Tradable CO2 permits in Danish and European energy policy

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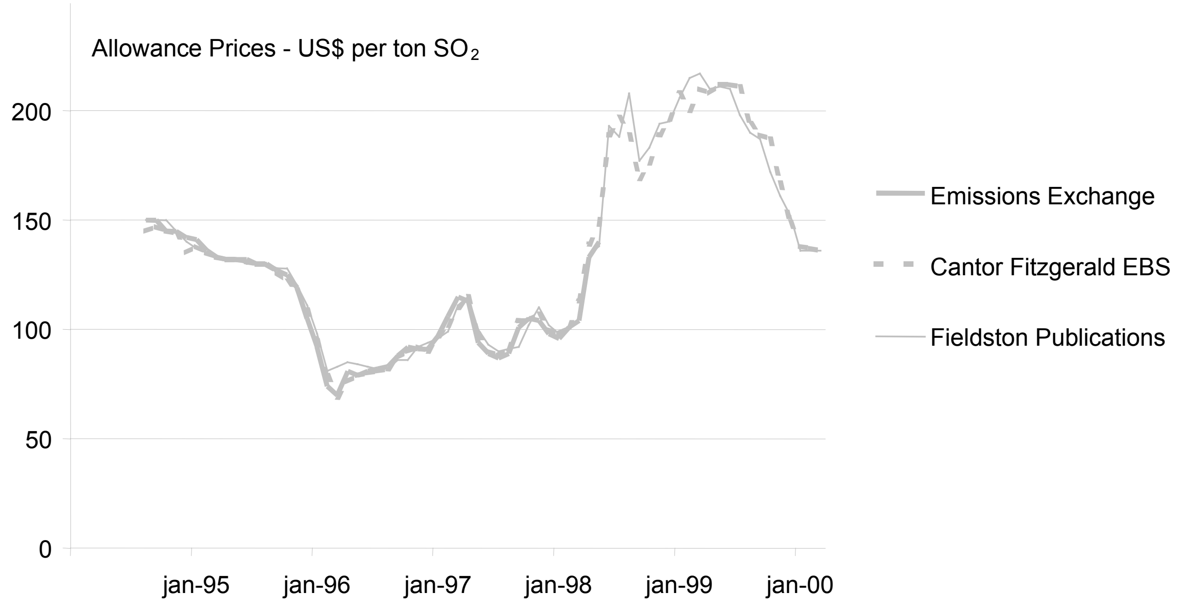

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Tradable CO_2 Permits in Danish and European Energy Policy

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Abstract

This report presents the results of the project "Tradable CO_2 permits in Danish and European energy policy". The project was financed by a grant from the Danish Energy Research Programme 1998 (Grant 1753/98-0002). The project was conducted in co-operation between Elsamprojekt A/S (project manager), Risø National Laboratory, Aarhus School of Business and I/S Eltra.

The three major objectives of the project were:

- To identify and analyse the economical and political issues that are relevant with regard to the construction of a tradable CO_2 permit market as well as proposing a suitable design for a tradable CO_2 permit market for the energy sector in the EU. Experience from the tradable SO_2 permit market in the US is taken into consideration as well.
- To present an overview of price estimates of CO_2 and greenhouse gas permits in different models as well as discussing the assumptions leading to the different outcomes. Furthermore, the special role of backstop technologies in relation to permit prices is analysed.
- To analyse the connection between CO_2 permit prices and technology choice in the energy sector in the medium and longer term (i.e. 2010 and 2020) with a special emphasis on combined heat and power and renewables. In addition, the short-term effects on CO_2 emissions and electricity trade of introducing tradable CO_2 permits with limited coverage (i.e. a national system) as well as complete coverage (i.e. including all the countries) in the Nordic electricity system are analysed.

Cover

Allowance prices for SO_2 quotas in the United States, source: Table 4.1

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Preface

This report presents the results of the project "Tradable CO_2 permits in Danish and European energy policy". The project was financed by a grant from the Danish Energy Research Programme 1998 (Grant 1753/98-0002). I/S Eltra provided additional funding by putting up working resources for the project.

The project was conducted in co-operation between Elsamprojekt A/S (project manager), Risø National Laboratory, Aarhus School of Business and I/S Eltra.

During the period of the study, the issue of tradable CO_2 quotas has become increasingly important on the political agenda. The application for the project was made before the Kyoto Conference in December 1997. With the inclusion of tradable quotas as one of the flexible mechanisms of the Kyoto Protocol, international attention has increased considerably. In many ways, the focus has changed from the project oriented mechanisms, like Joint Implementation, towards the more generalised concept of emissions trading.

The Danish law on CO_2 quotas for the electric utilities has been approved by the European Commission and will be implemented within a year. The Commission has produced its own "Green book" on emissions trading and several countries including Norway, Sweden and UK have produced national studies on the issue. Transnational companies like Shell and BP Amoco have established test systems for emissions trading within the company.

With this report and the seminar on 11 May 2000 this project is finalised. It does not contain all the final answers but hopefully some insights and inspiration for further studies.

The project group consisted of:

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Abbreviations

AAU	assigned amount units
ARP	Acid Rain Program
BP	British Petroleum
CAC	command-and-control
CCGT	combined cycle gas turbine
CDM	Clean Development Mechanism
CGE	Computable General Equilibrium (CGE) model
CHP	combined heat and power
CO_2	carbon dioxide (greenhouse gas)
CoP	Conference of the Parties
E3	energy-environment-economic
EC	European Communities
ECU	European Currency Unit (until 1998)
EdF	Électricité de France
EEA	European Economic Area
EFOM	Energy Flow Optimisation Model
EnBW	Energie Baden-Württemberg
EPA	Environmental Protection Agency (USA)
ETSAP	Energy Technology Systems Analysis Programme
EU	European Union
FERC	Federal Energy Regulatory Commission
GAMS	General Algebraic Modelling System
GATT	General Agreement on Tariffs and Trade
GW	gigawatt
GWh	gigawatt hours
HFC	(greenhouse gas)
IEA	International Energy Agency
IPCC	Intergovernmantal Panel on Climate Change
JI	Joint Implementation
kW	kilowatt
kWh	kilowatt hours
MARKAL	Market Allocation (optimisation model developed by the IEA)
Mtoe	million ton of oil equivalent
MW	megawatt
MWe	megawatt, electric
MWh	megawatt hours
N_2O	nitrous oxide (greenhouse gas)
NOx	nitrogen oxides
NGO	Non-Government Organisation
PFC	(greenhouse gas)
PJ	petajoule
PSO	public service obligation
PUC	Public Utility Commission
SF_6	sulphur hexafluroride (greenhouse gas)
SO_2	sulphur dioxide
TJ	terajoule
toe	ton of oil equivalent
TWh	terawatt hours
UNFCCC	United Nations Framework Convention on Climate Change
VEAG	Vereinigte Energiewerke AG
WTO	World Trade Organization

0 Summary and Conclusions

The subject of this report is the possible use of tradable CO_2 permits in European energy policy. Many different issues are involved in this subject, which is reflected in the multitude of approaches that are used in this study.

0.1 The global context

The interest in reducing emissions of greenhouse gases stems from the wish to reduce the risk of climate change. This risk is of a truly global nature and arises from the aggregate global emissions of CO_2 and other greenhouse gases accumulated in the atmosphere. The global nature of the issue makes it necessary to establish international institutions to achieve common goals. It is clear that many conflicts will arise in creating such institutions taking into account the uneven distribution of potential costs and benefits arising from the reduction of greenhouse gases.

The process of creating global institutions has so far resulted in the UN Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. Depending on the point of view, these institutions can be seen as weak and insufficient or as a remarkable result taking the difficulties into account.

The Kyoto Protocol establishes the frame conditions for the reduction of greenhouse gases and especially the following two conditions are important with respect to a tradable CO_2 permit market in the EU:

- It sets an emission target for the EU as a whole as well as for each of the member states – an 8 % reduction of the emissions of a basket of six greenhouse gases in the commitment period 2008-2012 in relation the 1990 level of emissions.
- It establishes flexible mechanisms (the Kyoto mechanisms) like emissions trading as legitimate means in pursuing the most cost efficient reduction of emissions.

It is worth noting that the EU has been a very active player in the international negotiation process, but it was necessary making a number of internal compromises in order to establish a common position. This has resulted in the Burden Sharing Agreement, where the overall EU reduction target has been distributed between the Member States. The variation in the emission reduction targets of the Member States spans from a 21 % reduction commitment by Germany, on one hand, whereas Portugal is allowed to increase its emissions by 27 %. This is a much wider span than between any of the other industrialised countries.

The Kyoto Protocol has not entered into force yet. For the Kyoto Protocol to enter into force it is required that at least 55 countries representing at least 55 % of the greenhouse gas emissions in 1990 must ratify the protocol. This means that USA, representing approximately 25 % of the global CO_2 emissions, in practice will have a veto position in relation to the ratification of the Protocol. Given the extreme scepticism of the US Congress towards the Kyoto Protocol this poses a serious threat to the continuation of the process in the future. In the following, the targets and objectives of the Kyoto Protocol are nevertheless taken as the basis for the analysis.

0.2 CO_2 emissions from the power and steam sector as the starting point

From an economic efficiency viewpoint, there is no doubt that a common framework – that being a tax or a permit system – that includes the basket of the six greenhouse gases in the Kyoto Protocol would be the preferred solution. Ideally, a common framework could secure that all gases and sectors are treated equivalently, thus securing that greenhouse gas emissions could be reduced in the cheapest way possible.

However, from a more pragmatic viewpoint, there are a number of factors that point to an emission-trading scheme covering only CO_2 emissions from the power and steam sector as being a sensible starting point, including:

- CO_2 emissions are by far the largest contributor to greenhouse gas emissions and will remain so for any foreseeable future;
- CO_2 emissions stem almost entirely from fossil fuel use, which is most easily monitored. Credible verification of emissions is a precondition for any trading scheme to develop;
- The power and steam sector is and will remain the largest contributor to CO_2 emissions. Furthermore, many low-cost CO_2 emission reduction opportunities are present within the power sector;
- The companies are relatively well-informed of the overall opportunities to reduce CO_2 emissions in the market, which can work to encourage trading early on;
- It is likely to be politically simpler to start with a single sector.

Clearly, focusing on CO_2 emissions, let alone only a subset of CO_2 emissions, cannot be the final answer, since emissions of other greenhouse gases make a significant contribution as well. If emission reductions of the other greenhouse gases are to be achieved by applying other policy instruments, it is likely to result in differentiated treatment of different sectors and gases. From an overall efficiency viewpoint this is not preferable. However, getting a tradable permit system underway at all is likely to pose a significant political challenge and in this respect it makes sense to start out with a limited system, as long as it will not prevent a more cost-effective solution to emerge later on.

We can, however, also try to compensate for the limited coverage of emissions by taking the expected opportunities for reducing the other greenhouse gases into consideration. Model calculations for the EU have suggested that the cost-effective reduction of CO_2 emissions correspond to a 6.2 % reduction of emissions compared to the 1990 level. This reduction percentage is lower than 8 %, which corresponds to a uniform reduction of all gases, due to the many low-cost reduction opportunities of methane and nitrous oxide

0.3 The political economy of a tradable CO_2 permit market in the EU

The underlying constellation of actor interests in this policy area will clearly have implications for the possible design options. Two important observations can be made about the positions of Member States. First of all, the initial distribution of permits in any tradable permit system in the EU will somehow need to reflect on the Burden Sharing Agreement. Secondly, any expansion of the use of fiscal measures at Community level is strongly opposed by some Member States as it is still very much seen as a national responsibility. Thus, in order to assure that all Member States find it in their own best interest to participate in a tradable CO_2 permit scheme, it seems that the distribution principle from Community level to the Member State level must involve grandfathering. In other words, the revenue stream generated by the sale of permits will be fully redistributed to the Member States.

Furthermore, two important observations can be made about the influence of private parties on the EU policy-making process as well. First of all, any attempts to implement an upstream trading system, which is essentially a tax on all fossil fuels entering the economy, is likely to result in political deadlock. The existing voluntary agreement between the automobile industry and the European Commission is a strong indication of this. On the other hand, the European electricity producers have a less clear-cut agenda towards the climate change issue due to the asymmetric interests of the producers. As a result, Eurelectric has emphasised that policies and measures should not distort competition and therefore, they are generally supportive of market-based instruments and especially tradable permits. The position of some energy companies in the national policy agenda will make it unlikely, though, that the distribution principle to private parties will not involve some sort of grandfathering.

The establishment of a tradable CO_2 permit market in the EU is an area of “shared competence” between the European Community and the Member States. In order to try to avoid deadlock in the negotiations over the design options of a tradable CO_2 permit market, the principle of subsidiarity could be applied, thus leaving some conflicts unresolved at the Community level and shifting them to the implementation phase. This would suggest that the overall framework be defined at Community level while leaving as much scope for subsequent Member State action as possible.

In other words, the level of decisional competence will be a fundamental aspect with respect to the design options. What is absolutely necessary to shift to the EC level and what can be kept at the Member State level? Given the decisional structure of the EU there is a permanent struggle for decisional competence between the different levels of Government. Undoubtedly, the larger the role assigned to Member States the easier it is to come up with a solution. However, the global nature of the climate change problem and the profound economic impact that measures to limit emissions of greenhouse gases will have, reinforce the case for a supra-national policy response in the EU.

It is important to note, however, that in areas of shared policymaking the institutional sequence might play a strong role. Thus, if a decision is first taken at the European level and a framework is defined which will contain all subsequent national decisional processes, then options for national actors are reduced. If, by contrast, a decision is first negotiated within one Member State, the chances of manoeuvring to resolve interest conflicts are more limited at the supranational level, and the zone of possible agreement is reduced for European actors. This suggests that it is important to start out with a scheme that includes all Member States and where the overall framework is defined at Community level. This can be accomplished by a scheme that starts out with the power and steam sector.

0.4 Market design

The most fundamental design options we need to consider in establishing a tradable CO_2 permits market for the power and steam sector is the following:

- Total amount of permits to be put into the bubble (the target level)
- Permit contributions from each country’s emission target

- Distribution mechanisms for permits to individual power plants.

Target level

The total number of permits assigned to the system determines the price of the permits and thus the marginal cost of emissions. Therefore, in choosing the overall allocation of permits to the trading system it should be taken into consideration that the opportunities for emission reductions vary between different sectors. This is important for two reasons. First of all, you minimise the distortion from not including all sectors and gases in the trading system from the outset and, secondly, the impact that the inclusion of more sectors over time will have on the equilibrium price of the permits is likely to be smaller. That is why it is clearly preferable with a top-down element in the setting of the overall reduction target for the sector so this should take place at Community level.

However, any enlargement of the trading scheme to include other sectors, gases or even countries will affect the equilibrium price of CO_2 permits. This is unfortunate because investments in cleaner technologies undertaken prior to the enlargement can turn out to be stranded. This problem is inherent in all tradable permit schemes that start out with less than complete coverage of emissions and it is not easily dealt with.

The calculations based on the Primes model predicts that app. 260 Mt of CO_2 emissions reductions relative to the emissions baseline should take place in the power and steam sector in order to minimise abatement costs. This corresponds to *a reduction in the level of emissions in 2010 by app. 22 % compared to 1990-level*, or alternatively to an overall allocation of permits to the electricity and steam sector in the neighbourhood of *950 Mt CO_2 equivalents*. Due to the many low-cost reduction opportunities in the power sector, the suggested least-cost allocation to this sector requires a much larger reduction in emissions (22 %) compared to the overall reduction requirement of CO_2 (6.2 %). These figures along with simulation in other model studies could serve as a starting point for future negotiations.

Target Group

If abatement costs are to be minimised, it is preferable that the share of total emissions covered by an emissions permit system be as large as possible. Notably, the emissions from heat production and from combined heat and power production should also be included in the permit market. The inclusion of emissions stemming from heat as well as power production will secure an equal treatment of the two products. However, monitoring and enforcement costs will be incurred by any policy measure and may limit the coverage of emissions sources that is cost effective to include in the market.

Monitoring and enforcement costs are likely to be too high to make it worthwhile to include all smaller industrial plants. All plants that are not included in the market should be regulated by a tax or some other measure to ensure that they are faced with approximately the same cost per unit of emissions.

It is suggested to include all boilers larger than 25 MW in the trading scheme. The total number of fossil-fuelled boilers in the EU amounted to app. 7050 in 1999, while the number of boilers larger than 25 MW_e amounted to 1690. The 1690 boilers are in the same order of magnitude as the US Acid Rain Program, which has proven to be a workable number. Secondly, the total number of companies is reduced from app. 3000 to 375 while most of the installed capacity of fossil-fuelled boilers is still included in the market. In other words, most of the emissions are still kept within the system. By doing this the administrative procedures can be developed and prepared for a larger scheme.

If the permits are grandfathered to the existing electricity producers the concentration of permits on a few large producers can be a real problem. However, it should be noted that the problem in terms of abuse of market power is not so much that the permits are concentrated on a few companies. Rather, it is the difference between the cost-effective permit allocation and the allocation that the company receives free of charge from the outset that is the real problem. It seems clear, though, that there will be a reasonable number of sources of CO_2 emissions in the power sector to use it as a testing ground for an EU-scheme of emissions trading. In the longer run, it will be important to broaden the scope of the trading scheme and the inclusion of other sectors will limit the risk of market power.

Distribution rule

Two questions need to be considered with respect to the distributional aspects of the trading scheme:

- Permit contributions from each country's emission target
- Distribution mechanisms for permits to individual power plants.

With regard to the first point, the allocation of permits to certain sectors by individual Member States can be carried out in such a way as to distort competition in that sector. The importance of the energy sector taken together with the ongoing liberalisation of the gas and power sector will make the energy sector an obvious candidate for a favourable allocation by Member States. For that reason, the allocation of permits to the power and steam sector from each country's emissions target needs to be harmonised.

The least distortive approach is undoubtedly to construct a "true" EC emission trading bubble from the outset. This would mean assigning 950 Mt of CO_2 permits to the emissions trading bubble, emissions that are to be taken out of the total amount of greenhouse gas emissions assigned to the European Community. The revenue from the sale of the permits goes into the EC budget and the revenue is recycled to the participating companies according to some standardised rules of allocation (or redistributed to the Community at large if deemed possible).

The political reality of the Burden Sharing Agreement will, however, make it very hard to go through with this approach. A more feasible solution is to let the total amount of permits, that is being allocated to the power and steam sector bubble, consist of assigned amounts from each Member State. The amount of CO_2 permits that is assigned to the emissions trading bubble by each Member State will then need to be deducted from the overall assigned amount of each Member State as defined by the Burden Sharing Agreement. Furthermore, the revenue generated from the sale of CO_2 permits will be redistributed to the Member States corresponding to the number of permits assigned by each individual Member State.

The potential problem with an approach based on assigned amounts from each Member State is the possible distortion of competition, given that some Member States will have a large amount of permits compared to what their power sector actually need to cover their emissions of CO_2. Taking this problem into account, it is shown that a proportional rollback of the emissions defined by the Burden Sharing Agreement does not seem like a bad starting point. In the long run, however, the distribution of responsibilities between Member States should gradually converge to a per capita allocation rule.

With regard to the distribution of permits to private parties, it should be noted that under ideal conditions different distribution rules can coexist and in theory it is not necessary with a common distribution rule. This conclusion can, however, be challenged.

Notably, there should be a common agreement as to how *grandfathering can be out-phased* from the system over time because there are large welfare gains if the revenue is used to reduce other taxes in the economy rather than being given away for free to the existing emitters. From a perspective of fairness this is also a better solution, as the revenue is distributed broadly and reflects the fact that every citizen has the same right to emit CO_2 into the atmosphere (per capita allocation rule). One way of achieving this could be to gradually convert the units assigned to the bubble to EC assigned amount units. The revenue from the sale of these units would then go into the EC budget and the revenue should be distributed to society at large.

However, it seems unlikely that the distribution rule from the outset will not involve some sort of grandfathering. Therefore, we need to consider whether or not the grandfathering principle needs to be the same or whether it can be left to Member States. If it was left entirely up to the Member States the possible lack of competition in the power sector can be a problem, because some companies might be able to use a favourable allocation of CO_2 permits to gain market shares in the power market.

The least distortive option would be to decide on a common distribution principle to the market participants. Notably, an allocation of permits to individual power plants based on a percentage reduction of the current size of emissions is to be preferred over an allocation principle based on past emissions, i.e. emissions in 1990.

Leaving it to the discretion of Member States with regulatory oversight by the Commission is a more feasible solution. If it were left to the discretion of Member States, the Commission would have to approve of the principle chosen by each Member State. This could mean that some Member States would not be able to redistribute all the revenue to the participating parties because it would be in violation with the EC rules on state aid.

Trade rules

By an individual permit we will understand a right to emit 1 tonne of CO_2. Each permit will specify what particular Member State has issued the permit and the year of issue (vintage year). Once the permit has been used to show compliance it will be withdrawn from the market. The duration of the compliance period is set to one year.

The entitlement is not a full property right but rather a limited permission to emit CO_2. This allows the government to make changes over time without any compensation to the market participants. This approach is also valid here to a limited extent.

Obviously, any changes in the entitlement to CO_2 permits have to be done with extreme caution, since a full property right is essential for a well functioning market. However, we need to distinguish between two things:

- changes to the overall allocation of permits to the trading system, which in turn determines the market price of CO_2 permits,
- and changes to the distribution of revenue between market participants and society in general.

It is important that a credible economic value of CO_2 permits is established for a considerable time period reflecting the long investment horizons in the power sector. Therefore, *any alterations in the overall allocation of permits to the permit market must be the responsibility of the EC and not the market participants.*

On the other hand, the distributional principle can be changed over time and grandfathering can be out-phased. However, the out-phasing of grandfathering must be completely unrelated to the actual closing down of production plants, otherwise this will also inflict on long-term resource allocation.

The system should allow for unlimited banking of permits. Borrowing of permits is preferable but problematic and could be excluded. When borrowing of permits is not allowed, the inter-temporal flexibility of the system is linked to the fine for being in non-compliance, as the fine will put a price ceiling on the permit market. A low level of the fine will introduce more flexibility into the system because essentially the EC has extra permits for sale at a price equal to the level of the fine. Thus, *the level of the fine should not be set too high and a suggestion could be app. 40 EUR/t*CO_2.

We propose that the EC should undertake a yearly EU-wide auction where all or a large share of the permits are put out for sale. The inclusion of a large share of the permits in the auction will secure equal access to the permits in all the Member States and thus an efficient allocation of the permits. Furthermore, this will provide price information and transparency to the market, which is important especially in the beginning when market participants are not that familiar with the market.

By putting all the permits out for sale at an auction we are separating the issue of allocation from the issue of distribution. The revenue from the auction is redistributed to the Member States according to the overall distribution of responsibilities that is decided upon.

We propose to use a non-discriminatory pricing principle for the auction where all bidders of permits pay the clearing price for the permits (provided that their bid was below the clearing price).

To make sure that there are buyers as well as sellers in the permit market and that the risk sharing capabilities of the marketplace will come into play, everybody should be allowed to participate in the market.

Like in the US the system could start before the first compliance period. Possibly, the regulators should also release permits that are valid in the current year as well as permits that are valid in years to come (i.e. selling vintage year 2008 permits and vintage year 2013 permits at the same time).

Control system

The purpose of the control system is to make the whole trading scheme credible by assuring that there is a one-to-one correspondence between a permit to emit one tonne of CO_2 and the actual emission of one tonne of CO_2.

In the context of a European-wide scheme of emissions trading it would be natural that the ultimate responsibility for ensuring compliance will be on a European level. It is the general assumption, however, that monitoring and enforcement in relation to the companies from the starting point will be a Member State task, because the Member State Authorities are equipped with the necessary regulatory power in relation to the private parties. On the other hand, the system could gain in general efficiency and credibility by the establishment of a common European institution. This could be EEA (European Environmental Agency).

In terms of monitoring of emissions, calculating the CO_2 emissions from the fuel input is a very cheap and efficient method, especially for a gas fired plant. This will be relevant for many of the smallest installations and thus not put a lower limit to the size of plant that can be part of the trading scheme. For coal fired plants the uncertainties can be so large that direct measurement should be preferred. These installations are usually large and the extra costs for measurement of CO_2 emissions will be of minor importance. As long as the levels of uncertainties are comparable (in fact, as long as the uncertainties are not biased so that they sum out over time), the use of different methods of measuring will pose no difficulties.

The emissions data will be collected by means of self-reporting by the companies.

The most important role to be played by EC institutions will be to establish minimum requirements with regard to the measurement of emissions while to a large extent leaving actual monitoring and verification of emissions to the Member State Governments.

The annual reporting of emissions from the power and steam sector must be faster than today. The final data for the preceding year should be available in January in order to allow for a true-up period for the emission rights. To give the best possible market information it is proposed to report and publish emission data for companies included in the trading scheme on a monthly basis. This will mean speeding up of the existing reporting procedures, but it should be possible to do this with only minor extra costs.

The Member States could verify the emissions reported by companies on a yearly basis and submit their result to an EC institution. Obviously, the Member States might have incentives to cheat as well, however, the scope for cheating should be relatively small with respect to the power and steam sector.

With respect to the enforcement of the permit market, a central registry must be created at the EU level. This function can be computerised and should not give any theoretical or practical difficulties, which has been clearly demonstrated by the US Acid Rain programme. Data for emissions may be collected by national authorities but shall at once be transmitted to a European institution. Through the trading system, a registry of permit holdings of each of the actors in the market is established. Likewise, through the monitoring process, a registry of the actual emissions of each actor is established. The "trick" of the enforcement is to compare the two numbers for each actor and have the necessary authority to deter actors from breaking the emission limits.

First of all, we need to deter cheating by companies. Taking into consideration that the likelihood of detecting cheating is pretty high in this trading scheme, it will probably not be necessary with sanctions such as prison sentences to deter cheating. A high monetary sanction should be sufficient.

The next step will be to establish sanctions against market participants exceeding their permit holdings. The suggestion here is straightforward. Market participants whose emissions are exceeding their current permit holdings must pay a fine for their excess emissions. The level of the fine must be the same in all Member States. Otherwise, there could be carbon leakage to areas with lower fine levels.

If the fine is kept very low, the emissions trading scheme will work very much like a price instrument (tax), whereas a high fine will secure that the emission target is reached (at any cost to society). Thus, a relatively low fine is proposed for the trading scheme, and the fine could be set at in the neighbourhood of 40 EUR/tCO_2. The fine payments could be used by the enforcement institution to buy emissions permits internationally, in order to secure that the overall emission target of the trading system is met.

Potential gains from trading

There are clear benefits from allowing private party emissions trading at Community level compared to unilateral action by Member States. A tradable CO_2 permit scheme with comprehensive coverage of emissions within the EU, which would have to be an upstream permit market, could reduce the total abatement costs by some 32 % compared to a system with no trading between Member States. In comparison, a Community-wide system containing only the electricity and steam sector would reduce the total abatement costs by 13 % only.

These differences in abatement costs are, however, without taking advantage of any of the other Kyoto mechanisms. A full CO_2 emission trading system between Annex B countries suggest overall cost savings in the order of 40 % compared to a situation with no trading at all between Member States. Obviously, these gains from trade are not as easily appropriated as within the EU given that no international institution can effectively enforce an Annex B market.

In conclusion, a tradable CO_2 permit market for the power and steam sector can provide significant gains from trading. However, the overall gains from trade in a CO_2 permit market for the power and steam sector are significantly lower than from a system including all sectors in the EU. Thus, it is important to maintain that it can only be the starting point and that the system must be organised in a way that provides opportunities for other sectors to “opt-in” over time. In this way, the system can achieve a more comprehensive coverage of emissions in the longer run.

0.5 The price of CO_2 permits

Several model calculations have been made trying to estimate the market price of 1 ton of CO_2 (in 2010). All cost estimates are subject to a number of highly uncertain assumptions, and as a consequence, these estimates must be interpreted with caution. Having said that, though, we do believe that cost estimates carry important information.

Obviously, the price of CO_2 permits will be linked to the geographical coverage of the system. Any enlargement of the trading scheme to include countries outside the EU will alter the supply and demand side conditions of the permit market, which can lead to higher or lower permit prices. The effect on the permit price depends on the reduction opportunities as well as the obligation to reduce emissions in the countries that join the scheme. In case the enlargement of the trading scheme leads to a lower equilibrium permit price, the actual reduction of emissions that takes place in the EU will also be lower and vice versa.

On the other hand, if the market participants can exploit the project-oriented mechanisms in the Kyoto Protocol, JI and CDM, this will only alter the supply side conditions of the permit market. The project-oriented mechanisms will provide the market participants with alternative emission reduction opportunities, thus shifting the supply curve downwards and lowering the permit price (the demand for CO_2 permits remains the same). If there are plenty of low-cost emission reduction opportunities outside the EU, this could result in the extreme situation that all the sellers of CO_2 permits would be located outside the EU. In this case, all the market participants inside the EU would be buyers of permits and no reduction of emissions would take place in the EU. The most likely result is a combination of internal and external emissions reductions.

If 'tradable EU permits' is the only flexible mechanism available to the market participants, the EU permit price will be equal to the marginal cost of reducing CO_2 emissions within the EU as a whole.

Studies of permit prices when backstop technologies matter

The present analysis stresses the importance of backstop technologies (i.e. emission reduction technologies), the prices at which they become profitable and their emission reduction potentials, in studies of permit prices and costs of CO_2 reductions. The present analysis indicates that failure to include backstop technologies may give permit price estimates of limited value.

Upper limits to the permit price

If there are backstop technologies, which have great emission reduction potentials within the EU, the CO_2 reduction price of one of these technologies serve as an upper limit to the permit price. The cheapest backstop technology will be implemented first.

Within the EU power sector there is a large emission reduction potential in fuel switching and higher fuel efficiency. The prices of CO_2 reductions carried out through fuel switching range from 70 to 300 DKK per ton CO_2, depending on which fuel is being substituted, the type of power plant etc. The price span is not defined as the largest possible, but as the price span within which the bulk of emission reduction potentials are to be found. And furthermore, at the upper limit of the price span another technology with great potential takes over.

The cost of extending the EU wind turbine capacity as a mean to reduce emissions, depends on the wind conditions on location, and the technical possibilities of fitting fluctuating wind power into the overall power system. It will be technically possible to extend the EU wind capacity considerably at prices below 280 DKK per ton CO_2.

According to the Kyoto Protocol, the EU must reduce emissions by 8 % as compared to the level of emissions in 1990. If it is technically possible to reach the 8 % target level through fuel switching in the power sector and increased wind power production, the upper limit to the EU permit price is app. 280 DKK/ton CO_2, which is the estimated price of reducing emissions trough installing new wind mills.

If wind turbines are the marginal CO_2 reduction investment on a European permit market, the price of the permits will be around 280 DKK/ton CO_2. If fuel switching in the power sector is the marginal investment, the permit price will probably be somewhere between 70 and 280 DKK/ton CO_2, depending on the price and potentials of alternative CO_2 reduction investments.

The lower limit to the permit price

The lowest possible permit price is zero. This price will only be realised if:

- New technology makes CO_2 reductions almost free, or
- Due to low activity levels (within the EU or outside) there is sufficient ‘hot air’ to reach the total EU target – and, none of the ‘hot air suppliers’ are able to exert monopoly power, thus being willing to sell permits at prices next to nothing.

Other policies, new technology etc.

In general, all EU policies as well as National policies that have an impact on CO_2 emissions stemming from the sectors included in the permit market will affect permit prices. For example, limitations of car traffic (through taxes or direct regulation such as ‘no cars in city centres’ policies) or heavy taxation of trucks (on a per kilometre basis) probably reduce emissions, and reduce the demand for and price of permits.

New technologies may affect the supply and demand of permits and the permit price. If new energy saving cars were introduced, if renewable electricity production became cheaper or new energy saving inventions were made, this would increase the low cost potentials for emission reductions and likely reduce the permit price.

Permit prices and technology choice

The present study also includes an analysis of permit prices and the effect on technology choice. The model results for the electricity and heat market – in a region with a large and diversified market for district heating and where the electricity market is subject to competition – indicates that tradable CO_2 permits may lead to a very rapid substitution of gas for coal. The model results – assuming strictly rational techno-economic optimising agents – indicate that the implementation of CO_2 permits to meet the Kyoto targets is likely not to be a major driver for new capital intensive technologies with no CO_2 emissions. However, tradable permits can be a major catalyst for the penetration of new technologies with CO_2 emissions in the longer run.

In summary, the following can be concluded from the model results:

- Tradable CO_2 permits are likely to lead to a very rapid substitution of natural gas for coal.
- Tradable CO_2 permits are unlikely to be a major driver for new technologies with no CO_2 emissions, but high investment costs – at least in the short and medium term (i.e. until 2008-12).
- Some elements of regulation apart from CO_2 permits will be necessary to reduce the financial risk of investment in low-emission technologies.
- However, an appropriate regulatory framework is essential not only for the 'green' market, but for any organised commodity market.

A common European taxation of fuels or a European market for CO_2 emission permits may be favourable for capital-intensive, clean technologies that will reduce the demand for fossil fuels. However, even very high taxes or permit prices are unlikely to have much effect on the development of CHP unless further measures are taken e.g. long-term contracts supported by a market for 'green certificates'.

1 Introduction

The European energy sector has for some time been facing the dual challenge of opening markets and tightening of environmental controls – especially with regard to CO_2 emissions. This dual challenge demands new approaches from all actors both energy companies and legislators. The traditional command and control regulation is not adequate for the new market conditions. For a while, a common European CO_2 tax seamed to be the solution, but it proved difficult to implement a new tax.

Tradable CO_2 permits are an interesting alternative to consider when addressing the new situation. Tradable permits have been implemented in the United States to reduce SO_2 emissions. This project will investigate the possibilities and barriers in using the tradable permit approach to regulate CO_2 emissions in a European context.

Looking at the Danish policy debate it seems that there are two levels of difficulties in the decision to introduce tradable permits in environmental regulation. The first step is to accept the concept of establishing tradable property rights to emitting CO_2 into the atmosphere. We shall return to this aspect shortly. The second step is to decide on an actual design for a trading system once the principle is accepted. This second step is the focus of the research project and will be developed throughout the report.

But back to the first step: accepting the principle of emissions trading. Without this acceptance, the rest of the report will be utterly uninteresting. The scepticism towards emissions trading has been prominent not at least among environmentalists. The first part of the introduction will address the arguments against emissions trading. The second part will give a brief overview of the report.

1.1 Why emissions trading?

("Believers" and environmental economists can skip this section)

The basic virtue of emissions trading is that it is a strong instrument to achieve cost-efficient emission reduction. And already we encounter the first attack-point against the instrument:

Statement 1: If emissions reductions become too cheap the necessary technology development will not take place.

The answer to Statement 1 is that different objectives need different instruments. It is important to separate the instruments to achieve a technology development and the instruments for large-scale implementation of emission reductions. The high Danish subsidies for wind turbines have been very effective in promoting development of the wind technology and the Danish wind turbine industry. But it has only been politically acceptable because it was – also – support for national industrial development.

If CO_2 reductions are to be implemented globally and on a large scale, it is necessary that the reduction costs are as low as possible. And here tradable permits are one of the options. Public support for technology development will have to find other forms.

Statement 2: It is unethical that large firms can buy permits to keep up pollution.

The basic trouble with the second statement is that large firms also get a permit to pollute under a traditional command-and-control system. Under the existing Danish system of environmental licensing, an industry gets a permit to pollute for eight years at a time without paying. And without incentive to do better than the conditions in the license. The tradable permit system puts a value on the continued improvement of the environmental performance because reduced emissions give the possibility to sell permits or to buy less.

Statement 3: Tradable permits will be bureaucratic and will allow cheating

Here the US Acid Rain programme is an important inspiration as it shows that it is possible to create a simple, yet credible system for emissions trading. To keep the system simple in an international context, it is necessary with high entry standards to the market for emissions trading. It is paramount only to allow countries with a comparable standard in verification and enforcement into the same market place. Once 'bad' allowances are traded, the credibility of the system erodes and the value of the allowances decline. This mechanism gives some kind of incentive among the participants in the market to control each other. In a European context, the structure of the European Union can also play an important role in securing a common tradable unit and thus a common currency for tradable CO_2 permits.

Statement 4: The flexible mechanisms of the Kyoto protocol are designed to allow 'hot air' and thus water down the emission reduction targets.

Regarding the Kyoto-protocol it is important to keep the discussion of ambition level in the target setting and the discussion of the mechanisms separate. Emission trading is equally good in implementing weak and strong emission targets.

In fact, compared to a tax instrument a tradable permits market can be seen as putting more emphasis on the environment. This has to do with the different ways in which a tax and a permit system respond to uncertainty. A tradable permit market adjusts by allowing the permit price to rise or fall while holding the emissions level constant. A tax system, on the other hand, adjusts by allowing the total level of emissions to rise or fall while holding the price associated with emissions constant. In this way, tradable permits distribute more risk to the costs of reducing emissions and less risk to the level of emissions that is actually being achieved.

This initial discussion only has the aim to set the stage. In the rest of the report, the discussion is not so much IF a trading system should be used as HOW a trading system should be implemented. Experience shows that the questions asked regarding implementation are much more intriguing than the quite simple IF question.

1.2 The structure of the report

Chapter 2 takes its starting point in the Kyoto Protocol and discusses in broad terms the flexible mechanisms with focus on emissions trading (Article 17 of the Protocol). The main conclusion is that trading between private parties is a prerequisite for the emissions trading to be efficient.

Chapter 3 compares the virtues of emission taxes with two kinds of systems for emission trading – grandfathered permits and auctioned permits. The chapter treats efficiency aspects and possible market failures in the three types of regulation from a theoretical point of view. The political aspects are discussed in a public choice perspective.

Chapter 4 gives a short description of the US acid rain programme and evaluates the developments in this market. The system is simple and successful, but there are important differences between CO_2 and SO_2 and between USA and Europe.

Chapter 5 gives a more detailed discussion of the design of a European CO_2 trading scheme. It also discusses the distributional effects of different allocation principles for permits.

Chapter 6 is the first of three chapters with a focus on quantitative analysis of different aspects of emissions trading. Chapter 6 analyses the Scandinavian and German electricity system with focus on the consequences of a national Danish CO_2 quotas system compared to the situation without CO_2 restrictions and to a system with a common regulation on CO_2.

Chapter 7 models the effect of tradable permits on the choice of technology in the electricity and heating sectors. The chapter builds on results from the PRIMES-model developed for the European Commission and an optimisation model for standardised generators of electricity and heat or steam. It was the expectation at the start of the project that the PRIMES-model would be available for analyses in the project, but with time it became clear that only results from PRIMES would be available, not the model as such.

Chapter 8 gives an evaluation of different estimates of the quota-price in a European CO_2 -trading market. There is a very broad band of the results of previously published studies. A maximum level of the quota-price is estimated by applying the concept of backstop technologies.

Finally Chapter 9 sums up the results of the whole project

2 The Global Agenda: The Kyoto Protocol and emissions trading

The main focus of this study is the application of emissions trading in Danish and European energy policy. Climate Change is a global issue, however, and for that reason it is necessary to see the discussions in the context of the negotiations regarding the UN Framework Convention on Climate Change. This chapter will take a closer look at the Kyoto-protocol and the possible ways it can be implemented.

2.1 Essential features of the Climate change problem

Climate change has been a key issue on the global environmental agenda during the 1990s. The potential consequences of rising temperature and other changes in the global climate have been the driving force behind major scientific and political initiatives on an international scale.

Climate change is characterised by a number of features that raise difficult questions in relation to the political process:

1. Climate change is global in nature

As opposed to most other environmental challenges climate change is global in nature. There is no direct connection between emissions in a certain region and the impacts in that region. Rather the situation is that the industrialised countries, which are the most important emitters of greenhouse gases, also have the best opportunities to adapt to the climate change.

The global nature of the problem will make an international co-operative solution involving all countries the most economical. However, the asymmetric interests between many countries due to the very uneven living conditions will put a lot of strain on this solution. Many developing countries will rightfully argue that the countries in the developed world are responsible for the greenhouse gases that are accumulated in the atmosphere today. Therefore, developing countries are not willing to commit themselves to any binding restrictions on emissions or are not willing to do so without significant compensation. If some developing countries are left uncontrolled, the expected costs for the countries that do have a binding commitment will be driven up, which in turn will make their willingness to participate less likely.

Since nations are sovereign, any international environmental agreement is self-enforcing. All nations are free to leave an international agreement whenever they like. Therefore, it is important to explore the possibilities of getting a large number of countries to participate by designing the rules of the game in such a way that a lot of countries find it in their own interest to do so.

2. There is a high degree of uncertainty with respect to the ecological and economic consequences of global warming

In its Second Assessment Report (SAR) from 1995 the Intergovernmantal Panel on Climate Change (IPCC) concluded that:

"The balance of evidence, from changes in global mean surface air temperature and from changes in geographical, seasonal and vertical patterns of atmospheric temperature, suggests a discernible human influence on global climate. There are uncertainties in key factors, including the magnitude and patterns of long-term natural variability."

However, it is safe to assume that, in the near future, the aggregate international benefits of greenhouse gas or carbon emission reductions can not be determined with any great degree of precision. As a result, an optimal level of emissions cannot be estimated. Instead, any target for an agreement among a set of countries will be cast in terms of staying within a certain, more or less arbitrarily chosen, level of aggregate emissions.

3. The stock-pollutant property of greenhouse gases

Greenhouse gases are uniformly mixed accumulative pollutants. Greenhouse gases do not stay in the area where the source of emissions is located and location of sources is irrelevant to subsequent damages. In fact, neither the source of emissions nor their timing is important from an environmental standpoint. In this respect, the greenhouse gas effect is a global mutual externality.

Climate change is driven by the amount of greenhouse gases accumulated in the atmosphere over the last century. In other words, the flow of greenhouse gases coming from all sources within any individual year is likely to have an insignificant impact on climate change. Of course, the stock of pollutants in the atmosphere builds on the flow of pollutants, but it is only the accumulated stock that matters for climate change.

As a consequence, there is a long time lag between the timing of emissions and possible effects. This long time lag between the costs and benefits of avoiding climate change poses a serious political difficulty since political decision-making is so short term by nature. In other words, there is a time consistency problem since the policy makers will have incentives to postpone any real reduction of emissions to some future election periods. It is worth noting that this very much separates the issue of climate change from most other environmental policy issues where the damages from emissions are usually real (and local) and not projected.

2.2 UN Framework Convention on Climate Change

Despite the difficulties listed above, the United Nations Framework Convention on Climate Change (UNFCCC) was adopted at the Rio Summit in 1992. The ultimate objective of the convention is the stabilisation of atmospheric concentrations of greenhouse gasses at safe levels. The UNFCCC commits the industrialised countries (listed in Annex I of the convention) to a non-binding aim of returning their emission of greenhouse gasses to 1990 levels by the year 2000. In this context it is also important that the UNFCCC recognises the principle of global cost-effectiveness of emission reductions (in Article 3.3) and thus opens up for the use of flexible instruments.

Finally, it should be noted that the UNFCCC includes a clause, stating that the first Conference of the Parties (CoP1) should review the adequacy of the commitments in the Convention. CoP1 took place in Berlin 1995 and it was agreed that the current Convention commitments were inadequate, and consequently, a process enabling appropriate action for the period beyond 2000 should begin, including the strengthening of the commitments of industrial countries and countries with economies in transition.

2.3 The Kyoto protocol

In December 1997 at the Kyoto Conference (CoP3) a protocol to the UNFCCC was adopted. The Kyoto Protocol included two major new elements:

1) The industrialised countries committed themselves to legally binding national limits to the emission of a basket of six greenhouse gasses in the period 2008-2012 – The commitment period.
2) Three flexible mechanisms were defined to achieve an economically efficient implementation of the emission reductions.

The Kyoto Protocol will enter into force once it is ratified by at least 55 Parties representing at least 55 % of the total greenhouse gas emissions of Annex I countries in the year 1990.

It is not intended to give a full overview of the Kyoto Protocol, but rather the focus will be on the issues relating to emissions trading. There are a number of Articles in the Kyoto Protocol that directly or indirectly relates to trading:

Table 2.1. Selected articles from the Kyoto Protocol.

Article 3.1	Defines individual and overall commitments; multiple gases are included; defines five year commitment period (2008-2012)
Article 3.10 to 3.12	Defines credits and debits in emissions trading
Article 3.13	Banking for subsequent periods is allowed; banking and borrowing is allowed within each commitment period
Article 4	Allows the forming of "bubbles".
Article 6	Emissions reduction units in Annex B (Joint Implementation)
Article 12	Certified Emission Reductions with non-Annex B (Clean Development Mechanism)
Article 17	Acceptance of trading between Parties and possibly also between private legal entities

2.3.1 Definition of emission targets

Article 3.1 of the Kyoto Protocol defines the five-year commitment period (2008-2012) in which the emissions targets for individual countries listed in Annex B have to be reached.

The emission targets are defined for a basket of six greenhouse gasses (Listed in Annex A of the Protocol): carbon dioxide, methane, nitrous oxide, HFCs, PFCs and sulphur hexafluroride.

Table 2.2. Global Warming Potentials (GWP) of the gases covered by the Kyoto-protocol

Gas	CO_2	Methane	N_2O	HFC's	PFC's	SF_6
GWP	1	21	310	140-12100	6800-12500	23900

Global Warming Potential is a simple measure of the relative greenhouse effect of different greenhouse gasses using CO2 as the basis of comparison. (Data from IPCC 1996: Climate Change 1995: The Science of Climate Change)

Overall, Annex B countries must reduce their emissions of greenhouse gases (measured in CO_2 equivalents) by at least 5 % below 1990 levels (base year) over the commitment period 2008-2012. Most countries have committed themselves to a reduction of 8 % of their 1990 emissions, including the EU. Some countries have lower percentage-reductions, notably USA and Japan that have committed themselves to a 7 % and a 6 % reduction respectively. A few countries aim at a stabilisation on 1990 level: Russia, Ukraine and New Zealand. Norway is allowed to increase its emissions by 1 % in the commitment period compared to 1990, Australia by 8 % and Iceland by 10 %.

2.3.2 Monitoring, verification and enforcement

The Kyoto Protocol has a number of provisions concerning monitoring, verification and enforcement **regardless of whether an Annex 1 country is engaged in trading or not.**

Article 5 of the Protocol requires each Party included in Annex 1 to have in place a national system for the estimation of man-made emissions of all greenhouse-gases no later than one year prior to the start of the first commitment period (2007). The methodologies for estimating emissions must be accepted by The Intergovernmental Panel on Climate Change (IPCC) and agreed upon by the Conference of Parties (CoP). The IPCC and the Subsidiary Body for Scientific and Technological Advice are charged with regularly reviewing and, if appropriate, revising such methodologies subject to approval by the Parties.

The Protocol is quite vague when it comes to issues of compliance. It does have some provisions about the institutional set-up, notably Article 8 and 18.

Article 8 of the Kyoto Protocol concerns the establishment of expert review teams that will review national inventories and communications (information submitted under Article 7), and provide a “thorough and comprehensive technical assessment of all areas of implementation.” It is not fully clear, though, to what extent this assessment process determines compliance with the Protocol. The expert teams are to be nominated by Parties to the Convention and serve under the authority of the Secretariat.

While the national governments will monitor domestic compliance, international review teams will review the data, assess the implementation of the commitments of the Parties, and identify any problems in, and factors influencing, the fulfilment of the commitments.

Article 18 of the Protocol concerns the enforcement issues in cases of non-compliance:

> The Conference of the Parties serving as the meeting of the Parties to this Protocol shall, at its first session, approve appropriate and effective procedures and mechanisms to determine and to address cases of non-compliance with the provisions of this Protocol, including through the development of an indicative list of consequences, taking into account the cause, type, degree and frequency of non-compliance. Any procedures and mechanisms under this Article entailing binding consequences shall be adopted by means of an amendment to this Protocol (UNFCCC, 1997).

Article 18 raises the question whether or not the penalties adopted will be sufficient to ensure compliance. Penalties could be as minor as a warning or could include more substantive restrictions. It is important to remember that an international agreement between sovereign nations is self-enforcing, so any nation can choose to leave the agreement whenever it wants. Seen in this light, any mechanism that is included in the Protocol to ensure compliance carries with it a trade-off against national sovereignty for all countries. However, in the case of emissions trading a permit does not hold any value unless there is enforcement, and possibly, if emissions trading go forward between a group of countries, there is a need for stronger enforcement than what would otherwise be the case.

2.3.3 Bubbles

Article 4 of the Kyoto Protocol states the following:

> Any Annex 1 Parties that have reached an agreement to fulfil their commitments under Article 3 jointly shall be deemed to have met those commitments provided that their total combined emissions do not exceed their commitments in Annex B. Ultimately, however, each Party is responsible for its own Annex B commitment if the entity formed fails to meet its overall commitment (UNFCCC, 1997).

Article 4 was drafted to authorise and regulate the EU "bubble" or burden sharing agreement that was part of the EU negotiation position before Kyoto (see below). The Article allows alteration of national emission targets assigned in Annex B within a group of co-operating countries provided that the total emissions of the participating countries do not exceed their aggregate total as listed in Annex B. A "bubble" must be declared when the ratification is deposited.

The EU has an overall commitment target of reducing the average emissions of the six greenhouse gases by 8 % in the period 2008-2012 in relation to the emissions in 1990 (base year). The EU has agreed upon sharing this commitment target between the individual member states according Figure 2.1.

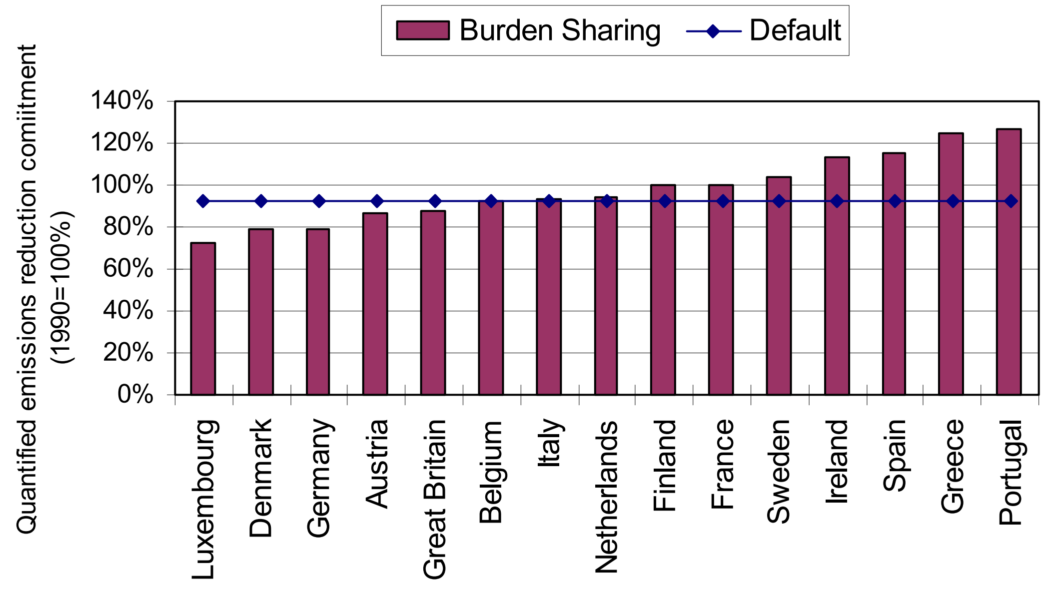

Figure 2.1: EU Burden Sharing Agreement

In the case of Denmark, the 21 % reduction commitment is not related to actual emissions in 1990 but instead the baseline is based on adjusted import/export figures from 1990. Because of the highly integrated electricity system between the Nordic countries and the extended use of hydropower in Norway and Sweden, there are very large fluctuations in net exports between these countries.

The United States was interested in forming an emissions trading "bubble" which would include Japan, Canada, Australia, New Zealand, Russia and Ukraine – The so-called Umbrella-group. But due to the fact that each country would be ultimately responsible for its own emissions should the formed "umbrella" fail to meet its commitments, these "umbrella" countries are now pursuing an arrangement to trade co-operatively under Article 17. Such an approach would not revise the obligations of individual participants under

Annex B. Given the potential ramifications of failing to meet a joint target under Article 4, it is difficult to imagine a proliferation of such arrangements outside of regional economic organisations that are moving towards a common economy and political integration (The Business Roundtable, 1998).

The "bubble" approach is often termed as "trading without rules" because it sets few restrictions on trading between parties. If it turns out to be too difficult to agree on the common rules and guidelines "for verification, reporting and accountability for emissions trading" pursuant to the Kyoto Protocol, the "bubble" approach at least opens the possibility of trading emissions permits within the voluntarily formed group (UNCTAD, 1998).

2.3.4 The project based mechanisms

Articles 6 and 12 in the Kyoto protocol define two project-based mechanisms Joint Implementation (JI) and Clean Development Mechanism (CDM) respectively. Both mechanisms allow for trading in emissions reductions achieved through concrete projects. The main difference is that where JI is used between Annex B countries, the CDM is directed towards countries without a national emission target in the commitment period. The other main difference is that CDM crediting can start already in the year 2000 whereas JI cannot start until the beginning of the commitment period.

2.3.5 Emission trading

Article 17 of the Kyoto Protocol contains the following:

- Allows Parties included in Annex B to "participate in emissions trading for the purposes of fulfilling their commitments under Article 3"
- Requires the Conference of the Parties to the FCCC to define the "relevant principles, modalities, rules and guidelines, in particular for verification, reporting, and accountability for emissions trading."
- Limits emission trading to that which is "supplemental to domestic actions for the purpose of meeting quantified emission limitation and reduction commitments" under Article 3.

Participation in Article 17 trading will be voluntary. Under this Article Annex B Parties can sell their possible surpluses during the first commitment period (years 2008-2012) to Parties that have surpassed their assigned amount under Article 3. Annex B to the Kyoto Protocol and Annex I to the UNFCCC are now identical in nature, this change from Annex I into Annex B potentially allows a developing country to engage in emissions trading if it voluntarily adopts an emissions target and is inscribed in Annex B (Michaelowa, 1998a).

Clearly, the wording "supplemental to domestic actions…" needs to be given a practical interpretation. While trading will not erode the 5 % Annex I reduction target as long as seller countries can be held accountable for their compliance, it will reduce domestic action in buyer countries. Some Parties and NGOs find this objectionable but it is nevertheless sanctioned by the Protocol.

2.4 Evaluations of the Kyoto-protocol

2.4.1 The costs and benefits of avoiding climate change.

The Kyoto Protocol suggests applying a quantity instrument to the five-yearly emissions of greenhouse gases rather than applying a tax-instrument. From a cost-benefit viewpoint, the choice of instrument should depend on how effectively the instrument can be used to equalise the marginal costs with the marginal benefits of avoiding climate change damages.

However, to make a firm recommendation based on this principle you need to know the marginal damages attributable to each party. Even though climate change modelling has certainly improved over time, the benefits of avoiding climate change are still highly uncertain. Even so, something can still be said about the relative attractiveness of a quantity or a price instrument when you consider marginal costs as well as benefits. Specifically, it can be questioned whether the Kyoto Protocol specifies the right approach to deal with the problem at hand.

The "business-as-usual" emissions of greenhouse gases in the future are highly uncertain and depend on a number of factors like population growth, productivity improvements, carbon intensity and energy efficiency. As a consequence, the costs to society of reducing the stock of greenhouse gases in the atmosphere to a pre-specified level are highly uncertain as well. Two opposite cases can now be identified. If the climate change problem is characterised by a potential catastrophe that will occur when the accumulated amount of greenhouse gases in the atmosphere pass a certain threshold, then the right approach would be to avoid this threshold at all costs. This can be done effectively by a quantity (permit) instrument. If, on the other hand, the damages resulting from climate change only rise proportionally with the accumulated stock of greenhouse gases in the atmosphere, the best way to correct this externality would be by using a price instrument (tax)[1]. As noted by (Pizer, 1999), the important distinction between the two instruments is how they adjust when costs change unexpectedly. A quantity instrument adjusts by allowing the permit price to rise or fall while holding the emissions level constant. A tax system adjusts by allowing the total level of emissions to rise or fall while holding the price associated with emissions constant.

Most models on climate change suggest that the damages resulting from climate change only rise proportionally with the accumulated stock of greenhouse gases in the atmosphere, so it seems that a price instrument rather than a quantity instrument should be advocated. Furthermore, if the assigned amounts that are defined in the Kyoto Protocol for the budget period 2008-2012 are assumed to continue unaltered in the future, the total stock of greenhouse gases in the atmosphere will not be stabilised for a long time to come. In fact, given that a large developing country like China has refused to take on a binding commitment, there is no guarantee that the total stock of greenhouse gases will be stabilised at all even if the assigned amounts of Annex B countries were to be cut down further in the future. From an efficiency viewpoint this would tend to reinforce the conclusion that a price instrument should be preferred over a quantity instrument.

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[1] This is the famous result by Weitzman. In the words of (Newell & Pizer, 1999): "Weitzman's insight was that, on economic efficiency grounds, a flat expected marginal benefit function (relative to marginal costs) favours prices, while a steep benefit function favours quantities. Intuitively, relatively flat marginal benefits imply a constant benefit per unit of control, suggesting that a tax could perfectly correct the externality. In contrast, steep marginal benefits imply a dangerous threshold that should be avoided at all costs – a threshold that is efficiently enforced by a quantity control."

The Kyoto Protocol is just a starting point, however, reflecting a whole range of conflicting political interests and there is at present no way of knowing what might happen with future allocations of greenhouse gases. Specifically, the international conflict between industrialised countries and developing countries raises a number of equity issues as well. Nevertheless, it is important to keep in mind that costs to limit the yearly greenhouse gas emissions to a pre-specified quantity could run high and that this should not happen without a reason[2].

2.4.2 Country positions to the Kyoto Protocol

The attitudes towards the Kyoto Protocol have been very different ranging from the green-NGOs arguing that the Protocol does 'too little, too late' to members of the US Congress and representatives of the industry feeling that the Kyoto-protocol ruins the economy to solve a non-existing problem.

The Kyoto-protocol has to be seen as a compromise and as a step in the process of establishing the international institutions necessary to reduce the risks of climate change. Although some steps forward were taken at Kyoto, such as the establishment of quantified and binding emissions targets in the commitment period, a lot of questions were left unanswered.

The fundamental disagreement concerns the use of the Kyoto mechanisms and is centred on two interrelated questions:

- Should the developing countries take on binding emissions constraints?
- And should 'hot air' from Russia and other countries with economies in transition be seen a problem in relation to emissions trading?

The answer to these questions depends on the weight that is put on an *economic effectiveness viewpoint* compared to an *equity viewpoint.*

From an economic effectiveness viewpoint, the problem can be formulated in the following way: The global climate cares about the total level of emissions (in fact the accumulated level of greenhouse gases in the atmosphere) and not about 'hot air'. 'Hot air' could be seen as a way to distribute the permits between countries so that the number of countries that are willing to take on binding emissions constraints is maximised. By making a larger number of countries participate the total level of emissions will be lower, and at the same time, the overall costs of reducing climate change will also be lower (Barrett, 1998).

Especially the whole discussion about 'hot air' from Russia and other countries with economies in transition seems quite arrogant and misses this important point. There is nothing scandalous about Russia trying to sell emissions rights if the country does not return to its 1990-emission level in 2010. The Russian people have suffered enough because of the economic breakdown of the country and should they be compensated nobody could argue against that.

The problem with 'hot air' is that even though it transfers funds to countries like Russia it will also make it cheaper for the industrialised countries to comply with the Protocol. From an equity viewpoint, reductions of emissions should take place in the rich and industrialised countries that are mainly responsible for the greenhouse gases accumulated in the atmosphere today. Developing countries should not have a cap on emissions but should be allowed to increase their emissions in the future as they see fit. Obviously, this line of

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[2] As a consequence, (Pizer, 1999) suggests that the Kyoto Protocol should include provisions on a tax instrument rather than a quantity instrument.

argument leads to the conclusion that developing countries should not take on binding emissions targets. Furthermore, flexibility mechanisms should be kept at a minimum because they will tend to spread out the geographical location of emissions reductions and consequently reduce the costs of emissions reductions in the industrialised countries.

Both these limitations will, however, make the participation of some of the industrialised countries less likely and as such could seriously challenge the ratification of the Kyoto Protocol. Furthermore, they will tend to reduce the environmental effectiveness of the Protocol because emissions will tend to rise in the areas that do not have a binding commitment.

The debate on 'hot air' is brought into the practical implementation of the Kyoto-protocol through the definition of the wording in the protocol that the flexible mechanisms should be "supplemental to domestic action". After difficult internal negotiations the EU in May 1999 presented a concrete proposal on the interpretation of 'supplemental'. The proposal is quite complicated consisting of three different formulas to calculate a ceiling to the use of the mechanisms, but the general result is that approximately half of the reductions must be domestic.

The G-77 and the green NGOs argue that the proposal leaves too much room for the flexibility mechanisms, where as the 'Umbrella' group is strongly opposed to any restrictions to the use of the mechanisms. This is just one of many examples of remaining issues to be resolved before the international framework for implementing the Kyoto protocol is in place.

At CoP4 in Buenos Aires in 1998 the so-called "Buenos Aires Plan of Action" set the agenda for resolution of a long list of unresolved issues. Not surprisingly, there are many unsolved questions regarding the flexible mechanisms. The conclusions on the negotiations are planned to take place at CoP6 in Den Haag in November 2000. It is not likely, however that all the issues regarding the Kyoto mechanisms will find their solution. At best the process will stay alive and progress will be achieved in limited areas.

There are still major differences in the point of view between the three main groups in the negotiations: EU and the accession countries, USA and the rest of the Umbrella-group and finally the G-77, the developing countries.

These differences make it still very uncertain whether the Kyoto-protocol will be ratified at all. Most critical is the attitude of the US Congress that has made a ratification of the Kyoto Protocol contingent on "meaningful participation of developing countries". The G-77 on their side maintains that the threat to the climate stems from emissions from the industrialised countries, therefore it is the responsibility of these countries to achieve the necessary emission reductions. In this 'clash' the EU tries to mediate and keep the process alive.

In the rest of the report it is an underlying assumption that the Kyoto-protocol will enter into force as planned. At least it is expected that the Kyoto-protocol will continue to form the basis for the climate policy in the EU. This seems a robust assumption. Taking into account the huge challenge of getting the USA to ratify the Kyoto protocol it is not very likely that the climate policy in the EU will become more stringent than the present. On the other hand, the political leaders of EU have committed themselves so strongly to the goals of the Kyoto-protocol that it will be difficult to abandon the targets even in the case that the USA does not ratify.

2.5 A closer look at emissions trading

The emission targets according to Annex B are sometimes referred to as assigned amount. Each country has been assigned with the right to emit an amount of CO_2 equivalents. Emission trading transfers “assigned amount units” (AAU). Such transfers can take place under the provisions of Article 3.10.and 3.11 assuring that the amount transferred will be added to the buyer’s assigned amounts and deducted from the seller’s assigned amounts. Figure 2.2 below depicts two possible trading options for Annex B Parties (inter-governmental trading). The first option illustrates bilateral trades where no formal market is established, while the second option has included a formal market.

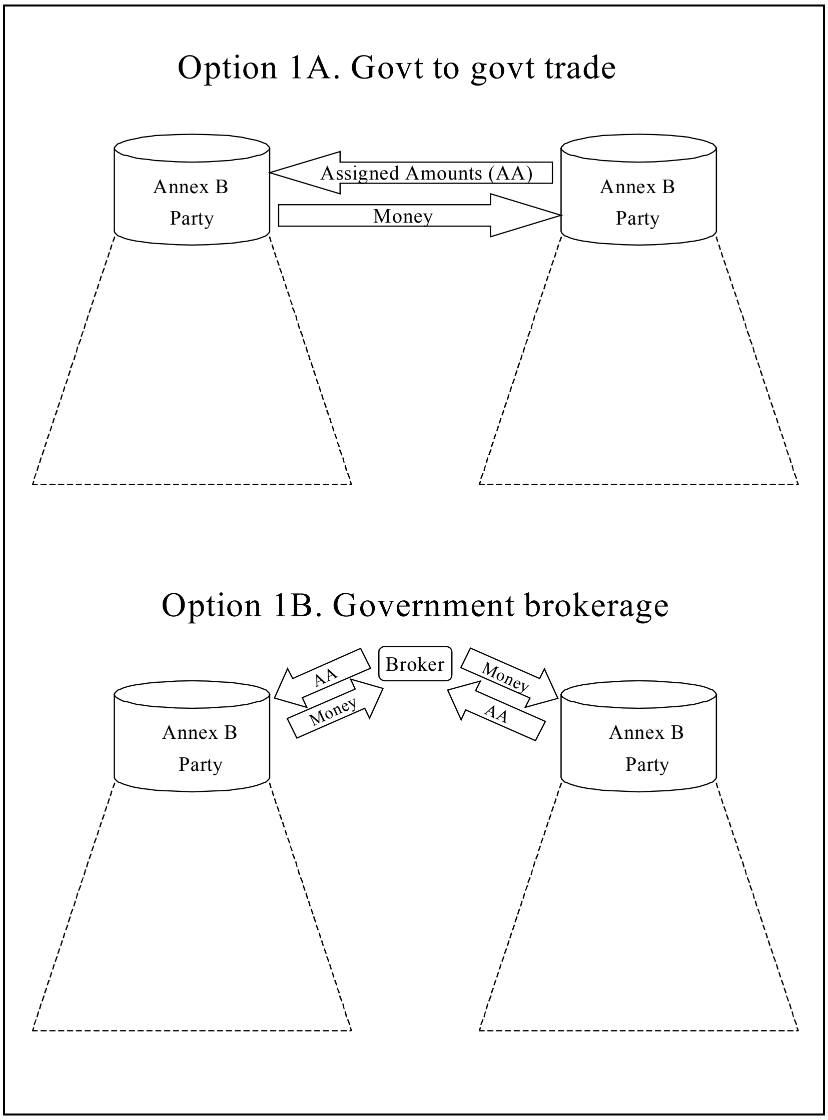

Figure 2.2: Inter-governmental trading

In contrast to JI and CDM, such transfers do not necessarily have to be based on actual emission reductions from projects. Emission reduction units and certified emission reductions may be interchangeable with assigned amounts, but clearly have a different background, and possibly different characteristics. (Jepma, 1998).

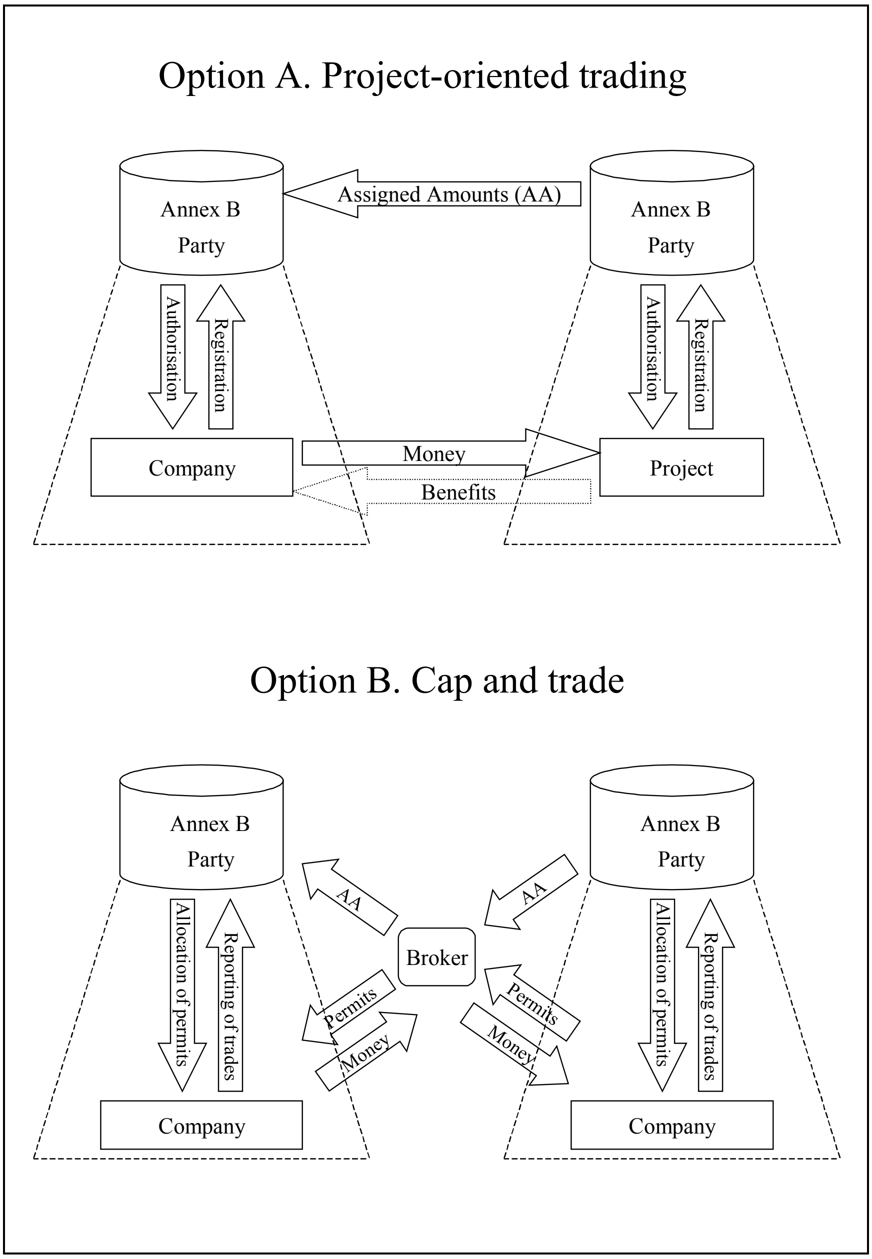

Figure 2.3: Private party trading

An emission-trading program like the one depicted in Figure 2.3 B is known as a cap and trade programme. In a cap and trade program issues such as baselines and allocation of allowances are dealt with in the initial phase of establishing the overall program. Allowance trading can then proceed without the need to revisit these issues in individual trades, greatly reducing the need for government oversight. Credit trading (JI and CDM), on the other hand, is project based, and requires that these issues are analysed and certified for each trade. Each project must establish its emissions baseline, reduction plan and enforcement mechanisms. This system requires a process of verification and government oversight as well as continued monitoring. As a result, the institutional requirements in a cap and trade program and in a credit-trading program are quite different. Moreover, inter-governmental trading differs from the "bubble" approach as specified in Article 4 because the latter pre-determines the transfers and acquisitions of assigned amounts within the voluntarily-formed group prior to the beginning of the commitment period (UNCTAD, 1998).

Needless to say, our focus will be on a cap and trade type program. Furthermore, there is a need to distinguish between inter-governmental trading and trading involving private parties as well. While Article 17 opens up for trading between Parties (inter-governmental trading) it is not fully clear whether it also opens up for international trading between authorised legal entities. In fact, the Kyoto Protocol leaves most of the major questions concerning how an emission trading system should actually function unanswered. Some may be solved at CoP6.

2.6 Allowing private party emission trading

The problems concerning private party emissions trading are, of course, quite central to this report. The following is merely intended to give an introduction to some of the issues that will be dealt with in more detail later in the report.

2.6.1 The allocation process

All existing emissions trading programs have involved private parties. The reason for involving private parties is that they are the ones who actually have control over emissions, and by giving them the right to trade they can profit directly from emissions reduction activities, thus providing them with strong incentives for seeking cost-effective abatement measures. These incentives will not be effective in an inter-governmental trading scheme, unless the incentives are provided by some other regulatory measures[3].

If international trading among private parties (inter-source trading) is allowed, the first important question that needs to be addressed is how the overall permits of an Annex 1 country should be allocated within the country itself. The translation of a country's national commitment into individual parties' commitments may prove to be a very contentious issue as valuable economic rights are being allocated.

A serious complication concerns the fact that Governments can allocate the permits in a way that favours domestic sectors that are exposed to international competition or sectors that are considered strategically important. Furthermore, if some countries allocate the permits to some sectors by means of grandfathering while others use auctions, this could also be used in a trade-distorting manner.

As noted by Zhang (1998), the allocation process itself represents the establishment and distribution of private property rights over emissions, and itself lies outside the mandate of the WTO. However, given the great concern about international competitiveness the allocation of permits does have the potential to bring parties into conflict with the WTO provisions.

Even more complex issues include whether multinational companies could trade within their own firms across international borders. This is a topic that has received considerable attention lately following British Petroleum's proposal to develop an internal emissions trading system (Browne, 1998).

Once the admittedly troublesome allocation process is over, the workings of a cap and trade system could be fairly simple. Again, it is useful to distinguish between a project-oriented system and a cap and trade system (see Figure 2.3). In a project-oriented system (Option A)

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[3] For example, allowing emissions trading within the national borders is one way to provide these incentives. Of course, the possibilities for seeking cost-effective opportunities will be somewhat limited, especially in countries with small and open economies.

every single trade has to be certified[4], which includes verification of the baseline and the size of the emissions reductions. This is not necessary in a cap and trade system (option B), as the authenticity of each allowance is built into the structure of the program (defined in the allocation process).

2.6.2 Compliance issues in relation to private party trading

It is useful to distinguish between what the requirements are for monitoring and verification when trading between Parties is allowed and when trading is allowed between private parties as well, private parties here being electric utilities and large industrial sources. If there is no trading between countries most of the existing national inventories of the Annex 1 countries will probably be adequate (Rypnski, 1998). The only problem is that regulatory data are different from information gathering for purely statistical purposes, because the stakes are higher for the companies involved and therefore the incentive structure is different. That is to say, if there is widespread use of self-reporting of emissions by companies there need to be significant penalties for cheating. If governments are allowed to trade with each other obviously it will be necessary to keep track of the trades and the resulting changes in assigned amounts of the individual countries as well. If the monitoring of a country's emissions is credible in the first place the extra monitoring of trading activity should pose no real problems. However, the quality and/or frequency of monitoring may be greater for emissions trading than it generally is under the Protocol. Finally, if the right to trade permits between individual companies is allowed, each country will have to specify criteria for compliance for the companies involved, possibly subject to approval by the trading partners. For emissions monitoring purposes the national inventories will have to be partitioned in order for this to work.

Liability is straightforward for allowance trading because all covered sources need simply show that they have sufficient allowances to cover their emissions at the end of the compliance period. There are some compliance issues to be addressed if private parties are allowed to trade though. For example, what will happen if the overall country objectives are not met while sector targets are met?

If each country properly manages measurement, monitoring, verification and enforcement of reductions, then the only additional risk introduced by trading is possible seller country non-compliance. This is difficult to deal with because remedies against non-compliance will not take effect until the next compliance period (Jepma, 1998). Also, there is no international framework that can effectively punish countries for non-compliance[5]. Any mechanism that is included in the Protocol to ensure compliance carries with it a trade-off against national sovereignty for all countries. The Kyoto Protocol does not give the international expert review teams explicit authority to inspect private facilities. Nevertheless, the Protocol does not prohibit such practises, and it is possible that participation in emissions trading could require a heightened level of supervision by international authorities. Possible mechanisms to deal with seller country non-compliance can be:

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[4] A project-oriented system is by no means incompatible with the existence of brokers. The World Bank among others is currently trying to establish itself as a broker with respect to such a system by bringing potential buyers and sellers together and subsequently managing the individual projects.

[5] This limits the extent to which one can transfer the US experiences with tradable permits to an international trading regime, since prosecution can not be carried out internationally.

Each buyer's country (buyer liability):

- Keeps track of AAUs added to its assigned amount, whether purchased by government or private parties[6].
- Agrees to make up the lost reductions associated with its share of assigned amounts (in the next compliance period). This is not the same as borrowing, because it is only used in case of actual seller default – it is not a buyer option[7].
- May file a claim for damages against defaulting seller country

Each defaulting seller country (seller liability):

- Will have its assigned amounts in the future deducted with interest
- Will be forbidden so sell but not to buy quotas.

It is also worth considering a system with a grace or "true-up" period after the compliance period has ended. This will give a Party a period of time to come into compliance after it has been identified as being in non-compliance.

2.6.3 What sources can be included in a private party trading system?

Emissions sources have traditionally been classified according to their mobility and generating capacity (Tietenberg, 1974):

Table 2.3. Classification of Emissions sources.

	Point sources	**Area Sources**[8]
Mobile sources	Large cruise ships, ferries and large aeroplanes.	Cars, trucks, buses and other transportation.
Immobile sources	Electric Utilities, refineries and other large industries.	Residential houses, farmers, offices and other small companies

The spatial distribution of sources is not important in relation to GHG-emissions so the mobility of sources is not a problem for the working of a GHG-emissions rights market. Rather, it is the size of the sources that poses the problem. A relatively large amount of GHG-emissions are, unlike emissions of SO_2 and others, produced by the residential and transport sectors. Enforcement of an emissions rights market that applies to these sectors will undoubtedly be too expensive to be practical because the sources are simply too numerous. This limits the extent to which a trading system applied at the point of emissions (*"downstream*" trading system) is useful. The sources regulated through a "downstream" trading system would have to be limited to electric utilities and large industrial sources, while other sectors would have to be reached through other policy measures.

One way of dealing with this could be to model the national trading system as an *"upstream"* system. An "upstream" system would target fossil fuel producers and importers, and so would reduce the number of allowance holders to oil refineries and importers, gas pipelines, LNG Plants, coal mines and processing plants. Implemented

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[6] Each AAU would have to be identifiable in order for this to work possibly with a serial number as in the US Acid Rain Program (Brian Mclean, 1998).

[7] One could also argue for a system where just the marginal buyer should be liable and not all buyers.

[8] The phrase "area sources" is used for relatively small emitters because in terms of meteorological modelling they are aggregated and treated as a single source emitting uniformly over a geographic area. See Tietenberg (1974).

effectively, an upstream system would besides being easy to administer capture virtually all fossil fuel use and carbon emissions in a national economy (Zhang, 1998). However, if the authorities for reasons of political feasibility wish to differentiate the burden of reducing CO_2 emissions between sectors, that might come into conflict with an upstream system. Otherwise, a system that combines elements of an "upstream" and a "downstream trading system is also possible.

At the same time, the difficulties of monitoring emissions of some greenhouse-gases may also limit the ability of some sources to participate in a cap and trade system. Monitoring of CO_2 emissions from electric utilities and other large industries is fairly straightforward, however, monitoring of methane emissions from agricultural or land-based sources or biotic carbon sources is much more difficult. This could call for limiting trade to a subset of gases but the Kyoto Protocol would have to be further amended to partition the assigned amounts into two categories – tradable and non-tradable gases with separate goals assigned for each (UNCTAD, 1998).

In short, private party emissions trading involving emissions of CO_2 does not seem as a bad starting point.

3 Economical and political considerations for policy design

This chapter will look at CO_2 emissions trading between private parties from an idealised perspective[9]. The chapter is split up in two sections. First of all, we are interested in comparing a tradable CO_2 permit system with other policy instruments in terms of economic efficiency. Thus Section 3.1 focuses on an economic comparison of the following three instruments:

- “Grandfathered” permit system
- Auctioned permit system
- Emissions tax

Secondly, we are also interested in the political feasibility of the different instruments. In Section 3.2, we then take into consideration that any environmental policy has to pass through a political decision process. A policy must be designed in a politically acceptable way so that it is not changed beyond recognition and away from its cost-effective design during the political decision-making process.

It is not attempted to merge the two perspectives at this point, because the ways that the political and economical considerations interrelate obviously depend on the actual institutional structures and actors.

3.1 Efficiency aspects of tradable CO_2 permits

A fundamental aspect of environmental policy is that the utilisation of scarce resources should be costly. That is why it should be costly to use the atmosphere as well. A free market without any restrictions on emissions will fail to take account of this cost and correspondingly result in over-utilisation of the atmosphere. Any efficient form of regulation must make CO_2 emissions scarce, thereby raising the marginal cost of emitting CO_2. In this way, a system of tradable allowances is really about introducing the right bottleneck (resource constraint) in private-party decision-making.

The underlying assumption of this section is that the instruments are to be used to meet the politically specified targets in the Kyoto Protocol. This means that marginal damages (or benefits from reduction) are irrelevant and the comparison of different instruments will depend on whether or not the chosen level of aggregate emissions (i.e., the Kyoto level) can be achieved at the lowest cost to society. This can be stated as follows:

The total cost of a tradable CO_2 permit system (or any other instrument) is minimised (the system is cost-effective) when the present value of marginal abatement costs for each period are equalised across participants and periods, which in turn equals the permit price[10].

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[9] In particular, the distributional consequences of different allocation principles are not considered here. The presence of other distortionary taxes in the economy could significantly alter some of the conclusions, in particular if revenues from CO_2 taxes or auctioned CO_2 permits can be used to offset taxes on labour or capital (known as a ‘double dividend’). See Chapter 5.

[10] The words permits and allowances will be used interchangeably.

In order to be able to do such a comparison it is necessary to apply a common yardstick. Economic theory tend to focus on static efficiency (also known as allocative efficiency because the focus is on how resources can be allocated efficiently within given frame conditions) where both price and quantity instruments alike have the potential to produce a least cost solution for society. However, there is no way of knowing if an optimal solution in a static setting will also be optimal in a dynamic perspective, which is obviously a lot more realistic. The concept of dynamic efficiency (also known as adaptive efficiency because the focus is on how able a system is in adjusting to external changes such as technological change and price levels) is much more blurred in comparison and provides no clear-cut solutions. In the following, we will start out by focusing on a static perspective and then move on to consider some dynamic perspectives as well.

In Subsections 3.1.1 and 3.1.2 we start out by considering the fundamental working of a tradable CO_2 permit market. Starting with Subsection 3.1.3, we then move on to compare the working of a permit market where the permits are distributed via an auction or given away for free, with a tax system. In turn, the comparison focuses on the following topics:

- Efficency aspects without uncertainty
- Carbon leakage effects
- Efficiency aspects under uncertainty
- Institutional flexibility
- Possible economic market failures
- Dynamic incentives

Finally, a summary of the comparison is presented with some guidelines on the best design of the system.

3.1.1 Efficiency aspects between participants

Let us return to the EU target level. The private reduction costs that follow the CO_2 reduction will vary over different countries, industries and firms according to burden sharing agreements and marginal reduction cost curves. Assume, for example, that a country has agreed in reducing CO_2 by 15 % and transfers this target level to its individual electric utilities in the market. Compare then two individual firms with low and high marginal reduction costs.

Firm F_l has a low MC_l for the units first reduced, F_l can earn money by trading, as illustrated in Figure 3.1 (left).

Firm F_l will choose to reduce the first 15 % itself at the cost of area *B*. However, because F_l can reduce an additional 42 % at a cost per unit that falls below the price, P^*, it will do so and sell a corresponding number of permits. The firm's revenue from selling these permits corresponds to the area *abcd,* and its profit corresponds to *abcd* minus the costs from private reduction, *D*. Because the profit is greater than area *B*, firm F_l will earn the difference when a permit market is introduced.

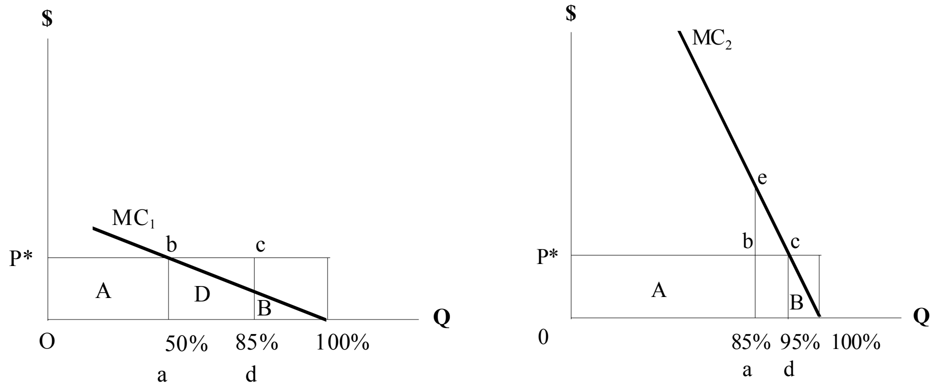

Figure 3.1. Polluters with low and high marginal reduction costs

In contrast, if the MC curve for a polluter F_2 has a greater slope than the aggregate *MC* curve, then F_2 will choose to buy permits. This situation is depicted in Figure 3.1 (right), where polluter F_2 has the high marginal reduction costs of MC_2.

As shown in Figure 3.1, F_2 will reduce emissions by 5 %. Hereafter, it is cheaper not to reduce emissions but rather to buy permits from others at price *P**. The costs of buying permits correspond to the area *abcd*. If F_2 were prevented from buying these permits under command-and-control (CAC) regulation, for example, its costs would include area *aecd*. So, in a permit market, F_2 must in total pay the areas *B* and *abcd*, but it saves the area *bec* relative to the situation where trading is not allowed.

In conclusion, the working of a tradable permit market can ensure that marginal abatement costs are equalised between the participants in the market, which is a prerequisite for a cost-effective solution.

3.1.2 Efficiency aspects over time.

In order to be cost-effective, the system should also be able to secure an equalisation of marginal abatement costs over time (in fact, an equalisation of the net present value of present and future marginal abatement costs).

The inter-temporal cost-effectiveness of a tradable permit system is linked to the flexibility in the timing of emissions. Allowing private parties the freedom to choose when to abate can significantly reduce the costs of abating. However, if the Authorities want to be certain that an environmental target is reached then the question of borrowing emissions allowances from future allocations and using them today becomes a contentious issue. As mentioned earlier, the Kyoto Protocol also puts restrictions on borrowing allowances from the future.

The following set-up can illustrate the effect of restrictions on borrowing allowances from the future[11]. Allowances are assumed to be valid in one specific period (year) known as the vintage period (year). For each period there will be a total number of allowances issued to all the participating units. As will be discussed in the next subsection, the operation of the market is independent of how the allowances are distributed, in particular whether the allowances are given away for free to the participating units depending on some historic emission level, i.e. grandfathering, or whether the allowances are distributed via an auction,

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[11] The set-up is taken from Schennach (1998), who uses this model for SO_2 allowances. It is cast in discrete time, which is a bit more intuitive.

as long as the industry structure is competitive[12]. If not all of the allowances are used in a given period, the difference between actual emissions and the number of allowances can be saved and used in future periods. The industry(ies) included in the market are now faced with an optimisation problem: In their own self-interest they will try to minimise the present value of their marginal abatement costs, however, they are constrained by the fact that they cannot borrow allowances from the future. It is assumed that there is a well-functioning spot and forward market in allowances, meaning that at any given point in time the units can buy and sell not only allowances valid for the current period but also allowances for any given future period. The problem can now be stated in the following way:

$$\text{Min} \sum_{t=0}^{8} [c_t(a_t)*(1+\delta)^{-t}]$$

Subject to: $S_{t+1} = S_t + Y_t - e_t$, S_0 given.

$S_{t+1} \geq 0$ (no borrowing from future compliance periods)

Where:

e_t: CO_2 emitted into the atmosphere at time t from all units after any abatement has taken place.

ε_t: The CO_2 emissions that would be needed to satisfy the demand for electricity at time t without any restrictions on CO_2 emissions. This is known as the baseline or "business-as-usual" emission level. The baseline level of emissions is counterfactual, since they cannot be observed in reality.

a_t: The number of tons of CO_2 abated by all units at time t; $a_t = \varepsilon_t - e_t$.

$c_t(a_t)$: The industry cost of abating a_t tons of CO_2 at time t[13], which is the same as the price of a vintage year t permit in a well functioning permit market.

δ: Time preference of actors in the market equal to riskless rate of interest. Assumed constant for simplicity.

S_t: Total stock of allowances available at time t.

Y_t: Total number of allowances with vintage time t issued to all units.

The first-order condition for this problem is the following:

$$mc_{t+1}(a_{t+1}) = (1+\delta)(mc_t(a_t) - \lambda_t),$$

where $mc_t(a_t)$ is the marginal abatement cost at time t, which is increasing in a_t. λ_t is the shadow price in period t associated with the constraint $S_{t+1} \geq 0$. If the constraint is not binding, λ_t is zero, and then the marginal abatement cost simply rises at the discount rate. If the marginal cost of abatement in the future, discounted to the present, is higher than the present marginal cost, units will be willing to save more allowances for future use, because by doing so, they decrease their discounted future cost by more than they increase their present cost. Of course, the opposite holds true if discounted marginal abatement cost is lower than present cost. Incentives to save more or less will persist until the discounted

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[12] As noted earlier, in this chapter we are not considering the presence of other distortionary taxes in the economy and thus the possible redistributional effects of the instruments

[13] To focus on inter-temporal efficiency it is assumed that marginal abatement costs are equalised across all participants in any specific compliance period, so $c_t(a_t)$ represents the industry cost of abatement at time t.

marginal cost is equalised across all times (Schennach, 1998). Or in other words, incentives to save more or less allowances will persist until the discounted forward price of an allowance, $(1 + \delta)^{-n}mc_{t+n}(a_{t+n})$, is equalised across all periods (for n = 0, 1, …, ∞; n = 0 being the spot price equal to the industry abatement cost at time t = 0, $mc_0(a_0)$).

On the other hand, when the constraint is binding, say between period t and t+1, no allowances will be carried over between the two periods. This means that $\lambda_t > 0$ and the marginal cost increase at a rate less than the rate of interest. The units would like to borrow allowances from the future but are prevented from doing so by the non-negativity constraint. In other words, a restriction on borrowing limits the freedom of timing of emissions reductions and as such will limit the proper working of the market.

In conclusion, if the tradable permits market is free of restrictions, the price of a vintage-year t+n allowance at time t will equal $(1 + \delta)^{-n}(mc_{t+n}(a_{t+n}) = mc_t(a_t)$, so the discounted allowance price is equalised across periods. If the borrowing constraint becomes binding the price of a vintage year t+n allowance at time t will be less than the price of the vintage-year t allowance.

3.1.3 CO$_2$ emission control by quantity or price.

To what extent is the efficient inter-temporal allocation obtainable by using other incentive-based environmental instruments, i.e. a tax? In fact, if we assume ideal competitive conditions and still disregard time-dependent phenomena like technological innovation and uncertainty, i.e. the actors have perfect foresight, then there is a clear symmetry between controlling emissions by price (tax) and controlling them by quantity (tradable permit).

This symmetry can be seen from the following set-up taken from Pezzey (1992). First, consider the emissions control by price, where each firm has to pay:

$$\mu^*(e - e_b)$$

where

μ =	the scarcity rent (tax) set by the authorities (in EUR/ton of CO$_2$ emissions), which is the same for all firms.[14]
e =	emissions of CO$_2$ within a given period measured in tonnes/time. This is under the firm's control and as such may vary from firm to firm and over time.
e_b =	the baseline emission right within a given period measured in tonnes/time, which is given as a property right to each existing firm by the authorities. e_b may vary from firm to firm but does not change over time. This distribution rule is known as grandfathering.

If there is no baseline emissions rights given away to private parties by the authorities (e_b = 0), then we have the traditional pollution charge where firms have to pay for all their emissions. The factor μ is chosen to equal the industry's marginal abatement cost[15], thus achieving short-run efficiency[16]. If on the other hand a firm is given a positive baseline, and its emissions are less than its baseline ($e < e_b$), then the firm receives a subsidy from the authorities and vice versa if $e > e_b$. Pezzey refers to this scheme as a charge-subsidy

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[14] Ideally, for CO$_2$ this should involve not only all firms but also all emissions sources in the world.

[15] In this world of perfect foresight the Authorities know the true marginal abatement costs of the industry.

[16] As is usually the case, short run refers to a situation where the firms that exist in an industry are given, while long run allows for entry and exit of firms.

scheme. It is the control by price equivalent to a grandfathered tradable permit market. In fact, both a price and a quantity type of instrument can involve a varying degree of private ownership in the atmosphere, which is illustrated in Table 3.1.

Table 3.1. Control by price or quantity?

	Emission rights owned by firms		
	Zero	**Intermediate**	**Free market level of emissions**
Price	*Pure charge*	*Charge-subsidy*[*]	*Pure subsidy*
Quantity	*Sold or auctioned emission permits*	*Grandfathered emission permits*	*Granted and bought back emission permits*[*]

Source: Pezzey (1992). [*] These instruments are usually not considered.

The criterion for achieving long-run efficiency is that private opportunity cost of production is equal to social opportunity cost of production. This is achieved when the opportunity cost to any firm of producing output q and emissions e is equal to C(q, e) + μ*e, where C(q, e) is the explicit cost of production excluding emissions taxes and subsidies and μ*e is the implicit cost of emissions.

Long-run efficiency is obviously fulfilled for both a price and a quantity instrument if firms do not own any emissions rights at all, since the opportunity cost to any firm is exactly C(q, e) + μ*e. It is not immediately apparent that this will also be the case with a grandfathered emission permit scheme or a charge-subsidy scheme. The condition for achieving long-run efficiency under a grandfathered emission permit scheme or a charge-subsidy scheme is that e_b is a full property right. This means that new firms entering the industry are not given emissions rights ($e_b = 0$), while existing firms that leave the industry keep their emissions rights and receive a subsidy of $\mu^* e_b$ in perpetuity. Under these entry-exit rules, the opportunity cost to any firm of producing output q and emissions e rather than closing down production (or not starting production in the first place, in the case of a new firm) is the sum of: C(q, e), the explicit cost of production excluding emissions taxes and subsidies; $\mu^*(e - e_b)$, the cost of emitting the amount e to the atmosphere; and $\mu^* e_b$, the income stream that would have been generated had the firm chosen to close down. The net opportunity cost to the firm is then

$$C(q, e) + \mu^*(e - e_b) + \mu e_b = C(q, e) + \mu^* e$$

so long-run efficiency is achieved. The baseline emissions right e_b disappears from the formula, so it has no effect on marginal production costs or resource allocation. Of course, the actual out-of-pocket payments are lower in the case of grandfathering than in the case where no emissions rights are given away to existing emitters:

Out-of-pocket costs when using grandfathering $= C(q, e) + \mu^*(e - e_b) <$

Out-of-pocket costs when no rights are given away $= C(q, e) + \mu^* e$

Owning e_b emissions rights simply increases the wealth of firm owners by lowering the average costs of production.

So, in this highly idealistic world there is complete symmetry between price and quantity instruments. This symmetry does not hold, though, in a more realistic setting. This is what we turn to next.

3.1.4 Carbon leakage effects

Market based instruments like a CO_2 tax or CO_2 permits work through the changes in relative prices that they bring about throughout the economy. These changes in relative prices in turn cause behavioural changes of producers and consumers alike. The fundamental ways in which a CO_2 tax as well as a tradable CO_2 permit work to reduce CO_2 emissions are the following:

- *Less CO_2 per unit produced* because the cost of CO_2 intensive inputs to production will be relatively higher.
- *Less consumption of CO_2 intensive goods* because the consumer prices for CO_2 intensive goods will be relatively higher.
- *Less production of CO_2 intensive goods within the regulated area or sectors.*

As we just saw in the previous paragraph, in a world without uncertainty the first two effects will be similar under any permit scheme and any tax scheme. Both types of instruments will provide the same marginal incentives to take measures against CO_2 emissions throughout the regulated area, which is the efficient way to deal with the issue. The third effect, however, has to do with the fact that the regulated area does not cover all sources and gases. This effect is not desirable as long as the production of CO_2 intensive goods relocates somewhere else without resulting in any CO_2 reductions on a global scale. This effect is known as carbon leakage.

The problem of carbon leakage is very much the same under a system using a CO_2 tax and a system using tradable CO_2 permits as the marginal costs of production will be equally higher within the regulated area or sector. The sources that are included in the regulation can avoid the increase in marginal costs by investing in production capacity outside the regulated area, which makes the country or countries that have undertaken the carbon regulation relatively worse off without resulting in any CO_2 reductions overall. Importantly, the carbon leakage effect will still be present even if the permits are grandfathered to existing sources. That is to say, the opportunity cost expressed as the difference between the marginal cost of production for a firm (source) operating under the regulation and a firm operating outside the regulation, is the same under grandfathering and an equivalent CO_2 tax. This assumes, however, that if a firm close down some production plants, it will still be entitled to the permits that were initially assigned to it. If that is not the case, a system using grandfathering will tend to preserve the initially polluting plants, because the firm cannot gain so much from closing down and reallocate the production, since by doing so, it is not entitled to keep the permits and the revenue stream generated thereby.

So, grandfathering CO_2 permits to emitters is not equivalent to exempting firms from the CO_2 tax altogether. A grandfathered permit market will still entail a substitutional effect away from the polluting activity, while tax exemptions will switch the demand towards the sectors that are exempted from the tax, which is exactly the reaction that such a tax should avoid.

International carbon leakage will be greater the greater are the between-country differences in marginal costs. This is especially a problem between countries that have undertaken a binding commitment to reduce greenhouse gas emissions and countries that do not have such a commitment. In relation to the Kyoto Protocol this is primarily a problem between industrialised countries (Annex B) and development countries without a commitment, although a few development countries have taken on a voluntary commitment. However, if trading in CO_2 permits between countries with binding commitments is restricted, there can still be significant marginal cost differences between these countries as well, which can also lead to carbon leakage. As noted by (Barrett, 1998) the problem of carbon leakage is two-folded: it will drive up the costs for the controlled sources and at the same time reduce the benefits because the total emissions will be higher.

With regard to a trading system solely for the electricity sector in the EU a potentially much larger problem is carbon leakage to the rest of the EU economy. Electricity competes with other energy carriers, i.e. different fuels and heat, as input to production in other sectors and in final consumption. If other sectors are not included in the market (or regulated by a CO_2 tax app. equivalent to the permit price) the marginal costs of using combustible fuels as an input to electricity production will be higher than for other sectors. This could be the case if the electricity sector is used as a buffer for fulfilling the overall commitment of the EU Member States. The resulting CO_2 emissions reductions could be very costly.

3.1.5 Efficiency aspects under uncertainty

There are some crucial differences between a price instrument (tax) and a quantity instrument (permits) when we consider the uncertainty in the CO_2 reduction costs. A CO_2 tax will entail uncertainty about what the total level of emissions will be while keeping the price fixed, while a permit system will fix the total amount of emissions but entail uncertainty about the costs (price of the permits). This distinction is important because as long as there is no realistic “end-of-pipe” solution to the reduction of CO_2 emissions the cost of reducing emissions to a certain level will be highly uncertain.

To get to the desired level of emissions by using a CO_2 tax a trial and error method can be deployed. Trial and error when fixed capital is at stake can be very costly, though. This is not just because of the overbuilding penalty either. It will often be true that getting to emission reduction level x by first building to remove x/2 and then adding another x/2 capability will be more expensive than going to x directly (Russell and Powell, 1996). Also, the nominal value of the tax has to be changed from time to time to keep the real value of the tax unchanged. Changing the size of a CO_2 tax at the EU level will however be a very complicated political process, as there are large differences in carbon intensity between the electricity sectors in the EU countries.

With respect to a CO_2 permit scheme the uncertainty about the overall costs should be reflected in the design. In effect, it is important that an emissions trading scheme allows for flexibility in the timing of emissions reductions. Banking of unused permits is important for improved efficiency when regulatory targets are such that marginal reduction costs are rising over time faster than the relevant interest rate. This has been the case in the US Acid Rain Program because of the tightening of the regulatory standards in the year 2000 with the beginning of Phase II (all boilers larger than 25 MW_e will be included). On the other hand, if costs of reducing emissions are high in the short-term and expected to be lesser so in the longer term it will be attractive to allow borrowing of permits from future allocations. As noted by (Fischer et al. 1998), this could occur because the composition of energy-using capital is more flexible in the longer term than in the shorter term, and because tougher short-term requirements provide relatively less opportunity to embed technical improvements over time. If carbon permits can be borrowed from the next commitment period, unnecessary short-term costs from excessive capital obsolescence can be avoided and there will be greater prospect for incorporating new technological innovations over time. In this way unexpected fluctuations in energy prices or economic growth can also be smoothed out over time.

The reason for including a borrowing constraint is to ensure that the intended emissions reductions will actually result from the permit scheme. If unlimited borrowing of permits from future allocations is allowed there could be a potentially large time inconsistency problem. This has to do with the fact that the political decision process is notoriously short-term by nature. This is particularly problematic with respect to the climate change issue since the timing of costs and benefits is such that the costs of reducing emissions will be visible today while the potential benefits will be visible in a time horizon of a 100 years from now. The regulators who enforce the market must be consistently committed to the problem of climate change and not put similar weight to other factors like economic growth and job creation. That is not credible. This creates incentives for emitters for letting their emissions run uncontrolled and claim that their particular firm has experienced strong organic growth and thus is not able to restrict their emissions to the pre-specified level. The further they deplete their future allocations of permits the less credible is it that the regulators will actually be able or willing to impose sanctions because the costs to society of imposing the sanctions will run higher. Furthermore, it is hard for the authorities to know up-front whether a particular timing of emissions will lead to a steady state or whether it involves an ever-increasing debt-burden in the future. There are some counteracting forces as well, though. Firms that have depleted their future allocations of permits to a large extent might be identified as being dirty in the public eye, which could tend to lessen the problem with borrowing.

The Kyoto Protocol establishes five-year compliance periods and within each compliance or budget period the market participants are free to borrow or bank allowances. There is a borrowing constraint only between compliance periods. In any case, the length of the compliance period will be a trade-off between inter-temporal flexibility and ecological effectiveness (ensuring that the reductions are realised).

So, borrowing of permits from future allocations raises a number of difficult questions. However, in the absence of borrowing the costs to control emissions could run higher, which will also create a credibility problem for the regulators. So, too much flexibility can be regarded as a problem with regard to eventual compliance but so can too little flexibility. In any case, this needs to be carefully considered in relation to a CO_2 permit market for the power sector.

Again the model considered by (Schennach, 1998) will provide a useful illustration. By introducing uncertainty into the model we must replace the perfect foresight assumption with expectations about the future. Assuming that the electricity producers are risk-neutral, they now try to minimise the sum of their expected discounted costs:

$$\text{Min} \left\{ E_0 \left[\sum_{t=0}^{8} [c_t(a_t)*(1+\mu)^{-t}] \right] \right\}$$

subject to: $S_{t+1} = S_t + Y_t - e_t$, S_0 given.

$S_{t+1} \geq 0$ (no borrowing between compliance periods)

where:

$E_t[.]$ is the expectation value given all the information known at time t.[17]

μ $= r + \rho$, where r is the riskless interest rate and ρ is the asset-specific risk premium.

The solution to this control problem can be shown to be the following:

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[17] This formulation abstracts from transactions costs, notably that information gathering is costly at each point in time.

$$E_t[mc_{t+1}(\varepsilon_{t+1} - e_{t+1})] = (1 + \mu)(mc_t(\varepsilon_t - e_t) - \lambda_t)$$

As long as we have banking, so that $\lambda_t = 0$, we equalise the present value of the expected marginal cost of abatement across periods. There is still full flexibility over time, and the optimal path can still be obtained. However, the no-borrowing constraint has changed a bit, which can be seen by iterating the equation:

$$mc_t(a_t) \ = \lambda_t + (1 + \mu)^{-1}E_t[(mc_{t+1}(a_{t+1}))]$$

$$= \lambda_t + (1 + \mu)^{-1}E_t[\lambda_{t+1} + (1 +\mu)^{-1} E_{t+1}(mc_{t+2}(a_{t+2}))]$$

$$= \sum_{s=0}^{n-1} (1 + \mu)^{-s}E_t[\lambda_{t+s}] + (1 +\mu)^{-n}E_t[mc_{t+n}(a_{t+n})]$$

This shows that the discounted forward price, $(1 +\mu)^{-n}E_t[mc_{t+n}(a_{t+n})]$, will be less than the spot price of allowances, $mc_t(a_t)$, if there is a possibility of an empty bank (the market for permits being well-functioning otherwise). The market participants would have liked to demand more permits from future allocations but are prevented from doing so by the non-borrowing constraint resulting in relatively higher spot prices. This last equation can be rearranged to show:

$$E_t[mc_{t+n}(a_{t+n})] = (1 + \mu)^n mc_t(a_t) - (1 +\delta)^n \sum_{s=0}^{n-1} (1 +\mu)^{-s}E_t[\lambda_{t+s}]$$

If units assign a positive probability to an empty bank, the expected price will rise at a rate less than μ. In fact, the downward correction in the expected price rises with the probability of an empty bank. So in a way the units are a bit more pessimistic than under perfect foresight in that it is the expectation of an empty bank and not an actual empty bank that will make the constraint binding. The units will be more inclined to save allowances when there is a possibility of an empty bank.

The main point of the foregoing is that it is the expectations of the market participants that drive the allowance price. If new information becomes available at a certain time this will immediately change the entire price path in the future. As also noted by (Schennach, 1998), the market can, for instance, absorb an unexpected downward fluctuation around the expected trend in electricity demand by saving more allowances than expected, thereby smoothing the effect of this chock on allowance price. An unexpected upward fluctuation of the same size, however, can only be absorbed by a use of allowances from the existing bank. This is true if the compliance period is short, but if the compliance period is longer, i.e. 5 years as in the Kyoto Protocol, there is always the possibility of smoothing the effect of the upward shock by borrowing from within the compliance period. Due to the fact that the market cannot borrow from future compliance periods the shock-absorbing capabilities will be less in case of an upward shock than a downward.

The opportunity to mitigate the cost of error is an attribute that is not indicated by the usual analyses of emissions trading which assume perfect foresight, nor is it an attribute shared by regulatory mechanisms that operate by other means than the use of allowances (Ellerman, 1998).

3.1.6 Institutional flexibility

As noted above, it is not to be expected that the cost of the greenhouse effect will be known with any great certainty now or in the near future. Accordingly, assigning the correct amount of emission allowances or choosing the right tax level is practically impossible.

Rather, any regulative system that tries to deal with this problem should be able to deal with uncertainty and changing expectations over time.

Tradable CO_2 permits are property rights, which can be bought and sold. That such permits hold any value at all is a result of the political and legal framework that makes it so. The working of a permit market is intrinsically linked to the credibility and stability of this political and legal framework. This limits the ability of a permit market to cope with changing the amounts of permits allocated, e.g. as a result of new information on the critical stock of CO_2 (greenhouse gases) allowed in the atmosphere. However, in the real world changes in assigned amounts will only result from lengthy international political debates, and as such these changes can be phased-in over time.

An emissions tax is not likely to deal with uncertainty in any effective way. At each point in time, the authorities, in setting the level of the tax needs information on future scientific, technological and economic development, which adds to an already existing informational overload in meeting environmental standards.

The following simple example taken from Schneider and Wagner (1998) can illustrate this. If new evidence comes up on increased global warming, the market participants, especially market speculators, will bet on lower permit allocations in the future. This will immediately raise the price of permit-futures, incite banking of permits and stimulate increased efforts of mitigation. Some of these responses might also occur with taxes. For instance, some investment may be reduced due to expected higher or lower tax rates. However, taxpayers can neither advance nor postpone their payments. Thus they cannot react to changing expectations in the short term. In fact, it is rather plausible that some long-term investments are rejected since cash-flow return on investment is too low compared to a setting with tradable permits. Dynamic efficiency will thus be lost due to this sluggishness of the tax policy[18]. In other words, tradable permits can be more responsive to changing scientific knowledge than taxes. The same is obviously true for technological progress and other changes in economic parameters like economic growth or inflation.

3.1.7 Possible economic market failures of a permit system

There are a variety of possible reasons why firms might fail to reap the apparent gains available from the trade of CO_2 permits, including:

- Market power in the permit market
- Strategic interaction between the output market and the permit market
- Grandfathering as barrier to entry
- Private transaction costs

In turn, we will now consider these possibilities

Market power in the permit market

The possibility that not all participants in an emission-trading scheme will be price takers and that some will be large enough to exercise market power can have significant impacts on the working of the market. As we have seen, When all participants are price takers the cost-effectiveness of the system does not depend on the initial allocation of permits. However, when there is market power present the ability of the monopolist to exercise

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[18] This sluggishness stems from the fact that there a number of political barriers to changing the tax rate up and down on a short notice.

market power depends on his initial allocation of permits, so the traditional result where considerations of cost-effectiveness are separable from considerations of equity (how the permits are distributed) is not valid in this case. So, if some sort of grandfathering is being used as a distribution principle the present value of marginal abatement costs can fail to be equalised across periods and participants as a result of market power. That said, it must also be stressed that the whole notion of market power in the permit market is definitely more relevant when Nations rather than private parties are engaged in permit trading.

To illustrate the potential problems that can be encountered with a grandfathering scheme we will consider a set-up taken from (Hagem and Westskog, 1996). They consider a monopolist that sells permits to a group of small buyers or, alternatively, a monopsonist that buys permits from a group of small sellers. Using this set-up, they then compare how this affects the working of the two following permit systems:

- A system where the permits entitle the holder to emit a certain amount of CO_2 over the whole length of the compliance period with no restrictions on the allocation of emissions between the different sub-periods within the compliance period. Trade is arranged at the beginning of the period. This system is referred to as a *flexible permit system.*
- A system where there are restrictions on emissions in each sub-period. The permits entitle the holder to emit a certain amount of CO_2 in each sub-period, and trade is arranged at the beginning of each sub-period. A permit bought in the first period has a value for the holder in each of the following sub-periods. This is referred to as a *durable permit system.*

Intuitively, under the flexible permit system each participant will be able to distribute abatement costs effectively across periods. When market power is present in the permit market, however, this relative advantage of the flexible permit system can be lost due to larger differences in marginal abatement costs across participants. In other words, the durable permit system has a relative advantage in terms of avoiding the abuse of market power and thus equalising abatement costs across participants. The reason is that if the monopolist holds back permits in the initial sub-periods to drive up the permit price he will have incentives to lower the price in the later sub-periods to sell more units. Assuming that the buyers will be able to foresee this, they will be willing to pay less for the permit today. In this way, a durable permit system will limit the inefficiencies stemming from the use of market power. Hence, there is a trade-off between reducing the exercise of market power and allowing for flexibility over time.

If the monopolist is a seller of permits, then, in a flexible permit system, the inefficiencies stemming from the use of monopoly power will increase the more the initial allocation favours the monopolist, i.e. the more permits he is given compared to the rest. Likewise, if the monopolist is a buyer of permits (monopsonist) decreasing the initial allocation of permits to the monopsonist will also increase inefficiencies due to the use of market power. In conclusion, the more the initial allocation of permits deviates from a cost-effective distribution of abatement across participants, the lower is the cost of the durable permit system compared to the flexible permit system[19]. However, the inclusion of private parties

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[19] In the preceding set-up the monopolist charges a constant price for all permits sold. As noted by (Munro et al., 1995), however, the only reason why the monopolist would do this is because he cannot successfully price discriminate or, more fundamentally, because the costs of organising price discrimination outweigh the gross profits achieved. For example, with a small number of potential buyers, each purchasing a sizeable fraction of units sold organisational costs are greatly diminished. It is a well-known result from industrial economics that perfect price discrimination achieves a socially optimal allocation of resources. However, all the benefits from trading will accrue to the

in any trading scheme will drastically increase the number of participants and as such limit the scope for exercising market power in this way.

Strategic interaction between the permit and the output market.

As we have seen, the argument for efficiency of a tradable permit market is intuitive in perfectly competitive markets. In such markets the price that clears the market for emission permits equalises marginal abatement costs. However, the implication of tradable emission permits may crucially depend on industry market structure, especially if the firms that compete in the output market are the same firms that trade in the permit market. This is especially a problem for grandfathering.

Generally, when strategic interplay between the permit market and the output market is possible, grandfathering will not result in the minimisation of marginal abatement costs. In such a case, a firm that receives a favourable allocation of permits can, by holding on to these permits, expand its own production at the expense of other firms. The other firms will now find it harder to underbid the first firm since their production is constrained by the amount of permits. They would now have to lower their emissions to output ratio presumably at a very low cost in order to expand their market share. Clearly, this will not result in an equalisation of marginal abatement costs and thus permit prices between participants, and as a result the cost-effective reduction in emissions will be realised.

In conclusion, strategic interplay between the permit market and the output market can be a real problem for grandfathering. However, we have to distinguish between whether or not a formal marketplace for trading emissions permits has been set up or not. If there are only very few participants and setting up a formal market is not deemed feasible, then the buyers and sellers will all know each other and consequently be able to use this knowledge strategically. If, on the other hand, there are enough participants to set up a formal marketplace for permits, buyers and sellers will not know the identity of each other. Then the problem goes away.

Grandfathering as a barrier to entry

On a related note, if the industry structure is not competitive, grandfathering can also be a barrier to entry.

This can be seen from the following reasoning. Assume that the industry structure is not competitive due to the presence of economies of scale. Economies of scale mean that there is a minimum efficient scale of production necessary to generate rents to cover the fixed costs. If in addition this minimum efficient scale is a significant proportion of the total industry demand, the market can sustain only a small number of firms. In this way, the presence of fixed costs has the potential to generate an imperfectly competitive market structure by limiting entry (Tirole, 1990). Of course, the threat of entry by other firms may still serve to discipline the established firms so the degree of imperfect competition will depend on the concrete case at hand.

If emissions permits are grandfathered to an existing industry with large fixed costs, the permits can serve as an extra barrier to entry. First of all, entrance into the industry may be restrained because potential entrants need a large share of permits to meet the minimum efficient scale of production. Knowing this, the existing firms may be reluctant to sell

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monopolist. Monopoly or monopsony is only a potential source of inefficiency when the numbers of agents on the other side of the market makes price discrimination impracticable excess permits to newcomers. Secondly, as we saw before, the existing firms may be reluctant to sell permits to each other, because by doing so, they can force competitors to close down some or all of their plants if they are not able to create the necessary rents. On the other hand, given a reasonable auction design, auctioning emissions permits guarantees immediate access to the market for any new firm[20]. In other words, the auctioning of permits will not tend to further the already present market failures to the same degree.

In conclusion, grandfathering can be an extra barrier to entry if other market failures are present. However, it is clear that the larger the actual number of participants in the permit market and the more evenly distributed the permits are, the less will be the possible problems of market abuse related to grandfathering.

Private transaction costs

(Munro et. al, 1995) make the following assumptions about the nature of transaction costs in a permit market:

- Transaction costs are increasing in the number of firms that have to be party to any particular deal.
- Transaction costs are increasing for a firm, the larger the number of potential partners it has to contact to set up a deal.

In a frictionless world it is clear that the more firms participating in a permit market the better. At first sight it seems, however, that the presence of transaction costs will put an upper limit to the number of participants that is it practical to include. However, it is necessary to make a distinction between whether or not a formal marketplace for trading CO_2 permits has been set up. There are fixed costs of setting up a formal market, which create an externality across permit market participants. With a few possible traders the fixed costs of setting up a formal market place may be too large. If, however, the number of possible market participants is large then these set-up costs can be overcome.

No formal marketplace

In a market with few participants each individual firm can consider all possible trades quite easily. Also, each firm may have better knowledge of the marginal abatement costs of the other firms, which would suggest that a market with few participants is superior to a market with many participants. So, the problems with transaction costs are most pertinent when there are many traders but not so many that a formal market can be set up.

In the absence of a formal market the sequential nature of individual trades can be a big problem, since there is no way of knowing that the “right” parties will make a deal. As noted by (Munro et al., 1995), the sellers with the lowest reservation prices and the buyers with the highest willingness to pay are likely to be the most active searchers for deals and as such are likely to make deals with each other. This could mean that other buyers and sellers, i.e. parties with higher reservation prices and parties with lower willingness to pay, would not be able to make deals.

Asymmetric information would also pose a problem in the case where no formal market is established. When the same firms have to deal directly with each other several times, they may be reluctant to let their bids and offers reflect their true costs in the beginning, since by doing so they could earn more money. In contrast, in a formal and impersonal permit trading system with many participants there are no incentives for firms not to let their bids and offers reflect their true private information.

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[20] See for example (Cramton and Kerr, 1998a, b) or (Svendsen and Christensen, 1998). We will leave it to later chapters.

With formal marketplace

The presence of a formal market or broker can drastically reduce the transaction costs of the individual firm. However, even with a formal market there can still be positive transaction costs. One cost is the commission fee paid to the market maker or broker for rendering their services. A second type a transactions costs is the search costs incurred from deciding which broker to use and the search costs incurred if the firm decides instead to act as its own broker. A third transaction cost is the cost of having to negotiate a contract and the accompanying terms of sale. Search costs could be noticeable in the beginning but may decline over time as firms become more experienced with executing transactions in the permit market (Bailey, 1996).

The presence of transaction costs in a formal permit market will result in qualitatively the same price effects as observed in a permit market with uncertainty and a restriction on borrowing. In Subsection 3.1.5 it was shown, that if there is a possibility of an empty bank, then the discounted forward price of permits will be less than the spot price of permits because the firms will be inclined to save more permits. In the same way, the presence of positive transaction costs will result in an extra benefit from holding a stock of permits on hand, called a convenience yield, which is the transaction cost saved from not having to make additional transactions and/or undo the transaction just done (Bailey, 1996). This will heighten the spot price of a permit compared to the discounted forward price[21], because saving more and holding more permits on hand becomes more attractive.

So, the presence of transaction costs can not surprisingly prevent the equalisation of marginal abatement costs across periods. Furthermore, private transaction costs are only a problem for tradable permit systems and not for a tax instrument, so there is a danger of over selling such a system unless the details have been carefully dealt with (Russell and Powell, 1996). The extent to which private transaction costs are a real problem depends on the magnitude, which will be considered in the subsequent chapter dealing with the American experience with primarily the Acid Rain Market.

3.1.8 Dynamic incentives

Much of the foregoing has analysed CO_2 externalities in a static context. Static in the sense, that the state of technology is exogenous. In such a case, the choice between different environmental policies is determined entirely by their ability to allocate resources in a cost-effective manner without giving much thought to how this effective allocation might change over time. That is to say, the analysis is concerned with how markets operate and not how markets develop.

However, in a dynamic context the state of technology is endogenous, and environmental policies can also affect welfare through their effect on the incentive to invest in environmental research and development (R&D). As noted by (Parry, 1996), this dynamic efficiency effect arises because, in the absence of any policy intervention, the level of environmental R&D in the private sector is likely to be sub-optimal for two reasons. First, firms lack incentives to adopt cleaner technologies if they are not rewarded for pollution reduction (the usual environmental externality problem); second, firms may not take into account spillover benefits to other firms that may copy or learn from their innovations (the usual externality in the R&D literature).

There is a potential asymmetry between how an emissions tax and a tradable permit system using grandfathering will influence on these matters even under competitive conditions.

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[21] This is known as weak backwardation in the term structure of permit prices.

The asymmetry between the two schemes stems from the different mechanisms by which innovation rents are generated. Under an auction, firms are willing to pay for a new emissions-reducing technology because it will reduce their tax liability. Therefore, the rents earned by innovators ultimately come at the expense of government tax revenues. Under grandfathering, firms adopt cleaner technologies if they can use the resulting spare emissions permits to increase their own output or sell to other firms. That is, a diffusion of a cleaner production leads to an expansion in production; and the rents to the innovator come from the surplus created by this extra production and at the expense of rents to the initial permit holders. In theory at least, this causes a crucial problem: it may be optimal for an innovator to restrict diffusion of a new technology to limit the fall in permit price, and hence the reduction in the amount other firms will pay to adopt the technology (Parry, 1996).

Clearly, the effect that an innovation has on the emissions to output ratio plays a crucial role here. We can distinguish between two cases: one in which the innovation is marginal and only has a small impact on the emissions to output ratio and one in which the innovation is drastic and fundamentally changes the emissions to output ratio.

Drastic innovation

If the permit design allows for appropriate flexibility in the timing of emissions, the forward price of permits will always reflect the underlying expectations of the market participants. In this way, the permit price will always provide the necessary incentives for the market participants to reduce their emissions to the required level. However, there are no incentives to abate further than that. Secondly, if borrowing of permits from future allocations is allowed, it will result in lower incentives of permit holders to uptake cleaner technologies in the short term, because the shadow price on emissions (the price of the permits) will be lower in the short term. In any case, new information about technological innovations will result in an uncertain drop in permit prices, which may work to limit the incentives to develop new technologies. If the innovation is really drastic involving a major cut in the emissions to output ratio this can result in a major drop in permit prices, which means that the private return to innovation will be significantly lower under grandfathering than under emissions taxes.

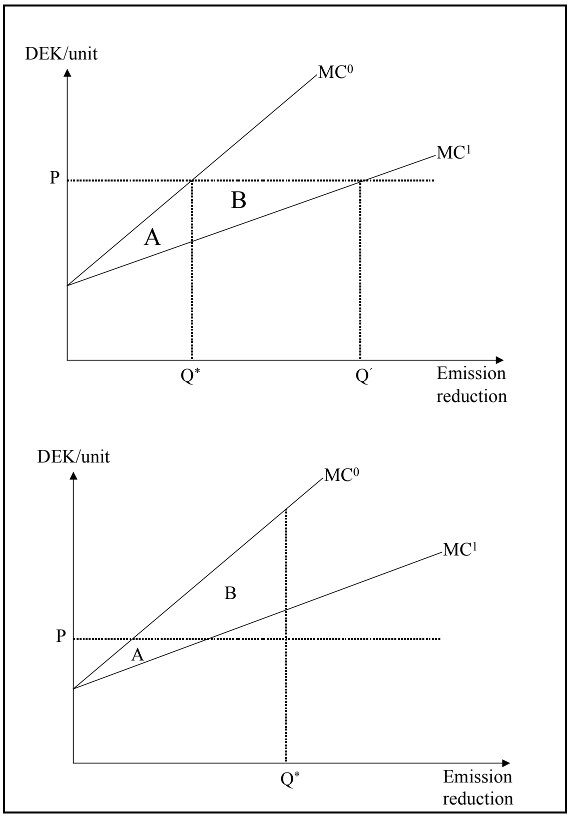
A tradable permit system using auctions will place itself in between a system using taxes and a system using grandfathering. Under such a system, the rents to the innovator will come from the surplus that is created from the extra production at the expense of government tax revenues. An innovator still has an incentive to restrict diffusion of a new technology to limit the fall in permit price, and hence the reduction in the amount other firms will pay to adopt the technology. However, the fall in permit price leads to a reduction in tax liabilities and not to a reduction in rents to the initial permit owners. This will lead to a higher willingness to pay for new technology under an auction than under grandfathering.

Marginal innovation

If the innovation only has a marginal impact on the emissions to output ratio, then the introduction of this new technology will only have a negligible effect on permit price. In this case, the incentives to innovate will not be very different under the two schemes.

However, it is also interesting to compare the dynamic incentives of firms to adopt cleaner technologies in a permit system with no trading and a permit system with trading. The following figure can be used to for that purpose. It is assumed that permit prices will not change as a result of adopting new technology and as consequence the incentives to adopt new technology under a tax system or under a permit system are the same. The horizontal price line in the top and bottom figure is therefore the resulting price in a tradable permit system or, alternatively, the size of the tax.

Under a permit system with no trading the firm must achieve emissions reductions by the size of Q^*. There are two technologies represented by the marginal reduction costs lines MC^0 and MC^1 where MC^1 is the cleaner technology in that the costs of reductions are lower. The marginal emissions costs are assumed to be linear and increasing in the size of reductions. The economic incentives to adopt the cleaner technology under a permit system with no trading is clearly equal to the size of the area A in the top graph and the area A+B in the bottom graph (see Figure 3.2).



Source: Malueg, 1989.

Figure 3.2. Incentives to adopt new technology

If the firm is given the opportunity to trade in permits at price p we must distinguish between whether the firm will be a buyer or seller of permits. The top graph depicts a seller of permits. This firm will choose to reduce its emissions by an amount equal to $Q^{'}$ and sell the extra permits at price p. So the incentives to adopt new technology are now equal to the area A+B, which is higher than the incentives with no trading. In the bottom graph the situation is reversed. This firm will choose to abate an amount less than Q^* and buy permits to cover the last emissions reductions. So when a firm is a buyer of permits its incentives to adopt the cleaner technology is equal to the size of the area A, which is less than with no trading.

Of course, this result only reflects the way a permit market works. Any firm that has relatively high emissions reductions costs will use the permit market as a cheap alternative and consequently do less reductions of their own. To what extent this is a real problem, however, depends on what constitutes the right amount of innovation. The buyer’s lower incentives to reduce emissions by themselves could be a problem if, on average, firms that are buyers in the permit market are firms that are quite energy efficient to begin with and as such are also the firms that move the technological frontier. This remains quite speculative, however.

In conclusion, both types of tradable permit designs can result in lower innovation rents than the tax scheme, especially if the introduction of new technology involves a major drop in the emissions to output ratio. Furthermore, the problem is worse when grandfathering is used as a distribution principle.

3.1.9 Concluding remarks

The results of the comparison are summarised in the following Table 3.2:

Table 3.2: Summary of comparison between different instruments.

	"Grandfathered" permit system	**Auctioned permit system**	**Emissions tax**
Efficiency aspects without uncertainty	Is able to achieve the cost-effective reduction of CO_2 emissions; if no borrowing costs will run higher	Is able to achieve the cost-effective reduction of CO_2 emissions; if no borrowing costs will run higher	Is able to achieve the cost-effective reduction of CO_2 emissions
Effect on carbon leakage	Marginal cost in regulated area increases due to opportunity cost (no out-of-pocket cash flow)	Same marginal cost increase in regulated area but due to tax payment.	Same marginal cost increase in regulated area due to tax payment
Efficiency aspects under uncertainty	Self-adjusts to given total amount of permits; is able to mitigate errors but less so with no borrowing	Self-adjusts to given total amount of permits; is able to mitigate errors but less so with no borrowing.	Requires price adjustment to maintain feasibility
Institutional flexibility	Limited ability since value of permits derives from stable framework; changes in permit allocations must be phased in	Limited ability since value of permits derives from stable framework; changes in permit allocations must be faced in	Can be lost due to sluggishness in tax policy
Private transaction costs	Potentially thin markets. Details have to be carefully dealt with.	Transactions costs lower than grandfathering	None
Dynamic incentives	Path of prices hence incentives unclear; Innovation rents low	Incentive to innovate larger than grandfathering	Incentive to innovate larger than under an auctioned permit system[22]
Special problems	The initial allocation of permits + possible extra barrier to entry.	Gov't revenue: Recycle or reduce other taxes	Gov't revenue: Recycle or reduce other taxes.

In an idealised setting the efficient working of a tradable allowance market will hold irrespective of whether the allowances are distributed freely to the existing producers, i.e. grandfathering, or whether the allowances are distributed via an auction.

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[22] This assumes that the tax is not changed in the face of a major innovation.

In a more realistic setting, the analysis suggests that an auctioned CO_2 permit scheme with comprehensive coverage of CO_2 emissions is the most effective. The scheme must, however, allow for flexibility in the timing of emissions, preferably with the possibility of borrowing as well as saving of CO_2 emissions. The tax system will not be able to respond effectively to uncertainty in the level of emissions.

Grandfathering can be expected to be the least effective option. Given that the target group for the permit market is reasonably large the grandfathered permit market will not create a barrier to entry, however.

3.2 Political market failure

As noted in the beginning of the chapter, this section will take into consideration that any environmental policy has to pass through a political decision process. A policy must be designed in a politically acceptable way so that it is not changed beyond recognition and away from its cost-effective design during the political decision-making process. In particular, this section deals with how different actors, specifically large energy-intensive industries and environmental groups, are muster their opposition to specific policy designs.

3.2.1 Target group

A single instrument is hardly appropriate for all sources. The choice of target group must be based on both the contribution of emissions by that group and whether control is administratively feasible. As such, the benefits connected with individual control must be weighed against the administrative costs. The administrative costs of, for example, controlling every single car owner or housekeeper are likely to exceed the potential gains to them from an individual control system that lowers emissions reduction costs. The transport and household sectors contain numerous small sources, and for this reason they may be rejected as a target for individual CO_2 emission control systems. Larger stationary sources, such as electric utilities, are of rather more interest. These larger, stationary sources will typically be regulated and controlled already, so that a permit market could build on the existing administrative infrastructure without adding further administrative costs. Also, by regulating electric utilities, the main part of the total emissions are 'caught'. The administrative choice of this target group is reinforced by the fact that well-organised interest groups, like electric utilities, have strong lobbying power, as we shall see in the next section.

Concerning exports of electricity to countries outside the EU, e.g. Norway, the bubble model from Denmark may be applied. Here, two SNO_x bubbles are in effect for the two consortia in the electric utility sector, ELSAM and Elkraft. To protect exports of electricity, only net numbers are considered. Similarily, when net exports are positive in the market which we consider here, the CO_2 surplus should be added to the permit holdings of ELSAM and Elkraft.[23]

3.2.2 Lobbyism

What will be the role of the State and the main interest groups in environmental regulation? First, it is important to distinguish between organisations inside and outside the market. Second, it is important to know what kind of regulation will lead to a politically acceptable

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[23] Svendsen (1998b).

outcome, that is a politically acceptable equilibrium between the State as tax collector and the main organised interests.

The State, the Market and the Political Arena

The main organised actors in environmental regulation are the democratic state (regulator), the polluting industry, and the environmental groups.[24]

The State's objective is suggested to be the maximisation of tax revenues when considering its constituency. The use of 'green taxes' is an innovation in tax collection because it results both in the provision of a collective good (environmental improvement) and in the collection of state revenue. If a small country like Denmark were to introduce green taxation on global pollutants, such as CO_2, State revenue could then be used for lowering other distortive taxes, for example income taxes on labour. Lowering distortive taxes on labour could bring about higher employment and increased national income (higher tax revenue) over time.

In a democracy, the State is counteracted by interest groups. A balance of power exists. Lobbying by interest groups in the political arena affects the final design of a given policy and determines thereby the resulting economic outcome. The democratic State cannot just pursue the economic interests of the majority. In order to achieve political acceptability, reduce conflict and consequently implement rules of legislation, it must also mediate among the main organised interests.

Let us look closely at the difference between industrial and environmental groups organised in the market and the political arena, respectively, to understand past behaviour and predict future behaviour. How will the main actors lobby? What are their interests? In what way can they be expected to affect environmental regulation?

Organisation takes place both in the market (market groups) and outside the market (non-market groups). This distinction is important because the attitude of a group member toward the size of the group differs. In the market, a firm strives for monopoly. It seeks to create barriers to entry – to keep new firms from coming in and sharing the market – and it tries to get as many rivals as possible to leave the industry. In contrast, a non-market group member seeks to maximize group membership. Rather than bringing about more competition, larger membership means lower costs for the individuals already in the group. Again the free-rider problem occurs, just as in the market place: it is not rational for the individual agent or firm to sacrifice time and money to support a lobby organisation to obtain government assistance for the industry. For this reason, non-market groups often choose to make membership compulsory.

This difference in the desires of the two groups is caused by the type of collective good and its benefits. In the market, the collective good is that of higher profits. All firms in an industry have a common interest in higher profits. Higher prices can be charged, however, only if fewer units of output are supplied. Therefore, organisations may operate in *both* the market (to raise prices by restricting output) and in the political arena (to further other common interests). Along with the incentive to exclude competitors, there is, paradoxically, an incentive to include competitors as well, because the larger the group, the more likely it is to influence government policy. Market action encourages exclusion of both existing and potential competitors, whereas political action encourages the inclusion of other firms: 'whether a group behaves exclusively or inclusively depends upon the nature of the objective the group seeks' (Olson 1965:39). Once a group becomes large enough to succeed

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[24] Svendsen (1998a; 1999).

politically, it will typically become exclusive. At this point, it is in the interest of the existing members to exclude new entrants.[25]

When an interest group has accomplished the task of organising for collective action, it will try to steal as much money as possible from, for example, the treasury and redistribute as much as possible from the taxpayers to itself. A typical lobbying group in the US, for example, represents 1 % of the national income. It follows that the group will only stop redistributing to its clients when the reduction in its share of national income is 100 times as great as the amount it wins in the redistributional struggle. In contrast, if the interest group tries to influence policy in the interest of society as a whole, the group will only receive 1 % of the benefits, but will bear all the costs.

If the lobbying group is bigger in size, it will stop the redistribution at an earlier point. For example, a group that represents 50 % of the national income will stop redistributing to itself when its share of the national income is reduced by twice the gain. Similarly, the group will get half of the benefits from better policies, so that it pays to promote policies that increase the group's share of the national income by more than twice of its costs of undertaking this action. In this way, less redistribution will take place than in the case of the group that represents only 1 % of national income. If the smaller group is strong enough to win its desired favours in the political arena, its individual members stand to gain much more from the redistribution.

In contrast, in non-market situations, the benefit from a collective good is not fixed in supply. The collective good is inclusive. Assume that an environmental organisation achieves the common goal of better environmental quality. Then everybody will benefit, no matter how many members there are in the group. Members have no incentive to exclude each other. Therefore, bargaining or strategic interaction is much less important in inclusive groups. An individual in a non-market group that prospers may even have an incentive to pay a larger share of the cost of the collective good. Also, in an inclusive group, it is not essential that every individual participates, because lack of participation does not take away benefits from those who do participate.[26]

The incentives facing industry and environmental groups are summarised in Table 3.3.

Table 3.3. Market and Non-Market Groups

	Common Goal (Exclusive)	**Market** (Inclusive)	**Non-Market**
Electric utility industry	Higher price	Monopoly	Lobbyism
Environmental Groups	Improved environment	n.a.	Maximise membership

Attitudes toward Environmental Regulation

When considering what kind of environmental regulation the main organised actors – the State, electric utility industry, and environmental groups – would each choose, three options are considered relevant: first, traditional command-and-control (CAC) regulation, where proportional roll-backs for individual sources are defined; second, an emission tax on all emitted units; and third, a grandfathered permit market, in which polluters are given their initial distribution of permits for free, according to historical emissions. One can therefore

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[25] Ibid.

[26] Ibid.

presume that the State would choose environmental taxes in an effort to maximize state revenue.

What kind of regulation would industry choose? The distribution of benefits and costs from regulation can either be concentrated in a small, narrowly defined part of society (small groups) or spread out over a large and more general part of society (large groups). This distribution of costs and benefits from regulation determines the incentive for political actors to organise.

If we look at the electric utility industry in a competitive setting, there is a strong incentive to promote permit markets because the trading of permits can lead to lower pollution-reduction costs and more flexibility in responding to consumer demand than is possible with traditional CAC regulation or emission taxes. Also, electric utility industry can be expected to demand regulation that creates the collective good of barriers to entry for potentially competing producers. This is the case when using grandfathering. Existing sources are given permits for free whereas new sources are forced to buy their way into the market.

3.2.3 Taxation without refund

What are the costs of environmental regulation to the regulated parties? This question is important because the answer may determine the political feasibility of any proposal, no matter how well-designed it may be. The intention here is to make a cost comparison between a tax and a grandfathered permit market, and to use the case of CO_2 taxation in the EU. The negotiated 8 % target level from the Kyoto negotiations will be used as an illustrative example.

Nobody knows the exact position and slope of the marginal CO_2 emissions reduction curve for the EU industry. Assume that these marginal costs (*MC*) decline linearly as the quantity of CO_2 emissions (Q) rises, as illustrated in Figure 3.3.

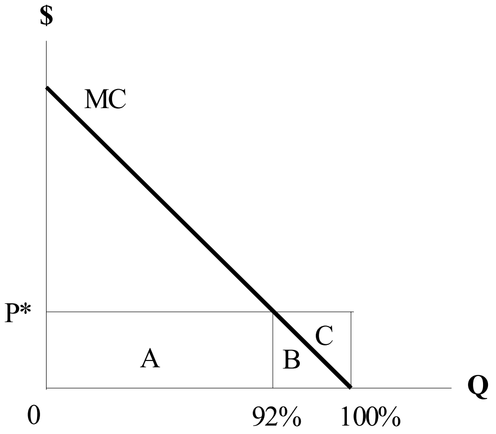

Figure 3.3. Cost comparison between a tax and a grandfathered market

Assume, now, that the correct CO_2 tax to accomplish the 8 % target reduction level is the price *P**. What are the aggregated costs under a tax and a grandfathered permit market, respectively?

Let us first consider the case without any tax refund to sources. In Figure 3.3 total costs under a CO_2 tax will be the areas *A* and *B*. Polluters will reduce 8 % of their emissions at a cost to them of area *B* and pay the tax on each of the units they continue to emit for a total tax bill of area *A*. In contrast, the explicit costs to the polluter in a permit market will be *B* only. A tax requires the polluter to pay for all units emitted, whereas under the permit market, the polluter receives the right to emit the targeted level of emissions.

Take a closer look at the costs associated with the 8 % CO_2 reduction. In a permit market permits will be transferred among polluters. Polluters will reduce or increase their individual CO_2 emissions until all firms' marginal reduction costs are equal to the permit price. Consequently, the total reduction costs to industry will be the area *B* when the permit price is *P**.

In contrast, the tax payments under a tax regime are the area *A* whereas *B* is the level of private reduction costs for the industry: the costs to industry under this approach include the tax payment, *A*, plus private reduction costs, *B*. If the sum of areas *A* and *B* is divided by area *B*, it shows up that taxation without refund is 24 times more costly to polluters than the permit market.

The sum of areas *A* and *B* can now be divided by area *B*. The triangle and the rectangle areas can easily be calculated by using *P* and Q** (level of reduction).[27] This gives us:

$$(A+B)/A = 2/Q^* - 1$$

This formula shows the distributional effect when considering tax or permit market at a target level, here denoted by the proportional number, *Q**.

Consider the distributional effects following different target levels. In Denmark, a target level of 20 % cut in CO_2 emissions applies (from 1988 to 2005). For $Q^* = 0.2$, we get the result that taxation is nine times more costly than the grandfathered permit market.

The reduction target level from the UN conference in Kyoto, Japan (December 1997), is also an illustrative example. Here, the industrialised countries voluntarily agreed on reducing CO_2 by 5 % from 1990 to 2012. In this case, for $Q^* = 0.05$, it can be calculated that taxation without refund would be 39 times more costly to polluters than the permit market! In the case of the EU CO_2 target level, the negotiated 8 % target level from the Kyoto negotiations can also be used as an example. When $Q^* = 0.08$, the permit market is 24 times cheaper to polluters than a corresponding tax without refund. Another example is the US Acid Rain Program, which aims to reduce SO_2 emission by 50 %. In this case, for $Q^* = 0.5$, taxation would be three times more costly to the polluters, provided that the MC curve is linear.

3.2.4 Taxation with full refund

As we saw in the previous section, the polluter must pay for all emitted units under a tax solution. In this way, the tax solution without refund may involve enormous increases in costs to polluters, and this lowers the political acceptability of the tax. The tax represents a transfer payment from the viewpoint of society, but it is an operating cost for the firm.

Why, then, is the tax met with political opposition in practice? Why cannot the tax revenue be refunded in a politically acceptable way? The problem is that the refund must be independent of the pollution. Otherwise, the incentive to reduce pollution would be removed; that is, it would not matter to the polluter how much he discharged or emitted, because all of the money paid in taxes would be refunded. If, for example, a source is given back its CO_2 tax payments, then it will have no incentive to reduce CO_2 emissions at all.

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[27] $(A+B)/A = B/A + 1 = P^*(1-Q^*)/ ½P^*Q^* + 1 = (2 – 2Q^*)/Q^* + 1 = 2/Q^* – 1$. See Svendsen et al (2000).

Still, one could argue that increased production costs under the tax solution could be avoided by constructing other types of general refund systems not linked to emission, for example in the form of a reduced tax contribution to labour market services, or a reduced company tax. However, energy-intensive polluters will, as potential losers in a small group, more aggressively oppose taxation with the argument that their competitiveness will weaken; labour-intensive polluters may, as potential winners in a large group, fail to seek a taxation and refund system because they may not organise. Therefore, the refund system can hardly be modelled such that it would satisfy the small group of potential losers.[28]

This political asymmetry against taxation with full refund may be explained by the size of the group and may be illustrated in the following way. Consider first a group consisting of 1 million identical, small and labour-intensive polluters, where the total value of a tax refund to the group is $1 million and the total cost of providing it through lobbyism is $100.000. Further assume that the value of the refund, if provided, would be shared equally among all the members, so each would receive a benefit valued at $1. This is the case, for example, if each member in the large group pays $2 in CO_2 tax and receives $3 in general refund.

Although the group as a whole would get benefits worth $1 million (ten times the $100.000 invested in providing the good), the net benefit to any individual member who chooses to provide the good on his or her own is clearly negative. In the absence of organisation, the good will therefore not be provided. This group would thus be classified as 'large' and the collective good of tax with full refund will not be provided.

Now consider another group that has only five identical energy-intensive members. This group wants to avoid taxation with full refund because they pay much more in taxes (due to high CO_2 emissions) than they get back from a general refund system. So if this 'small' group loses the same amount that the large group gains, each member will experience a benefit valued at $200.000 from preventing a tax with full refund. This is the case, for example, if each member in the small group pays $400.000 in CO_2 tax but receives only $200.000 in general refund. If the costs of successfully lobbying against taxation is $100.000 again, each individual member's net benefit is $100.000. Therefore, this collective good of avoiding green taxation will now be provided for the small group even in the absence of organisation, see Table 3.4.

Table 3.4. Individual net gain from a general refund system.

	Pro tax (labour-intensive)	**Con tax** (energy-intensive)
Number of firms (identical)	1 million	5
Total tax payments	$2 million	$2 million
Total general refund	$3 million	$1 million
Total gain	$1 million	$1 million
Individual gain	$1	$200,000
Total lobbying cost	$100,000	$100,000
Individual net gain	Negative	$100,000

In this way, the small group of large and energy-intensive firms holds a stronger position than the large group of small and less energy-intensive firms and because of this opposition within the well-organised industry lobby, it is hardly possible to impose a CO_2 tax high enough to achieve the 20 % target level in Denmark on industry as a whole.

Concerning unorganised and numerous CO_2 emitters, such as the transportation sector and households, it is reasonable to expect that they will not protest in an organised manner

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[28] Svendsen (1998a) and Svendsen et al (2000).

against taxation. This argument follows the logic developed for large groups in this section. The taxpayers are only affected by the tax at the margin, and calculated individual benefits from starting organising interest group opposition are expected to be smaller than the costs of doing so. Again, it does not pay the individual taxpayer to protest and provide the collective good of avoiding CO_2 taxation.

It follows that it is easier to impose green taxation on households (large group) than industry (small group with energy-intensive firms) due to differences in lobbying power. Therefore, public choice theory does not predict uniform green taxation but differentiated green taxation where the tax level will be high for households and low (or non-existing) for industry.

3.2.5 Enforcement

Control systems rely on precise monitoring and well-functioning sanction mechanisms, typically based on the economic incentive of fines. If these two conditions are not met, sources may find it profitable to cheat. Also, local authorities may have strong free-rider incentives to protect their 'own' firms against strict control, so some kind of central control is needed.

How will an economically rational source consider its option of cheating? What should be the size of the fine per unit? To establish a well-functioning fine system, the expected fine (including the risk of detection) must always be set higher than the tax (or the permit price). Local firms may be given substantial room for cheating in this kind of system because local authorities may accept violations in the interest of attracting industry (and a larger tax base) to their area.

3.2.6 Concluding remarks

The grandfathering of CO_2 permit rights may be the most politically feasible solution for regulating CO_2 in the EU and in the world at large. Taxation without refund is shown to be 24 times more costly to polluters than the grandfathered permit market when considering the 8 % target level as agreed upon in Kyoto.

Furthermore, the worst-hit CO_2 emitters are large and capital-intensive firms, which, as part of a privileged group, are able to protest quickly and with success. This behaviour contrasts with that of the latent group of potential net winners, which are typically numerous and small service firms unable to organise. So even if the tax were refunded in a transparent and general way as a monetary transfer without reducing the number of jobs, the political opposition against CO_2 taxation would probably persist because capital-intensive firms, which are also the most energy-intensive, are normally the largest and can organise for collective action – they may behave as a single collective actor or small group Therefore, the political opposition against CO_2 taxation is likely to stay asymmetrically in favour of potential losers, in this case the electric utility industry in the EU. The overall problem is that potential winners cannot organise their lobbying powers to counteract the potential losers in the political decision-making process. Electric utilities must therefore, as a well-organised group with lobbying power, be expected to choose a grandfathered permit market. It is the solution that leaves them with a maximum of flexibility, lowest possible reduction cost and a barrier to entry.

These theoretical suggestions on how to fill the gap between economics and politics in designing cost-effective and politically attractive instruments point to the use of a permit market in relation to well-organised interests. In contrast, a CO_2 tax should be applied to non-organised interests, such as households and the transportation sector. These interests are not well-represented in the political arena because the individual benefits from organising interest-group opposition are smaller than the added costs of doing so. Furthermore, it can be argued that taxation is the only practically applicable solution in this case, as we deal with rather small amounts of emission per economic entity. Also, in the case of tradable permits for households, transaction costs would form a large share of the total permit cost, and it would be difficult to apply effective measures of control.

In Chapter 5 we shall focus on the collection of data on this potential CO_2 market in the EU. It is useful to describe the target group, distribution rule, enforcement system and market structure more fully and to calculate the expected market price. Such research can help uncovering the risk of strategic behaviour in the potential CO_2 market, to estimate potential cost savings, and to identify the level of fines needed to deter violations of quota limitations. This potential CO_2 market for electric utilities in the EU, matching the design of the US Acid Rain Program (as presented in Chapter 4, has not yet been discussed among academics.

4 The US Experience

4.1 Introduction

In the US, the Acid Rain Program (ARP) is now well-established. It is the first large-scale and long-term environmental program to rely on tradable permits. This landmark experiment comes at a particularly important time 'since emission trading is under serious consideration, with strong US backing, for use to deal with global climate change' and 'the economic stakes in climate change surpass those in acid rain by several orders of magnitude'.[29]

The ARP allows the 1,000 major electric utilities all over the US to trade SO_2 permits. Such permit markets have been attractive to the political main actors in the US because of "grandfathering." Grandfathering means that the property right to historical emission rights have been transferred for free. In this way, the polluter receives the right to emit the targeted level of emissions and must only pay for the emission units that must be reduced.

This fact lowers costs to polluters compared to a tax system where the polluter must pay for all units emitted. For example, the ARP aims to reduce SO_2 emission by 50 %. Because permits have been grandfathered, the polluters only have to pay for the 50 % reduction. The other half is kept for free as historical emission rights. Alternatively, if the polluters had been taxed, then they would have to pay not only for their own 50 % reduction. They would also have to pay taxes for all units emitted in the other half as well.[30]

Svendsen (1998a) has analysed how the three main political actors in the US (environmental groups, private industry and electric utilities) preferred permit markets over other instruments. This result was to be expected for private industry, which wants to reduce costs and create a barrier to entry. Although this was not originally expected for environmental groups, these groups had recently learned from experience that the cheaper regulation could be for industry, the higher reductions in emissions industry would be ready to accept. The traditional opposition from environmental groups to licenses to pollute and the maintenance of a goal of zero pollution had reinforced the administrative problems in the early stages of the US permit market programs by blocking well-defined property rights to permits. With respect to the US electric utility sector, the recent rise of competition in that sector gave even these traditional monopolies an incentive to prefer permit markets over traditional and complex Command-And-Control regulation.

Now, the assessment here intends to focus on the performance of the market. The question is: Does the ARP work in practice? Is the tradable permit system a useful tool to policy makers in Denmark and the EU?[31] To answer this question, it is necessary to develop an assessment model.

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[29] Schmalensee et al. (1998:53). See also the Intergovernmental Panel on Climate Change (1996).

[30] It was shown in Chapter 3 that if the marginal reduction cost curve for SO_2 reduction is linearly decreasing, then a tax solution (without refund) is three times more costly to the polluters than the grandfathered permit market.

[31] Svendsen (1998d).

Four main conditions must be fulfilled to ensure that the market is working. First, the market structure must be competitive in order to generate correct price signals. Second, property rights must be well-defined. Third, property rights must be well-enforced and fourth, the costs of making transactions, “transaction costs”, must be low.[32] As the design of a policy will determine performance in practice, the assessment model is constructed so that: design is described; the actual performance of the market and the auction is described, and finally, the actual transfer of property rights to the permits, is analysed.

4.2 Design

The design of the permit market is described by using a set of five variables. The first variable is a set labelled target level. It contains information about the pollutant and the reduction goal; the period in which the program is applied; the program’s location; and the potential cost savings from using a permit market rather than, for example, a traditional CAC approach for achieving a given target level. The second variable is the target group. It contains information on who can take part in the trading; the number of sources; the concentration of permit holdings among sources; and the variation in marginal reduction costs. The third variable is labelled distribution rule. This variable defines how the permits are distributed. The fourth variable is that of trade rules. A trade rule is a restriction on trade that limits the property rights conveyed by a permit. Some trade rules may be necessary for reaching the defined target level and for ensuring that no ambient standards are violated while trade takes place, that is that ‘hot spots’ are not created. The fifth variable, connected to the trade rules, is labelled control system. The control system defines how the regulator intends to monitor and sanction violations of the rules.

The target level is 50 % SO_2 reduction of the 1980 level by the year 2000. Trade has been allowed since 1990 and the 50 % reduction is to take place with a two-step devaluation. In phase I, which started in 1995, ‘dirty’ utilities in the mid-west must reduce emissions to 75 % of their 1985 level, and in phase II, which starts in the year 2000, these ‘dirty’ utilities, as well as the cleaner ones, must reduce emissions to 50 % of their 1985 level.[33] So, most of the trading can be expected in the year 2000, when a larger number of utilities will be significantly affected.

The potential cost savings are massive. ICF (1989) concludes that trading will cut yearly reduction costs by about 30 %, compared to the costs for a CAC policy. Rico (1995) - predicts that reduction costs will be lowered by 50 %. The latest estimates are even more optimistic. Burtraw and Swift (1996) indicate that if all potential trades take place, then the program will result in 70 % cost savings compared to CAC.

As mentioned, the reduction will take place in two phases. Phase I started in 1995 and includes the dirtiest 111 SO_2-emitters, those with greater than 100 MW net capacity and 1985 emission rates equal to or exceeding 2.5 lb/mmBtu. In the year 2000, phase II will involve an additional 900 utilities with greater than 25 MW net capacity and 1985 SO_2 emission rates greater than 1.2 lb/mmBtu. In total, about 1000 electric utilities will be covered by the program after the year 2000. The 1000 plants are owned by roughly 200 public, utility companies, which will be the trading partners in the market.

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[32] .See Svendsen (1998a;1998c) concerning this analytical framework and for a total review of the US experiences on tradable permit systems.

[33] .In actual numbers, Title IV of the Clean Air Act is designed to achieve a 10-million-ton annual SO_2 reduction from 1980 levels by the year 2000. Of this reduction, 8.5 million tons are to come from electric utilities, GAO (1994:2).

It was an administrative and political decision to include in the trading program only electric utilities with a net capacity greater than 25 MW. The affected utilities emit about 80 % of the total SO_2 emission in the US, and they are already heavily regulated on the state level. The target group includes the main emitters and to incorporate smaller sources would be a difficult task for administrators. In addition to the target group, the ARP allows all other interested participants to take part in the market such as brokers, coal companies and environmental organisations. At a later stage, the EPA plans to additional large industrial polluters to 'opt-in' and take part in the market. The marginal reduction costs vary significantly among sources in the target group.[34]

In starting up the market, the initial distribution rule is grandfathering. In this case, the basis for distribution is the historical use of fossil fuels in the period 1985–1987.[35] By basing the distribution rule on fuel input, utilities that have recently invested in SO_2 reduction are not punished by a relatively smaller allotment. If, for example, two utilities use the same amount of fuel, each of them will get the same number of SO_2 permits even though one of them has installed a scrubber and, therefore, emits only half as much SO_2. Variations in the use of fossil fuels are smoothed out by using an average over the three-year period, from 1985 to 1987.

The ARP ignores the risk of hot spots created by SO_2 emissions. No ambient standards are expected to be violated for two reasons.

First, total SO_2 emission will be reduced by 50 % in a 10-year period (from 1990 to 2000). And, since damage from acid rain is due to cumulative emissions rather than the level of emissions in a given year, fluctuations will neutralise each other. Second, the older and "dirtier" utilities, which are primarily located in the west, have lower marginal reduction costs than do the newer and cleaner utilities in the east. One can therefore expect eastern utilities to buy permits from western utilities. Since the wind direction is west-to-east, this is likely to improve environmental quality in the eastern areas where the problem of acid rain is most acute and hot spots would otherwise be most likely to occur.

Should an individual utility in the eastern zone want to sell permits, it may not be allowed to sell them to a source in the western zone because then the ambient standards in the eastern zone could be violated. For example, a utility in New York should not be allowed to reduce emissions and sell its permits to a utility in Ohio. Such trade could decrease the environmental quality in the eastern zone and perhaps violate the ambient standards in the Adirondacks, Canada, and other sensitive non-urban regions.

In this hypothetical case, the State of New York has to make its own decisions, because the EPA will not review individual trades. States will still apply the most stringent technology-based standards for new or modified sources and will prohibit new sources from circumventing the standards by trade.

An extra 'safety valve' mechanism has been added to the ARP in order to stimulate the market and to prevent the market price from turning out to be so high that the market does not work. The US Congress has therefore created a special reserve pool in which 3 % of the total permit quota (approx. 300,000 permits) is withheld. Its purpose is to ensure easily accessible permits for new sources. This pool is distributed through direct sale at a fixed price and through an open auction. Direct sale includes up to 50,000 permits a year. The fixed price is \$1500, or twice the expected equilibrium price in the market (EPA 1991). Surplus permits not sold are sold together with the remaining permits at a yearly auction to

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[34] Svendsen (1998a; 1998c).

[35] The years 1985–1987 were thought to be three representative years without recessions.

the highest bidders. This auction mechanism is applied at the Chicago Board of Trade and is further discussed in Section 4.4

Sources must themselves report the trades to the EPA, which only checks the aggregated annual figures. Because electric utilities are large and already heavily regulated units, it is furthermore possible to use a continuous emissions monitoring system (CEMS), which monitors both SO_2 and CO_2 emissions. All affected utilities must pay for and install the CEMS themselves. The cost of such a monitor is about \$120,000 annually.[36] The CEMS gives the EPA accurate data on tons emitted and makes it possible to run the ARP effectively from the federal level.

The EPA has developed a computer-controlled bookkeeping system for this specific control task and has combined it with an efficient penalty system. If two electric utilities trade permits, they are obligated to inform the EPA, which then registers the transaction. If one of them has superseded its permit, a fine of \$2000 per ton SO_2 is assessed, and the extra tons emitted must be reduced the following year.[37]

4.3 Market Results

Permit market results are characterised by a set of five effect variables. The first variable is labelled trade activity. It contains the number of trades; the price generated by the market; and whether a high concentration of buyers or sellers poses a risk of incomplete competition and strategic behaviour. The second variable is cost savings. It contains information on the cost savings resulting from trade and the trade option compared to the situation without trade. The third variable is labelled innovation. It reveals dynamic information about market-stimulated innovation and investments in new reduction technology. The fourth variable is labelled transaction costs. It reveals how big the transaction cost are, that is the costs of ‘making market transactions.’ These may include costs such as bargaining costs, broker compensation, fees, the expense of collecting information relevant to the transaction, and the expense of finding a trade partner and acquiring administrative approval. The fifth variable is environmental impact. It indicates whether any impact can be measured at present, and, if so, whether any receptors are violated

Through the end of 1999, over 9,300 transfers moving 81.5 million allowances were reported to the EPA. 62 % of these allowances (50.4 million) were transferred within organisations (internal trades). The remaining 31 million allowances (38 %) were transferred between organisations (external trades).[38]

This market activity has succeeded in generating prices, see Table 4.1.

Table 4.1 displays the supporting data for the SO2 Allowance Price Chart. Prices reported by the brokerage firms (Emissions Exchange and Cantor Fitzgerald) and the Fieldston Publications' market survey are rounded to the nearest whole dollar.

Prices have fluctuated as discussed in the next two sections. At the moment (March 2000), price has stabilised at \$136. A detailed comparison of market and spot auction prices is given below in Section 4.4.

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[36] Ibid.

[37] Ibid.

[38] EPA (2000): http://www.epa.gov/acidrain/ats/qlyupd.html

Table 4.1. SO_2 Allowance Prices, US $

Month/ Year	Emissions Ex-change	Cantor Fitz-gerald EBS	Field-ston Publications	Month/ Year	Emissions Ex-change	Cantor Fitz-gerald EBS	Field-ston Publications	Month/ Year	Cantor Fitz-gerald EBS	Field-ston Publications
8/94	150	145	150							
9/94	150	147	150							
10/94	145	145	150							
11/94	145	144	145							
12/94	142	135	140							
1/95	141	138	137	1/97	97	97	96	1/99	208	206
2/95	136	135	135	2/97	106	102	99	2/99	200	215
3/95	133	133	133	3/97	115	110	111	3/99	210	217
4/95	132	132	132	4/97	113	115	115	4/99	208	210
5/95	132	132	132	5/97	94	98	100	5/99	212	211
6/95	132	131	130	6/97	89	90	93	6/99	212	210
7/95	130	130	130	7/97	87	88	90	7/99	211	198
8/95	130	130	130	8/97	89	91	91	8/99	194	190
9/95	127	126	128	9/97	101	104	92	9/99	189	187
10/95	125	122	128	10/97	105	104	102	10/99	187	172
11/95	119	117	120	11/97	104	107	110	11/99	167	161
12/95	105	109	111	12/97	98	100	102	12/99	149	152
1/96	92	95	98	1/98	96	98	98	1/00	138	136
2/96	74	79	81	2/98	101	101	101	2/00	137	136
3/96	70	69	83	3/98	104	113	105	3/00	136	136
4/96	81	76	85	4/98	133	139	134			
5/96	79	79	84	5/98	140	148	138			
6/96	81	80	83	6/98	--	189	193			
7/96	82	81	82	7/98	--	197	188			
8/96	83	82	82	8/98	--	189	208			
9/96	88	87	86	9/98	--	169	177			
10/96	92	90	86	10/98	--	176	183			
11/96	91	92	92	11/98	--	189	194			
12/96	91	90	94	12/98	--	196	195			

Source*: http://www.epa.gov/acidrain/ats/pricetbl.html*

Actual cost savings are estimated to be 40 % compared with CAC. The potential 70 % savings have not been realised yet, in particular because all external trades have not yet taken place.[39] The incentive to minimise costs has grown stronger in recent years as a result of competitiveness in electricity production and strong pressure from consumers for lower prices.[40]

Another indicator is the market price from March 2000 ($136). It is less than one-fifth the market price of $750 that EPA projected in 1991 (EPA 1991). The costs of participating in the program are thus much lower than expected.

As Table 4.1 showed, market prices have dropped steadily in the last couple of years. This is primarily due to innovation.

Market prices have dropped steadily due to innovation. Four main reasons may be listed. First, the emergence of low sulphur coal is a major low-cost option for compliance. Prices of low sulphur coal have dropped 40 % in real terms between 1983 and 1993 due to improvements in the productivity of surface mining. Second, a reduction in the cost of rail transport of low sulphur coal has lowered rates as much as 50 %. This is due to major investments in new infrastructure and to innovations. Third, the technology of blending low and high sulphur coal has been improved. Fourth, the costs of installing and maintaining a

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[39] Burtraw and Swift (1996:10415).

[40] See Svendsen (1995).

new scrubber have fallen by 50 % during the early nineties. Also other options such as energy conservation, efficiency management and electricity despatching have played a role.[41]

Transaction costs are low because sources report their trades directly to the EPA, which only checks the aggregated annual figures. The only administrative requirement is that utilities must report in advance what they are going to do and must send in compliance plans in advance for every year. Also, the price signals from the annual SO_2 auctions lower transaction costs. Brokerage fees lie around 5 % which, compared to other tradable permit systems in the US, is low.

In 1995, phase I utilities emitted 40 % less than their permits allowed them to. This is a dramatic overcompliance that provides an opportunity for earlier ecological recovery.[42] This extra reduction has probably taken place because utilities are risk averse and like to hold a reserve. No hot spots have been created by the program so far.

4.4 Auction Results

As mentioned above, a revenue-neutral auction is used to distribute about 2 % of the permits in circulation. The EPA SO_2 auction is the first auction ever to be applied in environmental regulation. It will guide the design of future regulation such as CO_2 reduction within the US itself, Europe and worldwide, as discussed in the recent United Nations conference on climate change in Kyoto, Japan. Likewise, a European CO_2 market could be linked to an auction for the reasons mentioned below which both aims to make the permit market work and to make the design politically attractive.

The US Congress chose to use the auction as a mechanism to stimulate the SO_2 market for two reasons. First, it ensures the availability of permits and makes it possible for new sources to buy their way into the market. Second, it gives a clear price signal for SO_2 permits to the market and may thereby reduce transaction costs.

4.4.1 Revenue-Neutral Auction

The notion of a revenue-neutral auction was first suggested by Hahn and Noll in 1982.[43] In such an auction, all revenue is returned to the polluters according to a distribution rule. The distribution rule considered here is grandfathering. Every polluter gets its historical emission rights for free and must offer these rights (or some part of them) for sale in an auction. The political appeal of this system, compared to that of a traditional auction or a tax, is obvious: the revenue is refunded to all polluters participating in the program. All economic transactions take place among the polluters themselves. All interested parties may bid at the auction by specifying the number of permits they desire at each of the different prices. Potential buyers must in this way give the auctioneer their individual demand schedules for permits.

Revenue-neutral auctions can be divided into two types: discriminative and non-discriminative. The basic difference is that in a discriminative auction, there are several prices and the bidder pays what he bids, whereas in a non-discriminative auction, there is a

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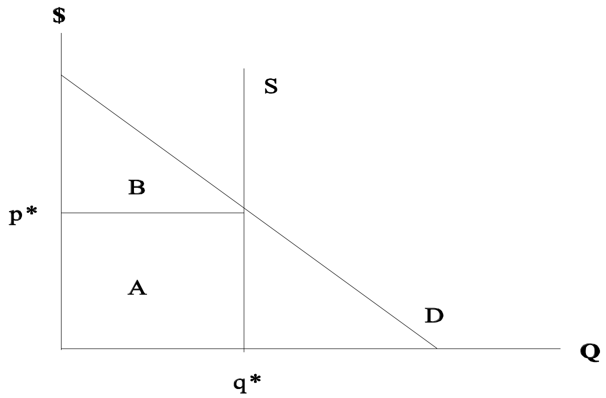
[41] Klaassen and Nentjes (1997:399), Burtraw and Swift (1996:10419), Burtraw (1996) and GAO (1994:4).

[42] Burtraw and Swift (1996:10414).

[43] Svendsen (1998a) and Svendsen and Christensen (1999).

single price, that is, the bidder pays the minimum or clearing price. This difference has an important implication for the size of the revenue. The two types of auctions can be depicted graphically, as in Figure 4.1, which depicts the difference in revenue generated when bidders bid their true value.



Source: Svendsen and Christensen (1999).

Figure 4.1. Revenue in Non-Discriminative and Discriminative Auctions.

Assume that q* of the permits in circulation are auctioned off. In a non-discriminative auction, the auctioneer will gather all individual bid-schedules and set the minimum price, *p**, as the single-price equilibrium where the (revealed) aggregated demand schedule for permits, *D*, meets the inelastic supply schedule, *S*. Because all winning bids pay the equilibrium price, *p**, total revenue from the non-discriminative auction is area *A*.[44]

When the auction is revenue-neutral, all payments are refunded to the contributing polluters, so total payments equal exactly the total revenue. If authorities withdraw permits from the market for the auction, then sources will receive the revenue from the sale. Suppose a source offers 100 permits and that the auction price is $100 per permit, that source will then receive $10,000.[45]

In contrast to the non-discriminative auction, a discriminative auction is multi-priced. The bidder pays what he bids, which allows the auctioneer to price-differentiate. If sources do not have any information about the expected equilibrium price, their bids will follow the demand curve, *D*. By this, revenue from the auction is maximised.

As shown in Figure 4.1, the extra revenue is illustrated by the triangle *B*. Revenue will be largest in the discriminative auction (*A* + *B*). In this case revenue will be returned to sources according to the average price, which is higher than the equilibrium price, *p**. In this case revenue will be returned to sources according to the average price, which is higher than the equilibrium price, *p**.

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[44] Each bidder pays the auctioneer p^*q_i , where q_i is the number of permits demanded by the i^{th} source. The collective payment is a summation of individual payments $\Sigma p^* q_i$.

[45] Let q_{0i} represent source *i*'s initial contribution of permits to the auction. Because q^* represents both the total number of permits offered and the total number sold at the auction, it must be so that $\Sigma q_{0i} = q^*$. Revenue is then returned in such a way that each polluter receives a payment equal to the market value of their initial contribution of permits at the auction, $p^* \ x \ q_{0i}$. If q_i represents the number of permits purchased by source *i* at the auction, each bidder makes a net payment of $(q_i - q_{0i})$ p^* to the auctioneer. If $q_i > q_{0i}$, the polluter is a net purchaser of permits and pays more than he receives. If $q_i < q_{0i}$, the polluter is a net seller and receives more than he pays. In sum, $\Sigma p^*(q_i - q_{\ 0i})$ $= O$.

In practice, the situation may differ from the hypothetical cases described above. Because only some of the permits are auctioned off, sources may have some knowledge from the permit market of what the expected equilibrium price will be. Therefore, they may bid in relation to their expectations rather than in relation to their marginal reduction costs. In both auction types, the bidders would then bid lower and attempt to get the permits cheaper than in the market, where it is always possible to buy.[46] A 'two-price' signal to the market whereby the minimum and average prices differ is non-desirable because it raises transaction costs. The seller wants to sell at the average price, whereas the buyer wants to buy at the minimum.

4.4.2 Empirical Results (spot auction performance)

In the early market, buyers could not buy at the spot auction clearing price which was $131 in 1993 and $150 in 1994. Information on market prices in 1993 and early 1994 is scarce, but all reported prices were above this level. The first price reported by the Emission Exchange Corporation in mid-1993 was $170, and their price remained at or slightly above this level until May 1994. The trade press also reported data on a few other private (bilateral) transactions in 1993, where prices spanned from $178 to $205[47].

Empirical evidence suggests the emergence of an efficient allowance market, obeying the law of one price, around the middle of 1994 (see Schmalensee et al., 1998). No single authorised registration of market prices for SO_2 allowances takes place. Three private organisations have independently kept track of vintage prices on a monthly basis from mid-1994: Cantor Fitzgerald, Emissions Exchange and Fieldston.

Figure 4.2 illustrates the relationship between the reported market prices in the auction month (March) and minimum prices at the auction. In calculating the grey, black and white columns are used the vintage prices reported by Cantor Fitzgerald, Emission Exchange and Fieldston respectively. The applied market price in March 1993 and March 1994 is the $170 reported by the Emission Exchange. This is probably a rough estimate, since information was scarce. With respect to the data from 1999 the latest published market prices were used, namely the February prices reported by Cantor Fitzgerald and Fieldston (see Table 4.1 above).[48]

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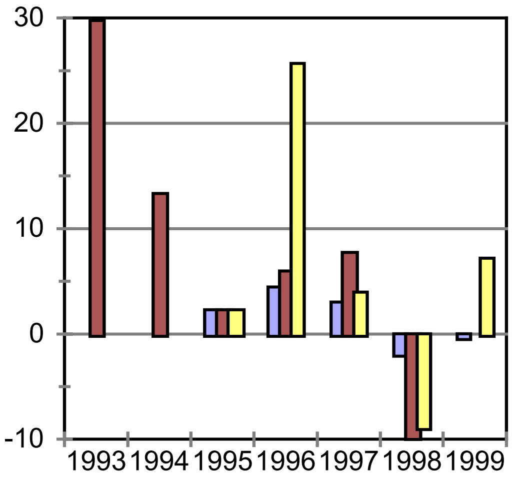
[46] Vickrey (1961).

[47] Svendsen and Christensen (1999).

[48] Christensen and Svendsen (1999).



Source: Christensen and Svendsen (1999).

Figure 4.2. How much market prices exceeded minimum prices at the auction (in percent).

Figure 4.2 shows that in the auctions of 1995, 1996, 1997, 1998 and 1999 there was practically no difference between market and auction spot minimum prices. Two qualitative remarks should be made. First, In March 1996 Fieldston did report a significantly higher market price than the two others. This was at a time where the permit price had reached a historically low level, so in absolute terms the difference is not that large. Fieldston reported $83 whereas Cantor Fitzgerald and Emission Exhange reported $69 and $70 respectively. Second, In March 1998 the inverse relationship emerged: the spot auction clearing price was above the market price. In 1998 two buyers, Cantor Fitzgerald and the Allowance Holding Coorperation, won 99.98 % of the total spot auction sale. The Cantor Fitzgerald share of totals was 73.33 % and as a matter of fact they bought it at prices which have later proven to be quite a bargain. The 1999 spot auction clearing price exceeds the 1998 spot auction clearing price by almost an order of magnitude: it was $115 in 1998 and $201 in 1999. [49]

In March 1998 Cantor Fitzgerald also did report a vintage price which was some 8 % above the vintage prices reported by Fieldston and Emissions Exchange, and Cantor Fitzgeralds winning bids at the auction was very close to their own reported vintage price. Perhaps Cantor Fitzgerald was simply better at foreseeing that prices would tend to rise. An alternative interpretation is that Cantor Fitzgerald bought the permits as part of a strategy to rise prices by dominating the market. This does not seem likely, since the auction is now only a small part of a huge market.

The relationship between average prices paid at the spot auction and minimum prices paid at the spot auction is illustrated in Figure 4.3.

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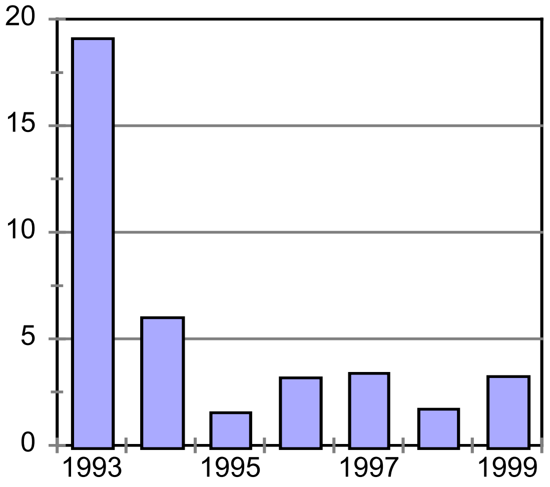
[49] Ibid.



Source: Christensen and Svendsen (1999).

Figure 4.3. How much average prices at the auction exceeded minimum prices at the auction (%).

It is remarkable how similar the pattern in Figure 4.3 is to the pattern in Figure 4.2. The figures show that in the early years of 1993 and 1994 the market price and the average price both exceeded the minimum price by some 10 –20 %, and since 1995 there has been hardly any difference between the minimum price, the average price and the market price. From 1995 and onwards the similarity of patterns is the result of a strong clustering of bids at the auction around the prevailing outside market price. From mid-1994 the traded volume on the market escalated, see e.g. Joskow et al. (1998, p.677), so that by March 1995 the auction price was more or less determined by the outside market price, and should as such not be interpreted as a price signal.

So, in the important starting phase, a non-discriminative auction would probably have generated more ‘correct’ price signals. If the auction mechanism is to be used, e.g. in a US or European CO_2 market, the recommendation is to use a non-discriminative design (single-priced design). This solution may be a politically plausible way to secure that new sources can enter the market and to give a single price signal to a CO_2 market in the important starting phase.

4.5 Property Rights

Finally, property rights to the permits must be fully transferred to make the market work. Utilities are fully allowed to bank permits, to shut down plants and use the related permits, and to take each of these actions without individual approval. Furthermore, the CEMS control system in the ARP makes it possible to enforce property rights clearly.

However, the risk of sudden regulatory intervention is present in the ARP. Permits may be confiscated without compensation or may be devaluated without notice. Note that the distributed permits do not represent a permanent right. A permit gives the right to emit one ton per year and is subject to renewal every year by the regulator.

Clean Air Act states clearly that the EPA or the Congress is authorised to terminate or limit the use of permits without compensation.[50] Such regulatory uncertainty connected to the future value of the permits is difficult to quantify and incorporate in the permit price. A critical concern then is whether the electric utilities have the full property right to dispose of the SO_2 permits. If not, the future value of the permits will become uncertain and utilities will then hesitate to participate. In other words, the question is whether authorities will tend to use the constitutional right to confiscate permits in practice. Arbitrary regulatory interventions are not likely to occur in the near future for two reasons. First, even though authorities reserve the right to formalise the property right of the permits, it seems unlikely that unannounced confiscations will take place in the short and well-defined devaluation period, given that both environmentalists and utilities have approved the program.[51] Second, the influential and well-organised utilities will resist permit confiscation, and so will any other holder of permits, for example, speculators. In general, the favourable political climate, the definition of a devaluation period, and the absence of significant trade restrictions all suggest that electric utilities in practice may gain the full property rights of the grandfathered SO_2 permits.

However, administrative matters for dealing with the property rights from the gains from trade are not settled yet. The Public Utility Commissions (PUCs) must settle administrative practice rules for determining how to treat costs and revenues from trade as soon as possible. There is one PUC in each state and the 50 PUCs are organised under the Federal Energy Regulatory Commission (FERC). The FERC has not settled the rules yet. This uncertainty inhibits trade because the PUCs are waiting for utilities to trade, whereas the utilities are waiting for the PUCs to describe how their costs and revenues will be treated.[52]

4.6 Conclusion

The results of the assessment are summarised in Table 4.2.

Table 4.2. Acid Rain Program

Market Results	
Trade Activity	High. Through the end of 1999 over 9,300 transfers (81.5million allowances where 62 % were internal and 38 % were external trades). Market price per ton SO_2: $136 (March 2000).
Cost savings	40 % compared to CAC. Market price in March 2000 about five times lower than expected.
Innovation	High
Transaction costs	Low
Environmental effect	40 % overcompliance in 1995. No hot spots and environmental improvement.

The overall conclusion is that the US Acid Rain Program (ARP) has performed well. A competitive market structure and auction mechanism have succeeded in generating extensive trade activity and prices. Property rights to permits have been well-defined and well-enforced and transaction costs are low.

The main reason for low transaction costs in the ARP is the fact that this program ignores source location and the risk of creating hot spots by trade. Individual administrative control

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[50]. Clean Air Act of 1990, Title IV, §403(f).

[51]. Svendsen (1998a; 1998c).

[52]. Ibid.

procedures for each trade were unnecessary because of favourable geographical and meteorological conditions and the 50 % SO_2 reduction. This new policy design is therefore recommendable for future environmental regulation, especially for cases in which source location may be ignored.

The annual SO_2 auction also lowered transaction costs. Empirical evidence from the early years showed that the *minimum* (i.e., the clearing) price at the auctions was approximately 10 % lower than the outside *market* price which was approximately equal to the *average* price paid at the auctions. Since 1995, however, the minimum price seems to be determined by the outside market price. The winning bids at the auction are clustered around the outside market price, implying that the average price paid is only slightly higher than the minimum price. Therefore, the auction has by now been made superfluous by the market. However, if there is a risk that the market should break down in the future, running the auction is still justified.

An important purpose of the auction was to “kick-start” the market by delivering a price signal to the market. In the early years a non-discriminative design would have yielded a single price signal which the discriminative design did not. And in the later years the market has been well functioning, so there has been no need for a price signal. Therefore, the policy recommendation is that the non-discriminative SO_2 auction is a very useful tool for lowering transaction costs and kick-starting an immature market. As such, it should be applied by policy makers, for example, when establishing future CO_2 markets.

In the EU, a potential CO_2 market for electric utilities, matching the design of the ARP, has not yet been described. This it what we will try to do in the next chapter.

5 A qualitative evaluation of a CO_2 permit market for the EU power sector

5.1 Introduction

The European Community and its Member States will upon ratification of the Kyoto Protocol legally bind themselves to the reduction of the basket of six greenhouse gases. For the EU this requires the reduction of greenhouse gas emissions by 8 % below 1990 levels in the commitment period 2008 to 2012. As mentioned earlier, the EU has agreed on a Burden Sharing Agreement that reallocates this obligation between the Member States through the provisions of Article 4 in the Kyoto Protocol. Given that there is no global authority to regulate the utilisation of the atmosphere, the possible role of the EU as the only international organisation that has signed the Kyoto Protocol is important to examine in this respect.

Furthermore, the EU has adopted a position that seems to acknowledge that the developed world does have a certain responsibility to reduce its own emissions, by suggesting that there should be a concrete ceiling on international emissions trading. The extent to which the developed countries will be able to buy their way out of their emissions obligations via cheap imports of permits from developing countries will therefore be limited. Again, this will force up the cost of reducing CO_2 emissions within the EU all things being equal, which may run counter to matters concerning the competitiveness of the EU industry. Therefore, it is necessary to exploit all low-cost opportunities for reducing greenhouse gas emissions within the EU.

Indeed, the goal must be to establish a common regulatory system that will equalise marginal reduction costs across all Member countries if not globally. In the actual process of getting such a system underway, however, it is necessary to consider a whole range of economical and political issues. We would like to establish whether or not the electricity sector is a suitable starting point for a tradable greenhouse gas permit market in the EU and also how such a market most suitably can be formed. Obviously, an initial trading scheme for the electricity sector should be constructed in such a way that the geographical and sectoral scope can easily be expanded.

Section 5.2 will start out by highlighting the climate change challenge in the EU and discuss whether or not CO_2 emissions are a sensible starting point for a market for emissions trading. We then move on to consider how CO_2 emissions can most effectively be capped. Specifically, we look at the different virtues of an “upstream” permit system and a “downstream” system. In Section 5.3 we then turn our attention to the political economy of a CO_2 permit market. Here we will use a public choice framework to analyse some of the political conflicts and difficulties by presenting the viewpoints of different stakeholders and taking into account their respective possibility to influence the political process. Section 5.4 discusses how the design of a CO_2 permit market for the power sector can most suitably be formulated. Finally, Section 5.5 concludes.

5.2 Climate Change in the EU: The nature of the problem

It is useful to distinguish between the greenhouse gases that are related to energy consumption and the ones that are not. The most important impacts of energy on climate change are emissions of CO_2, which are entirely energy related and, to a much lesser degree, of other greenhouse gases, such as methane (CH_4) and nitrous oxide (N_2O), which also have important non-energy sources such as agriculture and industry. The other greenhouse gases included in the Kyoto protocol (Hydrofluorcarbons (HFCs), Perfluorcarbons (PFCs), Sulphur hexafloride (SF_6)) are not related to energy use as such (European Commission, 1998).

A tradable CO_2 permit scheme must first and foremost be seen in an energy policy context, because the implementation of such a scheme influences deeply on other targets for energy policy such as security of supply and competitiveness. Furthermore, the implementation of such a scheme will entail a profound redistribution of resources in society in general, which needs to be considered.

Ideally, the coverage of emission sources and gases must be complete in order to assure that all low-cost opportunities for reduction are included. However, there are a number of factors that point to an emission-trading scheme covering only CO_2 emissions from the power and steam sector as being a sensible starting point, including:

- CO_2 emissions are by far the largest contributor to greenhouse gas emissions and will remain so for any foreseeable future;
- CO_2 emissions stems almost entirely from fossil fuel use, which is most easily monitored;
- Many low-cost CO_2 emission reduction opportunities are within the power sector.

In turn, we will now turn our attention to these three issues.

5.2.1 Contribution of CO_2 to greenhouse gas emissions

Several analyses have been made on estimating the “business as usual” greenhouse gas emissions in the future. In Table 5.1 we have presented the data from The Shared Analysis Project, Vol.11. The data for 1990 and 2010 in this study is mainly derived from the Second National Communications of the Member States and the EU to the UNFCCC. The projection of emissions in 2010 is derived from the “with measures scenario” proposed in the national communications. The “With measures scenario” describes the development of GHG emissions assuming no additional changes of present policies, i.e. assuming that the measures decided by the Member States until mid-1997 will be executed[53].

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[53] For further elaboration of assumptions and methodology we refer to the Shared Analysis Project, Vol.11.

Table 5.1: Expected development of Greenhouse Gas emissions, 1990-2010.

Mt CO_2 equivalent	CO_2		CH_4		N_2O		Total halogenated gases		All GHG	
	1990	2010	1990	2010	1990	2010	1995	2010	1990/95	2010
EU-15	3365	3507	481	355	383	315	64	90	4292	4267
Target	3190 (-5.2 %)		355 (-26 %)		315 (-17.6 %)		90 (+40 %)		3949 (-8.2 %)	

Source: The Shared Analysis Project, Vol. 11.

As can be seen from Table 5.1, the total emissions in the European Union (EU-15) from the basket of 6 gases amounted to approximately 4.292 Mt CO_2 equivalence in 1990/1995 (1995 is used for HFC, PFC and SF_6) and is expected to fall to 4.267 Mt CO_2 equivalence in 2010. The main reason for this is that emissions of methane and nitrous oxides are expected to fall by 26 % and 17.6 % respectively, due to a number of “no-regret” options for these gases. It should be noted, that some of these options are considered “no-regret” from a greenhouse gas policy perspective because they are not motivated by climate protection policy but by other policies such as waste reductions policies.

The uncertainties involved in such an analysis are very large, however. As an example, a study by (Coherence, 1998) projects a CH_4 emissions reduction in the EU-15 by only 8 % between 1990 and 2010. Another study by (Ecofys, 1998) is mainly supportive of the reductions of methane emissions found in this study but emissions of nitrous oxides are projected to increase by 13 % compared to the 1990-level[54]. Furthermore, it should be noted that non-anthropogenic sources of methane and nitrous oxide have a significant contribution to total emissions, by over 28 % and 32 % of the total emissions respectively (Ecofys, 1998).

The emissions of CO_2 are expected to increase its share from 78 % to 82 % in 2010, which clearly illustrates the importance of CO_2 emissions in the future.

Furthermore, The Shared Analysis Project, Vol. 11 highlights the fact that cheap emissions reduction opportunities of other greenhouse gases are likely to reduce the CO_2 emissions reductions that are necessary to comply with the Kyoto Protocol (the study suggests a 5.2 % reduction of CO_2 compared to the 1990-level). In other words, a uniform reduction of all greenhouse gases is not likely to lead to a least-cost response.

About 95 % of all CO_2 were energy related in 1990. The total level of energy related greenhouse gas emissions amounted to 3.220 Mt CO_2 equivalent, of which 3.068 Mt was CO_2. Methane is the second energy related greenhouse gas accounting for 108 Mt CO_2 equivalent, while N_2O accounted for 43 Mt (The European Commission, 1998).

In fact, energy-related CO_2 emissions contributed around 75 % to total GHG emissions in the EU in 1990. To get an idea of how the sectoral distribution of energy related CO_2 emissions are expected to develop, it is useful to look at another undertaken by the European Commission (Shared Analysis Project, 1999, Vol. 5). As before, the baseline projection of CO_2 emissions is meant to illustrate how greenhouse gas emissions would develop if no specific policy to control emissions were undertaken (a so-called “business-as-usual” scenario). This requires a whole range of assumptions about how the economy

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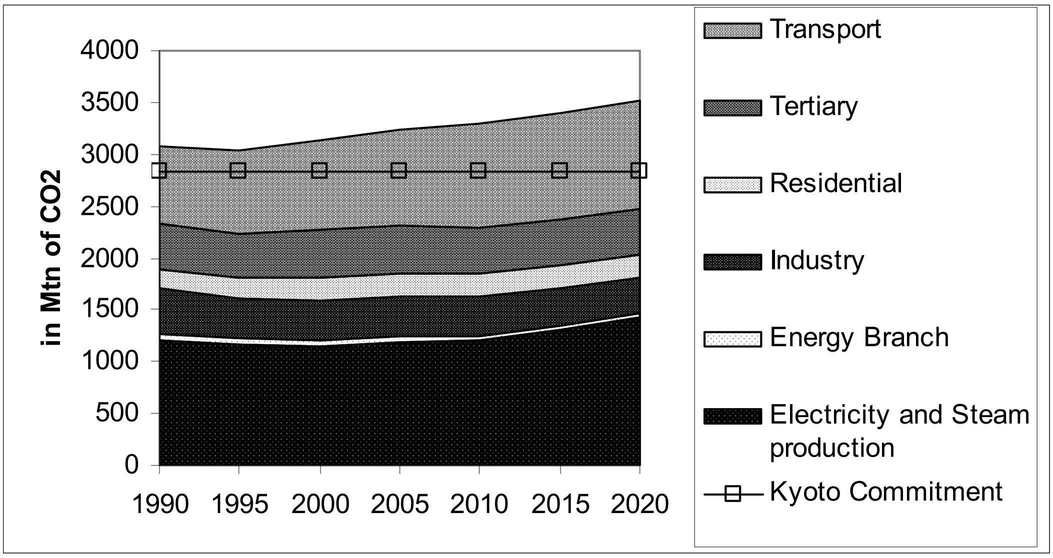
[54] The differences are mainly due to different projections of Nitrous Oxides emissions from car catalysts. The study by (Ecofys, 1998) also includes a baseline where current technical available measures are implemented (at very low cost), which will reduce emissions of Nitrous Oxides by 18 % in 2010 compared to 1990.

evolves, since the carbon intensity of an economy at any particular time reflects the interaction of technology, social structures and relative prices. The results of the baseline analysis are based on the following main assumptions[55]:

- The liberalisation of the electricity and gas markets will proceed in line with EC directives and is assumed to fully develop in the second half of the first decade;
- The restructuring is enabled by mature gas-based power generation technologies that are efficient, involve low capital costs and are flexible regarding plant size, co-generation and independent power production.
- No new policy measures will be undertaken in order to meet the Kyoto commitments;
- Energy policies that aim to promote renewable energy (wind, small hydro, solar energy, biomass and waste) are assumed to continue, involving subsidisation of capital cost and preferential electricity selling prices;
- On-going infrastructure projects in some Member States involving the introduction of natural gas are assumed to gain full maturity in the first half of the first decade after year 2000;
- Electricity generation investments are determined on the basis of long run marginal costs. Furthermore, countries like Austria, Denmark, Greece, Ireland, Italy and Portugal remain non-nuclear countries. Finland, Germany, the Netherlands, Spain, Sweden and United Kingdom do not further expand their nuclear capacity. Finally, for France and Belgium the assumption of further nuclear expansion, on the basis of economic criteria, is adopted beyond 2010. The lifetime of nuclear power stations is assumed to be as long as 40 years.
- Fuel price assumption based on the Poles model (see Table 7.3.)

The baseline analysis results in the following development in CO_2 emissions (see Figure 5.1).



Source: The Shared Analysis Project, Vol.5, 1999

Figure 5.1: CO_2 emissions under baseline scenario, EU-15.

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[55] For a more comprehensive coverage of assumptions we refer to The Shared Analysis Project, 1999.

This scenario results in 3298 mill. tonnes of energy-related CO_2 emissions in the year 2010. If we assume a uniform reduction of all greenhouse gases, which means that emission of CO_2 has to be reduced by 8 % compared to the 1990 level, the average yearly CO_2 emissions exceed the limit by some *468 Mt* (taking the year 2010 to be indicative of the whole period 2008-2012). In other words, the CO_2 emissions have risen by 7.6 % in 2010 from the 1990 level compared to a reduction by 8 % that is required by the Kyoto Protocol. Of course, if other greenhouse gases can be cost effectively reduced by more than 8 %, the required reduction of CO_2 will be less than 8 % but most certainly an increase in CO_2 emissions is not compatible with the Kyoto target. In fact, if we take the baseline level of CO_2 emissions using the Primes model and combine it with the greenhouse gas reduction potentials in the Shared Analysis Project, Vol. 11, the *cost-effective reduction of CO_2 is suggested to equal a 6.2 % reduction of CO_2 emissions in 2010 compared to 1990 levels*[56]. It is clear that extraordinary measures will need to be implemented and a "business as usual" approach is no longer sufficient. Interestingly, the CO_2 emissions have actually fallen from 1990 to 1995 due to an economic setback in the EU and some fuel switching, which illustrates that the link between economic growth and CO_2 emissions is still very strong.

The foregoing figure also shows that the transport sector is critical in the short term. The transport sector (road and air) is currently the fastest growing sector in the majority of the EU economies and also the fastest growing contributor to CO_2 emissions. The growth in CO_2 emissions from the transport sector is expected to be reversed over time (after 2015) due to improvement in energy intensity and a shifting of economic activity towards the service sector and high value added manufacturing activities, which tends to be less freight intensive. In the longer term (after 2010) production of electricity and steam is expected to be the fastest growing contributor to CO_2 emissions due to decommissioning of nuclear plants and increasing use of electricity in most sectors of developed economies. Overall, the link between economic growth and CO_2 emissions is expected to become weaker.

In conclusion, CO_2 is expected to remain by far the most important contributor to the accumulation of greenhouse gases in the atmosphere. The power and steam sector is expected to be a significant contributor of CO_2 emissions in the future (about 37 % in the year 2010), however, measures to control emissions of CO_2 cannot be confined to the power and steam sector only.

5.2.2 Monitoring of greenhouse gas emissions

With regard to the monitoring of emissions, it was mentioned that emissions stemming from fossil fuel use is most easily monitored. The following Table 5.2 illustrates the different origins of the various greenhouse gases:

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[56] As noted in Vol. 11, the level of baseline emissions of CO_2 are lower than in the baseline level of emissions based on the Primes model (Vol.5), due to the fact that the baseline level of emissions in Vol.11 includes measures decided up to the Kyoto Conference.

Table 5.2. Greenhouse gas emissions – different source categories

	CO_2	CH_4	N_2O	PFCs	HFCs	SF_6
Fossil carbon:						
- Combustion	X	X	X			
- Diffuse emissions	X	X	X			
- Feedstock	X	X	X			
By-product emissions	X	X	X	X	X	
Consumption of chemicals			X	X	X	X
Biological processes:						
- Landfills		X				
- Agriculture		X	X			
- Forests	X					

Source: Audun Rosland, Norwegian Control Authority (SFT).

Only emissions of CO_2 are almost entirely energy related[57], while other energy related greenhouse gases (methane (CH_4) and nitrous oxide (N_2O)) have important non-energy sources like agriculture and industry. As it turns out, this makes CO_2 an excellent starting point for an emissions trading scheme, because the uncertainties involved in the measurement of CO_2 are considerably lower than with the other greenhouse gases, which can be seen from the following Table 5.3:

Table 5.3: Greenhouse Gas Emissions: Roughly estimated uncertainty level

CO_2	± 1-5 %
CH_4	± 30-60 %
N_2O	± 30-100 %
HFCs	± 10 % 1)
PFCs	- 30 %, + 50 %
SF_6	± 5 %

1) Based on consumption (potential emissions). The data for the real HFC emissions are far more uncertain.

Source: Audun Rosland, Norwegian Pollution Control Authority (SFT).

Of course, it is not clear from the outset how much uncertainty can be handled in a permit market. However, since the value of tradable permits is intrinsically linked to the credibility of the whole system it seems sensible to start with a system that is fairly simple to monitor.

5.2.3 Options for CO_2 reduction

It is well known that many low cost opportunities for reducing CO_2 emissions are present in the power sector. At present there do not exist any well-defined “end-of-pipe” investment opportunities with respect to the reductions of CO_2 emissions. This reduces the opportunities for CO_2 emissions reductions in the medium term to the following areas:

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[57] Of course, increasing forest growth will increase the CO_2 uptake over a period of time. However, seen over the whole lifecycle of the forest there is no effect on CO_2.

- Reducing the use of fossil fuels with high carbon content
- Fostering the alternatives, i.e. renewables and more energy efficient technologies.
- Adapting the overall energy system, including the reduction in energy demand through behavioural changes.

The first two points relate to the supply-side. The IPCC emission factors for the main fuels used are 94.14 kg of CO_2/GJ for hard coal, 72.6 kg of CO_2/GJ for crude oil and 55.8 kg of CO_2/GJ for natural gas. This means that the proportion between the carbon intensity of gas and that of coal is less than 1:2. Keeping the US experience with the US Acid Rain Program in mind, it is worth noting that the same proportion with regard to SO_2 emissions is of the order 1:100. This means that the effect of fuel substitution is more limited with regard to CO_2 emissions, although still of significant magnitude. In sum, the crucial differences between the most common emissions from burning fossil fuel is:

- Difference in emission intensity between gas and coal
  - SO_2: 1 to 100
  - NO_x: 1 to 10
  - CO_2: 1 to 2
- Combustion controls (the percentages are indicative)
  - SO_2: 98 % reduction
  - NO_x: 90 % reduction
  - CO_2: no option currently available.

Due to the lack of viable “end-of-pipe” solutions for the reduction of CO_2, the ability of a Member State to stabilise CO_2 emissions through the reduction of fossil fuels depends on its economic and energy structure in the base year (1990). The dependency on fossil fuels in different sectors can be seen from the following Table 5.4

Table 5.4: Carbon intensity (tn of CO_2/toe) in different sectors across EU countries, 1990.

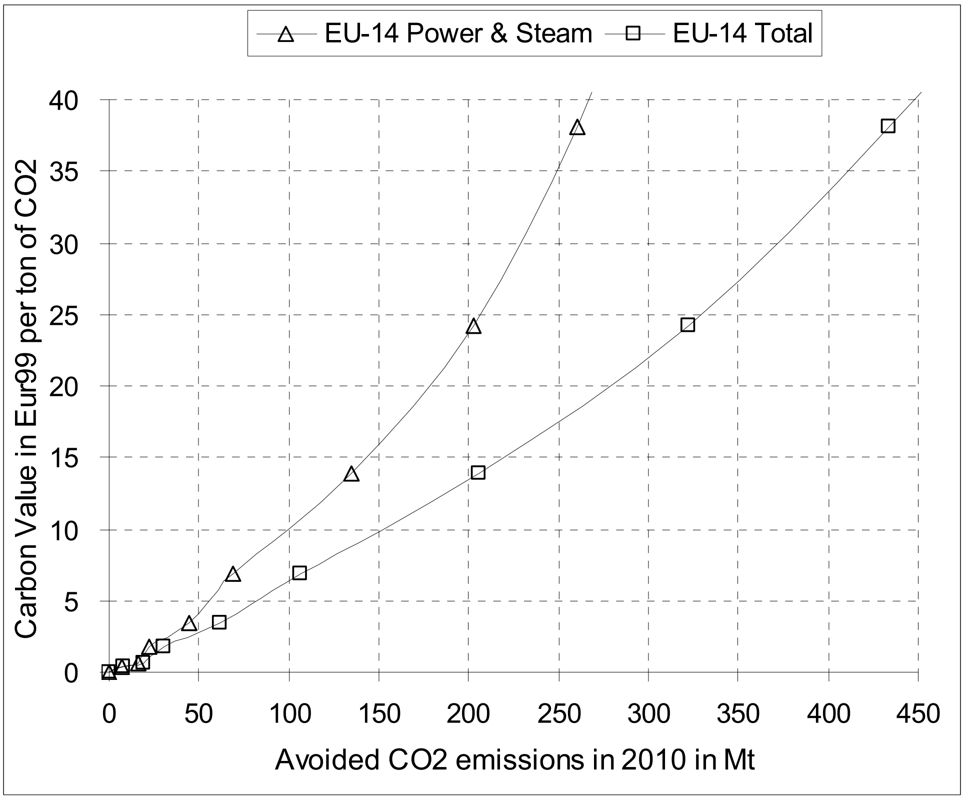
	Total	Public Thermal Power Generation	Autoprod. Ther. Power Generation	Energy Branch	Industry	Transport	Tertiary-Domestic
Austria	2.1	3.1	2.2	2.1	2.1	2.8	1.4
Belgium	2.2	3.5	2.8	2.3	2.5	2.9	2.2
Denmark	2.9	3.6		2.0	2.0	3.0	1.2
Finland	1.8	3.7	1.0	1.8	1.4	2.9	1.1
France	1.6	3.4	3.6	1.8	2.2	2.9	1.7
Germany	2.7	3.9	3.5	1.7	2.3	2.9	2.2
Greece	3.1	4.0	2.8	1.9	2.4	3.0	1.5
Ireland	3.0	3.5	3.4	1.4	2.5	3.0	2.8
Italy	2.5	3.0	2.8	2.4	2.1	2.9	1.9
Luxembourg	3.0	0.0	4.3	0.0	3.3	3.0	2.2
Netherlands	2.3	3.1	2.5	2.5	2.1	2.9	2.0
Portugal	2.3	3.6	1.8	2.3	2.0	3.0	1.0
Spain	2.3	3.9	3.0	2.4	2.1	2.9	1.5
Sweden	1.1	2.6	0.5	0.9	1.0	2.8	0.9
United Kingdom	2.7	3.8	3.2	2.2	2.3	2.9	2.0

Source: Eurostat, 1997

Of course, there are notable differences in the size of public thermal power generation between the individual Member States, which do not show up in this table. However, it is clear that public thermal power generation is overall most dependent on fossil fuels with a high carbon content (coal) followed by transport (oil). On the face of it, this will make fuel switching in the power sector a very likely option for reduction of CO_2.

Also, the scope for improving energy efficiency and reducing emissions are greater in the energy intensive sectors (power, metals, building materials, paper etc.) than the labour intensive sectors (e.g. electronics, services). The power sector in particular can have a potentially big impact through the penetration of renewable energies like wind, solar, biomass etc. and increased use of combined heat and power plants (CHP plants).

As, an illustration of the importance of the power and steam sector, we will use a recent study by (Capros and Mantzos, 1999) using the Primes model. For an elaboration of the methodology we refer to Appendix B. The Primes model allows the construction of marginal CO_2 abatement cost curves for individual sectors. In the figure below, the marginal abatement costs in the power and steam sector is compared with the marginal abatement costs in all sectors taken together. Clearly, a lot of low cost opportunities exist in the power and steam sector (mainly fuel switching) and the two marginal abatement cost curves show an almost identical path up till about 50 Mt of avoided CO_2 emissions. However, the figure also illustrates that forcing a lot of emissions reductions on the electricity and steam sector without taking similar measures towards other sectors is not a good solution.



Source: Capros and Mantzos, 1999.

Figure 5.2. Marginal abatement cost curves for CO_2.

In summary, focusing on CO_2 emissions seems to be a sensible starting point for an emission-trading scheme. Naturally, opportunities for reducing emissions of the other greenhouse gases need to be exploited as well, but this could be done by other policy measures. The question remains, however, what type of emissions trading system can most effectively capture CO_2 emissions.

5.2.4 Upstream vs. downstream systems

An emission trading system can be designed either as an upstream or a downstream system. An upstream system will target fossil fuel producers and importers as regulated entities, so it would reduce the number of allowance holders to: oil refineries and importers, gas pipelines, LNG plants, coal mines and processing plants (Zhang, 1999). In this way, an upstream system catches all fossil fuels going into the economy. A downstream system on the other hand, will target those entities that actually burn the fuels and emit CO_2 into the atmosphere. This includes all sectors in society where notably the household and transport sectors include a vast number of emitters.

Generally, to be most efficient environmental policy needs to be focused directly on the unwanted ‘bad’, the emissions. The proponents of an ‘upstream’ system argue, however, that this argument does not apply to CO_2, at least not until such time as technology for large-scale ‘scrubbing’ and storage of waste CO_2 become economical. In the absence of such technology, there is approximately a one-to-one correspondence between the carbon content of fossil fuels going into combustion and the CO_2 emitted. This means that it is possible to regulate CO_2 emissions by limiting fossil fuel use, which is why an ‘upstream’ system that catches all fossil fuels that enter the economy should be preferred (Fischer et al., 1998).

In other words, it seems that effective price incentives for producers or consumers to alter their behaviour throughout the economy can be reached by using an upstream system. This argument hinges on one very crucial assumption, though. The product and factor markets need to be reasonably competitive in order for an upstream system to have the same ultimate effects on fossil fuel and other prices as a downstream system (Fischer et al., 1998). The ongoing restructuring of the electricity and gas markets in the EU could work in this direction, but the very uneven implementation of the liberalisation directive can by no means guarantee this. Secondly, it can also be questioned whether or not indirect price incentives are sufficient to produce a least-cost response. In a static and perfectly competitive world an upstream system can provide a least-cost-response. As noted by (CCAP, 1998), however, if it is believed that direct incentives are a necessary adjunct to indirect price signals to stimulate innovation, a downstream approach would have appeal. Specifically, a downstream system including the electricity sector would target the sector with the best chances of coming up with a successful “end-of-pipe” solution to the reduction of CO_2 emissions.

That said, the case for an upstream system remains a strong one. A downstream system will need to target a whole range of sectors, which contain too many small sources to be suitable for an emission-trading program. In other words, the administrative burden using a downstream system will put an upper limit on how many sectors can be included. Needless to say, that some sectors would need to be targeted through the use of other policy instruments, which greatly increases the possibility of sources ‘leaking’ from the system.

As we shall see, the major challenge to the upstream system is political. The simplicity and transparency of the system, which really are its best features, can prove to be an insurmountable political hurdle.

5.2.5 Cost incidence of CO_2 permits

A CO_2 permit scheme, regardless of whether a downstream or an upstream system is chosen, will raise the costs of carbon-intensive products. The costs borne by sources included in the permit market can be pushed forward to consumers via higher prices or backwards to inputs of production via lower workers wages, capital losses and lower energy prices[58]. In this way, a CO_2 permit scheme is broadly consistent with the principle of *polluter pays*. Sectors with a high dependency on carbon intensive inputs coupled with large irreversible capital investments (i.e., sectors that are big polluters and where it is costly to reduce pollution) are likely to suffer more. In general, the extent to which the costs borne by market participants can be pushed on depends on the short and long run slopes of supply and demand curves (Kerr and Cramton, 1998).

Much of the debate on emissions trading concerns the issue of transferring the ownership of the atmosphere from the Commons to private parties. In fact, ownership is being transferred from the Commons to either the taxpayer, under taxes and auctions, or to the recipients of grandfathered permits.

The initial allocation of allowances to private parties involves the privatisation of a common right, namely the right to emit CO_2 into the atmosphere. In this respect, grandfathering can be seen as giving rise to serious distributional problems. Before any

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[58] Of course, in case of an ‘upstream’ system, the only way that costs can be pushed backwards is to workers and owners of capital since energy is the output.

legal provision for the limitation of CO_2 emissions has entered into effect, anybody has the right to emit CO_2 into the atmosphere. If total CO_2 emissions are now to be restricted and allocated by means of grandfathering, then the scarcity-induced profits will accrue only to those that made use of their right to emit CO_2 in the past, and not to those that held the same rights but simply did not make use of it (Schneider and Wagner, 1998). That is to say, the wealth effects of changing the ownership of the atmosphere only benefit the capital owners.

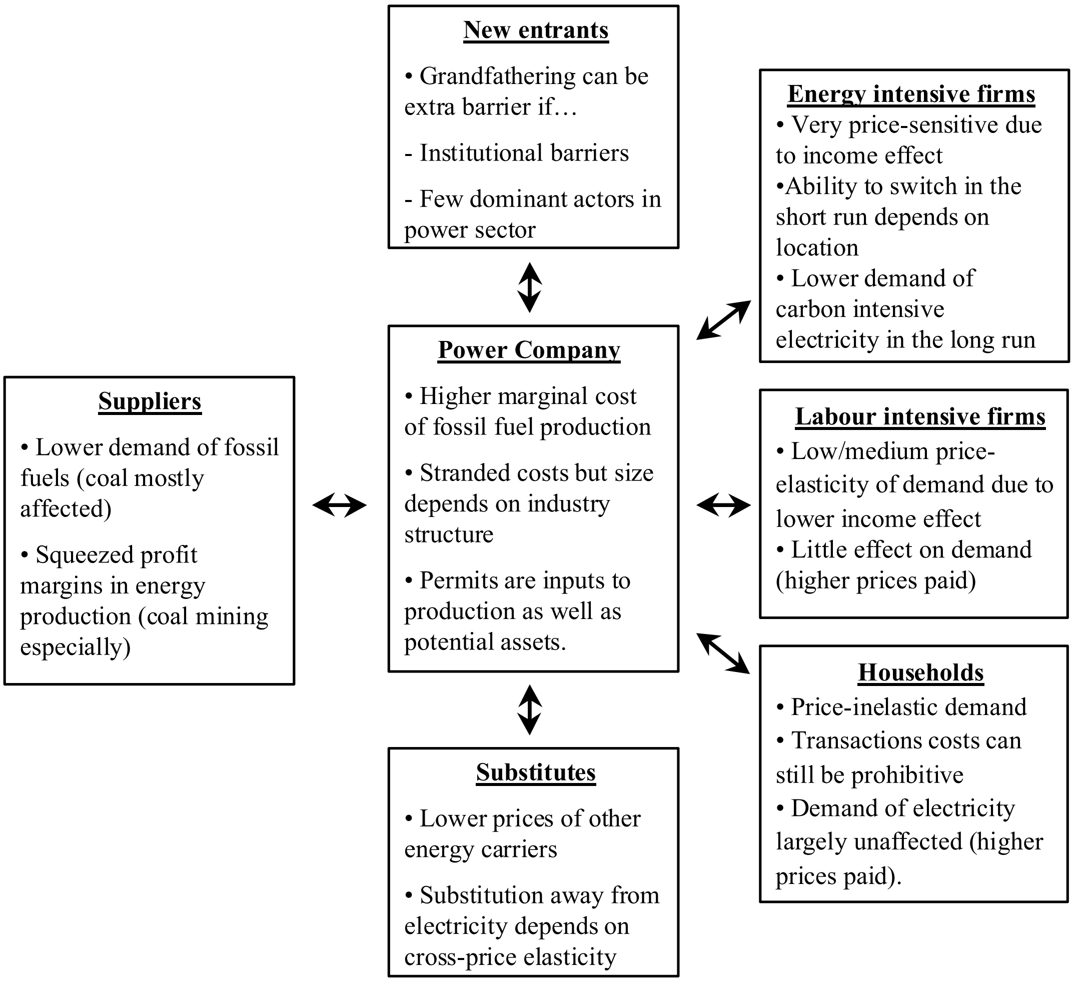
The introduction of a CO_2 permits market will inevitably put a price tag on CO_2 emissions. This price tag might show the price zero if the 'business-as-usual' emissions are lower than the total amount of permits but otherwise this introduction will entail a positive price on CO_2 emissions. What this means is that CO_2 permits will now serve as an input (cost) to production in line with other input factors such as labour and capital. As noted by (Kerr and Cramton, 1998), this will have distributional effects through the whole of society that consist of two parts, the effect that arises through changes in prices and returns to factors, and the wealth effects of changing ownership of resource.

The changes in prices and returns to factors are the same no matter what distributional principle is used, i.e. whether auctions or grandfathering is being used. Using grandfathering will however transfer some ownership of the atmosphere to the companies that are awarded the permits. In this way, the stockholders in the power sector will get relatively wealthier if permits are grandfathered to the power sector. Of course, the introduction of the carbon regulation will have a negative impact on the value of the rest of the company's assets, since capital investments in fossil fuel plants are largely sunk. So, giving away the permits for free is a way to compensate these stockholders.

The point is, however, that these stockholders are not the only ones that will be affected, since the costs borne by sources included in the permit market can be pushed backwards and forwards in the economy. As noted, the extent to which this will happen depends on the supply and demand conditions in general, so it is not immediately clear that the regulated sources will be the most adversely affected.

The slope of the demand curve for electricity depends upon how sensitive demand is to changes in electricity prices, also known as the price-elasticity of consumers. So, the question is what influences on the price-elasticity of consumers. Consumers do not demand electricity as such but rather they demand the derived services from using electrical energy. Naturally, some customers will be more inclined to move or substitute their consumption of electricity as a result of relative price changes than will other consumers. The main factors that determine the size of the price-elasticity of the individual consumer are the presence of relevant substitutes to electricity (the substitutional effect) and the overall impact that the cost of electricity has on the budget of the consumer (the income effect). Electricity used for heating have relatively close substitutes, which ceteris paribus will lead to a more price-elastic demand. Postponing the consumption of electricity to another time of the day, e.g. at night, is also a substitute for consumption now, which especially some firms may find advantageous. The income effect is of much greater importance for firms compared to households, which will also result in a larger price-elasticity for companies. Not surprisingly, estimates of the price sensitivity of demand vary depending on the region, country, time of year and type of customer, but in general, suggest that if prices rise by, say, 10-15 % as a result of CO_2 regulation, demand could decrease by anywhere from 1 % to 6 % or more in response to that price change.

Undoubtedly, part of the cost impact on a company that owns fossil fuelled power plants can be offset via higher electricity prices. This will, however, strongly depend on the actual location of the power plant. In the following figure we have tried to illustrate the possible ways that costs are channelled upstream and downstream in the economy.



New entrants

- Grandfathering can be extra barrier if…
- Institutional barriers
- Few dominant actors in power sector

Energy intensive firms

- Very price-sensitive due to income effect
- Ability to switch in the short run depends on location
- Lower demand of carbon intensive electricity in the long run

Suppliers

- Lower demand of fossil fuels (coal mostly affected)
- Squeezed profit margins in energy production (coal mining especially)

Power Company

- Higher marginal cost of fossil fuel production
- Stranded costs but size depends on industry structure
- Permits are inputs to production as well as potential assets.

Labour intensive firms

- Low/medium price-elasticity of demand due to lower income effect
- Little effect on demand (higher prices paid)

Households

- Price-inelastic demand
- Transactions costs can still be prohibitive
- Demand of electricity largely unaffected (higher prices paid).

Substitutes

- Lower prices of other energy carriers
- Substitution away from electricity depends on cross-price elasticity

Figure 5.3: Likely cost incidence of a CO_2 permits market

In the longer run, this could mean that households are likely to pay a higher price premium. However, since household energy consumption is less carbon intensive than many industrial processes the overall cost burden will be larger for these industries especially in the short run. None of these sectors will be compensated if the CO_2 permits are awarded gratis to the power companies. An auction, on the other hand, could potentially redistribute the funds in a much more flexible way.

The possible alternatives that these consumers are presented with will depend upon the way the liberalisation process of the electricity sector moves ahead. Clearly, there are still some noticeable differences in the way the individual Member states have chosen to implement the Liberalisation Directive. First of all, there are still large distinctions between the speed and extent of the liberalisation process. As concluded in (Shared Analysis Project, Vol. 8), there are generally two different paths in implementing the EU directive:

- A first group of countries (UK, Finland, Sweden, Germany, Denmark, Spain, Netherlands), of course led by the countries that liberalised their electricity market before the Directive, is allowing all or a major part of the final consumers to become free of choosing their supplier.
- A second group of countries (France, Italy, Portugal, Austria, Belgium, Greece, Ireland and Luxembourg is allowing a share of eligible consumers that is near the minimum threshold required by the EU

The second group of countries is also to a much larger extent dominated by the former regulated monopolies. The differences can persist for many years to come.

Also, the introduction of a CO_2 permit market will have a profound impact on the fuel markets. Coal being the most carbon intensive fuel is likely to be affected by a price drop following the introduction of a CO_2 permits market (depending on what goes elsewhere in the world, of course). This will have a negative impact on activity and employment in this sector, which is not easily relocated elsewhere in the economy. This will add to the already mounting pressure on indigenous fuel sources in the EU.

Most general equilibrium models that compare the costs to society by distributing the permits via an auction (or an equivalent CO_2 tax) and distributing them via some sort of grandfathering conclude that the possible savings using an auction are much larger (Jensen and Rasmussen, 2000; Kerr and Cramton, 1998). This is so, mainly because the revenue created from an auction can be used to offset other distortionary taxes in the economy, e.g. labour taxes, since CO_2 from the outset is a better tax base than labour. Furthermore, the permit owners will be largely over-compensated when the permits are given away for free. So the presence of other distortionary taxes in the economy very much reinforces the economic efficiency results from Chapter 3 with regard to grandfathering. *Auctioning permits is unambiguously more efficient than grandfathering*. There is no guarantee that the revenue will actually be used to reduce taxes on labour or capital, though, but unless the entire revenue is wasted the result still holds true.

An auction also has the flexibility of separating the issue of allocation from the issue of distribution in that the Government can choose to redistribute some of the revenue to those firms that have been most adversely affected. When using a grandfathered system both these issues will be determined by the initial allocation of permits. A similar view has also been presented by (Abare, 1998) stating that the most market based approach to allocating permits initially is to auction them. Auctioning removes any need for the issuing authority to balance various equity and efficiency considerations in deriving the allocation rule. In actual schemes in the United States, initial free allocation of permits has been the dominant allocation rule. However, none of these schemes has operated on such a scale that revenue raised by auctioning permits could have made a significant contribution to displacing other taxes.

In conclusion, the introduction of tradable CO_2 permit market will have a profound impact on competition and return to factors throughout the economy. The changes in prices and returns to factors are the same no matter what distributional principle is used, i.e. whether auctions or grandfathering is being used. Grandfathering will however transfer some ownership of the atmosphere to the companies that are awarded the permits, so the wealth effects of changing the ownership of the atmosphere only benefit the capital owners. This is problematic in two respects. As suggested by several studies, there are large welfare gains if the revenue is used to reduce other taxes in the economy rather than being given away for free to the existing emitters. In other words, auctioning permits is unambiguously more efficient than grandfathering. Secondly, from a perspective of fairness grandfathering is also problematic because it does not reflect the fact that every citizen has the same right to emit CO_2 into the atmosphere.

5.3 The political economy of a tradable CO_2 permit market

The intention of this section is to try to analyse the possible ways in which the effective design of a tradable CO_2 permit market can be affected by the interactions between private corporations, Member States and the Institutions of the European Community. The underlying assumption is that actors' interaction are guided by considerations of self-interest in that they attempt to achieve their goals, such as maximising their resources, in a specific context of institutional rules (Héritier, 1999). The goal is to point to an effective design of a tradable permit market that stands a chance of being implemented as well.

Subsection 5.3.1 briefly discusses some of the economic and political challenges that influence on the climate policy options in the EU. In Subsection 5.3.2 we move on to consider some of the institutional constraints that face a federal system like the EU in relation to climate policy and Subsection 5.3.3 considers how the different institutions in the European Community interact within this context. We then consider the positions of the different Member States towards climate change policy and the preference over policy instruments in Subsection 5.3.4. Subsection 5.3.5 then does the same with regard to major interest groups in the EU as well as considering if any rules or regulations are in place that can be considered a result of effective lobbying. Finally, Subsection 5.3.6 concludes.

5.3.1 Contingencies on EU energy and climate policy

The struggle over a common EU energy policy has taken many turns. Energy policy has been characterised by strong conflicts between a common policy, on the one hand, and diverse national interests on the other. In some respects it is the same conflicts that are at play with respect to a common climate policy, in as far as climate policy is inherently linked to energy policy.

In general, there are three goals of EU energy policy, also known as the energy policy triangle:

- increase competitiveness of European businesses through low energy prices
- secure a stable and diverse supply of energy to the EU
- limit the impact that human activities have on the environment (secure environmental sustainability)

The political focus on these pillars has changed over time and will continue to do so, largely as a result of changes that are external to the EU. Furthermore, the policy level that is deemed to be most appropriate in dealing with the issues is likely to change as well.

Economic and political challenges

Two general trends since the late 1980s have affected the focus of energy policy in the European Community.

First of all, the economic environment has become increasingly inter-dependent. Increasing international trades and direct foreign investments have brought along increased competition for many sectors and services. At the same time, the changes in the political environment, through successive rounds of GATT and WTO negotiations as well as the completion of the Single Market in Europe, has worked to reinforce this process. As a consequence of these changes in the economic and political environments, the room for National Governments to manoeuvre has been considerably narrowed. International factor mobility (i.e., capital and labour mobility) constrains the capacity of National governments to regulate processes of production and to tax the profits from production because investors, tax payers and consumers alike are now presented with the option to exit the regulated area (Scharpf, 2000a).

The impact on energy policy in the EU is likely to have been two-folded. First of all, the budgetary costs of protecting national energy markets to secure energy supply and in turn preserve regional employment has become more pressing. Together with the falling oil prices in the 1980s, this has tended to downplay the security of supply dimension in the 1990s. Secondly, the case for a supra-national energy policy response has become stronger. The changes in the policy environment has reinforced the use of market mechanisms as the favoured instrument to increase effectiveness and thereby competitiveness of national industries. This means that market distortions and trade barriers created by National Governments have come under pressure. As a result, the most important changes in the energy sector in recent years are related to the internal market directives on the electricity and gas markets.

Importantly, even though the restructuring process of the electricity markets still have a long way to go, these changes happened despite the fact that there are large differences in the socio-economic structures of the Member States. As a consequence, changes in the overall policy environment will not have the same impact on different Member States. In fact, the tension between national interests and the EU is the main reason why energy did not become a field of common policy during the Treaty revisions of Maastrict and Amsterdam. Nevertheless, the lack of overlapping interests between Member countries cannot explain the elements of common energy policy that has been implemented since the late 1980s. Important new EU energy policy initiatives seem to have been driven by the Commission which has exploited institutional rules to take the initiative, to redefine the energy sector in relation to the internal market, environmental policy and foreign policy (Andersen, 2000). Especially legal rules relating to competition and the internal market puts a number of legal restraints on the policy options that are open to individual Member States which has been exploited by The Commission.

The second trend is the arrival of the climate change issue on the international political agenda in the 1990s. Obviously, this has had the effect of putting environmental sustainability in focus. Due to the global nature of the climate change problem and due to the close connection between energy related greenhouse gas emissions and economic growth in general, there are clear benefits from a globally or at least internationally co-ordinated response to the problem. Achieving a fully co-ordinated global solution to the problem of climate change is, however, going to be difficult, as there is no global institution that can regulate such an agreement. The problem is that climate change mitigation is a public good, which makes the underlying constellation of country interests very much like a prisoner's dilemma. Each party will have an economic incentive to free-ride on a co-ordinated agreement, for in doing so each can gain more by avoiding steep mitigation costs than it loses from its own small slice of greenhouse-gas abatement (Barrett, 1998).

This could lead to the pessimistic conclusion that whenever international co-operation really matters, co-operation is not possible. At least, this is still a major challenge to the future negotiations over the Kyoto Protocol. However, in a European context, the signing of the Kyoto Protocol has clearly opened up a “window of opportunity” for the European Commission (Héritier, 1999). The Kyoto Protocol applies external pressure to the EU and to the Member States, which can be used to widen the European agenda and to press on with policy-making. The case for European policy-making builds on the principle that the independence of the European Commission can help to enforce an effective solution to the climate change problem between the Member States. By means of delegating power to an independent agent (principally the European Commission), the independent agent can sanction the Parties that are not in compliance with the co-ordinated agreement and thus prevent some of the problems concerning collective action among the Member States.

In other words, the climate change issue also seems to reinforce the case for a supra-national policy response in the EU.

5.3.2 Institutional dimensions of energy and climate policy in the EU

Consensus requirements in the EU

The European Union is characterised by a complex interrelation between institutional and other actors at EU, national, and sub-national level, which makes the institutional structure of the EU akin to a federal system characterised by “multi-level governance” (Scharpf, 2000a). As noted by (Schmidt, V.A. 1999), European federalism is a “balancing act” between the representation of territorial and non-territorial interests, with territorial interests much more fully embedded in every institution than in other federal systems (notably the United States):

- National governments appoint the judges of the European Court of Justice and the commissioners of the EU Commission;
- National ministers compose the Council of Ministers;
- National electorates elect members of the European Parliament;
- National governments are involved in the enforcement as much as the initiation of "federal" policies through regulations enforced by national governments and directives that are transposed into national law by National parliaments.

Obviously, there will be a contest for decisional power between the different levels of Government. As many Member States are markedly different with respect to their institutional structures (i.e. federal like Germany or unitary like France and the UK) this has made some countries quite unwilling to delegate decisional power to the Community level. Furthermore, these differences in institutional structures can leave considerable discrepancies in the actual implementation of EC directives by the Member States.

A number of issues with respect to cross-border environmental policies can make matters complicated. First of all, the interest constellation, which evolves from the anticipated costs and benefits of climate change, is re-distributive and therefore conflictual. Climate change mitigation is a public good and as such the Member States have a common interest in providing it. Yet on the other hand, there are significant differences with regard to the anticipated benefits of mitigating climate change, and the distribution and ability to bear the cost of emissions abatement (Héritier, 1999).

This is likely to influence on the possible ways in which policies can be implemented. The positions of Member States will vary depending on the economic interests at stake, the degree of environmental consciousness, the stringency of domestic environmental legislation and the level of economic development (Héritier, 1999).

In such a setting, the possibilities of reaching an agreement at Community level depend on the degree of consensus that is required to reach an agreement. In multi-actor systems with high consensus requirements, innovators will be at a competitive disadvantage in interactions with the beneficiaries and defenders of status quo (Scharpf 2000). In other words, unanimous decision rules have a strong conservative bias. For example, all attempts to introduce a common CO_2 tax in the EU have been blocked because single member countries oppose the taxes.[59] It is possible for one single member country to block such a common decision because the EU unanimity rule for fiscal measures applies to the CO_2 tax.

Importantly, the consensus requirements in matters relating to environmental policy and matters relating to energy policy are different. First, environmental policy, in contrast to

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[59] Svendsen (1998a).

energy policy had become part of the Treaty of Rome through the single act reform in 1987. After Maastrict (1994) it was possible to make decisions in the area of environmental policy based on majority decisions by the Council of Ministers, although there were exceptions for measures involving fiscal matters (Andersen 2000).

In fact, Article 175 (old 130s) of the EC Treaty says that decisions relating to taxation (fiscal measures), spatial planning and energy policy are only to be taken unanimously. However, measures relating to Article 175 as well as the harmonisation efforts specified in Article 95 (old 100a) due to the construction of the common market are to be taken by qualified majority. This can leave some possibilities in the hands of the Commission in any case, because they can try to change the Treaty basis for a decision, thus changing a unilateral decision to a decision taken by qualified majority (Héritier, 1999).

Shared competence and the subsidiarity principle

The European Community, being at the top level of the federal governance structure in the EU, is a unique legal entity. It is an international organisation which only has the powers given to it by its constituting Treaty, the EC Treaty, and any legislation based upon that Treaty. All other powers remain in principle with its sovereign Member States. In order for the Community to be able to act it needs to indicate a specific legal basis for its actions (Lefevere and Yamin 1999).

Obviously, the federal governance structure constrains the possible policy options of the Member States as well as the European Community. A distinction can be made on the basis of whether competence in a specific area is *exclusive* to either the Community or the Member States, or whether it concerns a *shared or mixed competence*.

In the field of environmental policy and legislation the division of competence, both externally and internally, between the Community and the Member States is generally seen as a *shared competence*. This also applies to climate change. As a result the UNFCCC has been ratified by the Commission as well as by the Member States and similarly, the EC as well as the Member States are signatories to the Kyoto Protocol (Lefevere and Yamin, 1999).

Shared competence between policy actions at Member State level and at the EU level is, in terms of the legal provisions, mainly a question of interpretation of the provisions in the EC Treaty dealing with *subsidiarity* and the provisions dealing with efficiency of the internal market.

It is generally accepted that concerns over excessive centralisation of decision-making and over the expanding competence of the Community at the expense of Member States formed a significant part of the motivation for introducing subsidiarity into European law (de Búrca, 1999). The subsidiarity principle has become a more integral part of the Community's legal and political culture in the 1990s, culminating in their inclusion in the EC Treaty by the Treaty of Amsterdam. A political statement is now contained in Article 1 of the Treaty of the European Union (TEU), stating that decisions have to be taken as closely as possible to the citizen. Its specific legal form is to be found in Article 5 in the Treaty of the European Community (TEC):

> "The Community shall act within the limits of its powers conferred upon it by this Treaty and of the objectives assigned to it therein. In areas, which do not fall within its exclusive competence, the Community shall take action, in accordance with the principle of subsidiarity, only if and in so far as the objectives of the proposed action cannot be sufficiently achieved by the Member states and can therefore, by reason of the scale or effects of the proposed action, be better achieved by the

> Community. Any action by the Community shall not go beyond what is necessary to achieve the objectives of this Treaty."

The principles of subsidiarity and proportionality are further elaborated in Protocol No. 30 to the EC Treaty, which sets up further guidelines to be examined in determining whether the Community (principally the Commission) should take action in the areas of shared competence. Specifically, paragraph 5 in the Protocol sets out three guidelines to consider whether or not it is appropriate for the Community to take action:

- Whether an issue has transnational aspects which cannot satisfactorily be regulated by Member State action;
- Whether Member State action or lack of Community action would conflict with Treaty requirements;
- Whether action at Community level would produce clear benefits of scale or effect.

These guidelines do not provide a hard legal context to the concept of subsidiarity as the guidelines are clearly open to political contestation. However, with regard to the establishment of a tradable CO_2 permit market in the EU some fairly clear-cut conclusions seem to emerge. First of all, in terms of the transnational aspects of the issue, cross-border environmental pollution such as emissions of greenhouse gases is an obvious candidate for Community action. With regard to the second point, the conflict with Treaty requirements concerns the need to correct distortion of competition and the need to avoid disguised restrictions on trade (specifically, this concerns the economic provisions of the EC Treaty concerning competition, state aid and approximation of laws). The various ways in which CO_2 permits can be allocated to specific enterprises and sectors clearly has the potential of being in conflict with these provisions, given that National Governments could have an incentive to favour certain industries that are exposed to international competition. Furthermore, Member States might be tempted to discriminate against foreign-owned enterprises compared to nationally owned enterprises. Finally, given the large differences between energy economic structures of the Member States and consequently large differences in the costs to mitigate climate change clear benefits of scale or effect could easily be identified as well.

The possible conflict with Treaty requirements can be expected to be the main driver towards action at Community level. In the words of (de Búrca, 1999): "The aspect of expansion and centralisation of Community action which is not apparently taken into account by the legal formulation of the subsidiarity principle is that there is a bias towards integration inherent in some of the economic provisions of the Treaty…". Especially European competition law through Article 86 (old Article 90) in the EC Treaty allocates far-reaching rights to the European Commission. In particular measures taken by the Member State Governments, in the form of financial aids or in the granting of special rights, can be overseen and regulated by the Commission quite independently. This gives the Commission the unusual ability to issue its own directives aimed at all Member States while other bodies, including the Council of Ministers, do not have any formal decision rights under this provision. The Treaty lacks procedural prescriptions for the use of Article 86, providing the Commission with a very powerful instrument against state interventions (Schmidt, S.K., 1998).

Likewise, Articles 94 and 95 dealing with the approximation of laws also have the ability to be used in adopting measures which seem to widen the reach of Community law. As further noted by (de Búrca, 1999), the problem is that the terms of the articles are premised on concepts which are extremely open-ended and in themselves the subject of political contestation. The 'Internal market' is a very general notion and its 'proper functioning' could mean many things, depending on how strong a vision of the internal market is being adopted. The interpretation of Treaty provisions and thus the vision of the internal market that is being adopted is in the hands of the European Court of Justice.

In fact, The European Court of Justice is the actor who may most effectively constrain the Commission. When called upon it can limit the powers of the Commission just as much as the Governments can through a Treaty revision (Schmidt, S.K., 1998). In this respect the European Court of Justice clearly has a political and thus policy-making role as well[60]. The Court of Justice has generally been reluctant to allow the concept of subsidiarity to play any great role, however. (Shaw and Wiener, 1999) note that if there is an emerging common agenda in the Court of Justice about the concepts of subsidiarity and flexibility, it appears to be in a general reluctance to allow these principles to fetter the judicial role. Obviously, this confirms the enforcing role of the Commission in terms of the economic provisions[61].

In conclusion, a clear role for Community action can be identified. Given the nature of some of the economic provisions in the EC Treaty and the rulings of the European Court of Justice in subsidiarity case law, the Commission seems to be in a strong position to negotiate a co-ordinated policy response at the Community level. Negotiated co-ordination may take two forms: ‘Negative co-ordination’, which merely avoids policies that would have negative external effects on other policy areas, whereas ‘positive co-ordination’ attempts to maximise the gains from co-operation (Scharpf, 2000a). Clearly, the economic provisions in the EC Treaty presents the Commission with a stronger case to negotiate a common tradable permit market agreement in terms of ‘negative co-ordination’ than in terms of ‘positive co-ordination’.

5.3.3 Modes of interaction in the European Community

The Commission

The members of the Commission are appointed by national governments and are subject to approval of the European Parliament. As noted by (Kohler-Kock and Quitkatt, 1999), The European Commission plays a decisive role in the European process of policy making due to its exclusive right to initiate European legislation; at the same time the Commission promotes the inclusion of affected interest groups into the process of policy formulation in order to draw upon the expert knowledge of external actors. Furthermore, The Commission acts as enforcement agent of EC lawmaking.

Furthermore, as noted by (Héritier, 1999), in a system of inter-organisational joint decision making such as the European polity, the actors controlling the borders between organisations, the ‘gatekeepers’, are powerful internally because they control the uncertainty arising from interactions with external organisations. In a European context the Commission plays this role.

Thus, the area of climate change was a natural area for the Commission to expand its competence. In this perspective, the expansion of environmental policy in the EU can be seen as a result of functional spill-over from the internal market. By making proposals, facilitate bargaining and supply of organisational skills, the Commission can exercise task-oriented leadership and promote the spill-over process (Gerhardsen, 1998).

The role of the Commission as an independent agent suggests that the main justification of the civil servants in the Commission is to secure efficiency in policy measures and thereby

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[60] Supreme Court justices in the United States, despite clear evidence to the contrary, have often asserted the myth that the Judiciary is non-political.

[61] Obviously, this also creates problems regarding democratic accountability in the European Union.

making ‘the pie as large as possible’. The Green Paper on greenhouse gas emissions trading presented by the Commission follows along these general lines. The scope for Community-wide action is highlighted and the Green paper points to significant savings following a broad scheme compared to unilateral action by Member States. Furthermore, the Green Paper suggests a “learning by doing” approach starting with large fixed point sources of CO_2, where monitoring and supervision of the system is more feasible. Clearly, the approach by the Commission is to establish areas where clear benefits of Community action can be identified while leaving as much scope for action at Member State level in remaining areas. That is a way to avoid deadlock in the future negotiations between the Member States and the Commission.

As commissioners are not up for election, however, they resemble bureaucrats in that they will try to extend their tasks in order to enhance their institutional position. In this respect, Commissioners will try to link climate-policy related measures with other promising policy fields to have room for negotiation (Michelowa, 1998a). This could create a bias towards choosing command-and-control instruments as they tend to enhance the power of European decision-makers in legislation and that of national and regional bureaucracies in implementation, whereas the self-regulation of industry and the use of fiscal instruments render both obsolete (Héritier, 1999).

The Council

Politics, of course, does play a role in the EU, which is most evident in the Council of Ministers. The membership in the Council depends on the results of national elections and as a result of this, the politics in the Council is generally the politics of national interest rather than party or money per se (Schmidt, V.A., 1999). As already noted, the nationally-elected members of the Council of Ministers have powers of approval in relation to the proposals by the Commission.

Thus Council members will try to introduce climate policy measures developed in national interest group interaction. Depending on its composition the Council has different targets – e.g. the energy and finance Councils are much more reluctant concerning climate policy while Environmental ministers can strengthen their domestic position through the adoption of stringent targets (Michaelowa, 1998a).

Both the Council of Ministers and the European Parliament are required to consider the consistency of the Commission’s legislative proposals, as well as the consistency of their own respective amendments and the Council of its common position, with the subsidiarity principle. (de Búrca, 1999).

Finally, as noted by (Kohler-Kock and Quitkatt, 1999), The Council, although probably still the most important European institution in the policy-making process, is difficult to get in touch with due to its inter-governmental and inter-national composition. Interest groups not only must try to convince their own national government of the legitimacy and appropriateness of their demands, they also have to make sure that their interests are supported by a sufficient number of states, either to form a veto-minority, or to ensure a stable majority of EU-member states.

The Parliament

Only in the European Parliament could one talk about the politics of party. But here, the parties are still so underdeveloped and the Parliament itself so lacking in power by comparison with the Council or Commission, that party politics are barely at play. Instead, another kind of interest politics is at work, that of public interest politics focused around groups representing environmental, consumer, and human rights concerns. This is not so much because all members of Parliament are necessarily sympathetic to such issues but because these issues generally have a broader public appeal and are less well represented in the Commission, and therefore serve to increase MEPs' political weight and to gain public attention (Schmidt, V.A., 1999).

The same view is presented by (Kohler-Kock and Quitkatt, 1999), who states that although the European Parliament has gained importance through the expanded application of the co-decision legislative procedure, it still has less influence on the policy-making process than the European Commission or the Council of Ministers. However, the EP is very interested in the communication with interest groups as this is a good opportunity to interact with the electorate and to become a "spokesman" for the voters' concerns, although this applies more to NGOs than to business interests.

Interest group influence on the policy process.

In an area such as climate change, policy information is incomplete and contested, and negotiations between stakeholders are impeded by high transaction costs. Under these conditions, it is likely that voters or members of organised interest groups will be able to oppose policy changes whose immediate impact on their status-quo position is negative (Scharpf, 2000a). This may in turn prevent the adoption of effective policy responses.

The policymaking processes in the European Union are somewhat similar to the pluralistic policy processes in the federal United States. Like the United States, the EU's policymaking processes tend to be open to interest group influence in the formulation process, while the process of implementing the policy is more rigid and regulatory. There are some notable differences between the EU pluralism and that of the United States, however. First of all, the nature of interest group access and influence at the policy formulation stage tends to be more selective and controlled in the EU given the role of its civil servants. Secondly, the policy process in the EU is more delegatory in the implementation stage, given the role of Member States in transposing and administering EU directives (Schmidt, V.A. 1999).

In the EU, lobbying is a highly technical affair, as civil servants make every effort to hear all sides and to base their decisions on purely technical and economic arguments. For European civil servants, the main justification for any policy is practicability and efficiency in promoting collective gains for the EU as a whole. For national politicians and civil servants, whether American or European, by contrast, the policy along with its justification may often sacrifice efficiency for more political goals (Schmidt, V.A. 1999).

But at the same time that the EU's pluralism may be less politicised than that of the US, it is less "pluralistic" in the kinds of interests represented as well as in their access and potential influence. The EU Commission has much greater control over the entire process of interest representation by comparison with the US, where any interest that organises itself is regarded as legitimate so long as it can make itself heard. In the EU, only those interests the EU Commission chooses to legitimise, and thus allow into the process, will be heard. (Schmidt, V.A., 1999).

There are two reasons to expect big European companies and multinationals to gain access to European political institutions without difficulty (Kohler-Kock and Quitkatt, 1999):

1. not only do they represent a considerable power in terms of investment capacities and working places, which is difficult to ignore, but
2. they can also – as single players – more easily adapt to the new European political environment than can trade associations having different members whose divergent interests need to be tuned before common action is possible.

It is further likely that European political institutions prefer to communicate with one single interlocutor rather than with fifteen or more different interest representatives. Therefore, European trade associations often aggregate and harmonise the various national or sectoral interests of their members and hence find it easier to gain access to European political institutions than national trade associations (Kohler-Kock and Quitkatt, 1999). Especially aggregated organised interest groups that represent a large share of the economy and whose members have a common agenda towards climate change mitigation are in a strong position to influence the policy process.

5.3.4 The positions of Member States

The EU Burden Sharing Agreement and possible cost impact

The general position of National politicians in different Member States towards climate change policy is markedly different. This is mainly due to the differences in perceived cost impact of climate change policies as well as being a reflection of National voters' interest in the climate change issue. Differences in cost impact is mainly due to the different income levels of Member States, the different opportunities for reducing CO_2 emissions and different economic growth patterns in the future.

These variations between Member States are reflected in the EC climate policy process. According to (Ringius, 1999), three distinct groups of member countries each play a significant role with regard to EC environmental policy:

- A first group, which might be labelled the ‘rich and green’ member countries, consists of Austria, Denmark, Finland, Germany, the Netherlands and Sweden. Generally, the ‘rich and green’ respond quickly to environmental problems by setting ambitious targets ahead of others. They subsequently attempt to pressure, shame or persuade other member countries to imitate their level of environmental protection.
- Belgium, Britain, France, Italy, and Luxembourg might then be labelled the ‘rich but less green’ member countries. Compared to the ‘rich and green’, they are less concerned about environmental protection and are unlikely to go first in protecting the environment. There is a clear tendency for this group to follow rather than lead others in the environment area. The main reason that they resist strong environmental measures are concerns about the economic cost of environmental protection, lack of strong domestic support and demand for environmental protection, or both.
- The cohesion countries[62] constitute the third group that significantly influences EC climate policy. These member countries, which might be labelled the ‘poorer and least green,’ act mostly as laggards in EC climate and environmental policy. The cohesion countries oppose aggressive environmental policy because of their comparatively low level of economic development, low administrative capacity, and low public environmental awareness.

Another study by (Aaheim and Bretteville, 1999) has looked at the different interests in cutting CO_2 emissions within the EU based on the assumption that interests occur as a result of different perceptions among stakeholders as to what the costs of cutting emissions might be. Sector-based comparisons of the larger countries within the EU suggests that

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[62] The Cohesion countries are Member States with a GDP lower than 90 % of the average GDP in the Member States. Because of this, the cohesion countries are entitled to financial support from the Community to ensure economic development. Today, Spain, Portugal, Greece and Ireland belong to this category (Gerhardsen, 1998).

conflicts arising from announcing emission cuts are likely to be moderate in Germany, the Netherlands and United Kingdom, while the possibilities for conflict in France, Italy and Spain are significantly higher. They conclude that the differences to a large extent can be found by the options for reducing emissions in the electricity sector.

Despite these large differences in the attitudes towards mitigation of climate change, the EU Member States have nevertheless managed to agree on the Burden Sharing Agreement. The Council has listed up a number of national circumstances that have been taken into account when deciding on the Burden Sharing Agreement. The distribution of responsibilities takes account of national circumstances and capabilities in sectors such as electric power generation, internationally oriented energy intensive industry, transportation, light industry, agriculture, households and services. Finally it takes account of the potential for energy efficiency improvement (Gerhardsen, 1998).

If we accept the grouping of Member States in the three groups listed above, it should be expected that the Burden Sharing Agreement represent a transfer of responsibility from Member States with a low willingness to pay for climate change mitigation to Member States with a high willingness to pay. In the following Table 5.5 we have shown the total abatement costs in percentage of GDP of individual Member States where the shaded areas represent the costs corresponding to meeting their Burden Sharing targets if all the emissions reductions are done domestically.

Table 5.5: Total abatement costs in percentage of GDP, 2010.

Total abatement costs in percentage of GDP, 2010

	1990 level, Mt	Burden Sharing	Carbon Value: Marginal Abatement Cost in EUR99 per ton CO2 avoided							
			14	24	38	55	76	100	128	159
AU	55	89%	0,01%	0,03%	**0,06%**	0,10%	0,15%	0,21%	0,32%	0,39%
BE	105	95%	0,01%	0,03%	0,07%	0,14%	0,24%	**0,40%**	0,66%	0,93%
DK	53	88%	0,02%	**0,04%**	0,09%	0,16%	0,25%	0,34%	0,49%	0,63%
FI	51	103%	0,03%	0,10%	0,13%	**0,21%**	0,38%	0,53%	0,70%	0,88%
FR	352	103%	0,01%	**0,02%**	0,04%	0,06%	0,13%	0,21%	0,34%	0,46%
GE	952	81%	**0,01%**	0,03%	0,07%	0,14%	0,24%	0,37%	0,52%	0,69%
GR	71	128%	0,08%	0,10%	0,15%	**0,23%**	0,35%	0,55%	0,83%	1,06%
IR	30	116%	0,02%	0,04%	0,08%	**0,17%**	0,28%	0,40%	0,56%	0,76%
IT	388	96%	0,01%	0,04%	**0,06%**	0,10%	0,16%	0,23%	0,34%	0,47%
NL	153	96%	0,02%	0,04%	0,06%	0,12%	0,22%	0,37%	0,59%	**0,81%**
PO	39	130%	0,01%	0,05%	0,12%	**0,36%**	0,50%	0,65%	0,89%	1,24%
SP	202	118%	0,01%	0,06%	**0,09%**	0,15%	0,27%	0,44%	0,59%	0,75%
SW	50	107%	0,01%	0,02%	0,07%	**0,11%**	0,19%	0,27%	0,37%	0,51%
UK	567	90%	0,01%	0,03%	**0,07%**	0,13%	0,23%	0,38%	0,59%	0,80%
EU14	3068	94%	0,01%	0,03%	**0,07%**	0,12%	0,21%	0,33%	0,49%	0,65%

🟧 Burden sharing, no trading

Source: Report by Capros and Mantzos, 1999, to the EC Directorate for the Environment. The total abatement costs have been derived by calculating the size of the area below the marginal abatement cost curves provided in that report. The Burden sharing Target has been adjusted to correspond to an overall CO_2 emissions reduction by 6.2 % rather than 8 % compared to the 1990 level (see Subsection 5.2.1).

Several observations can be made. First of all, it is clear that the emission reduction percentages in the Burden Sharing target (also shown in Table 5.5) represents a transfer of responsibility from Member States with low willingness to pay to Member States with high willingness to pay compared to a situation with uniform reductions in all Member States

(94 % of emissions in 1990). However, despite this transfer of responsibility it is clear from Table 5.5 that many of the Member States who have taken on a higher emissions reduction target and thus shown willingness to accept higher costs of reducing emissions are actually projected to have low costs in meeting their target. Likewise, some countries from the group called "poorer and least green" are actually projected to incur relatively high costs in meeting their burden sharing target in 2010 by domestic measures only[63]. Obviously, there can be more reasons for this. One possibility is that the Member State negotiators have focused more on the emissions reduction percentages rather than focusing on cost estimates, since the emissions reduction percentages correspond well to the grouping of Member States shown above. Another possibility is that there could be a difference between Member States where the Ministry of Finance or Foreign Affairs has been directly involved in the negotiations and Member States where the Ministry of Environment has been involved. The Ministry of Environment is likely to put less emphasis on economic matters and this has certainly been the case of Holland, even though Holland has a relatively high willingness to pay. Finally, it should be noted that the Member State Governments have been involved in the estimation of the baseline level of emissions in the data used by Capros and Mantzos (data from The Shared Analysis Project). This could create an upward bias in the setting of the baseline, as Member State Governments will have an incentive to develop an emissions baseline that is as pessimistic as possible.

Other explanations as to why the Member States have accepted the Burden Sharing agreement can also be thought of. (Gerhardsen, 1998) has noted that the reason that the Member States finally agreed to this transfer of competence and sovereignty is to be found in the interests of the major actors in the policy arena, which in the setting of a common climate target primarily have been the Commissions and the Council. Both the "green forces" and those that are most preoccupied with economical considerations had a common interest in setting a common EU target.

In conclusion, the EU Member States are markedly different in terms of willingness to pay for reduction of CO_2 emissions. The Burden Sharing Agreement represents a transfer of responsibility from countries with a low willingness to pay for emissions reductions to countries with a higher willingness to pay and as such it is a prime example of an internationally co-operated solution to an environmental problem. Despite the compensation given to some of the poorer Member States the total abatement costs still constitutes a burden on their economies comparable to that of other Member States. This could suggest that some negotiators have focused more on the emissions reduction percentages rather than focusing on cost estimates.

Importantly, implementing an EU-wide tradable CO_2 permit market will lower the costs of meeting the Burden Sharing Target for all Member States compared to domestic reductions alone. This favours the possibility of implementing a common tradable permit market in the EU. Especially Member States that are projected to have very high costs will be very interested in buying cheaper permits in other Member States and Member States with very low costs could be interested in selling permits. This suggests that Member States such as Holland, Belgium, Germany, France and Denmark will be relatively more interested in a common trading scheme than the others will. However, the flexibility mechanisms in the Kyoto Protocol present the Member States with other opportunities to reduce the costs in meeting their Burden Sharing Target. This will allow the Member States to exit to a broader policy arena, which will tend to reduce the zone of possible agreements at the Community level.

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[63] This is also true even if we compare the total abatement costs per capita instead of per GDP.

The choice of policy instrument

National politicians see climate policy as an issue among many others that becomes relevant only if it captures the attention of voters. Generally speaking, voters are mainly interested in the provision of private goods such as jobs. They become interested in climate change policy if urgent local environmental problems have been solved and the general economic situation is good. Several indicators show that the marginal utility of climate policy is positively correlated with income (Michaelowa, 1998b).

Due to the complex nature of the climate change issue, the information costs of voters are very high, which will make voters easily influenced by lobbying. From the outset it is very easy for any interest group to build a case in support of its own views. Emitters lobbies will stress the high costs of climate policy and the enormous loss of jobs while environmental lobbies will stress the possibility of a climatic catastrophe and the possibility for dynamic job creation (Michaelowa, 1998b). Undoubtedly, the prevalence of climatic extremes like the 1997/98 "El Nino" will make voters more interested in the climate change issue, irrespective of whether or not a causal relationship between climatic extremes and climate change has been established.

As a result of the high information costs of voters, politicians will try to develop a bundle of highly visible and easily understandable measures that benefit well-organised lobbies while their costs are distributed as widely as possible, preferably even shifted into the future or abroad (Michaelowa, 1998b). As an example, many Member States have set a target for the share of energy production in the future that is supposed to come from renewable energy sources. Such a policy is highly visible and easy to understand. Furthermore, the beneficiaries of such schemes are concentrated while the costs are widely distributed and in many cases shifted into the future. As a measure to reduce emissions of greenhouse gases, the overall costs of these types of schemes are likely to be high.

On the other hand, market-oriented instruments are more difficult to understand and only have indirect impacts that often accrue after the politicians' term is over. Moreover, lobbies cannot be granted advantages as easily as in the case of regulation and the discretionary power of politicians is also reduced (Michaelowa, 1998b). Thus, the policy horizon can be expected to work against the implementation of a tradable permit scheme. In terms of political acceptability, a tradable permit scheme does, however, have the advantage compared to an emissions tax that it delivers the environmental result with certainty. As a result, it is easier for politicians to claim that "something is being done" by applying a permit scheme rather than an emissions tax.

However, it is important to keep in mind that taxation of energy is also linked to fiscal interests of the Member States. Consumer taxes on import reduce the import bill since all Member countries except UK and Denmark are dependent on import. Furthermore, profits are being transferred from exporting to consuming countries (Andersen, 2000). Thus, taxes can in many cases be used strategically by Member States and this will tend to make Member States less interested in common and co-ordinated measures at the EU level.

In conclusion, it can be expected that National politicians will have a preference for easily identifiable instruments such as renewable support schemes, which can be a barrier for successful implementation of a tradable permit scheme. This is reinforced by the fact that by increasing the number of policy instruments dealing with the climate change issue the actual costs of the climate change policies become much less transparent compared to a situation where only a single instrument is applied. Tradable permits do however have the advantage compared to emissions taxes that they can deliver an environmental result with certainty.

5.3.5 Interest groups and a market for tradable CO_2 permits in the EU

In this subsection we will go through the positions of different interest groups towards climate change and emissions trading, as well as focusing on whether or not any concrete regulation or exemptions are in force today as a result of lobbying.

Industry lobbies make up two opposing groups: those who stand to lose from climate change policy and those who stand to gain from it. They are named emitters' lobbies and abatement lobbies respectively

Emitters lobbies

Generally speaking, lobbies representing large emitters will try to keep costs as low as possible or even gain additional rents. This means they favour subsidies such as grandfathering, preferably with an emissions target that responds to organic growth of the company in a flexible way. Otherwise, voluntary agreements are the favoured instrument. Voluntary agreements are always hard to assess because it is close to impossible to know what would have happened to the level of emissions if the agreement had not entered into force (the baseline level of emissions is counterfactual). For the same reason, (Michaelowa, 1998b) suggest that voluntary agreements allow labelling the autonomous rise in energy efficiency through cost-saving innovation as climate-policy-induced activity.

We will focus our attention on some of the larger lobbying organisations representing the largest emitters.

The European Automobile Manufacturers Association (ACEA)

The European Automobile Manufacturers Association (ACEA) can be regarded as a very powerful lobby. They represent a huge fraction of the EU economy and their interests in the political market are closely aligned. All the major car manufacturers in Europe are members of ACEA.

There are further indications that ACEA is well positioned to communicate with the Commission. For one they favour large-scale R&D-projects jointly funded by industry and the European Union (ACEA Policy Paper, 1997), which go hand in hand with the Commission's objective of expanding the budget. Furthermore, they are able to team up with the Commission in matters concerning distortive taxation on cars by Member States.

ACEA has a clear-cut agenda in relation to fuel prices. Higher fuel prices mean fewer cars sold and the possible ways that the Kyoto Protocol can be implemented will clearly pose a threat in this respect. In 1998, however, ACEA reached a voluntary agreement with the Commission on the reduction of CO_2 emissions from cars, commonly known as the "ACEA agreement". This agreement sets up minimum efficiency improvements (minimum requirement regarding km/litre of gasoline) for cars of various sizes and vintages. The main goal is to achieve an average CO_2 emission target of 140 g/km for the fleet of new cars sold in the EU in 2008 corresponding to an average fuel consumption of 5,7l/100km (ACEA Press Release, 1998). The European Commission will monitor the progress.

In this way, however, the car manufacturers will not be held responsible for emissions growth stemming from an increasing number of cars sold in the future. In other words, it introduces no absolute limits on overall emissions and in this respect it is not compatible with the Kyoto Protocol. Furthermore, any action by ACEA is made contingent on a number of factors (European Commission, 1998):

- car manufacturers internationally will undertake similar action
- the full market availability of fuels with a sufficient quality
- the unhampered diffusion of car CO_2 efficient technologies into the market

- impacts of the strategy on the general economic situation of the European Automobile Industry.

For these reasons, the “ACEA Agreement” can be considered a very favourable agreement for the European Car Manufacturers. The Agreement does specify that The European Commission has a prerogative to introduce fiscal measures but only after taking due consideration of these factors. Clearly, ACEA consider this voluntary agreement to be a sufficient answer to the climate change challenge and hence they do not consider it necessary to introduce other measures to limit fuel consumption or additional fiscal measures (ACEA Press Release, 1998).

The Coal Lobby

Due to the liberalisation in the power sector and the increasing economic interdependence in the 1990s, the budgetary costs of protecting national energy markets to secure energy supply and in turn preserve regional employment has become more pressing. This has had a major impact on coal consumption and the European hard coal consumption has fallen by more than 25 % since 1990 (World Coal Institute, 1999a).

For these reasons, there are only a small number of politically isolated domestic coal producers in the EU today. The relative abundance of alternative cheap fuel sources in the EU in the 1990s and the negative public image of the coal industry reinforce this. In other words, the position of the coal lobby in the EU today is weak.

Coal, being the most carbon intensive fuel, stand to lose significantly from the Kyoto Protocol. The World Coal Institute, being the ‘voice for coal’ in international debates on energy and the environment, is very aware of this threat (World Coal Institute, 1999b).

In a European context, the Coal Lobby has stressed the importance of the Kyoto mechanisms to keep the costs down. Furthermore, they have stressed the importance of a comprehensive approach including all greenhouse gases and sinks. In other words, the goal is to reduce global greenhouse gas emissions and this should be done in the most flexible way possible. This means that there should be no restrictions on technology choice in order to minimise the adverse impact of the Kyoto Protocol. In this respect, implementing instruments that reserve a minimum market share of electricity to be sourced from renewables - a renewables quota - is regarded as the most damaging of any subsidy arrangements (World Coal Institute, 2000). Such a scheme is currently underway in the European Community and this seems to underline the limited political role played by the coal lobby today.

Interestingly, many of the oil and coal lobbies in the USA have chosen a much more aggressive approach towards the climate change issue. They stress that the loss of jobs and the overall negative impacts on economic growth as a result of the obligations in the Kyoto Protocol are enormous (American Petroleum Institute, 2000). Furthermore, uncertainty with regard to the climate change issue should be reflected in the costs that society should be willing to spend on the issue. Preferably, more data should be collected before deciding to take any action. This difference in approaches can most likely be seen as a reflection of the political reality in the USA compared to the EU.

The Gas Lobby

Eurogas represents the European natural gas industry towards the European Union and all other relevant bodies at international level. Clearly, given the ‘right’ implementation of the Kyoto Protocol, it could be a major potential business opportunity for the gas industry. The carbon intensity of gas is about half the size of coal and an increased share of natural gas use is needed to support the Kyoto targets (Eurogas, 2000). In this respect, the gas lobby is almost like an abatement lobby.

EU should ratify the Kyoto Protocol parallel to other major Parties, particularly USA and Japan, to avoid the creation of market distortions. Eurogas is generally supportive of the Kyoto instruments, especially the project based instruments, JI and CDM, which could offer business opportunities for the gas industry (i.e. gas and renewables applications) (Eurogas, 1998).

The EU response measures against climate change should focus on voluntary agreements with the gas industry together with public support for research and development into improved gas technologies and an increasing share of gas-fired combined heat and power plants. Furthermore, fuel switching away from more carbon intensive fuels than gas (i.e. coal and oil) must be promoted (Eurogas, 1997).

Like the coal lobby they object to an energy tax. If taxes on energy are to be used as an emissions control instrument they should be structured as a carbon tax (contrary to the view of the coal lobby), to encourage fuel switching to gas from other fossil fuels (Eurogas, 1998).

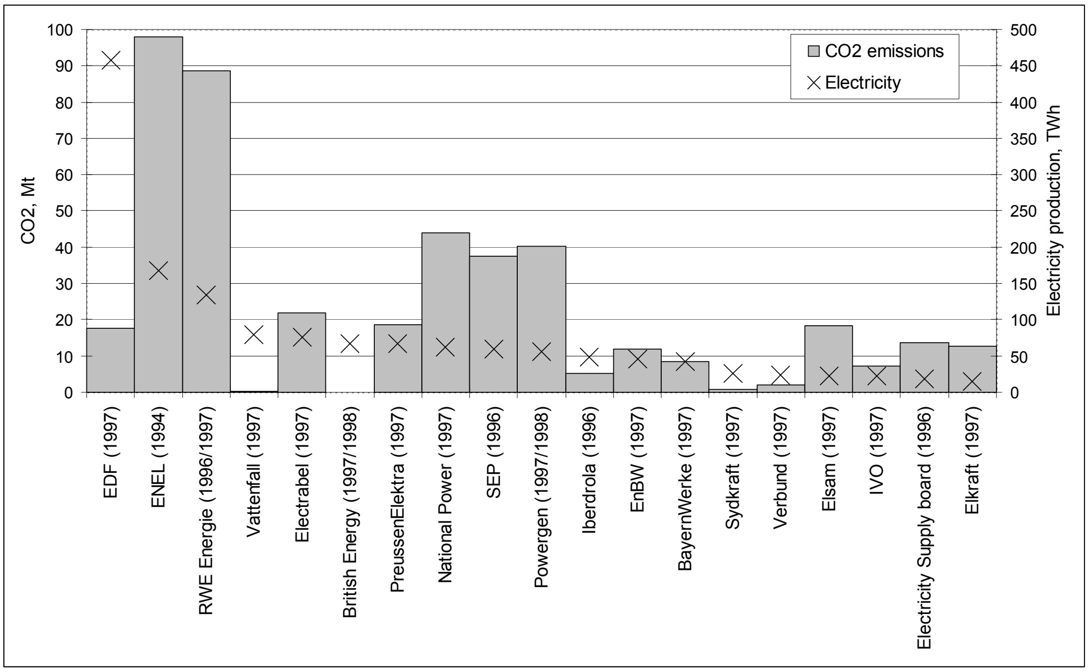
Finally, they are very eager to avoid any specific measures towards the problem with fugitive methane emissions from the gas chain and a voluntary agreement is the right way to deal with the issue.

EURELECTRIC

Eurelectric is the association of the European Union Electricity Supply Industry representing it in public affairs, in particular in relation to the EU institutions, in order to promote its interests at the political level.

As noted by (Greenwood and Webster, 2000), liberalisation of public sector monopoly sectors, classically, disintegrates the unity of homogenous business interest associations, as the structure of members interests changes, typically resulting in the development of specialist niche associations. Hence, a response to liberalisation of the electricity sector in Europe was the creation of specialist sectors representing electricity traders, municipal producers and renewable energy, rather than the monolith international electricity association, EURELECTRIC.

Climate change mitigation is an area where the business interests of the Members of Eurelectric are very different. The opposing interests of the largest electricity producers in the EU become very apparent by comparing electricity production and CO_2 emissions, which has been done in Figure 5.4 below.



Source:Annual and Environmental Reports from individual companies.

Figure 5.4: Production of electricity and CO_2 emissions from largest firms.

As can be seen, there are large differences between companies with a high share of nuclear or hydro capacity and companies with a high share of production from fossil fuels. This clearly limits the ability of a lobbying organisation to influence on policies in this area. However, the organisation can gain some credibility in this policy area because of the lack of a clear-cut agenda.

Eurelectric has been very active in the policy-making area of climate change. The view on emissions trading is that trading should be allowed at the company level where clear title to the emissions traded must be established. They suggest a 'learning by doing' approach to emissions trading where the first phase of emission trading is introduced on a manageable scale. Because the electricity industry is well regulated and its emissions well recorded, it should be among those involved in the initial stages. The initial allocation of permits should involve some sort of grandfathering but any allocation of permits should avoid market distortions and should recognise the overall benefits of a wider use of electricity.

To promote emissions trading as a favoured instrument, Eurelectric has arranged an emission trading game, called Greenhouse and Electricity Trading Simulation (GETS), which has been run among the electricity companies. This has been done to test different types of permit allocations and for further exploiting the mechanisms for electronic trading of greenhouse gas emissions permits (Eurelectric, 2000).

Likewise, Eurelectric is generally supportive of the other Kyoto mechanisms, JI and CDM.

A main concern of Eurelectric is that the electricity sector will be required to reduce emissions much more than other sectors. With respect to CO_2 emissions, the electricity sector should be recognised as a sector that has already done a lot, and in the long term, electricity offers the possibility of minimal emissions. (Eurelectric, 1998).

Finally, it should be noted that many power companies exert a considerable influence on the National policy agendas due to their size and the importance of electricity prices for economic growth. Through the National policy agendas, the power companies can be expected to exert considerable influence through the Council in a European policy context as well. Member States with relatively CO_2 intensive production will undoubtedly opt for grandfathering and less stringent targets for the sector.

Abatement lobbies

The Renewables lobby

Undoubtedly, the renewables lobby has gained in influence over the years although still of minor influence. A recent and significant development is the move of big European oil companies such as BP, Shell and Elf towards the renewable sector. This development show that they are hedging against the case of a strong climate policy in the future, a response that is markedly different from most of the American oil companies. Furthermore, some have taken on voluntary emission targets and BP has organised an internal trading scheme within their own company.

In general, the renewables lobby is not particularly interested in broad market instruments like tradable permits. Tradable permits will result in a price premium on electricity produced from conventional sources, which will benefit the competitiveness of renewables. The size of the price premium is uncertain, however. Furthermore, given that there is a surplus of installed production capacity in many areas of the European Union, the electricity prices are expected to be low for some years to come (prices will reflect the short-term marginal costs of coal or gas generators). So, the price premium resulting from tradable permits is most likely not sufficient to generate significant investments in renewables in the short term.

Renewable lobbies are much more interested in support schemes that will insulate the market for renewables from the market for electricity altogether. The European Wind Energy Association (EWEA) for one is a clear indication of this. EWEA is the only association representing the interests of the wind energy community at an international level. EWEA supports mandatory targets for renewable energies by individual Member States (i.e., a certain percentage of all electricity production must come from renewables). Furthermore, individual Member State should be allowed to maintain their National support schemes, thus recognising the principle of subsidiarity (EWEA, 2000a). This sort of scheme is sure to minimise the potential competition as much as possible, something that will clearly not be achieved by introducing a tradable permit market (or other common market measures aiming at the reduction of emissions at the lowest overall costs).

Currently, a Commission proposal for a Directive on electricity for renewables is underway, which is generally in line with the views of the renewables lobby (EWEA, 2000a). The proposal establishes indicative renewables targets for the Member States and suggests a slow out-phasing of the National support schemes. Rather than being a result of lobbying from the renewables lobby, however, the Proposal is a reflection of the asymmetric interests between the Member States in this issue, and the Commission has been forced to alter its views to avoid deadlock in the negotiations.

Finally, the renewables lobby has proclaimed that the CDM should be reserved for renewable energy projects only, because all other technologies are not regarded as being sustainable (EWEA et al., 2000b).

The Nuclear lobby.

The nuclear industry has been and still is under significant public pressure in some Member States today. Not surprisingly, the climate change issue has provided an important comeback opportunity for the nuclear sector. Several of the large power companies with a high share of nuclear power argue vigorously for the importance of nuclear power in relation to the problem of climate change (EdF, EnBW, British Energy). In their Environmental Reports several companies report figures on how much CO_2 is saved by producing nuclear rather than fossil fuelled electricity (and other emissions such as NO_x, SO_2 and heavy metals).

The nuclear industry in Europe is organised in the European Atomic Forum (Foratom). They present the same views. Given that nuclear energy produces 35 % of Europe's electricity today and that the demand for electricity is projected to grow in the years to come, nuclear has to be part of the solution to climate change. In order for the EU to meet its Kyoto targets, all the flexible mechanisms provided for in the Kyoto Protocol must be pursued (Foratom, 2000a).

However, the CDM should be given particular attention. The view of Foratom is that nuclear energy must be included in the CDM because nuclear power meets the test for sustainable development as required under Article 12 of the Kyoto Protocol (Foratom, 2000b). Clearly, the CDM is considered to provide the best business opportunities for the nuclear sector but it remains to be seen whether or not nuclear power will be included. A tradable permit market in the EU is not of major importance to the nuclear industry because decisions to construct nuclear power plants in the future will be a matter of political acceptability more than anything else.

Environmental NGO’s

Compared to the size and budget of industrial interest groups, the environmental interest groups are only of minor importance in relation to EU policy making (Michaelowa, 1998b).

A whole range of environmental organisations has organised their activities towards the climate change issue in the Climate Action Network (CAN). CAN is mainly concerned about international equity in the distribution of responsibilities between rich countries and developing countries. ‘Hot air’ is seen as a loophole for countries with high emissions per capita to maintain their domestic emissions level (CAN, 1999). They are not opposed to a tradable permit market for the EU power sector, since this can be regarded as domestic action within Annex B. The permits should be auctioned away, however, since they are not private property rights. Generally, though, CAN does not regard economic efficiency as an important issue, and preferably, the Annex B countries should reach their Kyoto targets by reducing emissions domestically only.

5.3.6 Conclusions on options for design

The establishment of a tradable CO_2 permit market in the EU is an area of ‘shared competence’ between the European Community and the Member States. In areas of shared policymaking, the European Commission can insert a strong influence primarily through the internal market provisions in the EC Treaty, which delegates a lot of decisional competence to the Commission. This means that the European Commission can influence on a co-ordinated policy response through ‘negative co-ordination’, which merely avoid policies that would have negative external effects on other policy areas.

As a consequence, the institutional sequence of decisions can be expected to play a strong role. Thus, if a decision is first taken at the European level and a framework is defined which will contain all subsequent national decisional processes, then options for national actors are reduced. If, by contrast, a decision is first negotiated within one Member State, the chances of manoeuvring to resolve interest conflicts are more limited at the supranational level, an the zone of possible agreement is reduced for European actors (Héritier, 1999).

From an efficiency viewpoint, this makes it important that the initiation of a tradable permit scheme in the EU is defined at the Community level from the outset. This will clearly affect the possible ways in which the Scheme can be expanded later on.

The underlying constellation of actor interests in this policy area will clearly have implications for the possible design options as well. First of all, the burden sharing agreement suggests that the interests of Member States towards climate change mitigation are very asymmetric. Inevitably, the initial distribution of permits in any tradable permit system in the EU will somehow need to reflect on the burden-sharing agreement. Secondly, any expansion of the use of fiscal measures at Community level is strongly opposed by some Member States as it is still very much seen as a national responsibility. The failed attempts by the European Commission to introduce a common CO_2 tax in the EU in the 1990s reinforce both these points. Thus, in order to assure that all Member States find it in their own best interest to participate in a tradable CO_2 permit scheme, it seems that the distribution principle from Community level to the Member State level must involve grandfathering. In other words, the revenue stream generated by the sale of permits will be fully redistributed to the Member States.

Furthermore, it is important to note that any action at Community level is constrained by the alternative opportunities for reduction of emissions that are presented to the Member States. Thus, the flexibility mechanisms in the Kyoto Protocol allow the Member States to exit to another policy arena, which will tend to reduce the zone of possible agreements at the Community level.

In order to try to avoid deadlock in the negotiations over a common climate policy the principle of subsidiarity could be applied, thus leaving some conflicts unresolved at the Community level and shifting them to the implementation phase (Héritier, 1999). This would suggest that the overall framework be defined at Community level while leaving as much scope for subsequent Member State action as possible.

The establishment of an overall framework for emissions trading at Community level should secure that the following criteria are met (Lefevere and Yamin, 1999):

- The necessity of common criteria to the subject of private enterprises (including upstream versus downstream) to minimise distortions of competition in the internal market;
- The necessity of a common framework for allocation of emissions allowances to prevent violation of the state aid rules, to prevent indirect discrimination and to minimise distortions of competition;
- A common, or at a minimum, compatible, framework for monitoring, compliance and enforcement: conflicts between Member States can be settled within the existing Community dispute resolution rules;
- The necessity to provide a common tradable unit to provide a common currency to facilitate Community trade;

Two levels in the allocation of emission permits need to be considered. First of all, the allocation of permits to specific sectors can be carried out in such as manner as to advantage certain sectors that are exposed to international competition over others. In this way, Member States could explicitly subsidise certain sectors to advance their export opportunities, which could be in legal conflict with the EC rules that prohibit the use of export subsidies for such a purpose. Secondly, Governments could allocate the permits to private parties in such a way to favour domestic firms against their foreign rivals, which could be in violation with the EC principle of non-discrimination.

The potential ramifications of the allocation of permits to individual sectors by Member State Governments are large, which clearly establishes a need for a harmonised solution to sector allocation of permits in the EU. The second issue mentioned above, i.e. the fact that some Member States will choose to grandfather permits to existing industries while others will use auctions, does not require a harmonised solution to the same extent. Given that grandfathering CO_2 permits to existing industry as defined by some historical baseline is not equivalent to exempting it from the tax altogether (see Chapter 3), the potential distortions of the internal market are much smaller. Thus, it could be left to Member States to decide what distribution rule they choose to apply to private parties. This might lead to a 'race to the bottom', which would consequently result in all Member State Governments choosing to grandfather CO_2 permits to existing industries. However, taking into consideration that CO_2 is regarded as an important tax base by some Member States, and given the potential for reducing other taxes in the economy, this negative conclusion of a 'race to the bottom' could at least be challenged.

Finally, the influence of interest organisations on EU policy making seem to suggest the following:

- Imposing measures in the transport sector that are in compliance with the Kyoto Protocol (notably absolute emission levels) is going to be difficult given the already existing agreement between the European Automobile Manufacturers Association (ACEA) and the European Commission.
- The protection of historical rights to emit CO_2 to the atmosphere will be seen as critical by some power companies dependent on fossil fuels. This is likely to play a stronger role in the national policy arena.
- The implementation of a renewables quota in the power sector will reduce the effectiveness of a tradable permit market although the two instruments can coexist without problems.

In short, a Community-wide 'upstream' CO_2 system, which can be regarded as the most efficient system, is likely to result in political deadlock.

5.4 Design of a tradable CO_2 permits market for the power and steam sector

5.4.1 Introduction

There are a number of reasons to why the power sector can serve as an interesting starting point for a CO_2 emissions trading scheme, including:

- the sector is important due to the large reduction opportunities;
- The companies are relatively well informed of the overall opportunities to reduce CO_2 emissions in the market, which can work to encourage trading early on.
- The liberalisation of the power sector and the international trading of electricity make it important that there are 'level playing fields' between the Member States. This also includes an equal treatment of companies in terms of the environmental frame conditions;
- CO_2 is most easily monitored;
- it is likely to be politically simpler to start with a single sector

Obviously, there are a number of reasons as to why establishing a tradable CO_2 permits scheme for the power sector cannot be the final answer. By excluding some sectors and greenhouse gases from the market the flexibility of the market is clearly reduced. Rather then letting the market find a way to reduce emissions cost effectively you have to establish reduction targets for individual gases and/or sectors based on model forecasts. Model forecasts are likely to be wrong and, as a result, there will be a differentiated treatment of sectors and gases and the cost-effective reduction of emissions will not be accomplished.

However, the main point is to get a system under way that does not prevent a more cost-effective solution to emerge later on. Generally, it seems that the establishment of a tradable greenhouse gas permit market in the EU can follow along two paths:

1. Individual Member States will establish their own schemes that will gradually merge into a larger system
2. The system includes all Member countries from the outset but has limited coverage of gases and sectors.

Given that many Member States are already considering a national trading scheme, the first approach seems to be the more likely of the two. In fact, the first alternative will probably not be limited to EU Member States but can equally well consist of Member States together with non-member States. In any case, the role of EU institutions in such a scheme is going to be limited.

Still, the view taken here is that the EU, being the only international organisation to sign the Kyoto Protocol, provides some interesting opportunities to harmonise some important features in a tradable permit market. Especially when taking into consideration that the allocation of permits can have a large impact on competition in certain sectors.

The EU burden sharing agreement has defined the overall cap for the individual EU countries. The establishment of an EU power sector bubble will require that the EU countries agree on the following:

- Total amount of permits to be put into the bubble (the target level)
- Permit contributions from each country’s emission target
- Distribution mechanisms for permits to individual power plants.

The section is organised as follows. Subsection 5.4.2 will consider the target level for the emissions trading bubble as well as the possible gains from trading in such a scheme. Subsection 5.4.3 considers what entities in the power and steam sector can take part in trading as well as the possibility of market power. Subsection 5.4.4 then goes on to consider the permit contributions from each country's emissions target as well as the distribution mechanism to individual power plants. Finally, Subsection 5.4.5 and 5.4.6 will look at the trade rules and the control system respectively.

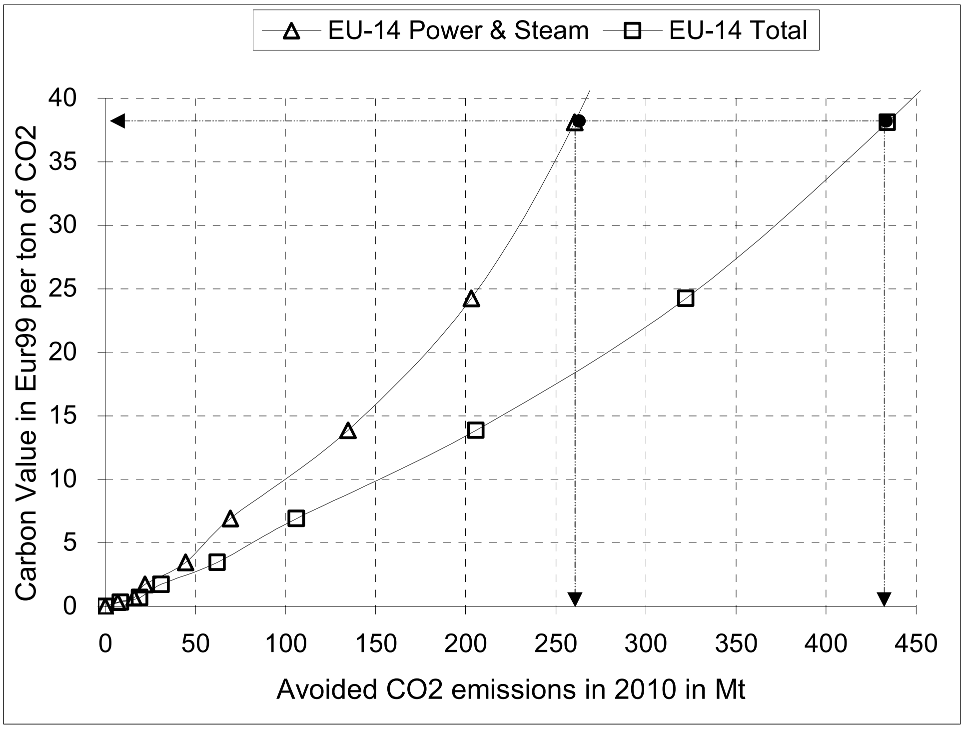
5.4.2 Target level

As mentioned earlier, there is a clear need for a harmonised solution to sector allocation of permits in the EU so the setting of a sector target for the electricity and steam sector should take place at Community level.

Pollutant and reduction goal

The total amount of permits to be put into an emissions trading bubble for the power and steam sector must reflect the expected emissions reductions needed from this sector in order for the EU to meet its overall Kyoto commitment. First of all, this requires that the reduction opportunities of other greenhouse gases be carefully examined. As noted in Subsection 5.2.1, many model studies point to a number of cheap reduction opportunities with respect to methane (CH_4) and nitrous oxide (N_2O) within the EU. If we take the results of The Shared Analysis Project, Vol. 5 and Vol. 11 to be indicative of a "best-informed guess", the cost-effective reduction of CO_2 emissions corresponds to a 6.2 % reduction in the year 2010 compared to the 1990-level. This corresponds to a target level for CO_2 emissions in the EU in the order of 2880 Mt, or alternatively, a reduction of The Shared Analysis Vol. 5 baseline level of emissions in 2010 by some 434 Mt.

Furthermore, we also need to come up with a 'best-informed guess' as to how many of these CO_2 reductions are to take place in the electricity and steam sector. Here we will use the marginal abatement cost curves for individual sectors estimated by using the Primes Model (Capros and Mantzos, 1999) as mentioned in Subsection 5.2.1 (see also Appendix B). The results are confined to the energy system at large and consider that the macroeconomic and sectoral patterns remain unchanged. In Figure 5.5 below the marginal abatement cost curve for the power and steam sector and the total abatement cost curve including all sectors is shown (the figure is identical to Figure 5.2).



Source: Capros and Mantzos, 1999.

Figure 5.5: Marginal abatement cost curves for CO_2

By applying a shadow value to CO_2 emissions coming from the whole energy system of the EU, which captures about 95 % of total CO_2 emissions, the figure shows that a 434 Mt CO_2 emissions reduction can be achieved at a shadow value equal to 38 Eur99/tCO_2. This is equivalent to a price of CO_2 permits equal to 38 Eur99/tCO_2 in a CO_2 trading scheme covering all emissions of CO_2 in the EU.

Preferably, the choice of a common CO_2 emissions target for the electricity and steam sector can be set by applying the same shadow value to CO_2 emissions as is required to reach the overall target, i.e. the 38 Eur99/tCO_2. This would reduce the carbon leakage between different sectors, which can be a real problem for a downstream trading system, especially as long as the coverage of the system is limited (see also Chapter 3).

As can be seen from the figure the model predicts that app. 260 Mt of CO_2 emissions reductions relative to the emissions baseline should take place in the power and steam sector in order to minimise abatement costs. This corresponds to *a reduction in the level of emissions in 2010 by app. 22 % compared to 1990-level*, or alternatively to an overall allocation of permits to the electricity and steam sector in the neighbourhood of *950 Mt CO_2 equivalents*. Due to the many low-cost reduction opportunities in the power sector, the suggested least-cost allocation to this sector requires a much larger reduction in emissions (22 %) compared to the overall reduction requirement (6.2 %). These figures along with simulation in other model studies could serve as a starting point for future negotiations.

Potential gains from trade

To get a picture of the potential gains from trade in a tradable CO_2 permits market in the EU, it makes sense to compare such a system to a situation with no trading at all between Member States. Furthermore, comparing it with other schemes with more comprehensive coverage of emissions will also be interesting. In the following, we focus on emissions of CO_2 alone so the coverage is only a matter of what sectors and geographical areas are being covered by the trading scheme. We also look into how the position of individual Member States changes under different schemes depending on whether they are net buyers or net sellers of permits.

A full-scale trading model in the EU would equalise the price of CO_2 permits throughout the EU. As we just saw, the Primes model suggests that the equilibrium price of CO_2 permits for the EU would be around *38 Eur99/tCO_2*[64] in order to ensure a reduction of CO_2 emissions by 6.2 % compared to the 1990-level. In the following Table 5.6 we have tried to illustrate the differences between a situation with full scale trading of CO_2 permits between Member States and one without. The emissions reductions that correspond to 38 Eur99/tCO_2 in Table 5.6 are the reductions that the individual Member states would choose to do domestically if trading was allowed. As a reference, the permit price (or marginal abatement costs) if Member States were to achieve their burden sharing target by unilateral action (no trading) is shown. In that case, the permit price will not be equalised and permit prices are likely to be very high in the Netherlands, and to a lesser extent Belgium, and consequently, these countries are the ones most likely to be buyers of CO_2 permits in a common trading scheme. Clearly, the larger the difference between the permit price of a Member State in a situation with trading and one without trading, the larger will be the gains from participating in a common trading scheme. Besides Belgium and Holland, the results suggest that Finland, Greece, Ireland, Portugal and Sweden would be net buyers of CO_2 permits while the net sellers will be Germany, Denmark and France. Despite the large emissions reduction requirements of Denmark and Germany, they will nevertheless end up as net sellers of CO_2 permits. Especially the situation of Germany is outstanding. Germany is the only country where the ‘business as usual’ (BAU) emissions of CO_2 are expected to be lower in 2010 than in 1990 and very much lower as well (by 112 Mt which is equivalent to a 12 % reduction). This is mainly due to the German reunification, which has resulted in a large decrease of emissions from former East Germany. Likewise, all the cohesion countries except Spain will end up as net buyers even though these countries are allowed to increase their emissions significantly compared to the 1990 level. The reason is that these countries are expected to experience relatively high growth rates in the coming years, and

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[64] Evidently, this price prediction is just one of many. We refer to chapter 8 for elaboration of different models and their price predictions.

consequently, their ‘business as usual’ emissions will run higher compared to the rest of the EU Member States[65].

Table 5.6: Marginal abatement costs in Member States with and without full scale trading.

Change of emissions in 2010 compared to 1990, Mt											
	1990 level	Burden Sharing	Carbon Value: Marginal Abatement Cost in EUR99 per ton CO2 avoided								
			0 (BAU)	14	24	38	55	76	100	128	159
AU	55	89%	3	-1	-3	-5	-7	-9	-11	-13	-14
BE	105	95%	18	13	10	6	2	-3	-8	-15	-20
DK	53	88%	2	-2	-5	-8	-11	-14	-16	-18	-20
FI	51	103%	21	13	6	4	0	-5	-9	-12	-14
FR	352	103%	41	20	8	-5	-11	-29	-46	-66	-82
GE	952	81%	-112	-171	-191	-220	-260	-298	-335	-369	-400
GR	71	128%	39	26	24	22	19	16	13	9	7
IR	30	116%	13	10	8	7	4	2	0	-1	-3
IT	388	96%	42	21	0	-15	-27	-40	-54	-69	-83
NL	153	96%	54	39	35	30	25	18	9	0	-7
PO	39	130%	26	23	21	18	11	8	6	4	1
SP	202	118%	73	61	41	33	22	7	-9	-20	-29
SW	50	107%	19	14	12	7	4	0	-2	-5	-8
UK	567	90%	5	-29	-46	-65	-84	-106	-132	-160	-181
EU14	3068	94%	244	38	-79	-190	-312	-452	-593	-734	-854

⬚ Trading　🟧 Burden sharing, no trading

Source: Based on estimates by the Primes, Ver. 2 model by (Capros and Mantzos, 1999).

Note: The burden sharing targets of the various Member States has been adjusted slightly upwards so that the overall EU target corresponds to a 6.2 % reduction in CO_2 emissions. The Danish burden sharing obligation is assumed to be based on an import/export corrected baseline so the reduction percentage related to actual emissions in 1990 has been reduced accordingly (as 1990 involved large electricity exports from Denmark).

In Table 5.7 we have illustrated the consequences of a 22 % reduction target for the power and steam sector compared to the 1990 level. Again it is evident that the majority of emissions reductions (‘business as usual’ reductions as well as avoided emissions due to the implementation of the permit scheme) will take place in Germany. Besides Germany, the ‘business as usual’ emissions level will also be significantly lower than the 1990 level of emissions in United Kingdom mainly due to the ‘dash for gas’ following the early liberalisation of the power sector.

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[65] It should be noted, however, that the Member State Governments have been involved in the development of their respective emissions baselines in the Shared Analysis framework, which could create a bias towards higher emissions baselines.

Table 5.7: CO_2 emissions avoided in power and steam trading model

Change of emissions in 2010 compared to 1990, Mt											
	1990 level	Burden Sharing	Carbon Value: Marginal Abatement Cost in EUR99 per ton CO2 avoided								
			0 (BAU)	14	24	38	55	76	100	128	159
AU	17	52%	-3	-5	-6	-7	-8	-8	-8	-9	-9
BE	28	80%	2	0	-1	-2	-3	-4	-6	-8	-9
DK	27	75%	2	-2	-5	-7	-9	-11	-12	-14	-15
FI	22	111%	19	13	6	5	2	-1	-4	-5	-6
FR	72	75%	-3	-10	-14	-18	-12	-16	-20	-26	-27
GE	430	68%	-87	-129	-136	-154	-177	-199	-215	-228	-238
GR	37	110%	18	7	6	5	4	2	0	-1	-2
IR	12	103%	6	4	3	2	0	-1	-2	-3	-3
IT	147	79%	17	2	-16	-25	-32	-38	-44	-48	-53
NL	64	81%	15	5	2	1	0	-2	-5	-9	-12
PO	19	104%	12	10	9	6	1	-1	-2	-4	-5
SP	79	131%	25	24	24	24	24	24	23	23	23
SW	9	72%	9	6	5	2	0	-2	-3	-4	-5
UK	251	70%	-42	-63	-69	-76	-81	-92	-106	-117	-124
EU14	1213	78%	-10	-145	-213	-271	-323	-392	-453	-505	-544

▭ Trading 🟧 Burden sharing, no trading

Source: Same as Table 5.6. The burden-sharing target has been adjusted so that the reduction targets for the power sector corresponds to the same marginal abatement costs as before.

As mentioned above, the potential gains from trade and thus the incentives to trade depend on the difference in marginal abatement costs in a situation with trading and one without. We will use the marginal abatement cost curves shown in Figure 5.5 to come up with an estimate of the potential gains from trade. In the following Table 5.8 the total abatement costs of individual Member States at different emissions reduction levels has been calculated.

In the case where no trading is allowed at all the total abatement costs in 2010 is equal to MEur99 10674 (the sum of all the shaded areas in Table 5.7. On the other hand, if marginal abatement costs are equalised through trading the total abatement costs of the EU is equal to MEur99 7071. In other words, the overall gains from trading in 2010 are app. equal to MEur99 3600 in a scheme with comprehensive coverage.

Again, Germany can be used as an illustrative example. As can be seen from Table 5.7, the total domestic abatement costs in Germany will amount to MEur99 383 without trading and to MEur99 1679 with trading. However, with trading Germany will be able to sell the extra permits created (app. 49 Mt of CO_2) at a price equal to 38 Eur99, which is equal to MEur99 1875. In total, the gains from trading in Germany in 2010 will be equal to app. MEur99 580.

Table 5.8: Total abatement costs in 2010 in full trading model in the EU.

Total abatement costs in MEur99										
	1990 level, Mt	Burden Sharing	Carbon Value: Marginal Abatement Cost in EUR99 per ton CO2 avoided							
			14	24	38	55	76	100	128	159
AU	55	89%	26	61	145	248	359	501	775	948
BE	105	95%	31	90	193	403	713	1163	1929	2719
DK	53	88%	31	90	174	328	499	685	993	1281
FI	51	103%	55	196	271	434	763	1081	1424	1783
FR	352	103%	152	382	784	1074	2265	3785	6048	8276
GE	952	81%	383	756	1679	3535	6042	9346	13220	17576
GR	71	128%	115	147	222	343	534	835	1257	1602
IR	30	116%	22	53	100	217	355	514	720	964
IT	388	96%	156	565	1020	1586	2481	3709	5343	7384
NL	153	96%	79	173	310	553	1033	1766	2818	3882
PO	39	130%	15	57	154	458	629	823	1121	1566
SP	202	118%	95	459	721	1240	2221	3607	4842	6193
SW	50	107%	33	77	223	364	627	865	1185	1645
UK	567	90%	174	485	1074	1976	3437	5760	8880	12000
EU14	3068	94%	1365	3586	7071	12767	21960	34414	50564	67813
					⬚ Trading		🟧 Burden sharing, no trading			

Source: The total abatement costs have been calculated by integrating the marginal reduction cost curves estimated in the Primes, Ver. 2 model (Capros and Mantzos, 1999). The total abatement costs correspond to the emissions reduction levels of Table 5.6.

A similar calculation has been done for all Member States in the following Table 5.9. Furthermore, we have compared the potential cost savings in an emissions trading system covering all CO_2 emissions in the EU with an emissions trading system covering only the power and steam sector, and as a further reference, an emissions trading scheme covering all the Annex B countries. The calculation of the gains from trade in a full scale Annex B trading model is based on a permit price estimate by (Coherence, 2000[66]) using the POLES model, which estimates the permit price to some 66,5$/tC (app. 23 EUR99/$tCO_2$). The same study suggests that the permit price of a world wide free emissions trading model would be 24 $/tC (app. 8 EUR99/$tCO_2$).

First of all, there are clear benefits from allowing private party emissions trading at Community level compared to unilateral action by Member States. A tradable CO_2 permit scheme with comprehensive coverage of emissions within the EU, which would have to be an upstream permit market, could reduce the total abatement costs by some 32 % compared to a system with no trading between Member States. In comparison, a Community-wide system containing only the electricity and steam sector would reduce the total abatement costs by 13 % only.

These differences in abatement costs are, however, without taking advantage of any of the other Kyoto mechanisms. A full CO_2 emission trading system between Annex B countries suggest overall cost savings in the order of 40 % compared to a situation with no trading at all between Member States. Obviously, these gains from trade are not as easily appropriated as within the EU given that no international institution can effectively enforce an Annex B market.

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[66] These estimates consider emissions of CO_2 alone and not the other greenhouse gases.

Table 5.9: Gains from trading CO_2 permits in different schemes.

	Total abatement costs, non-trading		Gains from trading in various schemes:					
			Annex B, All sectors		EU, All sectors		EU, Power sector	
	MEur99	% of GDP	MEur99	%	MEur99	%	MEur99	%
AU	145	0,06%	19	13%	0	0%	0	0%
BE	1163	0,40%	646	56%	425	37%	108	9%
DK	90	0,04%	0	0%	19	21%	14	16%
FI	434	0,21%	95	22%	30	7%	20	5%
FR	382	0,02%	0	0%	89	23%	25	7%
GE	383	0,01%	102	27%	578	151%	266	69%
GR	343	0,23%	75	22%	23	7%	11	3%
IR	217	0,17%	67	31%	22	10%	16	7%
IT	1020	0,06%	101	10%	0	0%	0	0%
NL	3882	0,81%	2696	69%	2147	55%	817	21%
PO	458	0,36%	168	37%	56	12%	49	11%
SP	721	0,09%	58	8%	0	0%	0	0%
SW	364	0,11%	100	28%	26	7%	13	4%
UK	1074	0,07%	131	12%	0	0%	0	0%
EU14	10674	0,10%	4258	40%	3415	32%	1341	13%

Source: Based on marginal abatement cost curves estimated by (Capros and Mantzos, 1999) using the Primes, Ver. 2 model and an Annex B permit price estimated by (Coherence, 2000) using the Poles model.

Furthermore, some observations can be made about the incentives of individual Member States to participate in a given emission-trading scheme. It is evident from Table 5.9 that all the buyer countries will have larger gains from trading if the system is widened to cover all the Annex B countries. Especially the Netherlands followed by Belgium, Portugal, Greece and Finland will have strong incentives to allow for as much flexibility in the system as possible. The situation is reversed when we look at the countries that are potential sellers of CO_2 permits in a system covering only the EU Member States. Especially Germany followed by France and Denmark will have strong incentives to limit the coverage of the system to the EU Member States. The reason is that the seller countries will sell fewer permits at a lower price when the system is widened to cover all the Annex B countries (the price of CO_2 permits in an Annex B trading scheme is not low enough to turn these countries into net buyers). Germany is actually projected to make a net profit in an EU trading scheme covering all sectors because the gains from trade is higher than their total abatement costs in meeting their own emissions target. This net profit will disappear if the system is widened to include all Annex B countries. On the other hand, all EU Member States will have an incentive to include as many sectors within the EU as possible and not limit the system to the power and steam sector. At least that is the case with the emissions reduction requirements shown in Table 5.7, where we have chosen a burden sharing target for the power and steam sector that results in marginal abatement costs identical to those that are expected to materialise in the system covering all sectors. In other words, if the individual Member States are planning to meat their burden-sharing target at the least costs to society they will all have incentives to broaden the coverage of the system as much as possible. As noted, though, the existence of voluntary agreements between certain sectors and the Member State Governments as well as with the European Commission will severely limit the possibility of starting out with a broad scheme.

Obviously, the same observations about possible gains from trade can be made at the company level as well. Firms with many cheap emission reduction opportunities do not want to include other firms with cheap reduction opportunities in the permit market because it can reduce their own profits from selling surplus permits. Unless, of course, the resulting drop in the market price of CO_2 permits after including a group of new firms (or a sector) is large enough to lower their cost of abatement by more than their profit from selling permits is being reduced.

In conclusion, the overall gains from trade in a CO_2 permit market for the power and steam sector are significantly lower than from a system including all sectors in the EU and clearly such a system should not be the final answer. Nevertheless, the system can still provide significant gains from trading.

5.4.3 Target group

The target sector is the power and steam sector in the EU. The questions we need to consider are the following:

- Who can take part in trading? (the boundaries of the trading system)
- The number of sources and companies
- The concentration of permit holdings among companies

The third point is particularly important when grandfathering is used as a distributional principle.

Who can take part in trading?

If abatement costs are to be minimised, it is preferable that the share of total emissions covered by an emissions permit system be as large as possible. However, monitoring and enforcement costs will be incurred by any policy measure and may limit the coverage of emissions sources that is cost effective (as noted earlier). Monitoring costs consist of the costs of measuring emissions. Enforcement costs consist of the costs of assessing whether there is compliance with the policy measure (whether permit rights are equal to emissions) and the costs of prosecuting violators. If the monitoring and enforcement costs required to keep violation within set limits for a source exceed the contribution of the source to reducing total abatement costs, it would be cost effective to exclude the source from control (ABARE, 1998).

The electricity sector is, however, very regulated from the starting point. This means that the fuel consumption and thus the CO_2 emissions can be easily monitored. Furthermore, in relation to the UNFCCC, the emissions of power stations are to be monitored closely in order to assure compliance with the overall emission targets. This is true even without emissions trading and the extra costs of monitoring in relation with a trading scheme are negligible.

The enforcement costs of a trading scheme will also be relatively small. However, given that the system should be expanded to other sectors later on, it is important to explore opportunities to limit the number of participants without significantly reducing the trading opportunities. In Table 5.10 the number of boilers in the EU with different primary fuels are shown:

Table 5.10: Number of units and legal entities with different primary fuels in the EU, 1999.

	Primary fuels			
	Coal	Oil	Gas	Total number of legal entities
Number of fossil fuelled boilers	916	2713	4280	2959
Installed capacity by primary fuel, GW_e	162	83	75	
Number of fossil fuelled boilers > 25 MW_e	695	492	579	375
Installed capacity by primary fuel, GW_e	160	72	66	

Source: UDI database, 1999.

The total amount of fossil-fuelled boilers amounts to 7038, while the amount of boilers larger than 25 MW_e amounts to 1690. The 1690 boilers are in the same order of magnitude as the US Acid Rain Program, which has proven to be a workable number. Secondly, the total number of legal entities is reduced from app. 3000 to 375 while most of the installed capacity of fossil-fuelled boilers is still included in the market.

The lesson learnt from Table 5.10 is that it will be possible to reduce the number of boilers to approx. 1700 and still keep most of the emissions in the system. By doing this the administrative procedures can be developed and prepared for a larger scheme.

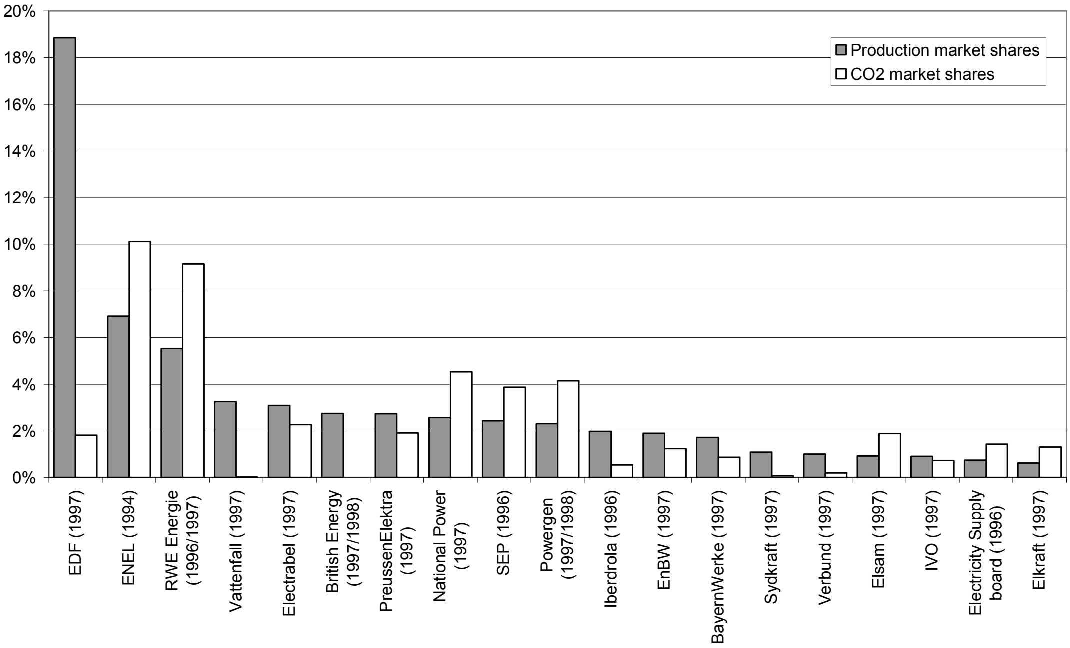
The system should be defined as broadly as possible. Notably, the emissions from heat production and from combined heat and power production should also be included in the market. Otherwise, given that the heat market is a natural monopoly, it might be possible for the CHP producers to allocate a disproportional share of the costs of CO_2 emissions to the production of heat, thereby providing them with a competitive edge in the production of electricity. Of course, the problem with how the costs of CO_2 emissions is shared between electricity and heat is no different than with any other input to production such as fuel, capital and labour. However, including emissions stemming from heat as well as power in the permit market will secure an equal treatment of the two products.

If monitoring costs are found to be too large for some smaller industrial plants these should be regulated by a tax or some other measure to ensure that they are faced with approximately the same cost per unit of emissions.

The possibility of market power

If the permits are grandfathered to the existing electricity producers the concentration of permits on a few large producers can be a real problem.

A simple snapshot picture of the concentration of the EU power industry is shown in the following Figure 5.6. We have illustrated the electricity market shares as well as the CO_2 market shares for the larger power companies in the EU.



Source: Company data collected from 1997 Annual Reports and Environmental Reports. Total production and emission figures from 1996 calculated from IEA Electricity Information 1997, 1998 edition. CO_2 market shares have simply been calculated as the percentage of total CO_2 emissions from power production that stems from individual power companies.

Figure 5.6: Comparison of market shares.

The likelihood of market power being present can also be illustrated by a concentration index for the EU power sector[67]. The possibility of strategic interaction between the permit and electricity markets can be expected to increase with higher market shares. The *m-firm concentration ratio* simply adds up the *m* highest market shares in the industry, which gives the following result for the electricity sector in the EU:

Table 5.11: M-firm concentration ratio for the EU power sector, 1996/1997.

	Production market shares	CO_2 market shares (largest producers)	CO_2 market shares (largest emitters)
R_5	37.70 %	24.76 %	33.70 %
R_{10}	50.59 %	40.07 %	43.56 %
R_{15}	58.32 %	43.17 %	48.52 %

Source: Same as Figure 5.6.

As can be seen, the 5 largest producers have an electricity market share of 37.70 % and are responsible for 24.76 % of the CO_2 emissions. Even though such an index is at best only

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[67] Only under highly simplifying assumptions will concentration indexes (actually the Herfindahl index) be an exact measure of industry profitability (see Tirole, 1990). However, the Herfindahl index requires knowledge of market shares of all market participants. When firms have asymmetric market shares (because of cost differences, say), there is no longer an unambiguous measure of concentration. Furthermore, in a dynamic perspective upholding a high industry-wide profit will require some sort of barrier to entry. Still, we will use a concentration index as an indicator of the possibility of market power being present.

indicative of the possibility of market power being present[68], the numbers indicate that the electricity sector is not unsuitable as a starting point for emissions trading. Especially since some of the largest companies are not among the highest emitters of CO_2.

The electricity sector should not be seen in a static perspective, however. The changing frame conditions following the liberalisation directive for the electricity and gas sectors have started to provoke a response from the industry itself. It seems clear that the size of a company is a shaping factor with regard to the type and dimension of risks that can be accepted and the ability to expand into new markets and businesses clearly depends hereon. So far, we have seen a tendency towards horizontal integration between power companies as well as power companies buying up distribution companies. Within the last few years, several of the larger companies in Figure 5.6 have merged (or have announced plans to do so). This is true for EdF/EnBW, PreussenElektra/Bayernwerke and RWE/VEW. This process is expected to proceed and the result will probably be only a handful of large companies within a relatively short period of time.

Moreover, the experience with the market liberalisation for the electricity sector so far clearly indicates that the lack of third party access to the grid in some cases have resulted in abuse of market power (Wolfram, 1997). The point is, however, that the market for CO_2 permits will extend Community-wide and not be regional in character like the electricity market itself. Furthermore, the establishment of a formal marketplace for the buying and selling of CO_2 permits means that the buyers and sellers of permits will not know the identity of each other. Finally, it should be noted that a large concentration of CO_2 permits on a few sources in itself would not result in possible abuse of market power. As noted in Chapter 3, it is the difference between the cost-effective permit allocation and the allocation that the company receives free of charge from the outset that is the real problem in terms of market power.

The conclusion is that there will be a reasonable number of sources of CO_2 -emissions in the power sector to use it as a testing ground for an EU-scheme of emissions trading. In the longer run, it will be important to broaden the scope of the trading scheme and the inclusion of other sectors will limit the risk of market power.

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[68] The fact that electricity has to be supplied via a grid makes the competitive situation quite unique. As there are no economically viable storage opportunities for electricity, supply has to equal demand at all times. This is coupled with the fact that the flow of electricity in a grid is governed by the law of physics and cannot be allocated in a certain direction. Thirdly, the power loss in a grid rises quadratically with the current and linearly with the distance. What all this means is that the competitive situation of a specific power plant can change dramatically during the day, week or year. At some hours the power plant may be exposed to competition by a range of other suppliers while at another time of day the competitive situation may be more like a local monopoly. The transmission capacities and the way the usage of this transmission capacity is priced determine the extent to which a Danish power plant will compete with a Dutch power plant. Even though a system with free third-party access to the transmission grid is established, securing that future investments in the transmission grid will actually reflect the scarcity in the grid can also be a potentially contentious issue, especially with regard to the building of international transmission capacity. However, as long as primary energy is by large cheaper to move around than electricity, there will be no need for moving around a substantial volume of base load electricity from the southernmost part of the EU to the northernmost part.

5.4.4 Distribution rule

As noted earlier, when having agreed on the target level for a tradable CO_2 permit market for the power and steam sector, we need to consider the two following things:

- Permit contributions from each country's emission target
- Distribution mechanisms for permits to individual power plants.

From a political point of view, distribution (and redistribution) of wealth is of paramount importance. The total yearly amount of CO_2 permits to be allocated to the power and steam sector in EU-15 is suggested to be in the neighbourhood of 950 Mt corresponding to a 22 % reduction of emissions compared to the 1990 level. With a modest value of CO_2 permits at 15 Euro per ton CO_2 this means that the sum to be distributed between the EU Member States will be app. 14 billion Euro per year, considering emissions from the electricity and steam sector alone.

Many arguments can be used in defining the 'just' allocation of CO_2 permits. Among the most important are:

- Existing emitters will claim a prescriptive right to continue their emissions.
- Those parties worst damaged by the limited number of emission rights will claim the need for a compensation
- New entrants will claim the right to be treated equally compared to the existing emitters
- It can be claimed that all citizens have the same right to emit CO_2. This leads to a per capita distribution rule
- The economically 'less' developed EU member countries might claim the right to emit much more than their historical emissions because compared to the strong economies in the EU, they did not emit much CO_2 in the past.

In the longer run, the most logical and fair allocation principle is a per capita allocation principle. Everything else is based on random political power struggles between countries (and sectors). However, in order to achieve a political feasible solution it will probably be necessary to use some kind of free allocation of permits to existing emitters, grandfathering.

There are two different levels of distributional aspects that are crucial in relation to the initial allocation of CO_2 permits:

- the redistribution of wealth between Member States, which relates to the Burden Sharing Agreement;
- and the redistribution of wealth between sectors (between capital owners, workers and consumers).

Some of the economically 'less' developed EU member countries have claimed the right to emit much more than their historical emissions because compared to the strong economies in the EU, they did not emit much CO_2 in the past. In that case, the flexibility of grandfathering might satisfy troublesome EU members by giving them a larger number of permits than their historical emission levels qualify them for, which is exactly what has been done by the Burden Sharing Agreement. The point of using a grandfathered system is to create incentives for a larger number of countries to participate in the system. In this way, 'hot air' can be thought of as compensation to some countries that might not otherwise have participated. The trick is to ensure that the amount of 'hot air' is kept as low as possible while still ensuring participation (Barrett, 1998).

However, any distribution rule based on historic emissions as defined by some base year will become irrelevant in the longer run. This applies at the Member State level (Burden

Sharing) as well as at the sector or company level. Therefore, grandfathering should be gradually out-phased thereby reducing the risk of over-compensating some Member States or sectors. Needless to say this will not happen easily. However, the existing Burden Sharing Agreement only deals with the compliance period 2008-2012 and reduction targets for periods later than that need to be renegotiated.

Permit contributions from each country's emission target

As noted earlier, the allocation of permits to certain sectors by individual Member States can be carried out in such a way as to distort competition in that sector. The importance of the energy sector taken together with the ongoing liberalisation of the gas and power sector will make the energy sector an obvious candidate for a favourable allocation by Member States. For that reason, the allocation of permits to the power and steam sector from each country's emissions target needs to be harmonised.

The least distortive approach is undoubtedly to construct a 'true' EC emission trading bubble from the outset. This would mean assigning 950 Mt of CO_2 permits to the emissions trading bubble, emissions that are to be taken out of the total amount of greenhouse gas emissions assigned to the European Community. The revenue from the sale of the permits goes into the EC budget and the revenue is recycled to the participating companies according to some standardised rules of allocation (or redistributed to the Community at large if deemed possible). The problem with this approach, of course, is the lack of incentives of some Member States to participate in such a scheme. First of all, this approach ignores the political reality of the Burden Sharing Agreement. If the allocation rule is standardised, the redistribution of wealth between Member States will almost certainly differ from the Burden Sharing Agreement and some Member states will stand to loose. Secondly, this approach transfers a lot of decisional competence to the EC level compared to the National Governments, which some Member States will be very reluctant to accept.

A more feasible solution is to let the total amount of permits, that is being allocated to the power and steam sector bubble, consist of assigned amounts from each Member State. The amount of CO_2 permits that is assigned to the emissions trading bubble by each Member State will then need to be deducted from the overall assigned amount of each Member State as defined by the Burden Sharing Agreement. Furthermore, the revenue generated from the sale of CO_2 permits will be redistributed to the Member States corresponding to the number of permits assigned by each individual Member State. In other words, we are considering a revenue-neutral auction at the EC level where some or all of the permits assigned by each Member State are put out for sale. Each Member State will then receive its particular share of the revenue (see Subsection 5.4.5).

To illustrate the consequences of applying different initial allocation principles, we will use the following three allocations of CO_2 emission permits:

- Uniform reduction in all Member States. Each Member State must reduce emissions of CO_2 from the power sector by 22 % compared to 1990.
- An allocation of permits based on the EU burden sharing agreement. Each Member State must reduce emissions of CO_2 from the power sector by their respective percentage compared to 1990. The actual reduction percentages of individual Member States have been proportionally rolled back so that the overall reduction corresponds to a 22 % reduction of emissions.
- Per capita allocation. The total CO_2 emissions from the EU power sector in 1990 reduced by 22 % is allocated to each Member State in relation to their share of the total population in the EU.

Figure 5.7 below illustrates the number of CO$_2$ permits that will be allocated to the power and steam sector from each Member State depending on the allocation principle.

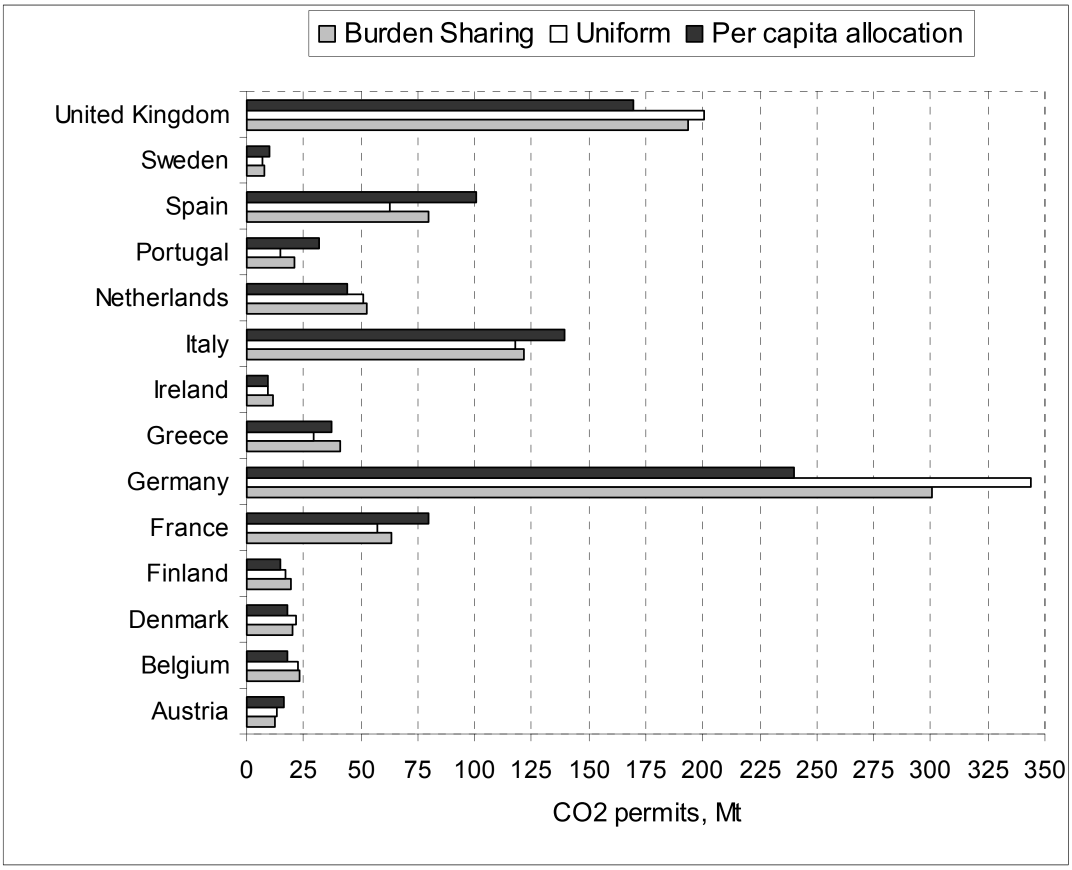


Figure 5.7: Comparison of different initial allocation principles.

It can be seen from Figure 5.7 that there are significant differences between the three allocation principles. Notably, an allocation of the permits based on a per capita principle will transfer a lot of wealth to the power sector in poorer and/or relatively less carbon intensive Member States. On the other hand, the power sector in rich and/or carbon intensive Member States like Germany, United Kingdom, Netherlands, Belgium, Finland and Denmark will loose from the per capita allocation principle.

In Figure 5.8 below we have compared the permit allocations in Figure 5.7 with a baseline projection of the CO$_2$ emissions from the power and steam sector in the EU-countries in 2010. The baseline scenario of The Shared Analysis Project mentioned earlier is used to illustrate the situation.

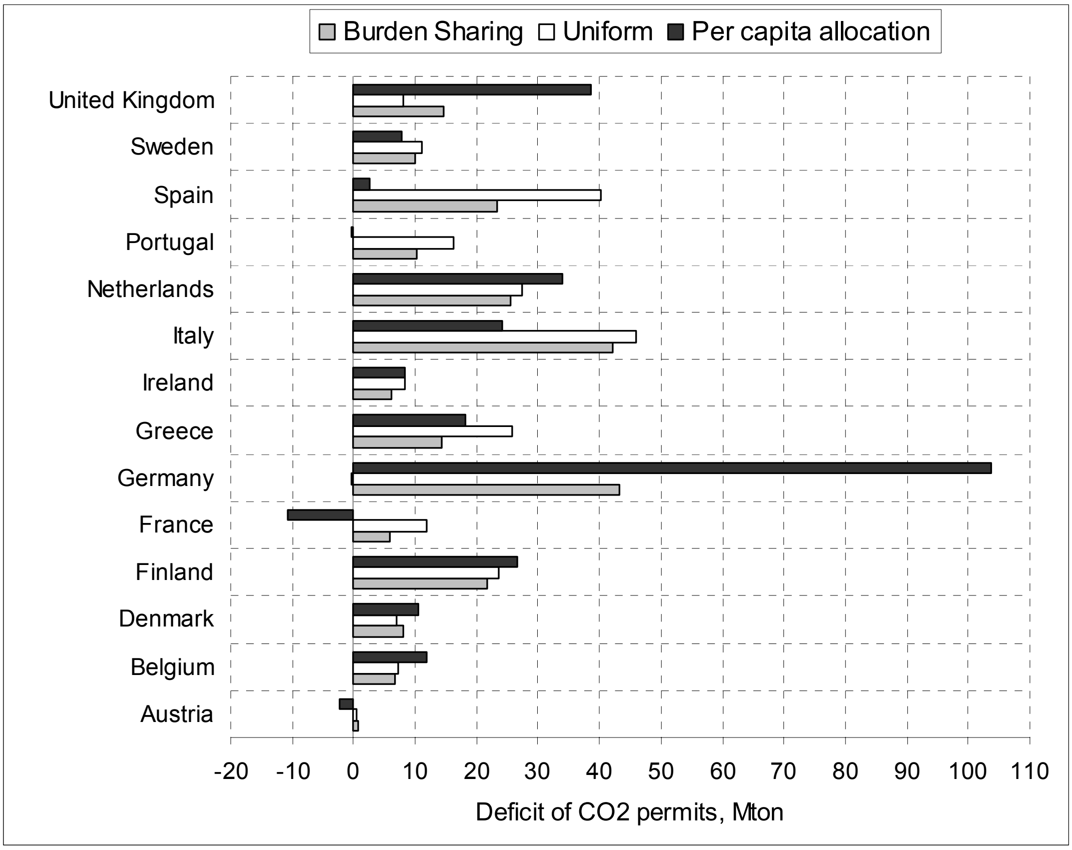
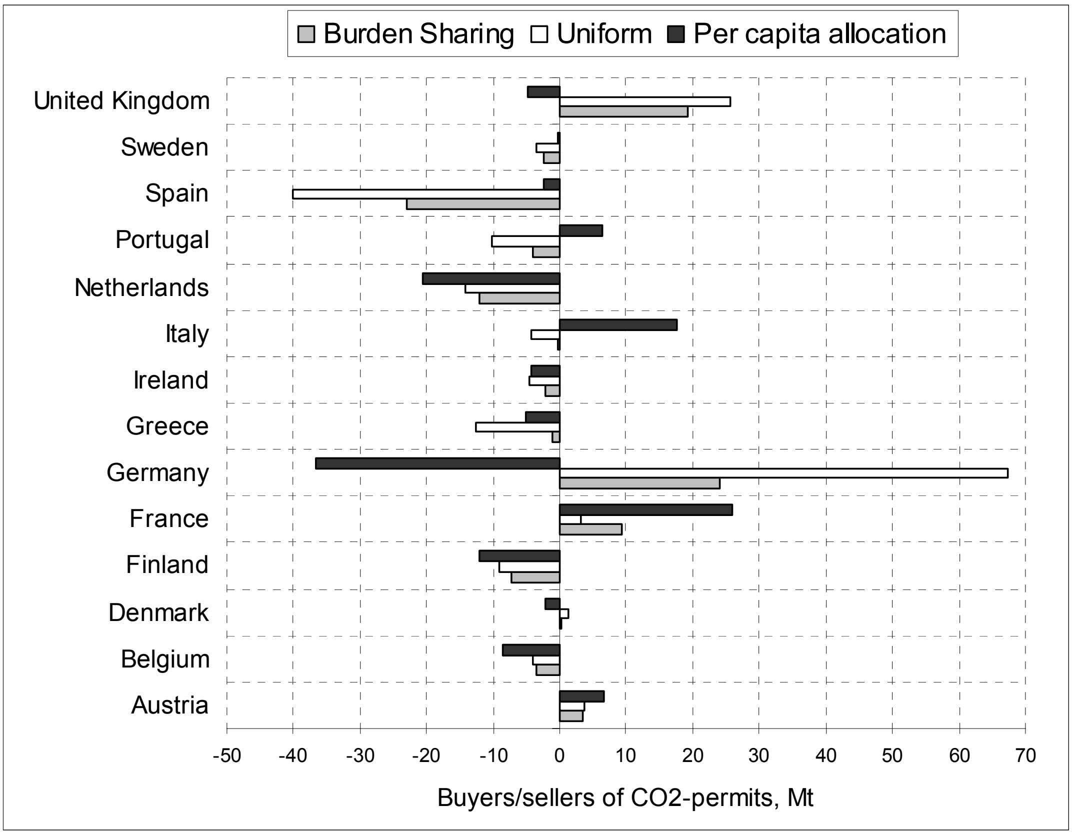


Figure 5.8: Different initial allocation principles and deficit of CO_2 permits in 2010

Figure 5.8 shows that for most countries and allocation principles the CO_2 permits will constitute a binding constraint on the economy in 2010. This is no surprise given that we are assuming that emissions from the power and steam sector are to be reduced by 22 % compared to the 1990 level of emissions. The notable exemptions are France and Austria, who will have 'hot air' for sale if the per capita allocation principle is applied. This means that these countries can fulfil their obligations by doing 'business as usual' and still have permits for sale. Clearly the allocation based on a per capita principle is not a feasible solution, since the power sectors in France and Austria will be massively overcompensated. Presumably, if these countries are still intending to meet their burden sharing targets, some other sectors in these countries would have to undergo massive emissions reductions, so this allocation might not be in the their own self-interest.

Figure 5.9 takes the analysis a step further. Here we have used the marginal abatement cost curves for the power and steam sector in the various EU Member States derived by (Capros and Mantzos, 1999) to see what Member States will be net buyers or sellers of permits in a common CO_2 trading regime. As we saw earlier, the overall emissions reduction target is met at a CO_2 permit price of 38 Eur99/tCO_2, and Figure 5.9 compares the emissions reductions that will be undertaken by each Member State at that permit price with the amount of permits allocated to the sector. If the actual emissions of a Member State are lower than its assigned amount (depending on the rule of allocation) that particular Member State will be a net seller of permits and vice versa.



Source: Own calculations based on (Capros and Mantzos, 1999) using the Primes, Ver. 2 model.

Figure 5.9: Buyers and sellers of CO_2 permits

It is worth noting from Figure 5.9 that Germany despite a high percentage reduction according to the burden sharing agreement is still a large net seller of permits using this allocation principle, whereas Spain, Portugal, Ireland and Greece with room for increasing emissions will still be buyers of permits. Only if the per capita allocation principle is applied will all the richer and carbon intensive countries become net buyers of permits. Germany, Denmark and United Kingdom become net buyers instead of net sellers while Belgium, Finland and the Netherlands will buy even more than before. On the other hand, Italy and Portugal become net sellers instead of net buyers of CO_2 permits under the per capita allocation rule while Spain, Greece and Ireland remain net buyers although to a lesser extent.

The potential problem with an approach based on assigned amounts from each Member State is the possible distortion of competition, given that some Member States will have a large amount of permits compared to what their power sector actually need to cover their emissions of CO_2. Figure 5.9 illustrates that an allocation based on the Burden Sharing Agreement is closer to the economic optimal allocation suggested by the Primes model than the two other allocation principles. In other words, the possibility for distorting competition is reduced. At the same time, however, the incentives for cross-border trading of CO_2 permits are smaller when the permits are allocated according to the Burden Sharing Agreement. In any case, the redistribution of revenue by Member States to the permit-market participants will have to be overlooked by the European Commission (see next paragraph).

As noted, the allocation rule between the Member States should change over time. In our opinion, the distribution of responsibilities between Member States should gradually converge to a per capita allocation rule.

In conclusion, a proportional rollback of the emissions defined by the Burden Sharing Agreement does not seem like a bad starting point. Possibly, this solution is also easier to deal with in terms of the distributional struggle between Member States. The overall emissions target for the power and steam sector bubble will remain a very contestable issue, however.

Distribution mechanism for permits to individual power plants.

We are now left with the question of how to distribute the permits to private parties. A fundamental question, of course, is whether the distribution principle used should be common to all Member States or up to the discretion of the individual Member States. There are two related questions we need to consider in this respect:

- Can some Member States distribute the revenue broadly while others return the revenue to the market participants (i.e., grandfathering)?
- Can Member States choose for themselves how to grandfather the permits or do there have to be a common grandfathering principle between the Member States?

With regard to the first point, it is important to note that under ideal conditions, grandfathering the permits to existing producers entails an opportunity cost on production that is equivalent to that of using an auction. This means that the long-term investment decisions will be affected in the same way under grandfathering and auctions. In this way, the choice of distributional principle will not distort long-term resource allocation and could be left to Member States to decide[69].

This conclusion can, however, be challenged. An important underlying assumption is the existence of perfect capital markets. When the revenue from the sale of permits is distributed to society at large, the tradable permit market works very much like a tax instrument (with the notable difference that uncertainty is on the price of emissions instead of the quantity). This means that the 'out-of-pocket' cash flow of existing emitters will be relatively large and the changes in the balance sheet of the company can be significant. Furthermore, the company might have to resort to loan financing of future investments, and if capital markets are not perfect, this could result in credit rationing. If the 'out-of-pocket' cash flow results in credit rationing like this, the choice of distributional principle will affect resource allocation in the long term.

A much more important issue has to do with the fact that the revenue from the sale of CO_2 permits is very large and can be used to offset other distorting taxes in the economy. As suggested by several studies, there are large welfare gains if the revenue is used to reduce other taxes in the economy rather than being given away for free to the existing emitters. From a perspective of fairness this is also a better solution, as the revenue is distributed broadly and reflects the fact that every citizen has the same right to emit CO_2 into the atmosphere. For these reasons, *grandfathering should be outfaced*. One way of achieving this could be to gradually convert the units assigned to the bubble to EC assigned amount units. The revenue from the sale of these units would then go into the EC budget and the revenue should be distributed to society at large.

From the outset, however, the initial distribution principle that many Member States will choose will undoubtedly involve some sort of grandfathering. Obviously, if some Member

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[69] Rather, it is the overall allocation or permits that really matters for long-term resource allocation.

States choose to distribute the permits to the market participants it is rather unlikely that other Member States will not do the same. In this way, every existing emitter will receive the right to emit a certain amount of CO_2. The second question raised above concerns the issue whether or not the principle used for grandfathering the permits should be common to all Member States or not.

Leaving it to the Member States requires that the power sector is reasonably competitive, otherwise some companies might be able to use a favourable allocation of CO_2 permits to gain market shares in the power market. As we have seen, the future situation in the power sector might not be that competitive. This could be a problem, especially since the distribution of permits between Member States is based on the premise that all Member States must have incentives to participate in the scheme. This means that some Member States will receive a relatively large proportion of the revenue and this revenue could be redistributed to domestic producers in a way that could help them to expand production internationally.

The least distortive option would be to decide on a common distribution principle to the market participants. Notably, an allocation of permits to individual power plants based on a percentage reduction of the current size of emissions is to be preferred over an allocation principle based on past emissions, i.e. emissions in 1990. This ensures that power plants or blocks, which are shut down or mothballed today, are not given rights to pollute, and likewise, that power plants, which were not in operation back in 1990 will still receive their fair share of the permits. This, on one hand, leaves little room for power companies to exercise potential market power and on the other hand will be able to achieve a given reduction in CO_2/kWh with the lowest negative impact on competitiveness.

Of course, politically this introduces a new set of problems. Firms that have lower emissions today will argue that this is a result of their dedication to reduce emissions and therefore they should be compensated for their early action.

A common allocation principle could ensure that the way the permits are allocated to individual power plants is not in violation with the EC rules on state aid. The allocation of permits to private parties could be in violation with the EC rules on state aid if the revenue created from selling permits is higher than the total abatement costs that the emissions reduction target inflicts on that particular company. In other words, if the company can make a net profit from taking on an emissions reduction target defined by the Member State. If it were left to the discretion of Member States, the Commission would have to approve of the principle chosen by each Member State. As noted, the Commission can overlook the EC rules on state aid quite independently. This could mean that some Member States would not be able to redistribute all the revenue to the participating parties because it would be in violation with the EC rules on state aid.

In conclusion, it will be preferable with a common grandfathering principle but leaving it to the discretion of Member States with regulatory oversight by the Commission is a more feasible solution. In any case, there should be a common agreement as to how grandfathering can be outfaced from the system over time.

5.4.5 Trade rules

A CO_2 permit market can be thought of as a public mechanism for buying and selling permits. This public mechanism is supposed to provide a solution to the following aspects:

Transaction aspects. The market will offer a method to perform economic transactions, which means buying and selling of CO_2 permits and clarifying issues such as property rights and contractual obligations in relation hereto.

Information aspects. The market will offer a method to collect and dissipate information on trade conditions, mainly price information, which means that potential buyers will gain information on price and quantity of CO_2 permits for sale. Likewise, potential sellers will know the demand for their permits.

The following will build on Chapter 3 and 4 to suggest the trade rules that need to be determined by the EC and its Member States in order to make the market function properly.

Definition of a CO_2 permit

By an individual permit we will understand a right to emit 1 tonne of CO_2. Each permit will specify what particular Member State has issued the permit and the year of issue (vintage year). Once the permit has been used to show compliance it will be withdrawn from the market. This means that for every new compliance period the permits will be reissued. As long as the permits have not been used to show compliance they stay in circulation and the permits are all identical no matter what vintage year is actually written on the permit. In other words, the permits can be banked for later use.

The US SO_2 legislature specifies that the entitlement is not a full property right but rather a limited permission to emit sulphur dioxide. This allows the government to make changes over time without any compensation to the market participants. This approach is also valid here to a limited extent.

Obviously, any changes in the entitlement to CO_2 permits have to be done with extreme caution, since a full property right is essential for a well functioning market. However, we need to distinguish between two things:

- changes to the overall allocation of permits to the trading system, which in turn determines the market price of CO_2 permits,
- and changes to the distribution of revenue between market participants and society in general.

With the liberalisation of the power sector it will be the market value of the assets that matter rather than the book value. The same will be true for tradable CO_2 permits. What matters for investment decisions is what the permits can be sold for today and for years to come. For that reason, it is important that a credible economic value of CO_2 permits is established for a considerable time period reflecting the long investment horizons in the power sector. Therefore, *any alterations in the overall allocation of permits to the permit market must be the responsibility of the EC and not the market participants.*

However, any enlargement of the trading scheme to include other sectors, gases or even countries will affect the equilibrium price of CO_2 permits as well. This is unfortunate because investments in cleaner technologies undertaken prior to the enlargement can turn out to be stranded. This problem is inherent in all tradable permit schemes that start out with less than complete coverage of emissions and it is not easily dealt with.

With regard to the second point above, we noted earlier that any distribution principle based on historic emissions will become irrelevant in the longer run and the gradual out-phasing of grandfathering will reduce the risk of overcompensating traditional emitters. Preferably, the gradual out-phasing of grandfathering should be determined from the outset. However, given that changes in the distribution principle will not affect the market value of the companies' assets but only the book value, the Authorities can make minor changes to the distribution principle that was not agreed upon from the outset without compensation.

Duration of compliance period

The market should be able to allocate efficiently between market participants as well as over time. To achieve efficient allocation over time the market participants should be allowed to allocate emissions freely over time. This would include banking (as noted) as well as borrowing of emissions. Banking means that any permits that are not used to show compliance during a specific time period can be carried forward to subsequent periods while borrowing means that future permits can be carried forward in time to show compliance in the current period.

Borrowing is only to a limited extent sanctioned by the Kyoto Protocol by the establishment of 5-year compliance periods (so far only one compliance period, namely 2008-2012) and within this compliance period countries are allowed to allocate their emissions anyway they choose. As noted earlier, borrowing of permits from future allocations of permits also poses a lot of problems in terms of credibility of the system. For these reasons, borrowing of permits is going to be limited.

In addition, the longer the compliance period the less liquidity can be expected in the marketplace, which could mean that the market price of permits would not be credible. *The duration of the compliance period is therefore suggested to be limited to a year.*

However, it is important to limit the adverse effects following from no or limited access to borrowing of permits. A potential problem with a trading system confined to CO_2 emissions is that once the opportunities for fuel switching are exhausted, the short run supply curve of CO_2 permits may be very inelastic. This is due to the fact that unlike SO_2 emissions there are no 'end-of-pipe' solutions for reducing CO_2 emissions and further reductions in CO_2 will require substantial investments in new technologies with low or no CO_2 emissions.

This could be a real problem if the compliance period is short. Especially, since the economic business cycles of the EU Member States are expected to become more aligned there could be a cyclical tendency in the pricing of the permits. In years with strong economic growth in the EU, the prices of the permits would be high and vice versa in periods with low economic growth. Given the long investment horizons of power projects this situation is far from ideal.

The size and heterogeneity of the EU electricity market will alleviate this problem, though. First of all, the weather conditions, such as mean temperature and precipitation, will fluctuate in the different areas of the EU. Yearly variations in mean temperature have a huge impact on electricity demand and yearly variations in precipitation will influence on the supply opportunities of hydropower stations, which in turn will influence on the residual demand for conventionally produced electricity. These variations are only correlated to a limited extent between the Member States and will therefore introduce some flexibility into the system.

Still, it would be preferable to allow for inter-temporal flexibility in the timing of emissions reductions. If borrowing is not allowed, the inter-temporal flexibility in the system is linked to the level of the fine for being in non-compliance. Obviously, the maximum price that anybody is willing to pay for extra permits will never be higher than the level of the fine. Thus, the level of the fine will put a price ceiling on the permit market. A low level of the fine will introduce more flexibility into the system because essentially the EC has extra permits for sale at a price equal to the level of the fine. In other words, the permit system will start working like a price instrument (tax) once the price ceiling has been reached. Unless the correlation between economic growth and CO_2 emissions becomes significantly weaker than today, the price of the permits would sooner or later approach the level of the fine. Introducing a permit market will however lead to innovations in carbon reducing technologies and will therefore tend to make the link weaker.

In sum, the fine for non-compliance should not be set too high because in that case the costs borne by the regulated entities can be potentially enormous (large dead-weight loss to society). *A suggestion could be app. 40 EUR/tCO_2.*

At the end of each annual compliance period the account of every individual market participant is settled. A one-month 'true-up' period is allowed and during this month the emitters have the opportunity to 'fine-tune' their stock of emissions with their accumulated emission level during the preceding year. If the actual emissions are lower then the current permit holdings the surplus permits are credited to next years account. If the actual emissions are higher than the current permit holdings a fine is paid for the excess emissions.

Auction design

We propose that the EC should undertake a yearly EU-wide auction where all or a large share of the permits are put out for sale. The inclusion of a large share of the permits in the auction will secure equal access to the permits in all the Member States and thus an efficient allocation of the permits. Furthermore, this will provide price information and transparency to the market, which is important especially in the beginning when market participants are not that familiar with the market.

By putting all the permits out for sale at an auction we are separating the issue of allocation from the issue of distribution. The revenue from the auction is redistributed to the Member States according to the overall distribution of responsibilities that is decided upon. As noted, the actual redistribution of the revenue to market participants could be left to the discretion of Member States with regulatory oversight by the Commission.

We propose to use a non-discriminatory pricing principle for the auction where all bidders of permits pay the clearing price for the permits (provided that their bid was below the clearing price). The non-discriminatory auction provides important information to the market and works fine except in the case of a few very dominant market actors[70].

To make sure that there are buyers as well as sellers in the permit market and that the risk sharing capabilities of the marketplace will come into play, everybody should be allowed to participate in the market. Obviously, this includes brokers and traders as well. Brokers will offer arrangements (bilateral contracts) that hedge the price risk of buyers and sellers in the permit market. Experience from the US SO_2 market have shown that contracts that address the volume risk directly and not necessarily the price risk are likely to be introduced, i.e. weather hedges. Traders (or speculators) on the other hand, take open positions in the permit market and speculate in future price changes. This adds liquidity to the market and reduces the difference between bids by buyers and sellers.

Like in the US the system could start before the first compliance period. Possibly, the regulators should also release permits that are valid in the current year as well as permits that are valid in years to come (i.e. selling vintage year 2008 permits and vintage year 2013 permits at the same time).

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[70] Neither a non-discriminatory (uniform) pricing principle nor a discriminatory ("pay-your-bid") pricing principle is fully efficient because it can be shown that bidding your true demand curve is dominated by other strategies. If market power is not significant, the uniform pricing principle is nearly efficient (See Cramton & Kerr, 1998).

5.4.6 Control system

The purpose of the control system is to make the whole trading scheme credible by assuring that there is a one-to-one correspondence between a permit to emit one tonne of CO_2 and the actual emission of one tonne of CO_2. The control system consists of two major parts, monitoring of emissions and enforcement. In this respect, it is important to clarify the relation between the overall compliance of Member States and the compliance of private entities included in the permit market. This leaves four cases as shown in Table 5.12.

Table 5.12: Various elements of a control system.

	Monitoring and verification of emissions	Enforcement
Market participants	Emissions must comply with permits held by market participant	National/EU sanctions against market participants
Member States	States must comply with Kyoto/EU burden sharing targets	EU/UNFCCC sanctions against states

One of the major issues in designing a single sector, single gas trading scheme will be the relation between the total national (or European) reduction targets and the target for the electricity sector. To make the emissions trading market as credible as possible, it is necessary that the total emission limit that applies to the permit market is known in advance – at least – for each commitment period and preferably much longer. This means that the target for the power and steam sector trading system should not be changed because of lack of compliance in other sectors, i.e. transportation.

The only way such an influence could come about would be if governments – or other entities – buy emission permits and withdraw them from the market to be used to comply with emissions in other sectors. In this way, the electricity sector will be compensated for tightening of emission targets.

Another issue is the relation between the national emissions targets as defined in the Burden Sharing Agreement and the overall EU target. Or in other words, if the EU will take the role as a party to the UNFCCC on behalf of all the Member States. In the context of a European-wide scheme of emissions trading it would be natural that the ultimate responsibility for ensuring compliance will be on a European level.

It is the general assumption, however, that monitoring and enforcement in relation to the companies from the starting point will be a Member State task, because the Member State Authorities are equipped with the necessary regulatory power in relation to the private parties. On the other hand, the system could gain in general efficiency and credibility by the establishment of a common European institution. This could be EEA (European Environmental Agency).

Monitoring and verification of emissions from market participants

The direct measurement of CO_2 emissions is expensive. As noted by (UNCTAD 1995), it is also unnecessary since accurate estimates can be made on the basis of the volume of carbon-based fuels that are burnt. All that is required is therefore that the flow of fuels is being monitored.

There is no doubt that in the case of gas-fired plants, the measurement of fuel will be a cheap and efficient way to calculate the total CO_2 emissions. The scope for cheating will be low, as there is a close relation between fuel input and electricity output for a given plant.

Both amounts can be found in the financial accounts of the company, accounts that are verified by external auditors.

For coal fired plants a number of complications are involved in calculating the emissions from the fuel input.

To estimate CO_2 emissions from the content of carbon in the fuel it can be necessary to distinguish between coal of different origins as the carbon content can differ substantially. As an example, the yearly weighted average of CO_2 emissions from the types of coal used by the Energy Company ELSAM is 95 grams of CO_2 per MJ. The emissions from the different types of coal lie in the range of 87 grams of CO_2 per MJ as is the case with coal from Canada and a maximum of 100 grams per MJ as is the case with coal from Great Britain. The variation in the yearly CO_2 emissions per MJ from any particular power plant is low, though (lies within a range of ± 1 %). If the emissions were to be reported every month the resulting variation in CO_2 emissions per MJ would be higher. This would make it practically harder to come up with a precise estimate of the CO_2 emissions, since closer attention must be paid to what type of coal is actually being used at every given point in time. This is not always obvious, as different types of coal usually get mixed when lying on a storage yard.

It also must be taken into account that part of the coal is left unburned in the ashes. This share varies between individual plants depending on the design. For pulverised coal firing the typical fraction of unburned is 5 %, but within a range of 3-10 %. For grate firing the typical fraction of unburned fuel in the ashes is as high as 30-40 %. Grate firing is a technology that is 'dying', but a number of small, mainly industrial plants still exist.

Finally, there is also a marginal emission of CO_2 from limestone used for desulphurisation.

As described, there are a number of uncertainties that must be handled if fuel input shall be used to calculate CO_2 emissions from coal fired plants. These uncertainties have to be weighted against the uncertainties of direct measurement. It is well known that it is quite easy to make very accurate measurements of the concentration of CO_2 in a gas, but measuring the flow of flue gas is much more uncertain.

Following another line of argument, (ABARE, 1998) notes that it would be desirable to base required permit holdings on a direct measurement of emissions since technologies are being developed for the post combustion capture and disposal of carbon dioxide emissions. However, these technologies are far from being economical at the moment due to large energy and investment costs. The argument is thus not very strong.

In conclusion, calculating the CO_2 emissions from the fuel input is a very cheap and efficient method, especially for a gas fired plant. This will be relevant for many of the smallest installations and thus not put a lower limit to the size of plant that can be part of the trading scheme. For coal fired plants the uncertainties can be so large that direct measurement should be preferred. These installations are usually large and the extra costs for measurement of CO_2 emissions will be of minor importance. As long as the levels of uncertainties are comparable (in fact, as long as the uncertainties are not biased so that they sum out over time), the use of different methods of measuring will pose no difficulties.

The emissions data will be collected by means of self-reporting by the companies.

The most important role to be played by EC institutions will be to establish minimum requirements with regard to the measurement of emissions while to a large extent leaving actual monitoring and verification of emissions to the Member State Governments.

At present two monitoring mechanisms of national emissions exists:

- National reporting to the secretariat of the UNFCCC
- EU monitoring mechanism

The national reporting to the UNFCCC is at present a relatively slow reporting system giving a time lag of 1-2 years between the timing of emissions and reporting. Even though this reporting may be speeded up it will probably continue to be too slow to serve as market information.

Despite its modest and technical name, the EU 'monitoring mechanism' must be considered the cornerstone of the EU climate policy in the second half of the 1990s. Adopted in June 1993, it obliges member countries to develop national programs for reducing greenhouse gases while the Commission evaluates the data provided by the member countries. An important feature of the monitoring mechanism is that it introduces additional and more specified commitments than the FCCC. However, inadequate reporting by the member countries has so far reduced its effectiveness. (Ringius, 1999)

The EU monitoring mechanism could be developed to be the reporting procedure for the emissions trading scheme. At least, the annual reporting of emissions from the power and steam sector must be faster than today. The final data for the preceding year should be available in January in order to allow for a true-up period for the emission rights. To give the best possible market information it is proposed to report and publish emission data for companies included in the trading scheme on a monthly basis. This will mean speeding up of the existing reporting procedures, but it should be possible to do this with only minor extra costs.

Finally, verifying that the emissions reported by companies are correct is most easily done by the Member States. The Member States could verify the reported emissions on a yearly basis and submit their result to an EC institution. Obviously, the Member States might have incentives to cheat as well, however, the scope for cheating should be relatively small with respect to the power and steam sector.

Enforcement

If emission trading is organised as proposed above with a single emissions target for all market participants, the issue of enforcement is 'reduced' to securing the individual compliance of all actors.

In order to verify that the actual emissions by market participants actually correspond to their permit holdings, the following question can be raised: What are the differences between what is required in a system with emissions trading and one without? Clearly, in relation to the Kyoto protocol monitoring of emissions is necessary in both cases. However, when trading is allowed the actual emissions have to be compared with the current balance of CO_2 permits so the trading of permits needs to be recorded at a central registry. This function can be computerised and should not give any theoretical or practical difficulties, which has been clearly demonstrated by the US Acid Rain programme.

This central registry must be at the EU level. Data for emissions may be collected by national authorities but shall at once be transmitted to a European institution. Through the trading system a registry of permit holdings of each of the actors in the market is established. Likewise, through the monitoring process, a registry of the actual emissions of each actor is established. The 'trick' of the enforcement is to compare the two numbers for each actor and have the necessary authority to deter actors from breaking the emission limits.

The first step will be to establish sanctions against market participants who cheat on their reporting of emissions. In a European trading scheme the national authorities will – today – be the first choice for the practical enforcement because the authority for imposing sanctions on the actors will rest at the national level. The sanctions must not be seen independently but in conjunction with the probability of being caught if you cheat. Taking into consideration that the likelihood of detecting cheating is pretty high in this trading scheme, it will probably not be necessary with sanctions such as prison sentences to deter cheating. A high monetary sanction should be sufficient.

The next step will be to establish sanctions against market participants exceeding their permit holdings. The suggestion here is straightforward. Market participants whose emissions are exceeding their current permit holdings must pay a fine for their excess emissions. The level of the fine must be the same in all Member States. Otherwise, there could be carbon leakage to areas with lower fine levels.

This raises the question of the level of the fine. As noted in the previous subsection, the level of the fine is the maximum price that anybody will be willing to pay for an emission permit. If the fine is kept low, the emissions trading scheme will work very much like a price instrument (tax), whereas a high fine will secure that the emission target is reached (at any cost to society). Thus, a relatively low fine is proposed for the trading scheme, and the fine could be set at in the neighbourhood of 40 EUR/tCO_2. The fine payments could be used by the enforcement institution to buy emissions permits internationally, in order to secure that the overall emission target of the trading system is met.

To sum up, Figure 5.10 below tries to give an overview of how the institutional framework of a ‘downstream’ trading model involving electric utilities in the EU might look like. In the figure, a lot of political authority is delegated to an EU enforcement institution (possibly EEA). It is important, that one central authority, like the EPA in the US, enforces the market so that local (or national) authorities are not responsible for the control and thus are tempted to protect their own firms. In the case of the EU, the European Environment Agency could be an appropriate choice for the enforcement of property rights in a potential CO_2 market.

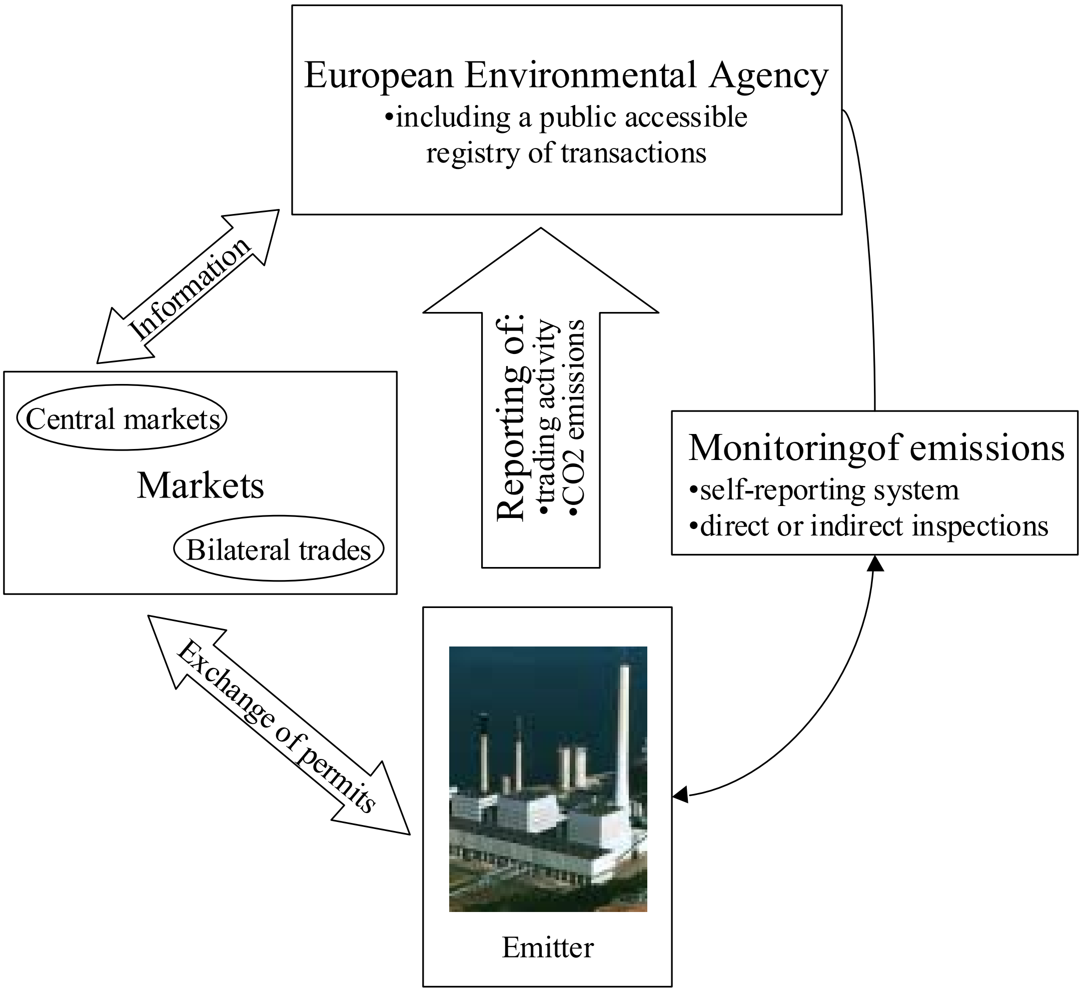

Figure 5.10: Institutional framework of a tradable CO_2 permits market.

However, it is possible that a substantial amount of political authority would have to be left to the national governments, which reflects the facts that:

- It is unclear whether the European Community or the Member States are ultimately responsible for overall compliance (and what is politically feasible);
- Member States are better placed to set rules, which protect themselves against non-compliance by private parties.

5.5 Summary and Conclusions

There are a number of factors that point to an emission-trading scheme covering only CO_2 emissions from the power and steam sector as being a sensible starting point, including:

- CO_2 emissions are by far the largest contributor to greenhouse gas emissions and will remain so for any foreseeable future;
- CO_2 emissions stems almost entirely from fossil fuel use, which is most easily monitored;
- Many low-cost CO_2 emission reduction opportunities are within the power sector;

- The companies are relatively well-informed of the overall opportunities to reduce CO_2 emissions in the market, which can work to encourage trading early on;
- It is likely to be politically simpler to start with a single sector

Clearly, focusing on CO_2 emissions, let alone only a subset of CO_2 emissions, cannot be the final answer, since emissions of other greenhouse gases make a significant contribution as well. If emission reductions of the other greenhouse gases are to be achieved by applying other policy instruments, it is likely to result in differentiated treatment of different sectors and gases. From an overall efficiency viewpoint this is not preferable. However, getting a tradable permit system underway at all is likely to pose a significant political challenge and in this respect it makes sense to start out with a limited system, as long as it will not prevent a more cost-effective solution to emerge later on.

We can, however, try to compensate for the limited coverage of emissions by taking the expected opportunities for reducing the other greenhouse gases into consideration. Model calculations for the EU have suggested that the cost-effective reduction of CO_2 emissions correspond to a 6.2 % reduction of emissions compared to the 1990 level. This reduction percentage is lower than 8 %, which corresponds to a uniform reduction of all gases, due to the many low-cost reduction opportunities of methane and nitrous oxide

The political economy of a tradable CO_2 permit market in the EU

The underlying constellation of actor interests in this policy area will clearly have implications for the possible design options. Two important observations can be made about the positions of Member States. First of all, the initial distribution of permits in any tradable permit system in the EU will somehow need to reflect on the Burden Sharing Agreement. Secondly, any expansion of the use of fiscal measures at Community level is strongly opposed by some Member States as it is still very much seen as a national responsibility. Thus, in order to assure that all Member States find it in their own best interest to participate in a tradable CO_2 permit scheme, it seems that the distribution principle from Community level to the Member State level must involve grandfathering. In other words, the revenue stream generated by the sale of permits will be fully redistributed to the Member States.

Furthermore, two important observations can be made about the influence of private parties on the EU policy-making process as well. First of all, any attempts to implement an upstream trading system, which is essentially a tax on all fossil fuels entering the economy, is likely to result in political deadlock. The existing voluntary agreement between the automobile industry and the European Commission is a strong indication of this. On the other hand, the European electricity producers have a less clear-cut agenda towards the climate change issue due to the asymmetric interests of the producers. As a result, Eurelectric has emphasised that policies and measures should not distort competition and therefore, they are generally supportive of market-based instruments and especially tradable permits. The position of some energy companies in the National policy agenda will make it unlikely, though, that the distribution principle to private parties will not involve some sort of grandfathering.

In order to try to avoid deadlock in the negotiations over the design options of a tradable CO_2 permit market, the principle of subsidiarity could be applied, thus leaving some conflicts unresolved at the Community level and shifting them to the implementation phase. This would suggest that the overall framework be defined at Community level while leaving as much scope for subsequent Member State action as possible.

In other words, the level of decisional competence will be a fundamental aspect with respect to the design options. What is absolutely necessary to shift to the EC level and what can be kept at the Member State level? Given the decisional structure of the EU there is a permanent struggle for decisional competence between the different levels of Government. Undoubtedly, the larger the role assigned to Member States the easier it is to come up with a solution. However, the global nature of the climate change problem and the profound economic impact that measures to limit emissions of greenhouse gases will have, reinforce the case for a supra-national policy response in the EU.

The most fundamental design options we need to consider in establishing a tradable CO_2 permits market for the power and steam sector is the following:

- Total amount of permits to be put into the bubble (the target level)
- Permit contributions from each country's emission target
- Distribution mechanisms for permits to individual power plants.

Target level

The total number of permits assigned to the system determines the price of the permits and thus the marginal cost of emissions. Therefore, in choosing the overall allocation of permits to the trading system it should be taken into consideration that the opportunities for emission reductions vary between different sectors. This is important for two reasons. First of all, you minimise the distortion from not including all sectors and gases in the trading system from the outset and, secondly, the impact that the inclusion of more sectors over time will have on the equilibrium price of the permits is likely to be smaller. That is why it is clearly preferable with a top-down element in the setting of the overall reduction target for the sector so this should take place at Community level.

However, any enlargement of the trading scheme to include other sectors, gases or even countries will affect the equilibrium price of CO_2 permits. This is unfortunate because investments in cleaner technologies undertaken prior to the enlargement can turn out to be stranded. This problem is inherent in all tradable permit schemes that start out with less than complete coverage of emissions and it is not easily dealt with.

The calculations based on the Primes model presented in this chapter predicts that app. 260 Mt of CO_2 emissions reductions relative to the emissions baseline should take place in the power and steam sector in order to minimise abatement costs. This corresponds to *a reduction in the level of emissions in 2010 by app. 22 % compared to 1990-level*, or alternatively to an overall allocation of permits to the electricity and steam sector in the neighbourhood of *950 Mt CO_2 equivalents*. Due to the many low-cost reduction opportunities in the power sector, the suggested least-cost allocation to this sector requires a much larger reduction in emissions (22 %) compared to the overall reduction requirement of CO_2 (6.2 %). These figures along with simulation in other model studies could serve as a starting point for future negotiations.

Target Group

If abatement costs are to be minimised, it is preferable that the share of total emissions covered by an emissions permit system be as large as possible. Notably, the emissions from heat production and from combined heat and power production should also be included in the permit market. The inclusion of emissions stemming from heat as well as power production will secure an equal treatment of the two products. However, monitoring and enforcement costs will be incurred by any policy measure and may limit the coverage of emissions sources that is cost effective to include in the market.

Monitoring and enforcement costs are likely to be too high to make it worthwhile to include all smaller industrial plants. All plants that are not included in the market should be regulated by a tax or some other measure to ensure that they are faced with approximately the same cost per unit of emissions.

It is suggested to include all boilers larger than 25 MW in the trading scheme. The total number of fossil-fuelled boilers in the EU amounted to app. 7050 in 1999, while the number of boilers larger than 25 MW_e amounted to 1690. The 1690 boilers are in the same order of magnitude as the US Acid Rain Program, which has proven to be a workable number. Secondly, the total number of companies is reduced from app. 3000 to 375 while most of the installed capacity of fossil-fuelled boilers is still included in the market. In other words, most of the emissions are still kept within the system. By doing this the administrative procedures can be developed and prepared for a larger scheme.

If the permits are grandfathered to the existing electricity producers the concentration of permits on a few large producers can be a real problem. However, it should be noted that the problem in terms of abuse of market power is not so much that the permits are concentrated on a few companies. Rather, it is the difference between the cost-effective permit allocation and the allocation that the company receives free of charge from the outset that is the real problem. It seems clear, though, that there will be a reasonable number of sources of CO_2 emissions in the power sector to use it as a testing ground for an EU-scheme of emissions trading. In the longer run, it will be important to broaden the scope of the trading scheme and the inclusion of other sectors will limit the risk of market power.

Distribution rule

Two questions need to be considered with respect to the distributional aspects of the trading scheme:

- Permit contributions from each country’s emission target
- Distribution mechanisms for permits to individual power plants.

With regard to the first point, the allocation of permits to certain sectors by individual Member States can be carried out in such a way as to distort competition in that sector. The importance of the energy sector taken together with the ongoing liberalisation of the gas and power sector will make the energy sector an obvious candidate for a favourable allocation by Member States. For that reason, the allocation of permits to the power and steam sector from each country's emissions target needs to be harmonised.

The least distortive approach is undoubtedly to construct a “true” EC emission trading bubble from the outset. This would mean assigning 950 Mt of CO_2 permits to the emissions trading bubble, emissions that are to be taken out of the total amount of greenhouse gas emissions assigned to the European Community. The revenue from the sale of the permits goes into the EC budget and the revenue is recycled to the participating companies according to some standardised rules of allocation (or redistributed to the Community at large if deemed possible).

The political reality of the Burden Sharing Agreement will, however, make it very hard to go through with this approach. A more feasible solution is to let the total amount of permits, that is being allocated to the power and steam sector bubble, consist of assigned amounts from each Member State. The amount of CO_2 permits that is assigned to the emissions trading bubble by each Member State will then need to be deducted from the overall assigned amount of each Member State as defined by the Burden Sharing Agreement. Furthermore, the revenue generated from the sale of CO_2 permits will be redistributed to the Member States corresponding to the number of permits assigned by each individual Member State.

The potential problem with an approach based on assigned amounts from each Member State is the possible distortion of competition, given that some Member States will have a large amount of permits compared to what their power sector actually need to cover their emissions of CO_2. Taking this problem into account, it is shown that a proportional rollback of the emissions defined by the Burden Sharing Agreement does not seem like a bad starting point. In the long run, however, the distribution of responsibilities between Member States should gradually converge to a per capita allocation rule.

With regard to the distribution of permits to private parties, it should be noted that under ideal conditions different distribution rules can coexist and in theory it is not necessary with a common distribution rule. This conclusion can, however, be challenged.

Notably, there should be a common agreement as to how *grandfathering can be outfaced* from the system over time because there are large welfare gains if the revenue is used to reduce other taxes in the economy rather than being given away for free to the existing emitters. From a perspective of fairness this is also a better solution, as the revenue is distributed broadly and reflects the fact that every citizen has the same right to emit CO_2 into the atmosphere (per capita allocation rule). One way of achieving this could be to gradually convert the units assigned to the bubble to EC assigned amount units. The revenue from the sale of these units would then go into the EC budget and the revenue should be distributed to society at large.

However, it seems unlikely that the distribution rule from the outset will not involve some sort of grandfathering. Therefore, we need to consider whether or not the grandfathering principle needs to be the same or whether it can be left to Member States. If it was left entirely up to the Member States the possible lack of competition in the power sector can be a problem, because some companies might be able to use a favourable allocation of CO_2 permits to gain market shares in the power market.

The least distortive option would be to decide on a common distribution principle to the market participants. Notably, an allocation of permits to individual power plants based on a percentage reduction of the current size of emissions is to be preferred over an allocation principle based on past emissions, i.e. emissions in 1990.

Leaving it to the discretion of Member States with regulatory oversight by the Commission is a more feasible solution. If it were left to the discretion of Member States, the Commission would have to approve of the principle chosen by each Member State. This could mean that some Member States would not be able to redistribute all the revenue to the participating parties because it would be in violation with the EC rules on state aid.

Trade rules

By an individual permit we will understand a right to emit 1 tonne of CO_2. Each permit will specify what particular Member State has issued the permit and the year of issue (vintage year). Once the permit has been used to show compliance it will be withdrawn from the market. The duration of the compliance period is set to one year.

The entitlement is not a full property right but rather a limited permission to emit CO_2. This allows the government to make changes over time without any compensation to the market participants. This approach is also valid here to a limited extent.

Obviously, any changes in the entitlement to CO_2 permits have to be done with extreme caution, since a full property right is essential for a well functioning market. However, we need to distinguish between two things:

- changes to the overall allocation of permits to the trading system, which in turn determines the market price of CO_2 permits,

- and changes to the distribution of revenue between market participants and society in general.

It is important that a credible economic value of CO_2 permits is established for a considerable time period reflecting the long investment horizons in the power sector. Therefore, *any alterations in the overall allocation of permits to the permit market must be the responsibility of the EC and not the market participants.*

On the other hand, the distributional principle can be changed over time and grandfathering can be out-phased. However, the out-phasing of grandfathering must be completely unrelated to the actual closing down of production plants, otherwise this will also inflict on long-term resource allocation.

The system should allow for unlimited banking of permits. Borrowing of permits is preferable but problematic and could be excluded. When borrowing of permits is not allowed, the inter-temporal flexibility of the system is linked to the fine for being in non-compliance, as the fine will put a price ceiling on the permit market. A low level of the fine will introduce more flexibility into the system because essentially the EC has extra permits for sale at a price equal to the level of the fine. Thus, *the level of the fine should not be set too high and a suggestion could be app. 40 EUR/tCO_2.*

We propose that the EC should undertake a yearly EU-wide auction where all or a large share of the permits are put out for sale. The inclusion of a large share of the permits in the auction will secure equal access to the permits in all the Member States and thus an efficient allocation of the permits. Furthermore, this will provide price information and transparency to the market, which is important especially in the beginning when market participants are not that familiar with the market.

By putting all the permits out for sale at an auction we are separating the issue of allocation from the issue of distribution. The revenue from the auction is redistributed to the Member States according to the overall distribution of responsibilities that is decided upon.

We propose to use a non-discriminatory pricing principle for the auction where all bidders of permits pay the clearing price for the permits (provided that their bid was below the clearing price).

To make sure that there are buyers as well as sellers in the permit market and that the risk sharing capabilities of the marketplace will come into play, everybody should be allowed to participate in the market.

Like in the US the system could start before the first compliance period. Possibly, the regulators should also release permits that are valid in the current year as well as permits that are valid in years to come (i.e. selling vintage year 2008 permits and vintage year 2013 permits at the same time).

Control system

The purpose of the control system is to make the whole trading scheme credible by assuring that there is a one-to-one correspondence between a permit to emit one tonne of CO_2 and the actual emission of one tonne of CO_2.

In the context of a European-wide scheme of emissions trading it would be natural that the ultimate responsibility for ensuring compliance will be on a European level. It is the general assumption, however, that monitoring and enforcement in relation to the companies from the starting point will be a Member State task, because the Member State Authorities are equipped with the necessary regulatory power in relation to the private parties. On the other hand, the system could gain in general efficiency and credibility by the establishment of a common European institution. This could be EEA (European Environmental Agency).

In terms of monitoring of emissions, calculating the CO_2 emissions from the fuel input is a very cheap and efficient method, especially for a gas fired plant. This will be relevant for many of the smallest installations and thus not put a lower limit to the size of plant that can be part of the trading scheme. For coal fired plants the uncertainties can be so large that direct measurement should be preferred. These installations are usually large and the extra costs for measurement of CO_2 emissions will be of minor importance. As long as the levels of uncertainties are comparable (in fact, as long as the uncertainties are not biased so that they sum out over time), the use of different methods of measuring will pose no difficulties.

The emissions data will be collected by means of self-reporting by the companies.

The most important role to be played by EC institutions will be to establish minimum requirements with regard to the measurement of emissions while to a large extent leaving actual monitoring and verification of emissions to the Member State Governments.

The annual reporting of emissions from the power and steam sector must be faster than today. The final data for the preceding year should be available in January in order to allow for a true-up period for the emission rights. To give the best possible market information it is proposed to report and publish emission data for companies included in the trading scheme on a monthly basis. This will mean speeding up of the existing reporting procedures, but it should be possible to do this with only minor extra costs.

The Member States could verify the emissions reported by companies on a yearly basis and submit their result to an EC institution. Obviously, the Member States might have incentives to cheat as well, however, the scope for cheating should be relatively small with respect to the power and steam sector.

With respect to the enforcement of the permit market, a central registry must be created at the EU level. This function can be computerised and should not give any theoretical or practical difficulties, which has been clearly demonstrated by the US Acid Rain programme. Data for emissions may be collected by national authorities but shall at once be transmitted to a European institution. Through the trading system, a registry of permit holdings of each of the actors in the market is established. Likewise, through the monitoring process, a registry of the actual emissions of each actor is established. The 'trick' of the enforcement is to compare the two numbers for each actor and have the necessary authority to deter actors from breaking the emission limits.

First of all, we need to deter cheating by companies. Taking into consideration that the likelihood of detecting cheating is pretty high in this trading scheme, it will probably not be necessary with sanctions such as prison sentences to deter cheating. A high monetary sanction should be sufficient.

The next step will be to establish sanctions against market participants exceeding their permit holdings. The suggestion here is straightforward. Market participants whose emissions are exceeding their current permit holdings must pay a fine for their excess emissions. The level of the fine must be the same in all Member States. Otherwise, there could be carbon leakage to areas with lower fine levels.

If the fine is kept very low, the emissions trading scheme will work very much like a price instrument (tax), whereas a high fine will secure that the emission target is reached (at any cost to society). Thus, a relatively low fine is proposed for the trading scheme, and the fine could be set at in the neighbourhood of 40 EUR/tCO_2. The fine payments could be used by the enforcement institution to buy emissions permits internationally, in order to secure that the overall emission target of the trading system is met.

Potential gains from trading

There are clear benefits from allowing private party emissions trading at Community level compared to unilateral action by Member States. A tradable CO_2 permit scheme with comprehensive coverage of emissions within the EU, which would have to be an upstream permit market, could reduce the total abatement costs by some 32 % compared to a system with no trading between Member States. In comparison, a Community-wide system containing only the electricity and steam sector would reduce the total abatement costs by 13 % only.

These differences in abatement costs are, however, without taking advantage of any of the other Kyoto mechanisms. A full CO_2 emission trading system between Annex B countries suggest overall cost savings in the order of 40 % compared to a situation with no trading at all between Member States. Obviously, these gains from trade are not as easily appropriated as within the EU given that no international institution can effectively enforce an Annex B market.

In conclusion, the overall gains from trade in a CO_2 permit market for the power and steam sector are significantly lower than from a system including all sectors in the EU and clearly such a system should not be the final answer. Nevertheless, the system can still provide significant gains from trading.

6 Quantitative evaluation using the EMPS model

This chapter investigates the consequences of different types of CO_2 regulations of the Northern European electricity market. Three different scenarios are analysed:

1) No CO_2 restrictions as baseline
2) Unilateral Danish CO_2 tax and no restrictions in the other countries
3) A harmonised CO_2 tax in all countries.

The analysis focus on the short-term response of the electricity markets and to simulate this situation the EMPS-model (EFI's Multi Area Power Scheduling Model) is chosen.

The description is structured as follows:

- Section 6.1 gives a brief description of the EMPS-model.
- Section 6.2 treats the basis of calculation including the assumptions regarding the model area, fuel prices, production facilities, electricity consumption etc.
- In Section 6.3 the results are shown and commented.
- The conclusion is outlined in Section 6.4.

6.1 Brief description of the EMPS-model (Samkøringsmodellen)

The System Planning department of Eltra has the EMPS-model at its disposal. The model is developed and up-dated by the EFI (Elforsyningens Forskningsinstitut) in Trondheim, Norway.

In brief, the EMPS-model is an integrated model tool for economic optimisation of hydrothermal production systems in which hydropower carries considerable weight. The model is also applicable to both expansion planning and operational planning, including the calculation of projected prices on power.

The model is an energy model with a time step of a week, however, it has the possibility of dividing the week into a number of accumulated time segments.

To be able to make the economic optimisation in the model, it is necessary to assess the value of hydropower relative to other resources in the system.

The value of hydropower is a function of the future development regarding the inflow to the reservoirs, the demand for electricity (guaranteed power) and the market for price dependent buying and selling of electricity. The value of water is therefore not a deterministic variable, but a stochastic variable. An expected value is applied in order to describe the variable. The water value in a given area is thus defined as the expected value of a marginally stored kWh water in the reservoir. The water value is then a function of time and the water level in the reservoir.

The EMPS-model calculations are carried out in two stages. Firstly, the water values are estimated and secondly, the values are applied together with the marginal variable costs of thermal power and spot prices for the supply/demand of electricity, for at any time being able to determine the optimum combination of hydropower and thermal power when it comes to production.

The EMPS-model could be interpreted as a market model in the sense that it is a process-oriented decision supporting tool, which week by week calculates the match between supply and demand in a hydro thermal power system with a stochastic varying inflow (to the reservoirs and run of river plants).

When applying the EMPS-model, the input data are set to:

- Description of the production systems in the model area.
- The description includes, among other things, an appropriate time series of inflow statistics (normally 40-50 years) to the hydroelectric power stations as well as data on accessibility, production capacities and variable operating costs of the thermal power stations.
- Description of the transmission system, including capacities, losses by exchange and price differences between areas prior to the exchange actually taking place.
- Description of the electricity demand, including e.g. a price independent demand curve for the guaranteed power supply (to households and the industry), and a price dependent demand curve for the flexible power market (e.g. the flexible heat boiler market in Norway).

The EMPS-model results cover for example:

- Production amount and distribution on production facilities, including hydroelectric power stations and thermal power stations.
- Emissions (e.g. CO_2, SO_2 and NO_x) from the production.
- Supply of guaranteed power and price dependent occasional power.
- Exchange between areas and countries.
- Power values in different price areas in the model, including price projection. (The power value in a given area is the value of the marginally produced/supplied kWh).
- Reservoir curves, i.e. the water level in the reservoirs as a function of time.
- Water value curves, i.e. the value of stored water as a function of the water level and time.

6.2 Basis for model calculations

The EMPS-model is made for the system consisting of the Nordic countries (Denmark, Norway, Sweden and Finland), Germany and the Netherlands, see Figure 6.1. Norway and Sweden are each divided into four areas, Denmark is divided into two main areas (Elkraft and Eltra) and Finland constitutes one area. The Continent is divided into the areas PreussenElektra (PE), VEAG, the remainder of Germany and the Netherlands.

All calculations apply to the year 2005. All prices are DKK prices at a 1998 price level.

The basis of the model calculations is “Kraftbalans för Nordelsystemet år 2005”, (Nordel 1997) prepared by Nordel's System Operation Group in June 1997.

The interconnections are assumed to be without losses. The consequence of losses on the transmission of energy is modelled by adding a minimum “toll” on exchange ranging from

0.003 to 0.007 DKK/kWh. The interconnections are not preloaded with already entered exchange agreements. The three planned new cable links in the North Sea between Norway and the Continent, as well as the Storebæltsforbindelsen, form part of the data too.

Data from a 41 year long time series of meteorology (1950-1990) is used in the calculations to describe the stochastic variation in inflow to the hydropower reservoirs/production facilities.

The natural gas supply to the electricity sector in Denmark is assumed to be contracted gas which has to be utilised. In the model this is simulated by giving priority to gas-fired units in the load dispatching.

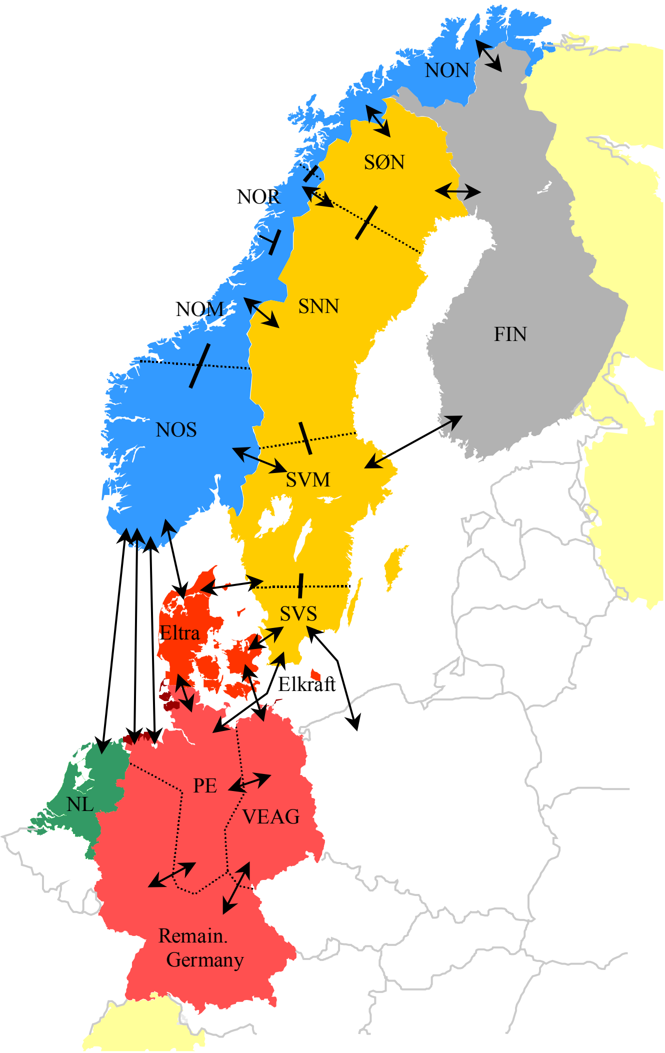

Figure 6.1. Model area.

Regarding the pricing of natural gas in Germany/the Netherlands it is assumed that:

- 50 % of the gas is priced very low such that this production capacity always is exploited (contracted gas that has to be utilised).
- 25 % of the gas power is priced correspondingly to coal power (buying on the spot market).
- 25 % of the gas power is priced correspondingly to oil-fired power (buying on the spot market).

These assumptions are drawn up by Nordel's System Operation Group (Nordel 1997) and are adopted in the present calculations.

The assumptions imply that a CO_2 tax of e.g. 100 DKK/tonne will make the gas power, which was priced as coal power, cheaper than coal power and correspondingly make the gas power, which was priced as oil-fired power, cheaper than oil-fired power. Gas power will thereby replace coal power and oil-fired power.

When calculating the CO_2 taxes on fuel, the following specific CO_2 emissions are assumed:

- Coal: 95 kg/GJ
- Orimulsion: 80 kg/GJ
- Oil: 74 kg/GJ
- Natural gas: 57 kg/GJ

Nordel's data (Nordel 1997) is updated on several areas in the present calculations:

- It is taken into consideration that the guaranteed power consumption in the Nordic countries is temperature dependent.
- The Eltra area being further divided into five smaller areas. This division has been done in connection with other studies and is based on congestion in the network.
- The wind power in Denmark being simulated as a time series based on 19 years of metering of the energy content in the wind. The wind power is thereby described in the same way as the run of river hydropower. On the grounds of the 19 years of metering is generated a synthetic time series of 41 years corresponding to the above-mentioned hydrological statistics, ranging from 1950 to 1990.
- The fuel prices (the year 2005) being adjusted so they are comparable to the prognosis in Energy 21:

Coal:	14.4 DKK/GJ
Heavy oil:	29.7 DKK/GJ
Light oil:	51.1 DKK/GJ
Orimulsion	9.0 DKK/GJ

The data basis for Denmark generally complies with Energy 21 and later up-dates of the planning basis; this goes for both data on supply (production technology, production volumes, fuels etc.) and on demand, i.e. figures regarding the electricity consumption.

From this the following aggregate data for Denmark is applied:

The Eltra area (figures in GWh/year)

Gas-CHP	8390
Bio-CHP	440
Coal-CHP (1)	520
Coal-CHP (2)	5325
Gas-condensation	1000
Coal-condensation (1)	8575
Coal-condensation (2)	5170
Wind	3690

Sum	33110 (production potential)
Demand	18700

The Elkraft area (figures in GWh/year)

Local CHP	3400
Central CHP	8000
Orimul.-condensation	4500
Coal-condensation (1)	1900
Coal-condensation (2)	1600
Oil-condensation	3800
Gas turbine	1600
Wind	1050
Sum	25850 (production potential)
Demand	12900

6.3 Model results

Three main simulations have been carried out using the model:

- Simulation 1: No CO_2 taxes are included
- Simulation 2: A CO_2-tax of 100 DKK/tonne is assumed for Denmark alone
- Simulation 3: A harmonised CO_2 tax of 100 DKK/tonne is assumed for all countries.

6.3.1 Outline of results

Following outline of selected results applies:

- Figure 6.2 and Figure 6.6 through Figure 6.8 show the *yearly values of the net exchange* (import is shown as a positive sign) of the countries and areas in the model. Results of 41 years' simulations, corresponding to the hydrological years 1950-1990, are indicated. Besides, value no. 42 is stated as the average value of the 41 years.
- Figure 6.3 through Figure 6.5 show the *exchanges between Denmark (Eltra and Elkraft) and the neighbouring countries* as an average of the 41 meteorological years.
- Figure 6.9 through Figure 6.12 show the *yearly CO_2 emissions* for countries and areas in the model. Results of 41 years' simulations, corresponding to the hydrological years 1950-1990, are indicated. Besides, value no. 42 is stated as the average value of the 41 years.
- Figure 6.13 and Figure 6.14 show a *grouping of CO_2 emissions* in the Nordic countries and as a total in the three simulations, as well as in a fourth simulation which is similar to simulation 3, but in which *coal and oil generally are replaced by gas.*

The above-mentioned simulations are in the figures indicated by:

- Simulation 1: <name>, 0
- Simulation 2: <name>, DKK 100

- Simulation 3: <name>, 100
- Simulation 3a: Gas scenario (Figure 6.13 and Figure 6.14).

6.3.2 Exchange of energy

Figure 6.2 shows the import/export from Denmark (Eltra and Elkraft) in simulations 1, 2 and 3. It appears from the figure that the export in average decreases from approx. 20 TWh in simulations 1 and 3 to less than 5 TWh in simulation 2. A unilateral Danish CO_2 tax of 100 DKK/tonne would therefore definitely influence on the possibilities of the Danish export of electricity.

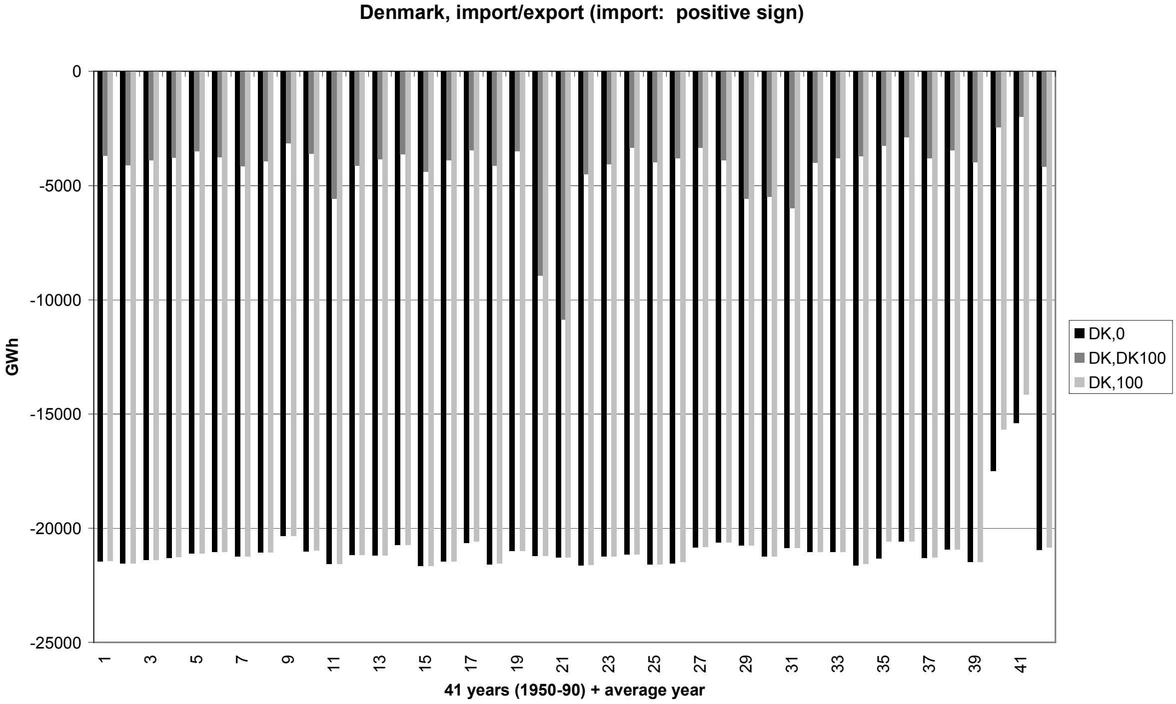

Figure 6.2. Denmark. Import/export.

Furthermore, the figure shows that the Danish export in simulations 1 and 3 to a high degree is independent of the variety in meteorology during the 41 years, however, with exception of the extremely wet years of 1889 and 1990 (years no. 40 and 41). Even in the “normal” wet years the Danish production potential (except from oil condensation) is exploited, because Danish production is assumed to be cheaper than the German, Swedish and Finish thermal production. Danish export is taken over by especially German production in the situation of a unilateral Danish CO_2 tax. In this case Danish production includes almost only non-dispatchable electricity production (wind power, CHP and contracted production of natural gas).

For further illustration *Figure 6.3 through Figure 6.5* show the yearly average of energy flows between Denmark and the neighbouring countries in the three simulations. It appears from the figures that the energy flows are almost identical in simulations 1and 3, while simulation 2 gives quite a different picture of a very limited net export from Denmark.

Figure 6.6 shows the situation for Norway. The great diversity in import/export from year to year reflects the variation in precipitation and thereby the potential of hydropower production. For instance are the years no. 12 and 21 (1961 and 1970) dry years with a large volume of imports, while the years no. 40 and 41 (1989 and 1990) are wet years with a large volume of exports from Norway. The variation within the individual year and in the average year (year no. 42) between the three simulations is in comparison to this of minor importance.

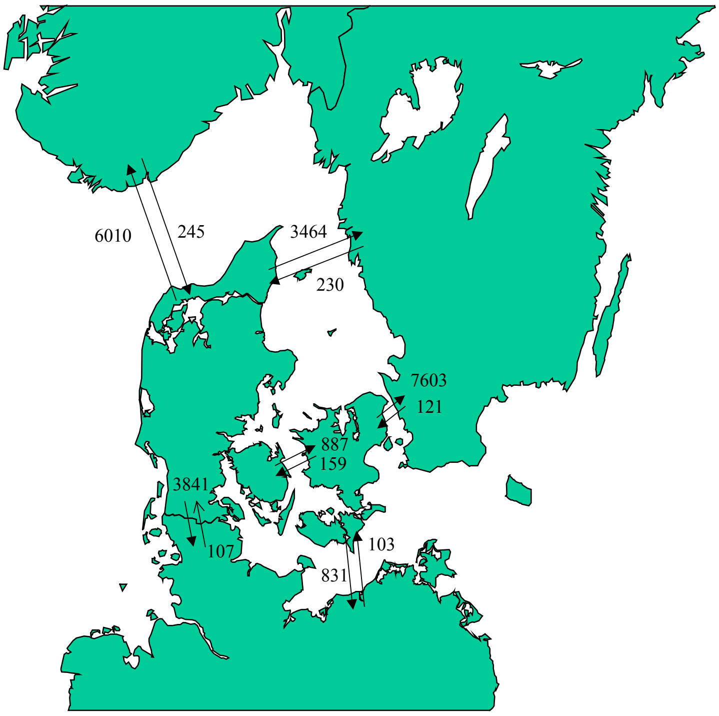

Figure 6.3. Exchange of energy (GWh/year). CO_2 tax: 0 DKK/tonne.

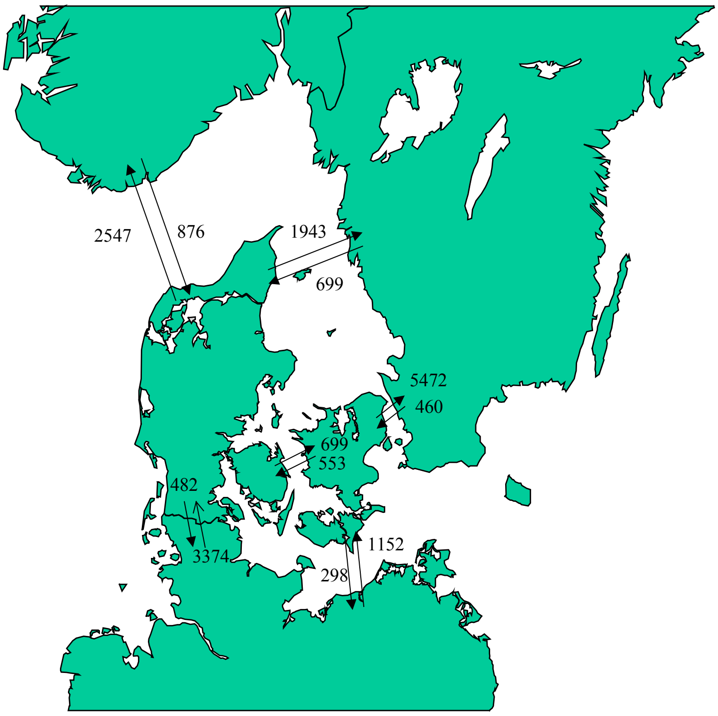

Figure 6.4. Exchange of energy (GWh/year). CO_2 tax: 100 DKK/tonne in Denmark

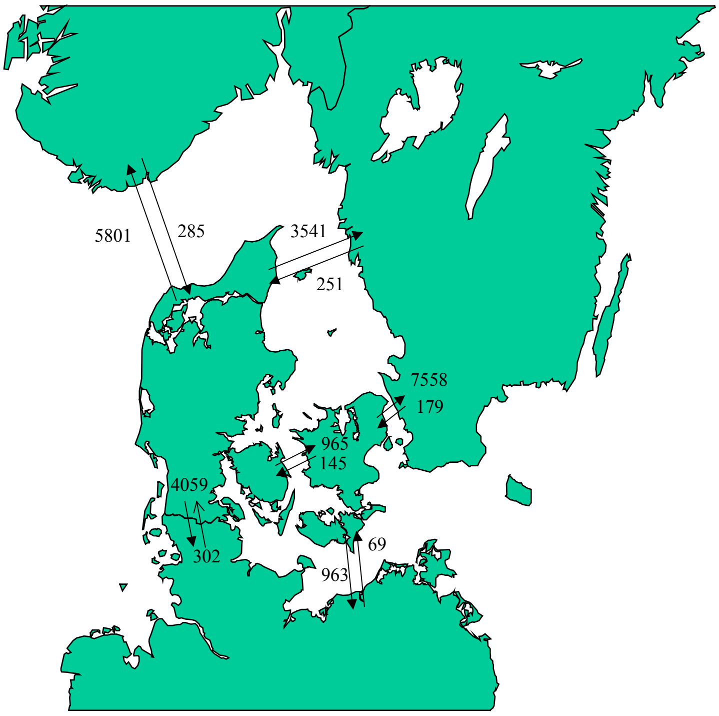

Figure 6.5. Exchange of energy (GWh/year). CO_2 tax: 100 DKK/tonne in all countries.

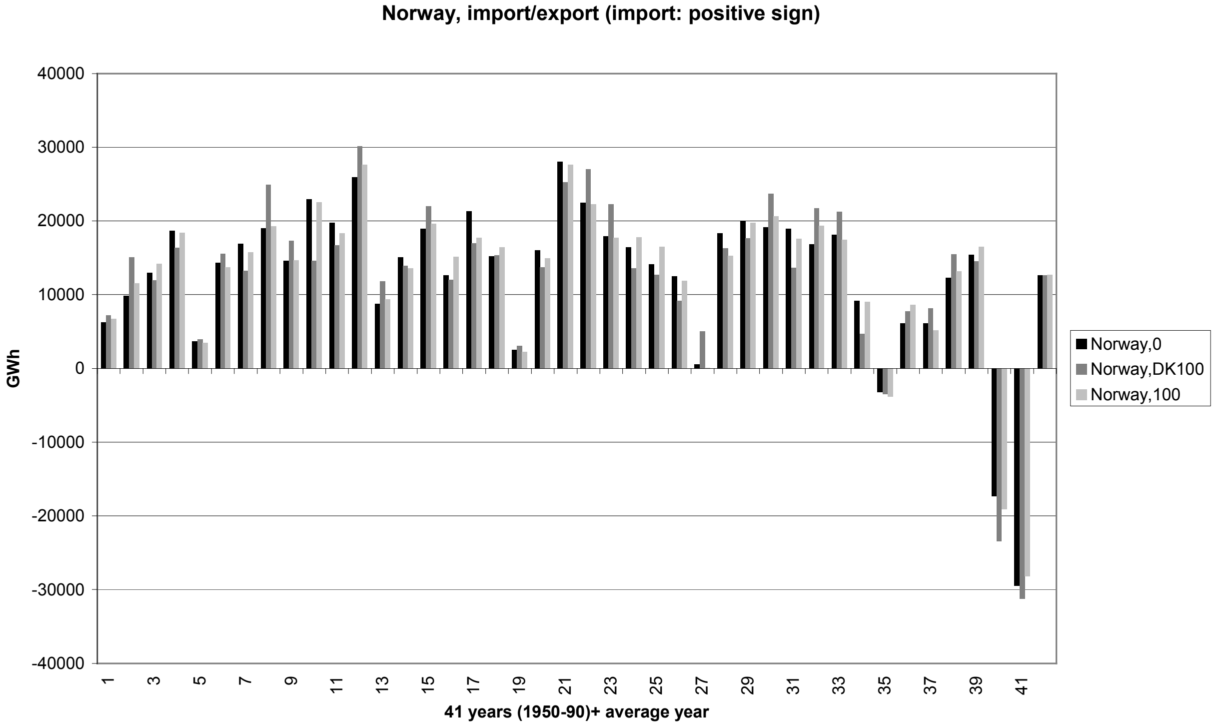

Figure 6.6. Norway. Import/export.

Finally *Figure 6.7 and Figure 6.8* show that PreussenElektra’s export is increasing and VEAG’s import is increasing from simulation 1 to 3. This is caused by the production being changed from coal power in the PreussenElektra area and the VEAG area to gas power in the PreussenElektra area (and the remainder of Germany and the Netherlands) due to a harmonised CO_2 tax of 100 DKK/tonne.

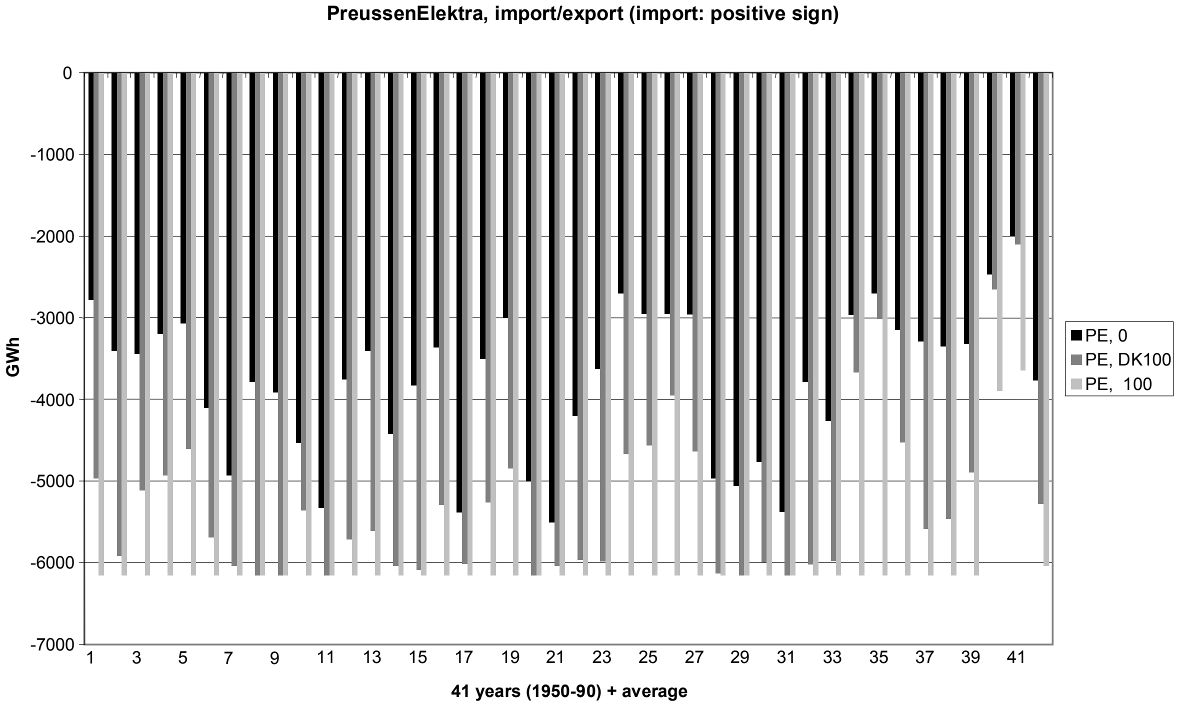

Figure 6.7. PreussenElektra. Import/export.

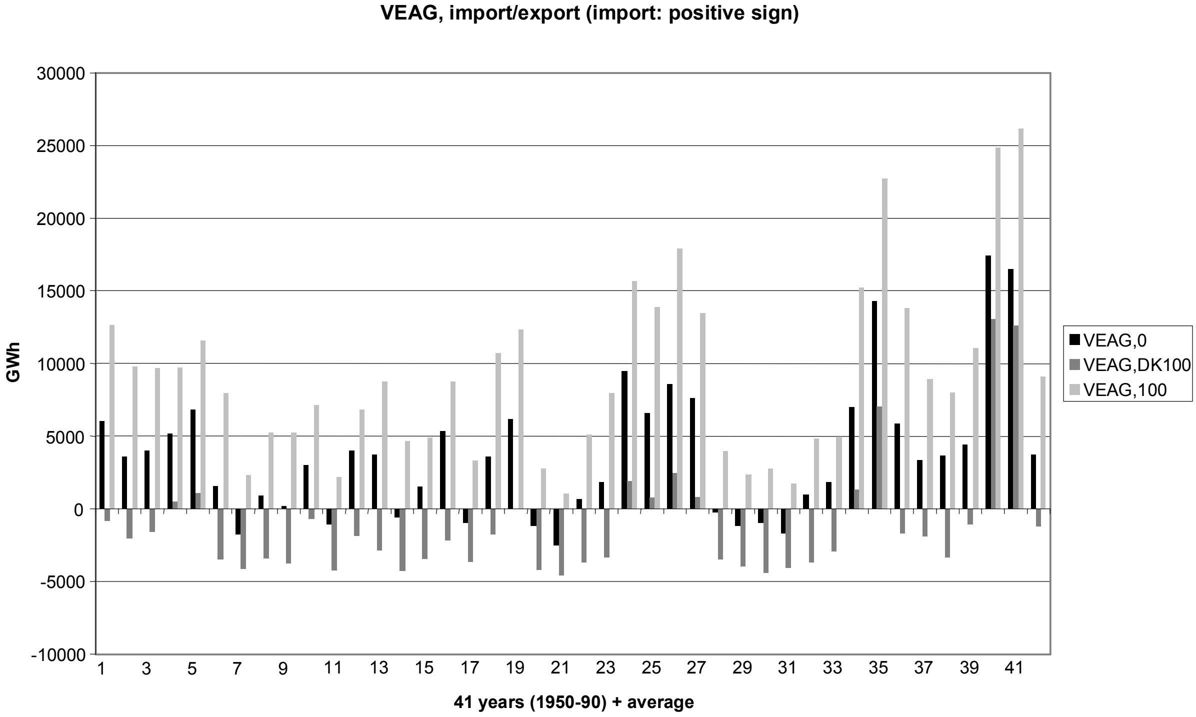

Figure 6.8. VEAG, Import/export.

6.3.3 Variations in annual CO_2 emissions

Figure 6.9 shows the CO_2 emission from the Danish production of electricity, exclusive of CO_2 emission from heat produced by a combined heating and power production. When distributing the CO_2 emission on power and heat by a combined production, the advantage of CHP is assumed to be attributable to the heat production. The figure shows that besides from the two extremely wet years in 1989 and 1990, all the Danish production capacity (exclusive of oil-condensation) is exploited in all of the years in simulation 1 and 3.

By comparison Figure 6.2 shows a little variation in the net export from year to year. The diversity is due to the wind power production in Denmark varying from year to year. Similarly is assumed a small yearly variation in the electricity consumption resulting from variations in temperature. Figure 6.9 further shows that a unilateral Danish CO_2 tax of 100 DKK/tonne on average leads to a yearly CO_2 reduction of approx. 28 million tonne to approx. 15 million tonne from the Danish electricity sector.

Figure 6.10 through Figure 6.12 show the corresponding results regarding the emissions from the PreussenElektra area, the VEAG area and the total amount of emissions from the entire model area.

It appears from Figure 6.10 that PreussenElektra's CO_2 emission (in average) increases marginally from simulation 1 (30.3 million tonne) to simulation 2 (31.3 million tonne), because of a growing production, see Figure 6.7.

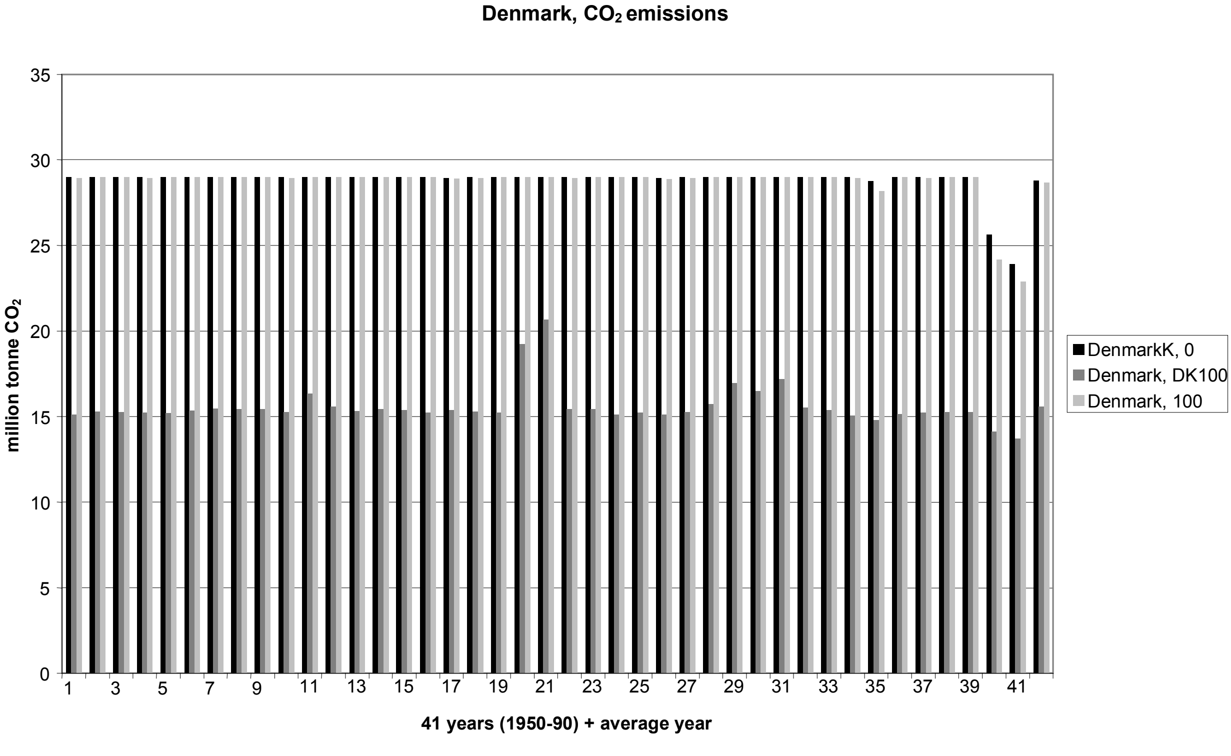

Figure 6.9. CO_2 emissions, Denmark.

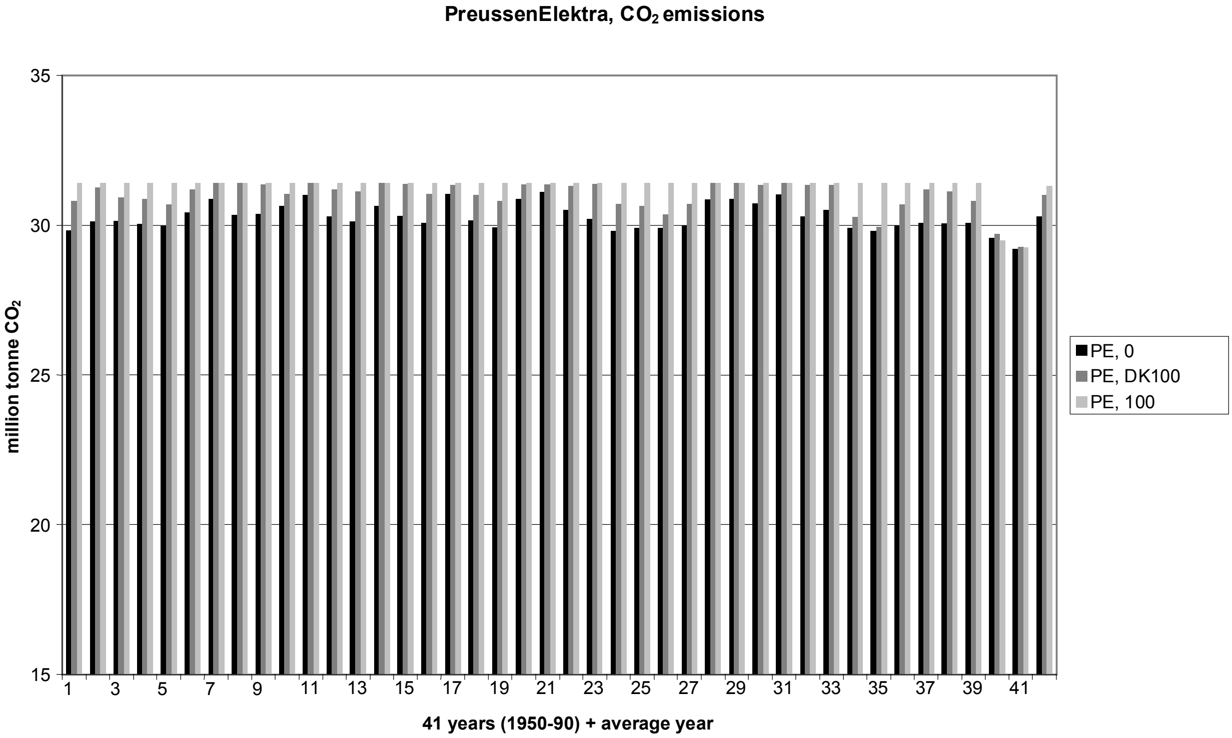

Figure 6.10. CO_2 emissions, PreussenElektra.

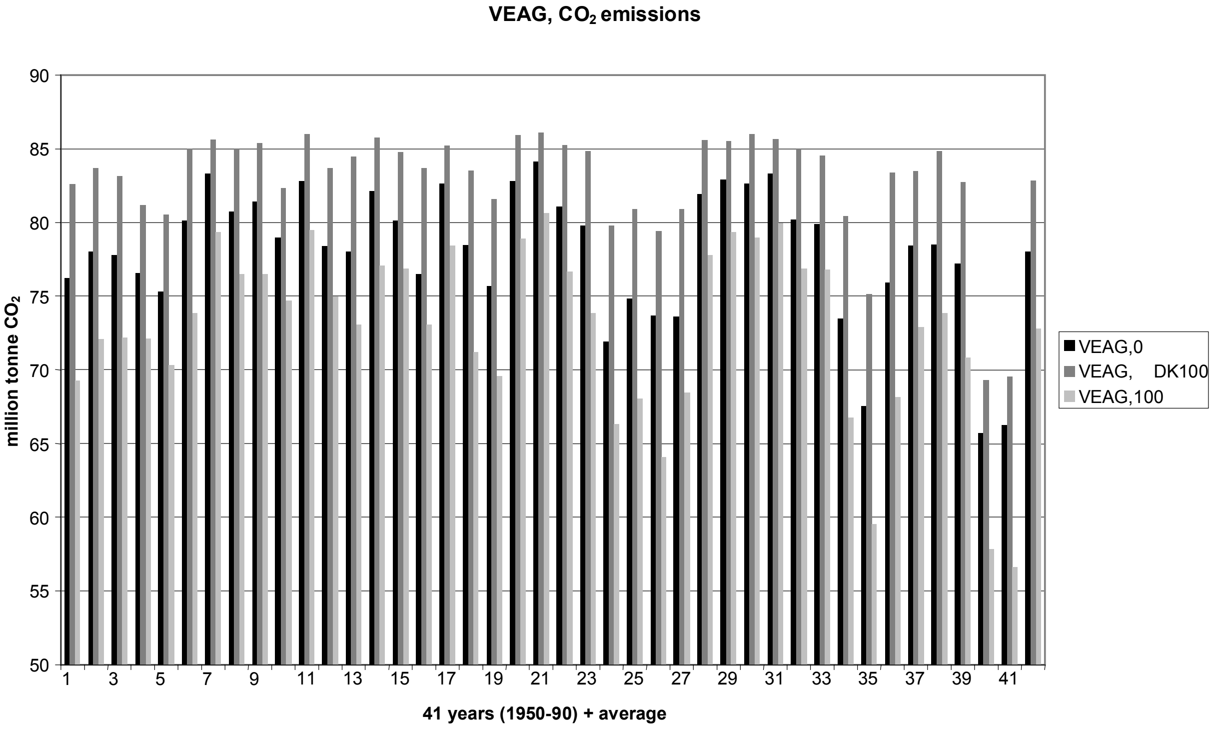

Figure 6.11. CO_2 emissions, CO_2 emissions, VEAG.

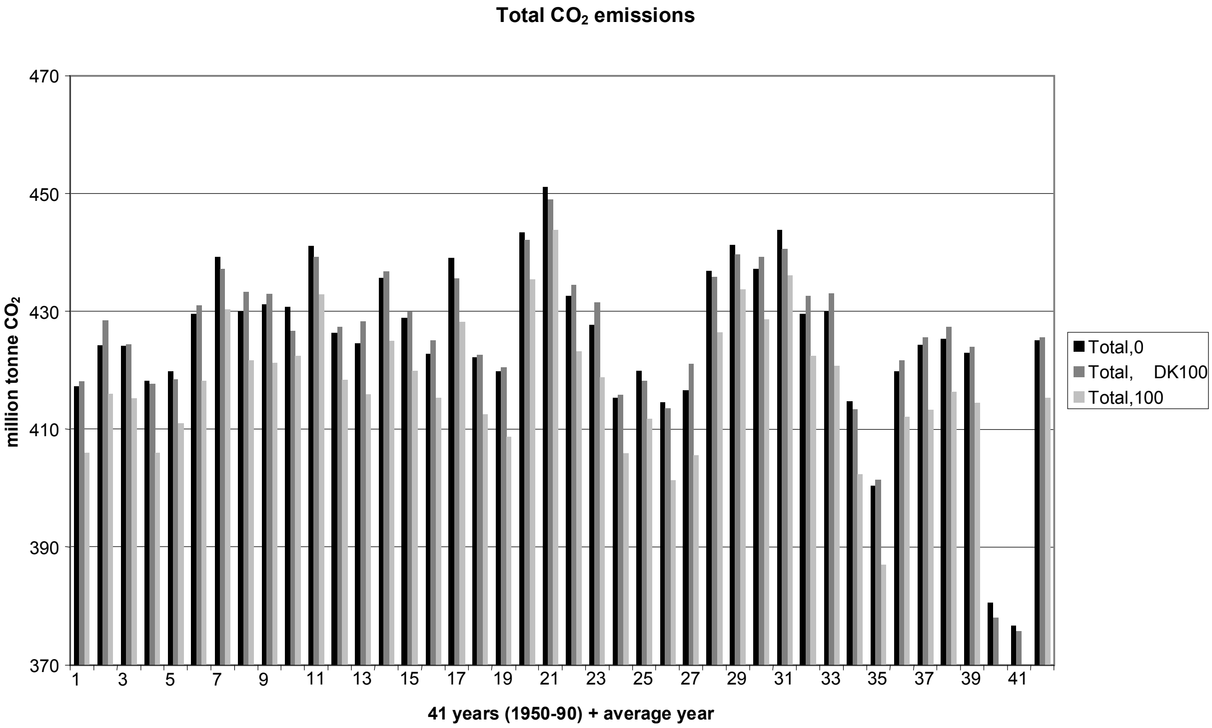

Figure 6.12. CO_2 emissions. Total emissions in model area.

Correspondingly, Figure 6.11 shows that VEAG's CO_2 emission (in average) increases from simulation 1 (78.0 million tonne) to simulation 2 (82.9 million tonne), because of a growing production for the replacing of Danish production. Furthermore, it is seen that the CO_2 emission is somewhat smaller in simulation 3 (72.8 million tonne), because VEAG's coal based production in this case to a certain extent is taken over by a gas-fired production in the PreussenElektra area, the remainder of Germany and the Netherlands.

Finally Figure 6.12 shows that a unilateral Danish CO_2 tax (100 DKK/tonne) is not leading to any CO_2 reduction in the model area in general. The total amount of CO_2 emission (in average) is approx. 425 million tonne/year in both simulation 1 and 2. A harmonised tax of 100 DKK/tonne in all countries results in a small reduction of the total amount of emission from 425 million tonne to approx. 415 million tonne, a reduction of 2-3 per cent. This very limited reduction is a lower value (pessimistic estimate) of the real reduction. This is caused by several factors:

- A given production unit is in the model specified as either being e.g. coal-fired, gas-fired or oil-fired. However, the model is not able to allow for some production facilities being fired with different kinds of fuel. The model is therefore not capable of optimising the choice of fuels for such facilities accordingly to the fuel price. The individual production units are thus "fixed" regarding fuel type and thereby specific emissions. The above estimated CO_2 reduction does consequently not include the changing of fuels in the units that are capable of being fired with several kinds of fuel, e.g. the changing from coal to gas.
- Besides, the model does obviously not include the change from e.g. coal to gas in the units, where this calls for re-buildings and relating investments. In e.g. Denmark such a change in the existing power stations would be a reasonable and economic applicable

option in case of increasing CO_2 taxes. The changing could probably many places be carried out with limited investments.

In order to get an idea of the potential for CO_2 reductions, a fourth simulation is carried out (simulation 3a, gas scenario), in which the assumptions are the same as in simulation 3, but where coal and oil is replaced by gas in the entire model area.

6.3.4 Comparison of average annual CO_2 emissions for the model areas

Figure 6.13 and Figure 6.14 show a grouping of results (average figures of results from 41 years) of the four calculations for the Nordic countries and the entire model areas.

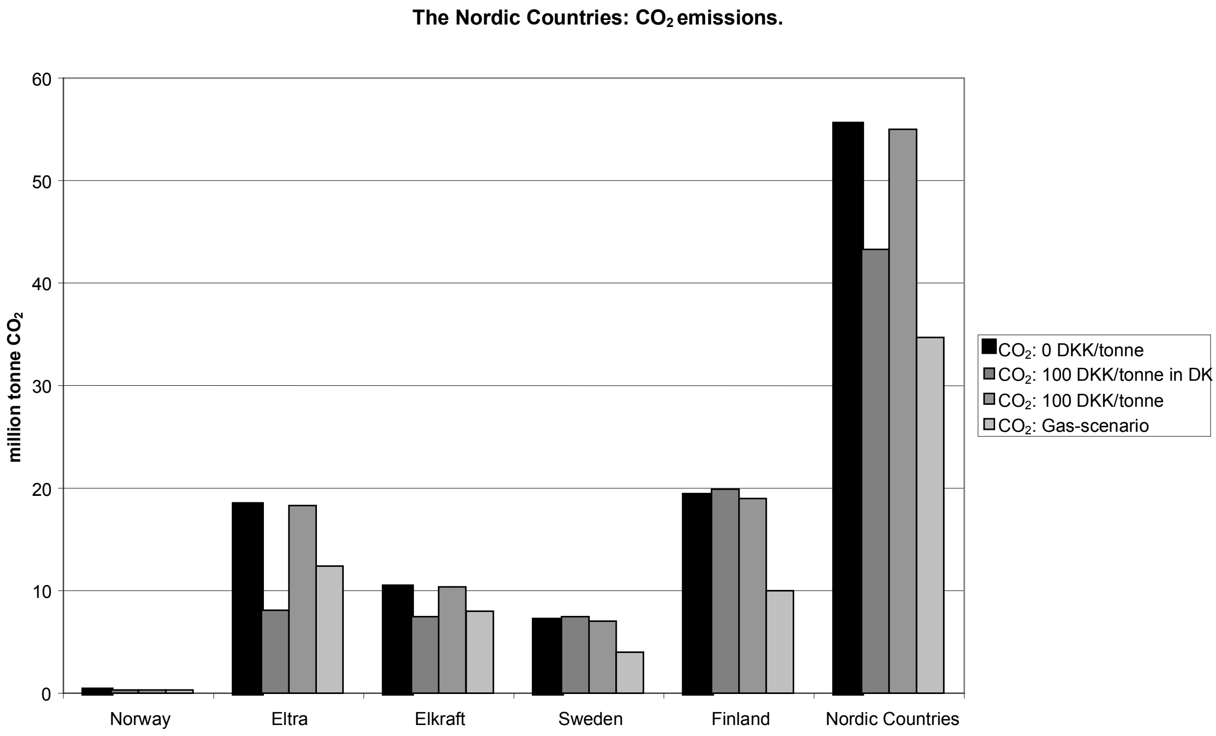

Figure 6.13. CO_2 emissions (million tonne per year) in the Nordic countries

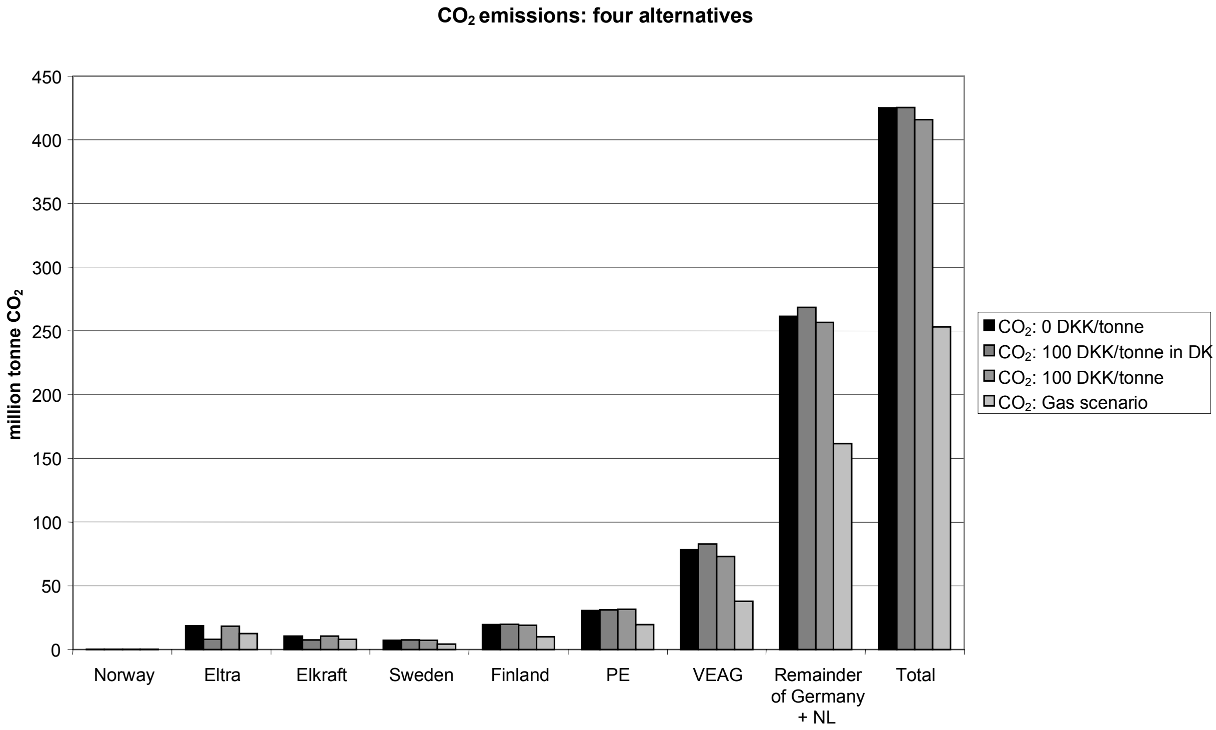

Figure 6.14. CO_2 emissions (million tonne per year) in the model area.

It appears from Figure 6.13 that the total CO_2 reduction potential for the Nordic countries amounts to approx. 20 million tonne (the difference between approx. 55 million tonne and approx. 35 million tonne in simulations 1 and 3a). A reduction distributed by approx. 8 million tonne in Denmark, approx. 3 million tonne in Sweden and approx. 9 million tonne in Finland.

Correspondingly, Figure 6.14 shows that the total reduction potential for the entire model area amounts to approx. 170 million tonne of CO_2, a reduction from approx. 425 million tonne (simulation 1) to approx. 255 million tonne (simulation 3a). The reduction potential is distributed by approx. 100 million tonne in the remainder of Germany and the Netherlands, 40 million tonne in the VEAG area, 10 million tonne in the PreussenElektra area and the above-mentioned 20 million tonne in the Nordic countries.

The CO_2 emissions in Denmark (Eltra and Elkraft) do, as mentioned earlier, only apply to the electricity production alone. The advantage of CHP is assumed to be attributable to the heat production.

Analogous to Figure 6.14, *Figure 6.15* shows the CO_2 emissions in the Nordic countries with the four alternatives (as in Figure 6.13), but this time including the Danish CO_2 emissions from the electricity production, inclusive of the total emissions from the CHP. By comparing Figure 6.15 directly with Figure 6.13 it is seen that the Danish CO_2 emissions increase by 2-3 million tonne, when CO_2 emissions from the heating production is included.

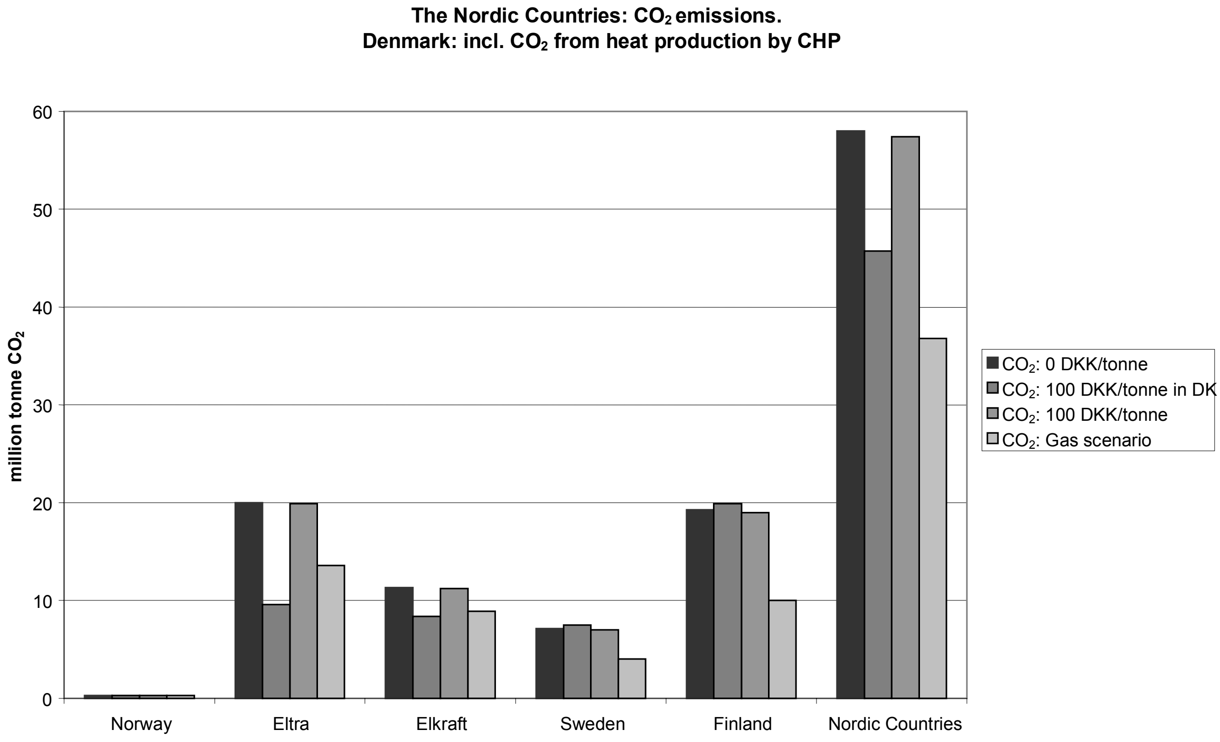

Figure 6.15. CO_2 emissions (million tonne per year) in the Nordic countries.

6.4 Unilateral vs. harmonised CO_2 payments

From the model simulations and evaluations carried out in this section the following conclusions can be summarised:

A unilateral Danish CO_2 tax or CO_2 quota will reduce Danish power production and so the Danish CO_2 emissions. However, the Danish production will be taken over by German production and the total CO_2 emissions in the Nordic countries plus Germany/the Netherlands will not be reduced.

A harmonised tax of DKK 100 per tonne of CO_2, corresponding to international trade in quotas, where CO_2 quotas are worth DKK 100 per tonne, will result in a smaller CO_2 reduction in the order of ten million tonnes (2-3 per cent) in the Nordic countries and Germany/the Netherlands (applies to year 2005). However, this estimate is a lower value for the actual reduction. The total CO_2 reduction potential for the 2005 production facilities is estimated at approx. 20 million tonnes in the Nordic countries (from approximately 55 million tonnes to approximately 35 million tonnes), distributed on approximately eight million tonnes in Denmark, three million tonnes in Sweden and nine million tonnes in Finland. The reductions correspond to a fuel switch-over from coal/oil to gas everywhere in the production facilities. The corresponding potential in Germany/the Netherlands for the 2005 production facilities is approximately 150 million tonnes of CO_2 (from 370 million tonnes to 220 million tonnes).

7 Modelling tradable permits and technology choice

This chapter discusses the impact of fuel and electricity prices on the choice of technologies over the next decades using technologies for combined heat and power (CHP) for different scales of district heating systems as an example. The presentation is based on quantitative analyses using a traditional modelling approach.

The methods and examples are based on contributions to several research projects for both national and international programmes:

- Danish utilities in a competitive market, Danish Energy Research Programme, 1993-1996.
- A Northern European Power Exchange. Danish Energy Research Programme, 1996-1998.
- Tradable CO_2 permits in Danish and European energy policy Danish Energy Research Programme, 1998-2000.
- The Shared Analysis Project (Energy analysis and forecast study after Kyoto). European Commission DG XVII (Energy) 1997-1999.
- Industrial Benefits and Costs of Greenhouse Gas Abatement: Applications of E3ME[71]. EU JOULE III Programme, 1997-2000.
- Balmorel – Baltic Model of Regional Energy Market Liberalisation. Danish Energy Research Programme, 1999-2000.

CHP producers are operating in two markets: the *electricity market*, which is becoming increasingly international and competitive, and a *heat market*, which may remain a natural monopoly. Industrial CHP plants are most often based on the steam or heat requirement from the particular industrial site itself, thus an external heat market may not be considered at all. An important driver for industrial CHP and industrial autoproducers of electricity in the past has been the autonomy from the public electricity supply industry and monopoly pricing. The same driver has also been very important for local utilities of any size, from small village co-operatives to metropolitan multi-utilities.

The motivation of autonomy may well survive in a liberalised electricity market. CHP technologies may be well-suited to enable a flexible response to changing market conditions as a contribution to a portfolio of facilities and technologies for hedging against the risks of price volatility, unexpected regulation and taxation, and market or regulation failures.

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[71] E3ME is a macroeconomic model, which was constructed as part of a project under the EC Non-Nuclear Energy Programme. JOULE II (1993 to 1995). The current version of the model covers 19 regions of Europe (the EU-15 member states plus Norway and Switzerland with Germany divided into east and west and Italy divided into north and south).

7.1 Modelling the penetration of new technologies

Optimisation models with detailed techno-economic assumptions for identified technologies are well suited to describe the penetration of new technologies. The same set of technology data and the same model structure can be used to model the development in different regions or countries, using different structural date for the initial infrastructure, and scenario assumptions for the energy market, development of the demand, prices, taxation, etc. Many of these assumptions may be based on the results from economic models describing the global energy market or the national economic development.

7.1.1 Optimisation with emission constraints

The impact of emission constraints on the technology choice in the energy sector has been the topic of numerous studies using 'bottom-up' models since the mid 1980s, when the reduction of SO_2 and NO_x was on the agenda, and later the same models were used to describe the impact of CO_2 emission reduction targets on the national energy systems. One of the first multinational studies using the method of emission cost curves was a study for the Commission DG XII covering all the then 12 Member States (Coherance 1991). The results were presented by the impact of stepwise tighter constraints on CO_2 on total energy system cost and the technology mix. An illustrative example was found for the Danish power system: The targets of constant CO_2 emission in 2005 compared to 1988 until 30 % reduction could be met mainly by the substitution of gas for coal. However, a stricter reduction target would be met by less gas and expensive non-fossil fuel technologies (renewables). To avoid 'stranded assets' in newly built natural gas generating units, investment in these non-fossil fuel technologies should start already by the year 2000, when the reduction target were less strict than five years later (Grohnheit 1991).

7.1.2 Liberalised market

Although optimisation models for the energy sector were designed for the traditional organisation of the industry, these models with their detailed representation of technologies and their simple optimisation algorithm are also useful for analyses of penetration of technologies in a liberalised model environment. However, the traditional application of these models for the national energy system covering all energy sectors is not very useful. They must be redesigned to describe a single agent or a homogeneous group of agents who are facing a large competitive market that may be characterised by a set of exogenous prices.

The structure and boundaries of the optimisation model used in a liberalised market is very important. A societal discount rate of perhaps 5 % may be applied for the common optimisation of the economy including elements that are regulated monopolies, while the optimisation for a particular agent in a competitive market must apply a higher discount rate of 10 % real or more, which also indicate a short time horizon. In the latter case all elements that have a regulated monopoly character must be exogenous.

The shadow prices of the emission limits will increase the effective price level of fossil fuel. These shadow prices may be implemented either by taxes or tradable permits, which will change the relative prices of fuel use and capital-intensive equipment in favour of the latter.

It has become conventional wisdom from numerous studies with econometric and macroeconomic models that the allocation effect of an excise tax on energy is small compared to the income and re-distribution effects of the compensation. The same type of result may be found for tradable permits when using equilibrium models.

An important issue for these measures is: who will pay the taxes or the price of the permits in the end?

For modelling purpose a CO_2 tax or tradable permit can be added as a price tag to the fuels that are used for electricity generation, but the full weight of this extra fuel cost may not be transferred fully to the electricity price on the international wholesale market, because a higher price on the spot or futures market for electricity would attract investment new large gas-fired power stations for sale on the wholesale electricity market. Such investments will limit further price increase by the competition among the potential investors.

7.1.3 CHP-combined heat and power

The penetration of CHP for both industrial processes and space heating is widely different among the European countries, ranging from more than 30 % in the Netherlands, Denmark, and Finland to less than 5 % in the UK, France, Greece, and Ireland. It is more dependent on traditions and legislative support than climatic and infrastructural difference.

The maximum technical potential of CHP has been assessed by different studies to be 40 % of the total electricity generation. This potential includes CHP for both industrial steam and district heating and cooling. Increased energy efficiency in industrial processes and space heating will reduce the technical potential for heat supply from CHP, which is dependent on the heat densities of the local heat markets. On the other hand, new technologies for CHP, in particular the combined cycle gas turbine (CCGT), have increased the efficiency of CHP technologies. These new technologies have a much higher power-to-heat ratio, which means that a given heat market will become the basis for a much larger generation of electricity.

The European Parliament has asked the Commission to encourage the ”wider application of CHP technology”. The key areas addressed for the 5th Framework Programme consider all levels of CHP applications for space heating, from large-scale district heating applications to gas-fired CHP applications in single-family houses, applications with a low demand for space heating, much lower than the normal capacity required in northern Europe (i.e. 5-10 kW).

This issue was also addressed within ‘The Shared Analysis Project published by the European Commission Directorate General for Energy in a Special Issue of Energy in Europe[72], December 1999. One of the individual volumes published with this report focus in particular on the potentials and obstacles for the penetration of CHP[73].

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[72] The Shared Analysis Project, *Economic Foundation for Energy Policy*. Energy in Europe. Special Issue, European Commission, Directorate General for Energy. December 1999, *www.shared-analysis.fhg.de./*.

[73] Grohnheit, P.E., (1999) Energy policy responses to the climate change challenge: The Consistency of European CHP, Renewable and Energy Efficiency Policies. The Shared Analysis Project, Volume 14. *www.shared-analysis.fhg.de./* (Printed as Risø-R-1147(EN). Risø National Laboratory, Roskilde, *www.risoe.dk/rispubl/SYS/ris-r-1147.htm*)

7.1.4 Bottom-up model analyses of technology choice

Optimisation models like EFOM[74] and MARKAL[75] are well suited to describe the penetration of new technologies. Thus, cogeneration of electricity and steam for industrial processes and heat supply to district heating grids is easily modelled by this type of models, because the heat is used for a single identified process. The demand for electricity and heat on the different markets for electricity and heat/steam are modelled using exogenous assumptions on the size of this market. These demand assumptions may be based on the results from different types of economic models, such as macroeconomic models or general or partial equilibrium models (top-down models).

Macroeconomic models in the Keynesian tradition describe short and medium-term economic consequences of policies but with a limited treatment of long-term effects, such as those from the supply side of the labour market. In contrast, Computable General Equilibrium (CGE) models have been widely used to analyse long-term energy-environment-economic (E3) policies. CGE models specify explicit demand and supply relationships and enforce market clearing.

Figure 7.1 shows the structure of a set of co-ordinated model results from techno-economic optimisation model for standardised CHP generators and partial equilibrium models that are used to describe the price formation and trade volume on an international electricity market. Selected results form this model system may further be used to produce date for macroeconomic models, e.g. the E3ME model, concerning the macroeconomic impact of the penetration of the selected technology.

In the optimisation model CHP generators are treated as standardised agents that are serving a given demand at minimum cost either by own-generation or by purchase of electricity from outside.

The model is focusing on the technology choice in the various sectors of the energy system, primary fuel demand and emissions. The technology choice will depend on both the techno-economic parameters for future technologies as well as fuel prices, demand for energy commodities or services, and emission constraints.

Electricity generators are operating on national markets facing international competition. In this study the total demands for electricity and heat (i.e. heat for district heating and steam for industrial uses) are based on the PRIMES Baseline Scenario used for the Shared Analysis Project[76], which covers the period until 2020. Non-fossil electricity generation

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[74] The EFOM model (Energy Flow Optimisation Model) was developed as to the supply part of the energy model complex of the Commission of the European Communities. It has been used for a number of studies since the 1970s. It was used during the 1980s for reference projections of the energy systems in the member countries; and scenarios with assumptions concerning economic growth levels, oil import prices, or the role of solid fuels and nuclear power were studied. An extension of the model to include emissions of pollutants and abatement techniques has been used for many international collaborative studies, e.g. for the construction of cost curves for emission reduction.

[75] The MARKAL model (MARKet ALlocation) is similar to EFOM. It was developed by the International Energy Agency and has been used worldwide over the last decades, in particular within the Energy Technology Systems Analysis Programme (ETSAP) of the IEA – *www.ecn.nl/unit_bs/etsap/main.html*. The Nordleden Project (Unger et al. 2000) is using MARKAL for a recent CO_2 reduction study for the Nordic countries.

[76] European Commission (1999), *The Shared Analysis Project: European Union Energy Outlook to 2020.* Energy in Europe. Special Issue, European Commission, Directorate General for Energy. November 1999, *www.shared-analysis.fhg.de./*.

(i.e. hydro, nuclear and wind) is exogenous. The potential markets for gas-fired micro-scale CHP are estimated on the basis of the same model results[77].

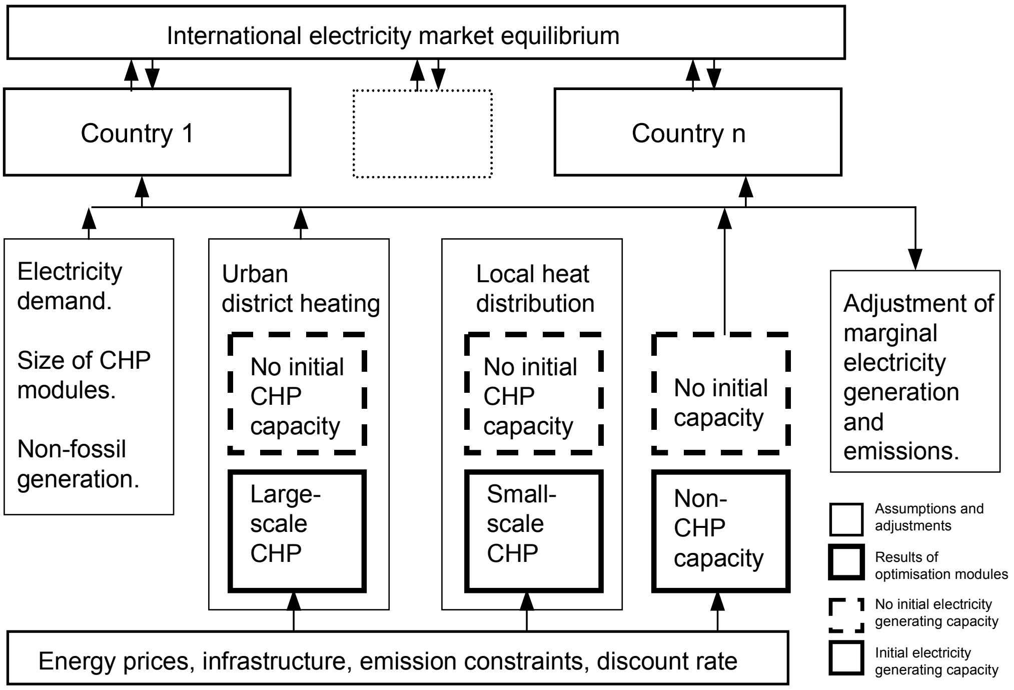

Figure 7.1. Electricity market model based on optimisation modules for CHP generators.

We have not used any model to determine the equilibrium of the international energy markets. Purchase and sale of electricity is a key feature of the optimisation model for the various standardised generators. The national markets are calibrated to comply with structural data for 1995 and using the forecasts of the PRIMES Baseline Scenario.[78]

7.2 PRIMES results for the European Union

PRIMES is a modelling system that simulates a market equilibrium solution for energy supply and demand in the Member-States of the European Union and the implications of energy use on the environment. It considers both national energy systems and the overall European energy market over the period 1990- 2030.

7.2.1 The PRIMES Model

The fundamental assumption in PRIMES is that producers and consumers respond to changes in price. The factors determining the demand for and the supply of each fuel are represented, so they form the behaviour of the agents. The model determines the economic

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[77] Norway and Switzerland are not covered by the PRIMES model. The forecasts for Norway are based on the Nordleden Project (Unger et al. 1999), the forecasts for Switzerland are based on the IEA forecast in Electricity Information.

[78] The development of a model for a market equilibrium for electricity trade in the Baltic region is the main target of the Balmorel project (Baltic Model of Regional Energy Market Liberalisation) for the Danish Energy Research Programme 1999, *www.balmorel.dk*.

equilibrium for each fuel market through an iterative process. In the current model for the European Union price-driven equilibria are considered in all energy and environment markets, including Europe-wide clearing of oil and gas markets, as well as Europe-wide electricity and natural gas networks.

The model is organised in modules by energy production sub-system (oil products, natural gas, coal, electricity and heat production, others) for supply and by end-use sectors for demand (residential, commercial, transports, six industrial sectors). Some demanders may be also suppliers, as for example industrial cogenerators of electricity and steam.

The formulation of the market equilibrium for each market is described by the equations

Demand = Function (Price)
Supply = Demand
Price = Inverse Function (Supply).

More detailed, the behaviour in the supply side is formulated as a set of linear programming models for cost minimisation, and the demand side has the form of a system of (non-linear) equations. Hence the equilibrium model can be written:

Solve for x,q,p,u that satisfy:
Supply side: Min $c \cdot x$
subject to. $A \cdot x \leq b,\ x \in X$
Demand side: $q = Q(p)$
Cost Evaluation: $u = f$ (c, x and other factors)
Equilibrium Condition: $p = u + \text{taxes}$
where
x and q denote supply and demand quantities, and
u and p denote producer and consumer prices.

The supply side may contain different mathematical programming problems to describe the behaviour of the various supplying agents (e.g. different for refineries, gas and electricity). The fact that some suppliers of energy commodities are demanding energy commodities from other suppliers (e.g. electricity for the refinery sector and vice versa) is included in optimisation modules.

7.2.2 The modular structure of PRIMES

PRIMES was developed during 1992-1995 under the JOULE II Non-Nuclear Energy Research Programme by a consortium of institutes from UK, Greece, Belgium, and France. It is a very large and data-intensive model system. It was developed on the basis of models previously used by the European Commission, e.g. EFOM, MEDEE, and MIDAS. The main source for economic data is the EUROSTAT national account statistics. The model system has been used for several studies for various Directorate Generals of the European Commission, and has been expanded to address further issues.. Table 7.1 shows the structure and contents of the PRIMES modules for the model version that was available for the Post-Kyoto scenarios of the Shared Analysis Project.

The model is written in the GAMS (General Algebraic Modelling System) with Excel-based input and output interfaces. In principle, the model is applicable to different countries or groups of countries by changing the data, the definition of industrial classifications and technologies etc., and eventually adapting the code. However, up till now the model is maintained and operated by the developing team at the National Technical University of Athens, managed by Professor Pantelis Capros.

Table 7.1. Survey of PRIMES modules

REGIONS	15 European Union countries
DEMAND	4 energy uses,
Residential:	
	4 types of households, 2 technology vintages, several types of electric appliances
Commercial:	4 sectors, 7 energy uses, full technology vintages thermal integrity, heat and cooling production, energy savings
Industry:	9 industrial sectors up to 4 types of sub-processes 11 energy uses defined full technology vintages heat production and recovery, energy savings pollution abatement.
Transports:	3 transport purposes with different transport modes 6 to 10 alternative technologies for each mode
Electricity production:	Several hundreds of different types of existing and new thermal plants Nuclear, hydro and renewable technologies chronological load curves, interconnection network, representation; three typical companies per country; cogeneration of power and steam, district heating;
Refineries:	4 refineries with typical refinery structure, 6 typical refining units (cracking, reforming etc.)
Natural gas:	Regional supply detail (Europe, Russia, Middle Africa, North Sea etc.), transportation, distribution network
Fuel types and emissions:	18 energy forms 7 types of atmospheric emissions
Markets	Country specific European level markets: refining, gas, electricity exchanges, World oil market: exogenous

7.2.3 The electricity and CHP sector in PRIMES

A fundamental characteristic of electric or steam producers is that they cannot store their product in order to meet fluctuations in demand. At the level of the electricity and steam sub-model in PRIMES, demand for electricity and steam is considered as exogenously given, varying widely between different times of the day and between different seasons.

The representation of demand is based on the definition of a chronological load curve, which depicts the load as a function of time in a year. Within an iteration of the overall PRIMES model, the demand sub-models provide estimates of demand using the same representation of time as the electricity and steam sub-model. Changes in the demand-side, for example, induced by prices or other factors, influence the electricity and steam sub-model. The latter may, for example, change prices that may further affect demand.

In the PRIMES version for the Shared Analysis Project, steam and electricity generation are grouped together as if they were a single industrial sector. The analysis includes the whole production of industrial steam and the heat that can be distributed through small-scale or large-scale district heating networks. The analysis deals with three standardised – or stylised – market suppliers, namely

- utilities
- industrial generators and
- other decentralised producers

Thus, an industrial sector can exploit any advantage in self-generation of steam or electricity provided that it does so in a cost-effective way. The other generators may also act as distributors of district heating. The three stylised market suppliers have different technology choice menus reflecting their differences in size and associated economies of scale. Utilities have an investment menu comprising of large-scale plants, while industrial generators may only invest in small-scale units.

The dynamics regarding economies of scale associated to plant size is an important driver of restructuring. For example technologies that close the cost gap between small and large size (such as small gas machines and fuel cells) favour decentralisation of supply and reduction of the share of traditional utilities. The analysis captures this mechanism and this explains the increased role of non-utilities over the outlook period under baseline assumptions.

The analysis treats stylised suppliers as if they were representatives of an unknown number of similar real-world companies. The discount rate applicable to all decisions on power generation capacity expansions has been assumed to be equal to 8 % per year in real terms. This is uniformly applied for all stylised generators. Tariffs are set to the level of long-run marginal cost of delivering a customer but are adjusted so as to recover total accounting costs plus a normal rate of profit. Steam (or heat) is considered as a by-product, but a minimum tariff is set to reflect reserve margin ensured from maintaining boilers.

7.2.4 Results from PRIMES Post Kyoto Scenarios

The macroeconomic assumptions for baseline scenario for the Shared Analysis Project was made early in 1998, and the various supply modules were developed during the following year in several stages and with communication to a network of scientists and national energy agencies in the Member States. Figure 7.2 shows the results concerning fuel supply for electricity and steam generation for the baseline scenarios and three scenarios with constrained CO_2 emissions.

The CO_2 emission limits – or the shadow price for CO_2 emissions will lead to little more renewables on a European level. but far more natural gas and a significant reduction in solid fuels. The most important technology for new investment in generating capacity is the combined cycle gas turbine for utilities as well as industrial cogenerators.

The key assumptions for the Baseline Scenario are:

- The baseline scenario projects a significant improvement of the energy intensity ratio. Annual energy intensity improvement is expected to average around 1.5 %/a throughout the projection period. It is due, first, to the changing sources of economic growth, and, secondly, to continued technological progress in the energy use and conversion.
- In per capita energy terms, EU primary energy is continuing to grow significantly, by 0.7 %/a, in the period to 2010. In the latter part of the period, however, per capita energy demand will slow down to just 0.3 %/a.
- Technological advances and changes in market structure will reduce the dominance of utilities in electricity generation. The use of gas turbines in combined cycle mode will

also greatly encourage the more widespread use of steam, especially by independent producers.

- The trends in fuel use for steam and power generation purposes reflect the trends in the choice of fuel for new capacity requirements and trends in efficiency. The use of coal and lignite will decline quite dramatically between 1995 and 2010 but after that it will recover to reach, and marginally exceed, its 1995 level.

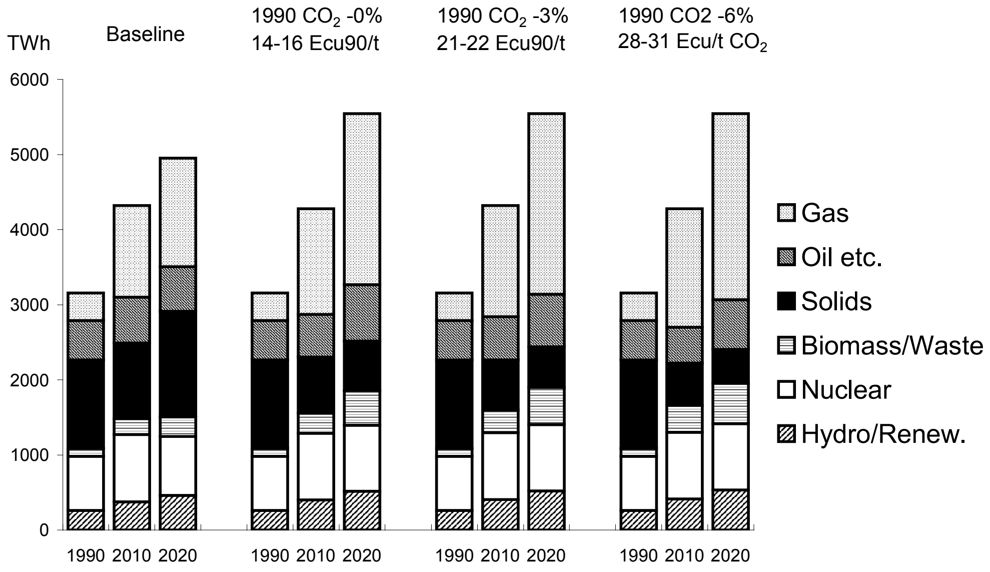

Figure 7.2. Electricity and steam generation in EU-15, 1990, 2010 and 2020.

The CO_2 reduction scenarios consider stabilisation, -3 % and -6 % compared to the 1990 emissions. These targets are achieved by iteration. The carbon values (Ecu90 per ton C avoided) are calculated from the results. Table 7.2 shows different representations of carbon values for different currencies and per ton carbon contents or per ton CO_2

Table 7.2. Different representations of carbon values in the PRIMES Post-Kyoto Scenarios

	Year	**Per ton C**		**Per ton CO2**			
		Ecu90	**US$ 98**	**Ecu90**	**Ecu98**	**DKK 98**	**US$ 98**
Scenario S0: 1990 level	2010	50	70	14	17	160	19
	2020	59	83	16	20	189	23
Scenario S3:1990 level minus 3 %	2010	78	109	21	27	250	30
	2020	81	114	22	28	259	31
Scenario S6:1990 level minus 6 %	2010	102	143	28	35	326	39
	2020	115	161	31	39	368	44

12 t C is equivalent to 44 ton CO_2.

The most important drivers for the determination of prices and volumes in an equilibrium model are income and price elasticities. However, the currently available documentation of the PRIMES model contains only a very limited – and theoretical – description of the elasticities.

Apparently, elasticities must be exogenous to the PRIMES models, based either on external data sources, guessed, or determined through the calibration process.

Results of the CO_2 reduction scenarios were published for the European Union as a whole, and not for the individual Member States.

7.3 Optimisation results for a CHP region

In the EFOM model, the energy system is described as a network of energy flows combining the extraction of primary fuels through a number of conversion and transport technologies to the demand for energy services or large energy consuming materials

The model is focusing on the technology choice in the various sectors of the energy system, primary fuel demand and emissions. The structure and optimisation method (linear programming) is similar to the supply modules of the PRIMES model, and it was one of the sources for the development of the PRIMES model. The technology choice will depend on both the techno-economic parameters for future technologies as well as fuel prices, demand for energy commodities or services, and emission constraints.

7.3.1 The EFOM model for CHP systems

The EFOM-CHP model is used as an element within a set of modelling tools that are available for analysing the options and strategies for electricity generators that are operating in a an electricity market with competition and environmental constraints[79].. This model structure may describe a country, but it may be disaggregated into regions or large utility companies. The natural boundary for a CHP system is a town or urban region with an interconnected district heating grid.

The physical network infrastructure for electricity, gas and district heating is exogenous. However, it is an important feature of a liberalised market for energy that the ‘pipes and wires’ remain a regulated monopoly with access for all market participants.

An EFOM-CHP model module for a single generating company or a group of homogeneous companies may be used to analyse the revenue requirement from long-term contracts, or the market conditions that will encourage or discourage particular generating technologies, e.g. renewables. A set of modules for different types of generators, operating in the same interregional electricity market, can be used to find a long-term price profile that will clear the market.

Figure 7.3 shows the types of links that are used to describe CHP either for industrial steam raising or district heating with a few technologies for separate production. Electricity and heat demand forecasts are exogenous, but the model can be extended to describe technology substitution in the demand sectors, or demand forecasts can be dependent of price assumptions using price elasticities. Each link in the figure can represent several competitive technologies or several vintages of the same technology (Grohnheit 1993). The links refer to a database containing techno-economic data, e.g. fuel efficiencies, investment and operating costs, emission factors, initially installed capacities and constraints on new capacities or energy flows.

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[79] The EFOM-CHP model is developed from the model version used for a study on analysis of CO_2 reduction options for the European Commission in 1990 focusing on CO_2 reduction cost curves (Coherance 1991).

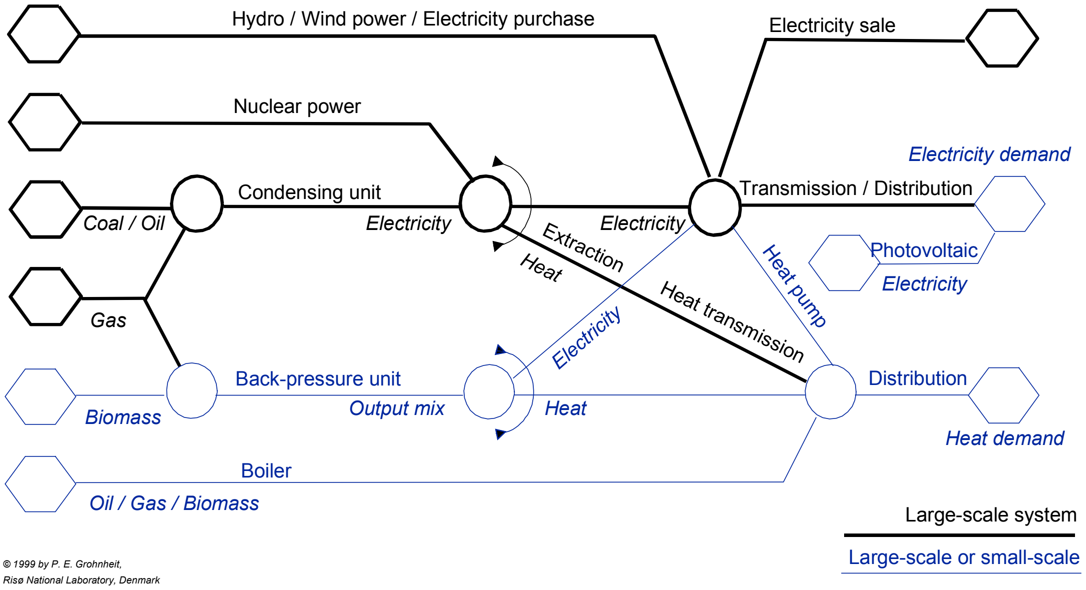

Figure 7.3. Optimisation model for large-scale and small-scale CHP networks

The upper part of Figure 7.3 shows electricity generating technologies for the interregional electricity market including extraction-condensing units for large-scale CHP systems. Non-thermal technologies (i.e. hydro, wind and photovoltaic cells) are technologies that are competing with CHP. At very high fuel prices the model may select these technologies or electricity purchase from the interregional electricity market instead of local or regional CHP generation. Existing nuclear capacity may compete with CHP generation and existing fossil-fuel condensing capacity may discourage investment in new CHP capacity.

Extraction-condensing turbines is modelled as condensing turbines generating electricity only. Then demand for heat from the urban district heating grid is modelled by converting part of the potential electricity to heat using the inverse of the power-loss-ratio. Thus the model is able to simulate the flexible combination of electricity and heat from extraction-condensing turbines.

The lower part of the figure shows small-scale CHP technologies that are available for small district heating grids, mainly back-pressure units that generate electricity and heat in a fixed proportion specified by the power-to-heat ratio.

Both the upper and lower parts of Figure 7.3 are available for large urban grids, or a small district heating grid connected to a particular extraction-condensing power station.

A CHP model region is specified using a set of consistent data for electricity and heat demand, equipment for generating electricity and heat, biomass resources, and infrastructure constraints. The same model and basic data are used to model different scales of district heating, using the capacity of heat transmission from large extraction-condensing power plants as a key parameter.

7.3.2 The impact of tradable CO_2 permits

The optimisation model is used for three examples of prices for tradable permits, CO_2 payments at 10,66 Ecu90 (rounded to 11 Ecu90) equal to 100 DKK-1998 per ton CO_2, the double (rounded to 21 Ecu90), and four times the first assumption (rounded to 43 Ecu90). The CO_2 payment is modelled as a price tag to fossil fuel prices, which may be fully or partial transferred to the electricity market price.

The PRIMES forecast for fossil fuel prices has been used, see Table 7.3. Similar to the PRIMES modelling for the Shared Analysis Project all prices are shown in ECU at 1990 price level, which is the price base for several consumer price indices and fixed price presentations of national accounts. The consumer price index in ECU for 1998 with 1990=100 is 125 (the conversion factors for DKK and NOK 1998 are 9.382 and 10.596, respectively (see Appendix A).

Table 7.3. Price assumptions for fuels and electricity trade.

	Ecu90/MWh				Ecu90/toe			
	1995	**2000**	**2010**	**2020**	**1995**	**2000**	**2010**	**2020**
Coal	4.92	4.79	4.87	4.99	57	56	57	58
Fuel oil	6.97	6.17	7.27	8.37	81	72	85	97
Gasoil	13.47	12.15	13.96	15.77	157	141	162	183
Gas	6.63	6.43	7.86	9.29	77	75	91	108
Straw	6.88	6.88	6.88	6.88	80	80	80	80
Wood	5.59	5.59	5.12	5.12	65	65	60	60
Urban waste	-8.31	-8.31	-8.31	-8.31	-97	-97	-97	-97
Electricity purchase (import)	17.21	16.92	17.10	17.36	200	197	199	202
Electricity sales (export)	13.75	13.46	13.63	13.89	160	157	159	162

Sources: PRIMES Post Kyoto Scenarios and Energistyrelsen 1995.

The very important prices for wholesale trade of electricity cannot be derived from the PRIMES assumptions. An annual contract price 2001 is assumed on the basis of price quotations in 1998 from the Norwegian-Swedish electricity exchange Nord Pool and the power broker Skandinavisk Kraftmegling for forward prices for annual contracts at 161 NOK per MWh (15 Ecu90). This price is divided into two components: the variable cost of a coal or gas fired power plant and a residual that represent the contribution margin for the marginal generator. However, this margin is very small, leaving much existing capacity as 'stranded assets'. In a preliminary model analysis the variable component was assumed to follow the price forecast for coal and gas respectively. The conclusion of the first iteration was that the price of an annual contract for electricity should follow the lowest of a coal or gas reference price with CO_2 payments, see Table 7.4. Given the remaining assumptions for the CHP model regions, this assumption tends to lead to a reasonable balance between electricity purchase and sales for the different types of CHP regions and power generation without heat supply. The difference between the prices for electricity purchase and sales in Table 7.3 reflects the costs of interregional or international transmission.

Table 7.4. Electricity forward prices for annual contracts with full transfer of CO_2 payments.

Ecu90/MWh	**1995**	**2000**	**2010**	**2020**
Reference	15.48	15.19	15.37	15.62
11 ECU per ton CO_2	15.48	19.56	22.41	23.73
21 ECU per ton CO_2	15.48	23.93	26.77	29.65
43 ECU per ton CO_2	15.48	32.66	35.51	38.38

Source: EFOM-CHP

In the first optimisation year, there is no CO_2 payment or other energy taxes. The CO_2 payment is assumed for the optimisation years: 2000, 2010 and 2020.

The reference scenario assumes a competitive market for all technologies, which will require a discount rate at 10 % for the optimisation. A 5 % discount rate can be interpreted as some legal or political support, cf. e.g. Article 8, Subsection 3: of the electricity Market Directive: "A Member State may require the system operator, when dispatching generating installations, to give priority to generating installations using renewable energy sources or waste or producing combined heat and power”[80]. In particular this may apply to small-scale CHP technologies and new investment in large-scale CHP.

Some model results were also tested using a 15 % discount rate to represent risk-averse agents in a very competitive market. This higher discount does not change the main pattern of the technology choice, but investment in new capacities and sale of electricity will be discouraged, while it becomes more attractive to purchase electricity from outside. This mechanism may lead to higher electricity prices after a decade with low prices.

7.3.3 Model assumptions for standardised CHP generators

Table 7.5 summarises the assumptions for the CHP regional modules describing different groups of homogeneous companies characterised by their access to different scales of heat markets and initial generating capacities.

Table 7.5. CHP regional modules

CHP module	**Technology and demand**	**10 % discount rate**	**5 % discount rate**
Small DH	Small-scale CHP – No initial CHP	X	X
Small CHP	Small-scale CHP – CHP capacity	X	X
Large DH	Large-urban DH – No initial CHP	X	X
Large CHP	Large urban DH – CHP capacity	X	
CHP from 2010	Local heat/steam – No CHP before 2010	X	X
Sep. Prod,	Local heat/steam – No CHP	X	
No Capacity	No district heating - Import constrained	X	
No-DH	No district heating - Initial old capacity	X	
New capacity 2010	No district heating - No demand before 2010	X	
New capacity 2020	No district heating - No demand before 2020	X	

The modules with initial CHP capacities are based on structural data from groups of Danish district heating networks ranging from large urban grids with heat supply from CHP units of different vintages to smaller grids with base load from a single CHP unit and a waste incineration plant. The techno-economic and structural data for these modules are documented in Grohnheit 1999 (the Shared Analysis Project, Volume 14), Sections 4.3.1 and 4.3.2.

The modules with no initial CHP capacity are based on the modules for large-scale and small-scale district heating networks, assuming that all the heat is supplied by heat-only boilers. Scenario results for the combinations of scale and initial capacity are documented in details in Grohnheit 1999, Section 4.3.4. Extracts of these results are shown in the following sections.

The remaining modules are specified adding further constraints concerning technology options or heat demand.

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[80] Directive 96/92/EC of 19 December 1996 concerning common rules for the internal market for electricity.

7.3.4 Electricity generation by technology

The various assumptions on fuel and electricity prices have significant influence on the amount of import of electricity and local generation. In general, there will be a shift from purchase on the national or international electricity market to local generation, and the higher the fuel and electricity prices the more electricity will be generated locally, see Figure 7.4.

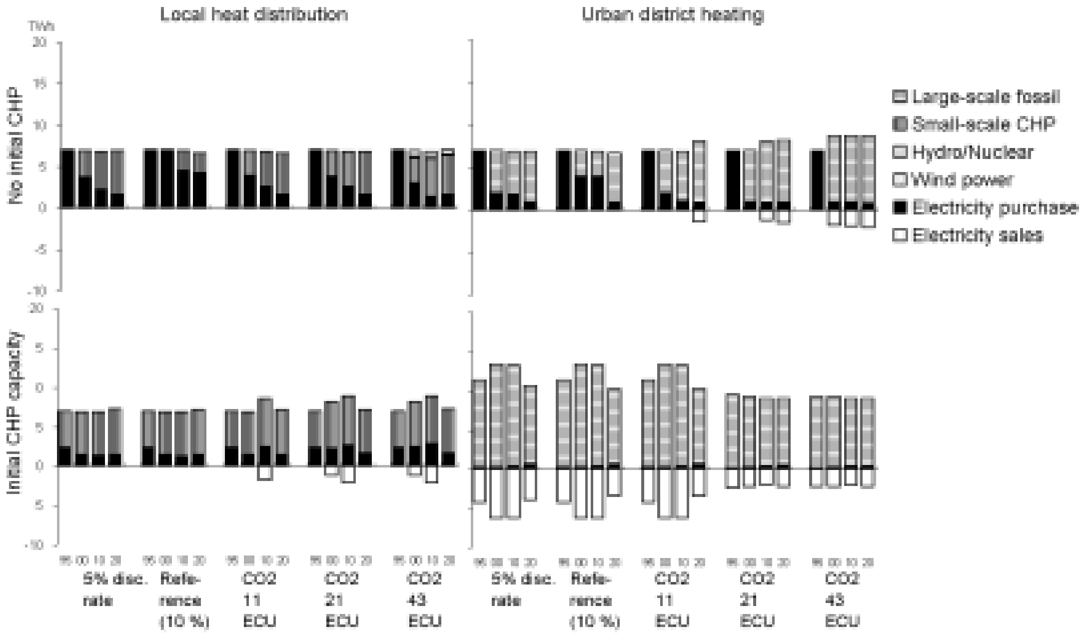


Figure 7.4. Electricity generation by technology, 1995, 2000, 2010, 2020

If the wholesale electricity market price followed the rise in coal price with the cost of CO_2 quotas and the full weight of the permit price were transferred to the electricity price on spot or futures markets, high export prices would create an incentive to invest in new capacity to generate for sales to the market. However, if this became the reaction of all utilities, there would be overcapacity, and market prices would be reduced by competition among generators.

Thus, the assumption chosen for the development of the electricity market price (i.e. the lowest of coal and gas prices with CO_2 payment) seems to develop market equilibrium with export from some regions and import to other regions.

At high CO_2 payment, operators of both small-scale and large-scale CHP will have an incentive to invest in new – gas fired – large-scale capacity for sale to their electricity customers or on the wholesale market for electricity in the period 2010-2020. At even higher CO_2 payment than those shown in Figure 7.4 they would invest in expensive non-fossil technologies, e.g. wind or nuclear power. However, only obsolete and tentative data has been included for nuclear technologies, and nuclear CHP has not been considered. For other technologies the assumptions on technology progress are very conservative and does not address the dynamics of technology progress, see Section 7.5.

An initial capacity in 1995 has little influence on the technology choice. Under most assumptions the optimisation will choose the same technologies as in the regions with a planned development. When large-scale CHP is available this technology seems to be dominant, i.e. it will be chosen both at higher CO_2 payments and lower discount rate. For small-scale CHP the technology choice is much more sensitive to variations in assumptions. However, the overall pattern of the results is not very sensitive to different assumptions.

In the regions with existing large-scale CHP capacity there is assumed an abundance of electricity generating capacity, because the access to a large heat market has been the primary criterion for location of large power plants (i.e. 250-500 MW extraction-condensing units). This location policy is justified only if there will be a significant sale from these units to the regional or interregional electricity market.

7.3.5 District heating supply technologies

The impact on district heating technologies is visible, but moderate as shown in Figure 7.5. In particular, there is an increase in biomass for the small-scale district heating grids at the expense of fossil fuel boilers. The large share of central CHP will remain unchanged, but – as shown in Figure 7.6 – the primary fuel will change from coal to gas.

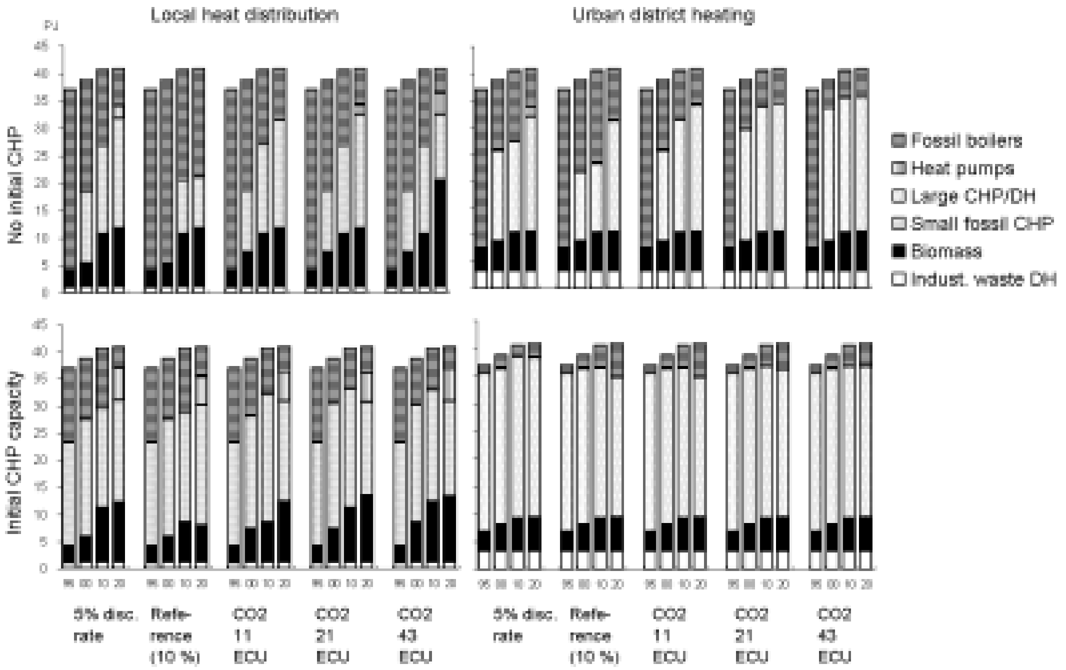


Figure 7.5. District heating technology choices 1995, 2000, 2010, 2020.

The overall picture is that both small-scale CHP and large-scale will penetrate, but large-scale CHP will dominate when available. A lower discount rate will speed up this penetration of small-scale CHP. The most important impact of higher CO_2 payments is that biomass technologies will penetrate further in the CHP regions without access to large-scale CHP.

An interesting feature, which appear at most of the different assumption is the emergence of heat pumps in the last period 2010-2020. These model results may even underestimate the potential for heat pumps, because the techno-economic assumptions are very conservative. The assumed efficiency factor is 2.7 only, while current vintages of large-scale heat pumps may have a much higher efficient factor.

7.3.6 Primary fuels in scenario results

Figure 7.6 clearly illustrate the dominance of gas for small-scale CHP applications. Only the default assumption are shown, but parameter variations within the range used for the previous figures have little impact on the dominance of gas.

In large-scale CHP regions with an initial capacity of coal-fired or multi-fuel capacity, the introduction of CO_2 payment will lead to the substitution of gas for coal, reflecting the somewhat lower carbon contents of gas compared to coal (56 kg CO_2 per GJ gas and 95 for coal). However, this result may be sensitive to the relative prices of coal and gas as seen in the lower right part of the figure, which shows a return from gas to coal in the last period, 2010-2020, because the assumed increase in gas price will outweigh CO_2 payment at the moderate level at 21 Ecu90 per ton CO_2.

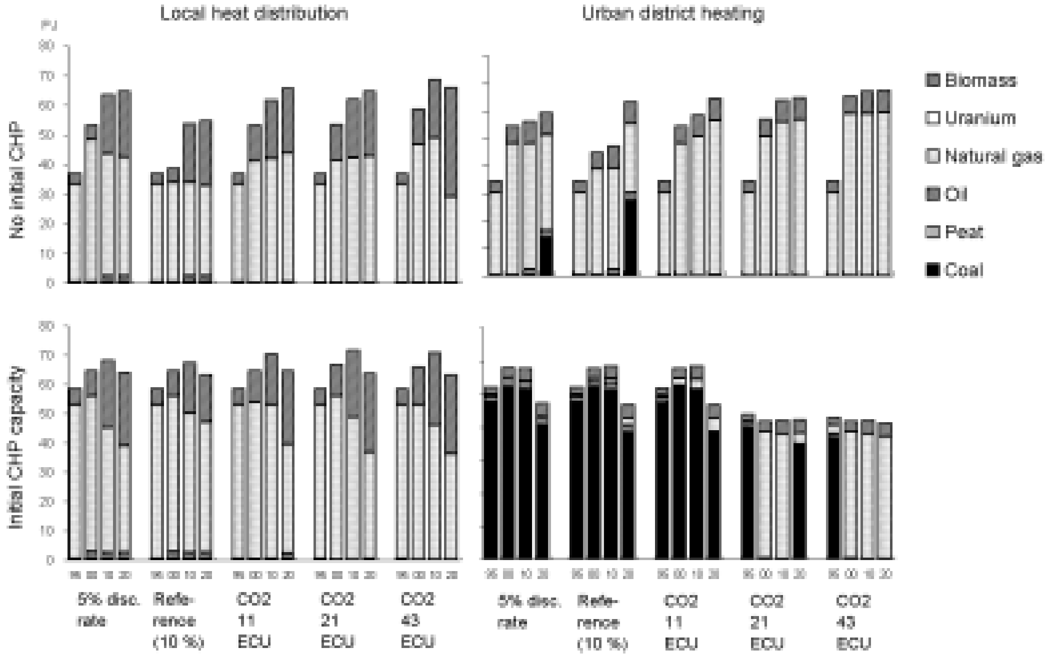


Figure 7.6. Primary energy for CHP regions 1995, 2000, 2010, 2020.

7.3.7 Model results as 'building blocks' for geographical regions

The model results from the EFOM-CHP model for the different types of CHP regions can be used as 'building blocks' or modules to represent the existing and future infrastructure of the electricity and heat markets in actual geographical regions facing competition from electricity generators in neighbouring regions.

It should be emphasised that the EFOM-CHP modules will address neither the important issue of network expansion nor the competition with improvement of the thermal standard of buildings.

Heat pumps are included as an alternative supply option for heat distribution networks, as well as renewables for electricity-only generation. The latter technologies are both competitive and complementary to CHP technologies. Heat pumps, which consume electricity and small-scale CHP, which generate electricity used in combination will add to ability of operators of district heating and heat distribution systems to take advantage of the volatility of electricity prices on a liberalised market.

7.4 The international electricity market

The model results from the EFOM-CHP model for the different types of CHP regions are also used as 'building blocks' for the electricity markets in the 17 western European countries covered by the E3ME macroeconomic model.

7.4.1 Modelling the electricity market in 17 western European countries

Table 7.6 shows in the first row the composition of the national electricity markets in six countries in northern Europe with strong transmission lines for electricity trade, or plans for further interconnections. The next row shows six countries in western Europe that take part in international electricity trade, and the last row show the remaining of the countries.

The national markets are calibrated for 1995, so that all heat or steam supplies according to PRIMES are covered by the CHP modules. Further calibration was made for consistency with the data heat/steam generation from CHP units and boilers according to the PRIMES scenarios until 2020. However, PRIMES has no distinction between heat or steam generation for district heating and industrial use, so consistency with 1995 data must be made using other sources. Unfortunately, consistent statistics for the potential markets for CHP is not available from any source.

As shown in Table 7.6 nearly 90 % of the Danish electricity market is described by the CHP modules. Existing and planned wind power is not included in the CHP modules. In 1995 wind power covered some 5 % of the market. The PRIMES Post Kyoto scenario increases the generation from wind considerably. In addition, in the optimisation a company may invest in electricity-only generation – including wind – if this technology is competitive.

Table 7.6. CHP modules for the European electricity markets

Northern European electricity market	Denmark	Finland	Germany	Netherlands	Norway	Sweden
Small-scale CHP. No initial capacity	15 %	10 %	7 %	10 %	2 %	20 %
Large-scale CHP. No initial capacity	12 %	10 %	5 %	5 %		12 %
Small-scale CHP, Initial CHP capacity	20 %	25 %	9 %	45 %	2 %	4 %
Large-scale CHP, Initial CHP capacity	40 %	20 %	10 %	5 %		4 %
Sum of CHP modules	87 %	65 %	31 %	65 %	4 %	40 %

Six countries in western Europe	Austria	Belgium	France	Italy	Spain	UK
Small-scale CHP. No initial capacity	5 %	1 %	6 %	8 %	10 %	4 %
Large-scale CHP. No initial capacity	5 %		3 %			
Small-scale CHP, Initial CHP capacity	15 %	10 %	6 %	20 %	15 %	17 %
Large-scale CHP, Initial CHP capacity	10 %					
Sum of CHP modules	35 %	20 %	15 %	28 %	25 %	21 %

Other European countries	Greece	Ireland	Lux.-bourg	Portugal	Switzerland
Small-scale CHP. No initial capacity	15 %	15 %	5 %	30 %	2 %
Large-scale CHP. No initial capacity					
Small-scale CHP, Initial CHP capacity	1 %	8 %	2 %		
Large-scale CHP, Initial CHP capacity					
Sum of CHP modules	16 %	23 %	7%	30 %	2 %

Source: Own estimates.

The Norwegian market can be represented by a small percentage of small-scale CHP modules without initial capacity and hydropower, which supply the interregional electricity market. The large Swedish district heating market will be represented by both small-scale and large-scale modules, mainly without initial capacities. Hydro and nuclear will supply a decreasing percentage of the market depending of the phase out of nuclear units.

The size and structure of the Finnish market for district heating is similar, but the total Finnish electricity market is much larger. In absolute terms the German district heating market is about twice the Danish, but it covers only about 10 % of the German electricity market. The Austrian district heating market can be represented by one large-scale CHP module with existing and planned CHP capacity.

In all other European countries the modules with no initial CHP capacity will be dominant. The large district heating systems in Sweden is represented by less than one of the modules with CHP capacity, but several large and small scale modules with no initial CHP. District heating in France outside Paris can be represented by a few small-scale modules with no initial CHP, while the large and unique Paris district heating system may be badly represented by the large-scale module.

Outside the district heating systems there are large markets for CHP for industrial processes and water-based heating systems for large institutions and blocks of flats. The industrial market is very significant in many countries. The best indication of the significance of this market is the penetration to about 40 % of the electricity market in the Netherlands. The size of the latter may be significant, but the statistical basis for quantification is very weak.

In many European countries, there is a very developed natural gas grid that supply gas boilers for space heating. If micro-scale CHP becomes available the market in these countries will be enormous, and this may considerably change the electricity supply industry. The potential for this technology is discussed in Section 7.5. The current liberalisation of the industry could be a driving force for the development of the necessary equipment and their penetration.

Figure 7.7 shows the result of a calibration of the model for 1995 for the 15 Member States of the EU plus Norway and Switzerland. The structure of electricity generation by the CHP modules is compared with available international statistics (the PRIMES Post Kyoto scenario, the statistics in the Annual Review of Energy from the European Commission, and Nordel statistics for the Nordic countries). For most countries it was possible to describe the structure of the electricity market in 1995 reasonably exact by the standardised generators of thermal electricity and CHP as shown in Figure 7.7. The difference for the heat markets as described by the PRIMES model are larger. However, any definition of the heat market for international comparison is dubious, and the international statistics is very bad.

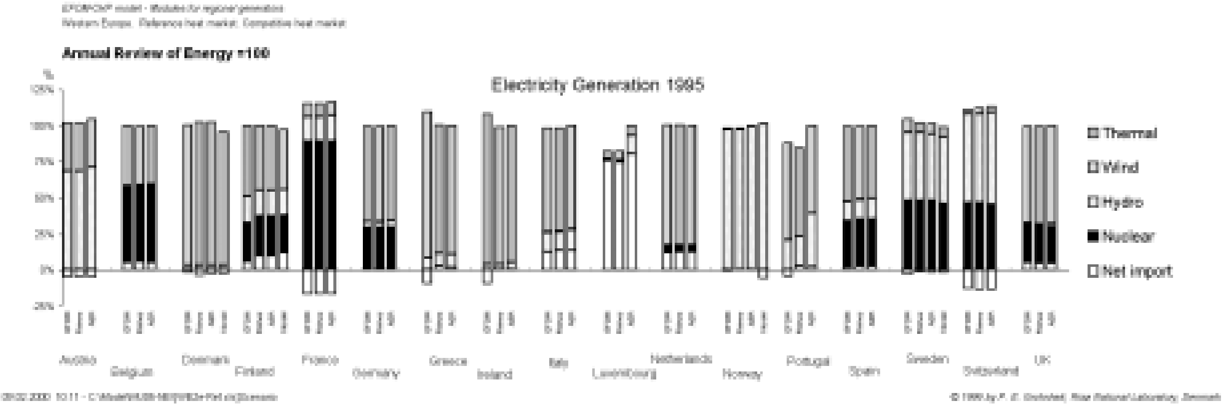


Figure 7.7. The structure of electricity generation in the 17 countries in western Europe.

There are significant differences among the countries. In France, Norway, Sweden and Switzerland hydro or nuclear power cover much more than half of the total supply, while the share in Austria, Belgium Finland, Spain and the UK is between one-third and two-thirds.

Hydro, nuclear and wind power are exogenous to the bottom-up model, and the generation from these technologies is taken from other scenario studies. Nuclear and wind are technologies that may be chosen by the optimisation. For example will significant economies of scale for gas-fired generating units make it cheaper to invest in electricity-only capacity elsewhere than in local small-scale CHP.

The difference between hydro, nuclear and wind is not significant for the current study. These are non-fossil technologies. Hydropower with reservoirs is important for peak load, while run-of-river, wind and nuclear are non-dispatchable. These issues are only limited addressed by the time-resolution used by the optimisation model (summer and winter; peak and base load).

7.4.2 CO_2 costs and international electricity trade

Only part of the assumptions necessary for modelling the European electricity market are listed in Table 7.6. A key constraint used for balancing of the international markets is the maximum net trade as a percentage of the national electricity demand. This constraint is shown in Figure 7.8 as a negative maximum additional export. In this market balance only Luxembourg may import all electricity demand, and the maximum net export is set equal to the national demand. The constraint on net trade is set at 50 % for smaller countries with high capacity international transmission lines (Austria, Belgium, Denmark and Ireland) or a potential for expansion of transmission capacity. The limit for Norway is set at 25 % and 20 % for most countries (France, Italy, Portugal, Spain, Sweden, Switzerland, and UK). Lower limits are used for large or isolated countries, or in case of a large share of industrial CHP (15 % for Finland and the Netherlands, 10 % for Greece, and 4 % for Germany). The model (implemented on a spreadsheet) will automatically correct surplus export by reducing electricity-only generation by fossil fuels, while surplus import must be corrected manually by assuming new capacity from 2010 or 2020, see the list of standardised generators in Table 7.5.

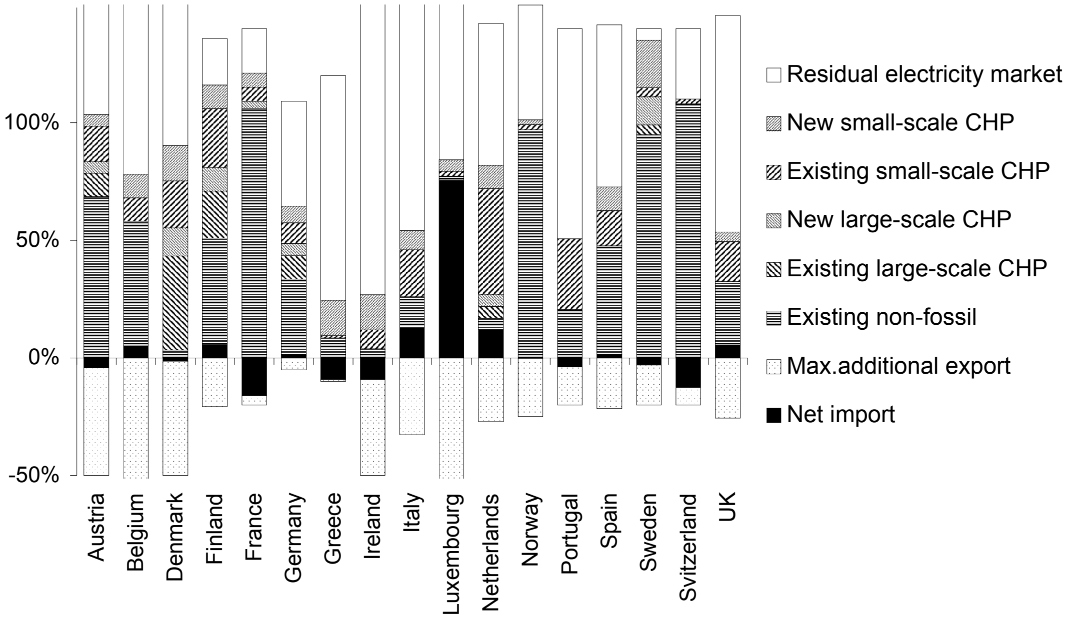


Figure 7.8. Electricity supply structure and market potential by 1995 for 17 European countries

Figure 7.9 shows the electricity trade among the countries. The data for 1995 is a result of the calibration shown in Figure 7.7 while the results for the years 2000, 2010 and 2020 are results that are mainly dependent on assumptions on new generating capacity for fossil electricity-only generation. These assumptions are chosen in order to balance the international market and minimise investment in new capacity, which can be postponed or avoided by import from neighbouring countries. In Figure 7.8 the residual electricity market illustrates the need for and the constraints of new electricity-generating capacity. In some of the larger countries – or the more isolated countries – such new capacity is constrained by the international transmission capacity. These constraint will also apply to investment in new renewable capacity, or micro-scale CHP capacity in addition to "New small-scale CHP", which reflects the heat or steam market that was identified in the PRIMES Post-Kyoto Scenario.

Reference scenario – Years 1995, 2000, 2010, 2020

11 Ecu90 per ton CO_2

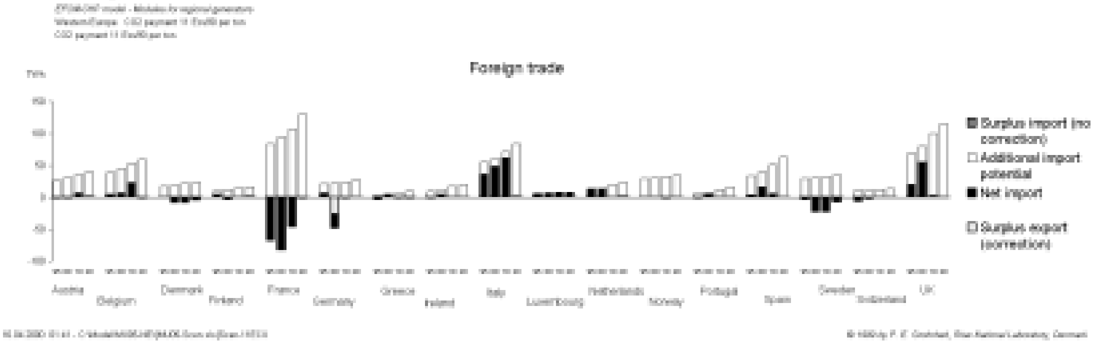


Figure 7.9. Net foreign electricity trade among 17 western European countries by CHP modules.

CO_2 payments will increase investment in small-scale CHP in nearly all countries. In Germany the export potential will increase above the constraint set in the scenario assumptions as shown in Figure 7.9. At higher values of CO_2 payments the constraints on export will be broken also in the Netherlands and France.

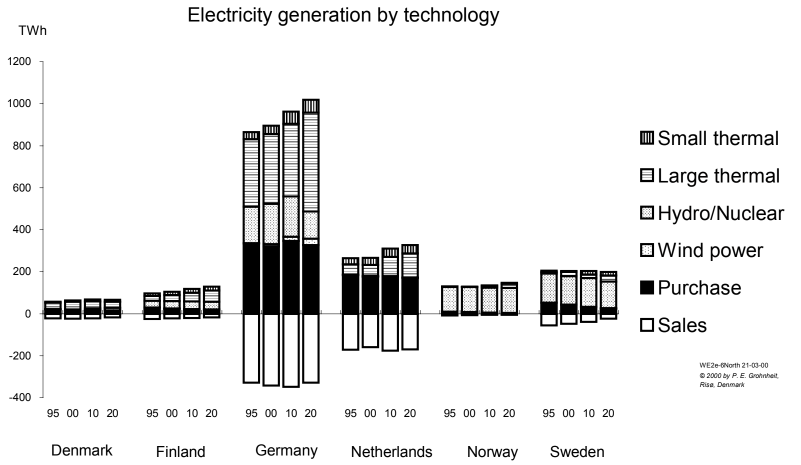
7.4.3 Model results for electricity and heat in 6 countries in northern Europe

Detailed results for electricity and heat generation is shown only for the six countries in northern Europe, Denmark, Finland, Germany, the Netherlands, Norway and Sweden, for which the model results of the standardised CHP generators are most appropriate, see Figure 7.4, Figure 7.5, and Figure 7.6.

In Figure 7.12 the upper graph shows the results of the reference scenario for these countries in absolute values for the six countries, which are very different in size. Trade among generators and distributors with a potential for investing in – mainly small-scale –

CHP is very important in Germany and the Netherlands, and there is a smaller, but relative large, potential for CHP in Sweden, while the remaining CHP markets in Denmark and Finland are small.

Reference scenario – Years 1995, 2000, 2010, 2020.



CO_2 payment 11 Ecu90 – Years 1995, 2000, 2010, 2020 – 20 times larger scale

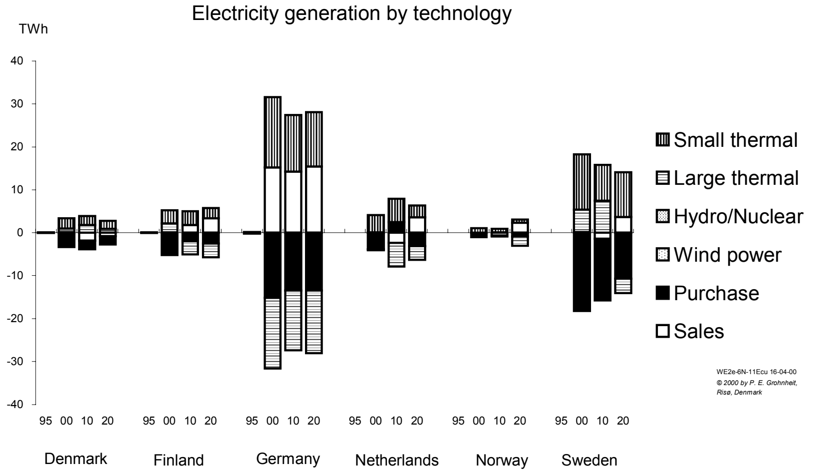


Figure 7.10. Electricity generation for 6 countries in northern Europe.

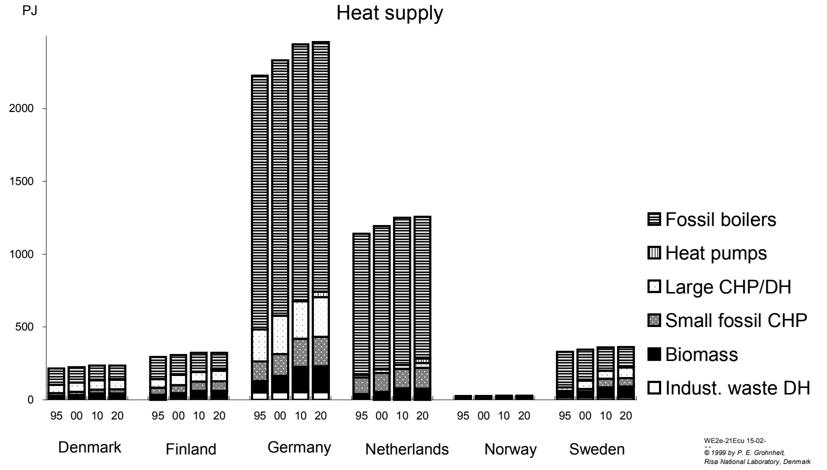
The development of hydro and nuclear power is exogenous, so the results of the standardised generators will apply to thermal generation only.

The lower graph in Figure 7.12 shows the impact of the CO_2 payment at 11 Ecu90 per ton. There is a shift from purchase of electricity to local generation by small-scale CHP units. The impact, however, is limited (the scale of the lower graph that shows the difference is 20 times larger than that of the upper graph).

Figure 7.11 shows the same scenario results for generation of heat for space heating by local distribution of hot water or industrial steam. The heat market is extended to include even small heat distribution system, which may be a potential market for micro-scale CHP, if this technology becomes economically available (see Section 7.5.2). In the scenarios shown here, CHP technologies below some MW-electric are not assumed available before 2020.

The increase in biomass and small-scale CHP in the reference scenario follow from the weight of the standardised generators, see Figure 7.5, and CO_2 payment at 11 Ecu90 per ton leads to some further penetration.

Reference scenario – Years 1995, 2000, 2010, 2020



CO_2 payment 11 Ecu90 – Years 1995, 2000, 2010, 2020 – 10 times larger scale

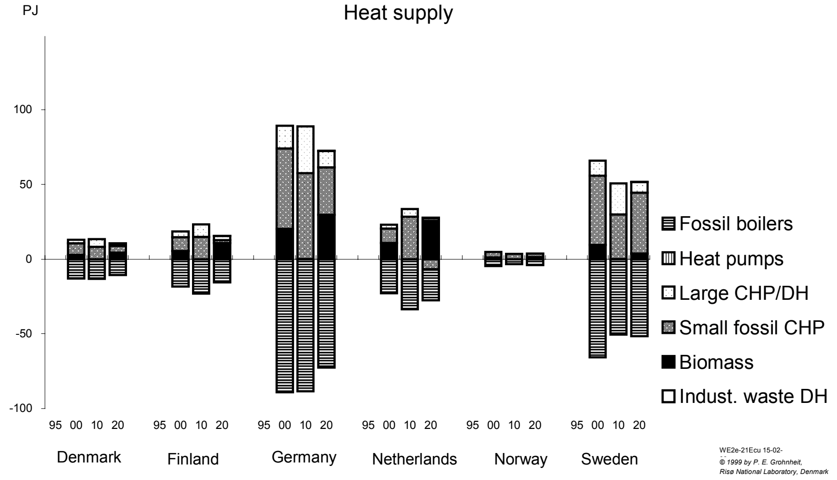
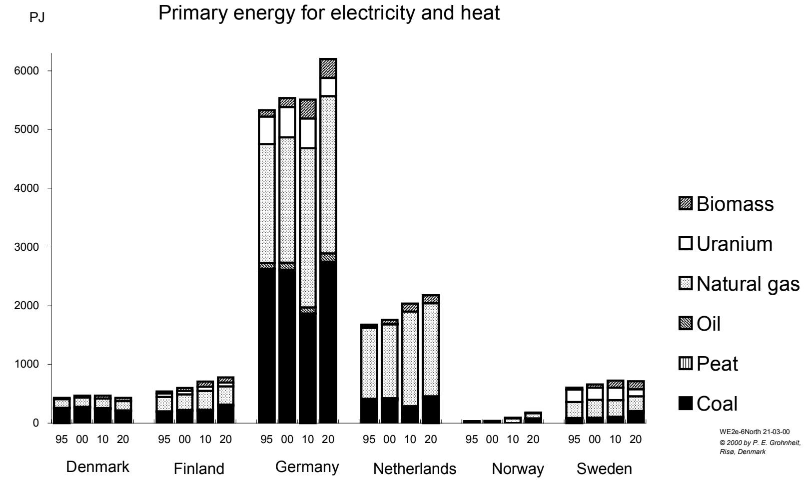


Figure 7.11. Heat and steam generation for 6 countries in northern Europe.

Figure 7.12. shows the development in primary energy. At the current price assumptions, there is some substitution of gas for coal in the reference scenario until 2010, while there is an increased use of coal in the last period. This revival of coal is very sensitive to price assumptions and CO_2 payment. The lower part of Figure 7.12 is shown in the same scale and indicates a significant shift from coal to gas.

Reference scenario – Years 1995, 2000, 2010, 2020



CO_2 payment 11 Ecu90 – Years 1995, 2000, 2010, 2020 – Same scale

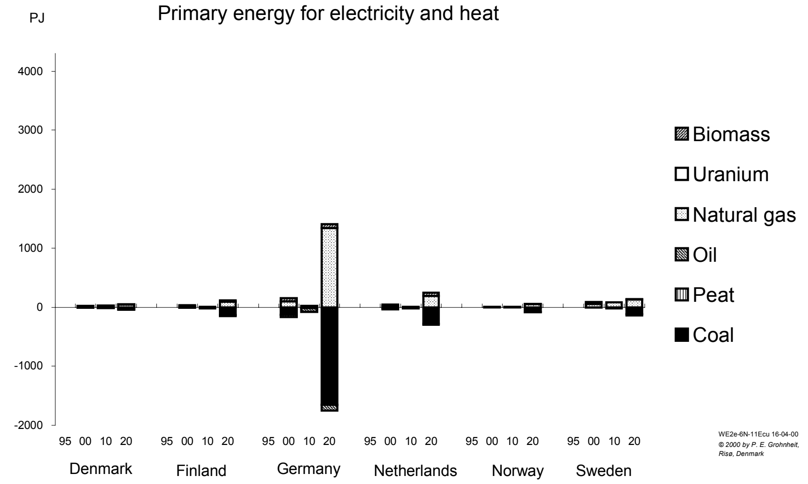


Figure 7.12. Primary energy for electricity and heat or steam for 6 countries in northern Europe

In contrast to the previous figures, Figure 7.13 is normalised per kWh consumed in each country. The most visible difference in the cost structure among the countries is the differences in trade activity. The unit costs are low, because they do not include sunk costs, and the need for new investment within the period is limited. The impact of CO_2 payment at 11 Ecu90 is shown in the lower part of Figure 7.13.

Although the trade activity will be reduced by more local generation, both purchase cost and sales revenue (negative) will increase. Thus, nearly all the difference in unit costs of electricity in the scenario with CO_2 payment 11 Ecu90/t are caused directly by the CO_2 payment and the assumed transfer of these payments to the wholesale electricity price, which also apply to hydro and nuclear electricity in Norway and Sweden. The extra costs of fuel substitution and investment in new capacity is negligible.

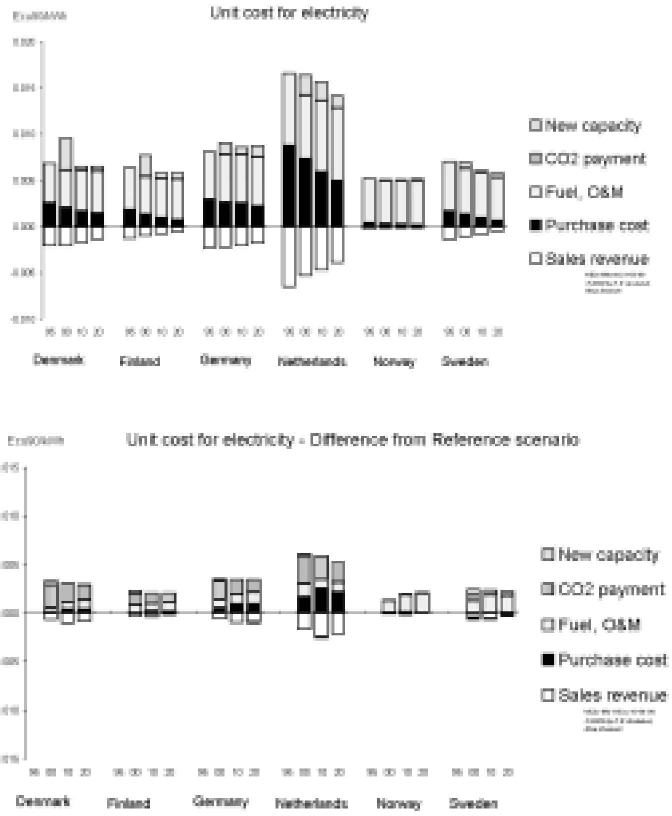


Figure 7.13. Annual unit electricity cost and CO_2 emissions for 6 countries in northern Europe. Reference and CO_2 payment 11 Ecu90/t.

7.5 Modelling technology development

In the bottom-up model studies described in the previous sections CO_2 tradable permits or CO_2 taxes was implemented as a price tag on fuel prices and electricity prices. The result was a shift from coal to gas or investment in technologies with less emissions of CO_2. Both fuel prices and the investment costs are exogenous, and a relatively high value of CO_2 payment would be necessary achieve a significant reduction of CO_2 emissions. Technological progress is taken into account by more efficient technologies becoming available from a future year or lower investment costs due to technological progress.

In summary, the model results were based on the relative costs of fuels and generating equipment. And the assumptions concerning technology development are rather conservative.

7.5.1 Technological progress

These conservative assumptions are not consistent with the experience that ‘once a technology penetrate the market, it tends to be cheaper’. There is little tradition to quantify this experience into a bottom up model, which would require specific quantitative assumptions on the development in investment cost and efficiency parameters.

As a part of a study “Industrial Benefits and Costs of Greenhouse Gas Abatement: Applications of E3ME”, for the JOULE III energy research programme, the EFOM-CHP model described in Section 7.3 was used to quantify the impact of a future availability of micro-scale CHP (e.g. for single family houses) at investment costs that would allow this technology to penetrate into the market for heat and electricity. Two scenarios depending on assumed development of vintages of technologies were specified: a moderate one and a high-speed development. These scenarios were compared with the reference scenario in order to find final impacts of the future CHP.

The key technology assumption concerns the availability of very small-scale gas fired CHP – either in the form of gas motors or fuel cells. In the reference scenario this technology will not be available in scales lower than those available for industrial CHP in many countries, 'decentralised CHP' in Denmark or *'Blockheizkraftwerke'* in Germany[81].

In a scenario on *moderate technology development* it is assumed that micro-scale CHP for single-family houses and small businesses at costs no higher than current small-scale CHP before 2010. The availability of such technologies will require an increase in R&D expenditure in selected sectors in the period 2001-2010. The penetration of the technology will depend on the same conditions as other technologies, using the discount rate at 10 % in an optimisation model. The result of this scenario is described in the following sections.

In a scenario on *fast technology development* it is assumed that this technology is supported by public R&D, and various types of market regulations or subsidies, which will allow investors of all types of small-scale CHP to use a lower discount rate. Under such a dissemination friendly environment technologies the discount rate at 5 % was used in the optimisation model.

The market potential for micro-scale CHP is identified combining the forecast for natural gas supply to boilers outside the market for district heating and industrial steam in the PRIMES Post-Kyoto Scenario and the "residual electricity market" in Figure 7.8.

The size of the market potential for micro-scale CHP is very dependent on a number of assumptions, concerning both technology parameters and the structures of the national markets. The key technology parameter is the power-to-heat ratio, which is highly dependent on the technology development and the actual choice of equipment. There are very significant differences among the countries, which mainly depends of the penetration of current CHP technologies and the existence of a natural gas grid. Assuming a moderate power-to-heat ratio (about 0.6) the potential for micro-scale CHP is larger than the electricity demand in 1995 in the Netherlands, where the space heating and horticulture markets are dominated by natural gas supply. The market potential for micro-scale CHP is much smaller in all other countries. It is between 30 and 60 % in most countries (Austria, Belgium, France, Germany, Ireland, Italy, Luxembourg and the UK), between 20 and 30 % in Denmark, Portugal, Spain and Switzerland, and between 10 and 20 % in Greece and Finland. In Norway there is no gas grid at all for domestic supply, and in Sweden the penetration of natural gas is very limited. However, in both these countries there is a potential for a massive introduction of natural gas.

7.5.2 Availability of micro-scale CHP

More local electricity generation means less generation from the utilities or an exportable surplus. It is assumed that local generation and utilities are competing in an international

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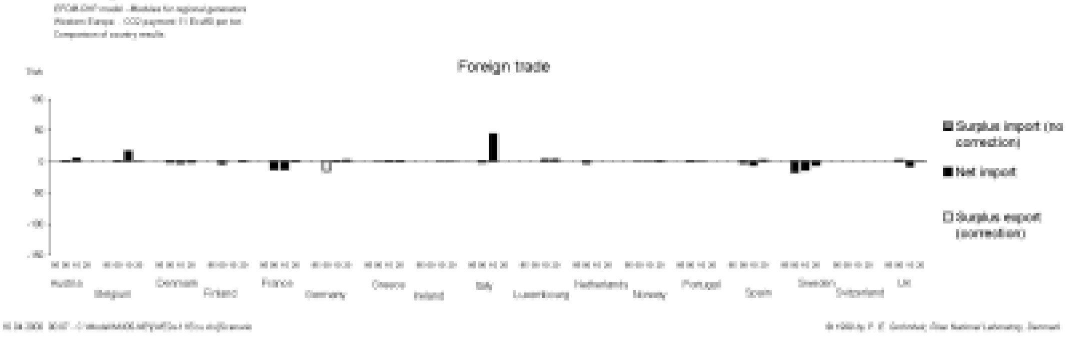
[81] The description of the infrastructure and the options for investment in new equipment and new technologies and their techno-economic data are based mainly on the most recent Danish energy plan "Energy 21" from 1996. The techno-economic data for the various scales and vintages of CHP have been compared with the data in the German IKARUS database.

competitive market. All generators, who have a given portfolio of electricity supply obligations, optimise their purchase or own generation on the basis of given annual average unit price for electricity purchase and sales.

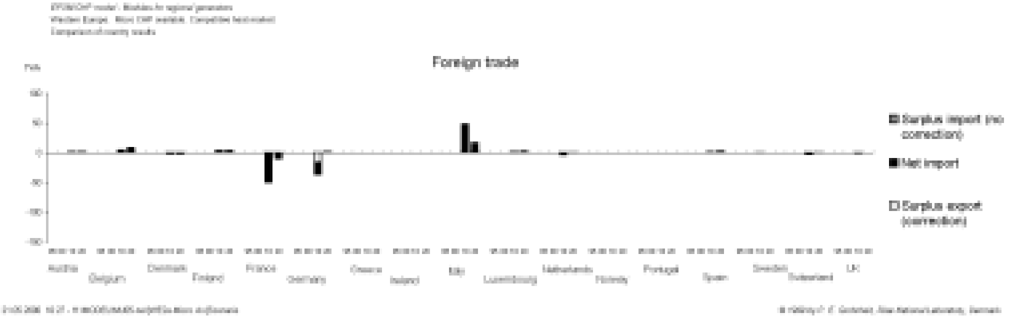
In Figure 7.14 the impact of the introduction of CO_2 payment at 11 Ecu90 per ton is compared with the technology scenarios. The figure shows the difference to the trade pattern shown in Figure 7.9 using the same scale.

If micro-scale CHP becomes available, generation will shift significantly from the utilities to local generators with a supply obligation for the heat market. but no access to access to large-scale CHP and no initial generating capacity. In the UK, Germany and Italy 15-30 % of the fossil thermal generation will shift from large-scale to small-scale generators. In Germany and France this will also lead to an exportable surplus, which can be balanced by import to Italy, and less investment in conventional generating capacity in Italy. The same mechanism will also be found among smaller countries, e.g. export from Denmark, the Netherlands and Switzerland, and import to Austria, Belgium, Finland and Luxembourg.

11 Ecu90 per ton CO_2



Micro-scale CHP available (moderate technology development)



Small and new CHP with PSO (fast technology development)

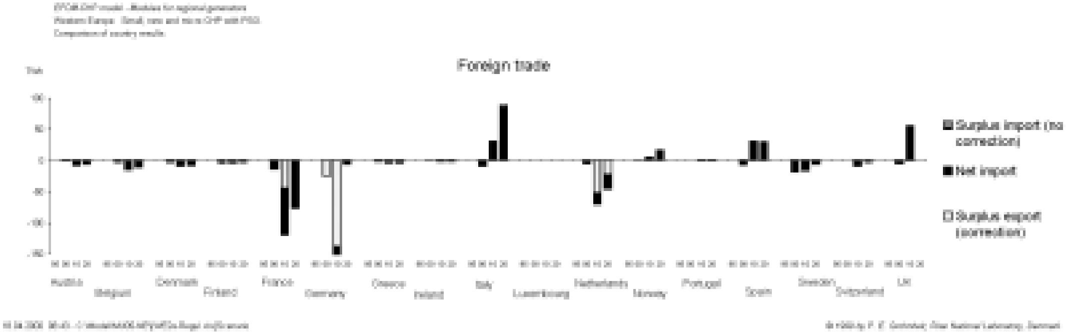


Figure 7.14. Differences in foreign electricity by CO_2 payment and if micro-scale CHP becomes available from 2010. 17 countries

In the scenario with fast technology development it is assumed that new and small-scale CHP is supported by some kind of regulation (e.g. a public service obligation, which is implemented into the model by assuming a lower discount rate). In this scenario the same pattern of development will be found, but the impact will be about twice as significant. In this scenario also Austria, Belgium, Finland and Sweden become exporters, while Spain and the UK become importers. In both these scenarios and in most countries there will be a shift in primary fuels from coal to gas. Obviously, CHP will replace boilers for heat supply

Thus efficiency gains in one country may lead to increased CO_2 emissions in this country and less emissions in the countries that are importing the surplus electricity instead of own generation by fossil electricity-only technologies.

In some countries the availability of micro-scale CHP will lead to no new investment in new large-scale capacity, in particular in 2010. In other countries, e.g. the UK, most investment in new capacity will still be large-scale. Part of the investment in new boilers for heat and industrial steam will be replaced by micro-scale CHP. This mechanism is less significant in countries with a tradition for district heating or industrial CHP. In these countries the impact of micro-scale CHP will be less significant.

7.5.3 Economic and environmental impact of CO_2 payments or new technologies

The most significant economic impact of the availability of micro-scale CHP is that electricity purchase is replaced by own generation for the standardised agents that has a portfolio of contracted electricity sales, but no initial generating capacity. Thus electricity sales by the utilities will be reduced. However, all these differences are small. Another consequence is that investment in new capacity will be made by different agent and in a different period.

Although the availability of micro-scale CHP will have a significant impact on the structure of the power sector, the CO_2 reduction caused by the technology development is modest, in particular compared with the model results for the impact of CO_2 payments. This is illustrated for the 17 countries in Figure 7.15. At the assumptions – mainly concerning fuel prices – used in the optimisation model CO_2 payments at 21 Ecu90 lead to significant reduction in the periods represented by the years 2000 and 2010. In some countries this reduction will be reversed by 2020. This is a consequence of the close competition between coal and gas. However, the more modest gain in CO_2 reduction by new, more efficient technologies will not be reversed.

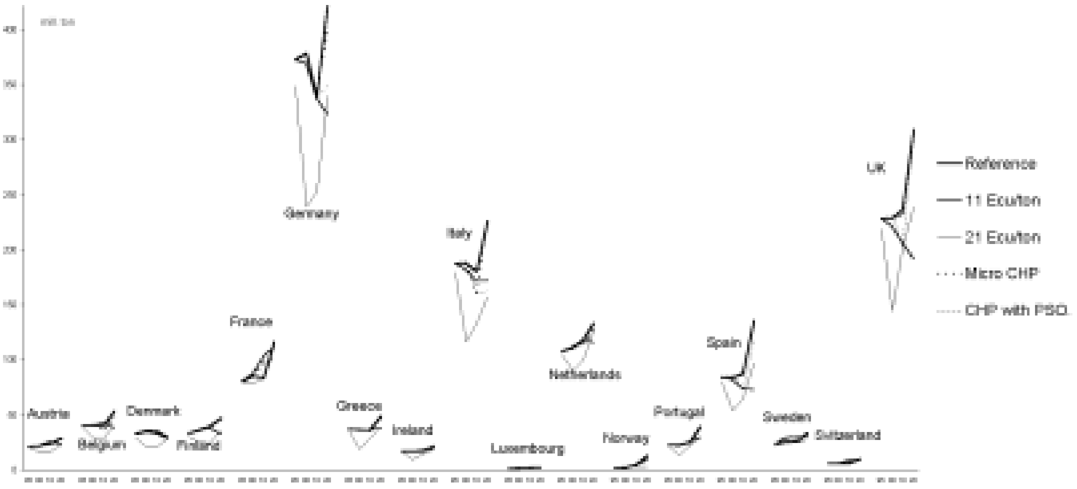


Figure 7.15. CO_2 emissions in 17 countries. Reference scenario and reduction scenarios.

7.5.4 Scenarios for CO_2 emissions in the European Union

In Figure 7.16 the results of the optimisation model concerning the total reduction of CO_2 in the power and heat/steam generating sector is compared with the results of the PRIMES results for the Shared Analysis project as described in Section 7.2.4. Although the results of the PRIMES model was used as the main data source for the structural data in the model used in this study, the CO_2 emissions in the Reference scenario is some 100-200 mill. ton larger in this study than the PRIMES results. This reflects the broader definition of the heat sector in order to cover all the market potential for small- and micro-scale CHP. With this difference the result for the scenario with CO_2 payments at 11 Ecu90 is similar to the PRIMES stabilisation scenario. On the other hand, the PRIMES 3 % and 6 % reduction scenarios are not well reproduced by the use of the EFOM-CHP model for standardised agents.

In contrast to PRIMES the EFOM-CHP model is a pure techno-economic optimisation model. It is well-documented, but it does not contain elastic demand, which would be necessary to clear the markets finding both prices and volumes.

7.6 Tradable permits and market design

The optimisation for the electricity and heat market in a region with a large and diversified market for district heating and subject to competition on the electricity market – consisting of different EFOM-CHP modules – indicates that tradable CO_2 permits may lead to a very rapid substitution of gas for coal, but CO_2 permits may not be the major driver for new technologies with no CO_2 emissions, but high investment costs.

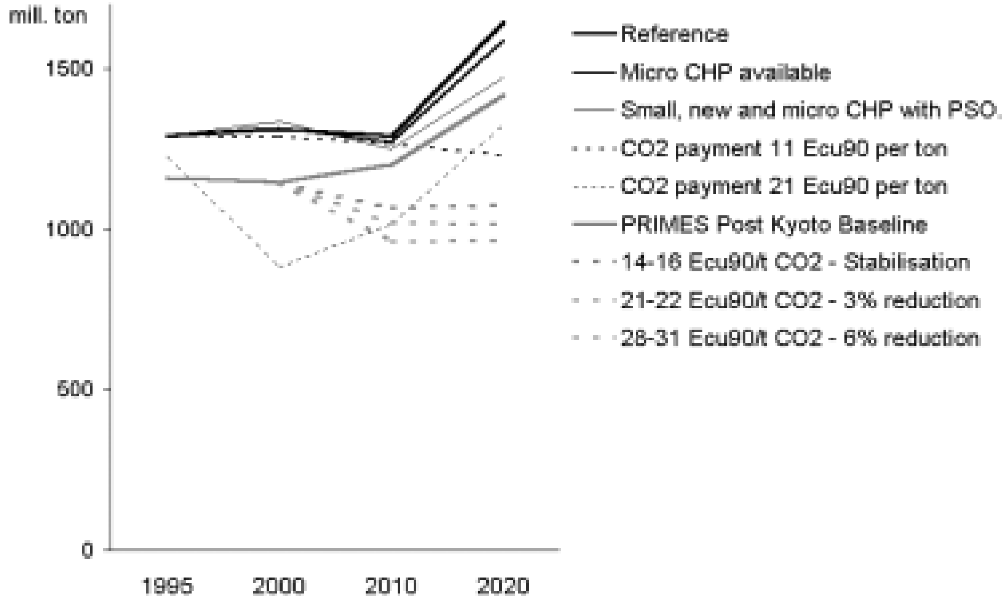


Figure 7.16. CO_2 emissions in the power and heat/steam sector in EU-15. Comparison of different scenarios by EFOM-CHP and PRIMES.

In summary it may be concluded from the generalisation of the model results:

- Tradable CO_2 permits are likely to lead to a very rapid substitution of natural gas for coal.
- Tradable CO_2 permits are unlikely to be a major driver for new technologies with no CO_2 emissions, but high investment costs - at least in the short and medium term (i.e. until 2008-12).
- Some elements of regulation apart from CO_2 permits will be necessary to reduce the financial risk of investment in low-emission technologies.
- However, an appropriate regulatory framework is essential not only for the ‘green’ market, but for any organised commodity market.
- Large-scale CHP from coal or gas fired power plants is the dominant technology for district heating supply, when this technology is available. The technology choice is more open for small-scale district heating systems.
- Local or regional generators of CHP, who are able to react on price signals, should not conclude long-term contracts that include fixed time-of-day tariff for sale of electricity.

A common European taxation of fuels or a European market for CO_2 emission permits may be favourable for capital-intensive, clean technologies that will reduce the demand for fossil fuels. However, even very high taxes or permit prices are unlikely to have much effect on the development of CHP unless further measures are taken e.g. long-term contracts supported by a market for ‘green certificates’.

An important conclusion from the liberalisation in the UK is that market liberalisation and privatisation will require an appropriate regulatory framework.

8 Quota prices

How high or how low will the CO_2 quota prices be if a system of tradable permits is agreed on? What are the costs to society of CO_2 reductions under alternative assumptions on quota trade (or Joint Implementation and CDM)? These are important questions to politicians, power producers, energy intensive firms and consumers.

A number of model based studies have estimated quota prices and costs to society of conducting CO_2 reduction policies. The estimated prices and costs vary so much that it is difficult to extract any clear message. The variance in results suggests that researchers (and model users) even disagree on assumptions of importance to the magnitude of quota prices and costs. In some of the studies there seem to be confusion with respect to the use of different cost concepts: It is not at all clear what is meant by 'costs of CO_2 reduction', 'costs to society', 'quota prices'. Often 'costs' are presented as 'costs per ton CO_2 reduced' and interpreted as an estimate of quota prices, but the cost concept include macro economic effects of quota prices.

Section 8.3 illustrates that estimates how costs to society and estimates of quota prices can vary from one study to another. At least estimates of costs to society seem to vary in a systematic way, dependent on the type of model used.

The present analysis briefly discusses the use of different types of models to estimate quota prices, emission reductions and costs to society of reducing emissions (cf. Sections 8.1 and 8.2).

The main focus is on the limitations of the models with respect to estimating quota prices. It is obvious that national models cannot be used to derive quota prices on an international market. Estimates for example of EU quota prices require EU models. If CO_2 reductions outside the EU are cheaper than within the EU, and if it is possible to buy these CO_2 reductions for example through JI or CDM – this will affect the EU CO_2 quota prices. If countries conduct policies, which support renewables within power production, or support other initiatives, which reduce greenhouse gases, this will have an effect on the quota prices (cf. Nielsen, 1999). If there are important backstop technologies with respect to CO_2 reduction, and reductions of other greenhouse gasses, this may have an effect on quota prices.

The analysis demonstrates that there are important backstop technologies with respect to CO_2 reduction. If a backstop technology is the marginal CO_2 reduction technique on the market, the quota price will be equal to the CO_2 reduction cost of that backstop technology. If the models used to estimate quota prices do not model the relevant backstop technologies, the estimated quota prices may be too high.

The analysis demonstrates that in Denmark and in the EU the power-producing sector is significant with respect to CO_2 reductions; and furthermore that there are important backstop technologies with large emission reduction potentials. Knowledge of the backstop technologies and their CO_2 reduction costs (under given assumptions) can be used to infer upper limits to the CO_2 quota prices. This is done for Denmark and the EU, given a number of assumptions.

The present analysis stresses the importance of attention on backstop technologies – their emission reduction potentials and the prices at which they become profitable – in studies of quota prices and costs of CO_2 reductions. The present analysis indicates that failure to include backstop technologies may give quota price estimates that are too high and of limited value.

8.1 The cost of CO_2 reduction

Different types of models have been used to evaluate the cost of reducing CO_2 emissions to a given level. The models differ with respect to their foundation in the technical sciences, microeconomics or macroeconomics.

The technical models focus on energy producing techniques (especially within the power-producing sector) and the techniques associated with energy consumption. The models evaluate emission reduction efforts and the costs of changing the existing technologies with new and less CO_2 intensive techniques. The technical optimisation models describing the power producing sector optimise the power producing techniques for given prices on electricity, taxes, quota prices, etc.

The macroeconomic models evaluate the macroeconomic responses to CO_2 quotas, CO_2 taxes, TP, TQ, JI or other instruments. They focus on the effects on aggregate energy consumption, international competitiveness, industrial output, the macroeconomic activity level, etc.

The assumptions forming the models and the cost concepts used differ. But both types of models have relevance.

In Denmark and internationally both types of models have been used to analyse the same questions concerning costs to society of reducing greenhouse gasses. But there seems to be a systematic difference between the models with respect to the estimated cost: The technical models seem to estimate lower costs to society than the macroeconomic costs (cf. Jacobsen et al., 1996, Chapter 2). Much effort has been done to integrate the models.

The present and the following section relates the concepts of quota prices, CO_2 reduction costs and costs to society of reducing CO_2 with the different types of models. It is important to be aware that these concepts do not cover the same.

The *quota price* is formed on a market where supply and demand for quotas are presented. The quota price is equal to the *marginal* CO_2 reduction cost on the market.

The *macroeconomic CO_2 reduction costs* – the *costs to society* – are the direct and indirect economic consequences of firms and consumers being forced to reduce emissions or to buy or sell quotas. CO_2 quota prices can be interpreted as CO_2 taxes on firms and consumers, and the wider economic consequences of these taxes can be analysed in the macroeconomic models.

For *given* quota prices the national macroeconomic models estimate the macroeconomic costs of the quotas. But if the national and international macroeconomic models are sufficiently specific with respect to techniques and emissions, it is in principle possible to estimate the CO_2 tax – or the quota price – which will imply that the CO_2 reduction target is reached.

National macroeconomic and technical models cannot estimate quota prices on quota markets, which include more countries.

Macroeconomic estimates of national and international quota prices have the advantage that there are feed backs between the quota market (prices) and energy consumption, economic activity, foreign competitiveness, etc. These feed back mechanisms are the more important the higher the quota prices and the larger the effects on energy consumption behaviour and macro economic activity. The amount of data needed for the international analysis may be considerable.

Marginal CO_2 abatement costs and CO_2 abatement costs curves can be estimated from *technical models*. Cost curves for all the countries participating in a quota system combined with country specific emission reduction targets will say something about the quota market, the amount of trades and the quota price. Cost curves are estimated for given activity level, prices and technological development. It is obvious that quota prices estimated by technical models reflect the assumptions of the technical cost curves.

It is typical that output from the one type of model is used as input in the other type of model. The technical models use activity levels, prices and perhaps elasticities from the macroeconomic models and the macroeconomic model use emission reduction potentials and microeconomic CO_2 reduction costs from the technical models.

8.2 Relations between quota prices and macroeconomic costs of CO_2 reductions

This section shows that there is no ‘one to one’ relation between the size of quota prices and the macroeconomic costs of CO_2 reductions. And demonstrate why it is important to distinguish between quota prices and macroeconomic costs.

The higher the economic activity in a country, the more emissions (in general) and the more emission reductions needed to reach a fixed emission target for the country. On a national quota market higher economic activity *may* increase quota prices, because the price of the marginal emission reduction increases. But it is not at all obvious that an international quota price is affected. Even if the quota price is unaffected of an increase in the national activity level, the national macro economic costs may be higher.

Along the same lines, changes in the fixed emission target for the country do not necessarily lead to changes in (international) quota prices. But the macroeconomic cost change.

A higher quota price may be less damaging to the macro economy, if the high quota price is co-ordinated between countries and the low quota price is not. Co-ordination means that the international competitiveness is less affected.

A given quota price will have different macroeconomic implications dependent on for example the structure of a country's industry. The extremes could be an economy, which produce emission-reducing technologies, and therefore would have an economic advantage of international policies towards emission reductions. Or an economy where firms and processes are exported to countries without environmental regulation.

Studies of macroeconomic costs of CO_2 reductions reflect that the time horizon analysed is short. The reason why policies to reduce the greenhouse gasses are conducted are that there are positive welfare gains in the long run. And that these gains are bigger than short-term economic costs.

The time perspective is also important with respect to the quota price: Investments in CO_2 reductions can be very expensive if the CO_2 investments are not coordinated with other investments or not planned properly.

8.3 Quota prices in selected empirical studies

Estimates of quota prices are important as measures of the costs of climate policy to the individual emitters of CO_2. At the national level estimates of quota prices are important as input in macroeconomic analysis of the costs to society.

The following presentation of a few estimates of the quota price is very brief. The purpose is to show that estimates differ a lot. All the different estimates of the quota prices may be "correct" given the different assumptions. But it leaves the reader rather confused – and with a need for a method or guidelines to evaluate the quota prices. The following sections tries to develop such a method or guidelines concerning reductions of emissions.

A recent article by Criqui et al. (1999) use the POLES and EPPA models to estimate both costs of fulfilling the Kyoto agreement in different regions of the world and quota prices for these regions. Estimated quota prices are listed in Table 8.1. All prices are in constant 1990 US dollars or constant 1990 Danish currency (DKK). EPPA is a general equilibrium macroeconomic model and POLES is an energy system model with some common features with the 'top-down' models. The abatement costs calculated by the POLES model are 'sectoral cost', whereas the EPPA model takes the "full range of impacts of reduction policies" into account (Criqui et al., 1999, p 588). The size of the quota prices are much dependent on the model: According to Table 8.1 the EPPA model estimate prices twice the size of the POLES model prices for the Annex B market and EU market. In the article it is said that these differences are due to different reference scenarios: If the POLES reference scenario is used in the EPPA model, quota prices will be almost the same.

In 2010 the CO_2 reduction needed in the EU to go from the reference to the Kyoto target is 20 % in the POLES model and 29 % in the EPPA model. The quota prices are, following Table 8.1, 166 and 330 $/ton C respectively. Comparing the two models gives that reducing emissions 9 % more (to reach the same target) gives a quota price increase of 100 %! Will that be credible? It is difficult to say, without having anything to evaluate it against. (The amounts of emissions reduced are 204 and 308 million ton C in the two models).

Table 8.1. Quota prices for year 2010

Region/Model	**POLES**		**EPPA**	
World*	21.3 $/ton C	(41.9 DKK/ton CO_2)	24 $/ton C	(47 DKK/ton CO_2)
Annex B	63 $/ton C	(124 DKK/ton CO_2)	127 $/ton C	(250 DKK/ton CO_2)
EU	166 $/ton C	(326 DKK/ton CO_2)	330 $/ton C	(650 DKK/ton CO_2)

Source: Criqui et al. 1999.

Notes: All prices are in constant 1990 US dollars or constant 1990 DKK.
Non annex B countries are assumed to have reduction target equal to their baseline.

A special issue of the Energy Journal (1999) is dealing with "The costs of the Kyoto Protocol: A multimodel evaluation". Thirteen different modelling teams use their particular model to analyse some standard questions:

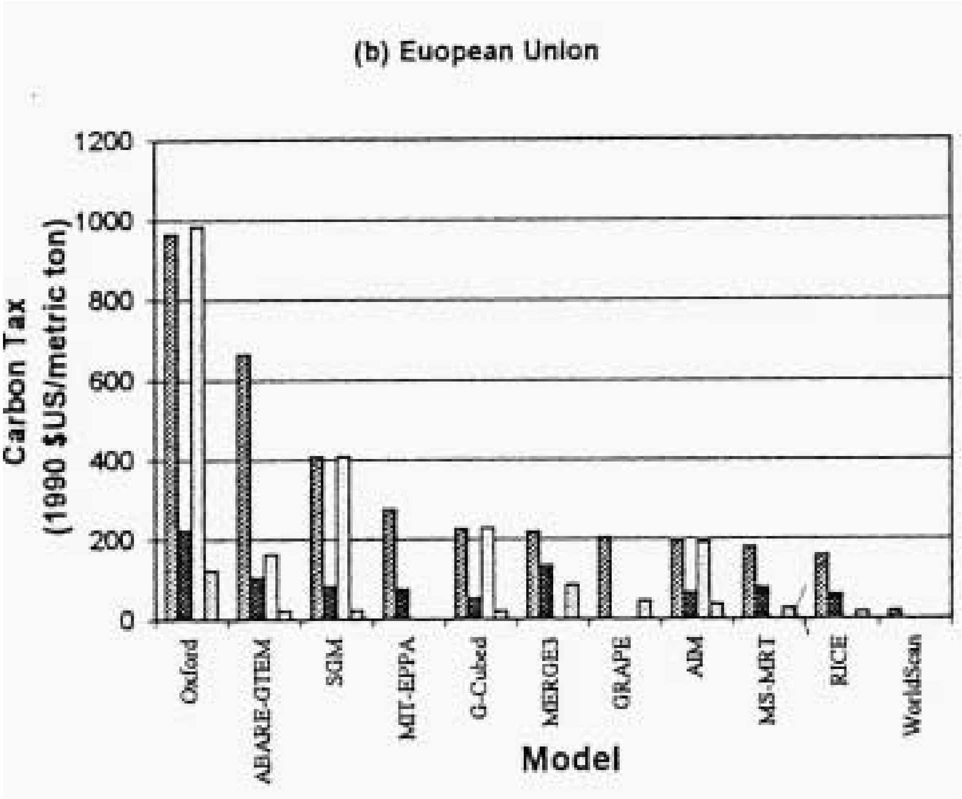
"First, each team was asked to run a 'modellers reference' scenario, with modeller chosen GDP, population, energy prices, etc. This scenario was to assume no new policies other than those currently in effect (e.g., nothing new from Kyoto).

Second, the modelling teams were asked to run a number of stylised Kyoto scenarios varying on three dimensions: (i) The amount of international emissions trading assumed, (ii) The availability of sinks and 'other greenhouse gas' emission reductions to satisfy the Protocol's requirement, and (iii) The required emission reduction beyond 2010."

The modelling teams estimate emission quota prices (carbon taxes) for different areas. With respect to the European Union the results are summarised in the following Figure 8.1 showing four different emission trading scenarios: 1. No international trade, 2. Annex 1 trading, 3. "Double Bubble", i.e. separate EU and separate "rest of Annex 1" trade, and 4. Global trading.

The EU carbon tax in the no international trade scenario is equal to the quota price in the "Double bubble" EU emission trading scenario (there may be minor differences). It is seen that there is an extreme variance between the most optimistic (<20 \$/t C = 5 \$/ton CO_2) and most pessimistic price estimates (>900 \$/t C = 245 \$/ton CO_2). Apart from the most optimistic model study, all the quota prices exceed 300 DKK/ton CO_2 (175 \$/ton C, exchange rate 6.19 DKK/\$). The Annex 1 trading scenario in most cases more than half the model based quota prices. This is to a large extent due to Russian 'hot air'.

The different quota prices of course reflect the different reference scenarios, assumptions and models. In principle all the quota prices can be equally relevant, but it could be very convenient to have a method or guidelines to evaluate the empirical relevance of the different outcomes.



Source: Weyant and Hill (1999)

Figure 8.1. Year 2010 Carbon Tax Comparisons

Table 8.2 describes the results of three Nordic model based studies of quota prices on a Nordic or a national market. Again the quota prices reflect the assumptions and models. What could be interesting to evaluate is the development of quota prices over time, and the very high quota price in 2020 in the Delmark study: According to Hauch (1999) an important difference between his own analysis of Sweden and Delmark's is that Hauch assumes that Sweden import electricity from the other Nordic countries. But why can Sweden not invest in the same power producing technologies as the other Nordic countries and bring the quota price down?

Table 8.2. Quota prices in three Nordic studies

Analysis	**Amundsen**	**Delmark**	**Hauch**	**Hauch**
Model type	Partial equilibrium	General equilibrium	General equilibrium	General equilibrium
Market	Nordic[1]	Sweden	Sweden	Nordic[1]
Sectors	Power sector	Power sector	All	All
Reduction relative to target	Swedish nuclear power phase out, 1990 emission level	Swedish nuclear power phase out, 1990 emission level	Swedish nuclear power phase out, Kyoto (EU) targets[1]	Swedish nuclear power phase out, Kyoto (EU) targets[1]
Year for quota price(s)	2000	2000, 2020	2000, 2020	2000, 2010, 2020
reduction in pct. of reference				year 2010: 26 % year 2020: 38 %
Quota price[3]	65 DKK/ton CO_2	Year 2000: 125 DKK/ton CO_2 Year 2020: 1045 DKK/ton CO_2	Year 2000: 62 DKK/ton CO_2 Year 2020: 680 DKK/ton CO_2	Year 2000: 75 DKK/ton CO_2 Year 2010: 340 DKK/ton CO_2 Year 2020: 600 DKK/ton CO_2

Sources: Amundsen: Amundsen 1999, Delmark and Hauch: Hauch 1999.

Notes: 1) Sweden, Norway, Finland and Denmark. 2) The EU distribution of the Kyoto target implies that Denmark reduces emissions by 21 % compared to a revised 1990 level. The other Nordic countries have reduction targets close to their 1990 emission level. 3) Prices are constant 1990 prices.

8.4 A method to evaluate the size of quota prices

Quota prices are results of supply and demand for emission quotas and indirectly results of supply and demand for emission reductions. Estimates of a future CO_2 quota price may be given by the intersection of supply and demand curves for CO_2 reductions. But supply and demand curves are difficult to construct because of the amount of data needed.

With respect to the power producing sector estimates of future quota prices are often based on technical optimisation or simulation models describing the existing power producing system and a number of alternative investment possibilities. A model based supply curve for CO_2 reductions can be constructed from registering the changes in the models emissions following different levels of quota prices. Of cause the supply curve reflects the alternative investment possibilities given in the model, fuel input prices, prices on electricity, and all the other assumptions of the model.

The method used in this section to evaluate the size of quota prices is to analyse important backstop technologies with respect to CO_2 reductions. *These backstop technologies may form a maximum-price supply curve for CO_2 emission reductions*. Given that these backstop technologies have large emission reduction potentials this supply curve may have large flat segments. The cheaper the backstop technologies – with respect to CO_2 reductions – the more likely it will be that the backstop supply curve will be close to, or even equal to, the ‘real’ supply curve for CO_2 reductions.

The idea is illustrated in Figure 8.2, which shows prices and emission reduction potentials for three backstop technologies. At a price equal of P(b3) there is a reduction potential of z-y. y-x is the reduction potential for a backstop technology, b2, with CO_2 reduction costs equal of P(b2), and x-v is the potential at a quota price equal of P(b1). Figures are constructed so that the reduction potentials can be added. Together the tree backstop technologies have a reduction potential of (z-v).

Assume a tradable emission quota system. Then, *if the 'demand' for emission reductions is between z-y, the quota price can never exceed P(b3)*, which is the price of the cheapest backstop technology. If the required level of emissions are between x and y the price will not exceed P(b2), and given a required emission level between v and x the price will not exceed P(b1).

If the emissions reduction potentials for the three backstop technologies are significant compared to the total reduction requirements, and if the CO_2 reduction costs are relatively low compared to other possibilities, one of these prices could be a good estimate for the emissions quota price. At least the prices of the backstop technologies will form maximum quota prices within different ranges of the total level of emission reductions.

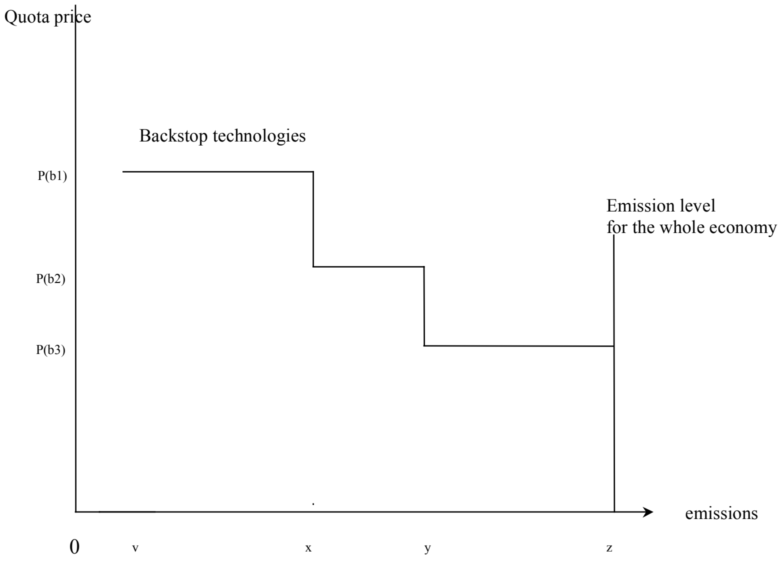


Figure 8.2. Backstop technologies, prices and potentials

The method can be motivated by at least two different arguments:

Knowledge of the emission reduction costs for backstop technologies with a large reduction potential (relative to the required reductions) can be used to question for example model based quota prices, which are either much higher or much lower than costs for the relevant backstop technology.

Part of the explanation why prices of American SO_2 quotas fell much below the predicted level was the presence of cheap backstop technologies with a huge emission reduction potential. But also investments in high cost emission reductions options[82] based on false expectations of high SO_2 quota prices (partly justified on the predicted high SO_2 quota price) played a role (Ellerman, 1998). The irreversibility of the investment decisions increased the supply of quotas at sunk costs (implying an outward shift in the supply curve). Because of the 'over-investment' in high cost emission reduction methods, the marginal SO_2 reduction technique was a low cost technique. Table 8.3 copied from Ellerman (1998) summarises reduction costs and emission reductions in the American SO_2 market. "… early studies of compliance cost estimated (prices) at about $300 per ton, although it was possible to find even higher estimates" In 1993 the auction clearing price

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[82] The backstop technology in question is 'scrubbers', which clean SO_2 emissions to air.

was $131, in 1996 allowance prices were slightly below $70 and in 1998 again around $130 (Ellerman, 1998).

Table 8.3. Reduction and compliance costs in 1995

Method of compliance	Emission reduction ton SO_2	Emission reduction Percentage	Avg. cost $95/ton	Min. cost $95/ton	Max. cost $95/ton	Total cost Million $
Title IV Scrubbers	1,733,743	45 %	267	186	773	463.1
Non-Title IV Scrubbers	20,698	1 %	65	65	65	1.3
Coal Switching	1,707,819	44 %	153	60	297	261.3
Non-cost Switching	425,242	11 %	0	0	0	0.0
Total	3,887,502	100 %	187	0	773	725.7

Source: Ellerman, 1998.

The preceding section showed wide differences among predicted future CO_2 quota prices. Of course these differences reflect the different models and the different assumptions. Some of them may be compatible. But if there are important backstop technologies with large emission reduction potentials, and if the investment costs of these are well known, all the studies must be able to relate to this information. The intention behind the next sections is to develop, or demonstrate, a method that can be used to evaluate predicted quota prices and the assumptions of the models used. Section 8.5 describes CO_2 reduction costs and potentials within the Danish power producing sector. These reduction costs are used to say something about maximum quota prices in a purely Danish CO_2 quota system. The analysis is broadened to the whole EU in Section 8.6.

8.5 CO_2 reduction costs for the case of Denmark

Table 8.4 gives a brief impression of alternative costs of reducing CO_2 within the Danish electricity sector. Figures are calculated based on a number of assumptions as to for example the interest rate, which type of power production is substituted, and which level of capacity the new and substituted plant is run at. The sizes of the figures are highly dependent on the assumptions, which are therefore relevant in evaluating the figures:

Table 8.4. Costs for CO_2 reductions in Denmark in 1996

Country/ Technology	Denmark DKK/ton CO_2
Electricity export reduced by 50 %	40
Electricity export reduced by 100 %	100
Fuel conversion	
– coal to gas	76
– coal to straw, 10 %	275
– coal to straw, 10 % in separate boiler	446
New capacity	
Industrial CHP, gas	326
Central KAD, coal	–
Central GAD, gas	129
Central CC, gas	93
Wind mills, placed at land	241
Wind mills, offshore	282

Source: Elsam, 1997.

The higher the interest rate the more expensive are new investments in CO_2 reductions.

A given investment in CO_2 reductions will reduce more CO_2 – and the CO_2 reduction costs per ton CO_2 will be cheaper – if the substituted plant is very inefficient and emits a lot of CO_2. Therefore, if figures are based on the assumption that the substituted plant is always the highest CO_2 emitter, the figures may be valid only at the margin and have little or no relevance with respect to large scale emission reductions: One should notice that the CO_2 reduction costs are dependent on the reference scenario and which investments have already been carried out.

If the calculations assume that the new investments are always operating at full capacity (irrespective of whether it is profitable or not), it is likely that the amount of CO_2 reductions will be higher, compared to a situation where the investments are run below full capacity: The larger the CO_2 reductions, the cheaper these may be.

For a detailed list of assumptions behind Table 8.4, readers are referred to ELSAM, 1997. Some of the important general assumptions are: an interest rate at 5 % p.a., market prices of electricity (implying less than full capacity use) and market prices on input fuels. All costs are measured in constant 1996 prices. One implication of this is that improvements in technologies compared to the 1996 'levels', or more intense price competition in markets for certain technologies (wind mills) are not taken into consideration. But these factors may be significant for certain technologies and may press investment costs – and the CO_2 reduction costs – down. Real fuel prices are kept constant at their 1997 level. (This assumption is in line with projections for 1997-2010 in World Energy Outlook, IEA, 1998). Electricity prices are close to variable costs in conventional electricity production, meaning that there are no incentives in the electricity prices to invest in new capacity. This price assumption may be very realistic in a 'strategic' market, or a market with excess capacity, but increases the CO_2 reduction costs because investments in general are less profitable.

The general impression of the costs for CO_2 reduction given in Table 8.4 is that the magnitudes of costs are valid within a relevant Danish CO_2 reduction range. The interest rate may be too low for private investors. Table 8.4 is further commented in the following subsections.

8.5.1 Reducing export

The level of the Danish electricity production has traditionally been closely related to electricity production in Sweden and Norway, and in particular to the Norwegian hydropower production. In some years Denmark is a net importer of Norwegian hydropower (wet years in Norway) and in other years Denmark is a net exporter of coal produced electricity.

The new Danish electricity act from May 1999 introduces a CO_2 emission quota (on an annual basis) on the Danish electricity producers. If this quota is violated the producers has to pay a fee of 40 DKK per ton CO_2. This fee will make it less profitable to produce electricity at marginal Danish coal fired power plants (it will not make coal fired power plants unprofitable in general). It is estimated (see Chapter 6) that the fee will reduce Danish exports of electricity by around 50 %, given constant prices on electricity and constant export prices. Under the same assumption of constant export prices, and therefore sufficient international supply of electricity at that prices and sufficient cable capacity, a 100 DKK pr ton CO_2 fee will reduce Danish electricity exports to zero.

The new electricity law does not necessarily squeeze the marginal coal fired power plants out: If the international electricity prices are sufficiently high, production at these plants may still be profitable.

A Danish fee will reduce Danish emissions, but not necessarily reduce global emissions: if the Danish electricity export to for example Norway is substituted by Norwegian import of electricity produced by a technology which also emits CO_2, and maybe emits the same amount of CO_2, the global CO_2 reductions may be limited or be zero. On the other hand, if Norway instead of importing from Denmark import electricity from Germany, the German emissions will rise and put pressure on the German government to take measures to reduce emissions in order to fulfil the German Kyoto emission reduction target.

8.5.2 Fuel conversion

The economics behind fuel conversion depends on the technology of the power plant in question, and on the prices and emission factors of the substituted and substituting fuels. Fuel conversion may be very cheap or very expensive. In Table 8.4 a typical Danish coal fired condensing power plant is converted to either gas or straw. Conversion to gas is relatively cheap – around 80 DKK per ton CO_2 – whereas conversion to straw, for both technologies, is relatively expensive. The reason why conversion to straw – which is often a waste product in the agricultural production – is so expensive is the transportation costs, and the more complicated technology needed to make the straw fired power plant function properly (for example to avoid Dioxin and dangerous emissions other than CO_2).

Back pressure or extraction power plants have higher fuel efficiency than the condensing power plants, and of course the technical properties are different. But fuel conversion does not change the basic technical functionalities of the power plants. And assuming that the investments needed for fuel conversion are the same irrespective of the condensing or combined heat and power technology – we further assume that the CO_2 reduction cost of condensing power plants apply to combined heat and power[83].

Waste from households and biomass other than straw (for example wood chops and energy crops) have zero CO_2 emissions factors and may be used as fuels in the heat and power production. The table does not cover conversion to these fuels. But compared to the CO_2 reduction prices for the two straw technologies, wood chop prices will be lower and energy crop prices probably higher. This relation reflects relative prices of tree chop, straw and energy crop, and reflects that using straw in the power production is technically more difficult than using wood chops and energy crops.

8.5.3 Building of new capacity

The fuel efficiency of power plants has much to say regarding emissions. Even substituting old coal fired power plants with new coal fired may reduce emissions. Therefore building new power plants with a) high fuel efficiency and b) a low emission fuel type may be the cheapest way to reduce emissions. Alternatively new renewable capacity may be built. For example windmills or solar cells. In Denmark windmills are relatively cheap because of good wind conditions.

The table refers to a relatively new coal fired power plant with relatively high efficiency as reference. Therefore it makes no economic sense to substitute this type of power plant with another coal-fired power plant. The chosen reference gives the CO_2 reduction costs in the table more credit, as these numbers are applicable beyond the margin.

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[83] The intuitive reasoning behind this assumption is that fuel conversion is related to the input into the power plant, whereas the question of condensing, back pressure or extraction is related to the energy output of the plants.

The relatively high CO_2 reduction price of industrial combined heat and power is due to the Danish industrial structure with many relatively small firms and few very energy intensive firms. Investments in the cheapest industrial combined heat and power plants have already been carried out.

The CO_2 reduction cost related to windmills may be exaggerated as the investment cost are declining due to falling prices of windmills. Falling prices are a result of the size of the markets for wind-mills, increased competition and improved technology. Included in the investment costs are investments needed to cope with the fluctuating nature of power production from windmills. These costs may be smaller the larger the electricity net and the more dispersed the wind conditions.

Building new power production capacity will in practice be a much slower way to reduce emissions than fuel conversion. Investments, risks and losses are far bigger – and the planning horizon is longer.

8.5.4 Prices in a national CO_2 quota market

At the national level the Danish *total costs* of reducing CO_2 will be at a maximum if no international trade is assumed. Given international – for example European trade – the Danish national costs of CO_2 reductions will be lower. That is, quota trade reduces costs at the national level.

An international – for example European – *quota price* may be higher or lower than a purely national – for example Danish – quota price. If the international quota price is higher Denmark will be net exporter of quotas, and if it is lower Denmark will be a net importer.

If emission reductions are cheaper abroad, and if it is possible to substitute international emission reductions for national, the international price of emission reductions will also be the price of quotas on a domestic market. If foreign emission reductions are cheaper than the cheapest domestic emission reduction, no emission reductions will be carried out domestically. And there will be no quota trade on the national market.

There have been several attempts to prognosticise quota prices using different methods and assumptions.

The method used in this paper may be useful when only limited information about emission reduction curves is available. The method used has got the advantage that it tries to identify the lowest upper limit to the quota price. And this information may be very valuable to planners and firms – especially if the quota price identified in this way is relatively low.

In short the method is to focus on already known backstop technologies. That is, to select a few technologies, with great emission reduction potentials within the analysed area, and see at which quota prices these technologies will be profitable. The price estimates combined with estimates on emission reduction potentials can tell something about likely price ranges for emission quotas.

The European Union must follow the Kyoto protocol in reducing emissions by 8 % compared with the 1990 emissions level.

Within the European bubble Denmark has agreed to reduce emissions by 21 % compared to an adjusted 1990 level.

The question analysed in this section is what will the quota price be on a purely national CO_2 quota market? Denmark is taken as an example, but exactly the same analysis could be carried out for all the EU countries.

Assume no substitution of foreign emission reduction for national. That is, only emission reductions carried out nationally will be accounted for, and the national emissions must not exceed the Kyoto targets.

The energy sector is by far the most important emitter of greenhouse gasses. According to the table below 68 % of Danish emissions of greenhouse gasses in 1994 originated from the energy sector and around 16 % from transport (Fenhann et al., 1997 and NERI, 1997, p. 40).

So, even though electricity production and export in 1994 was considerable and the table may therefore overestimate the contribution from the energy sector, emission reductions in the energy sector are important factors in a national Danish strategy to reach the Kyoto and EU emission targets.

Table 8.5. Greenhouse gas emissions in 1994 apportioned by sector in percent of total emissions.

Sector	Percent of total emissions
Energy	68
Transport	16
Agriculture	16
Waste	3
Forestry	-6
Industry	2

Source: Fenhann et al., 1997.

Assume a national Danish CO_2 quota market within the electricity sector alone. And assume the extreme situation that this sector is the only sector to reduce emissions. If Denmark has to fulfil the EU reduction target, the CO_2 reduction target in 2010 for the power producing sector should then, given the assumptions below, be in the range of 31 to 62 %

The electricity sector reduction target of 31 % is calculated in the following way: Assume total national emissions are the same in 2010 as in 1990 and the share of the energy sector is 68 % in 2010. The national Kyoto reduction target of 21 % is fulfilled by the electricity sector alone. Then (100-79)*100/68 = 31 % The 62 % is calculated under the assumption that total national emissions have increased by 15 %[84] in 2010 as compared to 1990, and the share of the energy sector is 50 % in 2010. Then (115-79)*100/(0.5*115) = 62 %

How can these reduction targets be reached, and at what prices?

Following Table 8.7 what happens within the power producing sector, when quota prices rise (or a fee is introduced), is that the Danish electricity export diminish. This effect is of course only seen in years with electricity export, and presupposes that no other countries relevant for the electricity import or export introduces CO_2 taxes, quotas or emission trading. So production on marginal Danish coal fired power plants decrease. By how much emissions are reduced by reducing exports is difficult to say, but Danish electricity export was in the period 1984-1997 7 % of total Danish electricity production (Statistisk Tiårsoversigt, 1996, 1999). Given this average, if the Danish electricity export vanished this would reduce emissions by at least 7 % (the marginal electricity production is more CO_2 emitting than the average).

At a quota price of 80 DKK/ton CO_2 fuel conversion will be profitable (cf. Table 8.4). Assuming that approximately 60 % of Danish power production, in a 'normal' year without

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[84] The EU assumes an increase in emissions of 14 % over the same period in European Economy, no. 51, 1992.

electricity export, is coal based (cf. Table 8.6), conversion from coal (95 ton CO_2/TJ) to natural gas (57 ton CO_2/TJ) would reduce emissions by 28 % (0.6*(95-57)/79, where 79 is the average ton CO_2 emission/TJ in Danish electricity production. Converting orimulsion (80 ton CO_2/TJ) to natural gas would further reduce emission by 3.5 %

Table 8.6. Total electricity generation by energy source, net export and import in 1997.

Energy source	TWh	Percent of total excl. export
Import	0.0	
Export (assumed coal based)	7.3	
Coal	27.2	58.0
Oil	1.0	2.9
Natural gas	7.0	20.1
Wind	1.9	5.5
Biofuel	0.5	1.4
Orimulsion	4.2	12.0
Danish electricity generation	41.8	
- excluding (coal based export)	34.8	100.0

Summing the emission reductions from the decrease in exports (a fee of 100 DKK/ton CO_2) and fuel conversions (there is no double counting) gives a total of 38.5 %. of total emissions within the electricity sector. This reduction should in principle – and given 1997 market prices for coal, natural gas and oil – be obtainable at a quota price below 100 DKK/ton CO_2.

At a quota price around 100 DKK/ton CO_2 (93 DKK. in Table 8.4) it will be profitable to substitute even relatively new coal fired power plants with new combined cycle natural gas power plants. New power plants have the advantage (compared to fuel conversion) of higher fuel efficiency. So if for example gas prices rise, this will make the construction of new power plants relatively more attractive compared to fuel conversion.

A CO_2 quota price of 100 DKK/ton CO_2 increases electricity prices and reduces electricity demand. The price increase depends on how CO_2 polluting the power sector is, and to what extent the quota price is reflected in electricity price increases. If the average CO_2 emissions from Danish electricity production in 1999 was equal to 0.8 ton/MWh a fully reflected quota price of 100 DKK/ton CO_2 would raise electricity prices in Danish industry and households by approximately 20 % and 6 % (differences are due to different tax levels and price discrimination). Table 8.7 assumes that consumer prices of electricity increase by on average 10 %.

A demand elasticity equal to -0.27 (as estimated in the Indus III model (1998), modelling energy consumption within Danish industry) means that if electricity prices rises by 1 %, electricity demand will fall by 0.27 %. If electricity demand and production fall by 0.27 %, emissions will fall by at least this percentage.

Included in the CO_2 reduction costs for windmills are cost to compensate for the fluctuating nature of wind power production. Therefore the windmills in the table in principle can substitute conventional power production.

Table 8.7. Emission reductions at quota prices below 250 kr/ton CO_2. Different scenarios. Denmark

	Quota price per ton CO_2. Approximately	Decrease in exports	Decrease in marginal production	Decrease in CO_2 emissions within electricity sector
Change in demand for electricity				
Decrease in foreign demand (average year)	100 DKK	100 %	7 %	> 7 %
Decrease in domestic demand for given elasticity	100 DKK		2.5 %**	> 2.5 %**
Decrease in domestic demand for given elasticity	250 DKK		6.3 %**	> 6.3 %.**
Change in power production				
75 % coal substituted by renewables***				
25 % coal converted to gas	<300 DKK		0	60 %*
50 % coal substituted by renewables***				
50 % coal converted to gas	<250 DKK		0	49 %.*
100 %coal converted to gas	<100 DKK		0	28 %.*

* The decrease in foreign electricity demand is subtracted before calculating the emission reduction. Therefore the decrease in exports may be added to this figure. The decrease in domestic electricity demand is not subtracted before calculating the emission reduction. Therefore the decrease in domestic demand cannot be added to this figure.

** Numbers are calculated for a demand elasticity in electricity consumption equal to -0.27. Feed back effects are *not* taken into account, which it should be especially when considering big quota prices. Elasticities may be smaller when more than marginal changes in consumption prices are considered.

*** It is assumed that wind power substitutes coal fired condensing power production (i.e. up to a maximum of 55 % of the total Danish electricity production).

At quota prices of around 250 DKK/ton CO_2 wind mills will be profitable. As the reference to the wind mills is a relatively new coal fired condensing power plant, it is in principle possible, at this price, to substitute all the coal fired *condensing* power plants with wind power production (provided that the wind conditions where the new mills are placed are good enough). Coal fired back pressure and extraction power plants can not directly be substituted by wind power, but may be substituted by straw, waste, wood chops or other renewables. In the table above different alternatives are shown.

It may seem relatively extreme to let the coal based electricity production be substituted by 50 or even 75 % renewables. But remember that even if coal was 100 % substituted by renewables there would still be 35 % oil, natural gas and orimulsion based electricity production. The examples suggest a different mix of fuel conversion and renewables and give a maximum quota price. But it is important to note that if a quota price of for example 300 DKK was settled on the market, the investors and their investment behaviours would decide the optimal mix of CO_2 reducing technologies.

Taking the 50 % fuel conversion/50 % wind mill (renewables) production as an example, the table may be read in the following way: The stop of electricity export reduce emissions by at least 7 % in an average year (1984-1997). The specified changes in the power production structure adds 49 % reduction to this figure. So emissions within the sector will fall by at least 56 % But higher electricity prices will cause domestic electricity demand to fall. A very rough estimate of electricity price increases, a rough use of elasticities, and no use of feed back mechanisms, would suggest a 6 % decrease in domestic electricity demand and a higher decrease in emissions. Given the 6 % decrease, total emissions will fall by

59 % instead of 56 % (avoiding double counting). The quota price is below 300 DKK/ton CO_2.

Looking at the emission reduction costs and potentials in the rest of the economy – not just the electricity sector – complicates the analysis: Technologies are more diverse, potentials are smaller and consumption patterns differ. Macroeconomic demand elasticities may be a very easy way to represent aggregated responses of other sectors to a given quota price. Car driver's response to increased gasoline prices, consumer's response to increased oil and gas prices etc. tell how drivers and consumers reacted to price increases in the past, and tell something of past potentials for energy savings. One of the problems using demand elasticities is whether these elasticities are valid for very large price changes.

A quota price of 100 DKK/ton CO_2 raises the price of gasoline by 0.24 DKK/l or 3-4 %. Given a demand elasticity of approximately -0.5 as estimated in the ADAM model (Danmarks Statistik, 1996), this quota price will reduce emissions from private cars by 1.5-2 %.

According the ADAM and Indus models the fuel price elasticity within Danish industry, the primary sectors and transport industry is approximately -0.25. If this elasticity holds true fuel consumption may fall by as much as 10 % following a CO_2 quota price of 100 DKK/ton CO_2.

The macroeconomic responses and costs of Danish quota prices at for example 100 DKK/ton CO_2 depend on the design of the system.

To conclude on a national Danish CO_2 quota price:

As the main emitter of CO_2, the power sector has to reduce emissions considerably. At quota prices below 300 DKK per ton CO_2, the power generating sector is capable of reducing by far the largest part of the Danish CO_2 reductions needed to fulfil the Danish reduction commitments. Even at a quota price of 100 DKK per ton CO_2 emissions within the power generating sector can be reduced significantly. This is due to in- and external decrease in electricity demand, fuel conversion and substitution of old capacity with new.

If wind power in large scale is promoted by policies other than CO_2 emission quotas, the price of CO_2 emission quotas will almost certainly not be higher than the CO_2 costs of fuel conversion as this is a technology with a very large emission reduction potential. It is likely that the quota price for the power sector, and the whole economy, will be *equal to* the CO_2 costs of fuel conversion.

8.6 Estimated price range for EU CO_2 emission quotas

An exact estimate of future quota prices on a European CO_2 emission quota market is impossible to give. The price will be dependent on CO_2 reduction costs within and outside the EU countries, the country specific levels of economic activities and how much to be reduced. Below we try to give price ranges within which the quota price alternatively will be – under different conditions. Of course the more narrow these price ranges, the more informative the analysis.

The analysis is very similar to the analysis above of a national Danish CO_2 quota system. But of course the uncertainties with respect to the quota price are bigger. It may be easier to overlook important country-specific emission reduction potentials. Liberalising European energy (especially electricity) markets may have great emission reduction potentials and implications for a quota price. Fuel prices may be sensitive to for example large-scale fuel conversion from coal to gas.

The CO_2 quota prices will be extremely dependent on the possibilities of buying emission reductions outside the EU: Prices at an EU quota market will not be higher than alternative, comparable prices on emission reductions outside the EU.

To limit the analysis it is assumed, in what follows, that only emission reductions within the EU will be accredited. It will be highly relevant later to loosen this assumption to analyse whether the European quota market will survive 'competition' from outside, and to analyse the price implications.

Two 'areas' are especially interesting with respect to CO_2 emission reductions, because of a considerable contribution to the overall problem: The power generating sector and CO_2 emissions from transport. Within the EU the power generating sector contributed with 31 % of total CO_2 emissions in 1990, and this percent is expected to increase to around 38 in 2010 (cf. European Economy, No 51, May 1992). According to the same source, CO_2 emissions from European transport contributed with around 24 % in 1990 and this share is expected to remain constant. Total CO_2 emissions are expected to increase 14 % over the years 1990-2010. So if the EU, following the Kyoto target, must reach a reduction in its emissions by 8 % before 2010 (compared to the 1990 emission level), this reduction could be achieved by either:

- reducing CO_2 emissions from the power generating sector by 51 %, or
- reducing CO_2 emissions from cars with 80 %, or
- reducing CO_2 emissions from cars and the electricity sector by 31 %.

These three extreme alternatives assume that no other sectors reduce their CO_2 emission compared to the reference scenario, and the other greenhouse gases mentioned in the Kyoto protocol are reduced to their 1990 level.

If it is possible to find a minimum marginal CO_2 reduction price of one or more of these reduction strategies, the minimum price will be the maximum price of European CO_2 quotas.

The following analysis focuses on the power-generating sector. But it is worth noting that consumer prices on energy – electricity prices, prices on gasoline, etc. – differs widely within the EU (see for example statistics in Energy Prices and Taxes from the IEA), and so does energy intensity in for example private consumption. Price differences are due to monopolised energy markets, taxation, countries endowments with primary fuels, environmental considerations, competitiveness of domestic industries etc., etc. According to main stream economics it is reasonable to believe that these price differentials has resulted in different energy consumption patterns among the EU countries. Therefore narrowing the price differentials by rising the lowest energy prices may have large emission reduction potentials. This effect may be reflected in different sizes of price elasticities amongst EU countries. (Effects on energy consumption of very low energy prices are seen in the former Eastern Europe).

8.6.1 Reducing CO_2 emissions from the power generating sector

Table 8.8 shows by which fuel electricity is produced within the EU.

Table 8.8. Electricity generation in the EU by fuel. Year 2000.

Fuel	Fuel input, %	Electricity production, %
Solids	20.7	
Oil (including refinery gas)	11.4	
Gas	16.9	
Biomass – Waste	3.5	
Thermal incl. biomass	52.5	52.5
Hydro and wind		13.2
Nuclear		34.3

Source: Shared Analysis Project, Vol.5. Appendix.

Very rough estimates suggest that: If we assume that the main part of emissions from the power generating sector originates from coal fired power plants, fuel switch to natural gas will reduce emissions by around 40 % (Coal is assumed to have an emission factor of 95 tonne CO_2/TJ and natural gas 56.9 tonne CO_2/TJ. ((95-56.9)*100/95=40.1)). If 50 % of the emissions stem from coal[85], the reduction will be 20 %

$$(95-56.9)*20.7*100/(20.7*95+11.4*74+16.9*56.9)=\ 20.8$$

(Remember that nuclear power, biomass, renewables and hydro power has got no emissions). If both oil and coal fired power plants fuel switch to natural gas emissions will be reduced by 26 %.

Alternatively, if an extra 10 % of the total electricity production is supplied by renewables (compared to the reference), and this production substitutes coal fired power plants, this would reduce emissions by 20 % if coal fired electricity production is 50 % of total electricity production and coal is the main cause of CO_2 emissions within the EU power producing sector ((95-0)*.1*100/(.5*95)). Emission reductions would be 26 % if coal fired electricity production was 20 % (and the percentages for gas and oil was 16.9 and 11.4) of total electricity production (cf. Table 8.8).

The following Table 8.9 is almost identical to Table 8.4. It shows prices on CO_2 reductions within the European power-producing sector under the same assumptions as in Table 8.1. The question is whether fuel conversion prices and investments in new capacity are the same in the rest of EU as in Denmark.

Of course there are differences between the EU countries. The power producing sectors differ much with respect to the share of hydro, nuclear, wind and thermal power. But from a CO_2 reduction point of view it is only the thermal power production, which is interesting to look at either to fuel convert or to substitute by more efficient power plants or renewable energy.

The efficiency of Danish power plants is high compared to the average efficiency within the EU. This is an argument for low EU CO_2 reductions costs compared to the Danish costs. Maybe the potentials in fuel switch to wood chops are higher in the EU than in Denmark. Prices on waste, straw and wood chops may be determined on local markets and may differ widely between the EU. But otherwise, given the same fuel input prices, electricity prices and prices on investments, and given the relative efficient reference coal fired power plants, the CO_2 reduction costs in the table should be the same in the different EU countries.

Effects on CO_2 reduction costs from different price assumptions are shown in column 3 in Table 8.9. Coal prices are the same as in column 2. Prices on gas and electricity are higher, 27 and 66 %, and prices on straw are lower, 56 % The relative price of electricity is much

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[85] This assumption is in line with Table 8.8 and standard emission factors.

higher in Column 3 than in Column 2, because it in Column 3 is assumed that the electricity prices increases to a level where it is profitable to invest in new power plant capacity. The market prices in Column 2 are near variable costs for conventional electricity production.

Higher relative gas prices make fuel conversion from coal to gas more expensive and CO_2 reduction costs higher. Lower prises on straw, lowers the CO_2 reduction costs. CO_2 reduction costs on new gas fired power plants increase with increasing gas prices and fall with increasing electricity prices. The net effect is falling CO_2 reduction costs. Investments in windmills are more profitable – also from a CO_2 reduction point of view – the higher the electricity prices.

The changed fuel and electricity prices change the ranking of technologies with respect to the cheapest CO_2 reduction costs. But fuel substitution from coal to gas, and investments in an increased share of renewables, are still possible at relatively low costs. All CO_2 reduction prices in Column 3 are below 307 DKK/ton CO_2.

Table 8.9. Prices for CO_2 reductions in EU

Country/ Technology	EU DKK/ton CO_2 Market prices 1997 level	EU DKK/ton CO_2 Changed relative fuel prices
Fuel conversion		
– coal to gas	76	190[1]
– coal to straw, 10 %	275	136[2]
– coal to straw, 10 % in separate. boiler	446	307[2]
New capacity		
Industrial CHP, gas		
Central KAD, coal	0	0
Central GAD, gas	129	-70[3]
Central CC, gas	93	-90[3]
Wind mills, placed at land	241	143[3]
Wind mills, offshore	282	184[3]

Source: Elsam, 1997.

Notes: 1) Coal prices are the same as in column 2. Gas prices are 27 % higher. 2) Coal prices are the same as in column 2. Prices on straw are 56 % of the prices in column 2. 3) Coal prices are the same as in column 2. Gas prices are 27 % higher. Prices on electricity are 66 % higher.

Table 8.10 combine the CO_2 reduction prices in Table 8.8 with very rough estimates of the EU potentials for CO_2 reductions. The CO_2 reduction costs are based on market prices for fuels. A quota price equal to 100 DKK is assumed to increase electricity prices with 6 % But this price increase is highly uncertain[86]. Given demand elasticities equal to -0.25 this price increase will result in a 1.5 % decrease in electricity demand (and production) and a more than 3 % decrease in CO_2 emissions from the electricity sector (if the marginal productions is assumed to be coal based).

A hundred percent fuel conversion from coal to gas gives a decrease in emissions from the power producing industry by 20 % The quota prise inducing this conversion would be under 100 DKK/ton CO_2. If an extra 10 % of the electricity production were based on renewables this would reduce emissions by 26 %, if the marginal electricity production were coal based. The quota price inducing this would be below 300 DKK

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[86] The 6 % is a little lower than the assumed Danish electricity price increase. The simple, but highly uncertain, reasoning is: European net taxes on electricity are lower than the Danish, but Danish electricity production is more CO_2 emitting. The first effect suggest a higher EU price increase than the Danish, the last effect a lower price increase. The net effect could be 6 %.

The quota price giving incentives to extra 10 % renewables will also be an incentive to fuel conversion and maybe a higher percent of renewables. Fuel conversion may be very profitable at a quota price well above 100 DKK To the existing conventional power plant owners fuel conversion may be much more profitable than investments in renewables, for example wind mills. But to other investors windmills will be profitable and they will invest.

If capacity in the power-producing sector increases and electricity prices fall – quota prices may rise to compensate the electricity price fall and induce further investments.

Following the table, CO_2 emissions will be reduced by 33 % if quota prices induced extra 10 % renewables and 50 % fuel substitution from coal to gas Taking the demand effects into account would add an extra 5 % (if the marginal production is oil based).

Halving emissions from the EU power sector, which is what is needed to fulfil the Kyoto target (if the power sector is the only sector to reduce emissions, and if emission projections are as previously mentioned) imply heavy reliance on renewable energy. The "halving" could be implemented in the following way:

- Substituting coal based power production (20 % of total EU production) with (17 %) renewables (decrease in demand is 3.8 %).
- Substituting oil and gas based power production (28 % of total EU production) with renewables. Leaving the coal based power production unchanged.
- Some combination of the two alternatives above
- Converting oil based power production to gas, and substitution 14 % of coal production to renewables. (Decrease in electricity demand is 3.8 % coal based).

Whether it is possible to substitute almost all conventional coal based power production with renewables (at least 14 % of total electricity production) at a price not higher than 300 DKK/ton CO_2, is difficult to answer. With respect to wind power it depends on wind conditions, the size of the transmission net and the technical problems with the fluctuating wind power.

The new Danish electricity act demands that 20 % of Danish electricity consumption should be based on renewables (which in practice will say almost 20 % wind). Compared to Denmark the EU has got very little combined heat and power. This means: 1) that wind power in principle can substitute almost all the thermal power production, and 2) that it is easier to use conventional power plants to compensate for the fluctuating wind. (In Denmark much of flexibility of the electricity production is hindered by the production of heat).

In other EU countries conversion to biomass or other renewables than wind, may be cheaper than in Denmark.

The conclusions with respect to an EU quota price are:

As one of the main emitters of CO_2, the power sector has to reduce emissions considerably. At quota prices equal to the costs of fuel conversion or costs of investments in new conventional capacity (i.e. below 100 DKK per ton CO_2, given the assumptions in this section) the power generating sector is capable of reducing emissions by 20 % Given the emission projections hold, a 20 % emission reduction is the average reduction needed in all sectors to fulfil the EU Kyoto commitment.

If the EU power sector has to reduce emissions by much more than 20 %, renewables (hydro power or nuclear power) must be an important part of the strategy. There is a large EU potential for wind power at quota prices below 300 DKK/ton CO_2. It is possible that biomass is cheaper in the EU than in Denmark.

If renewables – for example wind power – is promoted by other policies than CO_2 emission quotas, the price of CO_2 emission quotas can be effected.

There is a large emission reduction potential in renewables; therefore it seems likely that an EU CO_2 quota price will not exceed the price of the marginal investment in renewables.

Table 8.10. Emission reductions at quota prices below 300 DKK/ton CO_2. Different scenarios. European Union

	Quota price per ton CO_2 Approximately	Decrease in marginal production	Decrease in CO_2 emissions within electricity sector
Change in demand for electricity			
Decrease in EU electricity demand, for given elasticity and price increase	100 DKK	1.5 %**	3 %***
Decrease in EU electricity demand, for given elasticity and price increase	250 DKK	3.8 %**	7 %***
Change in power production			
Extra 10 % of electricity production based on renewables	< 300 DKK	0	26 %*
100 % coal converted to gas	< 100 DKK	0	20 %*
Extra 10 % renewables 50 % coal converted to gas Increasing fuel efficiency	< 300 DKK	0	33 %*

* The decrease in domestic electricity demand is not subtracted before calculating the emission reduction. Therefore the decrease in domestic demand cannot be added to this figure.

** The effect is highly uncertain. Price increases are assumed lower and elasticities identical to the Danish, but percentage price increases and price elasticities may differ widely between countries, and the true effects may be higher or lower than the Danish. Feed back effects are *not* taken into account, which it should be especially when considering big quota prices.

*** It is assumed that the marginal power plant is coal based.

8.7 Conclusions on CO_2 quota prices

This sections conclusions with respect to the price on especially an EU quota market are listed below. All cost estimates are subject to a number of highly uncertain assumptions. Therefore these estimates must be interpreted with a high degree of caution. But having said that, we believe that the cost estimates do carry information.

A precondition for trade on an EU market is a sufficient supply of quotas at prices, which are equal to or lower than alternative emission reduction opportunities.

If CDM or Joint Implementation with countries outside the EU is a possibility, or if a system of quotas including other countries than the EU counties exists, it will be a precondition for trade on the EU quota market that there is a supply of quotas at the equilibrium price on the EU market. That is, there must be at least one country within the EU, which have enough of low costs emission reduction options to fulfil their own international commitments and to sell quotas on an EU-market with profits. If emission reduction prices are lower outside the EU, there will be no trade on an EU market for quotas.

Given trade on an EU quota market, and if EU tradable quotas are one out of more alternatives to the agents, there will be a linking between the quota price and prices of the alternative emission reductions.

Prices on EU quotas will be equal to either the quota price on broader markets, or equal to the price on Joint Implementation emission reductions outside the EU, if these markets exists (i.e. in case of a broader than the EU-market for quotas exists or if Joint Implementation with countries outside the EU is a possibility).

EU quota price when EU tradable quotas are the only alternative to reducing your own emissions to the agents.

The EU quota price will be equal to the cost of the marginal CO_2 emission reduction within the EU as a hole.

Upper limits to the quota price

If there are backstop technologies (i.e. emission reduction technologies) which have great emission reduction potentials within the EU, the CO_2 reduction price of one of these technologies may be the upper limit to the quota price. The cheapest backstop technology will be implemented first.

Within the EU power sector there is a great emission reduction potential in fuel switching and higher fuel efficiency. The prices of CO_2 reductions carried out through fuel switching range from 70 to 300 DKK per ton CO_2, depending on which fuel is substituted by which, the type of power plant etc. The price span is not defined as the largest possible, but as the price span within which the bulk of emission reduction potentials are to be found. And furthermore, at the upper limit of the price span another technology with great potential takes over.

The cost of extending the EU windmill capacity as a mean to reduce emissions, depends on the wind conditions where raised, and the technical possibilities of fitting fluctuating wind power into the overall power system. It will be technically possible to extend the EU wind capacity considerably at prices below 280 DKK per ton CO_2.

According the Kyoto Protocol the EU must reduce emissions by 8 % as compared to emissions in 1990. If it is technically possible to reach the 8 % target level through fuel switching in the power sector and increased wind power production, the upper limit to the EU quota price must be around the 280 DKK/ton CO_2, which is the estimated price of reducing emissions trough installing new wind mills. Even if it is not possible to reach the target level solely by using these two techniques – if it is likely that cheaper CO2 reduction technologies in other sectors can reduce the rest, then the upper limit to the quota price will still be given by the marginal wind power investment.

If windmills are the marginal CO_2 reduction investment on a European quota market, the price of the quotas will be around 280 DKK/ton CO_2. If fuel switch in the power sector will be the marginal investment, the quota price will properly be somewhere between 70 and 280 DKK/ton CO_2, depending on the price and potentials of alternative CO_2 reduction investments.

The lower limit to the quotas price

The lowest possible quota price will be zero. This price will only be realised if:

- either new technology makes CO_2 reductions almost free, or
- due to low activity levels (within the EU or outside) there is sufficient of 'hot air' to reach the total EU target – and, none of the 'hot air suppliers' are able to expel monopoly power, and they are willing to sell quotas at prices next to nothing.

Other policies, new technology etc.

In general all EU and national policies having an impact on the CO_2 emissions will affect quota prices, given an overall reduction target. For example will limitations of car traffic (through taxes or direct regulation (no cars in city centres) and heavy taxation of trucks (on a per kilometre basis) properly reduce emissions, and reduce the demand for and price of quotas.

New technologies may affect the supply and demand for quotas and the quotas price: If new energy saving cars were introduced, if renewable electricity production became cheaper or new energy saving inventions were made, this would increase the low cost potentials for emission reductions and likely reduce the quota price.

The speed of CO_2 reductions

The speed of CO_2 reductions may be dependent on the size and wider implications of the investment decision, the profitability of the investments and technological factors. Fuel conversion and for example small-scale windmill investments may be fairly easy to decide on. Decisions to invest in new conventional power plants, large-scale wind or for example hydropower may be harder. High quota prices may ease the investment decisions, and fasten the CO_2 reductions.

Studies of quota prices when backstop technologies matter

The present analysis stress the importance of attention on backstop technologies, the prices at which they become profitable and their emission reduction potentials, in studies of quota prices and costs of CO_2 reductions. The present analysis indicates that failure to include backstop technologies may give quota price estimates of limited value.

The result of the analysis indicate that the quota prices estimated in many model studies, see for example Figure 8.1, are very high – and may be too high.

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Appendix A. Currency conversion and price levels

Table A shows conversion factors between some selected currencies between 1990 and 1998. The table is used as follows:

Amount in target currency = Amount in source currency * inflator

Table A. Conversion factors between ECU, USD and European national currencies 1990-1998

Source currency	Deflation	Target	1990	1991	1992	1993	1994	1995	1996	1997	1998
ECU		USD	1.273	1.236	1.295	1.167	1.184	1.293	1.253	1.129	1.122
ECU		DKK	7.857	7.909	7.809	7.594	7.543	7.328	7.359	7.484	7.500
ECU		NOK	7.964	8.024	8.032	8.295	8.352	8.192	8.088	7.993	8.471
ECU		DEM	2.052	2.052	2.052	2.052	2.052	2.052	2.052	2.052	2.052
USD		DKK	6.185	6.403	6.027	6.495	6.352	5.605	5.796	6.609	6.697
USD		NOK	6.257	6.492	6.204	7.107	7.053	6.337	6.455	7.079	7.550
USD		DEM	1.615	1.660	1.559	1.655	1.621	1.433	1.504	1.735	1.758
ECU 1990	EU Consumer price	ECU	1.000	1.042	1.084	1.120	1.148	1.177	1.207	1.231	1.251
ECU 1990	EU Consumer price	USD	1.273	1.288	1.403	1.307	1.360	1.522	1.512	1.390	1.403
USD 1990	US Consumer price	USD	1.000	1.040	1.070	1.110	1.130	1.170	1.200	1.230	1.250
ECU 1990	EU Consumer price	DKK	7.857	8.239	8.466	8.503	8.662	8.627	8.881	9.211	9.382
USD 1990	US Consumer price	DKK	6.185	6.660	6.449	7.209	7.178	6.558	6.955	8.129	8.371
DKK 1990	National cons. price	DKK	1.000	1.020	1.050	1.060	1.080	1.100	1.130	1.150	1.161
ECU 1990	EU Consumer price	NOK	7.964	8.359	8.707	9.288	9.590	9.645	9.760	9.839	10.596
USD 1990	US Consumer price	NOK	6.257	6.751	6.638	7.889	7.969	7.415	7.746	8.707	9.438
NOK 1990	National cons. price	NOK	1.000	1.030	1.060	1.080	1.100	1.130	1.140	1.170	1.193
ECU 1990	EU Consumer price	DEM	2.052	2.138	2.225	2.298	2.356	2.416	2.476	2.526	2.567
USD 1990	US Consumer price	DEM	1.615	1.727	1.668	1.838	1.831	1.677	1.805	2.134	2.198
DEM 1990	National cons. price	DEM	1.000	1.040	1.090	1.140	1.170	1.190	1.210	1.230	1.238

Sources: Eurostat: Harmonised Indices of Consumer Prices. / Official ECU exchange rates calculated and published by the European Commission. Annual averages 1993-97(98) / Danmarks Statistik. Tiårsoversigt 1998.

Notes: Development of a method for conversion of prices in different currencies and different years. (Harmonised Indices of Consumer Prices from Eurostat and the official exchange rates from the European Commission DG II covering ECU exchange rates between ECU and most European currencies, US $ and Yen in monthly and annual averages since 1993).

PRIMES is generally using ECU 1990. Fuel prices are quoted in US$ 1998. (inflation factor used for USD98/USD90 1.25 exactly, which is consistent with a consumer price index for the US – 1997-value 124, Statistics Denmark). By chance the ECU inflation factor 1990-1998 is also 1.25 (ECU weighted consumer price index until 1995, HICP 1995-1997 and Euro convergence inflation 1997-1998)

Appendix B. Methodology for the construction of marginal abatement cost curves using the Primes model

From Capros and Mantzos, 1999:

The calculations carried out within the present study followed the steps explained below:

1) The analysis started from a baseline scenario projecting the EU energy system from 1995 to 2010. The baseline scenario, also constructed by using the PRIMES model, reflects current policies and trends without including specific effort to reduce CO_2 emissions. The definition of the baseline scenario has been a result of shared analysis activity, which is on going under the auspices of DG XVII of the European Commission. The version of the baseline scenario is that delivered on February 5,1999.

2) Starting from that baseline, the model ran to compute the least cost solution corresponding to a given level of CO_2 emissions in 2010, which is constrained to be lower than the level of the baseline in 2010. A large range of such emission levels were defined, all of them being towards reducing emissions from baseline. An emission reduction level is imposed as an exogenous global emission constraint applied to the whole energy system of a member-state, letting the sector without any specific constraint (except those that have already been imposed in the baseline scenario). The model determines the allocation of effort by sector within each member-state that is necessary to meet the global constraint.

3) The analysis exploits the differences between the results of each model run corresponding to lower emissions and the results of the baseline. These differences span the whole energy system, showing changes that are necessary to reach the lower emission level. Such changes may concern behaviour in using energy, structural changes in energy uses and processes, possible accelerated adoption of new technologies, changes in the fuel mix, etc. The exploration of the series of least cost solutions, varying according to the magnitude of the emission reduction level, provides a rich set of information revealing the priority of changes that are recommendable by sector and country, and their nature. This information can further support design of concrete policies and measures.

4) The model provides simultaneous estimations of the marginal and average costs of these changes, by sector and member-state. Following a least cost methodology, the marginal costs plotted against the varying levels of emission reduction, in other terms the model-based marginal abatement cost curves, can be used as a basis for defining the sharing of the emission reduction effort by country and furthermore by sector.

5) The PRIMES model simulates the overall market equilibrium of the energy sector. It computes the prices of energy products that lead to balancing demanded and supplied quantities of each energy product in a period of time (usually a five-year period). Since the PRIMES model is formulated as a complementary mathematical problem (dual to a mathematical programming problem), the imposition of a global constraint is mathematically strictly equivalent to the inclusion of a shadow variable which appropriately affects all economic costs, exactly as the global constraint would do. Let us call the value of the shadow variable "carbon-value" of the global emission reduction constraint. Obviously, there will be a single carbon value associated to a given emission reduction level for a given member-state. To facilitate the analysis, we prefer to present the results in terms of carbon value, which was set to vary from a small level of 1 EUR/ton-of-carbon up to 900 EUR/ton-of-carbon. The comparison of the obtained emissions with the level of baseline scenario (per member-state) shows the magnitude of abated emissions that is dual to the level of the carbon-value. The adjustment of the energy demand and supply system, as computed by the model, is therefore exactly identical to the results from imposing the associated emission reduction level as a global constraint to the system of a member-state.

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Abstract (max. 2000 characters)

This report presents the results of the project "Tradable CO_2 permits in Danish and European energy policy". The project was financed by a grant from the Danish Energy Research Programme 1998 (Grant 1753/98-0002). The project was conducted in co-operation between Elsamprojekt A/S (project manager), Risø National Laboratory, Aarhus School of Business and I/S Eltra.

The three major objectives of the project were:

- To identify and analyse the economical and political issues that are relevant with regard to the construction of a tradable CO_2 permit market as well as proposing a suitable design for a tradable CO_2 permit market for the energy sector in the EU. Experience from the tradable SO_2 permit market in the US is taken into consideration as well.
- To present an overview of price estimates of CO_2 and greenhouse gas permits in different models as well as discussing the assumptions leading to the different outcomes. Furthermore, the special role of backstop technologies in relation to permit prices is analysed.
- To analyse the connection between CO_2 permit prices and technology choice in the energy sector in the medium and longer term (i.e., 2010 and 2020) with a special emphasis on combined heat and power and renewables. In addition, the short-term effects on CO_2 emissions and electricity trade of introducing tradable CO_2 permit with limited coverage (i.e. a national system) as well as complete coverage (i.e. including all the countries) in the Nordic electricity system are analysed.

Descriptors INIS/EDB

AIR POLLUTION ABATEMENT; CARBON DIOXIDE; COGENERATION; DENMARK; ECONOMIC ANALYSIS; ELECTRIC POWER INDUSTRY; ENERGY POLICY; ENVIRONMENTAL POLICY; EUROPEAN UNION; INTEREST RATE; LICENSES; MATHEMATICAL MODELS; SPOT MARKET; SULFUR DIOXIDE; TRADE; USA

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