April 2002 ECN-C--02-022

ECONOMIC EFFECTS OF GRANDFATHERING CO_2 EMISSION ALLOWANCES

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Acknowledgement

On behalf of the Dutch Ministry of Housing, Spatial Planning and the Environment (VROM), the unit Policy Studies of the Energy research Centre of the Netherlands (ECN) has conducted the study on the 'Economic effects of grandfathering CO_2 emission allowances'. It has been registered at ECN under project number 7.7342.

The work has been overseen by a steering committee of representatives of the ministries of Housing, Spatial Planning, and the Environment; Economic Affairs; Finance as well as the Netherlands Bureau for Economic Policy Analysis (CPB), and the National Institute of Public Health and the Environment (RIVM).

Abstract

The present study analyses the potential capital transfers between economic sectors resulting from the grandfathering of tradable CO_2 emission allowances in Western Europe over the period 1990-2030. Four different policy variants of grandfathering are studied by means of a bottom-up optimisation model called MARKAL-MATTER3.0. In addition to the potential capital transfers, the study estimates the abatement costs of these policy variants.

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SUMMARY

S.1 Background and objective of present study

Emissions trading is a market-based instrument to achieve environmental objectives in a cost-effective manner. Faced with demanding CO_2 emission reduction targets as laid down in the Kyoto Protocol, several countries, including the Netherlands, are presently preparing the introduction of a trading system for CO_2 allowances. These allowances, which are denominated in tonnes of CO_2, entitle the holder to emit a corresponding amount of CO_2 during a specified period. Basically, emission allowances can be allocated to the participating parties by either auctioning or 'grandfathering', i.e. giving them for free. Recently, the proposal for an EU directive on emissions trading has expressed a preference for grandfathering. A major concern of grandfathering, however, is that some parties may receive more allowances than actually needed, while others may get too little. This may lead to trade in grandfathered allowances and, hence, to substantial capital transfers between these parties. As such transfers may affect the profitability and the competitiveness of participating companies, these transfers may raise questions or even opposition to allocating allowances for free, thereby reducing the socio-political acceptability of emissions trading based on grandfathering.

The main objective of the present study is to estimate the potential capital transfers between economic sectors resulting from the grandfathering of tradable CO_2 emission allowances in Western Europe over the period 1990-2030. Insight in the determinants of the size and direction of these capital transfers - notably which sectors will receive or pay a capital transfer - may be helpful in designing and implementing a scheme of grandfathering emission allowances that is more widely accepted.

S.2 Methodology

The present study distinguishes four major policy variants of grandfathering based on two design variables, namely (i) the question which sectors will receive allowances for free and which emissions will be covered by these allowances, and (ii) the specific method to account the amount of allowances that each sector will receive. With regard to the first design variable, two variants are distinguished:

- *Variant A.* In this variant, only the so-called 'exposed sectors' participate in emissions trading. They receive CO_2 allowances for free to cover exclusively their own emissions. In this study, the exposed sectors of variant A include: agriculture, basic metals, glass and ceramics, inorganic chemicals, iron and steel, paper, petrochemicals, power plants, and refineries. The other, 'sheltered sectors', including transport, energy extensive businesses and households, are assumed to be subject to other policy measures to curb their emissions by the same rate as the exposed sectors.
- *Variant B.* In this variant, all CO_2 emissions by all economic sectors are covered by a single system of grandfathering and trading CO_2 allowances. For administrative considerations, however, these allowances are all grandfathered to the exposed sectors in order to cover not only their own emissions but those of the sheltered sectors as well (i.e. a so-called 'upstream' system of emissions trading). As the CO_2 emissions of the sheltered sectors result primarily from the use of fossil fuels, in variant B three extra sectors of fossil energy suppliers, i.e. gas, liquid fuels and solid fuels, have been added to the above-mentioned classification of exposed sectors in variant A.

With regard to the specific accounting method of allocating emission allowances, the above-mentioned variants have been further subdivided by means of the following two systems:

- A *flat rate system* - or *F-system* - in which each participating sector receives an amount of allowances based on its past emissions of a certain reference year, subtracted by the overall reduction target for the economy as a whole (for instance, minus 8 percent compared to 1990 emission levels).
- A *proportional system* - or *P-system* - in which the sectoral allocation of allowances is based on projected baseline emissions for a certain target year, subtracted by the overall mitigation target for that year (for instance, minus 20 percent of projected baseline emissions in 2010).

As a result, four different policy variants of grandfathering emission allowances have been distinguished (i.e. AF, AP, BF and BP). Moreover, in order to give a rough estimate of the sectoral benefits of emissions trading, both AF and AP have been further subdivided into a variant excluding emissions trading - denoted as AF1 and AP1 - versus a variant including emissions trading (AF2 and AP2).

In addition to the policy variants mentioned above, capital transfers due to grandfathering depend on (i) trends in sectoral emissions, and (ii) differences in marginal abatement costs among sectors participating in emissions trading. With regard to the trends in sectoral emissions in Western Europe, the present study distinguishes a *baseline scenario* versus a so-called K*yoto Plus mitigation scenario*.

The baseline scenario provides estimates of CO_2 emissions over the period 1990-2030 based on (i) an exogenously fixed demand for final goods and services in a certain year, (ii) an optimal, i.e. least-cost use of technical production options which meet that demand, and (iii) no further abatement policies. The Kyoto Plus mitigation scenario, on the other hand, assumes additional policy measures to mitigate CO_2 emissions in Western Europe. More specifically, this scenario presumes that Western Europe will reduce its CO_2 emissions in 2010 by 8 percent - compared to 1990 - and by an additional 8 percent in 2020 and beyond, compared to 2010 (or by a cumulative 15.4 percent compared to 1990). In addition, the Kyoto Plus mitigation scenario assumes that (i) final demand is responsive to policy-induced price changes ('elastic demand'), and that (ii) an optimal mix of technical production annex abatement options is used to meet both this demand and the Kyoto Plus mitigation targets.

In order to analyse the size, direction and underlying determinants of sectoral capital transfers due to grandfathering emission allowances, the present study uses a partial equilibrium model called MARKAL-MATTER3.0. Besides estimating trends in sectoral emissions for the baseline and mitigation scenarios mentioned above, this model generates marginal abatement cost curves at the sector level of Western Europe, based on a large, comprehensive set of production annex abatement options covering both materials and energy flows. These cost curves or, more specifically, the differences in abatement costs among sectors, together with the initial grandfathering of allowances, determine which sectors will be either selling or buying allowances at different target levels of CO_2 mitigation.

Any initial grandfathering of allowances that does not correspond to equality of marginal abatement costs among economic sectors encourages allowance trading, and attendant capital transfers, between these sectors. On the one hand, sectors with relatively high abatement costs, i.e. higher than the market price of an allowance, will buy additional allowances, resulting in a capital outflow from these sectors. On the other hand, sectors with relatively low marginal abatement costs will sell their surplus of allowances, leading to a capital inflow towards these sectors. Equilibrium is reached when the marginal abatement costs of each participating sector is equal to the market price of the emission allowance.

S.3 Major results

Trends in sectoral emissions vary widely. Table S.1 provides the main trends in CO_2 emissions in Western Europe over the period 1990-2030 for both the baseline scenario and the Kyoto Plus mitigation scenario, as estimated by MARKAL-MATTER3.0. It shows that in the baseline scenario, total emissions of the exposed sectors in variant A are expected to decline autonomously, while those of the sheltered sectors are projected to increase very substantially. Within both groups of exposed and sheltered sectors, however, emission growth rates of individual sectors vary significantly. Due to these differences in growth performance, those sectors with emission growth rates that are lower than average will prefer a flat rate system of grandfathering, whereas those with emission growth rates higher than average will be in favour of a proportional system.

Table S.1 *CO_2 emissions in Western Europe over the period 1990-2030 (baseline and Kyoto Plus scenarios;[Mt])*

	1990	2010	2020	2030
Baseline scenario				
Exposed sectors (variant A)	1734	1719	1549	1590
Sheltered sectors (variant A)	1700	2212	2431	2648
All sectors (variants A and B)	3434	3932	3980	4238
Kyoto Plus mitigation scenario				
All sectors (variants A and B)	3434	3159	2906	2906

Only a small part of the allocated allowances is traded

In both the flat rate and the proportional systems of variant A, only a small part, about 10 percent, of the total, initially allocated amounts of emission allowances will be traded between the exposed sectors, whereas the major part, some 90 percent, of these allowances will be retained by the exposed sectors themselves to cover their emission needs. More or less the same conclusion applies to the proportional system of variant B as only 13 percent of the initially allocated allowances will be traded over the years 2010-30. The major exception concerns the flat rate system of variant B as the corresponding share amounts to, on average, 25 percent over the years 2010-30.

Capital transfers are, on average, modest but can be significant at sector level

As a percentage of the value of industrial turnover in Western Europe, capital transfers due to grandfathering emission allowances are, on average, modest at the aggregated level, but they can be more significant at the disaggregated level of individual sectors. For instance, in the flat rate system of variant B, under which capital transfers are the largest, they range from 0.17-0.23 percent of total industrial turnover in the years 2010-2030. Under this system, however, the sector 'liquid fuels' would have to buy additional allowances in 2030 worth almost 31 billion Euro95, which corresponds with a capital outflow of approximately 15 percent of its industrial turnover in that year. Similarly, under the flat rate system of variant A, under which capital transfers are the smallest, they vary between 0.01-0.03 percent of industrial turnover in Western Europe over the years 2010-2030. Under this system, however, the power sector would have to acquire allowances in 2030 worth 3.7 billion Euro95, corresponding to 2 percent of its turnover.[1]

[1] All estimates in the present report should be interpreted with due care because of the usual disclaimers regarding model assumptions and data uncertainties.

Capital transfers are sensitive to differences in policy variants of grandfathering

Capital transfers, and their underlying determinants, are sensitive to the differences of the four policy variants of grandfathering distinguished in the present study. As illustrated by Table S.2, the differences in the four policy variants lead to:

a. Differences in the total amount of allocated allowances, notably between variants A and B - due to differences in sectoral emissions covered - as well as between the sub-variants AF and AP, due to differences in growth rates of baseline emissions between exposed and sheltered sectors.
b. Differences in the total amount of allowances traded between sectors, depending on the above-mentioned factor (a), the specific allocation of the allowances among the participating sectors, and the differences in abatement costs - before trade - between these sectors.
c. Differences in the price per allowance. This price conforms to the marginal abatement costs of those sectors participating in allowance trading.
d. Differences in the total amount of capital transfers resulting from the multiplication of the above-mentioned factors (b) and (c).

Table S.2 *Emissions trading and capital transfers due to different policy variants of grandfathering, 2010-30*

	Initial allocation of allowances [Mt]			Total trade in allowances [Mt]			Price per emission allowance [Euro95/t CO_2]			Total capital transfers [billion Euro95]		
Variant	2010	2020	2030	2010	2020	2030	2010	2020	2030	2010	2020	2030
AF	1595	1468	1468	105	132	189	15	13	32	1.6	1.7	6.0
AP	1382	1131	1091	45	188	145	32	27	39	1.4	5.1	5.7
BF	3159	2906	2906	565	771	922	41	36	48	23.0	27.5	44.1
BP	3159	2906	2906	302	401	502	41	36	48	12.3	14.3	24.0

Moreover, as illustrated by Table S.3, differences in policy variants of grandfathering result also in differences in capital transfers at the disaggregated level of individual sectors, not only in the size of these transfers but occasionally also in the direction of the transfers (i.e. a change from a capital inflow to a capital outflow, or vice versa). In the year 2030, for instance, the iron and steel sector receives a capital inflow of 1.4 billion Euro95 under variant AF and of 7.7 billion Euro95 under variant BF, whereas it has to pay a capital outflow of 0.9 billion Euro95 under variant AP.

Table S.3 *Differences in sectoral capital transfers by different policy variants of grandfathering in 2030 (selected sectors)*[1]

	Variant A Flat rate (AF)	Variant A Proportional (AP)	Variant B Flat rate (BF)	Variant B Proportional (BP)
Basic metals	-1563	50	-3403	-256
Glass and ceramics	41	-89	-518	-111
Inorganic chemicals	-1255	-1148	-2525	-1594
Iron and steel	-1396	915	-7737	-3892
Paper	595	306	-2050	-725
Petrochemicals	1653	1939	1115	1057
Refineries	-1699	-4292	-4241	-6414

[1] A minus (-) indicates selling emission allowances and, hence, receiving a capital transfer.

Abatement costs vary by policy variant of grandfathering

Assuming the same Kyoto Plus mitigation rates for both the exposed and sheltered sectors, the marginal abatement costs vary widely among the policy variants of grandfathering distinguished in the present study. In 2020, for instance, marginal abatement costs of the exposed sectors in variant AF1, i.e. excluding emissions trading, vary from 0 in the basic metals industries to 152

Euro95 for the petrochemical industries, while under variant AP1 they vary from 1 Euro95 for the inorganic chemical industries to 245 Euro95 for the basic metals industries. These differences in marginal abatement costs encourage allowance trading among the exposed sectors, resulting in major efficiency gains until the marginal costs of the participating sectors are equal to the price of the emission allowance. Table S.4 shows that in 2020 the marginal abatement costs of the exposed sectors will be equalised at an allowance price of 13 Euro55 per tonne CO_2 in variant AF2 and of 27 Euro95/t in variant AP2.

Table S.4 *Marginal abatement costs under different policy variants of grandfathering in the period 2010-2030 (Kyoto Plus scenario, [Euro95/tonne])*[1]

	2010	2020	2030
F-system, variant A2, exposed sectors	15	13	32
F-system, variant A2, sheltered sectors	139	162	115
P-system, variant A2, exposed sectors	32	27	39
P-system, variant A2, sheltered sectors	87	90	110
Least-cost scenario, variant A, all sectors[2]	40	36	48
F-/P-system, variant B, all sectors	41	36	48

1 Marginal abatement costs refer to the so-called system costs, i.e. investments and operational costs, of the production technologies and abatement options considered.

2 In the least-cost scenario of variant A, all sectors are assumed to participate in emissions trading, like in variant B. As the input conditions of the model are almost identical in these two variants, they yield almost identical results with regard to marginal abatement costs.

Under variants AF2 and AP2, however, there are still major differences in marginal abatement costs between the groups of exposed sectors on the one hand and the group of sheltered sectors on the other. More specifically, Table S.4 shows that:

a. For the exposed sectors, the marginal abatement costs are lower under variant AF than AP, whereas the opposite applies to the sheltered sectors.
b. Under both variants AF and AP, the marginal abatement costs are significantly lower for the exposed than for the sheltered sectors, although the differences in marginal abatement costs between these groups of sectors are smaller under AF than AP.
c. Under variant B, both BF and BP, the marginal abatement costs of all sectors are fully equalised and nearly identical to the marginal costs of all sectors in the so-called ‘least-cost scenario’ of variant A, as both the latter variant and variant B are based on the same assumption of full, unrestricted emissions trading within a single market covering the CO_2 emissions of all sectors.

These findings are confirmed by a comparison of the total abatement costs for the policy variants distinguished in the present study (where total abatement costs, excluding transaction costs, are defined as the total changes in consumer and producer surpluses). This comparison reveals that total abatement costs over the period 2010-2030 are: (i) significantly lower for variants including allowance trading (AF2 and AP2) than for variants excluding allowance trading (AF1 and AP1), (ii) substantially lower for variant AP than for variant AF, and (iii) far lower for variant B than for variant A (for both the F- and P-systems of grandfathering). Moreover, the total abatement costs of variants BF and BP are almost equal to those of the least-cost mitigation scenario of variant A, implying that under these variants total abatement costs are the lowest.

S.4 Main conclusions and policy implications

Based of the above-mentioned results with regard to the capital transfers of different policy variants of grandfathering and the abatement costs of these variants, the following main conclusions and policy implications can be drawn:

a. Capital transfers among economic sectors due to grandfathering are sensitive to the policy variants considered as it can effect both the size and the direction of these transfers. As a percentage of industrial output, however, these capital transfers are generally rather modest, although they are more substantial in variant B, notably BF, than in variant A. Moreover, in all policy variants, they can be quite significant at the disaggregated level of individual sectors.

b. Whereas the capital transfers in both variants BF and BP are generally higher than in variants AF and AP, the total abatement costs, excluding transaction costs, are usually substantially lower in the former than in the latter. This implies that from a cost perspective, either variant BF or BP should be preferred as both variants result in the same, least-cost situation. However, if for one reason or another variant A is chosen, total abatement costs will be lower under variant AP than under variant AF. The latter result can be explained by the dual fact that (i) under variant AP the sheltered sectors have to reduce less CO_2 emissions than under variant AP, and that (ii) the abatement costs of the sheltered sectors are generally higher than those of the exposed sectors.

c. Although each sector will prefer variant B above variant A - as the former results in the most efficient situation for each sector - those sectors with a growth rate of their baseline emissions below average, i.e. mostly exposed sectors, will prefer allocation system F, whereas those sectors with a growth performance above average, i.e. mostly sheltered sectors, will prefer allocation system P. This result can be ascribed to the fact that allocation system P is based on projected, future emissions and, hence, accounts for expected growth in these emissions, whereas allocation system F is based on past emissions and, therefore, does not account for future trends in CO_2 emissions.

1. INTRODUCTION

1.1 Background

Emissions trading is a market-based instrument to enhance the cost-effectiveness of achieving environmental objectives such as the mitigation of GHG emissions. At present, Denmark and a few private companies (Shell, BP) have already launched a modest system of GHG emissions trading, while several countries are either investigating or preparing the introduction of a national system of trading emission allowances in the next few years as part of meeting their GHG mitigation commitments as agreed in the Kyoto Protocol (e.g. Australia, Canada, the United Kingdom, and the Netherlands).[2] In addition, the European Commission (2001) has launched a proposal for a Directive to introduce emissions trading within and between the EU Member States, starting from the year 2005.

One of the major issues of introducing a system of emissions trading concerns the initial allocation of emission allowances to the participants of such a system. Basically, emission allowances can be allocated to the participating parties by either auctioning or 'grandfathering', i.e. giving them for free. For practical reasons, preference is often given to a system of grandfathering, as it does not imply an income transfer from the private to the public sector (or some mechanism to recycle this transfer to the private sector).

A major concern of grandfathering, however, is that some parties may receive more allowances that actually needed, while others may get too little. This may lead to trade in grandfathered allowances and, hence, to substantial capital transfers between these parties. As such transfers may affect the profitability and the competitiveness of participating companies, these transfers may raise questions or even opposition to allocating allowances for free, thereby reducing the socio-political acceptability of emissions trading based on grandfathering.

1.2 Objective, scope and limitations of the present study

The main objective of the present study is to estimate the potential capital transfers between economic sectors resulting from grandfathering tradable CO_2 emission allowances in Western Europe over the period 1990-2030.[3] Insight in the determinants of the size and direction of these capital transfers - notably which sectors will receive or pay a capital transfer - may be helpful in designing and implementing a scheme of grandfathering emission allowances that is more widely accepted.[4]

The present study will analyse the potential capital transfers of four different policy variants of grandfathering tradable CO_2 emission allowances, based on two design variables, namely (i) the question which sectors will receive allowances for free and which emissions will be covered by these allowances, and (ii) the specific method to account the amount of allowances that each sector will receive.

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[2] In the Netherlands, the so-called 'CO_2 Trading Committee', or 'Committee Vogtländer', has prepared an advice to the Dutch government on the desirability and feasibility of a national system for CO_2 emissions trading. For details, see CO_2 Trading Committee (2002).

[3] Western Europe includes all countries of the European Union (EU) as well as Norway, Switzerland and Iceland.

[4] Despite recent developments regarding the Kyoto Protocol (such as the withdrawal of the United States or the recent decisions at CoP-6 and CoP-7), the major findings of the present study do still hold as these developments have affected neither the mitigation targets of the countries of Western Europe nor any other major assumptions of the present study.

With regard to the first design variable, two variants are distinguished:

- *Variant A.* In this variant, only the so-called ‘exposed sectors’ participate in emissions trading. They receive allowances for free to cover their own emissions. In this study, the exposed sectors of variant A include: agriculture, basic metals, glass and ceramics, inorganic chemicals, iron and steel, paper, petrochemicals, power plants, and refineries. The other, ‘sheltered sectors’, including transport, small businesses and households, are assumed to be subject to other policy measures to curb their emissions by the same rate as the exposed sectors.
- *Variant B.* In this variant, all CO_2 emissions by all economic sectors are covered by a single system of grandfathering and trading CO_2 allowances. For administrative considerations, however, these allowances are all grandfathered to the exposed sectors in order to cover not only their own emissions but those of the sheltered sectors as well (i.e. a so-called ‘upstream’ system of emissions trading). As the CO_2 emissions of the sheltered sectors result primarily from the use of fossil fuels, in variant B three extra sectors of fossil energy suppliers, i.e. gas, liquid fuels and solid fuels, have been added to the above-mentioned classification of exposed sectors in variant A.

With regard to the specific method of grandfathering allowances, the above-mentioned variants have been further subdivided by means of the following two accounting systems:

- A *flat rate system* - or *F-system* - in which each participating sector receives an amount of allowances based on its past emissions of a certain reference year, subtracted by the overall reduction target for the economy as a whole (for instance, minus 8 percent compared to 1990 emission levels).
- A *proportional system* - or *P-system* - in which the sectoral allocation of allowances is based on projected baseline emissions for a certain target year, subtracted by the overall mitigation target for that year (for instance, minus 20 percent of projected baseline emissions in 2010).

As a result, four different policy variants of grandfathering emission allowances have been distinguished (i.e. AF, AP, BF and BP). Moreover, in order to give a rough estimate of the sectoral benefits of emissions trading, both AF and AP have been further subdivided into a variant excluding emissions trading, denoted as AF1 and AP1, versus a variant including emissions trading (AF2 and AP2).

In order to analyse the capital transfers due to the introduction of grandfathering emission allowances at the sector level of Western Europe, this study has used a partial equilibrium model called MARKAL-MATTER3.0. The major reason of applying this model is that it is able to generate marginal abatement cost curves at the sector level of Western Europe, based on a large, comprehensive set of GHG reduction options covering both materials and energy flows. These cost curves or, more specifically, the differences in abatement costs among economic sectors are a major determinant of the potential capital transfers resulting from grandfathering emission allowances.

Another determinant of such transfers concerns the emission reduction target, or, to put it slightly different, the difference between the baseline emission scenario and the mitigation scenario. With regard to the latter, the analysis of the present study is based on the so-called ‘Kyoto Plus’ mitigation scenario. This scenario implies that for the year 2010 the reduction commitments of the countries in Western Europe are based on the Kyoto Protocol (i.e. 8 percent below 1990 emission levels), whereas it is assumed that these countries will further reduce their emissions by an additional 8 percent in the year 2020 and beyond, compared to 2010.[5]

[5] In MARKAL-MATTER3.0, the year 2010 stands for the period 2005-2014, the year 2020 for the period 2015-2024, the year 2030 for the period 2025-34, etc.

As noted above, the analysis of the present study will be conducted at the sector level for Western Europe as a whole and, hence, not at a more disaggregated level of individual countries of firms. Another limitation of the present study is that the analysis will be mainly focussed on assessing the capital transfers due to grandfathering emission allowances and, hence, other socio-economic aspects of grandfathering will not or hardly be considered.[6] Moreover, although MARKAL-MATTER3.0 is able to cover other GHGs besides CO_2, the analysis will be restricted to the latter gas only, as policy makers are at present predominantly interested in introducing a system of emissions trading covering only CO_2. In addition, whereas the study is focussed on the analyses of emissions trading within Western Europe, it neglects the potential effects of other policy instruments, such as Joint Implementation (JI) or the Clean Development Mechanism (CDM), to achieve GHG reduction commitments, including the impact of these instruments on the capital transfers due to grandfathering emission allowances. Finally, the analysis of the present study is subject to other, usual assumptions and limitations such as the assumption of perfect competition and the uncertainty regarding the data on emissions levels and costs of mitigation options in the long run.

1.3 Outline of the study

The contents of the present study runs as follows. First of all, Chapter 2 will consider some methodological aspects of this study, including a discussion of some theoretical reflections on emissions trading (Section 2.1), the MARKAL-MATTER3.0 model (Section 2.2), the policy variants of grandfathering emission allowances considered in the present study (Section 2.3), and the emission scenarios used in this study (Section 2.4).

Subsequently, Chapters 3 to 5 will outline the major findings of the model analysis conducted as part of the present study. Chapter 3 will discuss the results with regard to the estimated capital transfers resulting from variant A of grandfathering tradable emission allowances, whereas Chapter 4 will analyse similar findings referring to variant B. In addition, the abatement costs of both variants will be compared in Chapter 5.

Finally, Chapter 6 will briefly summarise the main conclusions and policy implications of the present study.

6 Another possible economic effect of grandfathering emission allowances concerns the opportunity of creating market power and, hence, the restriction or rationing of economic production, resulting in higher output prices and additional (‘excess’) profits to the recipients of grandfathered allowances. This effect is not considered in the present study, but has been analysed by Bovenberg and Goulder (2000).

2. METHODOLOGY

2.1 Emissions trading: a theoretical explanation

The economic effects of grandfathering tradable emission allowances can be illustrated by means of Figure 2.1. This figure presents the marginal abatement cost curves for two sectors, i.e. MCI and MCII, with the amounts of emission reductions reflected on the X-axis and the corresponding marginal abatement costs on the Y-axis. The marginal cost curve for sector I (MCI) originates from the left corner of Figure 2.1, whereas MCII starts from the right corner. The area or integral below the marginal cost curve represents the total abatement costs of the sector concerned.

The overall mitigation policy objective for the two sectors is indicated by the amount OQ on the X-axis, with each point on this axis representing the allocation of this objective among the two sectors involved. At point Q', for instance, sector I is obliged to reduce its emissions by the amount OQ' and sector II by the amount QQ'. In a system of grandfathering emission allowances, this point Q' corresponds to a specific, initial allocation of allowances among sectors I and II. In principle, each point on the X-axis - and the corresponding grandfathering of allowances - can be chosen by policy makers as the overall policy objective (i.e. reducing GHG emissions by the amount OQ) will be achieved in any case.

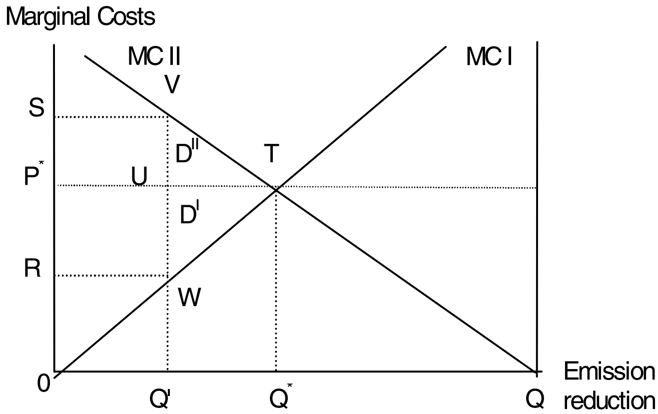

Figure 2.1 *Emissions trading*

At the sector level, however, the economic effects of a system of tradable emission allowances will differ depending on the initial grandfathering of emission allowances among the sectors involved. These effects can be illustrated by distinguishing two cases, i.e. case 1 in which no trade in emission allowances among sectors is allowed, and case 2 in which such emissions trading is permitted

In case 1, assuming an initial grandfathering of emission allowances corresponding to point Q' of Figure 2.1, the marginal abatement costs of sector I are significantly lower than in sector II (indicated by points R and S, respectively). These differences in marginal abatement costs provide a major incentive for emissions trading, as both sectors will benefit from such trading. In case 2, assuming a similar grandfathering of allowances, emissions trading will continue until the marginal abatement costs are equalised between the sectors involved, resulting in the most efficient allocation of sectoral emission reductions in order to achieve the overall mitigation target of OQ. In Figure 2.1, this situation is reflected by the intersection of the two abatement cost curves MCI and MCII (i.e. point T). At this point, the marginal abatement costs of sectors I and II are equal to the equilibrium price (P^*) of the allowances traded between these sectors (based on the assumption of a well functioning market with no trade restrictions and no transaction costs).

At price level P^*, sector I will reduce its emissions by an amount OQ^* and sell its surplus of grandfathered emission allowances (Q^* - Q'), whereas sector II will mitigate its emissions by QQ^* and buy the resulting deficit of emissions allowances (Q^* - Q'). As a result, a so-called '*capital transfer*' will take place from sector I to II, equal to $P^*(Q^* - Q')$, i.e. area $Q'Q^*TU$ in Figure 2.1. Both the size, the direction and the number of these sectoral capital transfers depend on several factors, including (i) the sector emissions in the baseline scenario, (ii) the overall emission limitation objective, (iii) the initial grandfathering of emission allowances among sectors, and (iv) the differences in marginal abatement costs between sectors.

Capital transfers resulting from the introduction of grandfathering tradable emission allowances should be distinguished from a related economic effect of such a system called *'trade benefits'*. Whereas capital transfers are paid by the one sector that buys allowances and received by the other selling allowances, trade benefits accrue to both sectors participating in such a system.

In Figure 2.1, sector I receives a capital transfer equal to area $Q'Q^*TU$ by selling a surplus amount of emission allowances $Q'Q^*$, but in order to generate this surplus it has to incur additional abatement costs equal to area $Q'Q^*TW$, resulting in a net trade profit of area TUW (equal to D^I). On the other hand, although sector II has to pay the capital transfer $Q'Q^*TU$ for buying the amount of emission allowances $Q'Q^*$, it also benefits from this transaction as it lowers its sectoral abatement costs by area $Q'Q^*TV$, leading to net cost savings equal to area TUV (or D^{II}). The area D^I can be assessed simply by means of the formula:

$$\tfrac{1}{2}\times(P^* - R)\times(Q^* - Q'),$$

while the area D^{II} can be roughly estimated by a similar formula:

$$\tfrac{1}{2}\times(S - P^*)\times(Q^* - Q').$$

Depending on the slopes of the marginal cost curve, the net cost savings of those sectors buying emission allowances may even be larger than the net profits of those sectors selling emission credits. Moreover, depending on the equilibrium price of the emission allowance, these trade benefits may even be more significant than the capital transfers among sectors resulting from grandfathering tradable emission allowances.

2.2 The MARKAL-MATTER3.0 model

2.3 General characteristics

In order to assess the capital transfers and trade benefits of a system of grandfathering CO_2 emission allowances among economic sectors in Western Europe, this study has used a partial equilibrium model called MARKAL-MATTER3.0. This analytical tool is a multi-sectoral, linear programming optimisation model to identify the least-cost combinations of technological production and innovation options that satisfy a specified level of demand for goods and services by maximising the sum of producers and consumers surpluses considered over a long term period covering several decades. This process of identifying and optimising input-output relationships can be subjected to certain policy constraints, notably the achievement of certain specified GHG reduction objectives.

MATTER3.0 is an extension of the MARKAL model, which was originally designed as a tool to analyse energy technologies and related policies within the context of a comprehensive energy system of a certain country or region.[7] Conventional energy systems models analyse energy flows from the supply of primary energy over conversion and transformation into final energy services and the subsequent final energy use in economic sectors. Although these models include industrial use of energy, for instance, to produce materials, and hence, cover energy efficiency gains in the production of materials, they do not analyse the effects of other changes in the life cycle of materials such as increased materials efficiency, materials substitution, and recycling of waste materials (Kram, et. al. 2001). These changes in the production and waste management of materials, however, are usually attended by significant GHG effects (Gielen, 1999).

In MARKAL-MATTER, both the energy and materials flows of an economic system are covered by including information on the physical inputs, economic costs and other characteristics, such as waste volumes or GHG emissions, of all major technological options to generate energy services, materials and end-use products (see Figure 2.2). As the energy and materials systems are intricately interwoven, such an integrated approach offers the advantage that the interdependencies between these systems can be analysed comprehensively by means of a formalised model, thereby reducing analytical shortcomings. Moreover, by adding materials flows to the model, the number of technological (improvement) options is expanded strongly, thereby enlarging the scope of policy options to reach objectives such as reducing GHG emissions more cost-effectively, for instance through waste management or product recycling.

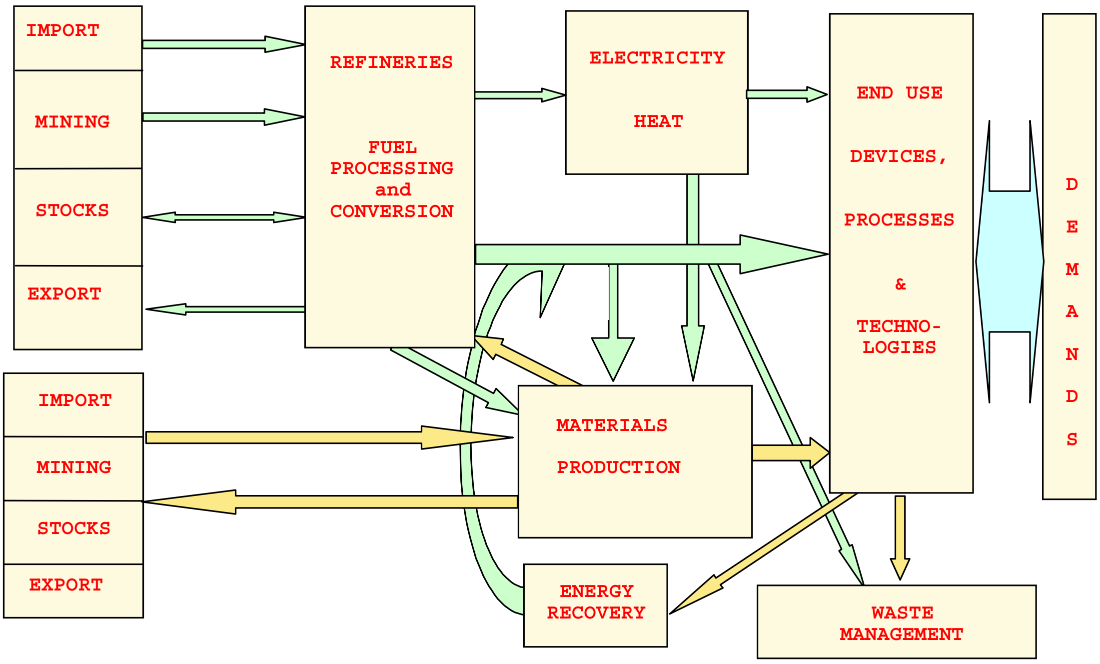

Figure 2.2 *Chart flow of MARKAL-MATTER*

Whereas version 1.0 of MARKAL-MATTER covered both the energy and materials systems of an economy, version 2.0 added a land use and food production module. In both versions, the choice of technological options is responsive to changes in investments and operation costs. A weak point of these versions, however, is that the final demand for output products, and hence, the derived demand for inputs such as energy services and materials, is exogenously defined and

[7] MARKAL-MATTER3.0 and its previous versions are extensively explained and documented on the Internet, see (http://www.ecn.nl/unit_bs/etsap/markal/matter). For a brief description of MARKAL-MATTER3.0, see also Franssen (1999), Gielen and Pieters (2001), and Kram, et al. (2001).

does not respond to price changes (i.e. the so-called 'fixed demand case' in which the levels of demand are exogenous extrapolations of present-day use, based on a certain demand scenario).

In version 3.0 of MARKAL-MATTER, the *initial* or baseline demand for goods and services is still exogenously extrapolated, but, in contrast to its two previous versions, this demand is responsive to price changes. These price changes can be induced by e.g. a GHG penalty (which may represent either the mitigation costs of GHG regulation, the price of a GHG tradable allowance, a CO_2 tax rate or just the carbon shadow price). This responsiveness is achieved by introducing price elasticities into the specification of the demand functions of the goods and services concerned (i.e. the so-called 'elastic demand case' of MARKAL-MATTER). The major effect of introducing elastic demand categories is that a certain GHG mitigation target is not only achieved by changing the production processes of goods and services through GHG abatement options in the energy and materials systems, but also by reducing the demand and, hence, the supply of products that are price-sensitive to GHG penalties (Franssen, 1999/Gielen and Pieters, 2001).

The major reason for applying MARKAL-MATTER3.0 for the present study is that this model is able to generate marginal abatement cost curves at the sector level of Western Europe, based on a large, comprehensive set of GHG reduction options covering both materials and energy flows. In order to construct these curves, the MARKAL-MATTER3.0 model is run under different constraints corresponding to different levels of CO_2 abatement such as 5, 10 or 15 percent of sectoral baseline emissions in a specific target year. For each level of carbon reduction (q) the corresponding marginal abatement costs - or *sectoral shadow prices of carbon* (p) - are an output of the model runs. By joining the points (i.e. the co-ordinates of q and p) together and fitting a line to these points, marginal abatement cost curves can be designed - and econometrically estimated - for each sector distinguished in MARKAL-MATTER3.0.[8] These cost curves are similar to those illustrated in Figure 2.1, although the cost curves of MARKAL mostly have an irregular, stepwise character rather than being a straight, upward-sloping line. In this study, the curves generated by means of MARKAL-MATTER3.0 have been used to estimate the volume of emissions trading among sectors, the capital transfers involved and the trade benefits resulting from a system of grandfathering CO_2 emission allowances at the sector level in Western Europe.

2.3.1 Underlying assumptions and limitations

Before presenting the results of the model calculations in Chapter 3, some general assumptions and limitations of MARKAL-MATTER3.0 should be noted:

- The model does not incorporate trade, rebound or other feedback effects at the macroeconomic level resulting from GHG policy-induced price changes).
- The model is based on the assumption of an ideal market economy with rational behaviour, perfect information and perfect foresight during the time horizon considered.
- The choice of technological options is based on cost minimisation but does not account for implementation barriers or other socio-political considerations. Assumptions with respect to such limitations, however, can be inserted, but have not been regarded as relevant for this study.
- Assumptions have been included with regard to cost reductions of technological options over time by means of so-called learning curves.
- The analysis is conducted at the sector level for OECD Western Europe as a whole and, hence, not at a more disaggregated level of individual firms or countries, thereby ignoring potential differences in emissions and marginal abatement costs within sectors or between individual countries and firms.

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8 MARKAL-MATTER3.0 is also able to construct marginal cost curves the other way round, i.e. setting a certain shadow carbon tax (p) and subsequently assessing the corresponding abatement level (q) for each sector.

In addition, some specific model adjustments and restrictions within the context of the present study should be observed:

- Although MARKAL MATTER3.0 may cover other GHGs than CO_2, within the context of the present study, i.e. a CO_2 emissions trading system, the analysis has been restricted to this gas only (accounting for about 80 percent of all GHGs in Western Europe).
- Total and sectoral CO_2 emissions recorded in this study account for the carbon stored in either materials (feedstocks and woody products) or biomass (sinks) and are, hence, net emissions.
- The original model has been adjusted by new demand projections based on the Market Drive scenario rather than the Rational Perspective scenario. The former scenario results in higher demand figures due to a higher rate of technological changes.[9]
- The import-export movements of electricity, a potential source of emission mitigation in reduction scenarios, are frozen for the time periods considered on the last known level (i.e. the 1998-based IEA figures). As a result, these movements do not respond to any change in the price or GHG penalty of electricity.
- Within MARKAL-MATTER3.0, price elasticities of demand may vary both over time and per demand category considered. In the present study, however, they have been set a constant, uniform level of -0.5 for all periods and most demand categories considered.[10]

2.4 Policy variants of grandfathering CO_2 allowances

A major policy issue with regard to the implementation of a system of tradable CO_2 emission allowances concerns the initial allocation of these allowances. Basically, two different systems of allocating CO_2 allowances can be distinguished:[11]

- *A Cap and Trade (CT) system.* In a CT system, a periodically fixed amount of CO_2 allowances is allocated among the participants by either auctioning these allowances, distributing them for free (i.e. grandfathering), or a combination of auctioning and grandfathering. If a participant emits more CO_2 than the initially allocated allowances, then supplementary allowances must be purchased. On the other hand, if a participant emits less CO_2, the surplus of allowances may be sold.
- *A Performance Standard Rate (PSR) system.* In such as system, participants must satisfy a certain CO_2 emission norm or reference value per unit input or output, called the Performance Standard Rate (PSR). Multiplying this PSR with the production volume results in the total assigned amount of CO_2 emissions. As this amount depends on the growth of production volume, it is called a relative cap (in contrast to the absolute cap of a CT system). If a participant emits less CO_2 per unit input or output than the PSR, then the surplus of the assigned amount of CO_2 emissions may be sold. On the other hand, if a participant emits more CO_2 than the PSR, than the additionally needed allowances have to be purchased.

In this study, the analysis will be restricted to a cap and trade system based on grandfathering emission allowances. Within such a system, however, several policy variants can be distinguished. First of all, two different systems of grandfathering emission allowances can be distinguished:

- A *flat rate system* - or *F-system* - in which each participating sector receives an amount of allowances based on its past emissions of a certain reference year, subtracted by the overall reduction target for the economy as a whole. In an F-system, each participating sector is

[9] Both scenarios are derived from 'European Energy to 2020 – a scenario approach' (CEC, 1996).

[10] Relevant, i.e. long-term future demand elasticities for Western Europe are scarce, but the available evidence suggests that the value of -0.5 may be regarded as an upper limit, notably for energy services, as most estimated demand elasticities vary between -0.1 and 0.5. Demand elasticities of materials, however, may be higher as suggested by recent research (Franssen, 1999; Kram, et al. 2001). Moreover, demand elasticities are generally higher in the medium or long term than in the short run.

[11] See for more details on the advantages and disadvantages of these systems of allocating CO_2 allowances EZ (1999), IVM (2001) or KPMG (2001a and 2001b).

obliged to reduce its emissions in the target year by the same rate compared to its emissions in a reference year. In line with the overall Kyoto target for Western Europe, this rate has been set at -8 percent for the target year 2010, representing the average target year of the first budget period (2008-2012), compared to the emission levels of the reference year 1990. This implies that each sector receives a quantity of CO_2 allowances for the year 2010 equal to 92 percent of its emissions in 1990. The major advantage of an F-system is that it is rather straightforward, as it is based on data of past or present emissions rather than on more uncertain and, hence, more debatable projections of future emissions. On the other hand, the major disadvantage is that an F-system does not consider past or present differences in sectoral efforts to mitigate CO_2 emissions and/or future differences among sectors regarding emissions trends and abatement costs.
- A *proportional system* - or *P-system* - in which the sectoral allocation of allowances is based on projected baseline emissions for a certain target year, subtracted by the overall mitigation target for that year. In a P-system, each participating sector is obliged to reduce its emissions in the target year by the same rate as the overall reduction target for all sectoral emissions of that year. For instance, if the total emission cap for a target year is set at 80 Mt CO_2 and the projected baseline emissions of all sectors are estimated at 100 Mt CO_2, each sector participating in a P-system has to reduce its projected baseline emissions by 20 percent, regardless its expected sectoral emission growth rate. This means that each sector receives a quantity of CO_2 allowances equal to 80 percent of its projected baseline emissions in the target year. Compared to an F-system, the major advantage of a P-system is that the latter accounts for differences in growth rates of sectoral baseline emissions. The major disadvantage, however, is that it is based on (uncertain) projections of baseline emissions and that in such a system each sector has an incentive to overestimate its projected baseline emissions for the target year.

In addition, different variants of grandfathering emission allowances can be distinguished based on the question whether and how economic sectors will participate in such a system. This issue is particularly relevant with regard to the question whether and how so-called 'sheltered' sectors such as transport (notably motorists) or the residential sector (i.e. households) should be part of grandfathering CO_2 allowances. Although including these sectors may be attractive, as they account for a major share of total CO_2 emissions, the allocation of allowances and monitoring of actual emissions may be administratively complicated, resulting in high transaction costs. In his respect, the present study distinguishes the following variants:

- *Variant A,* in which only the exposed sectors receive allowances to cover their own emissions, subdivided into a variant *without* emissions trading among the exposed sectors (*variant A1*) and a variant *with* emissions trading (*variant A2*). It is assumed, however, that the sheltered sectors as a whole have to reduce their emissions by the same (flat/proportional) rate as the exposed sectors, either through regulation or by setting a specific carbon tax on the CO_2 emissions of the sheltered sectors. It should be noted, however, that variant A1 is not a 'policy variant' in the context of emissions trading. It has been included only to give an indication of the sectoral benefits resulting from emissions trading.
- *Variant B*, in which the exposed sectors receive allowances to cover their own emissions as well as those of the sheltered sectors.[12] Hence, in this variant, the sheltered sectors participate in a system of tradable CO_2 allowances indirectly, i.e. by allocating the CO_2 emissions and corresponding CO_2 allowances of the sheltered sectors to their suppliers of electricity, gas, coal, oil, etc.[13] This variant has been included because on practical, cost-administrative

[12] A potential variant B that excludes emissions trading among sectors has not been analysed as this variant is considered to be even less policy relevant than variant A1. From a policy point of view, it seems rather unreal to set a cap of emission allowances on energy suppliers - covering also the emissions of their end-users in other, sheltered sectors - but not allowing these suppliers to trade these allowances with these sectors (resulting in a limited set of mitigation options and, hence, high marginal abatement cost at the sector level of energy suppliers).

[13] Moreover, in the MARKAL-MATTER3.0 model simulation of variant B, the technical abatement options to reduce the CO_2 emissions of the sheltered sectors have also been attributed to the exposed sectors.

grounds it might be difficult to ensure a direct participation of sheltered sectors in emissions trading.

In general, exposed sectors can be defined as energy intensive sectors that are subject to heavy international competition, whereas sheltered sectors either operate at relatively low energy costs or experience little competition with overseas companies. Table 2.1 presents an enumeration of the exposed and sheltered sectors as applied in this study, either in variant A or in variant B. In variant A, CO_2 emissions of the power sector refer to electricity deliveries to both exposed and sheltered sectors. In variant B, on the contrary, CO_2 emissions of the sheltered sectors are imputed to their energy suppliers - with the latter being part of the exposed sectors - whereas CO_2 emissions resulting from electricity deliveries to the exposed sectors have been allocated directly to these sectors. Hence, besides three additional sectors of fossil fuel suppliers - 'gas', 'liquid fuels' and 'solid fuels' - the group of exposed sectors in variant B includes a new sector, called 'electricity', which accounts exclusively for the power supply to the sheltered sectors. Moreover, as all CO_2 emissions in variant B are imputed to only the exposed sectors, the sheltered sectors will not be considered in these variants.

Table 2.1 *Enumeration of exposed and sheltered sectors in different variants used in present study*

Variant A	Variant B
Exposed sectors	*Exposed sectors*
Agriculture	Agriculture
Basic metal industries	Basic metal
Glass and ceramics	Electricity
Inorganic chemical industries	Gas
Iron and steel	Glass and ceramics
Paper	Inorganic chemicals
Petrochemical industries	Iron and steel
Power plants (including waste incineration)	Liquid fuels
Refineries	Paper
	Petrochemicals
Sheltered sectors	Refineries
Commercial & service sector	Solid fuels
Construction materials (including cement)	
Freight transport	
Other transport	
Public transport	
Residential sector	
Rest industry	

By combining the different grandfathering systems and variants discussed above, six different cases can be distinguished (see also Table 2.2):

- Cases 1-2: an F-system, variants AF1 and AF2.
- Cases 3-4: a P-system, variants AP1 and AP2.
- Case 5: an F-system, variant BF.
- Case 6: a P-system, variant BP.

Table 2.2 *Cases of grandfathering CO_2 allowances considered in present study*

		Flat rate	Proportional
Variant A	Excluding trade (A1)	Case 1 (AF1)	Case 3 (AP1)
	Including trade (A2)	Case 2 (AF2)	Case 4 (AP2)
Variant B	Including trade (B)	Case 5 (BF)	Case 6 (BP)

These cases have been analysed by means of the MARKAL-MATTER3.0 model. Tables presenting details of each case can be found in Annex B. The major findings of the cases analysed will be discussed in Chapters 3 to 5 below.

2.5 Emission scenarios

Capital transfers among sectors do not only depend on the modalities of grandfathering, but also on the level of emission reductions and the resulting marginal abatement costs at the sector level. With regard to the level of emission reductions, the present study basically applies three emission scenarios, i.e. a reference or baseline scenario and two mitigation scenarios called 'Kyoto Forever' and 'Kyoto Plus', respectively.

The baseline scenario provides estimates of CO_2 emissions at the sector level of Western Europe based on the least-cost solution to meet the exogenously given level of final demand in the absence of additional mitigation policies. It assumes technological innovations that are just extrapolations of present trends, resulting in autonomous changes in CO_2 emissions.

The 'Kyoto Forever' mitigation scenario is based on the assumption that the countries of Western Europe reduce their overall CO_2 emissions in 2010 by 8 percent - compared to the level of 1990 - and that in the years thereafter total CO_2 emissions will not surpass the level of 2010. The 'Kyoto Plus' mitigation scenario, on the other hand, assumes that the countries of Western Europe reduce their CO_2 emissions by 8 percent over the period 1990-2010 and by an additional 8 percent over the years 2010-20, i.e. by 15.4 percent in 2020 compared to 1990. In the years thereafter, CO_2 emissions are assumed not to exceed the level of 2020.

The baseline and mitigation scenarios of both policy variants A and B will be considered in more detail in Chapters 3 and 4.

3. EMISIONS TRADING BETWEEN EXPOSED SECTORS: VARIANT A OF GRANDFATHERING CO_2 ALLOWANCES

3.1 Introduction

This chapter analyses the potential capital transfers resulting from policy variant A of grandfathering CO_2 emission allowances in Western Europe at the sector level. As noted, this variant implies that emissions trading is restricted to the exposed sectors, which receive CO_2 allowances for free to cover their own emissions only, while the sheltered sectors are subject to other policy instruments to curb their emissions by the same rate as the exposed sectors. Capital transfers will be estimated for both a flat rate and a proportional system of grandfathering. First of all, Section 3.2 will discuss the baseline and mitigation emission scenarios based on the sectoral classification of variant A. Subsequently, Section 3.3 will analyse the capital transfers resulting from this variant of grandfathering CO_2 allowances. In addition, this section will provide an indication of the sectoral benefits owing to emissions trading.

3.2 Baseline and mitigation scenarios

The baseline scenario

Table 3.1 presents the baseline scenario of the sectoral CO_2 emissions in Western Europe for the period 1990-2030 (see also Figure 3.1). The sectors considered in this table are classified according to variant A as discussed in Section 2.3 (see Table 2.1). Overall, the emissions of all sectors are projected to increase by 23 percent over the years 1990-2030. On average, CO_2 emissions are projected to fall by some 8 percent in the exposed sectors compared to a rise of these emissions by 56 percent in the sheltered sectors. As a result of these differences in projected trends, the share of the exposed sectors in total CO_2 emissions will decline from 50 percent in 1990 to 44 percent in 2010 and even to 38 percent in 2030.

At the sector level, there are major differences in emission trends. For instance, CO_2 emissions will increase by more than 210 percent in the public transport sector, while they will decrease by almost 87 percent in the basic metal industries (see Table 3.1 and Figure 3.2).[14] These differences in sectoral emission trends can be explained by differences in expected autonomous trends in sectoral output demand and/or sectoral production technologies. For instance, the decline in CO_2 emissions of the power sector can be mainly subscribed to the use of more efficient plants and changes in fuel mix (i.e. from lignite or coal to gas). On the other hand, the steadily increasing emissions by the public transport sector are largely due to the rapidly growing demand for air transport and the resulting increase in the use of kerosene. Similarly, the significant growth in CO_2 emissions by the 'other transport' sector is predominantly explained by the autonomous growth in the use of private cars. Finally, improved production processes - notably for aluminium - account for the substantial drop in CO_2 emission by the basic metal industries.

A major implication of these expected differences in sectoral emission trends is that grandfathering CO_2 allowances based on either past or future emissions will have major consequences for the amounts of CO_2 allowances traded - and the capital transfers involved - at the sector level (see Section 3.3).

[14] It should be noted that the figures presented refer to CO_2 only, whereas in some sectors non-CO_2 emissions are of major significance. For instance, CH_4 is a major GHG emitted through coal mining, agriculture and the waste sector, whereas agriculture and the chemical industry emit significant amounts of N_2O. In 1990, non-CO_2 emissions accounted for about one-fifth of total GHG emissions in Western Europe.

Table 3.1 *Baseline scenario of sectoral CO_2 emissions in Western Europe, 1990-2030*[1]

	Absolute emissions [Mt CO_2]					Growth rates compared to 1990 levels [%]		
	1990	2000	2010	2020	2030	2010	2020	2030
Agriculture	40	63	63	16	42	61	-59	6
Basic metal industries	69	65	51	17	9	-25	-75	-87
Glass and ceramics	8	8	9	7	9	10	-9	8
Inorganic chemical industries	54	55	55	52	52	0	-4	-4
Iron and steel	233	220	240	210	192	3	-10	-18
Paper	85	95	119	117	101	39	37	19
Petrochemical industries	49	56	59	65	69	21	33	41
Power plants (incl. waste incineration)	1013	1054	842	747	820	-17	-26	-19
Refineries	185	238	282	317	297	53	72	61
Total exposed sectors	*1734*	*1855*	*1719*	*1549*	*1590*	*-1*	*-11*	*-8*
Commercial & service sector	230	250	270	332	365	18	45	59
Construction materials (incl. cement)	126	115	107	109	111	-15	-13	-12
Freight transport	297	337	380	398	422	28	34	42
Other transport	419	553	617	635	703	47	51	68
Public transport	120	169	238	308	375	99	157	213
Residential sector	381	378	404	432	439	6	13	15
Rest industry	127	177	197	216	233	55	70	84
Total sheltered sectors	*1700*	*1978*	*2212*	*2431*	*2648*	*30*	*43*	*56*
Total emissions of all sectors	3434	3834	3932	3980	4238	14	16	23
Share of the exposed sectors in total emissions [%]	50	48	44	39	38			

[1] Based on sectoral classification of variant A.

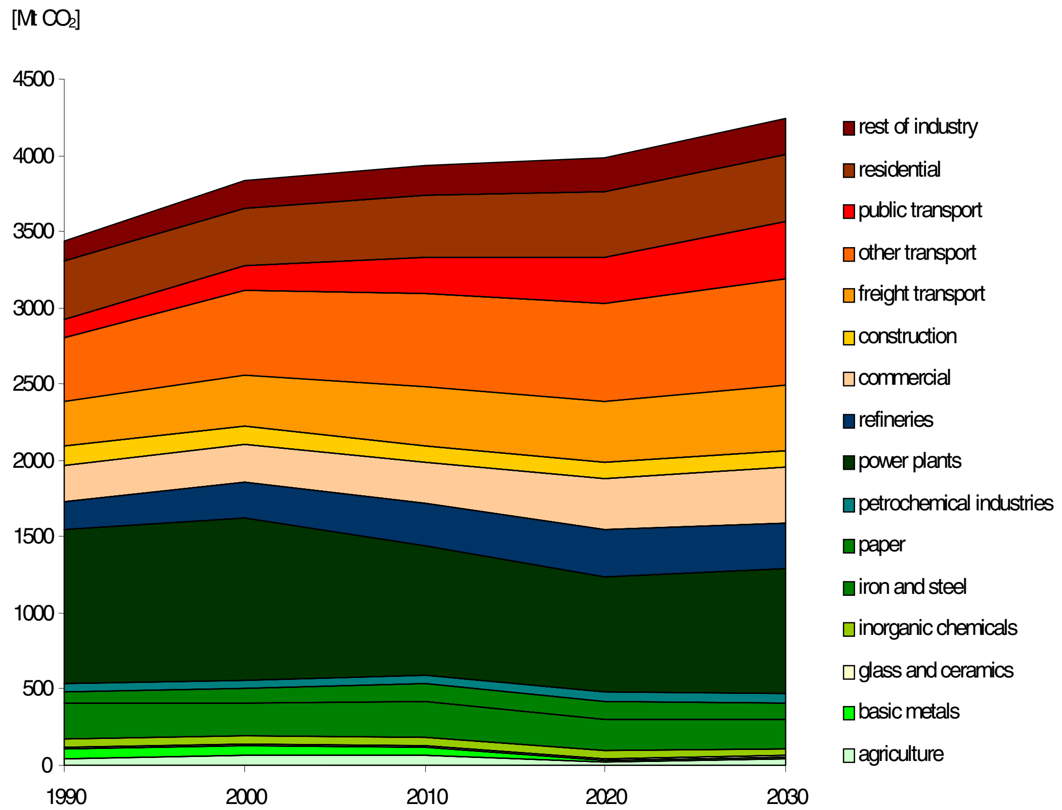


Figure 3.1 *Baseline scenario of sectoral CO_2 emissions in Western Europe, 1990-2030 (classification according to variant A)*

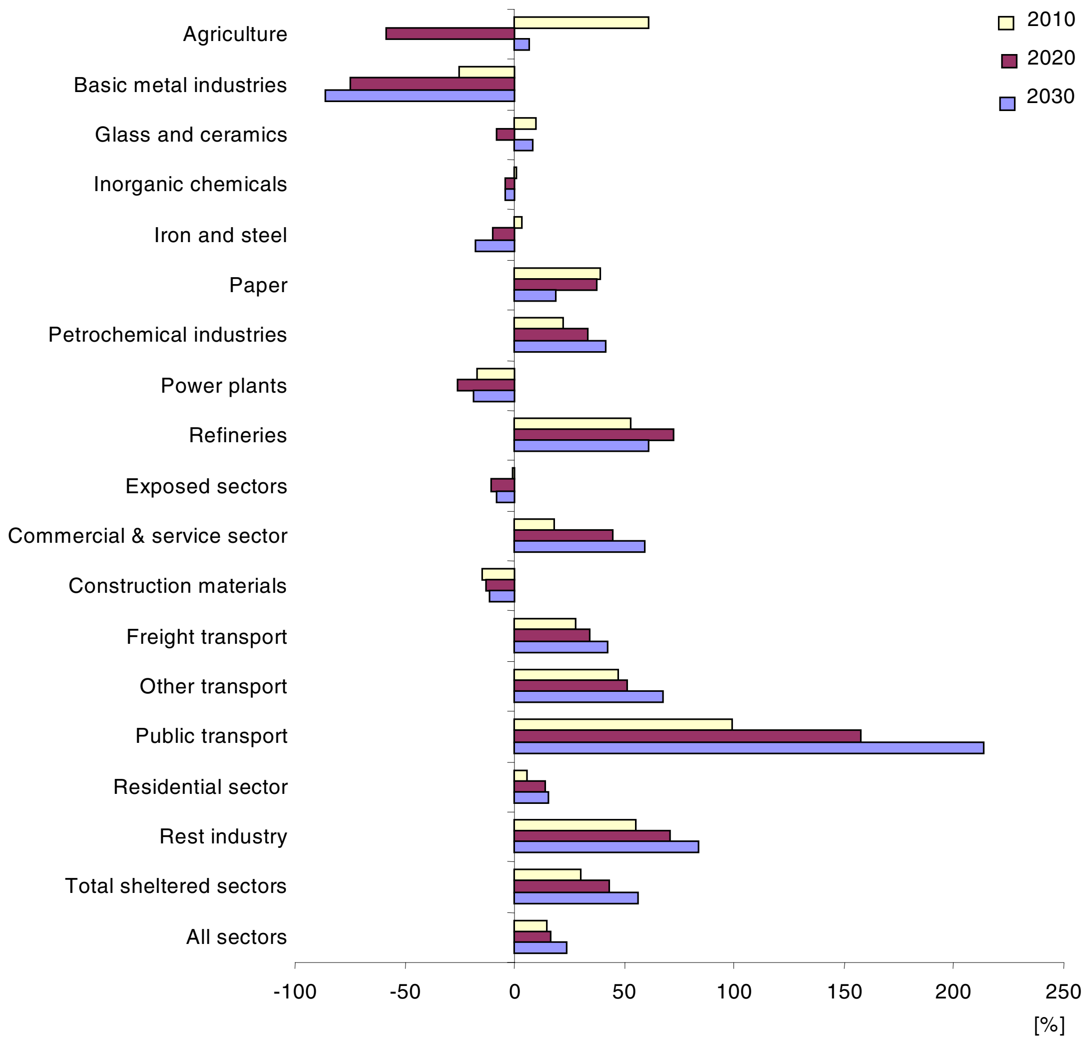


Figure 3.2 *Growth rates of sectoral baseline emissions in Western Europe for the years 2010-2030 compared to 1990 emission levels (variant A)*

The least-cost Kyoto Forever mitigation scenario

According to the Kyoto Protocol, the countries of Western Europe as a whole have agreed to reduce their GHG emissions over the first budget period (2008-2012) by, on average, 8 percent compared to their 1990 emission levels. Table 3.2 presents the results of the sectoral CO_2 emissions in Western Europe for the period 1990-2030 according to the so-called ‘least-cost Kyoto Forever scenario’, i.e. the scenario in which the Kyoto commitments will be achieved at the least costs, assuming that these commitments will be fully realised internally and that they will be maintained at the same level in the years beyond the first budget period (‘Kyoto Forever’). The term ‘least-cost’ refers to a situation in which emission reduction commitments can be freely traded among economic sectors, resulting in the most efficient outcome of meeting these commitments.[15]

A comparison of the baseline and least-cost Kyoto Forever scenario reveals that the Kyoto mitigation commitments of Western Europe will be mainly achieved in the exposed sectors - notably in the petrochemical industries, the refineries, the power plants, and the iron and steel industries - as the abatement costs in these sectors are, on average, lower than in the sheltered sectors. As a result, the share of the exposed sectors in total emissions declines even further

[15] In fact, such a situation resembles policy variant B of grandfathering CO_2 allowances in which such allowances cover all sectoral emissions and can be freely traded within a single market.

over the period 1990-2030 in the least-cost Kyoto Forever scenario than in the baseline scenario (see Tables 3.1 and 3.2).

Table 3.2 *Least-cost Kyoto Forever scenario of sectoral CO_2 emissions in Western Europe, 1990-2030 (elastic demand versus fixed demand case)*[1]

	Absolute emissions [Mt CO_2]					Growth rates compared to 1990 levels [%]		
	1990	2000	2010	2020	2030	2010	2020	2030
Elastic Demand								
Agriculture	40	63	43	3	24	9	-93	-40
Basic metal industries	69	65	51	16	8	-26	-77	-89
Glass and ceramics	8	8	4	3	4	-48	-69	-54
Inorganic chemical industries	54	55	19	6	7	-66	-89	-88
Iron and steel	233	220	175	132	113	-25	-43	-51
Paper	85	95	68	68	62	-21	-21	-27
Petrochemical industries	49	56	58	63	70	19	31	45
Power plants (incl. waste incineration)	1013	1054	607	576	505	-40	-43	-50
Refineries	185	238	97	82	74	-47	-55	-60
Total exposed sectors	*1734*	*1855*	*1121*	*948*	*866*	*-35*	*-45*	*-50*
Commercial & service sector	230	250	258	253	249	12	10	9
Construction materials (incl. cement)	126	115	88	103	100	-30	-19	-21
Freight transport	297	337	365	384	404	23	29	36
Other transport	419	553	617	635	684	47	52	63
Public transport	120	169	217	282	333	82	135	179
Residential sector	381	378	362	403	386	-5	6	1
Rest industry	127	177	131	151	138	3	19	9
Total sheltered sectors	*1700*	*1978*	*2038*	*2211*	*2294*	*20*	*30*	*35*
Total emissions of all sectors	3434	3834	3159	3159	3159	-8	-8	-8
Share of the exposed sectors in total emissions [%]	50	48	35	30	27			
Carbon shadow price [Euro95/tonne CO_2]			40	28	41			
Fixed Demand								
Agriculture	40	63	63	16	42	60	-59	6
Basic metal industries	69	65	52	17	9	-24	-75	-87
Glass and ceramics	8	8	4	3	4	-48	-68	-54
Inorganic chemical industries	54	55	7	6	6	-88	-89	-88
Iron and steel	233	220	130	81	49	-44	-65	-79
Paper	85	95	72	68	67	-16	-20	-21
Petrochemical industries	49	56	58	64	71	20	31	47
Power plants (incl. waste incineration)	1013	1054	604	576	496	-40	-43	-51
Refineries	185	238	77	81	74	-58	-56	-60
Total exposed sectors	*1734*	*1855*	*1066*	*912*	*818*	*-39*	*-47*	*-53*
Commercial & service sector	230	250	264	275	259	15	20	13
Construction materials (incl. cement)	126	115	79	81	102	-37	-36	-19
Freight transport	297	337	374	391	414	26	32	39
Other transport	419	553	618	636	684	47	52	63
Public transport	120	169	238	308	375	99	157	213
Residential sector	381	378	373	397	368	-2	4	-4
Rest industry	127	177	149	160	140	17	26	10
Total sheltered sectors	*1700*	*1978*	*2093*	*2248*	*2341*	*23*	*32*	*38*
Total emissions of all sectors	3434	3834	3159	3159	3159	-8	-8	-8
Share of the exposed sectors in total emissions [%]	50	48	34	29	26			
Carbon shadow price [Euro95/tonne CO_2]			47	29	48			

[1] Based on sectoral classification of variant A.

For comparative reasons, Table 3.2 provides data on sectoral CO_2 emissions in Western Europe estimated by two different versions of the MARKAL-MATTER3.0 model, i.e. the so-called 'fixed demand case' versus the 'elastic demand case' (as explained in Section 2.2.1). Overall, the differences in projected sectoral emissions between these two cases are small, mainly because the estimated carbon shadow prices in the least-cost Kyoto Forever scenario are relatively low for the period 2010-30 (i.e. less than 50 Euro95 per tonne CO_2). The major differences concern CO_2 emissions of the iron and steel industries, agriculture and public transport. These differences can be explained by price-induced changes in output demand and production technologies used.

In addition, Table 3.2 shows some differences between the fixed demand case and the elastic demand case with regard to the estimated carbon shadow prices for the years 2010-2030. These carbon shadow prices reflect the marginal abatement costs of one tonne CO_2 in order to achieve the overall Kyoto target in Western Europe at the lowest costs. As expected, these marginal costs are generally higher in the fixed demand case than in the elastic demand case of MARKAL-MATTER3.0. This results from the fact that in the elastic demand case part of the emission reductions is achieved through a lower demand, and hence, a lower supply, of CO_2-intensive products rather than through technical abatement options that are most expensive at the margin.

It should be noted that in both the fixed demand case and the elastic demand case a significant fall in carbon shadow prices can be observed for the year 2020 (compared to 2010, see Table 3.2). This fall can be explained by a combination of factors, including (i) the overall mitigation target is assumed to be the same for the years 2010 and beyond ('Kyoto Forever'), (ii) the baseline CO_2 emissions in Western Europe are expected to stabilise over the years 2010-2020, and (iii) owing to autonomous trends in available technologies, (marginal) reductions options are expected to be cheaper in 2020 than in 2010. For the year 2030, carbon shadow prices are expected to rise again, even above comparative levels of 2010. This rise can be mainly attributed to the fact that baseline CO_2 emissions in Western Europe are expected to increase over the years 2020-2030, thereby enhancing the total amount of emission reductions in order to achieve the emission cap of the Kyoto Forever mitigation scenario.

Unless stated otherwise, the data presented in the remaining sections of this study are based on the 'elastic demand case' of MARKAL-MATTER3.0.

The least-cost Kyoto Plus mitigation scenario
In order to avoid the fall in carbon shadow prices in the year 2020 occurring in the Kyoto Forever scenario discussed above, it is assumed that the countries of Western Europe will further reduce their emissions by an additional 8 percent in 2020 and beyond (compared to the emission levels agreed for the first budget period). As a result of this so-called optimal or least-cost 'Kyoto Plus' mitigation scenario, the total amount of sectoral CO_2 emissions in Western Europe will decline from 3192 million tonnes in 2010 to 2937 million tonnes in 2020 and beyond. Again, this mitigation will be mainly achieved in the exposed sectors, leading to a further decline of their share in total emissions over the period 1990-2030 (see Table 3.3 as well as Figure 3.3).

Table 3.4 presents a comparative summary of the two least-cost mitigation scenarios discussed above by indicating the changes in sectoral CO_2 emissions of these scenarios compared to the baseline scenario for the years 2010-30. It shows that the targets of these scenarios will be achieved at an overall carbon shadow price in Western Europe varying from 28 Euro95 per tonne CO_2 in 2020 (Kyoto Forever) to 48 Euro95/t in 2030 (Kyoto Plus). In addition, it can be observed from Table 3.4 that emission reduction rates in both scenarios are generally higher in the exposed sectors than in the sheltered sectors, mainly because abatement options in the former sectors are relatively cheaper than in the latter.

Unless stated otherwise, the Kyoto Plus mitigation scenario will be applied in the remaining sections of the present report.

Table 3.3 *Least-cost Kyoto Plus scenario of sectoral CO_2 emissions in Western Europe, 1990-2030*[1]

	Absolute emissions [Mt CO_2]					Growth rates compared to 1990 levels [%]		
	1990	2000	2010	2020	2030	2010	2020	2030
Agriculture	40	63	43	0	23	9.0	-100.0	-41.3
Basic metal industries	69	65	51	16	8	-26.0	-76.8	-88.9
Glass and ceramics	8	8	4	3	4	-48.1	-68.5	-54.4
Inorganic chemical industries	54	55	19	6	7	-65.6	-88.6	-88.0
Iron and steel	233	220	175	120	51	-24.8	-48.2	-78.1
Paper	85	95	68	64	63	-20.6	-24.4	-25.8
Petrochemical industries	49	56	58	65	71	19.1	34.7	47.1
Power plants (incl. waste incineration)	1013	1054	607	429	377	-40.1	-57.7	-62.7
Refineries	185	238	97	78	71	-47.5	-57.6	-61.6
Total exposed sectors	*1734*	*1855*	*1121*	*782*	*675*	*-35.4*	*-54.9*	*-61.1*
Commercial & service sector	230	250	258	236	243	12.3	2.8	6.0
Construction materials (incl. cement)	126	115	88	94	98	-30.0	-25.5	-22.6
Freight transport	297	337	365	381	404	22.9	28.2	35.8
Other transport	419	553	617	637	683	47.3	51.8	63.0
Public transport	120	169	217	274	333	81.6	129.4	178.6
Residential sector	381	378	362	372	356	-5.1	-2.4	-6.5
Rest industry	127	177	131	131	114	*2.9*	*2.8*	*-10.0*
Total sheltered sectors	*1700*	*1978*	*2038*	*2125*	*2232*	*19.9*	*25.0*	*31.3*
Total emissions of all sectors	3434	3834	3159	2906	2906	-8.0	-15.4	-15.4
Share of the exposed sectors in total emissions [%]	51	49	36	28	24			

[1] Based on sectoral classification of variant A.

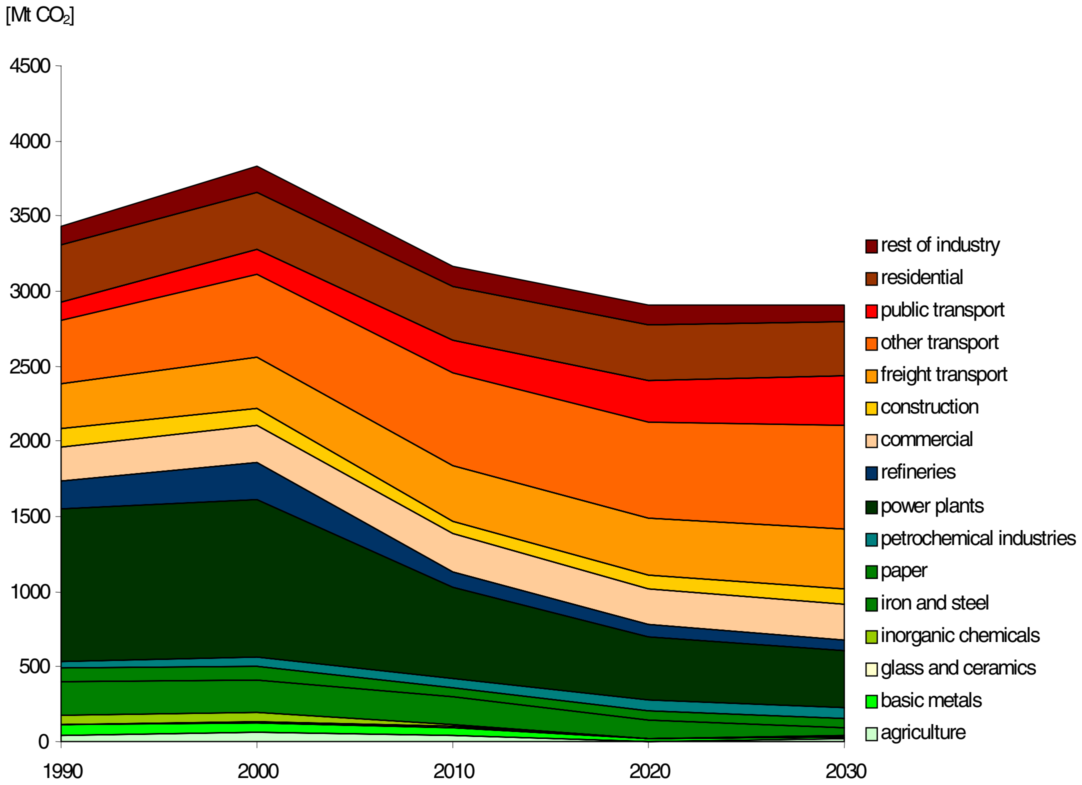


Figure 3.3 *Least-cost Kyoto Plus scenario of sectoral CO_2 emissions in Western Europe, 1990-2030 (classification according to variant A)*

Table 3.4 *Changes in sectoral CO_2 emissions in Western Europe of two mitigation scenarios compared to the baseline scenario, 2010-2030*[1]

	Least-cost Kyoto Forever			Least-cost Kyoto Plus		
	2010	2020	2030	2010	2020	2030
Agriculture	-32	-84	-43	-32	-100	-45
Basic metal industries	-1	-8	-17	-1	-8	-17
Glass and ceramics	-53	-66	-58	-53	-66	-58
Inorganic chemical industries	-66	-88	-88	-66	-88	-88
Iron and steel	-27	-37	-41	-27	-43	-73
Paper	-43	-42	-39	-43	-45	-37
Petrochemical industries	-2	-2	3	-2	1	4
Power plants (incl. waste incineration)	-28	-23	-38	-28	-43	-54
Refineries	-66	-74	-75	-66	-75	-76
Total exposed sectors	*-35*	*-39*	*-46*	*-35*	*-50*	*-58*
Commercial & service sector	-5	-24	-32	-5	-29	-33
Construction materials (incl. cement)	-18	-6	-10	-18	-14	-12
Freight transport	-4	-4	-4	-4	-4	-4
Other transport	0	0	-3	0	0	-3
Public transport	-9	-9	-11	-9	-11	-11
Residential sector	-10	-7	-12	-10	-14	-19
Rest industry	-34	-30	-41	-34	-40	-51
Total sheltered sectors	*-8*	*-9*	*-13*	*-8*	*-13*	*-16*
Total emissions of all sectors	-20	-21	-25	-20	-27	-31
Carbon shadow price [Euro95/tonne CO_2]	40	28	41	40	36	48

[1] Based on sectoral classification of variant A.

3.3 Capital transfers resulting from a flat rate versus a proportional system of grandfathering: policy variant A

This section analyses the potential capital transfers of variant A for two different systems of grandfathering CO_2 emission allowances, i.e. a flat rate system (F-system) and a proportional system (P-system), based on the overall mitigation targets of the Kyoto Plus scenario discussed above. In an F-system, which is based on past emissions, these targets correspond to -8 percent in 2010 compared to 1990 and an additional -8 percent in 2020 and beyond compared to 2010 (or a cumulative -15.4 percent in 2020 and beyond compared to 1990). In a P-system, which is based on future emissions, the Kyoto Plus mitigation rates correspond to -20 percent in 2010, -27 percent in 2020 and -31 percent in 2030 compared to the baseline emissions of these years.[16] In sub-variant A1, which excludes emissions trading among exposed sectors, the Kyoto Plus mitigation targets apply for each exposed sector individually, whereas in sub-variant A2, including emissions trading, they refer to the exposed sectors as a whole. In both sub-variants A1 and A2, it is assumed that the sheltered sectors as a whole have to reduce their emissions by the same (flat/proportional) rate as the exposed sectors.

3.3.1 Initial allocation of allowances

Table 3.5 shows the initial allocation of allowances under either an F- or P-system of grandfathering CO_2 allowances (see also Figure 3.4). In the F-system, the amount of allowances is set at a uniform rate for the year 2010 (i.e. for each exposed sector, at 92 percent of its emissions in 1990). In the P-system, the amount of allowances allocated to the exposed sectors depends on the projected trends in their baseline emissions compared to those of the sheltered sectors and, hence, may vary over time (as indicated by Table 3.5). As the baseline emissions of the exposed

[16] As outlined in Section 2.3, in a P-system each sector is obliged to reduce its emissions in the target year by the same rate as the overall reduction target for all sectoral emissions of that year. According to the baseline scenario of Table 3.1, sectoral emissions are projected at 3932 Mt CO_2 in 2010, 3980 Mt CO_2 in 2020, and 4238 Mt CO_2 in 2030. However, according to the Kyoto Plus mitigation scenario of Table 3.3, the target levels of these emissions should be 3159 Mt CO_2 in 2010 and 2906 Mt CO_2 in both 2020 and 2030, respectively. Hence, compared to the baseline scenario for these target years, the actual emissions of all sectors should be reduced by 20 percent in 2010, 27 percent in 2020 and 31 percent in 2030.

sectors over the years 1990-2030 are expected to grow less than those of the sheltered sectors, the amounts of allowances allocated to the exposed sectors in 2010 in a P-system are less than in an F-system, and decline even further in the years beyond.

Table 3.5 *Initial allocation of CO_2 allowances under different systems of grandfathering (Kyoto Plus scenario, variant A2, [Mt CO_2])*

	Flat rate		Proportional		
	2010	2020-30	2010	2020	2030
Agriculture	36	33	51	12	29
Basic metal industry	63	58	41	13	6
Glass and ceramics	7	7	7	5	6
Inorganic chemical industry	50	46	44	38	36
Iron and steel	214	197	193	154	131
Paper	78	72	95	85	69
Petrochemicals	45	41	47	47	47
Power & waste incineration	932	857	676	546	562
Refineries	170	156	227	232	204
Total exposed sectors	*1595*	*1468*	*1382*	*1131*	*1091*

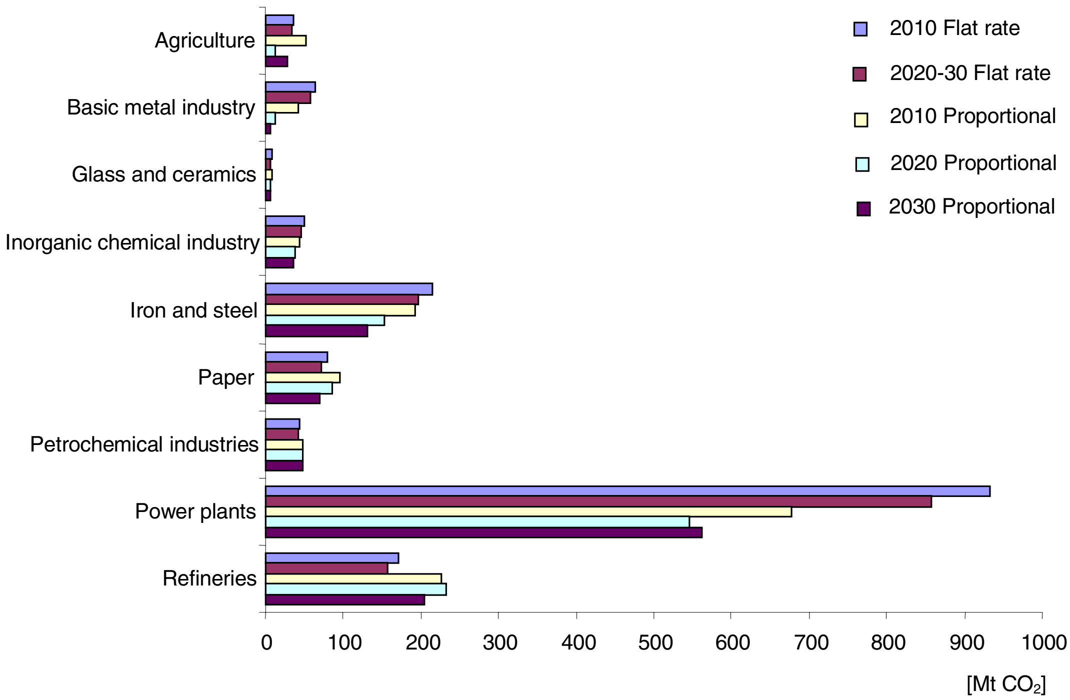


Figure 3.4 *Initial allocation of CO_2 allowances under different systems of grandfathering (Kyoto Plus scenario, variant A2)*

3.3.2 Marginal abatement costs

Before emissions trading

Table 3.6 presents an overview of the marginal abatement costs per tonne CO_2 in the exposed sectors of Western Europe for variant A1 of both the F- and P-systems of grandfathering CO_2 allowances (see also Figure 3.5). As emissions trading among sectors is not allowed in this variant, grandfathering allowances according to a uniform rate results in major differences in marginal abatement costs among the exposed sectors. In general, the marginal costs of the exposed sectors are higher under a P-system than under an F-system, mainly because for most years and most exposed sectors emissions have to be reduced more under a P-system than in an F-system.

Under an F-system, the marginal costs are even 0 in several cases considered, for instance, in the basic metal and inorganic chemical industries in the years 2010, 2020 and 2030. This results from the fact that, owing to autonomous declining trends in their CO_2 emissions, these sectors are not obliged to take (additional) abatement measures in order to meet their sectoral emission cap.

Table 3.6 *Marginal abatement costs in exposed sectors of Western Europe for different systems of grandfathering (Kyoto Plus scenario, variant A1, [Euro95/tonne CO_2])*

	2010	2020	2030
Flat Rate			
Agriculture (incl. sinks)	65	8	24
Basic metal industries	0	0	0
Glass and ceramics	28	0	57
Inorganic chemical industries	1	1	0
Iron and steel	6	23	8
Paper	67	88	83
Petrochemical industries	144	152	123
Power plants (incl. waste incineration)	15	23	33
Refineries	19	9	1
Proportional			
Agriculture (incl. sinks)	20	9	130
Basic metal industries	107	245	242
Glass and ceramics	30	30	54
Inorganic chemical industries	8	1	0
Iron and steel	26	41	43
Paper	26	9	83
Petrochemical industries	84	99	118
Power plants (incl. waste incineration)	34	31	49
Refineries	4	7	5

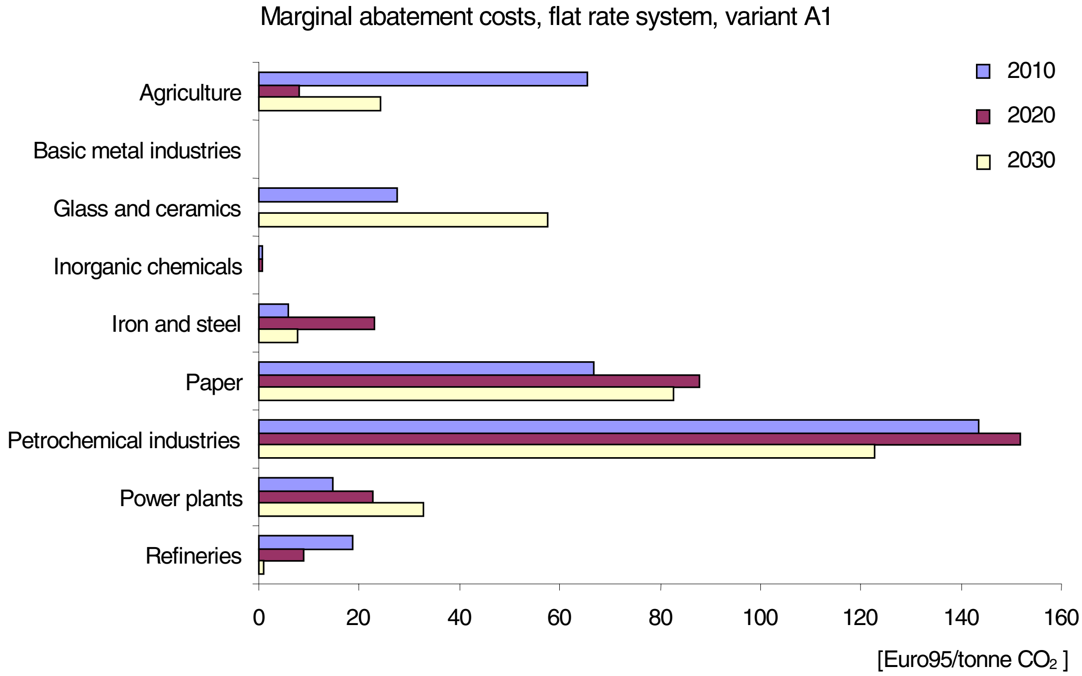
Table 3.6 and Figure 3.5 show considerable differences in the pattern of marginal abatement costs between sectors. Under the F-system, for example the basic metal industries would have zero marginal abatement costs, while the petrochemical industries are faced with high marginal abatement costs. Under the P-system, on the contrary, the basic metal industries would be confronted with very high marginal abatement costs, while the petrochemical industries would see their marginal abatement costs to be somewhat lower than under the F-system.

After emissions trading

Table 3.7 provides a similar overview of the marginal abatement costs for variant A2. As, in this variant, emissions trading is allowed among the exposed sectors, these costs are equalised to a uniform level across these sectors, resulting in major efficiency gains (see discussion at the end of this section). Table 3.7 reveals that if the exposed and sheltered sectors are subject to the same reduction rate - but no emissions trading is allowed between these two groups of sectors - the marginal costs of the sheltered sectors exceed those of the exposed sectors by a wide margin, indicating a severe loss in overall efficiency compared to a situation in which all sectors are allowed to participate in emissions trading on a single market. This latter situation is expressed by the least-cost Kyoto Plus mitigation scenario based on the sectoral classification of variant A (as discussed in Section 3.2). In fact, this scenario can be regarded as a special case of emissions trading in which all sectors, both exposed and sheltered, are allowed to participate directly in emissions trading on a single market, resulting in equal marginal abatement cost for all sectors.

Table 3.7 *Marginal abatement costs under different systems of grandfathering (Kyoto Plus scenario, variant A2, [Euro95/tonne CO_2])*

	2010	2020	2030
F-system, variant A2, exposed sectors	15	13	32
F-system, variant A2, sheltered sectors	139	162	115
P-system, variant A2, exposed sectors	32	27	39
P-system, variant A2, sheltered sectors	87	90	110
Least-cost Kyoto Plus mitigation scenario, all sectors	40	36	48



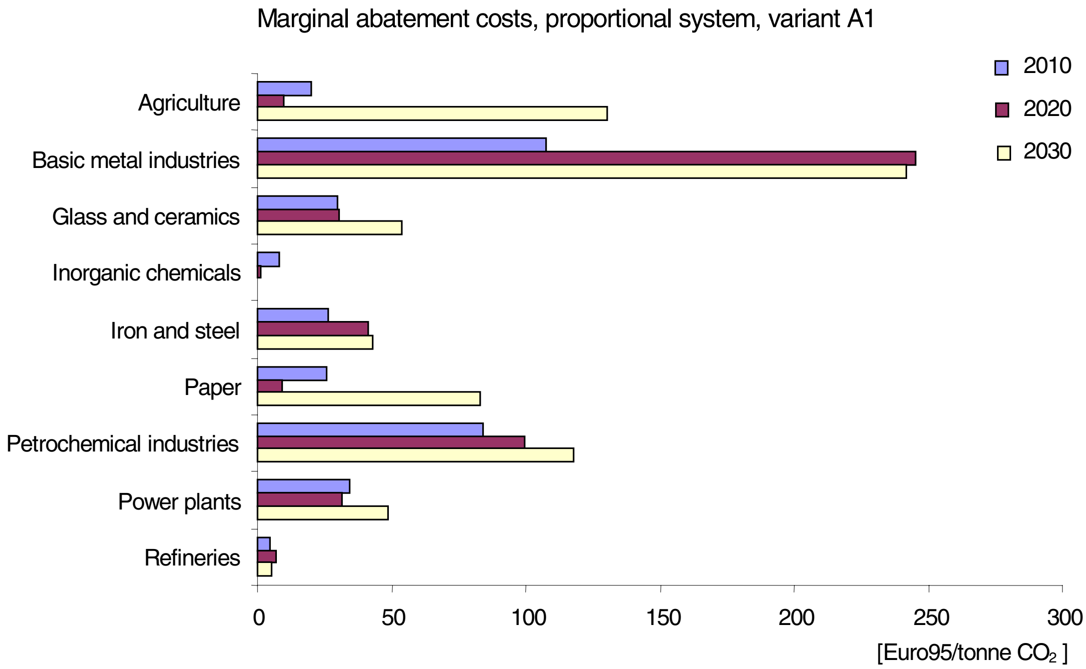


Figure 3.5 *Marginal abatement costs in exposed sectors of Western Europe for different systems of grandfathering (Kyoto Plus scenario, variant A1)*

3.3.3 Emissions trading and capital transfers

Tables 3.8 and 3.9 provide an overview of the trade in emission allowances and the capital transfers involved among the exposed sectors, resulting from either the F- or P-system of grandfathering CO_2 allowances (see also Figures 3.6 and 3.7). In the F-system, emission allowances will be mainly sold by the basic metal industries, the iron and steel industries, and the inorganic chemical industries, whereas they will be mainly bought by the paper sector, the petrochemical industries and the power plants (except in the year 2010 in which power plants will sell major amounts of allowances). In the P-system, however, emission allowances will be largely sold by the refineries and the inorganic chemical industries, whereas they will be bought predominantly by the power plants, the petrochemical industries and by the iron and steel industries. These differences among sectors and grandfathering systems considered can be explained by (i) differences in marginal abatement costs among sectors, (ii) differences in (baseline) emission trends among sectors, and (iii) differences in the amounts of allowances allocated among sectors depending on the grandfathering system considered.

Table 3.8 *Sectoral emission trade and capital transfers in Western Europe, 2010-2030, resulting from different systems of grandfathering (Kyoto Plus scenario, variant A2)*

	Trade in emission allowances [Mt CO_2][1]			Capital transfers [mEuro95][1]		
	2010	2020	2030	2010	2020	2030
Flat rate						
Agriculture	17	-14	-4	251	-185	-111
Basic metal industries	-11	-41	-49	-162	-525	-1563
Glass and ceramics	1	0	1	20	5	41
Inorganic chemical industries	-31	-36	-39	-463	-466	-1255
Iron and steel	-18	-12	-44	-266	-157	-1396
Paper	27	25	19	398	329	595
Petrochemical industries	44	59	52	650	769	1653
Power plants (incl. waste incineration)	-45	46	117	-659	599	3735
Refineries	16	-29	-53	232	-369	-1699
Proportional						
Agriculture	-4	-10	-3	-123	-278	-135
Basic metal industries	5	3	1	159	92	50
Glass and ceramics	-3	-3	-2	-93	-77	-89
Inorganic chemical industries	-25	-32	-29	-810	-866	-1148
Iron and steel	-3	19	23	-95	513	915
Paper	2	-15	8	50	-402	306
Petrochemical industries	38	49	49	1224	1339	1939
Power plants (incl. waste incineration)	-1	117	63	-29	3164	2456
Refineries	-9	-129	-110	-284	-3486	-4292

[1] A minus (-) indicates selling emission allowances and, hence, receiving a capital transfer.

As can be observed from Table 3.9, the total amount of allowances traded in variant A2 varies from 45 Mt CO_2 in 2010 in a proportional system to 189 Mt CO_2 in 2020 in a flat rate system. As a percentage of total allowances allocated, these amounts correspond to 3.2 and 13 percent, respectively. On average, the total annual amount of emission allowances traded over the years 2010-30 is estimated at 142 Mt CO_2 in a flat rate system and at 126 Mt CO_2 in a proportional system. As a percentage of the total amount of allowances grandfathered in these years, these average quantities correspond to 9.4 and 10.5 percent, respectively. Therefore, it can be concluded that, regardless the grandfathering system, only a small part, about 10 percent of the total, initially allocated amounts of emissions allowances in variant A will be traded among the exposed sectors, whereas the major part, some 90 percent of these allowances will be retained by the exposed sectors themselves to meet their mitigation targets.

Table 3.9 *Total amounts of CO_2 allowances traded and capital transfers involved, 2010-2030, resulting from different systems of grandfathering (Kyoto Plus scenario, variant A2)*

	Trade in emission allowances [Mt CO_2]				Total capital transfers [mEuro95]			
	2010	2020	2030	Average 2010-30	2010	2020	2030	Average 2010-30
Flat rate	105	132	189	142	1551	1702	6023	3092
Proportional	45	188	145	126	1434	5109	5664	4069
	As % of total allowances allocated				As % of industrial turnover[1]			
Flat rate	6.6	9.0	12.9	9.4	0.01	0.01	0.03	0.02
Proportional	3.2	16.7	13.3	10.5	0.01	0.03	0.03	0.03

[1] These calculations are based on the following assumptions (i) GDP of Western Europe in 2010: 12.000 billion Euro95, in 2020: 15.000 billion Euro95, and in 2030: 18.000 billion Euro95, (ii) industrial value added: 30 percent of GDP, and (iii) industrial turnover: 3.5 times industrial value added. Hence, in order to calculate capital transfers as a percentage of industrial value added, the figures presented as a percentage of industrial turnover have to be multiplied by 3.5. It should be noted that the assumption with regard to the industrial value added, i.e. 30 percent of GDP, is based on actual figures for the 1990s but this share might be significantly lower in the years 2010-2020.

Source: Eurostat, Yearbook 2000; and World Bank, World Development Indicators, 2001

Table 3.9 also reveals that, in terms of capital transfers between sectors, the total amounts involved vary from 1.4 billion Euro95 in 2020 in a proportional system to nearly 6.0 billion Euro95 in 2030 in a flat rate system. On average, the total amount of capital transfers involved in emissions trading among the exposed sectors in Western Europe over the years 2010-2030 is estimated at 3.1 billion Euro95 in a flat rate system and 4.1 billion in a proportional system.[17] As a percentage of total industrial turnover in Western Europe in the years 2010-30, these amounts correspond to about 0.02 and 0.03 percent, respectively. These average figures, however, may hide significant variances among individual sectors or years considered. For instance, according to the estimates of Table 3.8, the power sector has to pay an amount of about 3.7 billion Euro95 in order to buy 117 Mt CO_2 allowances under a flat rate system in 2030. This corresponds to some 14 percent of its allowances allocated in that year, and to about 2 percent of the estimated turnover of the power sector in 2030.[18] Under a proportional system, the sector refineries even sells about half of its allocated allowances in 2020-30 (compare Tables 3.5 and 3.8). Therefore, it may be concluded that in variant A, the total amounts of emission allowances traded and capital transfers involved are relatively small at the aggregated level of all exposed sectors in western Europe, but they may be far more significant at the disaggregated level of individual sectors.

Benefits from emissions trading among exposed sectors

Finally, Table 3.10 gives an indication of the trade benefits resulting from either a flat rate or a proportional system under the Kyoto Plus mitigation scenario. These benefits have been roughly estimated by assessing the areas D^I and D^{II} of Figure 2.1 by means of two simple formulas, i.e. either:

$$\tfrac{1}{2}\times(P^* - R)\times(Q^* - Q')$$

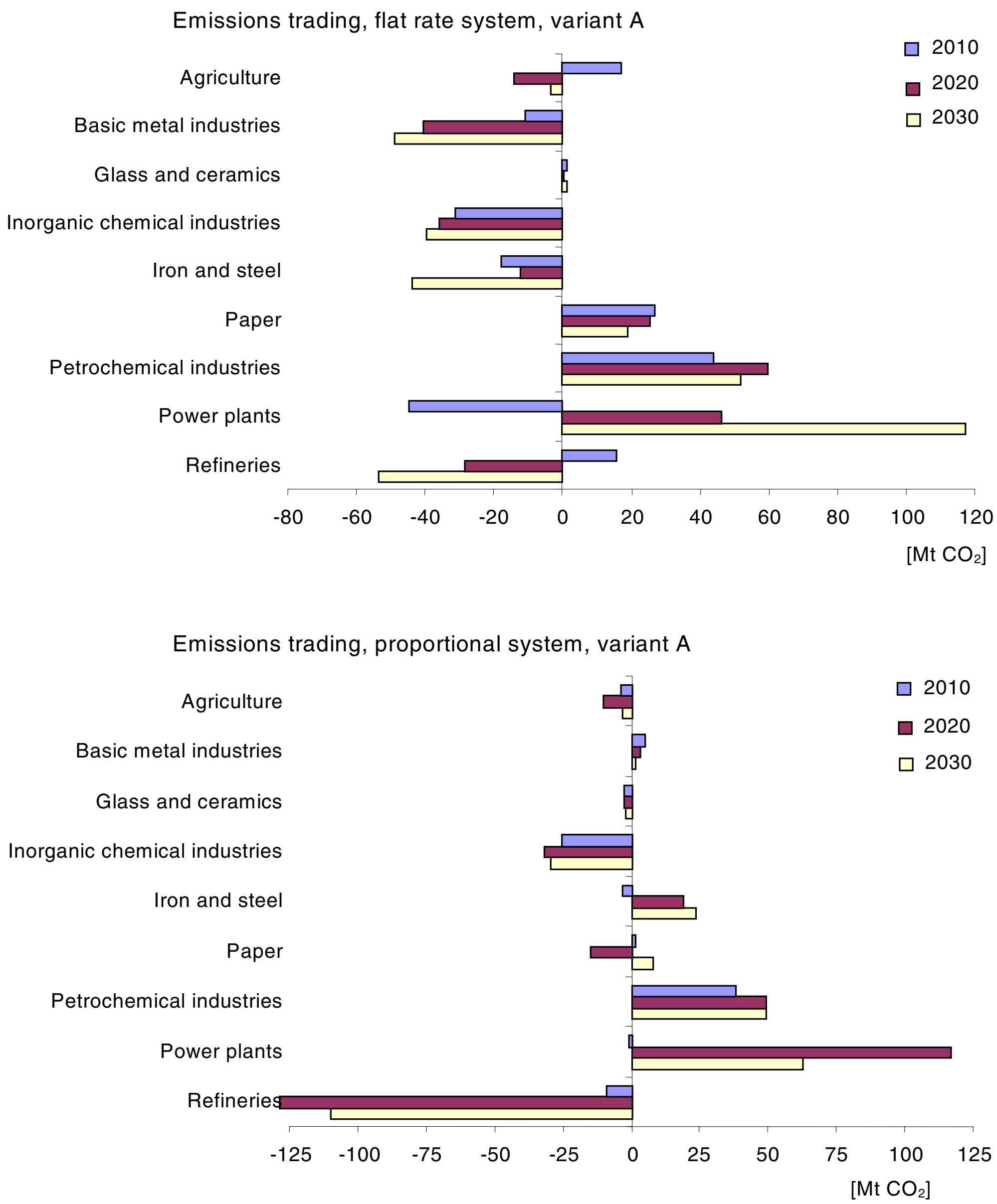
For those sectors selling allowances, or:

$$\tfrac{1}{2}\times(S - P^*)\times(Q^* - Q')$$

For those sectors buying allowances.

17 Note that despite a higher average annual volume of allowances trade in a flat rate system (compared to a proportional system), the average annual capital transfer is lower due to the fact that the weighted average allowance price is lower in a flat rate system than in a proportional system. This is due to the fact the total amount of allowances allocated to the exposed sectors is, on average, higher in a flat rate system than in a proportional system.

18 MARKAL-MATTER3.0 estimates the turnover of the power sector in the Kyoto Plus scenario under a proportional system at 192 billion Euro95 in 2030.

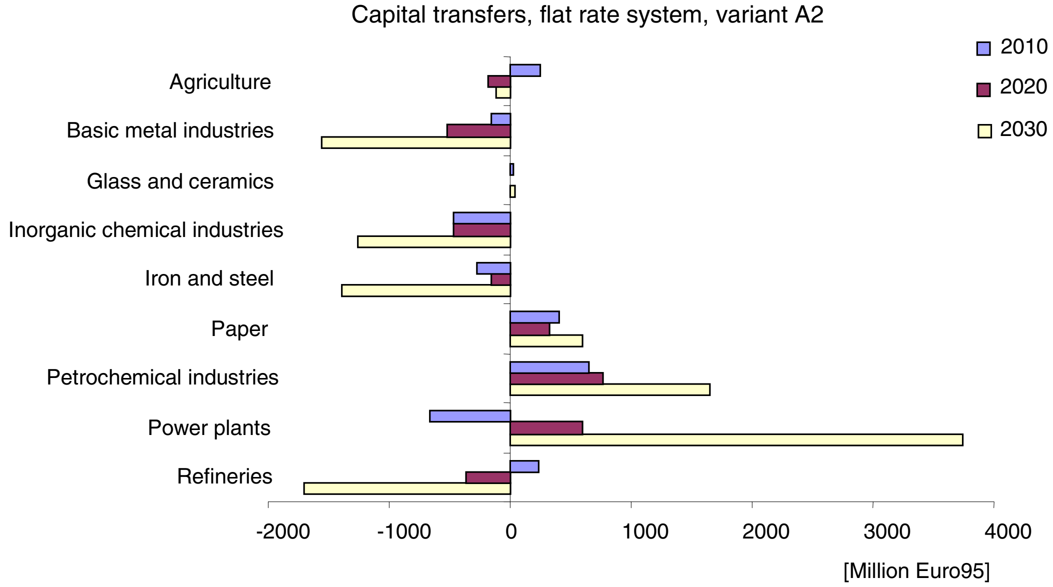


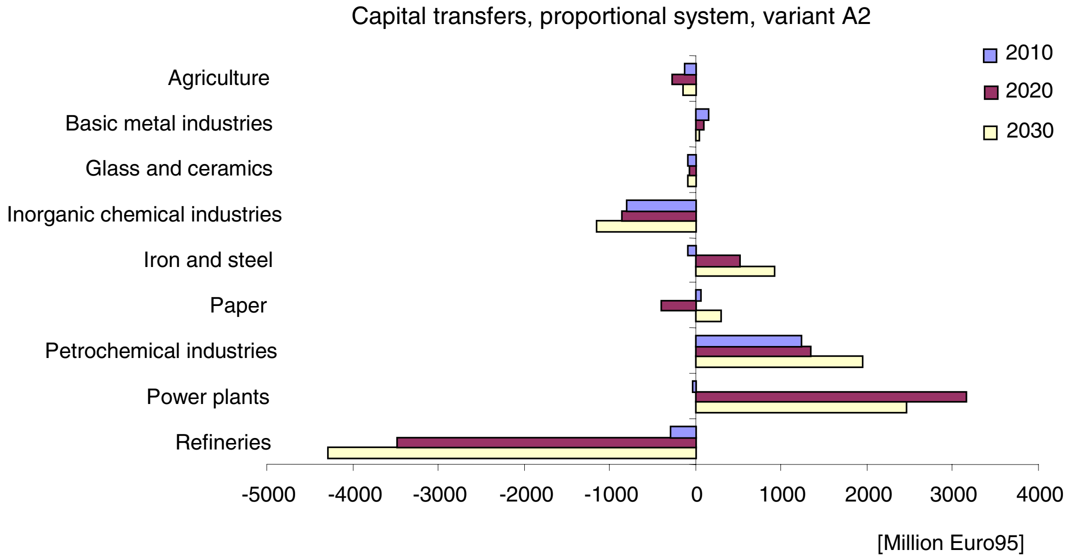
Note: The left part of the X-axis (negative figures) indicates selling emission allowances, whereas the right part refers to buying emission allowances.

Figure 3.6 *Trade in emission allowances according to different systems of grandfathering (variant A)*

In order to estimate the benefits due to emissions trading, the marginal cost curves and the corresponding data generated by MARKAL-MATTER3.0 have been used (see Section 2.1). It should be emphasised, however, that the cost curves generated by MARKAL-MATTER3.0 generally have an irregular, stepwise character rather than the straight, upward-bending lines of Figure 2.1. Therefore, the results achieved by the above-mentioned, simple formulas should be treated with due care.[19]

[19] An alternative, more sophisticated approach to estimate the benefits resulting from emissions trading would be to compare the total abatement costs per sector before and after trade (i.e. total sectoral abatement costs in A1 versus A2). Unfortunately, however, these cost data cannot be obtained directly from MARKAL-MATTER 3.0, but only through a laborious process of estimating abatement costs at the sectoral level.





Note: The left part of the X-axis (negative figures) indicates receiving a capital transfer due to selling emission allowances, whereas the right part refers to paying a capital transfer due to buying emission allowances.

Figure 3.7 *Capital transfers due to trade in emission allowances according to different systems of grandfathering (variant A2)*

The most striking feature of Table 3.10 is that the total trade benefits resulting from either a flat rate or proportional system of grandfathering CO_2 allowances are generally low, varying from 1.6 to 6.0 billion Euro95 depending on the year and the allocation system considered. This can be explained by the fact that (i) the volumes of allowances traded are relatively small in variant A, and/or (ii) the deviation between the sectoral marginal abatement costs in variant A1 and the equilibrium price in variant A2 is generally small (see Tables 3.5 up to 3.10).

Table 3.10 *Estimates of benefits resulting from CO_2 emissions trading in Western Europe for different systems of grandfathering (Kyoto Plus scenario, variant A2)*

	Flat rate			Proportional		
	2010	2020	2030	2010	2020	2030
Total trade benefits per sector			*[mln. Euro95]*			
Agriculture	428	36	14	23	90	157
Basic metal industries	81	263	781	187	370	128
Glass and ceramics	9	2	16	3	4	17
Inorganic chemical industries	223	224	627	306	416	644
Iron and steel	80	60	528	9	133	46
Paper	699	953	476	5	135	170
Petrochemical industries	2828	4130	2357	991	1785	1946
Power plants (incl. waste incineration)	2	225	54	1	245	294
Refineries	*30*	*58*	*826*	122	1319	1861
Total	4379	5952	5679	*1646*	*4497*	*5261*
Average benefits per allowance traded			*[Euro95/tonne CO_2]*			
Agriculture	25	2	4	6	9	46
Basic metal industries	7	6	16	38	109	101
Glass and ceramics	6	6	13	1	1	7
Inorganic chemical industries	7	6	16	12	13	22
Iron and steel	4	5	12	3	7	2
Paper	26	37	25	3	9	22
Petrochemical industries	64	69	45	26	36	39
Power plants (incl. waste incineration)	0	5	0	1	2	5
Refineries	2	2	15	14	10	17
Total	21	23	15	8	17	14

In some exceptional cases, however, trade benefits may be relatively high. Under a flat rate system, for instance, trade benefits for the petrochemical industries are estimated at 4.1 billion Euro95 in 2020 and for the basic metal industries at 781 million Euro95 in 2030. Both cases can be primarily attributed to the relatively large deviation between the marginal abatement costs of these sectors in variant A1 and the equilibrium allowance price in variant A2 (see Tables 3.6 and 3.7).[20] It is interesting to note, however, that the trade benefits of the petrochemical sector result from *buying* allowances, whereas those of the basic metal industries are due to *selling* allowances.

[20] This factor also explains that the average benefit per allowance traded is also generally low, although in individual cases - notably for those sectors buying allowances - this benefit may be quite significant (compare Table 3.8 and the lower part of Table 3.10).

4. EMISSIONS TRADING COVERING ALL SECTORS: VARIANT B OF GRANDFATHERING CO_2 ALLOWANCES

4.1 Introduction

This chapter analyses the potential capital transfers resulting from policy variant B of grandfathering CO_2 emission allowances in Western Europe at the sector level. As outlined in Section 2.3, this variant implies that all CO_2 emissions by all economic sectors are covered by a single system of grandfathering and trading CO_2 allowances. For administrative considerations, however, these allowances are all grandfathered to the exposed sectors in order to cover not only their own emissions but those of the sheltered sectors as well.

The present chapter is structured similarly to the previous chapter dealing with policy variant A of grandfathering CO_2 allowances.[21] First of all, Section 4.2 will discuss the baseline and mitigation emission scenarios based on the sectoral classification of variant B. Subsequently, Section 3.3 will analyse the capital transfers resulting from this variant of grandfathering CO_2 allowances.

4.2 Baseline and mitigation scenarios

The baseline scenario

Table 4.1 presents the baseline scenario of sectoral CO_2 emissions in Western Europe for the years 1990-2030 based on variant B of classifying 'exposed sectors' (see also Figures 4.1 and 4.2). It shows that the growth of total CO_2 emissions over the years 1990-2030 (+23 percent) is similar to the baseline scenario presented for variant A (Table 3.1). Again, however, there are major differences in projected emission trends between economic sectors. For instance, whereas the CO_2 emissions of the sector liquid fuels are expected to grow by about 76 percent in the period 1990-2030, they are projected to decline by 66 percent in the sector basic metal industries.

[21] The major exceptions are that the present chapter is focussed exclusively on the elastic demand case of the Kyoto Plus mitigation scenario and, hence, does neither consider the fixed demand case nor the Kyoto Forever mitigation scenario. Moreover, as explained in Section 2.3, variant B does not include a sub-variant that excludes emissions trading among exposed sectors and, hence, the present chapter does not provide estimates of sectoral benefits owing to emissions trading.

Table 4.1 *Baseline scenario of sectoral CO_2 emissions in Western Europe, 1990-2030*[1]

	Absolute emissions [Mt CO_2]					Growth rates compared to 1990 levels [%]		
	1990	2000	2010	2020	2030	2010	2020	2030
Agriculture	56	84	79	29	55	41	-48	-2
Basic metal industries	108	117	87	42	37	-19	-61	-66
Electricity	807	828	677	622	688	-16	-23	-15
Gas	301	380	437	375	358	45	25	19
Glass and ceramics	21	20	17	11	14	-21	-46	-35
Inorganic chemical industries	76	75	70	64	65	-8	-15	-14
Iron and steel	267	255	265	230	212	-1	-14	-21
Liquid fuels	1202	1446	1629	1879	2112	36	56	76
Paper	144	156	164	152	137	14	6	-5
Petrochemicals	63	72	71	74	79	13	18	26
Refineries	192	247	290	324	304	51	68	58
Solid fuels	180	154	147	168	160	-18	-7	-11
Non-allocated/deviation from variant A	17	-1	-1	8	17	-104	-52	2
Total emissions of all sectors	3434	3834	3932	3980	4238	14	16	23

[1] Based on sectoral classification of variant B.

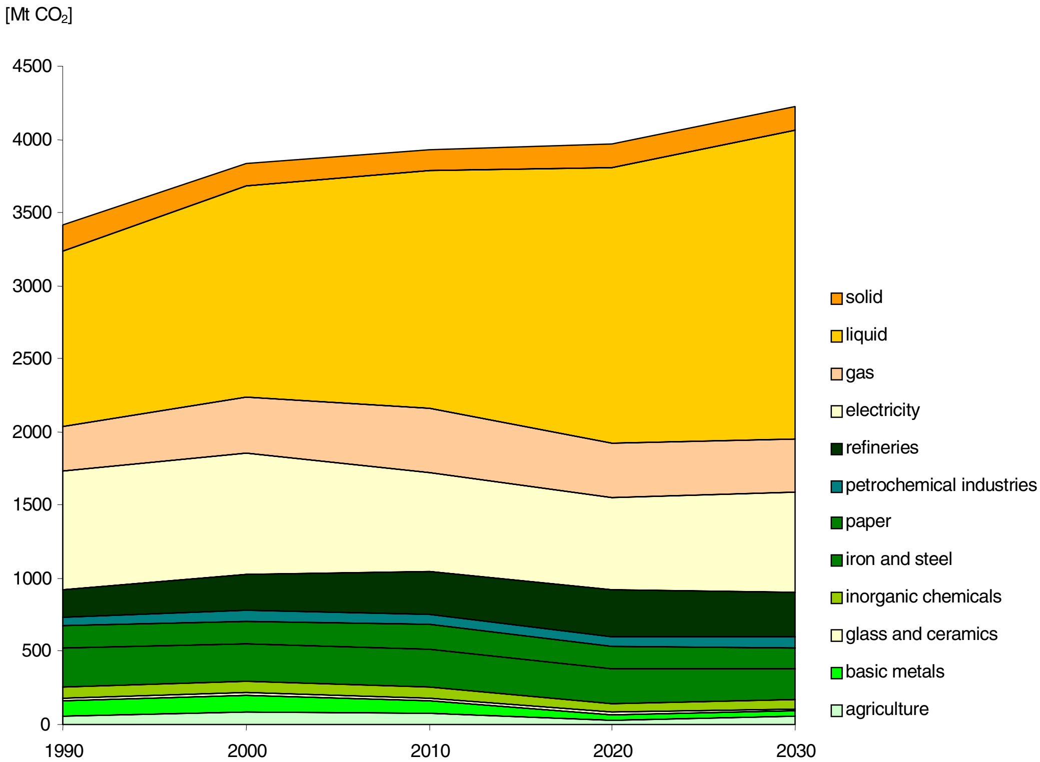


Figure 4.1 *Baseline scenario of sectoral CO_2 emission in Western Europe, 1990-2030 (variant B)*

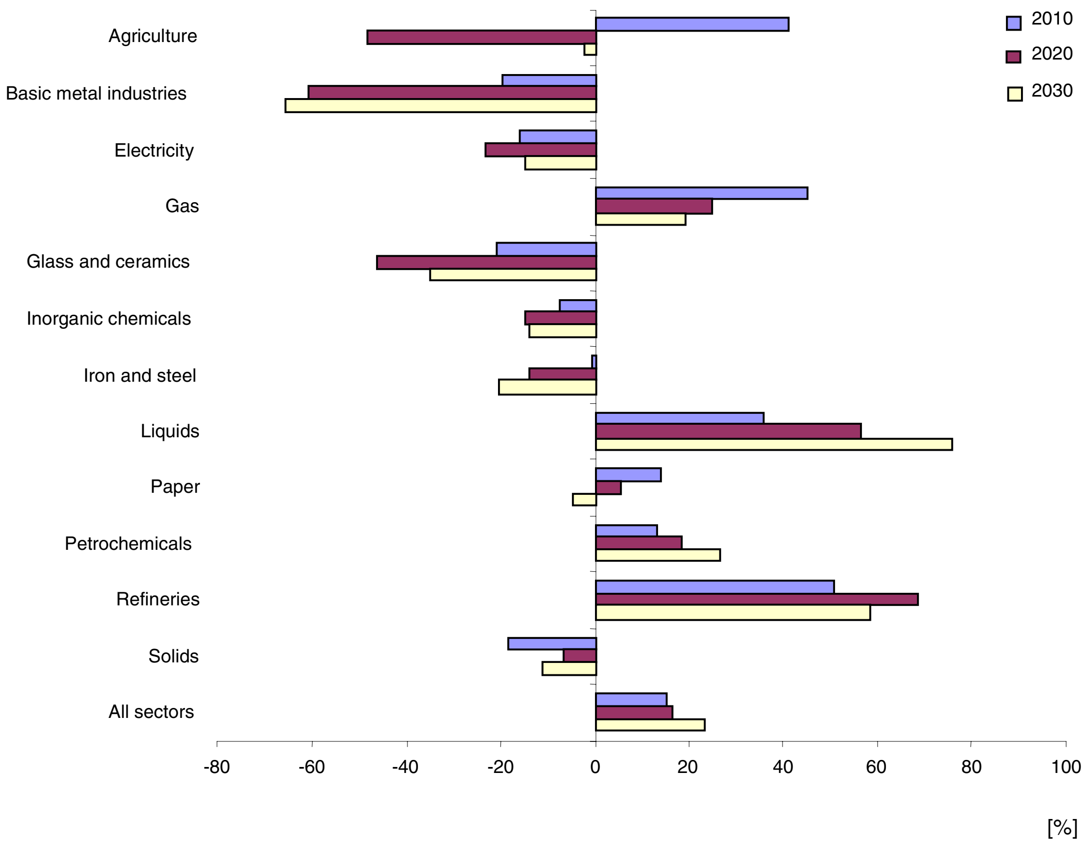


Figure 4.2 *Growth rates of sectoral baseline emissions in Western Europe for the years 2010-2030 compared to 1990 emission levels (Kyoto Plus scenario, variant B)*

The least-cost Kyoto Plus mitigation scenario

Both Table 4.2 and Figure 4.3 present the sectoral emissions in Western Europe for the period 1990-2030 according to the so-called 'least-cost Kyoto Plus mitigation scenario' (based on the sectoral classification of variant B). They show, for instance, that under this scenario the CO_2 emissions attributed to the gas sector will increase by 71 percent over the years 1990-2030, whereas those of the inorganic chemical industries will decline by 85 percent.

Table 4.2 *Least-cost Kyoto Plus mitigation scenario of sectoral CO_2 emissions in Western Europe, 1990-2030*[1]

	Absolute emissions [Mt CO_2]					Growth rates compared to 1990 levels [%]		
	1990	2000	2010	2020	2030	2010	2020	2030
Agriculture	56	84	53	6	30	-6	-89	-46
Basic metal industries	108	117	76	30	20	-29	-72	-82
Electricity	807	829	489	349	298	-39	-57	-63
Gas	301	380	430	459	514	43	52	71
Glass and ceramics	21	20	11	6	7	-49	-70	-66
Inorganic chemical industries	76	75	28	12	11	-63	-84	-85
Iron and steel	*267*	*255*	*200*	*135*	*63*	-25	-49	-76
Liquid fuels	1202	1446	1513	1566	1651	26	30	37
Paper	144	156	102	84	78	-29	-42	-46
Petrochemicals	63	72	67	70	76	6	12	21
Refineries	192	247	100	81	73	-48	-58	-62
Solid fuels	180	154	87	89	57	-51	-50	-68
Non-allocated/deviation from variant A	17	-2	5	18	28	-70	5	62
Total emissions of all sectors	*3434*	*3834*	*3159*	*2906*	*2906*	*-8*	*-15*	*-15*

[1] Based on sectoral classification of variant B.

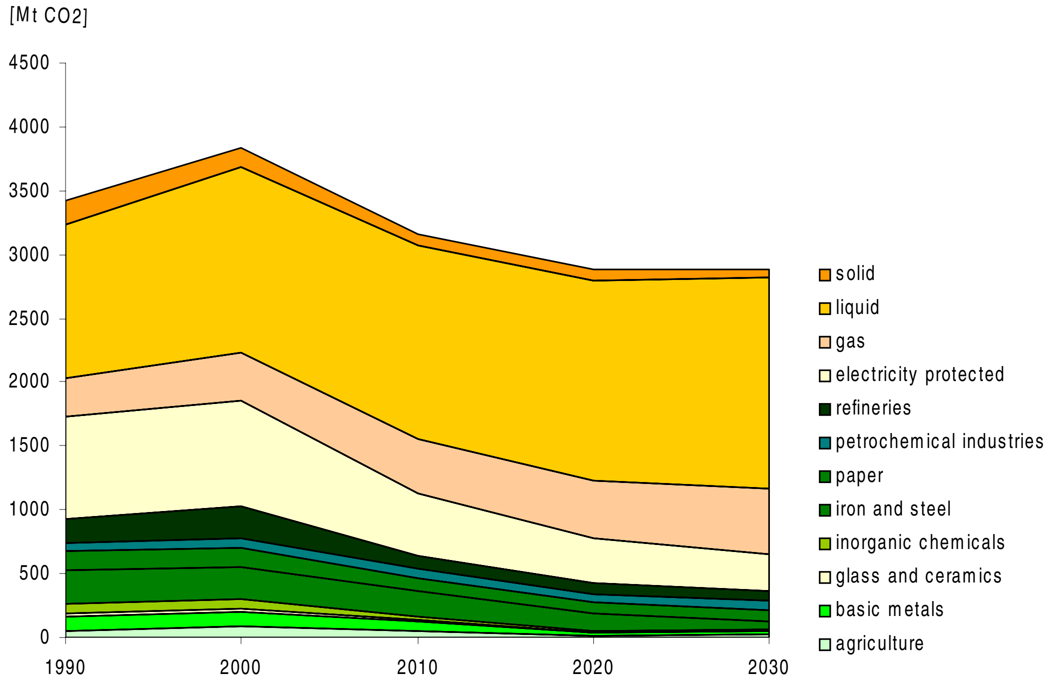


Figure 4.3 *Least-cost Kyoto Plus scenario of sectoral CO_2 emissions in Western Europe, 1990-2030 (classification according to variant A)*

4.3 Capital transfers resulting from a flat rate versus a proportional system of grandfathering: policy variant B

4.3.1 Initial allocation of allowances

Table 4.3 presents the initial grandfathering of allowances under the Kyoto Plus mitigation scenario (see also Figure 4.4). Compared to variant A, the amounts of allowances allocated are far higher under variant B. Moreover, whereas the total amount of allowances grandfathered in a specific year is different in variant A between a flat rate and a proportional system, this amount is equal for both allocation systems of variant B. This difference is explained by the fact that in variant A the allowance system covers only a (small and varying) part of total CO_2 emissions - depending on the year and the allocation system considered - whereas in variant B all CO_2 are included, regardless the year or the allocation system concerned.

At the sector level, however, the initial amount of allowances grandfathered varies between a flat rate and a proportional system (due to the differences in baseline growth rates of CO_2 emissions among the sectors concerned). In general, a flat rate system is more beneficial to sectors with a low (or negative) growth rate of their baseline CO_2 emissions, while a proportional system is more favourable to sectors with a high growth performance of their baseline emissions. For instance, CO_2 emissions of the basic metal industries are projected to decline by 66 percent in 2030 (compared to 1990). As a result, this sector will be allocated an amount of emission allowances equal to 91 Mt CO_2 under a flat rate system and of only 25 Mt CO_2 under a proportional system. On the other hand, CO_2 emissions of the sector liquid fuels are expected to increase by 76 percent over the years 1990-2030. As a result, this sector will receive an amount of allowances equal to some 1000 Mt CO_2 in 2030 under a flat rate system and an amount of more than 1400 Mt CO_2 under a proportional system (compare Tables 4.1 and 4.3 as well as Figures 4.2 and 4.4).

Table 4.3 *Initial allocation of CO_2 allowances under different systems of grandfathering (Kyoto Plus scenario, variant B, [Mt CO_2])*

	Flat rate			Proportional		
	2010	2020	2030	2010	2020	2030
Agriculture	52	47	47	63	21	37
Basic metal	100	91	91	70	31	25
Electricity	745	683	680	543	452	469
Gas	278	255	254	350	273	244
Glass and ceramics	20	18	18	14	8	9
Inorganic chemicals	70	64	64	56	47	44
Iron and steel	246	225	225	213	168	144
Liquid fuels	1110	1016	1013	1307	1367	1441
Paper	133	122	121	132	110	93
Petrochemicals	58	53	53	57	54	54
Refineries	177	163	162	232	236	207
Solid fuels	166	152	152	118	122	109
Non-allocated	5	18	28	5	18	28
Total	3159	2906	2906	3159	2906	2906

4.3.2 Marginal abatement costs

Table 4.4 shows the marginal abatement cost or (shadow) price of a CO_2 emission allowance resulting from the Kyoto Plus mitigation scenario under variant B of either a flat rate or a proportional system of tradable CO_2 allowances. As the total amounts of imputed CO_2 emissions, allocated allowances and mitigation options are equal under both systems, this price is also equal under both systems. Over the period 2010-30, however, the allowance price varies - from 41 Euro95 per tonne in 2010 to 36 Euro95 in 2020 and 48 Euro95 in 2030 - because of differences in trends of baseline emissions, reduction targets and costs of mitigation options.

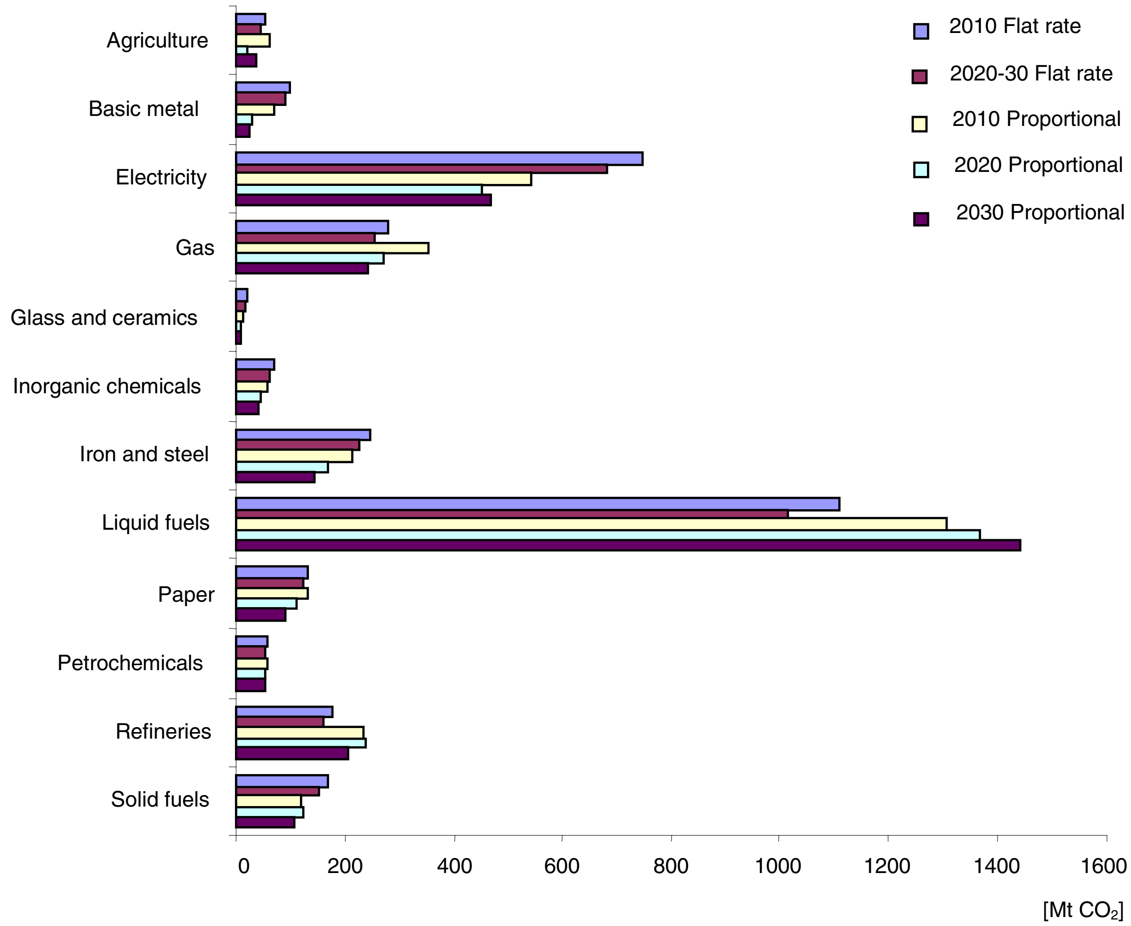


Figure 4.4 *Initial allocation of CO_2 allowances under different systems of grandfathering (Kyoto Plus scenario, variant B)*

Table 4.4 *Marginal abatement costs in exposed sectors of Western Europe resulting from different systems of grandfathering (Kyoto Plus scenario, variant B,Euro95/tonne CO_2)*

	2010	2020	2030
Flat rate	41	36	48
Proportional	41	36	48

4.3.3 Emissions trading and capital transfers

Table 4.3 indicates that in the Kyoto Plus scenario, the total amount of allowances allocated will be 3159 Mt CO_2 in 2010 and 2906 Mt CO_2 in the year 2020 and beyond. At a market price of 36 Euro95/tonne per allowance in 2020, this implies that in variant B the sectors involved in emissions trading will receive an amount of emission allowances equal to some 105 billion Euro95 in 2020. For 2030, when the estimated allowance price is equal to 48 Euro95/tonne, this amount rises to almost 139 billion Euro95.[22] Almost half the amount of allowances - and the initial value transfer involved - is allocated for free to the sector liquid fuels, while another major part, about 15 percent, is grandfathered to the sector electricity.

Table 4.5 presents data with regard to sectoral emission trade and capital transfers involved in Western Europe resulting from variant B of either a flat rate or a proportional system (see also

[22] The latter amount corresponds to about 0.7 percent of total projected GDP of Western Europe in 2030.

Figures 4.5 and 4.6). It shows that under both systems the sectors electricity and refineries sell large amounts of allowances. By contrast, the sectors gas and liquid fuels will buy large amounts of allowances, predominantly on behalf of their end-users in the sheltered sectors. In general, the amounts of capital transfers involved in trading allowances are much higher in variant B than in variant A, partly because of higher allowance prices but mainly due to larger amounts of allowances allocated and traded among the sectors concerned. For instance, under a flat rate system in 2030 - when the allowance price is estimated at 48 Euro95/tonne CO_2 - the sector electricity is expected to sell 382 Mt of CO_2 emission allowances at a total value of some 18 billion Euro95, whereas the sector liquid fuels is projected to buy 638 Mt CO_2 emission allowances at a total value of more than 30 billion Euro95.

Table 4.5 *Sectoral emission trade and capital transfers in Western Europe, 2010-2030, resulting from different systems of grandfathering (Kyoto Plus scenario, variant B)*

	Trade in emission allowances [Mt CO_2][1]			Capital transfers [mEuro95][a]		
	2010	2020	2030	2010	2020	2030
Flat rate						
Agriculture	1	-41	-17	41	-1459	-819
Basic metal	-23	-61	-71	-953	-2169	-3403
Electricity	-256	-333	-382	-10458	-11893	-18285
Gas	152	204	260	6209	7289	12458
Glass and ceramics	-9	-12	-11	-360	-417	-518
Inorganic chemicals	-42	-52	-53	-1700	-1857	-2525
Iron and steel	-47	-90	-162	-1905	-3228	-7737
Liquid fuels	403	550	638	16435	19610	30533
Paper	-31	-38	-43	-1264	-1343	-2050
Petrochemicals	9	17	23	349	618	1115
Refineries	-78	-82	-89	-3180	-2915	-4241
Solid fuels	-79	-63	-95	-3213	-2235	-4527
Proportional						
Agriculture	-11	-15	-7	-434	-524	-352
Basic metal	6	0	-5	264	-16	-256
Electricity	-54	-103	-171	-2219	-3669	-8175
Gas	80	186	270	3265	6635	12899
Glass and ceramics	-3	-2	-2	-109	-71	-111
Inorganic chemicals	-28	-35	-33	-1137	-1247	-1594
Iron and steel	-13	-32	-81	-531	-1159	-3892
Liquid fuels	206	199	210	8390	7099	10061
Paper	-30	-27	-15	-1221	-948	-725
Petrochemicals	10	16	22	390	586	1057
Refineries	-133	-155	-134	-5414	-5518	-6414
Solid fuels	-31	-33	-52	-1245	-1167	-2498

[1] A minus (-) indicates selling emission allowances and, hence, receiving a capital transfer.

Table 4.6 indicates that the amount of allowances traded in variant B varies from 302 Mt CO_2 in 2010 in a proportional system to 922 Mt CO_2 in 2030 in a flat rate system. As a percentage of total allowances allocated, these amounts correspond to 10 and 32 percent, respectively. On average, the total annual amount of emission allowances traded over the years 2010-30 is estimated at 753 Mt CO_2 in a flat rate system and at 402 Mt CO_2 in a proportional system. As a percentage of the total amount of allowances grandfathered in these years, these average quantities correspond to 25 and 13 percent, respectively. Compared to variant A, these percentages are significantly higher for variant B, notably for the flat rate system (i.e. 9 and 25 percent for a flat rate system of variants A and B, respectively, versus 11 and 13 percent for a proportional system of variants A and B, respectively; see Tables 3.9 and 3.15). Nevertheless, even under a flat rate system of variant B, the major part, some 75 percent, of the total initially grandfathered amount of emission allowances will be retained by the sectors themselves to meet their mitigation targets.

Table 4.6 *Total amounts of CO_2 allowances traded and capital transfers involved in Western Europe, 2010-2030, resulting from different systems of grandfathering (Kyoto Plus scenario, variant B)*

	Trade in emission allowances [Mt CO_2]				Total capital transfers [mEuro95]			
	2010	2020	2030	Average 2010-30	2010	2020	2030	Average 2010-30
Flat rate	565	771	922	753	23033	27517	44105	31552
Proportional	302	401	502	402	12310	14320	24016	16882
	As % of total allowances allocated				*As % of industrial turnover*[1]			
Flat rate	17.9	26.5	31.7	25.2	0.18	0.17	0.23	0.20
Proportional	9.6	13.8	17.3	13.4	0.10	0.09	0.13	0.11

[1] These calculations are based on the following assumptions (i) GDP of Western Europe in 2010: 12.000 billion Euro95, in 2020: 15.000 billion Euro95, and in 2030: 18.000 billion Euro95, (ii) industrial value added: 30 percent of GDP, and (iii) industrial turnover: 3.5 times industrial value added. Hence, in order to calculate capital transfers as a percentage of industrial value added, the figures presented as a percentage of industrial turnover have to be multiplied by 3.5. It should be noted that the assumption with regard to the industrial value added - i.e. 30 percent of GDP - is based on actual figures for the 1990s but this share might be significantly lower in the years 2010-2020.

Source: Eurostat, Yearbook 2000; and World Bank, World Development Indicators, 2001.

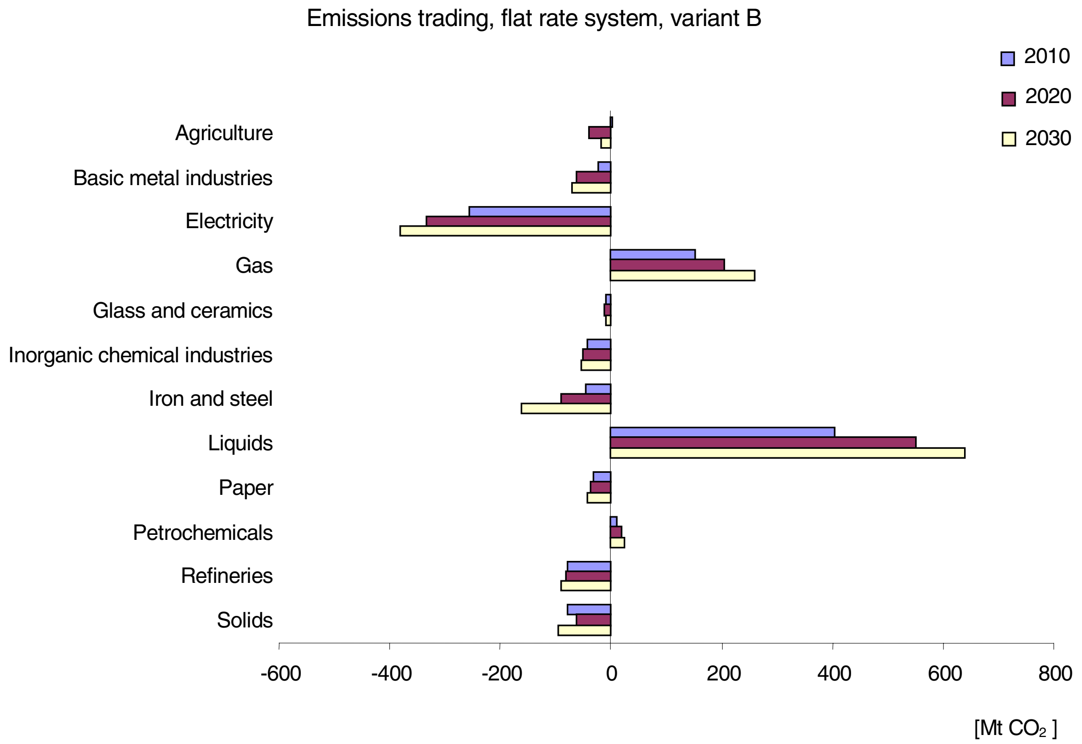
Table 4.6 also shows that, in terms of capital transfers between sectors, the total amounts involved vary from 12 billion Euro95 in 2010 in a proportional system to more than 44 billion Euro95 in 2030 in a flat rate system. On average, the total amount of capital transfers involved in emissions trading among the exposed sectors in Western Europe over the years 2010-2030 is estimated at 32 billion Euro95 in a flat rate system and 17 billion in a proportional system. As a percentage of total industrial turnover in Western Europe in the years 2010-30, these amounts correspond to about 0.20 and 0.11 percent, respectively.

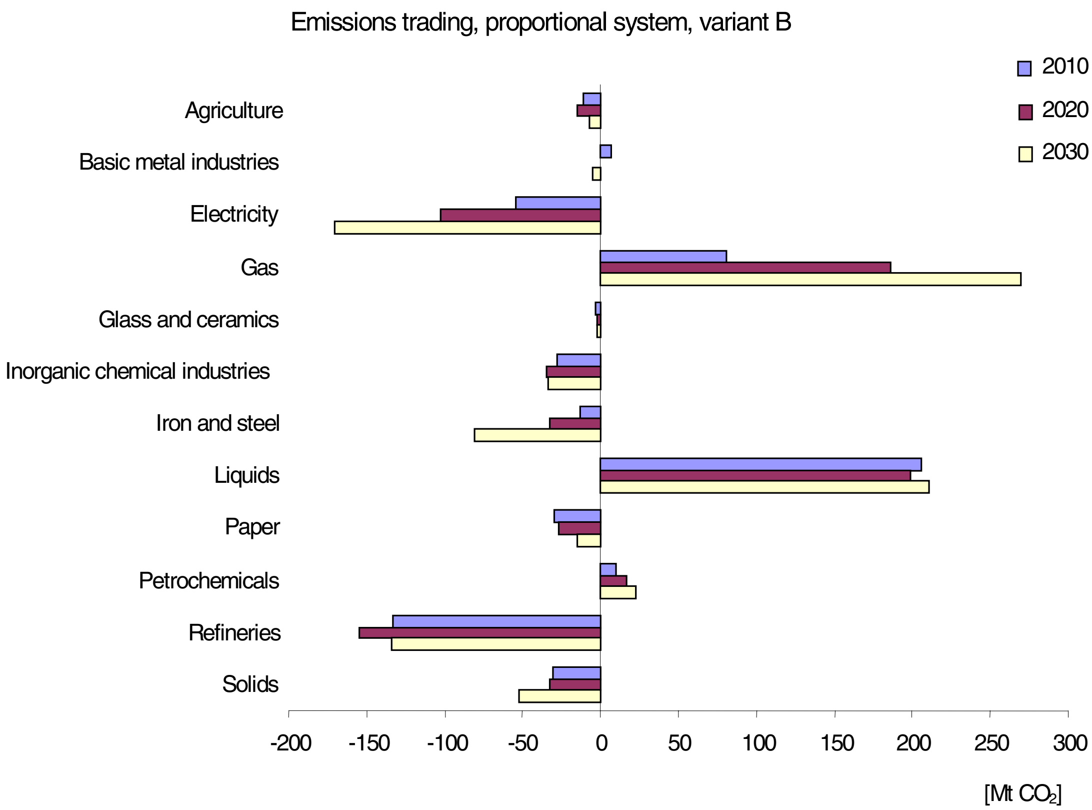
These average figures, however, may hide significant variances among individual sectors or years considered. For instance, according to the estimates of Table 4.5, the gas sector is expected to buy 270 Mt CO_2 of allowances in 2030 under a proportional system at a total value of almost 13 billion Euro95, corresponding to 110 percent of the amount of allowances grandfathered to this sector and to some 19 percent of its estimated turnover in that year, respectively.[23] On the other hand, the electricity sector is expected to sell 382 Mt CO_2 of allowances in 2030 under a flat rate system at a total value of some 18 billion Euro95, corresponding to 56 percent of the amount of allowances allocated to this sector and to some 10 percent of its estimated turnover in that year.[24]

Hence, it may be concluded that as a result of variant B of grandfathering CO_2 allowances, the total amounts of capital transfers involved in emissions trading among sectors in Western Europe are relatively small at the aggregated level, but they may be far more significant at the disaggregated level of individual sectors. A similar conclusion applies to the amounts of allowances traded, notably under a proportional system of variant B. Under a flat rate system of variant B, however, the amounts of allowances traded are significantly higher in both absolute and relative terms.

[23] According to MARKAL-MATTER3.0, the turnover of the gas sector in the Kyoto Plus scenario under a proportional system is estimated at 66 billion Euro95 in 2030.

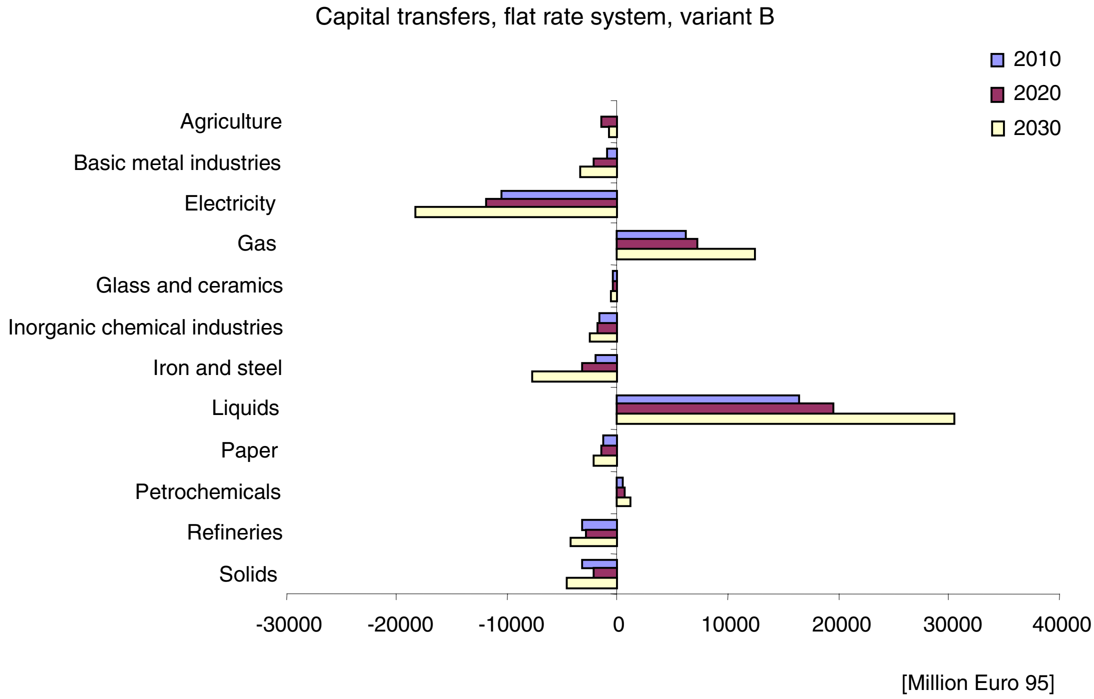
[24] The turnover of the electricity sector in Western Europe in 2030 is estimated at some 176 billion Euro95.

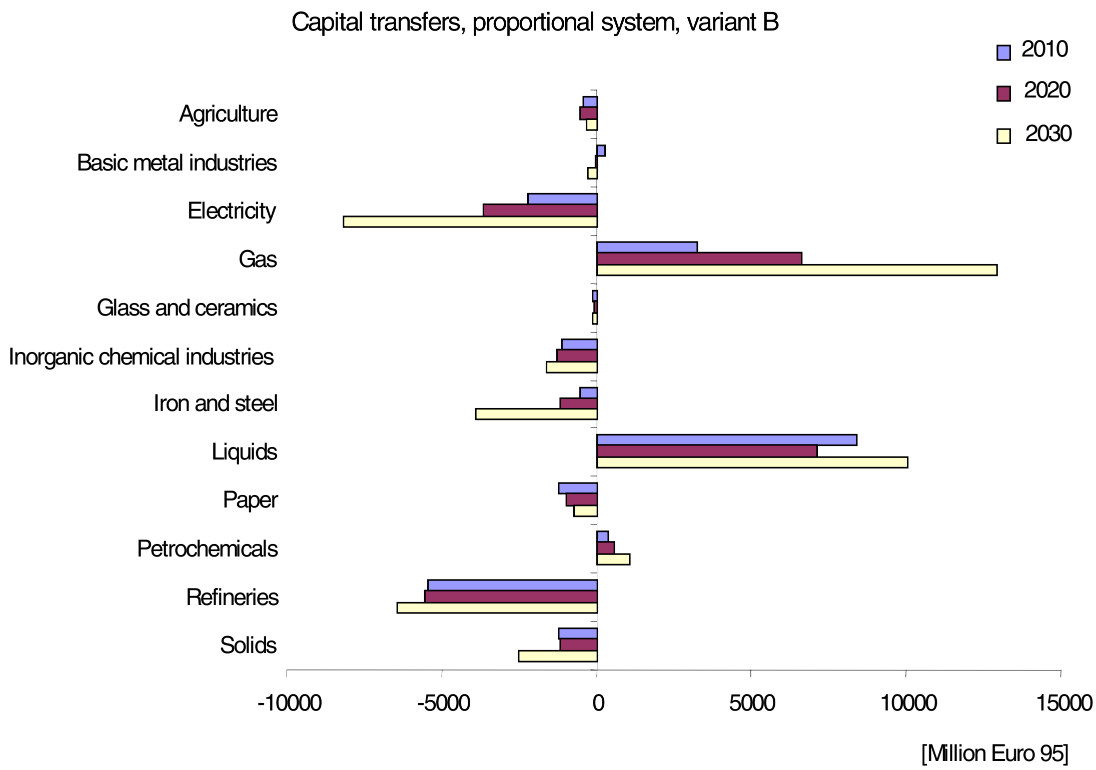




Note: The left part of the X-axis (negative figures) indicates selling emission allowances, whereas the right part refers to buying emission allowances.

Figure 4.5 *Trade in emission allowances according to different systems of grandfathering (Kyoto Plus, variant B)*





Note: The left part of the X-axis (negative figures) indicates receiving a capital transfer due to selling emission allowances, whereas the right part refers to paying a capital transfer due to buying emission allowances.

Figure 4.6 *Capital transfers due to trade in emission allowances according to different systems of grandfathering (Kyoto Plus, variant B)*

5. A COMPARISON OF ABATEMENT COSTS

This chapter present a comparison of the marginal, total and average abatement costs of the mitigation and grandfathering systems discussed in the previous chapters. These tables are based on the assumption that in variant A, the group of sheltered sectors as a whole is subjected to the same flat/proportional mitigation rate as the exposed sectors.

5.1 Marginal abatement costs

Table 5.1 summarises the marginal abatement cost of the different mitigation and grandfathering systems discussed in the previous chapters (see also Figure 5.1). The most important findings that can be drawn from this table include:

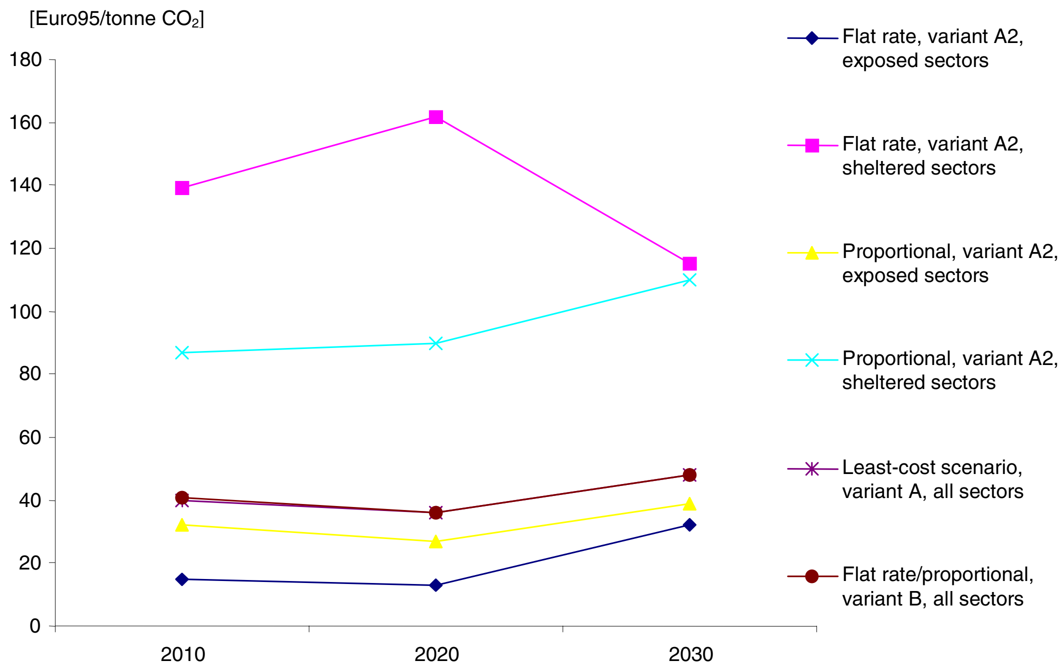
- The marginal costs of the exposed sectors in variant A of a tradable allowance system (A2) are lower in a flat rate system than in a proportional system, whereas the opposite applies for the sheltered sectors. This finding results from the fact that, in general, the baseline emissions of the exposed sectors over the years 1990-2030 show a lower growth rate than those of the sheltered sectors. The major implications of this finding are that (i) the exposed sectors will receive, on average, a higher amount of emission allowances under a flat rate system than under a proportional system, and (ii) that the exposed sectors, with few exceptions, will prefer a flat rate system, whereas the sheltered sectors will favour a proportional system.
- In both a flat rate and a proportional system, the marginal abatement costs are significantly lower for the exposed sectors than for the sheltered sectors. This result is due to the fact that, in general, reduction options are relatively cheaper in the exposed sectors than in the sheltered sectors. Due to these differences in abatement costs, both the exposed and sheltered sectors will benefit from emissions trading covering the emissions of all sectors.
- The marginal abatement costs of both the flat rate and the proportional system of variant B are (nearly) equal to the marginal costs of the least-cost scenario of variant A. This finding results from the fact that for both variants the crucial input assumptions of the model are almost identical (i.e. the same level of total baseline emissions over time, the same overall mitigation target, a similar set of least-cost mitigation options, and a similar opportunity to select the most optimal, i.e. least-cost, mix of these options to obtain the mitigation target). Therefore, variant B will lead to the least mitigation costs for the society as a whole.

Table 5.1 *Marginal abatement costs under different mitigation and grandfathering systems sectors in the period 1990-2030 (Kyoto Plus scenario, [Euro95/tonne])*[1]

	2010	2020	2030
Flat rate, variant A2, exposed sectors	15	13	32
Flat rate, variant A2, sheltered sectors	139	162	115
Proportional, variant A2, exposed sectors	32	27	39
Proportional, variant A2, sheltered sectors	87	90	110
Least-cost scenario, variant A, all sectors[2]	40	36	48
Flat rate/proportional, variant B, all sectors	41	36	48

1 Marginal abatement costs refer to the so-called system costs, i.e. investments and operational costs, of the production technologies and abatement options considered.

2 In the least-cost scenario of variant A, all sectors are assumed to participate in emissions trading, like in variant B. As the input conditions of the model are almost identical in these two variants, they yield almost identical results with regard to marginal abatement costs.



Note: The marginal abatement costs of the least-cost scenario, variant A, correspond to those of variant B (both flat rate and proportional system).

Figure 5.1 *Marginal abatement costs under different mitigation and grandfathering systems in the years 2010-2030 (Kyoto Plus scenario)*

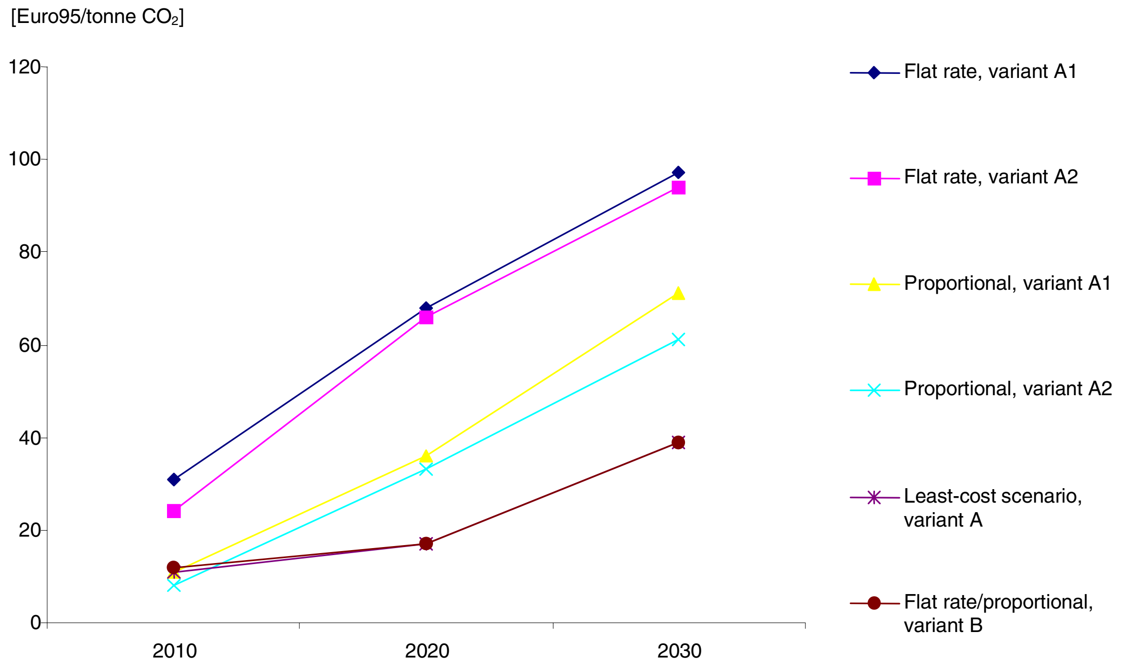
5.2 Total and average abatement costs

Table 5.2 provides some data with regard to both total and average mitigation costs of the different mitigation and grandfathering systems discussed above. It should be noted that the definition of mitigation costs in Table 5.2 deviates from the cost definition of Table 5.1. The marginal abatement costs of Table 5.1 refer to the so-called 'system costs' - including investments and operational costs - of the production technologies and abatement options covered by MARKAL-MATTER 3.0. Hence, these costs do not account for losses in consumer/producer surplus due to a lower, elastic demand for energy services and products resulting from higher prices. On the other hand, the total and average mitigation costs of Table 5.2 refer to the total loss of consumer and producer surpluses resulting from a mitigation strategy, including a lower demand for energy services and products due to higher prices.

Table 5.2 *Comparison of total and average abatement costs for different mitigation and grandfathering systems (Kyoto Plus scenario)*[1]

	Total abatement costs [billion Euro95]			Total emission mitigation [Mt CO_2]			Average abatement costs [Euro95 per tonne CO_2]		
	2010	2020	2030	2010	2020	2030	2010	2020	2030
Flat rate, variant A1	24.4	75.5	133.5	783	1.115	1.381	31	68	97
Flat rate, variant A2	18.6	70.5	124.7	773	1.073	1.332	24	66	94
Proportional, variant A1	8.2	39.1	96.3	773	1.074	1.355	11	36	71
Proportional, variant A2	6.1	35.9	80.9	773	1.073	1.332	8	33	61
Least-cost scenario, variant A[2]	8.4	17.7	51.4	737	1.043	1.302	11	17	39
Flat rate/proportional, variant B	9.6	17.8	52.0	773	1.073	1.332	12	17	39

1 Abatement costs refer to the total loss of consumer and producer surpluses.
2 In the least-cost scenario of variant A, all sectors are assumed to participate in emissions trading, like in variant B. As the input conditions of the model are almost identical in these two variants, they yield almost identical results with regard to marginal abatement costs.



Note: The average abatement costs of the least-cost scenario, variant A, correspond to those of variant B (both flat rate and proportional system).

Figure 5.2 *Average abatement costs under different mitigation and allocation systems in the years 2010-2030 (Kyoto Plus scenario)*

Table 5.2 shows that both the total and average mitigation costs vary widely between both the target years and the mitigation and grandfathering systems discussed in this study (see also Figure 5.2). The most important findings of this table include:

- The total/average abatement costs over the years 2010-30 are generally higher in variant A1 (excluding emissions trading) than in variant A2 (including emissions trading). Hence, as expected, a mitigation policy variant that allows emissions trading is more efficient than a variant forbidding such trading. This is due to the fact that in a system of tradable emission allowances a more optimal mix of least-cost reduction options will be selected.
- With regard to variant A, the total/average abatement costs are lower under a proportional system than under a flat rate system. This results from the fact that (i) reduction options are, in general, relatively cheaper in the exposed sectors than in the sheltered sectors, (ii) the growth of baseline emissions is projected to be higher for the sheltered than the exposed sectors and, hence, (iii) the amounts of CO_2 emissions to be reduced by the sheltered sectors are generally higher in a flat rate system than in a proportional system. From a social point of view, this implies that, under such conditions, a proportional system of variant A should be preferred above a flat rate system of variant A although the exposed sectors, as a group will be in favour of a flat rate system.
- The total/average abatement costs of both the flat rate and proportional systems of variant B over the years 2010-30 are (nearly) equal to those of the least-cost Kyoto Plus scenario of variant A. This implies that both grandfathering systems of variant B result not only in the same level of marginal, total and average mitigation costs but also in the most optimal, least-cost combination of mitigation options covering both the exposed and sheltered sectors. At the disaggregated level, however, those sectors with relatively low growth rates of their baseline emissions will favour a flat rate system of variant B, whereas those with a relatively high growth performance of their emissions will campaign for a proportional system of variant B.

6. MAIN CONCLUSIONS AND POLICY IMPLICATIONS

This study has analysed the potential capital transfers between economic sectors resulting from the grandfathering of CO_2 emission allowances in Western Europe over the period 1990-2030. Four different policy variants of grandfathering have been distinguished. First of all, variant A, which covers CO_2 emissions of the exposed sectors only, has been distinguished from variant B, which includes all CO_2 emissions of all economic sectors of Western Europe. Secondly, each variant has been further subdivided by distinguishing two different methods of grandfathering emission allowances, i.e. a flat rate (F) system, based on past emissions, versus a proportional (P) system, based on projected, future emissions. This latter distinction implies that differences in sectoral emission growth rates are accounted for in a P-system but not in an F-system.

In order to analyse the size, direction and underlying determinants of potential capital transfers due to grandfathering CO_2 emissions allowances, the present study has used a partial equilibrium model called MARKAL-MATTER3.0. This bottom-up optimisation model is able to (i) estimate trends in sectoral emissions for both baseline and mitigation scenarios, (ii) generate marginal abatement curves at the sector level of Western Europe, based on a large, comprehensive set of production annex abatement options covering both materials and energy flows, (iii) account for price-induced changes in final demand, (iv) estimate the most efficient allocation of sectoral emissions under different policy constraints and, hence, to analyse potential emissions trading and capital transfers, given a certain initial allocation of CO_2 allowances, and (v) assess the abatement costs of different policy options of grandfathering CO_2 allowances.

Based on the above-mentioned approach, the present study has led to the following main conclusions and policy implications:

a. Capital transfers among economic sectors due to grandfathering are sensitive to the policy variants considered as it can affect both the size and the direction of these transfers. As a percentage of industrial output, however, these capital transfers are generally rather modest, although they are more substantial in a variant covering all emissions - notably in a flat rate system of variant B - than in a variant covering the emissions of the exposed sectors only (i.e. variant A). Moreover, in all policy variants, they can be quite significant at the disaggregated level of individual sectors.
b. Whereas for both the flat rate and the proportional system of grandfathering the capital transfers are generally higher in variant B than variant A, the total abatement costs, excluding transaction costs, are usually substantially lower in the former than in the latter variant. This implies that from a cost perspective, either a flat rate or a proportional system of variant B should be preferred as both systems result in the same, least-cost situation. However, if for one reason or another variant A is chosen, total abatement costs will be lower in a proportional system than a flat rate system.
c. Although each sector will prefer variant B above variant A - as the former results in the most efficient situation for each sector - those sectors with a growth rate of their baseline emissions below average, i.e. mostly exposed sectors, will prefer a flat rate system of grandfathering CO_2 allowances, whereas those sectors with a growth performance above average, i.e. mostly sheltered sectors, will prefer a proportional system.

REFERENCES

Bovenberg, A.L. and L.H. Goulder (1999): *Neutralising the Adverse Industry Impacts of CO_2 Abatements Policies: What does it cost?* Paper prepared for the FEEM-NBER conference on behavioural and distributional effects of environmental policy, June 10-11, Milan, Italy.

Commissie CO_2-handel (2002): *Handelen voor een Beter Milieu, Haalbaarheid van CO_2-emissiehandel voor een beter milieu.* KPMG, De Meern.

European Commission (2001): *Proposal for a Directive of the European Parliament and of the Council establishing a scheme for a greenhoudse gas emission allowance trading within the Community and amending Council Directive 96/61/EC.* COM(2001) 581 final, Brussels.

Eurostat (2000): *Yearbook 2000.*

EZ (1999): *Milieu in de Markt; Emissiehandel als beleidsinstrument.* Projectgroep Verhandelbare EmissieRechten en -Reducties, Ministerie van Economische Zaken.

Gielen, D. (1999): *Materialising Dematerialisation - Integrated energy and materials systems engineering for greenhouse gas emission mitigation,* PhD thesis, Design for Sustainability Program, Technical University Delft.

Gielen, D. and J. Pieters (2001): *Instruments and Technologies for Climate Change Policy: An integrated energy and materials systems modelling approach,* OECD ENV/EPOC/GEEI(99)15/FINAL, Paris.

IVM (2001): *Praktische en Institutionele Aspecten van Verhandelbare Rechten van de Emissies van Broeikasgassen in de Nederlandse Landbouw.* Institute for Environmental Studies, Vrije Universiteit, Amsterdam.

Janssen, S. (1999): *MATTER3.0: Relaxing the Demand in the MATTER model*, Wageningen University.

Kram, T., et. al. (2001): *Integrated Energy and Materials Systems Engineering for GHG Emission Mitigation,* Final Report, ECN Policy Studies, Petten.

World Bank (2001): *World Development Indicators*, Washington DC.

ANNEX A COMPARISON OF DIFFERENT ESTIMATES OF GHG EMISSIONS FOR WESTERN EUROPE

Table A.1 compares the data on gross CO_2 emissions of the MARKAL-MATTER 3.0 model to those of the UNFCCC inventories for Western Europe in 1990 and 2000. As UNFCCC inventory data are only available up to 1998, these have been compared to the MARKAL-MATTER data of 2000. In addition, it should be noted that the difference in total emissions between Table 3.1 of the main text and Table A.1 below is explained by the fact that the figures of Table 3.1 are based on net emissions, i.e. including sinks and feedstocks, whereas those of Table A.1 refer to gross emissions.

Table A.1 *Comparison of estimates of gross CO_2 emissions between MARKAL-MATTER3.0 and UNFCCC inventories for Western Europe*

	Unit	MARKAL (1990)	UNFCCC (1990)	MARKAL/ UNFCCC [%]	MARKAL (2000)	UNFCCC (1998)	MARKAL/ UNFCCC [%]
CO_2	Mtonne	4016	3660	109.7	3972	3639	109.1

ANNEX B TABLES OF DIFFERENT CASES OF GRANDFATHERING CO_2 ALLOWANCES

Case 1: Flat rate system, variant A1

Table B.1 *Sectoral CO_2 emissions in Western Europe, 1990-2030, resulting from a flat rate system (Kyoto Plus scenario, variant A1)*

	Absolute emissions [Mt CO_2]					Growth rates compared to 1990 levels [%]		
	1990	2000	2010	2020	2030	2010	2020	2030
Agriculture	40	63	36	33	33	-8.0	-15.4	-15.4
Basic metal industries	69	65	52	17	9	-23.7	-74.6	-86.8
Glass and ceramics	8	8	7	6	7	-8.0	-25.0	-15.4
Inorganic chemical industries	54	55	50	46	46	-8.0	-15.4	-15.7
Iron and steel	233	220	214	197	197	-8.0	-15.4	-15.4
Paper	85	95	78	72	72	-8.0	-15.4	-15.4
Petrochemical industries	49	56	45	41	41	-8.0	-15.4	-15.4
Power plants (incl. waste incineration)	1013	1054	932	857	857	-8.0	-15.4	-15.4
Refineries	185	238	170	156	156	-8.0	-15.4	-15.4
Total exposed sectors	*1734*	*1855*	*1585*	*1426*	*1419*	*-8.6*	*-17.7*	*-18.2*
Commercial & service sector	230	250	217	152	207	-5.6	-33.8	-9.9
Construction materials (incl. cement)	126	115	0	0	26	-100.0	-100.0	-79.6
Freight transport	297	337	330	283	362	10.8	-4.9	21.6
Other transport	419	553	584	569	362	39.4	35.8	-13.6
Public transport	120	169	183	191	214	52.6	59.7	78.7
Residential sector	381	378	185	180	204	-51.5	-52.8	-46.4
Rest industry	127	177	66	64	65	-48.2	-49.6	-49.2
Total sheltered sectors	*1700*	*1978*	*1564*	*1439*	*1439*	*-8.0*	*-15.4*	*-15.4*
Total emissions of all sectors	3434	3834	3148	2865	2857	-8.3	-16.6	-16.8
Share of the exposed sectors in total emissions [%]	50	48	50	50	50			

Table B.2 *Marginal abatement costs in a flat rate system (Kyoto Plus scenario, variant A1, [Euro95/tonne CO_2])*

	2010	2020	2030
Exposed sectors			
Agriculture	65	8	24
Basic metal industries	0	0	0
Glass and ceramics	28	0	57
Inorganic chemical industries	1	1	0
Iron and steel	6	23	8
Paper	67	88	83
Petrochemical industries	144	152	123
Power plants (incl. waste incineration)	15	23	33
Refineries	19	9	1
Sheltered sectors	*144*	*164*	*117*

Case 2: Flat rate system, variant A2

Table B.3 *Sectoral CO_2 emissions in Western Europe, 1990-2030, resulting from a flat rate system (Kyoto Plus scenario, variant A2)*

	Absolute emissions [Mt CO_2]					Growth rates compared to 1990 levels [%]		
	1990	2000	2010	2020	2030	2010	2020	2030
Agriculture	40	63	53	19	30	34.8	-51.6	-24.3
Basic metal industries	69	65	52	17	9	-23.9	-74.6	-87.0
Glass and ceramics	8	8	9	7	8	9.1	-10.9	0.6
Inorganic chemical industries	54	55	19	10	7	-65.6	-81.7	-87.9
Iron and steel	233	220	196	185	153	-15.7	-20.6	-34.2
Paper	85	95	105	98	91	23.6	14.5	6.6
Petrochemical industries	49	56	89	101	93	82.5	107.3	91.8
Power plants (incl. waste incineration)	1013	1054	887	903	975	-12.4	-10.8	-3.8
Refineries	185	238	185	128	103	0.5	-30.8	-44.3
Total exposed sectors	*1734*	*1855*	*1595*	*1468*	*1468*	*-8.0*	*-15.4*	*-15.4*
Commercial & service sector	230	250	219	156	209	-4.8	-32.0	-9.1
Construction materials (incl. cement)	126	115	5	0	26	-96.4	-100.0	-79.4
Freight transport	297	337	327	280	299	9.9	-6.0	0.5
Other transport	419	553	564	561	337	34.6	33.8	-19.6
Public transport	120	169	187	206	209	56.2	72.3	74.7
Residential sector	381	378	198	171	290	-48.0	-55.1	-23.8
Rest industry	127	177	65	65	69	-49.1	-49.1	-45.6
Total sheltered sectors	*1700*	*1978*	*1564*	*1439*	*1439*	*-8.0*	*-15.4*	*-15.4*
Total emissions of all sectors	3434	3834	3159	2906	2906	-8.0	-15.4	-15.4
Share of the exposed sectors in total emissions [%]	50	48	50	50	50			

Table B.4 *Marginal abatement costs in a flat rate system (Kyoto Plus scenario, variant A2, [Euro95/tonne CO_2])*

	2010	2020	2030
Exposed sectors	15	13	32
Sheltered sectors	139	162	115

Table B.5 *Sectoral emission trade and capital transfers in Western Europe, 1990-2030, resulting from a flat rate system (Kyoto Plus scenario, variant A2)*

	Allowances [Mt CO_2]		Trade in emission allowances [Mt CO_2][1]			Capital transfers [mEuro95][a]		
	2010	2020-30	2010	2020	2030	2010	2020	2030
Agriculture	36	33	17	-14	-4	251	-185	-111
Basic metal industries	63	58	-11	-41	-49	-162	-525	-1563
Glass and ceramics	7	7	1	0	1	20	5	41
Inorganic chemical industries	50	46	-31	-36	-39	-463	-466	-1255
Iron and steel	214	197	-18	-12	-44	-266	-157	-1396
Paper	78	72	27	25	19	398	329	595
Petrochemical industries	45	41	44	59	52	650	769	1653
Power plants (incl. waste incineration)	932	857	-45	46	117	-659	599	3735
Refineries	170	*156*	16	-29	-53	232	-369	-1699
Exposed sectors	*1595*	*1468*	*0*	*0*	*0*	*0*	*0*	*0*
Price per allowance [Euro95/t]			15	13	32	15	13	32

[1] A minus (-) indicates selling emission allowances and, hence, receiving a capital transfer.

Case 3: Proportional system, variant A1

Table B.6 *Sectoral CO_2 emissions in Western Europe, 1990-2030, resulting from a proportional system (Kyoto Plus scenario, variant A1)*

	Absolute emissions [Mt CO_2]					Growth rates compared to 1990 levels [%]		
	1990	2000	2010	2020	2030	2010	2020	2030
Agriculture	40	63	51	12	6	29.1	-70.5	-85.3
Basic metal industries	69	65	41	13	6	-39.8	-81.5	-90.8
Glass and ceramics	8	8	7	5	6	-11.8	-33.1	-26.0
Inorganic chemical industries	54	55	44	38	36	-19.3	-29.9	-34.0
Iron and steel	233	220	193	154	132	-17.1	-34.0	-43.5
Paper	85	95	95	85	69	11.9	0.0	-18.6
Petrochemical industries	49	56	47	47	47	-2.4	-2.6	-3.1
Power plants (incl. waste incineration)	1013	1054	676	546	562	-33.2	-46.1	-44.5
Refineries	185	238	227	232	204	22.7	25.5	10.5
Total exposed sectors	*1734*	*1855*	*1382*	*1131*	*1068*	*-20.3*	*-34.8*	*-38.4*
Commercial & service sector	230	250	237	182	213	3.4	-20.7	-7.3
Construction materials (incl. cement)	126	115	20	25	15	-84.4	-80.4	-88.0
Freight transport	297	337	357	340	282	20.2	14.2	-5.2
Other transport	419	553	613	622	671	46.2	48.3	60.1
Public transport	120	169	192	255	300	60.9	112.9	150.4
Residential sector	381	378	295	286	267	-22.5	-25.1	-29.9
Rest industry	127	177	62	67	68	-50.9	-47.3	-46.2
Total sheltered sectors	*1700*	*1978*	*1778*	*1775*	*1816*	*4.6*	*4.4*	*6.8*
Total emissions of all sectors	3434	3834	3159	2906	2884	-8.0	-15.4	-16.0
Share of the exposed sectors in total emissions [%]	50	48	44	39	37			

Table B.7 *Marginal abatement costs in a proportional system (Kyoto Plus scenario, variant A1, [Euro95/tonne CO_2])*

	2010	2020	2030
Exposed sectors			
Agriculture	20	9	130
Basic metal industries	107	245	242
Glass and ceramics	30	30	54
Inorganic chemical industries	8	1	-5
Iron and steel	26	41	43
Paper	26	9	83
Petrochemical industries	84	99	118
Power plants (incl. waste incineration)	34	31	49
Refineries	4	7	5
Sheltered sectors	94	100	110

Case 4: Proportional system, variant A2

Table B.8 *Sectoral CO_2 emissions in Western Europe, 1990-2030, resulting from a proportional system (Kyoto Plus scenario, variant A2)*

	Absolute emissions [Mt CO_2]					Growth rates compared to 1990 levels [%]		
	1990	2000	2010	2020	2030	2010	2020	2030
Agriculture	40	63	47	2	25	19.4	-95.7	-36.1
Basic metal industries	69	65	46	16	8	-32.5	-76.5	-88.9
Glass and ceramics	8	8	4	3	4	-48.1	-68.5	-54.4
Inorganic chemical industries	54	55	19	6	7	-65.7	-88.6	-88.0
Iron and steel	233	220	190	172	155	-18.4	-25.9	-33.4
Paper	85	95	97	70	77	13.7	-17.4	-9.5
Petrochemical industries	49	56	86	97	97	76.3	99.3	99.0
Power plants (incl. waste incineration)	1013	1054	675	663	625	-33.3	-34.6	-38.3
Refineries	185	238	218	103	94	17.9	-44.2	-48.9
Total exposed sectors	*1734*	*1855*	*1382*	*1131*	*1091*	*-20.3*	*-34.8*	*-37.1*
Commercial & service sector	230	250	239	183	213	4.2	-20.2	-7.2
Construction materials (incl. cement)	126	115	20	33	20	-84.2	-73.4	-84.2
Freight transport	297	337	336	338	356	12.9	13.6	19.8
Other transport	419	553	592	601	622	41.3	43.3	48.4
Public transport	120	169	190	253	290	59.2	111.5	142.5
Residential sector	381	378	337	299	245	-11.6	-21.5	-35.7
Rest industry	127	177	63	68	69	-50.2	-46.8	-45.5
Total sheltered sectors	*1700*	*1978*	*1778*	*1775*	*1816*	*4.6*	*4.4*	*6.8*
Total emissions of all sectors	3434	3834	3159	2906	2906	-8.0	-15.4	-15.4
Share of the exposed sectors in total emissions [%]	50	48	44	39	38			

Table B.9 *Marginal abatement costs in a proportional system (Kyoto Plus scenario, variant A2, [Euro95/tonne CO_2])*

	2010	2020	2030
Exposed sectors	32	27	39
Sheltered sectors	87	90	110

Table B.10 *Sectoral emission trade and capital transfers in Western Europe, 1990-2030, resulting from a proportional system (Kyoto Plus scenario, variant A2)*

	Allowances [Mt CO_2]			Trade in emission allowances [Mt CO_2][a]			Capital transfers [mEuro95][a]		
	2010	2020	2030	2010	2020	2030	2010	2020	2030
Agriculture	51	12	29	-4	-10	-3	-123	-278	-135
Basic metal industries	41	13	6	5	3	1	159	92	50
Glass and ceramics	7	5	6	-3	-3	-2	-93	-77	-89
Inorganic chemical industries	44	38	36	-25	-32	-29	-810	-866	-1148
Iron and steel	193	154	131	-3	19	23	-95	513	915
Paper	95	85	69	2	-15	8	50	-402	306
Petrochemical industries	47	47	47	38	49	49	1224	1339	1939
Power plants (incl. waste incineration)	676	546	562	-1	117	63	-29	3164	2456
Refineries	227	232	204	-9	-129	-110	-284	-3486	-4292
Exposed sectors	*1382*	*1131*	*1091*	*0*	*0*	*0*	*0*	*0*	*0*
Price per allowance [Euro95/t]	32	27	39	32	27	39	32	27	39

[1] A minus (-) indicates selling emission allowances and, hence, receiving a capital transfer.

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Case 5: Flat rate system, variant B

Table B.11 *Sectoral CO_2 emissions in Western Europe, 1990-2030, resulting from a flat rate system (Kyoto Plus scenario, variant B)*

	Absolute emissions [Mt CO_2]					Growth rates compared to 1990 levels [%]		
	1990	2000	2010	2020	2030	2010	2020	2030
Agriculture	56	84	53	6	30	-6	-89	-46
Basic metal industries	108	117	76	30	20	-29	-72	-82
Electricity	807	829	489	349	298	-39	-57	-63
Gas	301	380	430	459	514	43	52	71
Glass and ceramics	21	20	11	6	7	-49	-70	-66
Inorganic chemical industries	76	75	28	12	11	-63	-84	-85
Iron and steel	*267*	*255*	*200*	*135*	*63*	-25	-49	-76
Liquid fuels	1202	1446	1513	1566	1651	26	30	37
Paper	144	156	102	84	78	-29	-42	-46
Petrochemicals	63	72	67	70	76	6	12	21
Refineries	192	247	100	81	73	-48	-58	-62
Solid fuels	180	154	87	89	57	-51	-50	-68
Non-allocated/deviation from variant A	17	-2	5	18	28	-70	5	62
Total emissions of all sectors	*3434*	*3834*	*3159*	*2906*	*2906*	*-8*	*-15*	*-15*

Table B.12 *Marginal abatement costs in a flat rate system (Kyoto Plus scenario, variant B, [Euro95/tonne CO_2])*

	2010	2020	2030
Exposed sectors	41	36	48

Table B.13 *Sectoral emission trade and capital transfers in Western Europe, 1990-2030, resulting from a flat rate system (Kyoto Plus scenario, variant B)*

	Allowances [Mt CO_2]			Trade in emission allowances [Mt CO_2][1]			Capital transfers [mEuro95][1]		
	2010	2020	2030	2010	2020	2030	2010	2020	2030
Agriculture	52	47	47	1	-41	-17	41	-1459	-819
Basic metal industries	100	91	91	-23	-61	-71	-953	-2169	-3403
Electricity	745	683	680	-256	-333	-382	-10458	-11893	-18285
Gas	278	255	254	152	204	260	6209	7289	12458
Glass and ceramics	20	18	18	-9	-12	-11	-360	-417	-518
Inorganic chemicals	70	64	64	-42	-52	-53	-1700	-1857	-2525
Iron and steel	246	225	225	-47	-90	-162	-1905	-3228	-7737
Liquid fuels	1110	1016	1013	403	550	638	16435	19610	30533
Paper	133	122	121	-31	-38	-43	-1264	-1343	-2050
Petrochemicals	58	53	53	9	17	23	349	618	1115
Refineries	177	163	162	-78	-82	-89	-3180	-2915	-4241
Solid fuels	166	152	152	-79	-63	-95	-3213	-2235	-4527
Non-allocated	5	18	28	0	0	0	0	0	0
Total	*3159*	*2906*	*2906*	*0*	*0*	*0*	*0*	*0*	*0*
Price per allowance [Euro95/t]	41	36	48	41	36	48	41	36	48

[1] A minus (-) indicates selling emission allowances and, hence, receiving a capital transfer.

Case 6: Proportional system, variant B

Table B.14 *Sectoral CO_2 emissions in Western Europe, 1990-2030, resulting from a proportional system (Kyoto Plus scenario, variant B)*

	Absolute emissions [Mt CO_2]					Growth rates compared to 1990 levels [%]		
	1990	2000	2010	2020	2030	2010	2020	2030
Agriculture	56	84	53	6	30	-6	-89	-46
Basic metal industries	108	117	76	30	20	-29	-72	-82
Electricity	807	829	489	349	298	-39	-57	-63
Gas	301	380	430	459	514	43	52	71
Glass and ceramics	21	20	11	6	7	-49	-70	-66
Inorganic chemical industries	76	75	28	12	11	-63	-84	-85
Iron and steel	*267*	*255*	*200*	*135*	*63*	-25	-49	-76
Liquid fuels	1202	1446	1513	1566	1651	26	30	37
Paper	144	156	102	84	78	-29	-42	-46
Petrochemicals	63	72	67	70	76	6	12	21
Refineries	192	247	100	81	73	-48	-58	-62
Solid fuels	180	154	87	89	57	-51	-50	-68
Non-allocated/deviation from variant A	17	-2	5	18	28	-70	5	62
Total emissions of all sectors	*3434*	*3834*	*3159*	*2906*	*2906*	*-8*	*-15*	*-15*

Table B.15 *Marginal abatement costs in a proportional system (Kyoto Plus scenario, variant B, [Euro95/tonne CO_2])*

	2010	2020	2030
Exposed sectors	41	36	48

Table B.16 *Sectoral emission trade and capital transfers in Western Europe, 1990-2030, resulting from a proportional system (Kyoto Plus scenario, variant B)*

	Allowances [Mt CO_2]			Trade in emission allowances [Mt CO_2][1]			Capital transfers [mEuro95][1]		
	2010	2020	2030	2010	2020	2030	2010	2020	2030
Agriculture	63	21	37	-11	-15	-7	-434	-524	-352
Basic metal industries	70	31	25	6	0	-5	264	-16	-256
Electricity	543	452	469	-54	-103	-171	-2219	-3669	-8175
Gas	350	273	244	80	186	270	3265	6635	12899
Glass and ceramics	14	8	9	-3	-2	-2	-109	-71	-111
Inorganic chemicals	56	47	44	-28	-35	-33	-1137	-1247	-1594
Iron and steel	213	168	144	-13	-32	-81	-531	-1159	-3892
Liquid fuels	1307	1367	1441	206	199	210	8390	7099	10061
Paper	132	110	93	-30	-27	-15	-1221	-948	-725
Petrochemicals	57	54	54	10	16	22	390	586	1057
Refineries	232	236	207	-133	-155	-134	-5414	-5518	-6414
Solid fuels	118	122	109	-31	-33	-52	-1245	-1167	-2498
Non-allocated	5	18	28	0	0	0	0	0	0
Total	*3159*	*2906*	*2906*	*0*	*0*	*0*	*0*	*0*	*0*
Price per allowance [Euro95/t]	41	36	48	41	36	48	41	36	48

[1] A minus (-) indicates selling emission allowances and, hence, receiving a capital transfer.

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