered. Higher variations will result in larger differences with respect to the respective CO_2 prices.

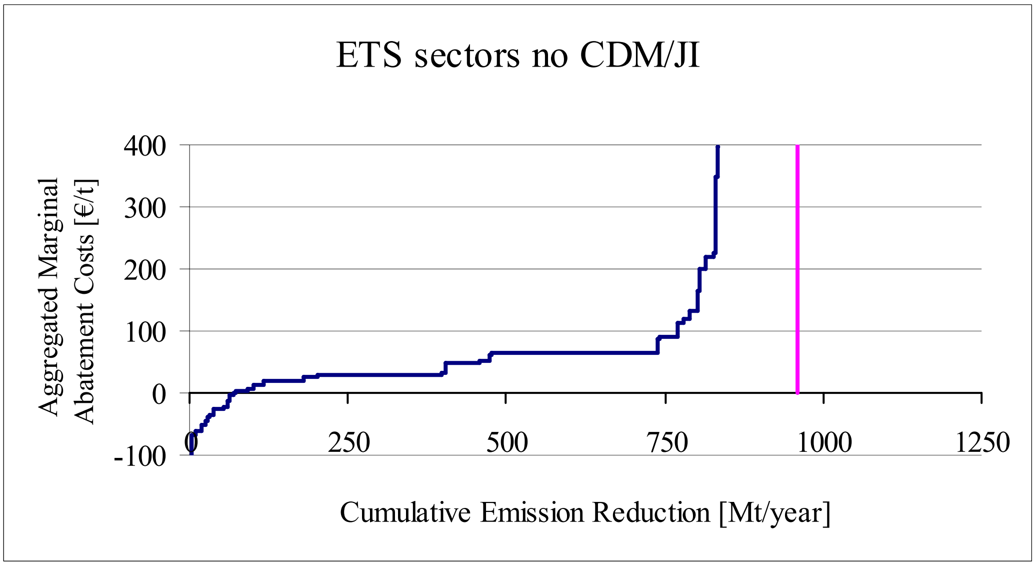
3.4 Scenario 28% reduction without CDM

3.4.1 Baseline scenario 2

Baseline scenario 2 again considers the case of only the current ETS sectors trading within EU ETS. The ETS sectors are now confronted with a more stringent cap of 72% of the 1990 level (958 Mton).
The marginal abatement cost curve is presented in diagram 11. Not included in this diagram is any potential from CDM and JI projects, since it is assumed that a far stretching agreement on participation of developing countries in the successor of Kyoto will restrict the amount of CDM available.

What can be seen from this diagram is that this reduction commitment will surpass the amount of technical potential included in the cost curve. Hence this cap is not conceived to be feasible within the sector itself. Of course a larger potential of savings is indirectly available covering electricity savings in the end user sectors like for example the built environment (households), small scale industry and service sector induced by raising electricity prices. The potential is roughly estimated to be 200 Mton, but not included here due to lack of data.

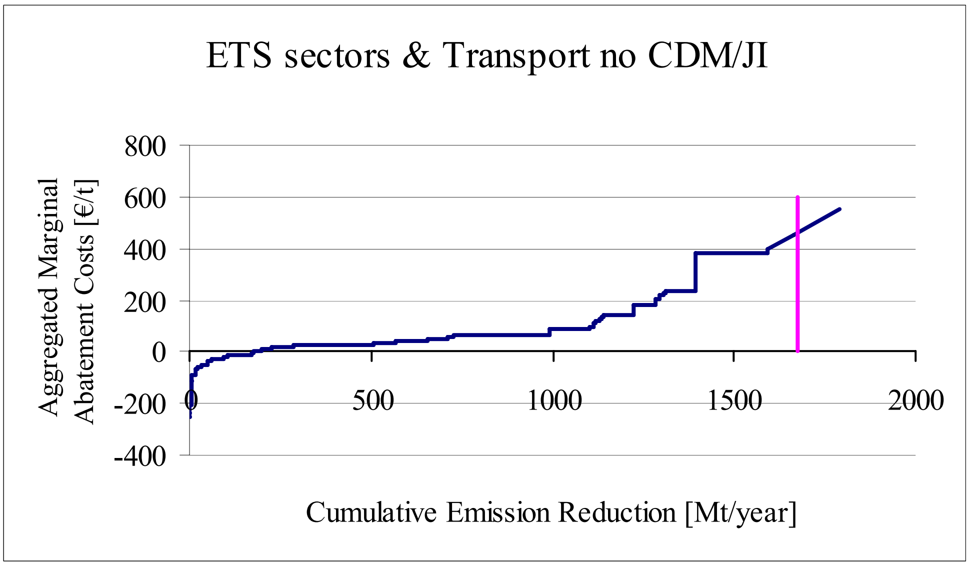
Figure 14 Marginal cost curve for ETS sectors for 2020, CDM/JI is excluded, the vertical line indicates 28% reduction compared to 1990



3.4.2 Policy option 2

In this scenario we incorporate the transport sector in the EU ETS and assume again no CDM credits are in circulation. Now both emissions of transport and current EU ETS sectors are capped, resulting in a targeted reduction of around 1670 Mton CO_2 emissions. We see that the common reduction commitment becomes feasible at a respective EUa price of € 480 per ton. The main reason for the feasibility of the joint commitment is that non technical measures, resulting from reducing transport demand due to higher fuel prices, will imply an indefinite potential for fuel saving, within the system boundaries of this analysis. It is thus assumed that kilometres driven will continue to reduce with increasing EUa price. At the other hand this potential can only be realized against high marginal abatement costs of measures.

Figure 15 Marginal cost curve for ETS sectors and transportation for 2020, CDM/JI is excluded, the vertical line indicates 28% reduction



3.4.3 Comparison

The analysis shows that abatement measures in the ETS sectors to fulfil the targets of -28% and even -22% will lead to very high costs, when no CDM/JI will be permitted within the European trading system. So even in the situation where transport sectors do not participate within ETS the current abatement objectives can be seen as far reaching and not easy feasible. Of course this conclusion is based on the conservative assumptions that abatement targets should be met by measures within the ETS sectors. If one considers also the potential of saving measures in the electricity using sectors, the target will be feasible but at high abatement costs.

When transportation will be allowed into the trading system this will imply access to an extra range of technical and non technical measures stretching the cost curve in length and eventually making the overall reduction objective feasible but only against high costs. Full use has to be made of the potential of reducing vehicle kilometres by behavioural change. The question what this would mean exactly for the EUa price is hypothetical since we could not determine the price in the baseline scenario.

3.5 Effects on competitiveness

From the analysis on the price effects it can be concluded that the effect of transport integration in the EU ETS can be expected to increase the EUa price from € 50 to € 65 per tonne in the scenario with limited scarcity (-22% and 50% CDM/JI allowed). However, we also see that the availability of CDM/JI and the level of the reduction target both have a much stronger effect. In a situation with significant scarcity of allowances (-28% reduction and no CDM/JI rights permitted) the EUa price can increase up to seven times compared to the situation with less scarcity (-22% and 50% CDM/JI allowed). The EUa price will equal € 480 per ton in the second case, and € 65 per ton in the first, assuming transport is included in the EU ETS. These prices will obviously affect the sectors involved. This paragraph therefore presents a non exhaustive view of the potential impact of the observed EUa price effects on the international competitiveness of the European industries.

The analysis in this paragraph is based on the assumption of changes in marginal CO_2 prices. In most studies addressing the competiveness effects of climate policy these changes in margins are expressed as a percentage of total cost. In economic theory production decisions are based on the individual company's marginal costs for the last unit produced.
It can be argued that as a consequence of higher CO_2 prices the current ETS sectors, that are able to take extra climate measures against reasonable costs, can sell more allowances against higher prices. This will ultimately lead to capital transfers between the transport sector to the industry. These transfers are not considered in this type of analysis which requires an average cost approach in stead of marginal costs.

Economic theory suggests that, in many sectors, businesses will pass on costs to customers and make net profits due to the impact on product prices combined with the extensive free allocations of allowances. The biggest single constraint on ability to pass CO_2 related costs on to customers is foreign competition from regions outside the EU ETS region.

Recent insights from literature highlight that the current structure of the EU ETS affects competitiveness of different sectors in very different ways. Estimates of the effects on competitiveness rely on the assumption on the ability of firms to pass through CO_2 costs in their product prices. We make a crucial difference between the power generation sector and the carbon intensive industry. Possibilities to pass through rising production costs differ significantly depending on the market they operate. For this analysis we assume a competitive power market, which will see the full pass through of CO_2 cost into electricity prices. This means that carbon costs are taken fully into account in production decisions. On the other hand, the steel sector, the pulp end paper, aluminium, cement industries have less possibilities to pass through rising CO_2 prices since they operate in international and highly competitive product markets often under the pressure of very low profit margins[20]. The geographical intensity of a trading scheme within the two scenarios is here of crucial importance. In the -28% scenario it can be assumed that emission trading will cover far more developing countries than in the -22% scenario.

Within the last group a second important difference has to be made between the carbon intensive and power intensive sectors. Of all trading sectors it is the aluminium industry that is most dependent on electric power. It should be noted that in case of free allocation cost increases due to rises of the electricity prices within the aluminium sector will not be offset by free allowances since the aluminium sector is no trading entity.

Assuming a CO_2 price of € 20 per ton, the overall average impact on industry margins across Europe in the short and medium term is limited (McKinsey, 2006). The conclusions are based on the assumption that industry can partially pass through the cost increase to customers and assuming. The exceptions are primary aluminium production and integrated pulp & paper production based on mechanical or thermo mechanical pulp. This might accelerate a migration of primary aluminium to countries with lower electricity cost and/or higher CO_2 efficiency, typically producing electricity from hydro or stranded gas, e.g., Iceland or the Middle East. McKinsey stresses that this conclusion relies on the dependency of various industries on the level of free allocation[21].

In general little evidence is observed in the empirical literature to support the hypothesis that climate policy has yet had large adverse effects on competitiveness (IPCC, 2001; Zhang and Baranzini, 2004). Without further exploring this into depth we assume here that the price increases calculated in this study will be within the same range as analysed in this literature, and that the effects of scenario 1 on competitiveness will thus be limited (scenario 2 does not give reliable results on price effects of inclusion of transport). This can be supported by a statistical analysis carried out on four energy intensive sectors in nine OECD countries by Baron and ECOEnergy, 1997 estimate an average 3% increase in production costs from a CO_2 tax of \$100/tC, supporting these conclusions. This conclusion by no means will exclude significant effects on a sector or firm level. Competitiveness is pre-eminently a concept relevant at a firm or sector level. Implementation of a uniform CO_2 emission price impacts sectoral competition, by reducing competitive advantage of CO_2 intensive sectors, and shifting advantage to less CO_2 intensive sectors. In addition, for a CO_2 intensive sector producing internationally traded goods such as steel, firms that are subjected to high CO_2 market price, will face loss of competitiveness.

---

[20] In the literature on this issue, the chemical industry is generally not considered to be a very vulnerable sector, even though its energy use is significant, and the international competition severe. In addition the chemical industry emits significant amounts of greenhouse gasses other than CO_2, such as N_2O and various F gases.

[21] Primary aluminum production is under heavy pressure in the short and mid term, because the probable large indirect cost increase resulting from the EU ETS is not covered by any free allowances.

The effects of higher CO_2 prices - say within the range of € 480 per ton - have not been explicitly researched, but it can be reasonably expected that serious consequences for several European industries will occur.

3.6 Other allocation options

Although grandfathering has several advantages in the sphere of acceptance of the instrument within the industry, recent economic literature suggests that grandfathering leads to serious allocation distortions (Neuhoff, 2006). The allocation option of auctioning gives an indication of the impact on marginal cost of *any fixed allocation*. As long as production of more or less output is accompanied by any change in free allowances, the sectors involved do not face the full cost of extra allowances, or the opportunity cost of not selling allowances. Auctioning will fix the amount of allowances *over a period of time* and is not depending on the level of production. Auctioning will give an incentive to a sector with a incremental small profit margin to cut down its production, whereas grandfathering will still lead to maintaining the level of loss making marginal production.
Although grandfathering on the base of historical rights will constraint the total amount of allowances to a particular firm *in one phase*, the *repeated* free allocation will discourage plant closure and will create distortions biased to coal (Neuhoff, 2006). As a consequence the CO_2 costs will not be reflected *fully* in the product prices and production decisions will not fully be in line with marginal CO_2 costs.
Of all options auctioning has the least distortions. Since in general firms maximize profits by pricing at or close to the marginal cost of last unit produced, the price effects of fully expressing the CO_2 costs (auctioning) will even be more significant than with free allocation. It is apparent that differentials in level of exposure to international trade and net value at stake imply that potential competitiveness impacts are again widely differentiated across sectors (Climate Strategies, 2007). The precise effects on these sectors is outside the scope of this research.

To some extent effects can be alleviated by more differentiation in the Allocation Plans. For example, EUa’s could be grandfathered to industries that face strong international competition, with auctioning used for other sectors (such as road transport, electricity). Yet a common theme across allocation plans in Phase I and II of the EU Emissions Trading Scheme was the limited nature of differentiation between sectors. Many plans treated virtually all sectors the same, by allocating according to their expected ‘business as usual’ needs, with the result that some sectors (electricity) are overcompensated more than others.

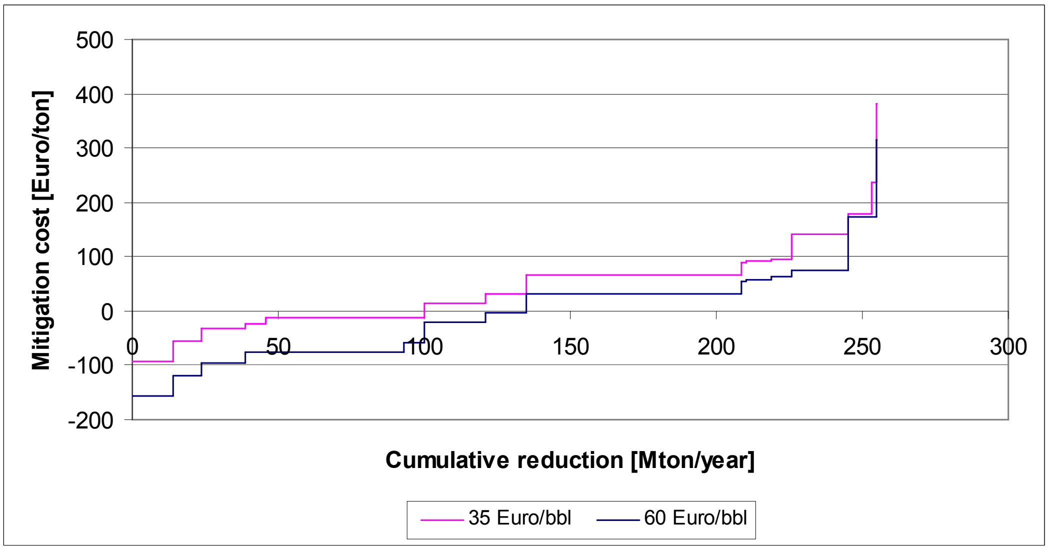
3.7 Considerations and uncertainties cost curves

In general we have used considerably conservative assumptions in constructing the cost curves of both sectors, which can be expected to lead to an underestimation of CO_2 reduction potential, and overestimation of costs:

- In ETS sectors a part of the savings potential is derived from the Icarus database which is generally considered as a conservative estimate.
- Saving measures in the electricity using sectors have not been included in the analysis. Inclusion of extra no regret measures induced by rising electricity prices will have a downward pressure on the EUa prices.
- Pay back periods of the majority the investments for transportation and industry firms will be shorter from the perspective of and end user compared to a national perspective (here used for most of the curves, with the exception of the curve for non technical measures in the transport sector). This will lead to a more favourable cost effectiveness of saving measures and smaller total costs of both sectors. This will particularly be the case for the transport sector, facing higher CO_2 incentives than industry.
- All along the line there is a trend that due to learning effects ex post cost effectiveness turn out better than was expected beforehand (ex ante). This consideration lead to the presumption that the here presented cost curves are more likely to form an upper limit than a lower limit for the overall efficiency of the reduction options.
- Cost curves leave out a number of intelligent ways that are disposable to an economy to save on their inputs. Price increases of these inputs will make substitution to less energy intensive inputs increasingly attractive and will reduce demand of energy intensive products through the whole economy. These dynamic, economy wide price effects can per definition not be included in this static analysis. This might be accompanied by welfare losses, but on the other hand opportunities can for new activities come into being.
- It can be expected that more stringent climate policy and a higher EUa price will lead to more R&D in the field of CO_2 abatement. Doubtlessly, this will lead to innovative solutions that we don't currently know about. We thus expect that the uncertainties in the cost curves increase with increasing reduction potential, and with time.

Another important uncertainty in these calculations is the future development of energy costs. Higher energy costs will make measures that improve fuel efficiency more profitable, reducing the costs of these measures. To illustrate this effect, we have recalculated the cost curve of the technical measures in the road transport sector for an oil prices of € 60/bbl (compared to the € 35/bbl used in this report). A comparison of the two curves is shown in Figure 16. Clearly, the costs of all mitigation options included in this figure are reduced at higher oil price, since the financial benefits of these measures (fuel savings) are higher at a higher oil (and thus fuel) price. A higher oil price can thus be expected to lead to lower EUa price[22].

Figure 16 Cost curve for the road transport sector for two different oil prices



3.8 Other climate policies in the transport sector

The EU is currently working on other types of climate policies in transport, in particular on CO_2 emission regulation of new cars, and the review of the biofuels directive. In this section, we will briefly assess how these policies might relate to the possible inclusion of transport in the EU ETS.

Perhaps at first sight, one might conclude that a cap and trade emission system would be sufficient climate policy, since it encourages implementation of the most cost effective abatement measures in a market based way. However, a closer look at the specific characteristics of the transport sector may lead to a different conclusion.

- First of all, there is a significant time lag between investments in fuel efficient cars, and achieving significant CO_2 reductions. Cars have an average life time of about 14 years, which means that the fuel efficiency of cars that are being sold now will have a large impact on CO_2 emissions in the next 14 years.
- Secondly, many consumers in the transport sector do not make economically rational decisions when buying a car. Research has shown that fuel efficiency is only a relatively minor issue in consumers criteria, other characteristics such as comfort, size, social status, acceleration power, etc. are often much more important considerations. Many of this characteristics have an adverse

[22] We were not able to quantify the effects of higher oil price on the EUa price within the scope of this study. This would require recalculation of the baselines, and a determination of the effect of higher oil price on the costs of measures in the EU ETS sectors.

effect on fuel efficiency. Fuel price increases thus only have relatively minor effect on the cars that are being sold.

- Thirdly, innovation in both alternative fuels and fuel efficient cars needs time, often in the order of a decade or more. An ETS system mainly encourages investments that achieve relatively short term gains, due to the relatively large uncertainties about long term EUa price developments. Investments in long term R&D and new technologies can better be promoted by other means.
- Finally, the calculations in this study show that abatement measures in transport are higher than that of measures in the EU ETS sectors, especially above a certain CO_2 reduction load. An integrated ETS system would thus lead to more reduction in industry and electricity, and less reduction in transport. This is compensated financially by the transport sector (the transport sector will have to buy more EUa's that the other sectors). However, this might hamper CO_2 reduction in transport, and investments in innovation in that sector.

On the basis of these considerations, we expect that the EUa price will decrease in an integrated EU ETS, if other policies are put in place to promote fuel efficient cars and R&D and market implementation of fuels with low CO_2 emissions (well to wheel). Since the EU ETS system will only promote investments in abatement measures through increased fuel prices, we expect that there is a significant risk that potentially cost effective measures in fuel efficient cars will not be implemented in time, due to the time lag and the economically irrational behaviour of consumers. This would increase the costs of the climate policy to the sectors and consumers involved. We therefore recommend to investigate this issue further.

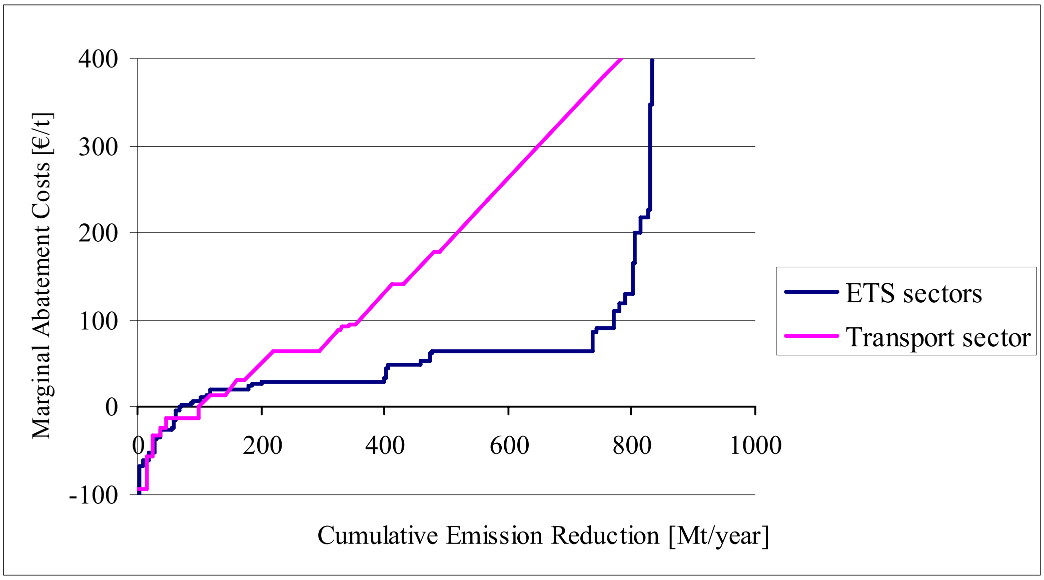
3.9 Transport in a separate emission trading system?

Instead of including transport in the EU ETS, it might also be an option to set up a separate emission trading system for the transport sector alone (CE, 2007 and CE, 2006). The transport sector would then have to reach its own CO_2 emission cap, and trade of emission allowances with other sectors would not be allowed. This would have the advantage that the transport emissions could be capped without risking negative effects on current EU ETS participants. However, a disadvantage of this option would be that this might lead to implementation of less cost effective CO_2 abatement options, and thus to higher costs of CO_2 mitigation.

Without going into details of this option, the transport cost curve shown in Figure 17 (a copy of Figure 11) can give an indication of what the resulting emission price would be in a separate trading system for the transport sector. We first assess scenario 1: an emission reduction target of 22% in 2020 in the road transport sector (with respect to 1990), and aviation emissions capped at 2005 levels. This would require a total emission reduction of about 670 Mton in these transport sectors. If 50% CDM/JI would be allowed (in line with scenario 1), the reduction target is reduced to 335 Mton CO_2. The allowance price of this target can be derived from Figure 17, and will be about

€ 90 per tonne. This is € 30 per tonne higher than the € 65 found earlier in scenario 1, in the combined EU ETS system.

Figure 17 Marginal cost curve for transport (road and aviation) and ETS sectors for 2020, JI/CDM is excluded



In the case that no CDM/JI would be allowed in the transport trading system, but the same target would be set (i.e., 670 Mton CO_2 reduction in 2020, compared to 1990), the transport cost curve in Figure 17 tells us that this would lead to an emission allowance price of about € 315 per tonne CO_2 in the transport sector. This result can be compared to the very similar case discussed in paragraph 0, in which the same targets and CDM/JI assumptions were assumed, but in which the transport sector was included in the EU ETS. The EUa price found for that option was € 90/tonne. This clearly illustrates that for these targets and scenarios, combining the sectors can be expected to reduce costs in the transport sector, and to lead to implementation of more cost effective CO_2 mitigation options. Based on the data used here, we would expect that the transport sector will then only reduce about 300 Mton CO_2 within the sector itself, the rest of the 670 Mton reduction required will be achieved in the other EU ETS sectors, where mitigation will be cheaper.

In scenario 2, we assume a reduction target of 28% in the road transport sector compared to 1990 emission levels and aviation emissions capped at 2005 levels. No CDM/JI is allowed. This would require a total of about 720 Mton CO_2 reduction in the transport sector in 2020. The graph shows that this would result in an emission allowance price in the trading system of the transport sector of about € 350/tonne CO_2. In contrast to the first scenario, this price is lower than the one found for this scenario in the combined EU ETS, which was € 480/tonne). This is due to insufficient CO_2 mitigation potential found in the current EU ETS sectors to achieve the 28% reduction target. Current EU ETS sectors would thus have to buy emission allowances from the transport sector, which would then have to reduce more than 28%.

4 Conclusions and recommendations

4.1 Conclusions

Cost curves

- Cost curves were derived for the current EU ETS sectors, for road transport and aviation. We were not able to derive a cost curve for maritime transport, due to lack of data.
- These cost curves are in line with findings in other literature: CO_2 abatement measures are more expensive in the transport sector than in the current ETS sectors. However, we also conclude that:
  - There is a significant potential of 'no regret' abatement measures, about 100 Mton in both the EU ETS and road transport sectors (a total of 200 Mton)[23]. These measures have higher economical benefit than costs. There can however exist non economic barriers that will prevent the measures from being taken, in particular in the transport sector.
  - Up to 180 Mton CO_2 reduction (per sector), there are no large differences between abatement costs of these sectors. At higher reduction levels, abatement costs in the transport sectors become significantly higher than in the ETS sectors. The curves seem to converge at about 800 Mton reduction. At this point, abatement costs in the ETS sectors rise steeply.
  - In the ETS sectors, the abatement potential is largely dependent on a limited number of reduction measures with very significant potential. If one or more of these options are withdrawn or limited for some reason (public acceptance, technical obstacles, etc.), this will increase the EUa price. In the transport sector, the abatement potential is much more equally distributed between a larger number of measures.

Effects of inclusion of transport in the EU ETS on the EUa price

- The effects were calculated for two different scenarios:
  - 22% emission reduction in 2020, with 50% CDM/JI.
  - 28% emission reduction in 2020, without CDM/JI.
- In the first scenario, inclusion of the transport sector in the EU ETS leads to an increase of the EUa price from € 50 to € 65 per tonne CO_2. These results seem to be relatively robust.
- In the second scenario, the target of 28% reduction can not be reached if the transport sector is not included in the EU ETS, according to the cost curve used. When transport is included, the target is achievable in our model, albeit at high EUa price: € 480 per tonne CO_2.
- The calculations show that the EUa price are very sensitive to the availability of (low cost) CDM and JI. The price will go up if less CDM/JI becomes available.
- The uncertainties involved in these calculations increase with the stringency of the CO_2 reduction. In general, we would expect the cost curves to be on the conservative side, overestimating costs of measures and underestimating

[23] Note that this 'no regret' potential is very dependant on oil price. In this report, € 35 per bbl was assumed.

the reduction potential. Some abatement measures (e.g. measures in the electricity using sectors and in maritime transport) could not be included in the calculations due to lack of data, and learning effects and innovation are probably underestimated. This is the main reason why the cost curves of the EU ETS sectors could not reach the target in the second scenario unless transport was included. In reality, this kind of very stringent climate policies could be expected to lead to new solutions in industry and society that fall outside the scope of current models and databases.

Effects on competitiveness of the EU industry

- Since we conclude that inclusion of transport in the EU ETS has an upward impact on EUa price, one can expect effects on competitiveness of the sectors involved. However, as long as the EUa price increase is limited (as in the first scenario), the overall effects are expected to be small. It should be noted, though, that this conclusion does not exclude significant effects on a sector or firm level. CO_2 intensive sectors will face a competitive disadvantage compared to less CO_2 intensive sectors, and firms that trade goods on a global market will face loss of competitiveness.

4.2 Recommendations

The current study provides, in our view, a first insight into the effects on EUa price that can be expected if the transport sector is included in the ETS. However, this study can by no means answer all the questions regarding this topic. Specifically, we recommend further research on the following issues:

- Integration of transport under ETS significantly increases the overall efficiency of the overall abatement targets in the EU. In practice the efficiency losses of extending and implementing the trading system to a sector with a large number of actors along with the competitive losses of industry facing higher CO_2 prices - possibly in the future partially under an auctioning regime - should be weighted against each other. Against the background of the signalled uncertainties we conclude that these first results - price rises within reasonable ranges under the condition of availability of sufficient and cheap CDM credits - give good reasons to focus further research on the costs and benefits of the integration option within one scheme.
- Costs curves and baseline emissions of the various sectors involved are crucial to the results of the calculations. However, data (especially in public literature) are scarce, and in some cases (namely maritime transport) lacking completely. Further research should, in particular, be carried out to determine potential and costs of abatement options in the various transport sectors and of end users of electricity.
- The non regret measures in the cost curves should be analysed further, in order to assess whether (or what part of) their potential can be realized with the emission trading system, and how this could be improved.
- We have only briefly analysed the potential effect on competitiveness of the EU industry in this study. Also, we have not yet assessed the effects of different EUa allocation options. Both issues deserve more attention. Since the impact of an ETS on costs to industry and thus on competitiveness

is dependent on the type of allocation used, this should be investigated further. We specifically recommend to further look into (allocation) options that may protect those branches of industry that are susceptible to global competition.

- Calculations were limited here to two policy scenarios. Clearly, many other scenarios could be designed and analyzed in order to asses possible effects, sensitivities and different policy options. Reduction targets and CDM potential and cost can be varied further, reduction targets can also be varied between sectors. In addition, since the potential and costs of (future) mitigation measures are uncertain, it is advisable to vary these as well and assess the effects.
- The potential benefits of combining this policy with other climate policies in transport, such as fuel efficiency regulations and climate neutral fuels policies should be investigated further.
- Apart from the policy options analysed here, it might also be worthwhile to further investigate the option of a separate emission trading system for the transport sector (possibly excl. international modes such as aviation and maritime transport). At higher abatement levels (where the cost curves of the various sectors diverge), this system may lead to implementation of less cost effective CO_2 abatement measures. However, it would have the advantage that the emissions of the sector can be capped without affecting the ETS sectors (by increasing the price of the EUa's). Negative effects on competitiveness can thus be avoided.

References

CE, 2007
Green4sure, Het Groene Energieplan, Achtergrondrapport
(incl. detailed analysis for industry, electricity and transport sectors)
Delft : CE Delft, 2007

CE, 2006
Dealing with Transport Emissions, An emission trading system for the transport sector, a viable solution?
Delft : CE Delft, 2006

CE, 2005
Giving wings to emission trading, Inclusion of aviation under the European Emission Trading System (ETS): Design and impacts
Delft : CE Delft, 2005

CE, 2002
External costs of aviation
Delft : CE Delft, 2002

EC, 2006
European energy and Transport, Trend to 2030 - update 2005
European Communities, 2006

Goodwin, 2004
Elasticities of Road Traffic and Fuel Consumption with Respect to Price and Income: A Review
P. Goodwin, J. Dargay, M. Hanley
Transport Reviews, Vol. 24, No. 3, 275-292, 2004

IVL, 2006
Greenhouse Gas Emissions Trading for the Transport Sector
Stockholm : IVL, Swedish Environmental Research Institute, 2006

Mc Kinsey, 2006
Mc Kinsey, EU ETS Review, Report on international competitiveness, 2006
EU DGE, 2006

Climate Strategies, 2007
Climate Strategies, Differentiation and dynamics of competitiveness impacts from the EU ETS, 2007 (Interim report)

IPCC, 2001
Third Assesment Report
Geneve : IPCC, 2001

IPCC, 2005
IPCC Special Report, Carbon Dioxide Capture and Storage
Geneve : IPCC, 2005

Neuhoff, 2006
Presentation: Actions to improve the current implementation of the ETS, Madrid, November 2006
www.elekctricitypolicy.org.uk

TenneT, 2007
TenneT
Kwaliteits- en capaciteitsplan 2008-2014
Arnhem : TenneT, 2005

CE Delft
Solutions for environment, economy and technology

Oude Delft 180
2611 HH Delft
The Netherlands
tel: +31 15 2 150 150
fax: +31 15 2 150 151
e-mail: ce@ce.nl
website: www.ce.nl
KvK 27251086

Price effects of incorporation of transportation into EU ETS

Annexes

Report

Delft, September, 2007

Author(s): M.J. (Martijn) Blom
B.E. (Bettina) Kampman
D. (Dagmar) Nelissen

In cooperation with: Ecofys BV (E. (Ernst) Worell and W. (Wina) Graus)

A Abatement measures in the EU ETS sectors

Sector	Sub sector	Measure
Energy supply	Iron and steel	CHP (Combined Heating Power) - Iron and Steel
Energy supply	Non ferrous metals	CHP - Non ferrous metals
Energy supply	Chemicals	CHP - Chemicals
Energy supply	Building materials	CHP - Building materials
Energy supply	Paper and pulp	CHP - Paper and pulp
Energy supply	Food, drink and tobacco	CHP - Food, drink and tobacco
Energy supply	Engineering goods	CHP - Engineering goods
Energy supply	Textiles	CHP - Textiles
Energy supply	Other industries	CHP - Other industries
Energy supply	Tertiary	CHP - Tertiary - Large
Energy supply	Tertiary	CHP - Tertiary - Medium
Energy supply	Tertiary	CHP - Tertiary - Small
Energy supply	Residential	CHP - Residential - Large
Energy supply	Residential	CHP - Residential - Small
Energy supply	Iron and steel	CHP - Iron and Steel (overcapacity)
Energy supply	Non ferrous metals	CHP – Non ferrous metals (implemented in situation of overcapacity)
Energy supply	Chemicals	CHP - Chemicals (implemented in situation of overcapacity)
Energy supply	Building materials	CHP - Building materials (implemented in situation of overcapacity)
Energy supply	Paper and pulp	CHP - Paper and pulp (implemented in situation of overcapacity)
Energy supply	Food, drink and tobacco	CHP - Food, drink and tobacco (implemented in situation of overcapacity)
Energy supply	Engineering goods	CHP - Engineering goods (implemented in situation of overcapacity)
Energy supply	Textiles	CHP - Textiles (implemented in situation of overcapacity)
Energy supply	Other industries	CHP - Other industries (implemented in situation of overcapacity)
Energy supply	Tertiary	CHP - Tertiary - Large (implemented in situation of overcapacity)
Energy supply	Tertiary	CHP - Tertiary - Medium (implemented in situation of overcapacity)
Energy supply	Tertiary	CHP - Tertiary - Small (implemented in situation of overcapacity)
Energy supply	Residential	CHP - Residential - Large (implemented in situation of overcapacity)
Energy supply	Residential	CHP - Residential - Small (implemented in situation of overcapacity)

Sector	Sub sector	Measure
Energy supply	Refineries	CHP - Refineries
Energy supply	Electricity and steam production	Replacement of capacity by natural gas fired combined cycles
Energy supply	Electricity and steam production	New capacity by natural gas fired combined cycles
Energy supply	Electricity and steam production	CO_2 removal
Energy supply	Electricity and steam production	Biogas
Energy supply	Electricity and steam production	Solid biomass
Energy supply	Electricity and steam production	Woody biomass sources
Energy supply	Electricity and steam production	Biowaste
Energy supply	Electricity and steam production	Geothermal electricity
Energy supply	Electricity and steam production	Hydro large scale
Energy supply	Electricity and steam production	Hydro small scale
Energy supply	Electricity and steam production	Photovoltaics
Energy supply	Electricity and steam production	Solar thermal electricity
Energy supply	Electricity and steam production	Tide & wave
Energy supply	Electricity and steam production	Wind onshore
Energy supply	Electricity and steam production	Wind offshore
Energy supply	Electricity and steam production	Biomass heat
Energy supply	Electricity and steam production	Geothermal heat
Industry	Iron and steel	Pulverised coal injection up to 30% in the blast furnace (primary steel)
Industry	Iron and steel	Recovery of process gas from coke ovens, blast furnaces and basic oxygen furnaces (primary steel)
Industry	Iron and steel	Application of continuous casting (steel)
Industry	Iron and steel	Efficient production of low temperature heat (heat recovery from high temperature processes) (steel)
Industry	Iron and steel	Thin slab casting techniques (steel)
Industry	Iron and steel	Miscellaneous I (Low cost tranche) (steel)
Industry	Iron and steel	Miscellaneous II (High cost tranche) (steel)
Industry	Building materials: Cement	Reduce clinker content of cement (cement)
Industry	Building materials: Cement	Improving wet process kilns (cement)
Industry	Building materials: Cement	Application of multistage preheaters and precalciners (cement)
Industry	Building materials: Cement	Optimisation of heat recovery of clinker cooler (cement)
Industry	Building materials: Glass	Improved melting technique and furnace design (glass)
Industry	Building materials: Glass	Batch and cullet preheating (glass)
Industry	Building materials: Ceramics	Miscellaneous (ceramics)
Industry	Building materials: Other Building materials	Miscellaneous - building materials (other building materials)
Industry	Pulp and paper: Pulp	Heat recovery in thermal mechanical pulping (pulp)
Industry	Pulp and paper: Paper	Pressing to higher consistency, e.g. by extended nip press (paper)
Industry	Pulp and paper: Paper	Improved drying, e.g. condensing belt drying (paper)
Industry	Pulp and paper: Paper	Reduced air requirements, e.g. by humidity control in paper machine drying hoods (paper)

Sector	Sub sector	Measure
Industry	Pulp and paper: Paper	Miscellaneous I (Low cost tranche) (paper)
Industry	Pulp and paper: Paper	Miscellaneous II (High cost tranche) (paper)
Energy Supply	Refineries	Reflux overhead vapour recompression (distillation) (refinery)
Energy Supply	Refineries	Power recovery (e.g. at fluid catalytic cracker) (refinery)
Energy Supply	Refineries	Improved catalysts (catalytic reforming) (refinery)
Energy Supply	Refineries	Miscellaneous I (Low cost tranche) (refinery)
Energy Supply	Refineries	Miscellaneous II (High cost tranche) (refinery)
Industry	Iron and steel	Integrated iron and steel
Industry	Iron and steel	electric arc steel
Industry	Building materials: Cement	Building materials: Cement
Industry	Building materials: Glass	Primary glass
Industry	Building materials: Glass	Secondary glass
Industry	Building materials: Ceramics	Building materials: Ceramics
Industry	Building materials: Other Building materials	Building materials: Other Building materials
Industry	Pulp and paper: Pulp	Pulp and paper: Pulp
Industry	Pulp and paper: Paper	Pulp and paper: Paper
Energy Supply	Refineries	Refineries