# Is a Cap-and-Trade System always Efficient?

# The Case of New Entrants in the Emissions Trading System of the EU

by

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*Abstract:*

This paper analyses the effects of allocating $CO_2$ permits to new power plants free of charge within a tradable permit system. We demonstrate that these free allocations distort investments. Furthermore, we distinguish the effects of a uniform benchmark from a fuel specific benchmark, as both are common elements in EU member states' national allocation plans. An empirical model for the European market is used to quantify the effects in a realistic framework.

*Keywords:* Electricity Markets; Energy Modeling; $CO_2$ Emission; Permit Trading Design

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## Introduction

The European Union has agreed to reduce $CO_2$ emissions using a cap-and-trade mechanism. Total reduction targets are defined by countries' commitments in the Kyoto protocol, which also determine the burden sharing between member states. Inside the trading scheme of the European Union, member states have to allocate emission rights between different interest groups. It is well known that auctioning of emission rights is superior to any other allocation method with respect to efficiency (e.g. Cramton and Kerr, 2002). However, in order to promote the acceptance of emission trading among participants, a cost free permit allocation was finally chosen in the European Union. Incumbent emitters are clearly better off under allocation free of charge than they would be under permit auctioning (see Burtraw et. al., 2001, for an example from the US).

It is well understood that allocation free of charge does not distort short-term production decisions as long as it is based on historic data. An efficiency problem can arise from the separation of sectors into those who participate in emissions trading and those who do not. Böhringer and Lange (2005) showed that free allocation of permits, efficiency of emission abatement, and “competition neutrality” can not be achieved at the same time. However, all three are fundamental objectives of the European Directive. Free allocation and “competition neutrality” cause marginal abatement cost in the trading sector and in the non-trading sector to fall apart. Therefore, a relaxation of at least one objective is required. In addition to Böhringer and Lange’s results, Åhman et. al. (2007) demonstrated that inefficiency can even become an issue within the trading sector itself. They give an example how plant closures and new entrants can cause inefficiencies. In earlier works Vesterdahl and Svendsen (2004) and Varming (2000) explored possible designs of EU emission trading.

Our paper builds up on this work. It is focused on inefficiencies resulting from free of charge allocations in the long run. These result from the question of how to allocate emissions rights to new entrants. As these do not have an emission history, allocation based on historic production is not an option and some other method must be used to determine allowance allocation. These cost free allocations of permits to new entrants often cause distortions of investment decisions. As pointed out by Mannaerts and Mulder (2003), allocating permits free of charge can be regarded as a transfer of wealth (or a subsidy). On the one hand, if the number of permits allocated is adjusted ex-post (depending on observed generation), this is equivalent to a subsidy on variable generation costs. The European Commission prohibited this approach. However, some member states took legal action against this rule. But recently, the European Court of Justice partly allowed ex-post adjustments of permit allocations. On the other hand, allocating permits without ex-post adjustment (e.g. based on expected production) is equivalent to a subsidy on fixed costs (investment costs) as production decisions are unaffected. In this latter case, inefficiencies can arise because free allocation of emission rights to new investments gives incentives for overinvestment – compared to auctioning off all emission rights.

In addition, when the benchmark distinguishes between fuels (usually implemented to protect coal fired generation), there are further investment distortions. When hard coal capacity receives more emission rights compared to gas-fired capacity, the incentive to invest in hard coal plants increases relative to gas. However, the effect is restricted by the overall emission cap: As hard coal emits more $CO_2$ than gas fired capacity, total potential for replacement is limited, regardless of the difference in the fuel specific benchmark. However, it is well known that new power plants are more efficient than old ones. Hence, an earlier replacement of capacity as the result of $CO_2$ emission rights passed on to new capacity reduces emissions. This effect in turn breaks ground for a shift from less to more emission intensive power plants.

In addition, this paper extends the existing literature by quantifying the inefficiencies applying an empirical model. Uniform benchmarks and fuel specific benchmarks are common elements in these allocation plans. They will be studied in more detail. The paper starts with a brief description of the basic concepts for permit allocations and their potential inefficiencies. The following section presents shortly the emission trading system of the European Union. The key section quantifies inefficiencies associated with a cost free allocation for new entrants applying a partial equilibrium model of the European power market. Finally, conclusions are summarized.

## Basic Concepts of Permit Allocation

Different types of permit allocation and their consequences have been frequently addressed in the literature. Basic concepts are often categorized into auctioning, grandfathering and different forms of performance standards as well as benchmarking (Burtraw et. al., 2002, Bode, 2006). A definition of these terms will be followed by a brief discussion of their main advantages and drawbacks.

Auctioning denotes a market-based allocation method, which awards the allowance budget to the highest-bidding participants. There is no influence arising from participants' past behavior. Grandfathering allocates allowances free of charge according to some historic measure, such as historic emissions or generation. The data needed is obtained from a base year (or a base period) before the start of the trading scheme. Performance standards look quite similar at first sight. A very significant difference is that performance standards use a more recent base year which needs not to be earlier than the initial year of the trading scheme. Benchmarking basically does not use any historic information to determine permit allocation. Such allocation methods define industry specific or technology specific standards. Often they refer to emission levels of some state-of-the-art technology.

Auctioning is a revenue-raising instrument. Permits will be traded such that emission reduction is achieved at least cost. Using revenues to reduce distorting taxes would create an additional benefit that is often referred to as double dividend. Even though cost free allocation methods may sometimes achieve the same reductions as auctioning, they do not allow tax reductions. Thus, they are only second-best approaches from a social perspective. Auctioning will lead to cost-efficient emissions abatement within the trading sector. It can be used for incumbent emitters as well as for new entrants.

Grandfathering can also lead to efficient allocations – but a different distribution of income. The choice of the base year used to define allowance allocation has no effect on participants' emission behavior. This is assured by defining a base year preceding the initial year of the trading scheme. As auctioning, grandfathering leads to cost-efficient emissions abatement. But it increases incumbent emitters' profits due to windfall profits according to the value of allowances. In addition, grandfathering can not be applied to new entrants.

Performance standards update allocation rules. A simple outline could consist of allocating permits according to the preceding period's emissions. Similarly, production of the preceding period might be used. Such schemes are also referred to as output-based allocation. They give rise to behavioral effects since utilities present decisions influence their future permit allocation. With performance standards emissions abatement can be expected to be inefficient (Fischer, 2001). Performance standards can not be applied to new entrants.

Benchmarking allows for cost free allocation to new entrants as well as to incumbents. For new entrants, allocation usually depends on the capacity of a new installation and some specific emission factor. The value of permits allocated can differ by technology. The higher a technology's allocation, the more attractive it becomes for investors. Therefore, just as performance standards, benchmarking is expected to cause inefficient emissions abatement.

Actual allocation rules in EU member states' allocation plans go beyond these pure concepts. So far, such particular allocation rules have rarely been addressed with regard to the efficiency of carbon abatement. Åhman et. al. (2005) discuss how efficiency and fairness aspects of allocation could be balanced.

## EU Allocation Designs and the Treatment of New Entrants

Directive 2003/87/EC constitutes the main framework on emission trading within the EU. But it also leaves much competence with member states, such as defining sector targets as well as emission allocation on installation level. Member states have developed national allocation plans to set up binding rules on a very detailed level. Actually, national allocation plans and their supplementary legislations comprise important rules that can influence the behavior of participants.

First and foremost, almost all allocation plans grant permits free of charge for the period 2005 to 2007. Although the Directive allows for some auctioning, only four out of twenty five member states used this option. In general, cost free allocation distinguishes between existing installations and new installations. For existing installations the number of permits is determined by their historical emissions according to some base year. As argued above, this may lead to inefficiencies if the base year is updated. However, these inefficiencies are not in the centre of this article.

Apart from this problem, EU allocation plans constitute a blend of different allocation methods. These include a broad variety of special allocation rules at sector and installation level, e.g. on early action, on combined heat and power, on allowance transfers to new installations, closure rules, modernization incentives and rules on benchmark allocations for new entrants. Many of these rules additionally influence emission abatement behavior. But apparently, it was not yet possible to fully assess allocation rules laid down in allocation plans of all member states. This is due to the number and complexity of allocation plans.

The efficient solution would be not to give any certificates to new installations. However, as incumbents received free emission rights, this approach may raise issues of fairness. In addition, giving permits to new entrants can be a method to increase competition in concentrated energy markets. However, as a consequence of giving allowances to new entrants, the question arises how many certificates they should get. Note that basic allocation concepts such as grandfathering do not apply as new capacity by definition does not have an emission history.

Therefore, national allocation plans implemented other concepts. Several combine benchmarks with forecasted production. The endowment of a new installation often depends on whether it replaces another installation (transfer of permits) or, in the case of a new entrant, what type of plant is commissioned (benchmark allocation). Transfer rules are not subject of this paper. But the basic consequences, which will be derived for benchmark allocations, apply here as well.

In most national allocation plans a ‘best available technology’ serves as benchmark for new entrants. Nevertheless, important details, such as specific emissions and assumed plant utilization, which are crucial for calculating permit endowment, are often not given by allocation plans itself. Most of these plans only determine whether the benchmark depends on the technology deployed or rather it refers to some sector specific best technology.

Of course, when different types of plants receive different endowments while producing exactly the same output (electricity), this will influence investment and dispatch decisions. A plant owner surely would try to optimize output production and permit endowment. It is worthwhile to the owner to adjust dispatch decisions accepting higher production costs as long as this is compensated by the value of additional permit endowment in a future period.

## Benchmark Allocations – Simulation Results from the German Market

So far, few authors have done extensive modeling on the subject. Among them, Neuhoff et. al. (2006) conduct a numerical analysis of auctioning and benchmark allocations assuming fixed $CO_2$ prices. Schwarz (2005) quantifies the possible outcome of the German allocation plan. In both papers, total emissions seem to exceed the envisaged emission cap in some cases. The reason for this is that the value of the subsidy for new entrants depends on the price of $CO_2$. In an investment model, this price however is determined by the chosen investment path in new power plants. The resulting optimization problem taking this into account is non-linear. While Neuhoff et al. are right to argue that this can be compensated by Clean Development Mechanism (CDM) and Joint Implementation (JI), the result does not fit well the cap-and-trade character of the EU trading scheme. Our paper chooses a different approach. We determine the pure cap-and-trade solution in an iterative process, finally converging to an equilibrium solution. Besides these improvements, we quantify the magnitude of the resulting cost differences associated to the different inefficiencies of new entrant allocations.

## Model description and data set used

The partial equilibrium model CEEM was used to derive results. It was developed at the Institute of Energy Economics at the University of Cologne, Germany (Starrmann, 2001). It solves a dynamic, linear optimization problem, which covers the supply side of 11 European electricity markets, namely Germany, the Netherlands, Belgium, Luxembourg, France, United Kingdom, Spain, Portugal, Italy, Switzerland and Austria. The objective function consists of total discounted costs for electricity generation, which comprises investment costs, fixed and variable production costs, fuel costs, costs for interregional power transmission. It solves for the least cost solution to satisfy an exogenously defined electricity demand while environmental targets must be fulfilled. Main decision variables are plant dispatch, commissioning and decommissioning of generation capacities.

Electricity and permit markets are assumed to be competitive. Fuel prices and technological progress are exogenously defined. All prices are given in real terms of the base year 2005. Table 1 depicts the main assumptions.

TABLE 1 ABOUT HERE

Electricity demand has been taken from Eurelectric (2005) for the period until 2020. Beyond 2020, separate assumptions were made. While regional demands show different trends, depending on today's specific consumption and future prospects of economic development, the average annual growth rate of all regions is about one percent. This causes electricity consumption to increase from 2246 TWh to 3305 TWh in 2030. Renewable energies are assumed to account for 22 % of electricity consumption in 2010, which is almost identical with the EU-15 objective. This share is to increase further to 29 % until 2030. Since electricity supply from renewable energies is mainly driven by special support schemes, it is assumed to be the same for all scenarios under consideration. Electricity consumption less renewable supply then yields remaining demand which must be met by other conventional generation, such as fossil-fuelled and nuclear power plants.

Despite a higher contribution of renewable energies, remaining demand increases in absolute terms. At the same time, a reduction of carbon dioxide emissions is to be achieved. Therefore, steps must be taken to fulfill the environmental requirements given in Table 1. Important measures to achieve this goal can be (i) increasing the electrical efficiency of power plants and (ii) switching generation to low or non-emitting fuels. To what extend a fuel switch is economically feasible will strongly depend on fuel prices. These were adopted from the recent reference forecast for the German energy sector (EWI, 2005, German Federal Ministry of Economics and Labour, 2005). Further research should be conducted to validate the paper's findings especially for higher oil and gas prices. The table also depicts assumptions on efficiencies of new power plants. While average plant efficiency is a model result, efficiency of new installations is exogenous input into the model.

For Germany, the phase-out of nuclear energy was assumed according to current law.

## Scenario definition

All scenarios assume an environmental policy that reduces carbon emissions by 8 % in 2010 and by 15 % in 2030 compared to 1990. The scenarios differ in the way the permit trading system is implemented with respect to permit allocation.

In the *auction case* all permits will be sold. While the results of this case are obviously more expensive than a case without emission objectives, they achieve a certain emission reduction with minimal distortions and costs. Hence, the design of this auction scheme is assumed to achieve the optimal reduction path to comply with defined emission objectives. In fact, the least cost argument was the main reason why emission trading was introduced in the EU. Within the model this is realized by imposing an emission constraint on all countries allowing for free permit trading between them. The auction case will be used to assess two other allocation schemes free of charge based on benchmark allocation to new entrants. These describe the realities in most EU national allocation plans.

The first alternative scheme modeled is the *fuel specific benchmark*. Here, allocations to new entrants depend on the plant's type of fuel. So, coal-fired plants receive more permits than gas-fired ones of the same size as the former emit more CO2 per MWh of electricity. Since gratis permit allocation can be thought of as a subsidy, there will be an incentive to build plants granted a high number of permits. To simplify the analysis, in the case of plant replacement no transfer of permits is allowed for. Thus, all new plants are treated the same way, whether they will be built by incumbents or by new entrants.

In contrast to that, the second alternative, the *uniform benchmark*, allocates the same amount of permits to all fossil-fuelled plants. The benchmark is set to the emission level of a gas-fired plant of best available technology. Even though fossil-fuelled plants are now treated equally, the uniform benchmark affects plant replacement rates. The higher the allocation, the more rapidly existing plants will be replaced by new ones. Apart from that, carbon free technologies might be worse off than fossil-fuelled plants, since they do not receive a subsidy.

In addition to some of the recent publications our methodology takes into account the cap-and-trade character of the trading scheme. To account for this an iterative approach was applied. For all scenarios the same emissions cap is enforced according to the assumption on environmental policy as defined above. This assures the environmental outcome of all scenarios to be exactly the same. The emissions cap in turn requires abatement measures to be taken. The type and extend of measures differs among the scenarios due to the distortion effects under benchmarking. Thus, marginal abatement costs deviate from those of the auctioning case. The iteration in the benchmarking scenarios consists of two steps which are repeated several times.

Step 1: We use carbon prices derived from the last model run to determine the value of the subsidy to new installations – and hence investment costs – for the next model run. Starting point for the first iteration is the reference case of auctioning all certificates. It is important to realize that carbon prices are an endogenous model output. The equation restricting total emissions to the emission cap shown in table 1 has a marginal – also called shadow price – which is the marginal costs of avoiding an additional ton of $CO_2$. In a competitive market, this marginal determines the equilibrium price for $CO_2$. Together with the exogenously given endowment of $CO_2$ emission certificates for new capacity, which are given by the benchmark, this price determines the total value of the subsidy for any new power plant. This value is deducted from investment costs of new installations.

Step 2: Based on these adjusted investment cost a new simulation is conducted. Investors now change their behavior in order to maximize their profits from electricity generation and permit allocation. Hence, a new model run gives a different investment path. As a consequence of the modified investment decisions, the marginal for $CO_2$ will change giving a new price for $CO_2$ which then sets the price for $CO_2$ in the next iteration.

We are looking for the equilibrium, where the implicit price for $CO_2$ fed into the model via the value of free allowances for new capacity equals the resulting marginal costs of the $CO_2$ restriction derived after solving the model. Hence, we repeat both steps until the relative change in marginal abatement costs compared to the preceding step is below 2 %. This happened after a maximum of ten iterations. Figure 1 presents an example of the iteration progress with respect to convergence of carbon prices. Please note that the emissions cap remains unchanged throughout the whole iteration. Only carbon prices change because of adjusted investment decision. This approach assumes competitive electricity and permit markets. Further, investors have complete foresight over the whole forecast period up to 2030.

## Simulation results

First, an auction case was set up which will serve as a reference for comparison. In the auction case permit allocation does not explicitly privilege any technology. All plants are required to purchase permits. This scheme neither distorts investment nor dispatch decisions. It is abstracted from inefficient auction design causing deviation from efficient emissions abatement. Then, a tradable permit system is being implemented obtaining emission reductions at least cost. Table 2 summarizes electricity generation and permit prices in the reference case.

As can be seen from the table, total generation increases until 2030 by about 36 %. This is nearly proportional to the assumed electricity demand. At the same time carbon emissions need to be reduced in absolute terms. Several options exist to achieve this. First, conventional power plants will use low carbon fuels. Also, average plant efficiency will be enhanced. On the other hand, the use of renewable energies is assumed to grow, which follows directly from the EU objective to increase the share of renewable energies in electricity generation.

TABLE 2 ABOUT HERE

From 2002 to 2030 electricity generation from gas and renewable energies increases considerably. Nuclear generation stays slightly above today's level. Lignite remains almost unchanged in the long run. Coal and oil suffer losses. In the medium-term the given emission cap is achieved at comparably low marginal abatement costs which results in a permit price below 10 EUR/t. These relatively low prices strengthen the argument that the replacement of old thus relatively inefficient capacity with new and highly efficient power plants is an effective and efficient way to reduce emissions. As carbon policy tightens further and electricity demand and gas price rise, the permit price reaches a level of 20 EUR/t. Note that costs for renewable energies are not included in the model. This reflects that actual renewable energy support schemes raise their budgets outside the emission trading scheme. So, the emission trading sector benefits from emission reductions at the expense of non-trading sectors, which have to bear the additional costs.

The next step from here is answering the questions: will free allocation to new plants affect this outcome? And to what extend? To answer this question, we computed the alternative scenarios of the uniform benchmark and the fuel specific benchmark. The commissioning of capacity, electricity generation, average plant efficiency and total generation costs will be explored and compared in all three scenarios. Table 3 shows relevant effects on conventional plants by fuel. There are only minor changes to oil, so these numbers were dropped from the table.

TABLE 3 ABOUT HERE

When compared to auctioning, under the uniform benchmark considered here generators feel compelled to build up some more gas-fired plants while investment in nuclear energy is less attractive in the long run. As already mentioned, $CO_2$-free technologies are likely to lose if new investments in coal and gas fired capacity are subsidized with free emission certificates. Cumulative capacity commissioning for gas turns out to be 9 GW higher. At the same time, 5 GW less nuclear capacity is built until 2030. Coal is slightly below the level in the auction case. This also affects future electricity generation. Gas is up by 41 TWh, while generation from nuclear and coal decreases by 27 and 18 TWh, respectively.

As a consequence of building so many new gas-fired units, average efficiency of that technology rises to 59.5 %. At the same time, less coal-fired plants will be built, causing their average efficiency to be lower than under auctioning.

The fuel specific benchmark causes mostly opposite effects. When compared to auctioning, generators feel now compelled to build up some more coal and lignite plants while investment in gas is less attractive in the long run. Cumulative capacity commissioning turns out to be 5 GW and 17 GW higher for coal and lignite, respectively. At the same time, 7 GW less gas-fired capacity is built until 2030. As a consequence, generation from coal and lignite are up by 17 and 24 TWh, respectively, while generation from gas decreases by 45 TWh. Nuclear energy remains almost unchanged.

The shift from gas to more coal-fired generation increases carbon emissions. In the presence of the emissions cap this requires additional emissions reduction. Generation from nuclear energy slightly benefits from that necessity. But most of the additional abatement measures stem from accelerated plant replacement as indicated by the increase in average electrical efficiency in Table 3.

Due to the allocation scheme’s modernization effect, average plant efficiency increases. Average efficiency of coal plants is 48.4 %, while it was 47.0 % in the auction case. The average lignite plant is more efficient as well, while the effect on gas-fired plants proves to be rather limited.

Of course, compared to total generation of more than 3100 TWh all these effects are not dramatic in size. Gas will still play an important role in electricity generation. The same holds true for nuclear power. Nevertheless, the fuel specific benchmark causes generation from lignite to rise by 15 % and coal by 8 % in 2030. Since lignite and coal possess similar technological characteristics, both are rather close competitors in base load generation. Therefore, the actual design of a fuel specific benchmark determines which of them will profit the most. In the case considered here, it is lignite.

Finally, Table 4 presents changes in total generation costs. They consist of the sum of annualized investment, operation and maintenance, variable production and fuel costs.

TABLE 4 ABOUT HERE

Since all allocation schemes impose the same emission cap, these cost changes indicate the cost-effectiveness of obtaining the emission cap. Compared to the auction case, additional costs are highest under the fuel specific benchmark. The net present value accumulates to about 1 billion Euros over a 25 years period at an assumed discount rate of 5 %. Additional costs under the uniform benchmark prove to be considerably lower, but nonetheless still significantly positive in the long run. Regarding the implications for electricity prices, it is likely that most of the increase in costs will be passed on to consumers. Hence, electricity prices rise due to the inefficiencies in the allocation systems.

Temporary cost savings in 2025 appear to be a dynamic effect of a net cost transfer to 2030. The commissioning of some lignite plants is being postponed from 2025 to 2030. At the same time gas-fired plants are advanced. Although overall capacity remains unchanged in each period, lignite-fired plants, being more expensive than gas-fired plants, additionally increase total costs in 2030, while the cost change in 2025 turns temporarily negative.

Although cost changes are moderate, their positive sign indicates that emission reduction is not efficient. If auctioning is not the first choice, e.g. due to political reasons, one might conclude that a uniform benchmark could be a second-best approach.

We want to look at one additional question that has not been addressed so far: how many permits have to be reserved for new installations? This is important as it may significantly influence the number of certificates remaining for incumbent generation capacity. This question depends both on the specific rules that determine the number of permits for a single plant and the number of new plants built. The former are set by politics. The latter is more difficult as it necessitates the estimation of how many new units will be built in the future. This very question was answered by our investment model. From these two information, we can compute the number of permits given to new installations. These are shown in Table 5 as a share of overall permits available for allocation. As can be seen, this share is highest in 2030 under the fuel specific benchmark. In that year, it reaches almost one quarter of total permits. As such results would have drastic implications for incumbents, most EU allocation plans define a fixed permit reserve. The reserve is then allocated either proportionally to all applicants or using a first-come-first-serve rule. The quantitative implications of these rules are left for further research.

TABLE 5 ABOUT HERE

A further issue arises when the value of permit allocation exceeds investment cost. In that case there would be the incentive to build up new installations regardless of the market's actual demand for generation capacity. In the scenarios considered here, this effect is most pronounced under the fuel specific benchmark. 2030 the permit value reaches 70 % of investment costs of lignite-fired power plants, while it is 50 % and 30 % for hard coal-fired power plants and gas-fired CCGT plants, respectively. This illustrates that benchmarks must be chosen very carefully as it might even hazard the basic market principle of supply and demand.

## Conclusions

This paper analyzed the potential inefficiencies for different permit allocation schemes. The inefficiencies caused by an updating of the reference periods were briefly discussed. However, the main part of the paper demonstrated that additional inefficiencies can result from the treatment of new power plants. New power plants often receive emission rights for free. This is done to compensate disadvantages compared to incumbents receiving free rights. However, these rights are similar to a subsidy for investment in new capacity. It is well known that subsidies tend to distort investments.

These effects were quantified for the European power market. The results of auctioning permits were used as an efficient reference case. They were compared to both a uniform and a fuel specific benchmark. Results were calculated for the electricity industry in ten EU countries and Switzerland using a technology-based bottom-up approach. It was found that both a uniform and a fuel specific benchmark incur higher costs compared to auctioning. Hence, both are inferior in terms of efficiency.

Inefficiencies result from an increased plant replacement as a cost-free allocation subsidizes new power plants. Hence, benchmark allocation in the EU hampers the efficiency of the tradable permit system. As a consequence, they may increase prices for electricity consumers.

The fact that the uniform benchmark is still superior to the fuel specific benchmark suggests that the former could be a second best solution.

Emission abatement will continue to pose an ambitious challenge to all industrialized countries. Undoubtedly, necessary changes will lead to significant costs. It is important that environmental targets are reached in an efficient way. As the results in this paper suggest, this might not be the case for the EU trading scheme. Further research is necessary to analyze the full range of allocation rules in all national allocation plans.

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Table 1: Main Assumptions

| | 2000 | 2010 | 2015 | 2020 | 2025 | 2030 |
|---|---|---|---|---|---|---|
| Total electricity demand, TWh | 2246 | 2610 | 2790 | 2962 | 3134 | 3305 |
| | | | | | | |
| Generation from renewable energies, TWh | 371 | 577 | 672 | 756 | 868 | 947 |
| Share of renewable energies in total demand, % | 16.5 | 22.1 | 24.0 | 25.5 | 27.7 | 28.7 |
| | | | | | | |
| Emission cap, Million tons $CO_2$ | 814* | 785 | 775 | 768 | 746 | 724 |
| Emission reduction compared to 1990-level, % | 4.4 | 8 | 9 | 10 | 12 | 15 |
| | | | | | | |
| Prices of fossil fuels for power plants, Euro/GJ | | | | | | |
| Coal | 1.59 | 1.72 | 1.82 | 1.82 | 1.84 | 1.86 |
| Oil | 4.60 | 4.31 | 4.61 | 4.89 | 5.13 | 5.47 |
| Natural Gas | 3.52 | 3.61 | 3.88 | 4.05 | 4.22 | 4.46 |
| Lignite | 0.83 | 0.83 | 0.83 | 0.83 | 0.83 | 0.83 |
| | | | | | | |
| Electrical Efficiency of new power plants, % | | | | | | |
| Coal plant | | 47.5 | 48.0 | 48.5 | 49.0 | 49.5 |
| Natural gas CCGT plant | | 58.5 | 59.0 | 59.5 | 60.0 | 60.5 |
| Oil plant | | 50.5 | 51.0 | 51.5 | 52.0 | 52.5 |
| Lignite plant | | 44.0 | 44.5 | 45.0 | 45.5 | 46.0 |

* Actual emissions

Source: Eurelectric (2005), EWI (2005) and own assumptions.

Table 2: Main Results, Auction Case

| | **2000** | **2002** | **2010** | **2015** | **2020** | **2025** | **2030** |
|---|---:|---:|---:|---:|---:|---:|---:|
| Total electricity generation, TWh | 2227 | 2303 | 2523 | 2669 | 2815 | 2973 | 3136 |
| *Nuclear* | *768* | *789* | *840* | *909* | *911* | *861* | *874* |
| *Coal* | *416* | *420* | *395* | *389* | *372* | *277* | *213* |
| *Lignite* | *151* | *162* | *144* | *156* | *162* | *165* | *159* |
| *Gas* | *400* | *446* | *598* | *602* | *692* | *900* | *1054* |
| *Oil* | *131* | *134* | *32* | *31* | *30* | *23* | *17* |
| *Renewable energy* | *363* | *353* | *514* | *583* | *647* | *747* | *819* |
| Permit price, EUR/t $CO_2$ | | | 8 | 6 | 8 | 13 | 20 |

Source: Own calculations; historical values: Eurelectric (2005).

Table 3: Effects of Allocation Scheme on the Electricity Industry

| | Nuclear | Coal | Lignite | Gas |
|---|---|---|---|---|
| Cumulative plant commissioning until 2030, GW | | | | |
| Auction | 112 | 21 | 12 | 107 |
| Uniform benchmark | 107 | 19 | 12 | 116 |
| Fuel specific benchmark | 113 | 26 | 29 | 100 |
| | | | | |
| Change in electricity generation in 2030, TWh | | | | |
| Uniform benchmark compared to auction | -27 | -18 | +1 | +41 |
| Fuel specific benchmark compared to auction | +2 | +17 | +24 | -45 |
| | | | | |
| Average efficiency of fossil-fuelled plants in 2030, % | | | | |
| Auction | | 47.0 | 43.4 | 59.1 |
| Uniform benchmark | | 46.8 | 43.5 | 59.5 |
| Fuel specific benchmark | | 48.4 | 45.6 | 59.2 |

Source: Own calculations.

Table 4: Effects of Allocation Scheme on Generation Costs Compared to Auctioning

| | **2010** | **2015** | **2020** | **2025** | **2030** |
|---|---|---|---|---|---|
| Change in total generation costs, Million EUR p.a. | | | | | |
| Uniform benchmark | -11 | +17 | +15 | +14 | +145 |
| Fuel specific benchmark | +87 | +190 | +55 | -146 | +906 |

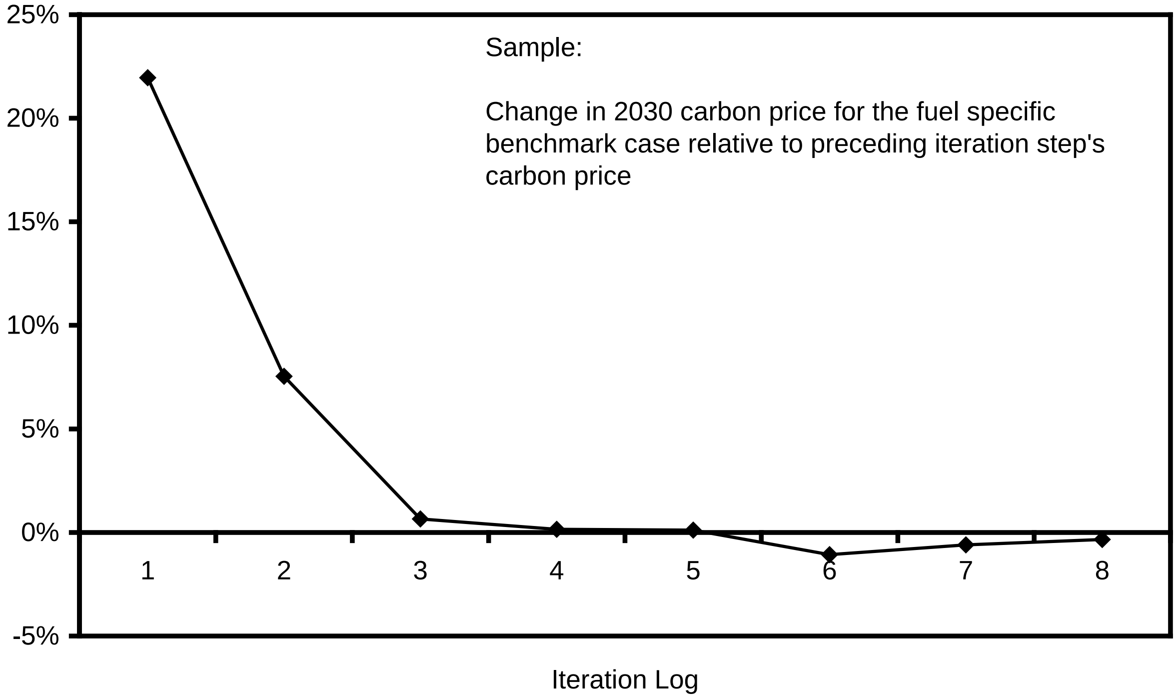
Source: Own calculations.

Table 5: Permit Allocation to New Plants as Share of Overall Permit Allocation

| | **2010** | **2015** | **2020** | **2025** | **2030** |
|---|---|---|---|---|---|
| Uniform benchmark | 6 % | 11 % | 16 % | 11 % | 13 % |
| Fuel specific benchmark | 4 % | 14 % | 6 % | 5 % | 24 % |

Source: Own calculations.

Figure 1: Sample for Convergence of Carbon Price during Iteration Procedure



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