**Kiel Institute for World Economics**
Duesternbrooker Weg 120
24105 Kiel (Germany)


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# Efficient Abatement in Separated Carbon Markets: A Theoretical and Quantitative Analysis of the EU Emissions Trading Scheme

**by**

**Sonja Peterson**

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# Efficient Abatement in Separated Carbon Markets: A Theoretical and Quantitative Analysis of the EU Emissions Trading Scheme*

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Abstract:
The European Emissions Trading Scheme for $CO_2$ established in 2005 is the world's largest emissions trading scheme. Since it covers only some sectors of the European economies it can nevertheless not ensure that the Kyoto targets are reached at minimal cost. This paper first analyzes the conditions for cost efficiency in the current separated carbon markets accounting also for the possibilities of purchasing international carbon credits from outside the EU. A computable general equilibrium model is then used to assess the cost efficiency of current EU climate strategies. Finally, based both on the theoretical as well as the quantitative analysis, recommendations are derived for a better allocation of the reduction burden between the sectors participating in emissions trading, those that do not participate and international carbon purchases.

Keywords: emissions trading, allocation, efficiency, separated markets

JEL classification: H21, D61, Q48, D58

**Sonja Peterson**
Kiel Institute for World Economics
24100 Kiel, Germany
Telephone:+49-(0)431-8814-406
E-mail: sonja.peterson@ifw-kiel.de

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# 1 Introduction

In theory, the case is very simple. The condition for reaching a given carbon target at minimal cost is the equalization of marginal abatement costs across all abating installations, sectors and countries. This can e.g. be achieved by implementing an emissions trading scheme (ETS) covering all sources of carbon emissions. Existing emissions trading schemes though are not encompassing all carbon sources, but are confined to some sectors and regions. The largest existing emissions trading scheme is the European emissions trading scheme (EU-ETS) that covers the $CO_2$ emissions of the major energy intensive sectors in the EU member countries - altogether around 2.2 $GtCO_2$ or 45% of the EU's total $CO_2$ emissions. The main reason for the implementation of this scheme is to reach the European Kyoto targets at minimal cost.

Theoretical and quantitative analysis of the current EU climate strategy have shown that the overall efficiency of reaching the Kyoto targets with the current separated carbon markets where only part of all relevant emissions are covert by the EU-ETS while emission reductions in the sectors outside the ETS have to be reached by other means, depends to a large degree on the allocation of allowances to the ETS-sectors compared to the stringency of measures planned outside the ETS. Currently, the member states of the EU have to decide on the allocation of allowances to the ETS sectors for the second EU-ETS trading period from 2008-12 that also coincidences with the first Kyoto commitment period. The question of an efficient allocation is thus of new interest.

What complicates the analysis is the fact that there is not only the EU-ETS and emission reductions in the remaining sectors but also the possibility to acquire carbon credits from international projects and via international emissions trading between states. Since the current separated carbon markets in Europe will be persistent at least in the medium term, the question is whether and how in this given system the EU Kyoto targets can be reached at minimal cost - in theory and in practice - and also how large the extra cost from inefficient allocation of reduction burdens are. From a theoretical point of view a detailed analysis of a stylized model - as developed and discussed in section 3 - reveals some interesting features of separated carbon markets in general. The model is used to derive conditions for an optimal allocation of emission reductions in the current system. To assess the efficiency of different practical approaches the computable general equilibrium model DART is used that is described in section 4 to simulate different climate policy scenarios of reaching the Kyoto targets in the EU. The scenarios are based on the recent recommendations published by the EU-Commission. The simulation results are discussed in section 5. To put the theoretical and quantitative results into perspective, the next section starts with a brief overview over EU and international climate policy in general and the EU ETS in particular.

# 2 EU Climate Policies and the EU ETS

In the Kyoto Protocol from 1997, the EU agreed to cut their overall greenhouse gas emissions relative to the 1990 level by 8% in the period from 2008-2012. In the Burden Sharing Agreement, this target was differentiated between between the (at that time) 15 different EU member states. The 10 new member countries that joined the EU in May 2004 are not part of this agreement, but have (except Cyprus and Malta) their own individual Kyoto targets. To reach the European commitments at minimal costs the EU-wide emissions trading scheme (EU-ETS) for $CO_2$ was designed that covers the major energy intensive sectors in the EU. The first 3-year trading period that started in 2005 is seen as a test for the second period from 2008-2012 that coincidences with the first Kyoto commitment period.

The allocation of allowances to the ETS sectors are laid out in the National Allocation Plans (NAPs) that also have to demonstrate how the Kyoto targets are to be reached. There are generally three ways for the governments of the EU member states to reduce greenhouse gas emissions and to reach the national Kyoto targets:

- *Domestic $CO_2$-emission reductions in the ETS sectors.* These are directly determined by the allocation to the ETS sectors
- *Emission reductions abroad.* Governments can either buy Assigned Amount units (AAUs) from other Annex B countries of the Kyoto Protocol or carbon credits from the project based mechanisms Clean Development Mechanism (CDM) and Joint Implementation (JI). The government plans to make use of these options are included in the NAPs.
- *Domestic reductions outside the ETS (in non-$CO_2$ gases and non-ETS sectors).* These are implicitly given by the allocation to the ETS and the plans to acquire international carbon credits as the necessary residual reductions to reach the Kyoto targets.

Furthermore, by the EU Linking Directive, CDM and JI credits can also be obtained by firms under the EU-ETS and converted into EU-allowances. An important issue in the context of carbon reductions abroad - by governments and ETS firms - is the supplementarity requirement laid out in the Marrakesh Accords to the Kyoto Protocol. It states that "the use of the mechanisms [International Emissions Trading, CDM, JI] shall be supplemental to domestic action". There is no official quantitative definition of this supplementarity obligations though. The EU itself, e.g. in the Proposal for the Linking Directive (EU-Commission 2003) seems to interpret the requirement such that no more then 50% of the total reduction from 1990 can be achieved via these mechanisms. When the supplementarity criterion was discussed in Marrakesh, the EU calculated limits to the use of the international mechanisms for its member countries, which have many drawbacks (Langrock and Sterk 2004) but can act a proxy. Concerning the ETS, member states have now to specify the maximum amount of JI and CDM credits that may be used for compliance purposes by installations under the ETS in the NAPs for the second trading period. In the original directive a review is foreseen once the use of CDM and JI credits reaches 6% of total allowances in the ETS. The EU can then consider setting a limit of e.g. 8% (EU-Commission 2003).

First evidence on the efficiency of the allocation in the first trading period suggests that if the aim is to reach the European Kyoto targets efficiently, the existing NAPs1 allocate emission allowances to the ETS sectors too generously and imply too severe emission reductions from the sectors not covered by the ETS (Böhringer et al. 2005, Klepper and Peterson 2004, 2006). These studies nevertheless have not or only insufficiently clarified how a cost effective solution can be reached under the current system - in theory and in practice. In particular they do not analyze the role of the international measures adequately. This will be done in section 3.

# 3 Cost-efficiency in Separated Carbon Markets - A Stylized Model of the EU System

In this section, a stylized model is used to discuss cost-efficiency under the separated EU carbon markets.

## 3.1 Separated Carbon Markets - A First Model

This sections starts with a simple model of the separated EU carbon markets that ignores for the moment the possibility of purchasing carbon credits from outside the EU.

### Cost Minimization

Let $Ky(r)$ be the Kyoto target of EU member state $r$ according to the Burden Sharing Agreement. Ignoring the possibility of purchasing carbon credits from outside the EU, efficient regulation comes down to minimizing compliance costs as the sum of abatement costs $C_{i,r}(e_{i,r})$ across all sectors $i$, where $e_{i,r}$ are the emissions of sector $i$ in member state $r$, subject to the emission constraint of the entire EU:

$$Min_{e_{i,r}} \sum_{i,r} C_{i,r}(e_{i,r}) + \lambda \left( \sum_{i,r} e_{i,r} - \sum_{r} Ky(r) \right) \quad (1)$$

where $\lambda$ is the Lagrangian multiplier or the shadow costs corresponding to the emission constraint. The associated first-order conditions state that marginal abatement costs are equalized across all sectors and countries at this shadow cost.

$$MAC_{i,r}(e_{i,r}) := \frac{\delta C_{i,r}(e_{i,r})}{\delta e_{i,r}} = \lambda \quad \forall\ i, r \quad (2)$$

This efficient solution could e.g. be reached with full European emissions trading including all sectors. In this case, $\lambda$ would be the carbon price that emerges in the European carbon market.

### The EU-System

Under the current system of separated EU carbon markets, the conditions for cost minimization are not necessarily fulfilled. The existing system can be formalized as follows, ignoring again the option to buy carbon credits from outside the EU.

To simplify notation, all ETS sectors in one region are summarized to one sector denoted with subscript $ET$ and equivalently all sectors that are not participating to one sector denoted with subscript $NET$. Cost minimization now implies that

$$\begin{aligned} MAC_{ET,r}(e_{ET,r}) &= MAC_{ET,r'}(e_{ET,r'}) \\ &= MAC_{NET,r}(e_{NET,r}) = MAC_{NET,r'}(e_{NET,r'})\ \ \forall\ r, r' \end{aligned} \quad (3)$$

Let NAP(r) denote the allocation of emission allowances to the $ET$ sector in member state $r$. The sectors are then allowed to trade emission rights in the European market so that an European carbon price $p_{EU}$ emerges. This price as well as the actual emissions of the $ET$ sectors and thus the net allowance trade are determined by the following system of equations

$$p_{EU} = MAC_{ET,r}(e_{ET,r})\ \ \forall\ r \quad (4)$$

$$\sum_{r} e_{ET,r} = \sum_{r} NAP(r) \quad (5)$$

To reach the individual burden sharing targets $Ky(r)$ each country then has to reduce emissions in the $NET$ sector such that

$$e_{NET,r} = Ky(r) - NAP(r)\ \ \forall\ r \quad (6)$$

This leads to shadow price $p_{NET}(r)$ of this emissions constraint

$$p_{NET}(r) = MAC_{NET,r}(e_{NET,r})\ \ \forall\ r \quad (7)$$

#### Efficiency in the EU-System

An efficient solution requires that $p_{NET}(r) = p_{EU}\ \forall\ r$. Taking the Kyoto targets $Ky(r)$ as exogenously given, the $3r+1$ unknowns $e_{NET,r}$, $e_{ET,r}$, $NAP(r)$ and $p_{EU}$ are uniquely determined by the system of equations (4) $-$ (7) with $3r+1$ equations. There is thus exactly one optimal set of national allocation plans that lead to cost minimization.

With EU governments deciding upon the partition of national emission caps to ETS and non-ETS sectors, cost minimization is only reached if each national government has chosen the one and only efficient allocation to the ETS sectors. The problem of of a hybrid-system discussed in this section was already formalized by Böhringer et al. (2005). But it gives only part of the picture since it ignores the role of international emissions trading for replacing both emission reductions in the ETS and the non-ETS sectors. This is formalized in the next section. In the context of the more realistic model also the policy implications of the current system can be discussed.

### 3.2 Adding the Possibility of International Emissions Trading

The model is now amended to account for the possibility to purchase carbon credits from outside the EU.

#### Cost Minimization

If $p_W$ is the price of international carbon credits, the overall cost minimization problem in the EU becomes

$$Min_{e_{ET,r},e_{NET,r}} \quad \sum_r (C_{ET,r}(e_{ET,r}) + C_{NET,r}(e_{NET,r})) + p_w \left( \sum_r (e_{ET,r} + e_{NET,r} - Ky(r) \right) \tag{8}$$

By the first order conditions cost minimization implies again that marginal abatement costs equalize across all sectors in all participating countries and are in this case equal to the international carbon price.

$$p_W = MAC_{ET,r}(e_{ET,r}) = MAC_{NET,r}(e_{NET,r})\ \ \forall\ r \tag{9}$$

#### The EU-System

As explained above, there are two options in the EU to make use of international carbon purchases. First, national governments can purchase CDM and JI credits or

AAUs to reduce the burden of emissions reductions in their country. Second, the Linking Directive allows firms under the ETS to acquire credits from CDM and JI projects and to exchange them for EU allowances. Let us assume that there is only one international price for carbon credits $p_W$ which is determined by the demand for international emission credits (IECs) from EU governments $IEC_{gov}(r)$ and ETS firms $IEC_{ET}(R)$. If $Ky(W)$ is the emission restriction of the rest of the world[1] and $e_W$ are the emissions of the rest of the world, the system of equations describing the current EU system becomes

$$\begin{aligned} e_{NET,r} &= Ky(r) - NAP(r) + IEC_{gov}(r) \;\; \forall\, r & (10) \\ \sum_r e_{ET,r} &= \sum_r NAP(r) + \sum_r IEC_{ET}(r) & (11) \\ p_{EU} &= MAC_{ET,r}(e_{ET,r}) \;\; \forall\, r & (12) \\ p_{NET}(r) &= MAC_{NET,r}(e_{NET,r}) \;\; \forall\, r & (13) \\ p_W &= MAC_W(e_W) & (14) \\ Ky(W) + \sum_r Ky(r) &= \sum_r e_{NET,r} + \sum_r e_{ET,r} + e_W & (15) \end{aligned}$$

Equation (10) is the Kyoto constraint, equations (11) and (12) describe the EU-ETS, equation (13) the resulting shadow costs in the non-ETS sectors and equations (14) and (15) the international carbon price and the world carbon constraint.

### Global Efficiency in the EU-System

Taking again the Kyoto targets $Ky(r)$ and $Ky(W)$ as exogenously given there are now $6r+3$ unknowns: $e_{ET,r}, e_{NET,r}$, $NAP(r), IEC_{gov}(r), IEC_{ET}(r), e_W, p_{NET}(r), p_{EU}$ and $p_W$ and $3r+3$ equations. A globally efficient solution implies that $p := p_{EU} = p_{NET}(r) = p_W \;\forall\, r$ which still leaves $5r+2$ unknowns, so that there is not a unique efficient solution anymore.

However, global efficiency has important implications for the choice of policy parameters. The subsystem of the $2r+2$ equations $(12) - (15)$ has exactly $2r+2$ unknowns $e_{ET,r}, e_{NET,r}, e_W$ and $p$. Hence this system of equations uniquely determines - for exogenously given caps for emissions in the EU member states and the rest of the world - the emissions for the ETS sectors $e_{ET,r}$, in the rest of the economy $e_{NET,R}$, and in the rest of the world, $e_W$ as well as the global carbon price $p$. Furthermore, given an efficient solution, equation (10) uniquely determines $NAP(r) - IEC_{gov}(r)$ for each country while equation (11) determines $\sum_r NAP(r) + IEC_{ET}(r)$. The choice of policy instruments by EU governments is thus restricted to either setting the NAPs with the

[1] Annex B countries are also restricted to their Kyoto targets. Since CDM and JI projects have to be additional, the restriction for non-Annex B countries are their business as usual emissions.

consequence that the government purchases of international carbon credits $IEC_{gov}(r)$ need to be adjusted to the Kyoto constraint (10), or to setting government carbon purchases $IEC_{gov}(r)$ with the NAPs being adjusted to the Kyoto constraints.

It is clear that for given $NAP(r)$ or given government carbon purchases $IEC_{gov}(r)$ global efficiency can only be reached as a simultaneous solution to system (10) − (15) with internationally equal prices for carbon. In fact, the current requirement of the EU to governments of member states that they simultaneously announce their NAPs and the intended government purchases of international carbon credits will not achieve efficiency unless the governments had computed the simultaneous solution to the equation system above and adjusted their decision accordingly. However, this does not leave the governments any leeway in setting policy parameters, except for the freedom to shift allocation rights between the ETS sectors and governmental carbon purchases.

Finally, three further things should be noted:

- Since the $NET$ sectors in each country are separated from any international carbon market, there is a unique solution for the emissions in these sectors given the efficiency requirement of equal carbon prices and the shadow prices in the non-trading sectors.
- The caps ($NAP(r)$) in the ETS sectors do not matter, since the arbitrage on international carbon markets will equalize $p_W$ and $P_{EU}$.
- The reason why only the entire sum of the international credits that enter the ETS is determined is that it is of no difference whether one country's ETS sectors buys within the EU-ETS or from international markets.

### 3.3 Policy Making in the EU system

Under a system of unrestricted European and international emissions trading, the Kyoto targets are automatically reached at minimal cost and national governments do no require any additional information. Under the current system of separated markets though it is important to look at the policy options of EU governments and how their decisions relate to efficiency.

As discussed in the last section, in the current system, the government of each EU member state decides simultaneously in the NAPs the allocation to the ETS sectors $NAP(r)$ and the governmental purchases of international carbon credits $IEC_{gov}(r)$. This has consequences for the efficiency. It was shown above that global efficiency is reached as a simultaneous solution to the system (10)−(15) for any given set of NAPs (or

$IEC_{gov}(r)$). Global efficiency can thus only be reached by accident. Note also, that the current system does not guarantee that marginal abatement costs equalize outside the ETS in each country, which is implied when aggregating all non-ETS emission sources to one sector in the stylized model. In reality, national governments are planning to introduce very different measures in the non-ETS sectors reaching from voluntary agreements, over technology standards and the promotion of new technologies to energy and emission taxes. Thus, a divergence of marginal abatement costs across the different non-ETS sources of GHG emissions is more then likely to be the result, leading to further inefficiencies.

For global efficiency, the policy intervention in the sectors not subject to emissions trading needs to be set in such a way as to equal the international carbon price $p_W$. Böhringer et al. (2005) thus suggest to impose a uniform emission tax equal to the EU allowance price or the world market price for carbon on the non-ETS sectors that are not eligible for emissions trading. The allowance allocation to the ETS, $NAP(r)$, and the governmental purchases of international carbon credits, $IEC_{gov}(r)$, then have to be chosen such that $Ky(r) - e_{NET,r} = e_{ET}(r) - IEC_{gov}(r)$. The problem with this approach though is that neither the international and EU carbon price nor the emissions in the non-ETS sectors resulting from a carbon tax are known beforehand. Böhringer et al. (2005) do not address this simultaneity problem and also ignore the role of international carbon credits. Such a system would work though, if the EU purchases of international carbon markets would not influence the world carbon price $p_W$, in other words, if the EU behaves approximately as a small country. In this case a possible policy to reach global efficiency would be to set the implicit tax on the non-ETS sectors equal to the international carbon price. Given any $NAP(r)$ in each region, the ETS sectors would then buy international carbon credits until ETS prices are equal to the international price and thus all prices and marginal abatement costs would equalize. Finally, each government would buy the carbon credits for which it falls short of meeting the Kyoto target. Note that this solution calls for a uniform EU tax in the non-ETS sectors.

A uniform EU tax in the non-ETS sectors is rather unrealistic though. Given the current approach of fixing $NAP(r)$ and $IEC_{gov}(r)$, the question is then, how governments can define efficient plans. This will be dealt with in section 4. Before though, the next subsections deals with one final issue, the supplementarity obligation, that was already mentioned in section 2.

### 3.4 Supplementarity and EU-Efficiency

Supplementarity implies that the use of international carbon trading is somehow restricted depending on the exact definition of this obligation. If the resulting constraints for purchases of international carbon credits are binding, a wedge is driven between the international carbon price and EU carbon prices even under a cost minimizing allocation of emissions to ETS and non-ETS sectors. In other words, overall Kyoto cost are higher then under unrestricted use of international carbon credits and the goal should then be to find an optimal allocation given the supplementarity constraints.

Possibilities to implement supplementarity are e.g. to restrict the entire use of international carbon credits in the EU, the use in each country and/or the use in the EU-ETS. In analytical terms, adequate parameter restrictions need to be added to the cost minimization (8) and the system of equations $(10) - (15)$.

From an efficiency point of view there should be one supplementarity constraint for the entire EU. There is some justification for such an approach, since the EU is treated as a bubble in the Kyoto Protocol. Also, as soon as there is (as in the EU-ETS) emissions trading on firm level one would not only need to restrict the purchases of CDM and JI credits in each country, but also the purchases of ETS allowances within the ETS, since otherwise it is possible for EU-ETS emissions trading to substitute for trading the restricted purchases of CDM and JI credits.

Under the assumption that the entire use of international carbon credits is restricted to $lim_{EU}$ in the EU and that this constraint is binding (which is realistic), the problem basically reduces to the problem in section 3.1 without international carbon credits. The EU as a whole than buys the limited amount of international carbon credits at the world carbon price (that might depend on the size of the limit) and then total emissions in the EU can reach $\sum_r Ky(r) + lim_{EU}$ while otherwise the cost minimization problem remains the same as in equation (1). A decision then needs to be made about who is allowed or will buy what share of the EU limit on international carbon purchases. This is not a question about efficiency and has no allocation effects. It has of course, distributional effects and determines the costs for the different EU governments and the ETS sector. A natural solution for the burden sharing between different EU governments would be to take individual national supplementarity obligations. Each EU government then has to decide how much of the restricted amount of international carbon credits it intends to buy itself (with tax payer money) and how much the ETS sector is allowed to buy.

In the current system, governments decide on $NAP(r)$, $IEC_{gov}(r)$ and $lim_{ET}(r)$ the maximal amount of CDM and JI purchases of national ETS firms such that $IEC_{gov}(r) + lim_{ET}(r) = sup(r)$, where $sup(r)$ is the maximal amount of international carbon credits one country can buy according to the supplementarity criterion. The cap for the non-ETS sectors is then implicitly given by $Ky(r) + sup(r) - NAP(r)$ and only by chance this allocation is efficient.

Finally, it should be stressed again, that in this case under an efficient allocation there is one single carbon price in Europe but it diverges from the world market price for carbon by the shadow cost of the emission constraint. For efficiency, the EU should thus concentrate on equalizing marginal abatement costs across all European sources of carbon emissions "EU-efficiency"). And the main question is again, how this goal can be reached at least approximately within the current system and without knowing marginal abatement cost curves in all sectors for certain. The approach that is currently proposed by the EU-Commission (EU-Commission 2005) calls to account for economic growth and trends in decarbonization to set targets for non-ETS and ETS sectors. According to EU-calculations, caps should not increase in any Member State from the first to the second trading period. The Commission also suggests that ETS sectors should contribute a proportionate share of the reduction in Member States with a gap to close. Overall the methodology would lower the annual EU-wide caps in the second phase by some 6% compared with the first phase. The next section will look at whether this approach leads to an efficient outcome and if not how it can be modified to do so.

# 4 Using the DART Model for a Quantitative Analysis

In order to calculate efficient EU-policies and NAPs and to assess the efficiency of current proposals, a computable general equilibrium (CGE) model of the EU is used, that is briefly described in this section.

## 4.1 The DART Model

The DART (Dynamic Applied Regional Trade) Model is a multi-region, multi-sector CGE-model of the world economy. Table 1 illustrates the 15 countries or group of countries of the EU-25 and eight other world regions of DART. In each region or country, the economy is disaggregated into 12 sectors including five energy sectors. Four of the sectors participate in the ETS. Although there is no perfect match between the installations subject to the ETS and the sectoral structure of DART, the deviations are relatively small. The economy in each region is modeled as a competitive economy with flexible prices and market clearing. There exist three types of agents: a representative consumer, a representative producer in each sector, and regional governments. All regions are connected through bilateral trade flows. The DART-model has a recursive-

Table 1: DART-Regions

| | | | |
|---|---|---|---|
| **European Union** | | **Other Annex B countries** | |
| AUT | Austria | ACC | Future EU accession countries (Bulgaria, Rumania) |
| BEL | Belgium, Luxembourg | | |
| DEU | Germany | USA | United States of America |
| ESP | Spain | FSU | Former Soviet Union |
| FRA | France | OAB | Rest Annex B (Australia, Canada, Iceland, Japan, New Zealand, Norway, Switzerland) |
| GBR | Great Britain | | |
| IRL | Ireland | | |
| ITA | Italy | | |
| MED | Mediteranian (Greece, Malta, Cyprus) | **Other World regions** | |
| | | LAM | Latin America |
| NLD | Netherlands | CPA | China, Hong-Kong |
| PRT | Portugal | IND | India |
| SCA | EU Scandinavia (Denmark, Finland, Sweden) | ROW | Rest of the World |
| BAL | Baltic (Estonia, Latvia, Lithuania) | | |
| POL | Poland | | |
| EEU | Eastern EU (Hungary, Czech Rep., Slovakia, Slovenia) | | |

dynamic structure solving for a sequence of static one-period equilibria. The major exogenous drivers are the rate of productivity growth, the savings rate, the rate of change of the population, and the change in human capital.

The model is calibrated to the GTAP6 database that represents production and trade data for 2001 and to current emission projections. For a more detailed description of the DART model, see Springer (2002) or Klepper et al. (2003). Each of the ETS scenarios described below is analyzed against a business-as-usual scenario (BAU) without any climate-policy measures enacted after 2001.

## 4.2 Scenarios

In order to assess the efficiency of different proposals for NAPs a number of scenarios are defined. First, there are two scenarios where the European Kyoto targets are reached efficiently with and without accounting for the supplementarity obligation.

**opt** In this scenario there is full EU emissions trading to reach the European Kyoto targets and there are no restrictions on the use of international carbon credits. This scenario delivers the globally efficient solution.

**sup** Again, there is full EU emissions trading but now the purchases of international carbon credits are restricted according to the supplementarity criterion as defined in Langrock and Sterk (2004) for each EU-Member State. This scenario corresponds to restricted efficiency under supplementarity and delivers an EU-efficient solution.

These two scenarios thus deliver the efficient emission levels in the ETS and non-ETS sectors and the resulting net international carbon purchases as well as the associated carbon prices and welfare costs (abatement costs). They can be used to assess the importance of the supplementarity criterion and also act as a benchmark for different proposals.

Second, there are three scenarios of EU climate strategies given the current separated carbon markets. In all these scenarios

- The EU governments purchase international carbon credits as announced in the NAPs for the first trading period.
- The governments of the other Annex B countries buy altogether 200 $MtCO_2$ from international markets (see Klepper and Peterson 2006 for a discussion).
- The ETS sectors receive a certain amount of allowances which they are free to trade. The purchases of CDM and JI credits by the ETS firms altogether are restricted to 8% of total allowances in the ETS.
- To reach the national Kyoto targets, each country implements a uniform $CO_2$ tax for all non-ETS sectors.

There are then three different scenarios for the allocation of allowances to the ETS. In $NAP1$ the current NAPs for the first trading period remain unchanged in the second trading period:

**NAP1** The ETS sector in each country receives the same amount of allowances as fixed in the NAPs for the first trading period from 2005-2007 also for 2008-2012.

The two remaining scenarios define NAPs for the second trading period according to the guidance of the EU-Commission (EU-Commission 2005) which proposes that the ETS sectors contribute a proportionate share of the reduction in Member States with a gap to close. There are at least two credible ways to calculate this gap starting from 2003 emissions[2]. A first possibility is to calculate the "gap" as the difference between overall 2003 emissions and the Kyoto target. A second possibility is to calculate the "gap"

[2]For 2004 there are not yet any official data.

as the difference between overall 2003 emissions and the Kyoto target PLUS planned governmental purchases of international carbon credits. In the first case, the actual relative reduction target for the non-ETS sectors is less then for the ETS-sectors, since the governmental purchases of international carbon credits reduce the national gap after accounting for the ETS reductions. The governmental purchases of international carbon credits are thus implicity a mean to reduce the costs of reaching a given target in the non-ETS sectors. Since the ETS firms themselves have the option to acquire CDM and JI credits, this can be regarded as "fair". It seems that the EU guidance paper has this first definition in mind. The second definition implies that the non-ETS sectors and the ETS-sectors have the same relative reduction target - but while ETS-sectors can achieve their reductions via carbon purchases from other ETS firms or from the international markets, the non-ETS sectors have to achieve all reductions at home. In the simulations, both scenarios are run:

**gap1** Compared to 2003, the emissions in the ETS sector are reduced by an amount that is calculated as "gap (=total emissions in 2003 - Kyoto target) * share of total emissions covered by ETS in 2003". Member States achieving Kyoto in 2003 or without Kyoto targets keep the allocation stated in the NAPs for the first trading period.

**gap2** This is the same as scenario *gap*1, but now the gap is calculated as "total emissions in 2003 - Kyoto target + amount of international carbon purchases as announced in the NAPs for the first trading period"

These scenarios are analyzed with respect to their efficiency and allocation effects. A comparison of these scenarios with an optimal scenario allows to derive recommendations for a cost-efficient definition of the NAPs2. For more detailed assumptions and the implementation of the NAPs see Appendix A.1.

## 5 Simulation Results

The simulation results of the different scenarios are derived from running the DART-model over the period 2001 to 2012. The subsequent figures and tables report the final results for 2012. All prices are denoted in Euros of the year 2000. The major focus in this analysis is on cost-efficient allocations in the current system of separated carbon markets in the EU. In the Appendix there are nevertheless tables with further simulation results, including besides welfare effects also carbon prices and carbon trades.

### 5.1 How Important is the Supplementarity Requirement?

The question that is addressed here is the additional costs of reaching the EU Kyoto targets when accounting for the supplementarity obligation. For this, the two scenarios *opt* and *sup* are compared. In both scenarios there is full EU emissions trading, but while in *opt* the EU can make unlimited use of international emissions trading, there is a restriction on international purchase of carbon credits in *sup*.

The first result is, that the restriction is indeed binding. Under unlimited international emissions trading in *opt* the EU buys 66% more international carbon credits compared to *sup*. As a result, the carbon price paid in the EU is in *sup* about 45% higher than in *opt*. The wedge between the average carbon price in the EU and international carbon price leads to welfare losses, even though these losses turn out to be rather small. Compared to *opt* the welfare losses of reaching the Kyoto target are 0.1 -0.2% lower in *sup* in basically all EU countries. On average, in the entire EU25, the welfare losses increase by 0.2%.

Also in other respects the two scenarios are relatively similar since the general structure of international carbon purchases from the different member states is the same in both scenarios. As the EU-Commission clearly stresses the importance of supplementarity in its recent guidance paper (EU-Commission 2005), the next sections will compare different scenarios for the NAPs2 with the *sup* scenario. One can keep in mind that the restriction on international carbon purchases, though binding, does only lead to small welfare and structural changes compared to the unrestricted *opt* scenario.

### 5.2 The Efficiency of current NAPs and NAP2 Proposals

To analyze the cost-efficiency of the EU climate strategies implied by NAPs for the first trading period and by the NAPs2 for 2008 - 2012 when following the guidance from the EU, three scenarios in the current EU system with restricted carbon markets are simulated. These scenarios differ in the allocation to the ETS sectors and the flip side of the coin - the necessary reductions in the non-ETS sectors in 2008 - 2012. Figure 1 shows for the three scenarios and for the countries with binding Kyoto targets the percentage reductions necessary in the ETS and the non-ETS sectors compared to the 2003 emissions before the start of the ETS. In the countries which are on track meeting their Kyoto targets (France, the UK, Greece) all targets for the ETS sectors remain the same as ins scenario *NAP1*.

Obviously, current NAPs imply with a few exceptions (which are mainly the countries on track for meeting their Kyoto targets) much more severe reductions in sectors not

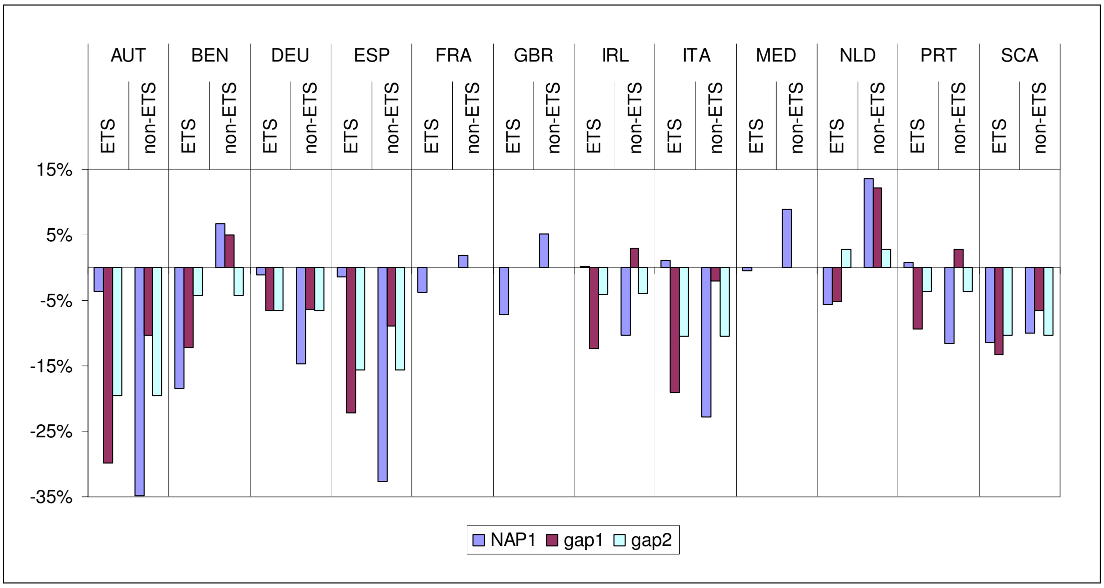


Figure 1: Targets for ETS and non-ETS sectors relative to 2003 emissions

covered by the ETS then in sectors under the ETS. In extreme cases such as in Austria and Spain, the current NAPs1 imply emission reduction outside the ETS by up to 35%. On average the emission reduction in the countries with binding targets (which are equivalent to the old EU15 countries), current NAPs imply a 3.8% emission reduction in the ETS compared to 2003 but a 8.5% reduction in the non-ETS sectors. This changes in the two *gap* scenarios. By definition, in $gap2$ non-ETS and ETS sectors have to achieve the same relative reductions except in France, the UK and the Mediteranian countries which are in 2003 in line with their Kyoto targets. In $gap1$ the relative reductions are lower in the non-ETS sectors, since their reduction burden is reduced by the governmental purchases of international carbon credits. Compared to the current NAPs 1, the burden is increased in the *gap* scenarios for the ETS sectors and decreased for the non-ETS sectors thus decreasing the wedge between the different carbon prices, which are shown in figure 2.

The larger the remaining wedge between the carbon prices, the larger the potential for further cost savings. This is also shown in Figure 3 that depicts the welfare losses of reaching the Kyoto targets relative to a business-as-usual (BAU) scenario for $NAP1, gap1, gap2$ and $sup$. The differences across scenarios are very large. While current NAPs imply an average welfare loss of 2.5% in the EU this loss reduces to 1.5% in $gap2$ and 1.1% in $gap1$. Under an efficient allocation it would only amount to 0.7%. In the countries with the largest gaps to the Kyoto targets which also currently put the largest burden on non-ETS sectors, the differences are more extreme. Clearly, the scenario $gap1$ comes closest to an efficient scenario $sup$.

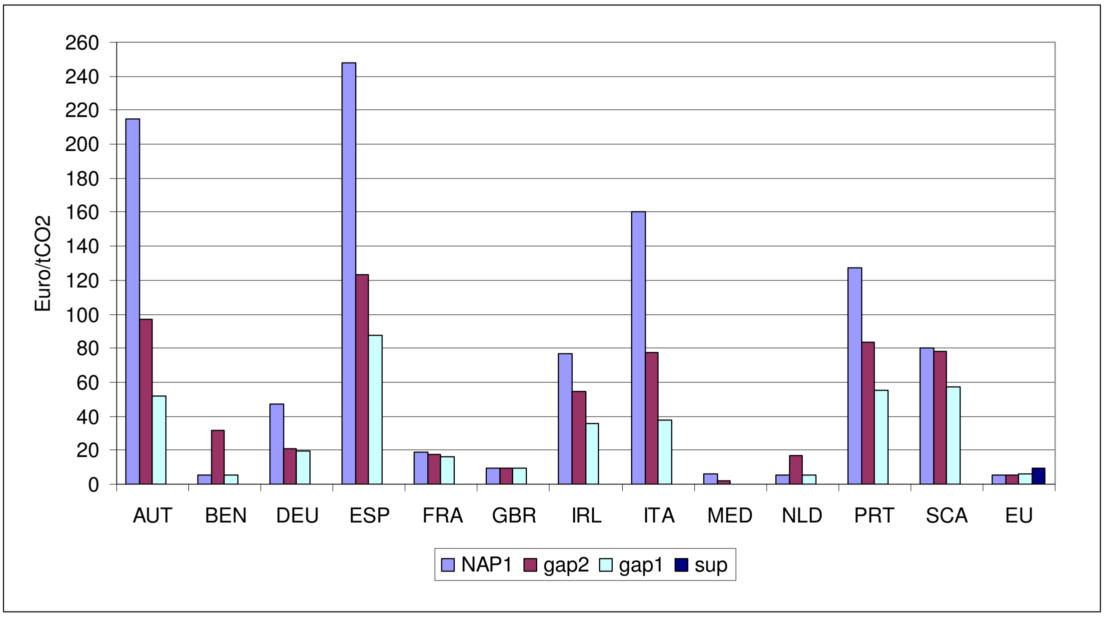


Figure 2: Carbon prices in 2012

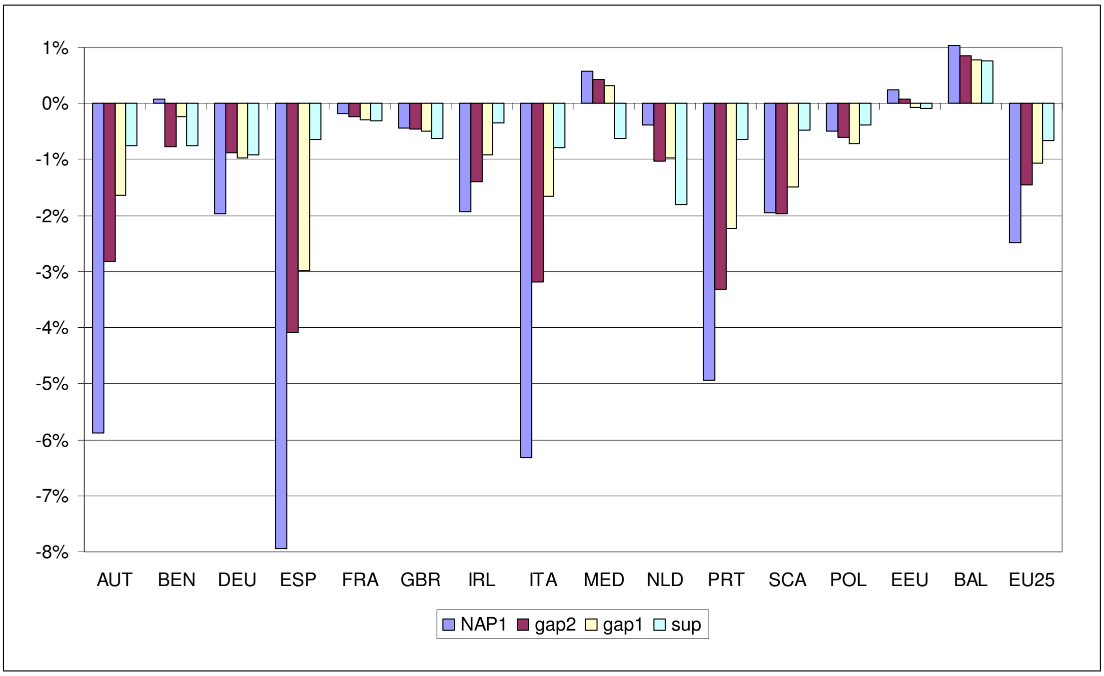


Figure 3: Welfare changes in 2012 compared to BAU

### 5.3 Defining Efficient Allocation Plans

Finally, the question is how to define efficient NAPs. Obviously, the current NAPs are highly inefficient. The proposal of the EU-Commission to calculate the current gap to the Kyoto targets and then to require proportional reductions from ETS and non-ETS sectors moves the allocation closer to efficiency but still, as the last section has shown, there is considerable potential for further cost savings.

As explained in section 3, there is no single optimal policy-mix of reductions within the ETS, reductions outside the ETS and governmental purchases of international carbon credits. While the emissions in the non-ETS sectors and thus the emission target for these sectors are uniquely defined by the efficiency criterion, it is necessary to either fix the government purchases of international carbon credits to derive the ETS target from the Kyoto restriction or to fix the ETS target to derive the amount of governmental purchases of international carbon credits.

Figure 4 shows - for the countries with binding Kyoto targets - the optimal emissions within the ETS and the non-ETS sectors and the optimal amount of national purchases of international carbon credits relative to each country's Kyoto target and compares them to the emissions under current NAPs. In $NAP1$ compared to the efficient scenario $sup$, emission are reduced too much in the non-ETS sectors and in addition not enough international carbon credits are bought by governments and ETS firms together.

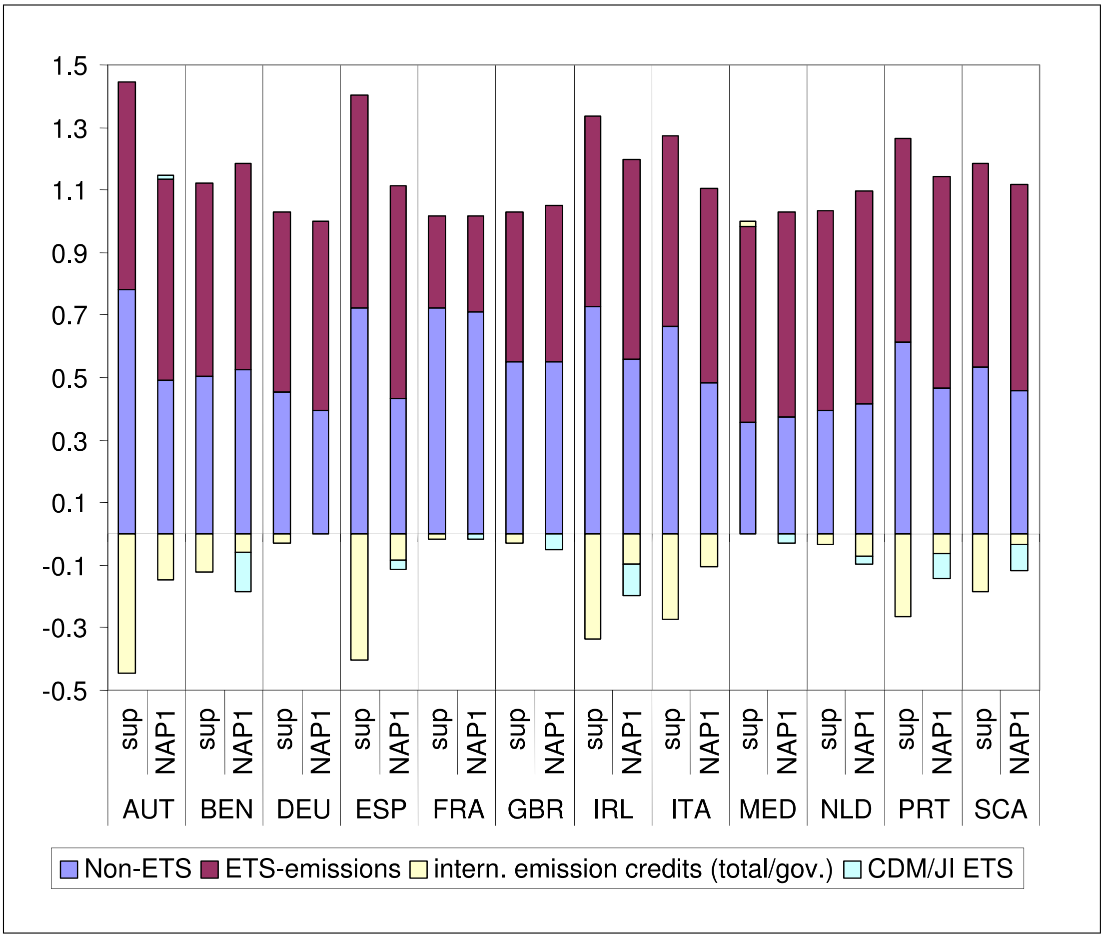


Figure 4: NAPs1 compared to the optimal policy mix(Kyoto target = 1)

The two extreme possibilities to reach a cost efficient scenario are:

- Keep the ETS-targets constant and increase the purchases of international carbon credits by governments ($sameETS$)
- Keep governmental purchases of international carbon credits (IECs) constant and reduce the targets for the ETS sectors ($sameIEC$).

Figure 5 shows the resulting ETS targets and governmental purchases of international carbon credits in these two extremes for the countries with binding targets and compares them to the scenario $gap1$ as the best approximation of an efficient allocation. In less extreme scenarios, the ETS targets are reduced to some degree, while also the international carbon purchases are increased accordingly.

For the countries that are on track to meet their Kyoto targets (France, Greece, the UK and the Baltic and Eastern European countries) the $gap1$ scenario is equal to the current NAPs and indeed a very good approximation to an efficient scenario. These countries are thus not shown in figure 5. For the Netherlands and Germany, $gap1$ is also close to an efficient scenario under current plans for the use of governmental

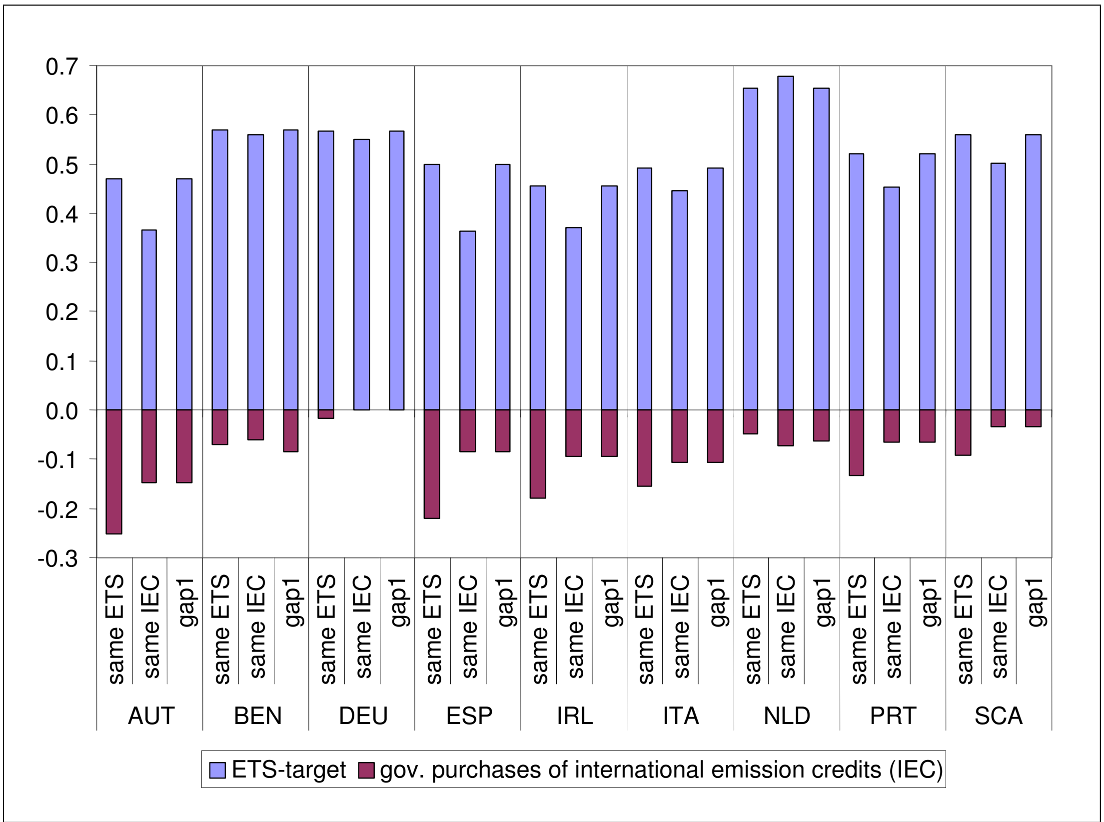


Figure 5: ETS targets and governmental purchases of international carbon credits as a share of the Kyoto target

purchase of international carbon credits. In these countries a small reduction in the ETS allocation compared to *gap*1 or a small increase in governmental purchases of international carbon credits would deliver an efficient allocation. Belgium/Luxemburg is a special case. The *gap*1 allocation is also close to an efficient solution, but this region can even buy slightly less then the currently planned international carbon credits or allocate slightly more emission allowances to their ETS sector than under *gap*1. In Austria, Spain, Ireland, Italy, Portugal and EU Scandinavia, the *gap*1 scenario is still rather far away from an efficient scenario. In these countries, also the welfare differences between *gap*1 and *sup* reach the highest level. Here, it is necessary either to significantly reduce the allocation to the ETS sector or to buy significantly more international carbon credits on government level. Since all of these countries individually already now plan to purchase more carbon credits on international markets then allowed by the their approximated supplementarity criterion, the only option remaining is to significantly reduce the allocation to ETS sectors, even compared to the *gap*1 scenario. Based on the simulation with DART, this reduction needs to be 22% above the calculated *gap*1 target for Austria, 27% for Spain, 19% for Ireland, 10% for Italy, 13% for Portugal and 10% for EU Scandinavia.

# 6 Concluding Remarks

The start of the European Emissions Trading Scheme (EU-ETS) in January 2005 marked the implementation of the world's largest emissions trading scheme. Even though the EU-ETS has in principle the opportunity to advance the role of market-based policies in environmental regulation and to form the basis for future European and international climate policies it does in its current form not guarantee that emission targets are reached at minimal cost. The problem is that the current regulation implies a hybrid regulation scheme where only some of the sectors participate in emissions trading while the remaining sectors of the domestic economies require complementary emission regulation. The current system is further complicated by the option for international carbon purchases - both from governmental side to lower the overall national reduction requirements as well as by firms under the EU-ETS - and the so-called supplementarity obligation which restricts the use of this instrument.

In the current system, domestic regulators must have perfect information on carbon prices on the international and the European market as well as on the (marginal) abatement cost curves across all domestic and international emission sources in order to implement a cost minimizing abatement policy. Furthermore, due to possible purchases of emission credits from outside Europe, there is not one single efficient policy but the are infinite options to distribute the burden of emission reductions between the emissions trading sectors and governmental purchases of international carbon credits. The regulator is thus not only faced with the question of how to find an efficient abatement policy, but also with distributional issues of who has to bear the burden of abatement.

The numerical simulations with the DART model have illustrated that a non-efficient policy mix under the current hybrid system with separated carbon markets can lead to large extra costs. While the current allocation as indicated in the National Allocation Plans (NAPs) for the first trading period of the EU-ETS is already known to put too much burden on the non-ETS sectors, this would still be the case, if member states follow the recent guidance from the EU Commission for defining NAPs for the second trading period from 2008-2012. Still, following the proposed approach of calculating the gap to the Kyoto target and then requiring proportionate reductions in the ETS sectors moves the allocation considerably closer to a cost minimizing policy. For the countries with large gaps to the Kyoto Protocol even more severe reductions in ETS sectors would be optimal. The simulations also show that the supplementarity obligation increases the cost of meeting the European Kyoto targets by 0.2%. On the other hand, this obligation leaves almost no room for further increasing the governmental purchases of international credits for countries with a large gap to the Kyoto targets beyond the levels announced in current NAPs.

All in all, an improved guidance from the EU would thus be: Countries that are on track to meet their Kyoto targets (The UK, France, Greece, Sweden and the Eastern European and Baltic countries) can stick to their current allocation to the ETS in the NAPs1 and their current plans to purchase CDM and JI credits. The countries with only a small gap (Belgium, Netherlands, Germany) should use the gap-approach to reduce their allocation to the ETS sectors compared to the NAPs1. The remaining countries (Austria, Denmark, Finland, Ireland, Italy, Portugal, Spain) with a considerable gap to the Kyoto targets should reduce the allocation to the ETS sectors below the allocation resulting from the gap-approach.

Despite the short-comings of the current system though, its inefficiencies are by no means an argument against emissions trading or market-based instruments per se. The problems arise from hybrid regulation that creates separate emission markets. The consequence should thus be to expand the EU-ETS in the future to include all domestic sectors of EU economies thereby creating a single emission market.

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# A Appendix

## A.1 Assumptions for the simulations

**Kyoto targets** DART includes only $CO_2$ emissions. Data about emissions from the EIA (2005) are used to calculate the Kyoto targets as the $CO_2$ target that has to be achieved after planned reductions in non-$CO_2$ greenhouse gases are taken into account. Reductions in non-$CO_2$ GHG are taken from current NAPs where available (Germany -6.9%, UK -40.9%, Netherlands -26.5%, Denmark -6.1%, Finland -10% relative to 2002 levels). In the remaining EU-25 countries with binding targets, a 10% reduction relative to 2002 was assumed, which is the median of the available plans.

**ETS targets** The allocation of permits to the ETS sectors and the reported historical ETS emissions are used to derive for each country the ETS targets for 2005 - 2007 as stated in the NAPS1 (see e.g. UBA (2005) for a summary of the NAPS1). These targets relative to 2003 ETS emission are implemented in DART, since there is not always a perfect match between the DART ETS emissions and those reported in the NAPs.

**International carbon purchases** Data on plans for CDM and JI are also taken from UBA (2005). The non European Annex B countries that have ratified the Kyoto Protocol are assumed to buy 200 MtCO2 of CDM credits per annum. The transaction costs associated with buying CDM/JI credits are assumed to be 3/t$CO_2$ (see discussion in Klepper and Peterson 2006).

Furthermore, it is assumed that no hot air is sold internationally. In most member countries the allocation to the ETS and the plans to acquire CDM/JI credits leave large reductions for the non-ETS sectors to reach the Kyoto targets. These implicit targets for the non-ETS sectors are reached in the scenarios by a uniform $CO_2$ tax that is differentiated between countries.

## A.2 Simulation results

| | Welfare change from BAU in % | | | | | Carbon prices in Euro/t$CO_2$ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | opt | sup | NAP1 | gap1 | gap2 | opt | sup | NAP1 | gap1 | gap2 |
| **AUT** | -0.5 | -0.7 | -5.9 | -1.6 | -2.8 | 6.5 | 9.5 | 214.9 | 96.8 | 52.0 |
| **BEN** | -0.6 | -0.7 | 0.1 | -0.2 | -0.8 | 6.5 | 9.5 | 5.4 | 31.9 | 5.7 |
| **DEU** | -0.7 | -0.9 | -2.0 | -1.0 | -0.9 | 6.5 | 9.5 | 47.4 | 20.5 | 19.3 |
| **ESP** | -0.5 | -0.6 | -8.0 | -3.0 | -4.1 | 6.5 | 9.5 | 247.7 | 123.2 | 87.8 |
| **FRA** | -0.2 | -0.3 | -0.2 | -0.3 | -0.2 | 6.5 | 9.5 | 19.0 | 17.2 | 16.0 |
| **GBR** | -0.5 | -0.6 | -0.4 | -0.5 | -0.5 | 6.5 | 9.5 | 9.5 | 9.3 | 9.1 |
| **IRL** | -0.3 | -0.3 | -1.9 | -0.9 | -1.4 | 6.5 | 9.5 | 76.7 | 54.9 | 35.9 |
| **ITA** | -0.6 | -0.8 | -6.3 | -1.7 | -3.2 | 6.5 | 9.5 | 160.3 | 77.4 | 37.9 |
| **MED** | -0.5 | -0.6 | 0.6 | 0.3 | 0.4 | 6.5 | 9.5 | 6.0 | 1.7 | 0.0 |
| **NLD** | -1.4 | -1.8 | -0.4 | -1.0 | -1.0 | 6.5 | 9.5 | 5.4 | 16.8 | 5.7 |
| **PRT** | -0.5 | -0.6 | -4.9 | -2.2 | -3.3 | 6.5 | 9.5 | 127.1 | 83.8 | 55.1 |
| **SCA** | -0.4 | -0.5 | -2.0 | -1.5 | -2.0 | 6.5 | 9.5 | 80.1 | 78.1 | 57.1 |
| **POL** | -0.3 | -0.4 | -0.5 | -0.7 | -0.6 | 6.5 | 9.5 | 0.0 | 0.0 | 0.0 |
| **EEU** | 0.1 | -0.1 | 0.2 | -0.1 | 0.1 | 6.5 | 9.5 | 0.0 | 0.0 | 0.0 |
| **BAL** | 0.6 | 0.8 | 1.0 | 0.8 | 0.8 | 6.5 | 9.5 | 0.0 | 0.0 | 0.0 |
| **EU25** | -0.5 | -0.7 | -2.5 | -1.1 | -1.5 | 6.5 | 9.5 | 5.4 | 5.6 | 6.4 |
| **EU15** | -0.5 | -0.7 | -2.6 | -1.1 | -1.5 | | | | | |
| **EU10** | 0.0 | -0.2 | -0.1 | -0.3 | -0.2 | | | | | |

* In *opt* the EU25 carbon price is equal to the international carbon price that holds for all non-ETS and ETS sectors in the EU25. In *sup* there is a wedge between the EU-25 carbon price and the international carbon price of 5.1 Euro/t$CO_2$ which includes transaction costs of 3 Euro/t$CO_2$.

Table 2: Welfare changes and carbon prices in 2012

| | Net trade in emissions in $MtCO_2$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **opt** | **sup** | **NAP1** | | **gap1** | | **gap2** | |
| | Total | Total | ETS | Non-ETS | ETS | Non-ETS | ETS | Non-ETS |
| **AUT** | 22.1 | 20.7 | -0.6 | 7.0 | 9.5 | 7.0 | 6.0 | 7.0 |
| **BEN** | 18.1 | 14.5 | 15.4 | 7.4 | 9.8 | 10.5 | 3.5 | 11.2 |
| **DEU** | 37.8 | 17.4 | -1.6 | 0.5 | 23.1 | 0.5 | 28.1 | 0.5 |
| **ESP** | 100.8 | 93.5 | 6.3 | 20.0 | 45.1 | 20.0 | 35.7 | 20.0 |
| **FRA** | 9.6 | 4.8 | 6.1 | 0.0 | 4.5 | 0.0 | 5.7 | 0.0 |
| **GBR** | 31.7 | 13.3 | 30.5 | 0.0 | 26.5 | 0.0 | 29.6 | 0.0 |
| **IRL** | 13.8 | 12.9 | 4.1 | 3.7 | 6.9 | 3.7 | 5.5 | 3.7 |
| **ITA** | 107.7 | 99.9 | -1.1 | 39.6 | 49.1 | 39.6 | 30.0 | 39.6 |
| **MED** | 0.3 | -2.5 | 3.1 | 0.0 | 2.2 | 0.0 | 2.9 | 0.0 |
| **NLD** | 15.8 | 6.7 | 5.6 | 17.3 | 3.6 | 15.2 | -7.0 | 20.0 |
| **PRT** | 16.4 | 15.0 | 4.5 | 3.7 | 8.6 | 3.7 | 7.0 | 3.7 |
| **SCA** | 29.0 | 26.3 | 12.1 | 4.9 | 14.3 | 4.9 | 11.8 | 4.9 |
| **POL** | -13.9 | -49.5 | 21.9 | 0.0 | 17.2 | 0.0 | 20.8 | 0.0 |
| **EEU** | -10.6 | -40.9 | 12.9 | 0.0 | 9.0 | 0.0 | 12.0 | 0.0 |
| **BAL** | -0.8 | -4.2 | -1.2 | 0.0 | -1.6 | 0.0 | -1.3 | 0.0 |
| **SUM** | 377.8 | 227.8 | 117.9 | 104.1 | 227.8 | 105.1 | 190.0 | 110.7 |

Table 3: Traded carbon credits in 2012