Rogge, Karoline S.; Linden, Christian

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Karoline S. Rogge
Christian Linden

Cross-country comparison of the replacement incentives of the EU ETS in 2008-12: The case of the power sector

Fraunhofer
ISI

Abstract

In this paper, we conduct a cross-country quantitative analysis of the replacement incentives generated by the EU ETS for the power sector in 2008-12. In order to do so, the allocation rules of the Member States are applied to concrete reference power plants for three different fuel types (lignite, hard coal and gas). Based on these calculations, we compare installation-specific replacement incentives across the Member States. Our analysis shows that replacement incentives vary significantly across Member States and typically deviate from the incentives provided in the reference case of full auctioning. Furthermore, the EU ETS allocation rules lead to perverse incentives in approximately 30% of the possible replacement options. Only 5 MS do not provide any perverse incentives. Finally, we explore the link between replacement incentives and allocation types. Based on our findings, we derive policy recommendations for the design of emission trading schemes emerging around the world.

Key words: EU emission trading scheme (EU ETS), replacement, adoption, diffusion, power sector, allocation rules

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1 Introduction

Climate change is one of the most important challenges facing humankind. In order to address this challenge and achieve its Kyoto target, the European Union launched an Emission Trading Scheme (EU ETS) in 2005 which covers large greenhouse gas emitting installations in a variety of industrial sectors, among them the power sector. While the Directive 2003/87/EC (EU, 2003) sets the ground rules of the trading scheme, such as the minimum share of gratis allocation, Member States were still given significant leeway when specifying the design elements of the EU ETS (Betz et al., 2004, Kruger et al., 2007) in their National Allocation Plans (NAPs). These determine both the limit on emissions at a macro level (the cap), and, at a micro level, the rules according to which EU allowances (EUA) are allocated to individual installations. The NAPs still had to be approved by the European Commission (EU COM) based on the criteria specified in Annex III of the ETS Directive and the NAP guidance documents (EU, 2004, EU, 2005).

These micro level allocation rules are important for the incentive structure for existing and new installations (Harrison and Radov, 2002). They can impact investment decisions on different levels, such as the timing, fuel choice and degree of efficiency, and thus may play an important role in steering industry towards low-carbon investments. However, in the first and second trading phases of the EU ETS, these allocation rules have often provided distorting incentives (Martinez and Neuhoff, 2005, Neuhoff et al., 2006b, Schleich et al., 2009), such as those arising from the treatment of closures and new entrants (Spulber, 1985, Ahman and Holmgren, 2006, Ahman et al., 2007, Ellermann, 2008). Such distortions are particularly problematic for the power sector with its capital-intensive investments in long-lived power plants (Reinaud, 2003).

Since the power sector is the largest sector in terms of its share of 32% in total EU greenhouse gas emissions (UNFCCC, 2008), these investments will greatly influence the future emission reduction potential of the EU. Therefore, a number of studies have analyzed the investment effects of the different allocation rules on the power sector. Matthes et al. (2005) make a detailed quantitative comparison of the investment incentives provided by phase 1 allocation rules across six EU MS by applying them to a set of standardized installations in the power sector. For phase 2, which runs from 2008-12, Betz et al. (2006) and Schleich et al. (2009) provide a cross-country assessment of the incentives for low-carbon and energy-efficient technologies for all sectors included in the EU ETS, but do not quantify the effects of allocation rules. In a more quantitative approach, Neuhoff et al. (2006a) briefly compare the phase 2 gratis allocations resulting for two types of reference power plants across EU MS. However, the study of Neuhoff et al. (2006a) does not incorporate changes in allocation rules in response to the cap reductions demanded by the EU Commission for almost all MS (e. g. EU, 2006). Among these changes were adjustments in the allocation rules for the power sector. For example, Germany has switched from grandfathering to benchmarking for existing plants, Sweden has eliminated gratis allocation to existing power plants and Finland has decided upon a strict compliance factor for coal-based power generation. These changes can have profound effects on the incentives generated by the EU ETS. Finally, none of these studies undertakes an in-depth analysis of the replacement incentives generated by the allocation rules in the second trading phase of the EU ETS (2008-12).

It is our aim to close this gap by presenting a quantitative analysis of the replacement incentives generated by the allocation rules of the EU ETS for the power sector in 2008-12 and contrasting these incentives across EU Member States. In doing so, we explore whether there is a link between replacement incentives and the allocation types, capacity renewal needs or today's power generation mix. Our analysis covers all EU MS (except Malta and Cyprus). It quantifies the resulting incentives for three different fuel types (lignite, hard coal and gas), applies the power sector's allocation rules to concrete reference installations and analyzes installation-specific replacement incentives for the same technology as well as across different fossil-fuel-fired technologies. Thereby, policy recommendations will be made which may also be relevant for emerging trading schemes around the world, such as the US ETS (ACES Act, 2009).

The remainder of the paper is organized as follows: Section 2 presents the methodological approach and section 3 provides an overview of general allocation mechanisms and the allocation rules applied in the EU Member States. Section 4 describes the results for the replacement incentives generated by the EU ETS. The final section 5 summarizes and discusses the findings and draws conclusions for the future improvement of the scheme's design with regard to the incentives for guiding the sector onto a low carbon path.

2 Methodology

2.1 Identification of allocation rules

Information about the national allocation rules is based on the notified NAPs (and other publicly available documents) of the EU MS. However, because these rules may have been changed after the EU Commission's ruling on the NAPs (EU, 2007), for each EU MS, excerpts featuring the allocation rules were sent to representatives of the national authorities in charge of the EU ETS for approval, together with a set of remaining questions. If the official country representatives did not respond, other national experts, mainly from companies, but also from associations, were contacted with the same set of questions.[1] Despite these information requests, in some instances, the lack of transparency in some NAPs could not be resolved.[2] In order to take this problem of data validity into account, in Table 2 the column "status" (1 for sure, 3 for unsure) indicates the degree of certainty attached to the allocation rules.[3]

2.2 Reference power plants

In order to quantitatively compare the allocation rules of MS, standardized reference power plants were chosen for the three fuel types of lignite, hard coal and natural gas. For these, the following carbon emission factors (in t/TJ) are used: lignite 113 t/TJ, coal 94 t/TJ and natural gas 56 t/TJ (IPCC, 2006, Matthes et al., 2005). Origin-specific quality differences of the combustibles were not taken into account.[4]

For each fuel type, a reference plant is specified for existing and for new plants, with the plant-specific features taking technological progress into account (see values in Table 1).

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1 Data collection was finalized in November 2008.

2 An analysis was not feasible for Hungary because of the lack of information in the available Hungarian NAP. Therefore the following diagrams and tables do not contain information about the Hungarian allocation rules.

3 The reasons for data uncertainty and corresponding assumptions are listed in Rogge and Linden (2008) in Table 38 (Annex) for each MS.

4 According to IPCC, emission factors vary across fuels: lignite: 90.9 – 115 t/TJ, anthracite: 94.6 – 101 t/TJ, natural gas: 54.3 – 58.3 t/TJ.

Table 1: Data of reference power plants

		Electric efficiency	Capacity [MW]	Load factor [h/a]	Electric production [GWh/a]	Emission coefficient [t/GWh]
Existing plants						
Lignite	E_L	39%	800	6,500	5,200	1,043
Coal	E_C	42%	600	4,000	2,400	806
Natural gas	E_G	56%	400	3,000	1,200	360
New plants						
Lignite	N_L	45%	1,000	7,000	7,000	904
Coal	N_C	48%	600	4,500	2,700	705
Natural gas	N_G	60%	500	4,000	2,000	336

Source: Fraunhofer ISI (2008b)

The specific emissions of the power plants are calculated as follows (considering an oxidation factor of 1):

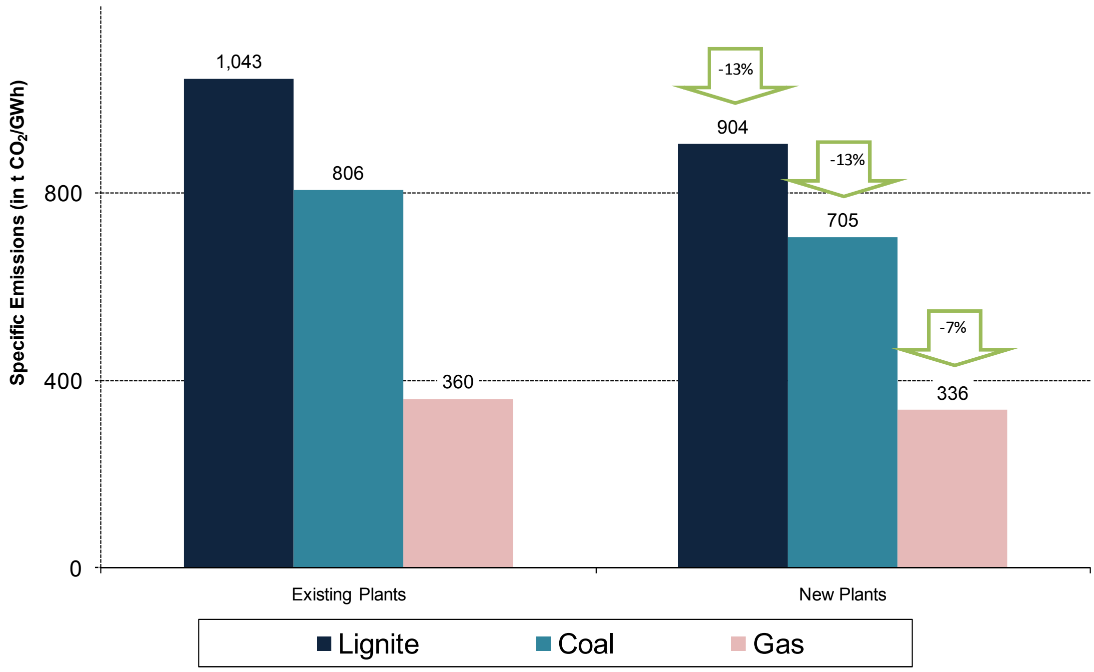
Formula 1: $$SpecificEmissions[t/GWh] = \frac{Emission\ factor_{fuel}[t/TJ] \times 3{,}6}{Efficiency_{el}}$$

Consequently, the set of power plants produces the specific emissions (in t CO_2/GWh) presented in Figure 1.

The existing power plants do not represent the standard of each country within the EU-27. However, the focus of this paper is on the comparison and resulting quantification of the allocation rules. Therefore, a fixed set of reference power plants without country-specific adjustments to the respective standards is used in order to highlight the differences in allocation rules across EU MS.

The main differences in each country's power plant park should occur with regard to the spread in capacities, efficiencies as well as the load factors (LF). In most cases, changes in capacity do not provoke any allocation increases or subtractions as long as the allocation is related to electricity production and emissions, whereas modifications of load factor or efficiency cause considerable changes in the results. If, for example, standardized load factors are used in the allocation method, changes in the plants' load factor will not affect the allocation, but of course the emissions will increase or decrease proportionately. Similar effects can be observed if efficiency modifications are made, and the country applies benchmarks. Since a Europe-wide harmonization in technical standards is taking place, the figures for new plants are more representative. But differences should still remain regarding the load factors, because different fuels may be used for base- or peak-load electricity production. Therefore, the lack of differentiation must be taken into consideration when evaluating the findings of this study.

Figure 1: Emissions of reference power plants



Source: Fraunhofer ISI (2008b)

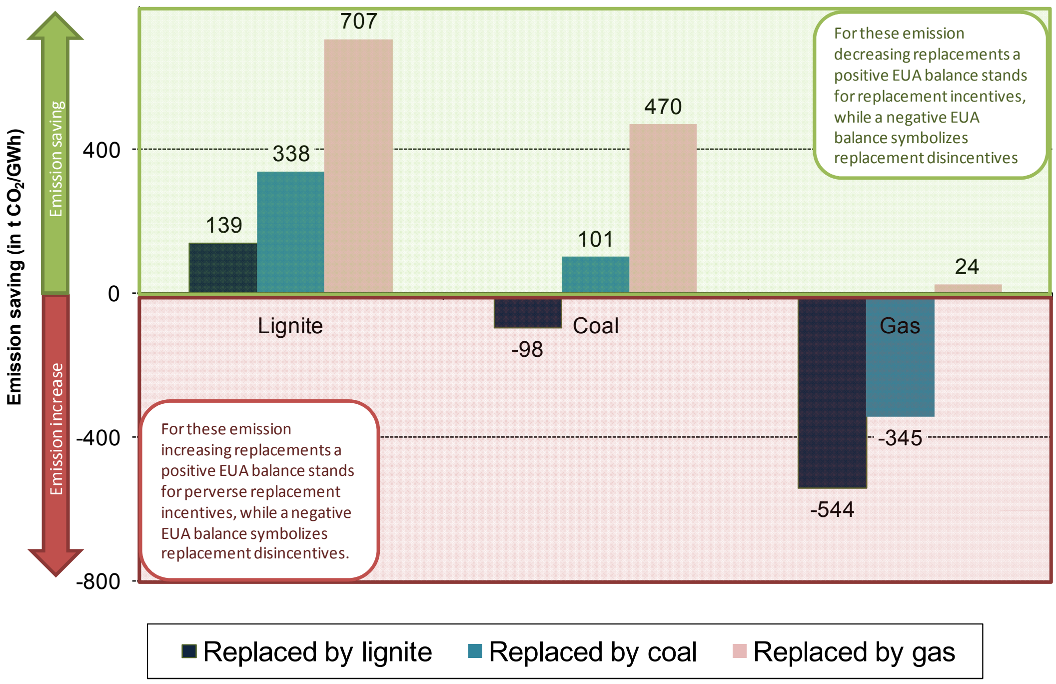
2.3 Criterion for evaluating replacement incentives

If operators close an old, less efficient plant with higher emissions and replace it with a new, more efficient one with lower emissions, overall emissions will be reduced. Since in the EU ETS the allocation of allowances is terminated after the year of closure, our criterion to evaluate the replacement incentives compares the shortage/surplus (in EUA/GWh) of an existing plant with that of a corresponding new one (see Formula 2). This comparison is made for a replacement with the same technology (e.g. old lignite with new lignite) and with a different technology (e.g. old lignite with new gas). The cross-technology comparison is important because not all replacements lead to a reduction of specific emissions, e. g. replacing an old gas-fired power plant with a new lignite-fired one. Consequently, such a replacement should be discouraged.

Formula 2:
$$C_{Re\,pl} = (Allocation\,[EUA/GWh] - Emissions\,[t/GWh])_{New\ plant} - (Allocation\,[EUA/GWh] - Emissions\,[t/GWh])_{Existing\ plant}$$

In order to evaluate the replacement (dis)incentives provided by the allocation rules of MS, we compare them with those of the reference case. Our reference case is given by the change in the EUA balance which would be created in the case of full auctioning. These reference values correspond to the specific emission savings associated with each of the nine possible replacements, as illustrated in Figure 2. That is, each replacement leading to emission savings is associated with a positive reference value, and each replacement leading to an emission increase yields a negative reference value, i.e. a disincentive.

Figure 2: Specific emission savings due to replacement



Source: Fraunhofer ISI based on its EU ETS database (Fraunhofer ISI, 2008a)

For our evaluation, we focus on a comparison of 'signage' as the weak replacement criterion and 'magnitude' as the strong criterion (for an overview of results, see section 5). First, regarding *signage,* for each possible replacement we pose the question whether MS provide (dis)incentives with the same sign as in the reference case of full auctioning. If so, then they comply with the criterion; if not, then they fail, meaning that these MS provide perverse replacement incentives. Second, regarding *magnitude,* we ask how high the replacement (dis)incentives provided by MS are, and how that compares to the reference case value. Clearly, if the (dis)incentive figures are the same as those of the reference case of full auctioning (i.e. the difference of $C_{Repl\ (MS)}$ - $C_{Repl\ (Ref)}$ = 0), then MS provide the correct (dis)incentives. If not, for each emission saving replacement (see green area in Figure 2), MS either provide too many (Δ>0) or too few (Δ<0) incentives, or even perverse incentives ($C_{Repl\ (MS)}$<0, Δ<<0). When looking at each emission increasing replacement (see red area in Figure 2), MS either do not sufficiently discourage such replacements (Δ>0) or do so too strongly (Δ<0), or may provide perverse incentives ($C_{Repl\ (MS)}$>0, Δ>>0). In addition to these two replacement criteria, we also assess whether the relative magnitude of replacement incentives for the three new power plant options for a given reference plant reflects the carbon efficiency order of these plants. This is the case if the incentive order corresponds to that of the reference case, because there should be greater incentives for a replacement resulting in higher emission savings than for one resulting in lower emission savings or even increased emissions

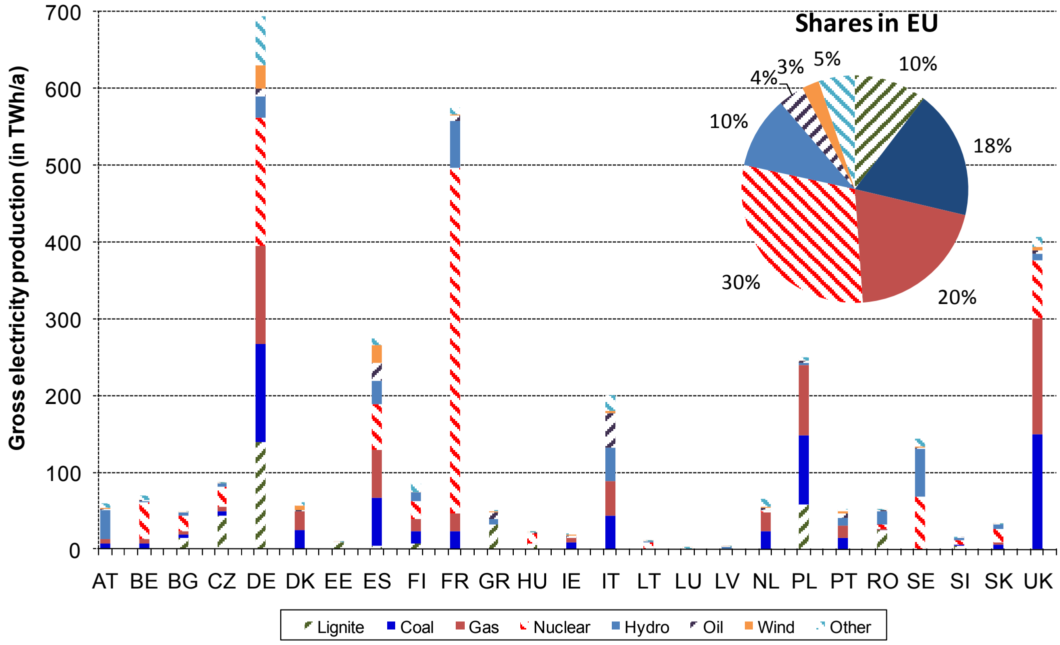
It is important to note that only the incentives provided by the EU ETS are evaluated here[5]. Country-specific legislation which could strengthen or weaken the EU ETS' incentives is not taken into account, nor are any other factors, such as fuel prices or their availability. The analysis conducted here aims to scrutinize the impact of allocation rules and including other factors would only confuse the issue. This is also the reason why we do not provide figures on the monetary incentives of the EU ETS and how they relate to investment costs.

2.4 Differences in power generation structure and renewal needs

In order to be able to relate the findings on the cross-country comparison of allocation rules to country differences in the power generation structure, we provide some key figures describing electricity production across the EU MS. Figure 3 shows the amounts of electricity generated by the combustion of gas, hard coal, lignite and the most important other fuel sources in each country.

5 Existing transfer rules in a few MS, which allow a transfer of allowances from existing to new installations under a set of very specific conditions, were not included in the analysis. These were excluded because information in the NAPs tends to be vague and evidence from Germany suggests these rules are only applied to a very limited extent.

Figure 3: Gross electricity production in Europe 2006

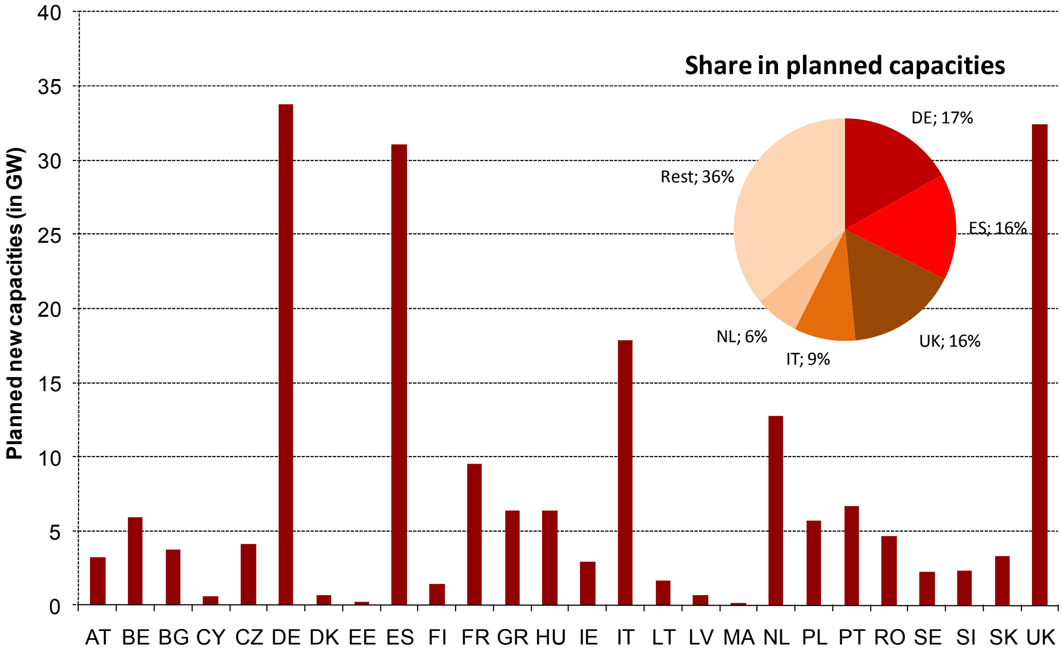


Source: Eurostat (2008)

Obviously gas, coal and lignite account for a large part of pan-European gross electricity production (about 48% in 2006) and play a crucial role in almost every country. Since the generation mix varies strongly across MS, the importance of the allocation rules within countries may be expected to vary accordingly.

In addition, we present the foreseeable amount of new investments because allocation rules may matter most in countries with an urgent need to invest in new power generation capacities. Figure 4 shows the planned investment capacities for the power sector across Europe. These are largest in Germany, Spain, the UK, Italy and the Netherlands (64% of overall planned capacities).

Figure 4: Planned new capacities in the EU power sector



Source: Platts (2008)

3 Classification of allocation rules and application in the power sector in 2008-12

3.1 Classification of allocation rules

In emission trading schemes, allowances can either be allocated free of charge or sold or auctioned to the regulated entities (Tietenberg, 1985). In the first two phases of the EU ETS, a minimum share of 95% (2005-12) and 90% (2008-12), of the EUAs had to be allocated free of charge, so that all the MS had to decide how to allocate their gratis allowances. In principle, gratis allocation can be based on emissions, output or capacity. In the case of *emission-based allocation*, it can refer to either historical or projected emission values, thus providing the allocation basis. In contrast, *output-based allocation* determines the distribution of allowances by using specific emission values per unit of production (e. g. t CO_2/GWh). These emission values can either be installation-specific or benchmarks for a larger group of plants (fuel- or technology-differentiated or uniform), which are then multiplied by an output level to yield the allocation basis. The output level can be calculated by applying past or predicted installation-specific or standardized activity rates. In the case of *capacity-based allocation,* the installed plant capacity itself can be used as a reference value (i.e. t CO_2/GW). Regardless of the allocation rules, the calculated allocation basis may then be multiplied by different factors (e.g. compliance or growth factors, as well as an auctioning share) to adjust the sum of allowances allocated to all installations to the specified emission cap.

Auctioning is the only allocation mechanism without distortions (e. g. Cramton and Kerr, 2002). Having to buy allowances for new plants provides strong monetary incentives to implement low-carbon technologies, since these require the purchase of fewer allowances. Auctioning is also the simplest and most transparent allocation method and thus to be preferred from an economic perspective. In contrast, any form of gratis allocation may encourage over-production, because gratis allowances amount to a subsidization of production, both of existing and new plants (Spulber, 1985, Ellermann, 2008). Output-based allocation using uniform *benchmarks* and uniform production rates is considered second-best (Ahman and Holmgren, 2006, Ahman et al., 2007, Cremer and Schleich, 2006). Such uniform benchmarks provide – independent of their level – strong incentives to invest in the most carbon-efficient technology within the benchmark group. However, any differentiation, e. g. by fuels, reduces the cost-saving potential of the trading scheme because incentives for carbon efficiency are then only assured within the group (Gagelmann, 2006). The innovation incentives for new plants are lowest when allowances are allocated according to *installation-specific emission values* or based on *emissions*. Also, since allocating allowances to existing installations based on benchmarks tends to result in fewer allowances than under emission-based or installation-specific allocation of existing plants, benchmarking typically provides greater incentives to substitute old carbon-intensive plants with more carbon efficient new plants.

In order to guarantee the correct functioning of the trading system as a whole, the evaluation of the allocation rules depends not only on the characteristics of each of the rules, but also on the *balance* they strike *between existing plants, new entrants and the replacement of plants* (Matthes et al., 2005, Sterner and Muller, 2006). Regarding the replacement of plants, it is important to note that within the EU ETS, shutting down a plant results in a subsequent termination of allocation which amounts to an output subsidy (Spulber, 1985, Ahman et al., 2007). The distorting effects of these closure rules in combination with the treatment of new entrants have been analyzed by Ellermann (2008) and others. It is because of the closure rules that the number of free allowances allocated to new entrants have to be balanced against those allocated to existing plants when analyzing replacement incentives. Since new plants are generally more efficient, they should not be disadvantaged when compared to existing installations (Gagelmann, 2006) because generous allocation to existing installations and not to new entrants holds the danger of prolonging the lifetime of less efficient plants ("mothballing"). One way to deal with the inefficiencies generated by the termination of allocation after closure is a transfer rule, according to which the gratis allocation of a closing plant can be transferred to a new one. Summing up, in general, the goal should be an equal treatment of existing and new installations, e. g. by allocation through auctioning or output-based uniform benchmarks.

3.2 Overview of EU ETS phase 2 (2008-12) allocation rules for the power sector

Table 2 provides a qualitative overview of the relevant allocation rules applied in EU MS to conventional power plants. It also includes the overall auctioning share. Regarding e*xisting installations,* a remarkably high share of EU MS bases their allocation on historical 'emissions'. 'Uniform benchmarks'[6], which would be favourable from an economic point of view (see section 2), are applied in fewer countries. A 'differentiated benchmark' is the most common rule applied in MS with high emissions. Only Slovakia is considering 'specific emission values' for existing installations. The allocation rules change with regard to *new plants:* The majority of MS use benchmarking (mostly differentiated) here, often combined with standard load factors. There is a noticeable decrease in the application of emission-based allocation. Plant-specific allocation, which was already rare for existing plants, is negligible for new ones.

6 In spite of the fact that the benchmark is uniform, variations in standard load factors or adjustment factors can occur. However, because only the benchmark is considered in this classification, countries with a uniform benchmark but, e. g. fuel-differentiated load factors, are still included in this group even though the resulting allocation is fuel-specific.

Table 2: Allocation rules of the EU Member States for the power sector

	Allocation basis*								Auctioning	Status***
	Existing plants				New plants					
	Emissions	Specific emission value	Differentiated benchmark	Uniform benchmark	Emissions	Specific emission value	Differentiated benchmark	Uniform benchmark	Share of total cap	
AT				Hist				Proj	1,3%	1
BE_BR	Hist				Proj					1
BE_FL			SLF				SLF			1
BE_WA			SLF					SLF		1
BG	Hist						Proj			1
CZ	Hist					Proj				2
DE			Hist				SLF		8,9%	1
DK				Hist				SLF	0,3%	1
EE	Hist				Proj					1
ES			SLF				SLF			2
FI			Hist				SLF			1
FR	Hist						Proj			2
GR	Hist						SLF			2
HU**									5,0%	3
IE	Hist							SLF	0,5%	1
IT			Hist				SLF			1
LT			Hist					SLF	2,8%	2
LU	Hist							SLF		1
LV	Hist						Proj			1
NL			Hist				Proj		4,0%	1
PL	Hist						Proj		1,0%	2
PT	Hist		SLF				SLF			2
RO	Hist						SLF			2
SE										1
SI	Hist							Proj		2
SK		Hist				Proj				1
UK			SLF					SLF	7,0%	1

* The reference values are marked by different indexes:
Hist: Historical; Proj: Projection; SLF: Standard load factor
** Since the large uncertainty with regard to the allocation rules in Hungary could not be clarified before completion of the study, this country is excluded from the analysis in the following sections.
*** The status of certainty of the allocation rules presented in this study is indicated (1 for sure, 3 for unsure).

Source: Fraunhofer ISI based on its EU ETS database (Fraunhofer ISI, 2008a)

In Table 3, we cluster EU MS according to their allocation method for existing and new installations. In order to do so, we combine both “emission-based allocation” and “specific emission value” into a more general category of “installation-specific allocation”, and keep “differentiated benchmark” and “individual benchmark” as the second and third broad categories. As can be seen, the majority of NAPs fall into the cluster of differentiated benchmarks for both existing and new installations (8), followed by the combination of individual allocation for existing and differentiated benchmark for new installations (7). Table 3 also highlights that only 3 NAPs apply uniform benchmarks to new installations and to existing installations as well, even though such uniform benchmarking is considered the second-best approach after auctioning.

Table 3: Clusters of EU MS according to allocation types

		Rules for existing plants				*Shares in EU planned new capacities**
		Individual allocation	Differentiated benchmark	Uniform benchmark	Σ	
Rules for new plants	Individual allocation	BE_BR, CZ, EE, SK (4)	-	-	4	*4%*
	Differentiated benchmark	BG, FR, GR, LV, PL, PT, RO (7)	BE_FL, BE_WA, DE, ES, FI, IT, NL, PT (8)	-	15	*70%*
	Uniform benchmark	IE, LU, SI (3)	LT, UK (2)	AT, DK, SE (3)	8	*23%*
	Σ	14	10	3	26	*97%*
*Shares in EU electricity prod.**		*34%*	*59%*	*8%*	*100%*	

* Sum not equal to 100% because of exclusion of MS without clear allocation rules (HU, MT, CY); appearance of PT in two groups for existing plants (individual allocation to coal and a benchmark based allocation to gas); value for Belgium allocated to Flanders and Wallonia because of the regional differentiations, SE uses complete auctioning, which corresponds to a uniform benchmark of 0.

Source: Fraunhofer ISI based on its EU ETS database (Fraunhofer ISI, 2008a)

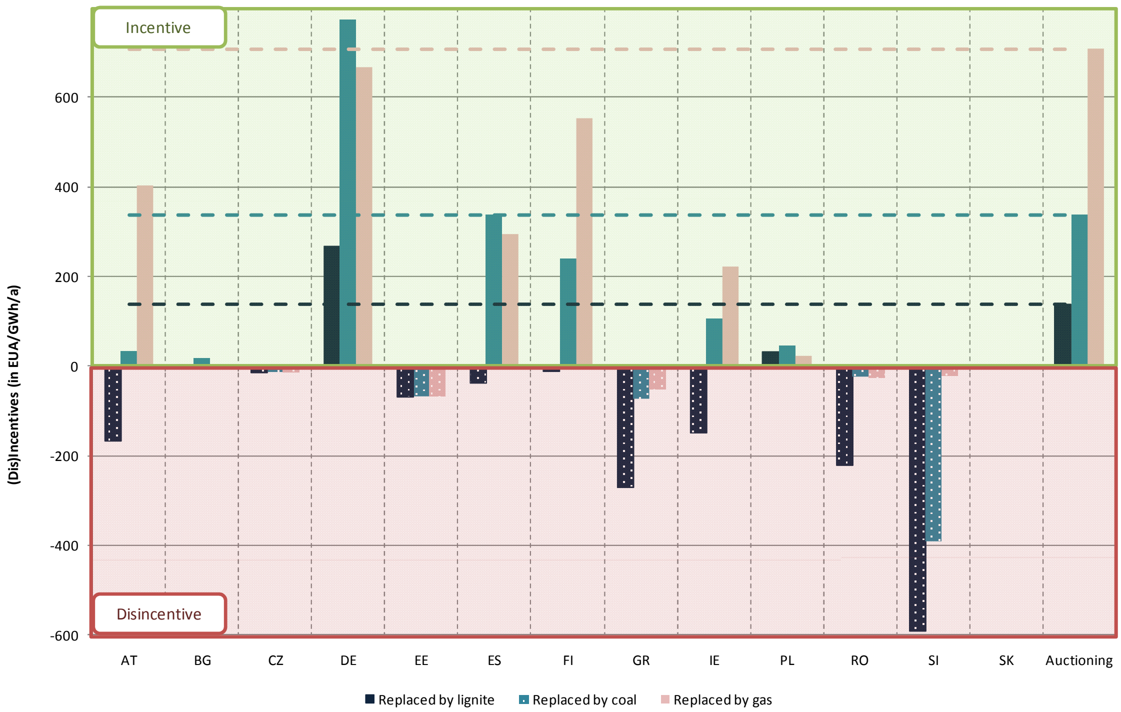
4 Results: Incentives for the replacement of plants

4.1 Replacement incentives for lignite power plants

The existing lignite plant has by far the highest specific emissions of the set of reference plants. Consequently, every replacement implies emission savings, meaning that any replacement should be encouraged, as illustrated by the positive values for the auctioning reference case. In comparison, the replacement (dis)incentives arising from MS' allocation rules are presented in Figure 5 and Table 4.[7]

7 The replacement criterion for lignite was applied to 13 MS, as only these MS use lignite as a combustible (Eurostat, 2008). In the following we assume that new coal and gas power plants can be built in every MS, whereas a new lignite plant can only be built where lignite combustion already exists. However, in some MS (AT, ES, IE, SI, SK, FI), the total share of lignite-based electricity production is very low.

Figure 5: Replacement incentives for existing lignite plant *



* The dotted patterns indicate perverse replacement (dis)incentives.

Source: calculations of Fraunhofer ISI based on its EU ETS database (Fraunhofer ISI, 2008a)

Replaced by a new lignite plant: Replacing the existing lignite-fired power plant with a new lignite plant leads to a reduction in the specific emissions of 139 t CO_2/GWh (-13%), but the new lignite plant still emits 904 t/GWh. In general, MS disincentivize this lignite-lignite replacement, which is underlined by the fact that only 3 out of 13 MS provide a replacement incentive and are thus in line with the auctioning reference. There is a large spread from -589 EUA/GWh to 267 EUA/GWh (range of 856 EUA/GWh), with the standard deviation of 200 EUA/GWh further highlighting the high variation among MS. However, this large range is mainly caused by Germany – the only MS to offer a strong replacement incentive for lignite-lignite, about twice as high as in the reference case.

Replaced by a new coal plant: Replacing the existing lignite plant with a new coal one leads to an emissions saving of 338 t CO_2/GWh (-32%). Replacement incentives vary widely across MS, highlighted by the range from -390 EUA/GWh to 774 EUA/GWh and a high standard deviation (270 EUA/GWh). As 7 out of 13 MS provide a replacement incentive, whereas 5 MS provide a disincentive, it is difficult to determine a general tendency. However, significant lignite-coal replacement incentives only exist in Germany, Spain and Finland, with Spain's incentive matching the one of the auctioning reference case, while the German incentive tops this by factor 2.

Replaced by a new gas plant: Replacing the existing lignite plant with a new gas plant saves 707 t CO_2/GWh (-68%). However, the results show that only 6 out of 13 MS provide a lignite-gas replacement incentive. Of these 6, 5 offer a significant incentive when compared to the auctioning reference (Austria, Germany, Spain, Finland and Ireland). Again, the replacement incentive is by far the strongest in Germany, but even here it remains slightly below the auctioning reference. The disincentives in 6 MS are relatively small, leading to a range from -68 EUA/GWh to +668 EUA/GWh. This large spread of 735 EUA/GWh and the high standard deviation of 251 EUA/GWh illustrate the differences across the MS.

Table 4: Replacement incentives for existing lignite plant

Country	Balance for replacement of existing lignite plant (E_L) by						Replacement (dis)incentives			
	Lignite (N_L)		Coal (N_C)		Gas (N_G)		Incentive	Disincentive	Perverse incentives	Carbon efficiency order
	Balance EUA/GWh	Order	Balance EUA/GWh	Order	Balance EUA/GWh	Order	Number	Number	X=Yes	
AT	-165	10	34	6	403	3	2	1	X	✓
BG	1	3	17	7	-6	6	2	1	X	
CZ	-13	6	-13	9	-13	9	0	3	X	
DE	267	1	774	1	668	1	3	0		
EE	-68	8	-68	11	-68	13	0	3	X	
ES	-37	7	338	2	293	4	2	1	X	
FI	-11	5	241	3	554	2	2	1	X	✓
GR	-270	12	-71	12	-51	12	0	3	X	✓
IE	-148	9	107	4	223	5	2	1	X	✓
PL	31	2	47	5	24	8	3	0		
RO	-221	11	-22	10	-25	11	0	3	X	
SI	-589	13	-390	13	-21	10	0	3	X	✓
SK	0	4	0	8	0	7	0	0		
Auctioning	139		338		707		3	0		✓

	N_L	N_C	N_G
MS with replacement incentive	3	7	6
MS with replacement disincentive	9	5	6
Statistical values in EUA/GWh			
Average	-94	76	152
Standard deviation	200	270	251
Range	856	1,164	735
Minimum	-589	-390	-68
Maximum	267	774	668

Legend: (shaded) Perverse incentive

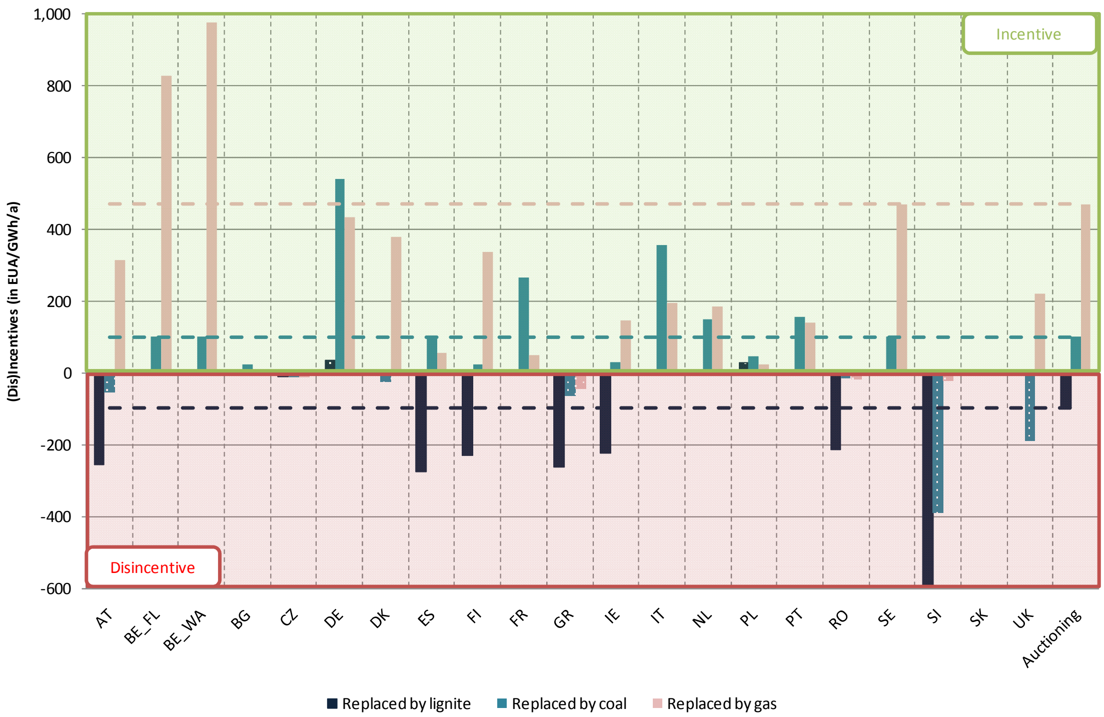
Source: Calculations of Fraunhofer ISI based on its EU ETS database (Fraunhofer ISI, 2008a)

Summary: of the 13 MS analyzed, 7 MS provide at least one replacement incentive, but only Austria, Germany, Spain, Finland and Ireland reach significant levels which are comparable to the auctioning reference. In contrast, 10 MS provide perverse incentives against the replacement of old lignite plants. Also, the incentive order in terms of carbon efficiency is fulfilled by only 5 MS (Austria, Finland, Greece, Ireland and Slovenia). Finally, Germany represents an outlier because in all three replacement situations it provides the largest incentives by far, which in the cases of lignite and hard coal go well beyond the level indicated by the auctioning reference.

4.2 Replacement incentives for hard coal power plants

From an environmental point of view, replacing an existing coal plant with a new lignite plant is harmful as it leads to an increase of specific emissions. Therefore, replacement incentives should only be provided for new hard coal and new gas plants, which is fully reflected by the auctioning reference case. Figure 6 and Table 5 show that replacement (dis)incentives vary significantly across the analyzed 20 MS[8].

Figure 6: Replacement incentives for existing coal plant *



* The dotted patterns indicate perverse replacement (dis)incentives.

Source: Calculations of Fraunhofer ISI based on its EU ETS database (Fraunhofer ISI, 2008a)

8 These are represented by 21 NAPs because for Belgium we had to consider two of the tree regional NAPs (Flanders and Wallonia), while Brussels was excluded due to the lack of an existing coal plant.

Replaced by a new lignite plant: Replacing an existing coal plant by a new lignite one leads to a 12% increase in specific emissions (+98 t CO_2/GWh). Therefore, supporting replacement corresponds to setting perverse incentives, which is the case for 3 of 13 MS (Germany, Poland and Bulgaria), albeit only at a low level. In contrast, the majority of MS are in line with the premise of carbon efficiency, even exhibiting disincentives of a magnitude well beyond the auctioning reference. Finally, replacement incentives vary from -589 EUA/GWh to 36 EUA/GWh (range of 625 EUA/GWh).

Table 5: Replacement incentives for existing coal plant

Country	Balance for replacement of existing coal plant (E_C) by						Replacement (dis)incentives			
	Lignite (N_L)		Coal (N_C)		Gas (N_G)		Incentive	Disincentive	Perverse incentives	Carbon efficiency order
	Balance EUA/GWh	Order	Balance EUA/GWh	Order	Balance EUA/GWh	Order	Number	Number	X=Yes	
AT	-253	4	-54	18	315	7	1	2	X	✓
BE_FL	NA		101	7	829	2	2	0		✓
BE_WA	NA		101	7	978	1	2	0		✓
BG	8	10	24	13	1	16	3	0	X	
CZ	-10	8	-10	14	-10	18	0	3	X	
DE	36	12	542	1	436	4	3	0	X	
DK	NA		-24	15	378	5	1	1	X	✓
ES	-275	2	101	7	56	13	2	1		
FI	-230	7	23	11	336	6	2	1		✓
FR	NA		267	3	51	14	2	0		
GR	-262	3	-63	19	-43	21	0	3	X	✓
IE	-223	5	32	4	148	9	2	1		✓
IT	NA		358	2	196	10	2	0		
NL	NA		150	5	186	11	2	0		✓
PL	31	13	47	17	24	15	3	0	X	
PT	NA		156	6	139	12	2	0		
RO	-214	6	-15	16	-18	19	0	3	X	
SE	NA		101	7	470	3	2	0		✓
SI	-589	1	-390	21	-21	20	0	3	X	✓
SK	0	9	0	12	0	17	0	0		
UK	NA		-189	20	221	8	1	1	X	✓
Auctioning	-98		101		470		2	1		✓

	N_L	N_C	N_G
MS with replacement incentive	3	13	16
MS with replacement disincentive	8	7	4
Statistical values in EUA/GWh			
Average	-165	60	222
Standard deviation	186	188	278
Range	625	932	1,021
Minimum	-589	-390	-43
Maximum	36	542	978

Legend: Perverse incentive (shaded cells)

Source: Calculations of Fraunhofer ISI based on its EU ETS database (Fraunhofer ISI, 2008a)

Replaced by a new coal plant: The majority of NAPs (13 out of 21) incentivize the replacement of an old by a new coal-fired power plants, which is associated with a reduction in CO_2 emissions of 101 t CO_2/GWh (or -13%). Yet, at the same time, the large spread from -390 EUA/GWh to 542 EUA/GWh (range of 932 EUA/GWh; standard deviation of 188 EUA/GWh) reflects the significant differences among MS. Our analysis also shows that, in 5 MS, the incentives are well above the auctioning reference (Germany, France, Italy, the Netherlands, and Portugal). At the same time, in 7 MS, disincentives for such a CO_2 emission reducing replacement exist, particularly in the UK and Slovenia.

Replaced by a new gas plant: Replacing the existing hard coal plant with a gas-fired plant leads to a large decrease in specific emissions (-470 t CO_2/GWh or -58%), which is reflected by the high incentive level in the auctioning reference case. In line with this, the majority of MS (16 of 21 NAPs) provide replacement incentives, some even well beyond the reference level (Belgium, regions Flanders and Wallonia). Our results vary between -43 to 978 EUA/GWh (standard deviation of 279 EUA/GWh), which illustrates not only the large differences across MS, but also that a few MS actually provide disincentives for such a CO_2 emission reducing replacement (e. g. Greece).

Summary: All 21 NAPs incentivize at least one replacement leading to emission reductions[9]. However, 10 NAPs (i.e. almost half of them) provide perverse replacement incentives, yet 11 NAPs are in line with the carbon efficiency order suggested by the reference case.

4.3 Replacement incentives for gas power plants

In the case of replacing an existing gas plant, every replacement other than a gas-gas replacement causes an increase in specific emissions. Therefore, according to the replacement criterion, allocation rules should not incentivize a replacement by coal or lignite plants. The results of our analysis of the allocation rules in 24 MS[10] are presented and compared to the reference case of full auctioning in Figure 7 and Table 6.

Replaced by new lignite plant: Replacing an existing gas with a new lignite plant would generate an enormous emission increase of 544 t CO_2/GWh (+151%) which is why the reference case exhibits a disincentive in the same magnitude. Correspondingly, 10 out of 13 NAPs provide disincentives for this replacement,

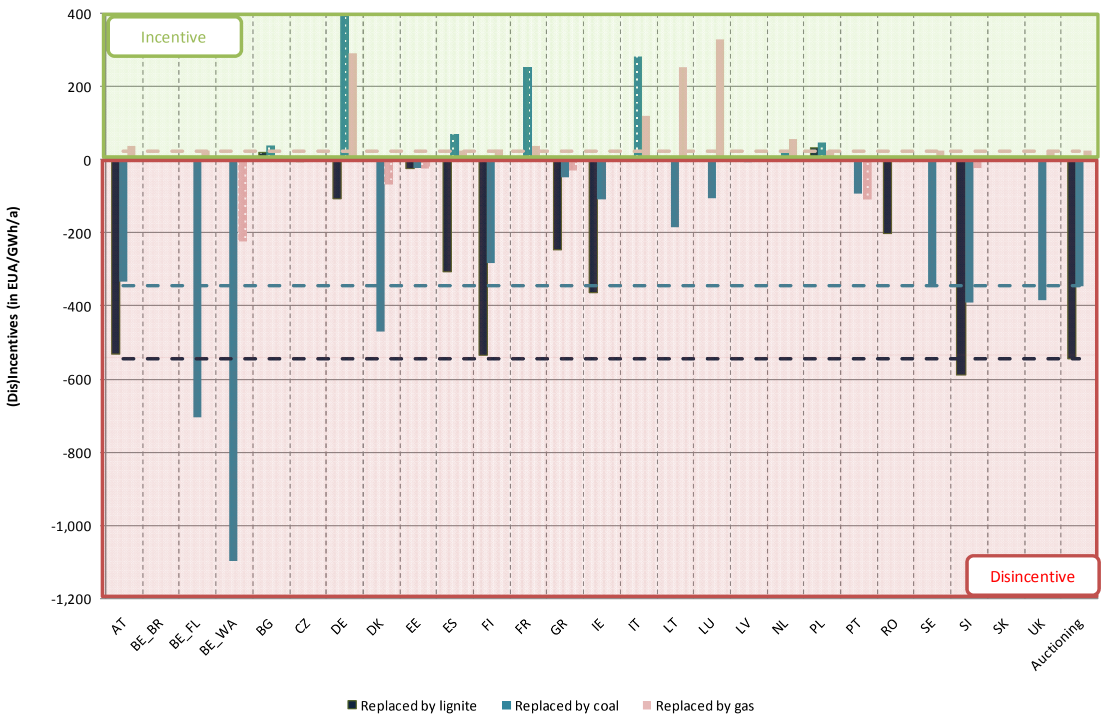
9 Strictly speaking, in Slovakia there are neither incentives nor disincentives.

10 These are represented by 26 NAPs because for Belgium we had to consider all three regional NAPs (Brussels, Flanders and Wallonia).

but 2 MS provide slight perverse incentives (Bulgaria and Poland). Again, the large spread of 620 EUA/GWh (-589 EUA/GWh to +31 EUA/GWh) and the standard deviation of 229 EUA/GWh illustrate the differences in allocation rules across MS.

Replaced by a new coal plant: If the existing gas plant were replaced by a new hard coal plant, this would lead to an increase in specific emissions by 345 t CO_2/GWh (+96%). The resulting reference disincentive of -345 EUA/GWh is contrasted with a range of disincentives as large as -1,099 EUA/GWh up to a perverse incentive of +398 EUA/GWh (highest range of 1,497 EUA/GWh). 7 out of 26 NAPs provide perverse incentives for such a replacement (by far the largest in Germany, France and Italy), while 17 NAPs comply with the criterion by providing disincentives (in Belgium (Flanders and Wallonia) as well as Denmark even well beyond the auctioning reference).

Figure 7: Replacement incentives for existing gas plant*



* The dotted patterns indicate perverse replacement incentives

Source: Calculations of Fraunhofer ISI based on its EU ETS database (Fraunhofer ISI, 2008a)

Replaced by a new gas plant: As the specific emissions of a new gas plant are 24 t/GWh (-7%) below the emissions of the existing gas plant, there should be incentives to replace the older plant. The range of +329 to -221 EUA/GWh underlines the variation among the MS and illustrates that not all MS incentivize this replacement: While 16 out of 26 NAPs provide replacement incentives, in some instances also much higher than in the reference case (Germany, Luxembourg, Lithuania, Italy), 8 NAPs provide disincentives for such a replacement (particularly large ones in Belgium-Wallonia, Portugal and Denmark).

Table 6: Replacement incentives for existing gas plant

Country	Balance for replacement of existing gas (E_G) plant by						Replacement (dis)incentives			
	Lignite (N_L)		Coal (N_C)		Gas (N_G)		Incentive	Disincentive	Perverse incentives	Carbon efficiency order
	Balance EUA/GWh	Order	Balance EUA/GWh	Order	Balance EUA/GWh	Order	Number	Number	X=Yes	
AT	-531	2	-332	7	37	9	1	2	X	✓
BE_BR	NA		0	17	0	17	0	0		
BE_FL	NA		-704	2	24	12	1	1	X	✓
BE_WA	NA		-1,099	1	-221	26	0	2	X	✓
BG	21	12	37	20	14	15	3	0		
CZ	-5	10	-5	15	-5	19	0	3	X	
DE	-108	8	398	26	292	2	2	1	X	
DK	NA		-470	3	-68	24	0	2	X	✓
EE	-23	9	-23	13	-23	22	0	3	X	
ES	-306	5	69	22	24	12	2	1	X	
FI	-536	3	-283	8	29	6	1	2	X	✓
FR	NA		255	24	39	8	2	0		
GR	-247	6	-48	12	-28	23	0	3	X	✓
IE	-364	4	-109	23	8	5	1	2	X	✓
IT	NA		282	25	120	4	2	0		
LT	NA		-183	9	255	3	1	1	X	✓
LU	NA		-106	10	329	1	1	1	X	✓
LV	NA		-6	14	6	16	1	1	X	✓
NL	NA		20	19	57	7	2	0		✓
PL	31	13	47	21	24	11	3	0		
PT	NA		-91	11	-107	25	0	2	X	
RO	-200	7	-1	16	-5	20	0	3	X	
SE	NA		-345	6	24	12	1	1	X	✓
SI	-589	1	-390	4	-21	21	0	3	X	✓
SK	0	11	0	17	0	17	0	0		
UK	NA		-385	5	25	10	1	1	X	✓
Auctioning	-544		-345		24		1	2		✓

	N_L	N_C	N_G
MS with replacement incentive	2	7	16
MS with replacement disincentive	10	17	8
Statistical values in EUA/GWh			
Average	-220	-134	32
Standard deviation	229	313	114
Range	620	1,497	550
Minimum	-589	-1,099	-221
Maximum	31	398	329

Legend: Perverse incentive (shaded cells)

Source: Calculations of Fraunhofer ISI based on its EU ETS database (Fraunhofer ISI, 2008a)

Summary: 16 out of 26 NAPs incentivize the only carbon-efficiency improving replacement of the existing gas plant with a new gas plant. However, at the same time, 19 NAPs provide perverse replacement incentives in one way or another[11]. Yet in 14 NAPs, the allocation rules lead to the same incentive order for the three replacement options as in the reference case.

5 Discussion and conclusion

This section summarizes and discusses the results of our analysis of the incentives provided by the EU ETS allocation rules (2008-12) in EU MS to replace an existing reference plant with a new plant. In Table 7, countries whose allocation rules lead to replacement incentives with the same sign as the ones in the auctioning reference case fulfil the weak replacement criterion (indicated by a green shaded "✓"). If MS (dis)incentives are not in line with the reference case, then they fail this criterion because their allocation rules provide perverse incentives (indicated by a red "x").[12]

The analysis shows that, in approx. 60% of the possible replacement situations, MS set incentives according to the reference case of 100% auctioning, whereas in approx. 32% of the possible replacements, MS provide perverse incentives. Only 5 MS do not provide any perverse incentives (Belgium (Flanders), Lithuania, Luxembourg, Latvia and Sweden).[13] In contrast, 5 MS provide perverse incentives in more than half of the possible replacement options (Czech Republic, Greece, Romania, Slovenia, and Slovakia).

11 In Slovakia and Belgium (Brussels Region), there are neither incentives nor disincentives.

12 Consequently, whether MS provide replacement incentives or disincentives can be derived from a comparison of the criterion fulfilment and the value of the reference case. For example, if, in the reference case, replacement is discouraged (indicated by a "-"), and the MS fails the criterion ("x", i.e. perverse incentive), then this means that the MS provides a replacement incentive which would lead to an increase in specific emissions.

13 Within the replacement options for one type of existing reference plant, 4 additional MS are in full "sign" alignment with the auctioning reference (Germany and Poland for existing lignite, Spain for existing coal, and Austria for existing gas. These are all MS which allocate using a benchmark approach).

Table 7: Compatibility of *sign* of replacement incentives with reference

Country	Replacement (dis)incentives in accordance with auctioning reference case															Total	
	Lignite (E_L)					Coal (E_C)					Gas (E_G)						
	Replaced by N_L	Replaced by N_C	Replaced by N_G	Sum E_L ✓	Sum E_L X	Replaced by N_L	Replaced by N_C	Replaced by N_G	Sum E_C ✓	Sum E_C X	Replaced by N_L	Replaced by N_C	Replaced by N_G	Sum E_G ✓	Sum E_G X	✓	X
AT	X	✓	✓	2	1	✓	X	✓	2	1	✓	✓	✓	3	0	7	2
BE_BR				0	0				0	0		O	O	0	0	0	0
BE_FL				0	0		✓	✓	2	0		✓	✓	2	0	4	0
BE_WA				0	0		✓	✓	2	0		✓	X	1	1	3	1
BG	✓	✓	X	2	1	X	✓	✓	2	1	X	X	✓	1	2	5	4
CZ	X	X	X	0	3	✓	X	X	1	2	✓	✓	X	2	1	3	6
DE	✓	✓	✓	3	0	X	✓	✓	2	1	✓	X	✓	2	1	7	2
DK				0	0		X	✓	1	1		✓	X	1	1	2	2
EE	X	X	X	0	3				0	0	✓	✓	X	2	1	2	4
ES	X	✓	✓	2	1	✓	✓	✓	3	0	✓	X	✓	2	1	7	2
FI	X	✓	✓	2	1	✓	✓	✓	3	0	✓	✓	✓	3	0	8	1
FR				0	0		✓	✓	2	0		X	✓	1	1	3	1
GR	X	X	X	0	3	✓	X	X	1	2	✓	✓	X	2	1	3	6
IE	X	✓	✓	2	1	✓	✓	✓	3	0	✓	✓	✓	3	0	8	1
IT				0	0		✓	✓	2	0		X	✓	1	1	3	1
LT				0	0				0	0		✓	✓	2	0	2	0
LU				0	0				0	0		✓	✓	2	0	2	0
LV				0	0				0	0		✓	✓	2	0	2	0
NL				0	0		✓	✓	2	0		X	✓	1	1	3	1
PL	✓	✓	✓	3	0	X	✓	✓	2	1	X	X	✓	1	2	6	3
PT				0	0		✓	✓	2	0		✓	X	1	1	3	1
RO	X	X	X	0	3	✓	X	X	1	2	✓	✓	X	2	1	3	6
SE				0	0		✓	✓	2	0		✓	✓	2	0	4	0
SI	X	X	X	0	3	✓	X	X	1	2	✓	✓	X	2	1	3	6
SK	O	O	O	0	0	O	O	O	0	0	O	O	O	0	0	0	0
UK				0	0		X	✓	1	1		✓	✓	2	0	3	1
Auctioning	+	+	+	3	0	-	+	+	3	0	-	-	+	3	0	9	0
No. ✓	3 of 13 (23%)	7 of 13 (54%)	6 of 13 (46%)			8 of 12 (67%)	13 of 21 (62%)	16 of 21 (76%)			10 of 13 (77%)	17 of 26 (65%)	16 of 26 (62%)				
No. X	9 of 13 (69%)	5 of 13 (38%)	6 of 13 (46%)			3 of 12 (25%)	7 of 21 (33%)	4 of 21 (19%)			2 of 13 (15%)	7 of 26 (27%)	8 of 26 (31%)				
Sum ✓	**16 of 39 (41%)**					**37 of 54 (69%)**					**43 of 65 (66%)**						
Sum X	**20 of 39 (51%)**					**14 of 54 (26%)**					**17 of 65 (26%)**						
Total ✓	**96 of 158 (61%)**																
Total X	**51 of 158 (32%)**																

Legend

✓	Replacement (dis)incentives in accordance with reference case (auctioning)
X	Replacement (dis)incentives not in accordance with reference case (auctioning)
O	Neither incentive nor disincentive provided
+	In the auctioning reference case a positive replacement incentive is provided
-	In the auctioning reference case a replacement disincentive is provided

Source: Calculations of Fraunhofer ISI based on its EU ETS database (Fraunhofer ISI, 2008a)

However, just looking at the right sign is a relatively weak replacement criterion because it does not provide any information about the magnitude of the replacement (dis)incentives, which could be either well below or above the auctioning reference. Therefore, Table 8 shows the – often strong – deviation of the MS' values from the (dis)incentive provided in the reference case of full auctioning (as indicated in the last row).[14] For each MS and replacement option, a value of zero ("0") indicates perfect alignment with the auctioning reference. However, only 4 MS and 7% of all replacement cases comply with this replacement criterion for at least one replacement option (Belgium (Flanders, Wallonia), Spain, Poland, and Sweden). Of these, only Sweden consistently sets the same (dis)incentives as in the reference case, which is due to the fact that no gratis allowances are provided. In 32% of replacement cases, MS provide perverse incentives (white figures with red shading). 54% of the remaining black figures fulfil the weak replacement criterion, but the magnitude of the (dis)incentives deviates from the reference case[15]. Of these, approx. 36% are too weak (black figures on light green shading) while 20% over-incentivize replacements (black figures on dark green shading). For example, in the case of existing lignite, Germany provides replacement incentives well above the level foreseen by the auctioning reference for replacements by coal or lignite, and incentives below the reference for replacement with new gas, thereby incentivizing sub-optimal replacement decisions.

14 See section 2 for criteria explanation.

15 In 7% of the replacement cases, neither incentives nor disincentives are provided (yellow shaded cells).

Table 8: Compatibility of *magnitude* of replacement incentives with reference

Country	Difference of replacement (dis)incentives provided by MS and those of the auctioning reference case									
	Lignite (E_L)			Coal (E_C)			Gas (E_G)			At least once auctioning balance
	Replaced by N_L	Replaced by N_C	Replaced by N_G	Replaced by N_L	Replaced by N_C	Replaced by N_G	Replaced by N_L	Replaced by N_C	Replaced by N_G	
AT	*-304*	-304	-304	-155	*-155*	-155	13	13	13	
BE_BR								345	*-24*	
BE_FL					0	359		-359	0	✓
BE_WA					0	509		-754	*-245*	✓
BG	-138	-321	*-713*	*106*	-77	-469	*565*	*382*	-10	
CZ	*-152*	*-351*	*-720*	88	*-111*	*-480*	539	340	*-29*	
DE	128	436	-39	*134*	441	-34	436	*743*	268	
DK					*-125*	-92		-125	*-92*	
EE	*-207*	*-406*	*-775*				521	322	*-47*	
ES	*-176*	0	-414	-176	0	-414	238	*414*	0	✓
FI	*-151*	-97	-153	-131	-78	-134	8	62	5	
FR					166	-419		*600*	15	
GR	*-409*	*-409*	*-758*	-164	*-164*	*-513*	297	297	*-52*	
IE	*-287*	-232	-484	-125	-69	-322	180	236	-16	
IT					257	-274		*627*	96	
LT								162	231	
LU								239	305	
LV								339	-18	
NL					49	-284		*365*	33	
PL	-108	-291	-683	*129*	-54	-446	*575*	*392*	0	✓
PT					55	-330		254	*-131*	
RO	*-360*	*-360*	*-732*	-115	*-115*	*-488*	344	344	*-29*	
SE					0	0		0	0	✓
SI	*-728*	*-728*	*-728*	-491	*-491*	*-491*	-45	-45	*-45*	
SK	*-139*	*-338*	*-707*	*98*	*-101*	*-470*	*544*	*345*	*-24*	
UK					*-289*	-249		-40	1	
Auctioning	139	338	707	-98	101	470	-544	-345	24	✓

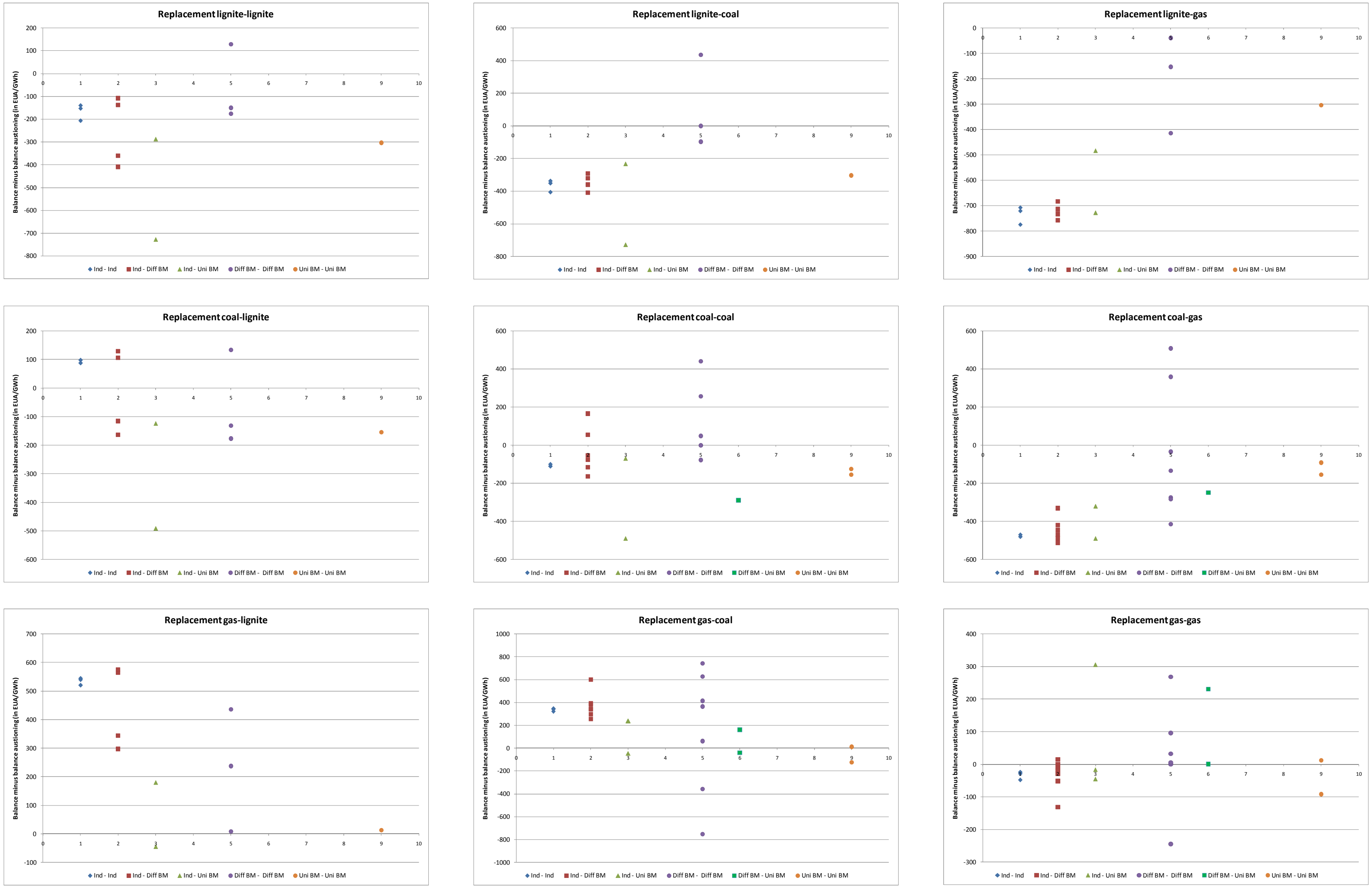
Legend

Green numbers	Same Balance as reference case
White numbers	Tendency of (dis)incentive correct but too strong
Black numbers	Tendency of (dis)incentive correct but too weak
White italic numbers	Perverse incentive
Black italic numbers	Neither incentive nor disincentive provided

Source: Calculations of Fraunhofer ISI based on its EU ETS database (Fraunhofer ISI, 2008a)

These variations across EU MS can only be explained to a limited extent by the type of allocation rule chosen by the MS (individual allocation, differentiated or uniform benchmark), as indicated by Figure 8. For example, the 5 MS in full compliance with the weak replacement criterion (sign) belong to 5 different allocation clusters (BE_FL: Diff-Diff, LT: Diff-Uni, LU: Ind-Uni, LV: Ind-Diff, SE: Uni-Uni (Auctioning)). Clearly, other factors – such as the specific benchmark values and whether these differ between existing and new plants, as well as correction factors – are more important than the type of allocation rule. In contrast, a clearer pattern emerges for MS with at least 5 perverse incentives, because existing installations are always allocated on the basis of individual allocation while new entrants either receive their allowances on the basis of individual allocation or differentiated benchmarks (CZ: Ind-Ind, GR: Ind-Diff, RO: Ind-Diff, SI: Ind-Diff, SK: Ind-Ind).

Figure 8: Correlation of replacement incentives and allocation rule cluster



Source: Calculations of Fraunhofer ISI based on its EU ETS database (Fraunhofer ISI, 2008a)

When looking at all three existing plants and the corresponding replacement incentives provided for a particular fuel/technology (including perverse incentives), then 2 MS stand out as particularly lignite-friendly (Germany and Poland). In the same vein, 7 MS provide very favourable incentives for replacements with new coal plants (Germany, Bulgaria, France, Ireland, Italy, the Netherlands and Poland). Finally, 3 MS particularly encourage replacement investments in new gas plants (Belgium (Flanders, Wallonia), Lithuania, and Luxembourg). We would therefore expect that in these MS adoption decisions are pushed towards plants with these fuels/technologies. However, these preferential treatments can only to a very limited extent be explained by the current generation mix of a MS (see Figure 3).

Finally, in most instances, Germany stands out as the MS providing the largest replacement incentives, often followed by Italy and Spain – including incentives for replacement options which actually lead to higher specific emissions. These big investment subsidies[16] may to some extent be explained by Germany's large replacement needs (see Figure 4), although other MS with similarly large planned new capacities still tend to be in much better compliance with the auctioning reference case (e. g. UK).

Three cautious remarks are in order: first, the results presented in this study clearly depend on the assumptions specified for the set of reference power plants and on the uniform emission factors of fuels. That is, no country-specific modifications are made regarding the set of reference power plants or emission factors (see section 2.2). However, it is precisely these simplifying assumptions which help to see through the complexities and variations of the EU ETS allocation rules to the (dis)incentives these rules provide. Second, while a great effort was made to collect up-to-date allocation rules of EU MS, uncertainty remains regarding the rules of the NAPs (see section 2.1). Third, in interpreting the findings, it needs to be considered that the impact of differences in free allocation depends on expected EUA prices and that the resulting incentives are just one element in the complex investment decision process of power generators, and not necessarily the most important one (see Cames, 2008). In addition, since the gratis allocation for the power sector will be phased out in 2013 (EU, 2008), the replacement (dis)incentives resulting from today's gratis allocation rules are

16 These replacement incentives would have been amplified even more if the Commission had not ruled against the 14-year rule which guaranteed the same level of gratis allocation for 14 years after commissioning (EU, 2006).

unlikely to have an impact on ongoing investment appraisals. Therefore, the potential harm resulting from the multitude of perverse incentives is likely to be limited. As a consequence of these caveats, it is not possible to use our analysis to predict actual investment behaviour. Rather, our findings underline the tremendous variation of replacement incentives among EU MS due to the MS-specific EU ETS allocation rules and the high share of perverse incentives that have been created through allocating allowances free of charge.

We conclude that the replacement incentives resulting from the allocation rules in the EU ETS in its second phase (2008-12) vary substantially across MS. More importantly, the share of perverse incentives generated due to gratis allocation reaches a strikingly high level of 32 per cent of replacement options. The findings of our study support the introduction of full auctioning for the power sector starting in 2013 (EU, 2008) as this will abolish any distorting replacement incentives. In addition, auctioning is the only solution which does not create distorting incentives between new investments in fossil-fuel-fired plants and renewables. Our findings reiterate the recommendations of earlier studies that the trading schemes emerging in the rest of the world, such as in the US, should refrain from gratis allocation in the power sector. If this is not politically palatable, we suggest that policymakers strive for a high share of auctioning (Burtraw et al., 2005) and predetermine a – rather short – period for allocating free allowances. Together, these moves would limit the harmful impact of the distorting replacement incentives likely to arise from politically bargained gratis allocation rules.

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Annex: Country Codes

AT	Austria
BE_BR	Brussels (Belgium)
BE_FL	Flanders (Belgium)
BE_WA	Wallonia (Belgium)
BG	Bulgaria
CY	Cyprus
CZ	Czech Republic
DE	Germany
DK	Denmark
EE	Estonia
ES	Spain
FI	Finland
FR	France
GB	Great Britain
GR	Greece
HU	Hungary
IE	Ireland
IT	Italy
LT	Lithuania
LU	Luxembourg
LV	Latvia
MT	Malta
NL	Netherlands
PL	Poland
PT	Portugal
RO	Romania
SE	Sweden
SI	Slovenia
SK	Slovakia
UK	United Kingdom

Authors' affiliations

Karoline Rogge

Fraunhofer Institute for Systems and Innovation Research (ISI), Competence Center Energy Policy and Energy Systems, Breslauer Strasse 48, 76139 Karlsruhe, Germany and

Swiss Federal Institute of Technology Zurich (ETH Zurich), Department of Management, Technology, and Economics, CH-8092 Zurich, Switzerland

Christian Linden

PricewaterhouseCoopers AG, Utilities & Regulation, Moskauer Strasse 19, 40227 Duesseldorf, Germany

Contact: Brigitte Kallfass

Fraunhofer Institute for Systems
and Innovation Research (Fraunhofer ISI)
Breslauer Strasse 48
76139 Karlsruhe
Germany
Phone: +49 / 721 / 6809-150
Fax: +49 / 721 / 6809-203
e-mail: brigitte.kallfass@isi.fraunhofer.de
URL: www.isi.fraunhofer.de

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