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Abstract:
Given the ambitious goal of the European Union to achieve CO_2 emission reduction, support to renewable energies, and increased energy efficiency a portfolio of different policies is going to be implemented or is already in place in the member states. These instruments have at least partly overlapping objectives; thus, a high degree of interaction is to be expected. In this paper we analyze how the EU ETS and renewable support mechanisms influence one another. We apply a static open economy computable general equilibrium (CGE) model of Germany incorporating different conventional and renewable generation technologies. We find that in case of an ETS with a green certificate trading scheme or a feed-in system the price for carbon drops to zero due to the high share of CO_2-neutral renewable generation. Furthermore, the welfare reducing effect of an additional renewable support mechanism is rather low for both schemes.

Key words: ETS, renewable support, Germany, CGE
JEL-code: D58, L94, Q42, Q52

1 Introduction

The ongoing discussion about climate change and high fuel prices has fostered an intense debate about a more environmentally oriented policy. The European Union has taken a lead in supporting environmental policies to counteract climate change and to increase the utilization of renewable energies. The ambitious "20-20-20" goals postulate a reduction of greenhouse gas emission of 20%, a share of renewable energy sources of 20%, and an increase of energy efficiency of 20% by 2020. Emission trading, the promotion of renewable energies, and efficiency measurement, all contribute to the reduction of greenhouse gases and impact electricity market prices. However, the different instruments interact with one another and thus may improve or worsen the desired outcome. Furthermore, the specific support schemes for renewables vary for the EU member states. Although, it is generally agreed that an emission trading system is the least costs alternative for emission reduction there are reasons to incorporate additional support schemes for other market segments, like renewables or energy efficiency. However, the design of those policies has to take the interaction of instruments into account.

In this paper we asses the interactions of an Emission Trading Scheme (ETS) with tradable green certificates and a feed-in system for renewable energies, respectively. We apply a numerical model of the German economy incorporating different conventional and renewable generation technologies and asses the impact of the different instruments on generation investment, electricity and emission allowance prices, the overall impact on other sectors, and the economy as a whole.

The remainder of the paper is structured as follows. In section 2 an overview about climate policy, renewable support schemes, and the interaction of both instruments is presented. Section 3 describes the underlying model; we apply a static open economy computable general equilibrium (CGE) model of Germany to analyze the interaction. The model is a combination of top-down and bottom-up modeling taking into account different generation technologies. In section 4 the scenarios and results are presented. After deriving the market benchmark representing the situation in 2004 we first analyze the impact of a pure emission trading scheme on generation investment and market prices. Afterwards the two renewable support schemes are implemented, respectively, assuming a target share of 20%. We find that in case of additional support of renewables the large share of CO_2-neutral generation sources leads to an excess supply of permits and thus a carbon price of zero, making the ETS obsolete. The welfare impact of renewable support is negative due to a more costly generation mix. However, the impact is relatively small. Section 5 concludes.

2 Tradable Emissions Permits and Renewable Energy Support

Environmental policies aimed at energy markets often have overlapping objectives and interact to a specific degree. This is particularly the case for emission reduction policies and renewable support schemes but also effects energy efficiency targets (see Meran and Wittmann, 2008, and Sorrel and Sijm, 2005). In this section we provide a review on different mechanism to obtain greenhouse gas reduction and present renewable support schemes. Afterwards the impact of both instruments on the different market segments is highlighted and the interaction is analyzed theoretically.

2.1 Climate Policy

The main aim of climate policy is to internalize the external costs of climate change caused by greenhouse gas emissions. Restricting ourselves to the class of market based policy instruments either quantities or prices can be regulated. In the case of emission control either price of greenhouse gas emission is set using a tax instrument or the quantity is regulated by a classical cap-and-trade system. Similarly, the amount of renewable energy production can be regulated by using subsidies for renewable energies or setting a lower bound on renewable energy production.[1] In order to achieve a Pareto optimal outcome, targets should be set in a way to equalize marginal costs and marginal benefit of regulation In the case of emission regulation, marginal abatement cost should equal the marginal benefit of emission regulation in terms of reduced climate impacts. In the case of renewable energy support the marginal cost are given by the increase in marginal cost of energy production. The benefit of renewable energy production is twofold: on the one hand emissions are reduced leading to reduced climate impacts. On the other hand, renewable energy technologies have strong learning effects and, therefore, decrease the cost of future emission regulation.

Although the intersection of marginal costs and damage is the theoretic aim to achieve most practical and policy discussion focus only on the quantity of emission reduction (e.g. the Kyoto protocol) or the share of renewables. However, this does not alter he policy options to achieve this aim either by setting a price or by fixing the quantity. In this section we shortly describe the market based instruments used in practice.

Emission Regulation

With a *Pigouvian taxes* the price *p* of pollution is set whereas pollution quantity *Q* results from of the cost minimization considerations of the market participants. Given perfect information about the aggregated abatement cost curves the price *p* is set such that a specific target is implemented and, thus, ecologically efficient Since all agents face the same price of emissions, the tax leads o equalization of individual marginal abatement cost and is, therefore, cost efficient. However, abatement cost curves are hard to obtain in real world environments. Therefore, emission taxes raise the problem of high informational requirements in order to implement a specific target.

Contrary to taxes with *permits* the total quantity *Q* of aggregated emissions is fixed. The carbon budget is subdivided into emission allowances which are traded at a market. The price of pollution *p* is the resulting market price. Firms have to own a permission in order to emit a specific quantity and thus will either abate emissions or buy emission permits whichever is the cheapest. Since permits set the upper emission quantity they are ecologically efficient. Furthermore, since all agents face the same

[1] It is also possible to regulate renewable energy production by either imposing taxes on the production of non-renewable energy sources or using a cap-and-trade system for non-renewable energy setting an upper bound. This methods draw parallels to emission regulation. However, it has become standard to support renewable energy instead of regulation non-

price, emission allowances are also cost efficient. Contrary to taxes the aggregated marginal abatement cost curve is not necessary to set the optimal price. Therefore, permits reduce the informative requirements. However, in a permit system the regulator/government has to allocate an initial amount of allowances to market participants. Although, the allocation will theoretically not affect the outcome in practice this issue is of particular relevance e.g. see Böhringer et al. (2005).

In this paper we focus on the permit option as Europe has implemented an emission trading scheme for the electricity generation and energy intensive industries which makes further emission specific instruments obsolete. Emission trading mainly has an impact on electricity prices and thus an indirect effect on consumption and investment. In general emission trading increases the generation costs of fossil fueled generation sources particularly coal fired power plants. Depending on the price of emission allowances less CO_2 intensive generation from gas or oil fired plants may become more favorable. The merit order change and the higher production costs lead to higher electricity prices which in turn lead to less electricity consumption and shall foster energy efficiency improvements. In the long run emission trading is supposed to lead to an investment shift in favor of clean and/or renewable energy sources.

The effect of emission regulation on electricity generation is depicted in panel (b) of Figure 1. Compared to the no regulation case shown in panel (a), emission regulation increases the marginal cost of fossil fuel based generation. Since costs are increasing, the electricity price is increasing and demand is decreasing. The actual emission costs depend on the specific carbon content of the used fuel thus more CO_2 emitting energy sources like coal have higher costs than “cleaner” fuels like natural gas. In case of auctioning permits or using tax regulation the expenses for emission allowances can be interpreted as government’s revenue. Depending on the revenue recycling mechanism these income could create a double dividend (e.g. Goulder 1995, Bovenberg 1999).

Renewable Energy Support

Renewable Energy support started in the 1970s and 1980s mainly as a result of the increasing oil prices and security of supply concerns. During that time support was focused on research and development of renewable technologies. Expenditures for research amount to about 200 million US$ per year in the US and Europe respectively (Blok, 2006). Since the 1990s the focus of support has shifted to the actual implementation of renewable energy sources (RES). In the European Union these ambitions gained legal ground with the White Paper in 1997 and the corresponding renewable directive in October 2001 stating an implementation goal for renewables of 12% for total energy and 22% for electricity by 2010. However, the actual support mechanism to reach those goals is left to the national governments.

Given the high import dependency of most industrialized countries secure energy supply plays a major role in governmental policies. Utilization of national (renewable) energy resources thus is a key element of those policies. Beside the security of supply concern the promotion of RES is justified by

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renewable production. The reason might be, that emission regulation is essentially taxation of conventional, fossil fuel base generation.

several means. As RES are CO_2 neutral they are considered a valid option in the climate change prevention. Support for RES may lead to reduced pollution, and provides employment and investment opportunities (Gonzáles, 2007). Due the cost disadvantage of renewable energies compared to fossil fuels an implementation support normally leads to higher expenses for consumers either in increased taxes or direct markups on electricity prices. However, in the short run RES also tend to reduce electricity prices as they lead to a right shift of the merit order curve and thus lower the price setting marginal generator (the merit order effect). For the German wind capacities studies show that the wholesale electricity prices decreased about the same amount as final consumer prices increased due to the feed-in tariff (Sensfuß et al. 2007, Weigt 2008). On the other hand an increase of stochastic RES production like wind and solar has impacts on operating reserve requirements and back-up capacities (e.g. Luickx et al. 2008, Hoogwijk et al. 2007) and large scale implementation also impacts grid investment (e.g. Leuthold el al. 2008).

Long term effects of RES on power plant investments and electricity prices have not yet been quantified. However, another argument for the support of RES is that an early promotion can foster the learning by doing effects and thus lead to reduced energy costs in the future. As these earnings are generally not taken into account by markets the need for governmental intervention can be justified. Rosendahl (2004) analyzes the issue of learning effects and technological change with respect to costs effective environmental policy highlighting the importance to take those effects into account when designing mechanism. Particularly if spillovers exist a pure free market solution may not provide the long term least cost solution.

In principal there is a large variety of different support mechanism for RES. In Europe mainly quotas and feed-in tariffs, and in the US also production tax credits are applied (Palmer and Burtraw, 2005). We will focus our analysis on the first two methods.

Feed-in tariffs (FITs) parallel to Pigouvian taxes in emission regulation. By setting a specific price p for renewable support the actual quantity is defined by market participants via their investment behavior. FITs guarantee the purchase of green energy by the system operator at a fixed price which in turn is subsidized by the consumers. The price can either be a premium on top of the electricity market price or a total payment for the delivered energy. Feed-in tariffs allow a differentiated support of different technologies. Generally, more costly RES like solar energy also have higher feed-in tariffs. The guaranteed returns reduce the investment risk for RES and thus this mechanism is effective in bringing large numbers of renewable capacities to the marker (e.g. 23 GW of wind energy in Germany). However, the differentiated tariffs also create a higher cost burden for consumers compared to a least cost investment of green technologies as a higher share of more costly capacities is utilized. Under perfect information it is possible to set the FITs in a way such that the imposed renewable energy share is implemented.

Quotas or renewable portfolio standards are equivalent to the permit system of emission trading as they set an external target Q for the share of RES. In general, this system is combined with tradable green certificates (TGC). Either energy generators or consumers have to guarantee that the target share is met by their sales or purchases by owning a corresponding amount of TGCs. Thus, RES generators receive the market price for the energy delivery as well as the certificate price. The market mechanism is supposed to increase competition and obtain the quota in a least cost way. However, this mechanism has a higher investment risk than feed-in tariffs as the resulting certificate price is uncertain. Furthermore, possible gains from learning effects in high costs technologies like solar are not utilized as these technologies will not penetrate the market without specified support schemes. As quotas define the minimum level of renewable energies they implement the renewable target for sure. Like in the case of emission regulation, the information requirements to implement a specific renewable share are lower for the quantity regulation approach.

The effect of renewable support on electricity generation is shown in panel (c) of of Figure 1. Due to the granted subsidy, the marginal cost of renewable production is decreasing, the electricity price is decreasing due to the merit order effect, and, consequently, demand is increasing. The price reduction for RES can be interpreted as the amount of government spending on renewable support. Note that the refinancing issue has been neglected in the figure. In practice, feed-in tariffs are financed via taxes on the electricity price. Similarly, renewable quotas increase the cost of fossil fuel based generation since these technologies have to hold renewable certificates to fulfill the quota. Consequently, generation costs of fossil fuel based generation increases. Therefore, the price effect is ambiguous if refinancing is taken into account.

Interaction of emission trading and support for RES

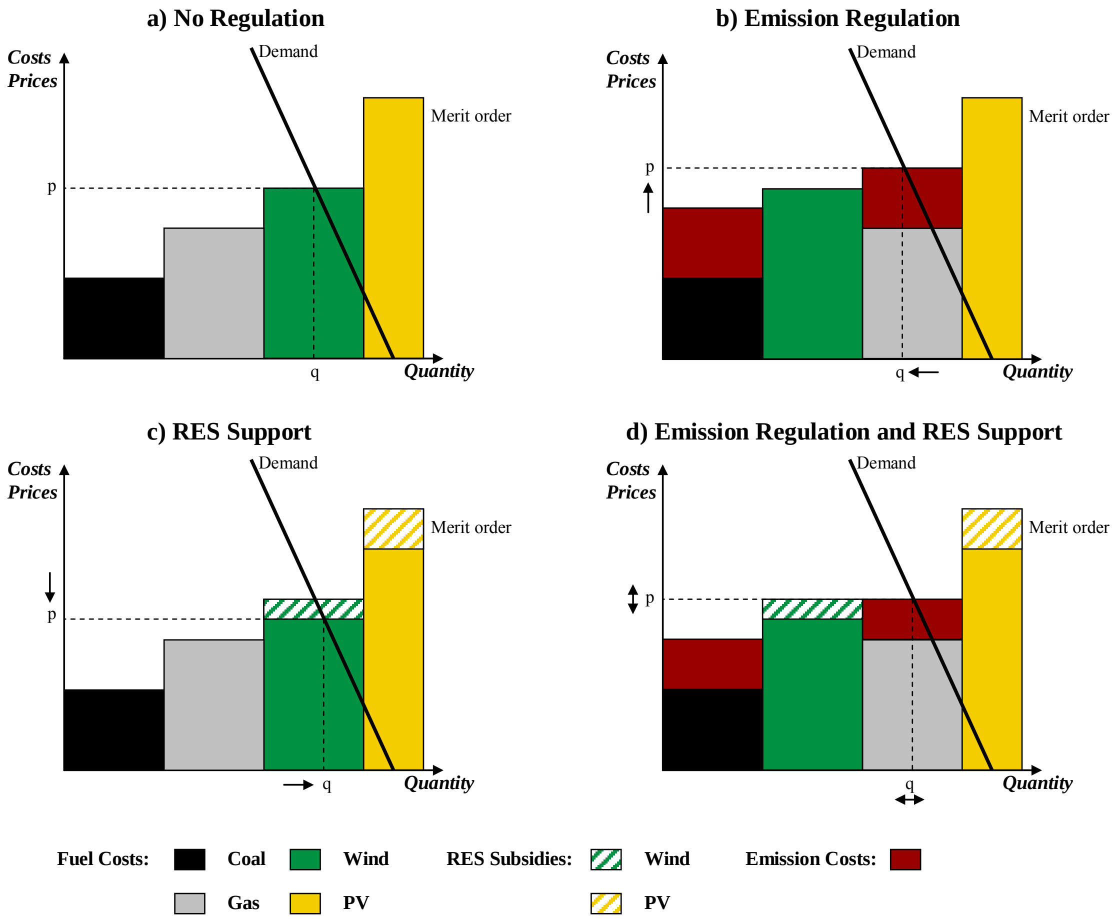
Emission trading and renewable support mechanism partly fulfill the same objective: the reduction of greenhouse gas emissions. Furthermore, they are aimed at the same market segment. Thus, this interaction leads to synergies as well as conflicts. Gonzáles (2007) provides an overview of the current literature on the interaction between both instruments including theoretical studies and applied analyses. The typology of interactions between and ETS and other policy instruments can be classified into three groups according to Sorrel and Sijm (2005): *direct interactions* were several instruments directly affect the target groups (e.g. if a company takes part in an ETS and is subject to CO_2 taxes); *indirect interaction* were instruments have a downstream effect on a target group (e.g. electricity consumers subject to an energy tax additionally face higher prices due to an ETS); and *trading interaction* were instruments influence themselves by a trading commodity (e.g. between the EU ETS and Kyoto allowances). Furthermore, they highlight the problem of double regulation of specific sectors and double counting of emissions.

Independently whether the support mechanism is implemented via a price or quantity target the increases share of RES has a direct impact on the emission level. A larger share of RES reduces the demand for emission allowances and thus brings allowance prices and in turn electricity prices down. The principal interaction of emission regulation and renewable energy support in electricity generation is highlighted in Panel (d) of Figure 1. The renewable support scheme lowers the generation cost for renewable energy production. Since the increased renewable share lowers the share of fossil fuel based generation, demand for emission allowances and thus emission costs are decreasing. Therefore, the increase of generation cost of fossil fuel based generation is less than in the case of pure carbon regulation (panel (b)). The overall effect on electricity prices and demand is ambiguous.

Depending on the RES support mechanism the introduction of an ETS can also help to improve the competitiveness of RES. Jensen and Skytte (2003) and Skytte (2006) show that if either a RES and/or emission quota should be reached the optimal instrument design depends on the correlation of consumer prices and the respective quotas. If increased RES utilization leads to reduced prices only a RES quota should be applied to reach a RES target whereas a combination of ETS and RES support should be applied in case of a price increasing effect. If only an emission goal is to be reached a RES system should again be applied if it reduces consumer prices and a pure emission trading in the other case. If a combination of RES and emission quotas is to be reached either a pure RES support or a mixture should be applied but not a pure ETS scheme.

Bräuer et al. (2001) provide a comparison of an isolated analysis of emission trading and green energy promotion with a combined analysis. They show that in the case of a closed coexistence like in a feed-in tariffs scheme the increased share of RES leads to a reduced need for emission allowances and thus to lower prices. They highlight that an open coexistence with tradable green certificates and an ETS is the most beneficial solution for those market participants that have to fulfill the renewable and emission quota as on both markets prices are lower than in an isolated system.

Figure 1: Effect of climate policy on electricity prices



3 Model and Parameterization

Our model is a static open economy computable general equilibrium (CGE) model designed to investigate the interaction between tradable CO_2 permits and different policies to promote renewable energies. CGE models have become standard in the analysis of economy wide policies (see Conrad, 1994, Wing, 2007). Their main advantage is the concise representation of price dependent market interaction on the basis of microeconomic theory.

The model is based on the German input-output table of the year 2004 (German Statistical Office, 2008a) which identifies 71 industries and commodities. Furthermore, the German statistical office provides energy flows and emissions of the German economy (German Statistical Office, 2008b) which are used to construct physical energy flows corresponding to value flows of the input-output table and carbon emissions. In order to account for different carbon contents of fuels, energy commodities are represented in a disaggregated way. Remaining industries are aggregated along the NACE classification except energy intensive industries which are aggregated along Annex I of the European emission trading directive (Directive 2003/87/EC). Detailed aggregation is given in Table 1.

Table 1 Production Sectors in the Model

	Production Sector	Code	Aggregation
Non-energy	Agriculture	AGR	NACE A, B
	Mining	MIN	NACE C
	Manufacture	MAN	NACE D, F
	Energy Intensive Industries	EINT	European emission trading directive
	Services	SER	NACE G-H, J-P
	Transport	TRN	NACE I
Energy	Electricity	ELY	
	Coal	COA	
	Natural Gas	GAS	
	Crude Oil	CRU	
	Refined Oil	OIL	

Germany is treated as a small country with respect to international trade, i.e. world prices are not influenced by German trade activities. Following the Armington assumption (Armington, 1968) domestic produced and imported commodities are imperfect substitutes. The only exception is crude oil which is assumed to be an international homogenous commodity. In all scenarios the trade imbalance of the benchmark equilibrium is held constant.

Beside material and energy, sectoral production takes capital and labor as input. Both primary factors are supplied inelastically by a representative consumer. Factors are homogenous and sectoral mobile but international immobile. Production in non-electricity sectors is modeled via separable nested constant elasticity of substitution (CES) functions. The production structure is shown in Figure 3 in the Appendix. At the top-level, material inputs are combined with an aggregated of the composites value-added and energy commodities in a Leontief manner. The value-added composite combines primary factors capital and labor. The energy aggregate combines electricity and a fossil fuel aggregate.[2] At the bottom level, each fossil fuel is combined with carbon dioxide according to its carbon content. Substitution elasticities are listed in Table 4 in the Appendix.

For a detailed modeling of the electricity sector it is necessary to represent different electricity generation technologies. The production structure of the electricity sector is depicted in Figure 4 in the Appendix. At the top level, electricity generation is combined with an aggregate of the value-added composite and material inputs. Generation technologies are represented using the combined top-down bottom-up modeling approach (Böhringer, 1998, Böhringer and Rutherford, 2008). Each technology is characterized by a Leontief unit input vector of capital, labor, and fuel input. The unit inputs vectors are derived from engineering bottom-up studies which are calibrated to fit into the top-down input-output framework using the method proposed by Wing (2006). Each technology is associated to base, mid, or peak load. A list of technologies input vectors, their respective load segment, and benchmark output is given in Table 1. The table also provides cost disadvantage for initially inactive technologies in form of markups as well as exogenously imposed capacity limits due to technological and political constraints (BMU, 2007).

Within the load patterns technologies are perfect substitutes. The perfect substitutability assumption leads to a problem known as flip-flop behavior: small changes in relative prices lead to extreme changes in the technology structure of electricity generation. To avoid these unrealistic reactions, we use a CES function with a high substitution elasticity of 10 to combine electricity output of technologies in the specific load segments. The high elasticity results in isoquants which are nearly straight lines (perfect substitutes). However, the share preserving character of the CES function prevents technologies' generation share not to react in an extreme manner (Wing, 2008). Capacity adjustments are modeled via technology specific capital stocks. The supply of technology specific capital provides an upper bound on the generation activity and, thus, is interpreted as technologies' installed capacity. In turn, the price of the specific capital is interpreted as the rent on generation capacity which is different from the standard malleable capital rent. Capacity adjustment is governed by a constant elasticity of transformation (CET) function which takes malleable capital as input and provides technology specific capital as output (Wing, 2008). The value of transformation elasticity indicates how easy capacity can be adjusted. Since there are no empirical values of this elasticity we take it as 1 and perform sensitivity analysis.

The representative agent maximizes utility subject to the budget constraint. The utility function is modeled as separable CES function (Figure 5 in Appendix). At the top level, a composite of energy commodities and other consumption commodities is combined with constant substitution elasticity. The energy composite aggregates electricity and fossil fuels, which are combined with carbon in a Leontief manner. Government consumption and investment demands are hold constant across scenarios and modeled with Leontief functions.

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[2] Crude oil does not enter the fossil fuel nest but is seen as an intermediate input.

Table 2: Electricity Generation Technologies

Technology	Load	Capital	Labor	Fuel	Markup	Output (TJ)	Capacity Limit (TJ)
Active Technologies							
Lignite	Base	46.41%	19.47%	30.94%		579457	-
Nuclear	Base	59.44%	22.09%	15.40%		596346	596346
Biomass	Base	63.14%	34.27%	-		41245	41245
Other	Base	58.11%	39.51%	-		49327	49327
Hard Coal	Mid	37.50%	15.42%	43.75%		526995	-
Natural Gas Combined Cycle	Mid	16.32%	8.70%	71.38%		145363	-
Wind Onshore	Mid	74.70%	22.23%	-		91658	245000
Natural Gas Open Cycle	Peak	32.91%	17.81%	46.04%		53335	-
Oil	Peak	25.57%	6.60%	64.15%		36520	-
Water	Peak	79.13%	17.62%	-		100178	100178
Inactive Technologies							
Coal CCS	Base	63.39%	22.00%	11.53%	25%		-
Hard Coal	Base	37.50%	15.42%	43.75%	19%		-
Natural Gas Combined Cycle	Base	16.32%	8.70%	71.38%	19%		-
Natural Gas CCS	Mid	51.87%	20.00%	24.98%	15%		-
Photovoltaic	Mid	92.06%	4.15%	-	150%		378000
Wind Offshore	Mid	77.5%	22.5%	-	10%		534000

Source: Authors own calculations based on Naini et al. (2005), Kaltschmitt et al. (2007). Markups of hard coal and combined cycle natural gas in base load are equal to average spread between base and mid load price at the European Energy Exchange (EEX) in 2004. Data of CCS technologies are taken from McFarland et al. (2004). Since shares net of taxes are presented, shares do not sum to one.

4 Scenarios and Results

Beside the business-as usual scenario (BAU), which replicates the German economy of the year 2004, we implement three different scenarios: First, the electricity sector and energy intensive industries are obliged to reduce their emission by 20%. Allowances trade between these sectors is allowed. Second, the scenario 20-20-uniform implements a 20% renewable energy quota for electricity generation on top of the 20% reduction target. Third, the scenario 20-20-differentiated also implements the additional 20% renewable generation target. However, a feed-in tariff is used to implement the target. Subsidies for renewable generation are differentiated by technologies and financed by a tax on electricity sector output. Each renewable technology receives a basic subsidy multiplied with a technology specific multiplier. The differentiation is oriented towards the German feed in tariff system

(EEG, 2008): onshore wind power is rewarded with the base subsidy, biomass generation gets 127%, offshore wind power 141%, and photovoltaic 467% of the base subsidy.

Table 3 shows the impact of the different policy instruments on the electricity sector and on carbon prices. In the 20% emission reduction scenario, the carbon price becomes 3.43 €/t CO_2. This leads to a cost increase and, thus, the electricity price increases by 2.16%. The higher prices lead to a decrease of electricity demand and, therefore, of electricity supply. Figure 2 and Table 5 in the Appendix show the impact on the technology mix in electricity generation. Due to the carbon constraint, conventional generation becomes more costly. Thus, offshore wind energy becomes competitive and enters the technology mix. Since wind energy enters the mid load segment, generation from hard coal is decreasing. In contrast, the share of the more polluting lignite production remains nearly constant. The reason behind this counterintuitive result lies in the fact that lignite is generating in the base load segment. However, except CCS which does not become competitive, there is no less carbon intensive alternative in base load since nuclear, biomass, and other generation are not allowed to increase further. The welfare impact of the 20% emission reduction of the electricity and energy intensive sector is slightly negative.

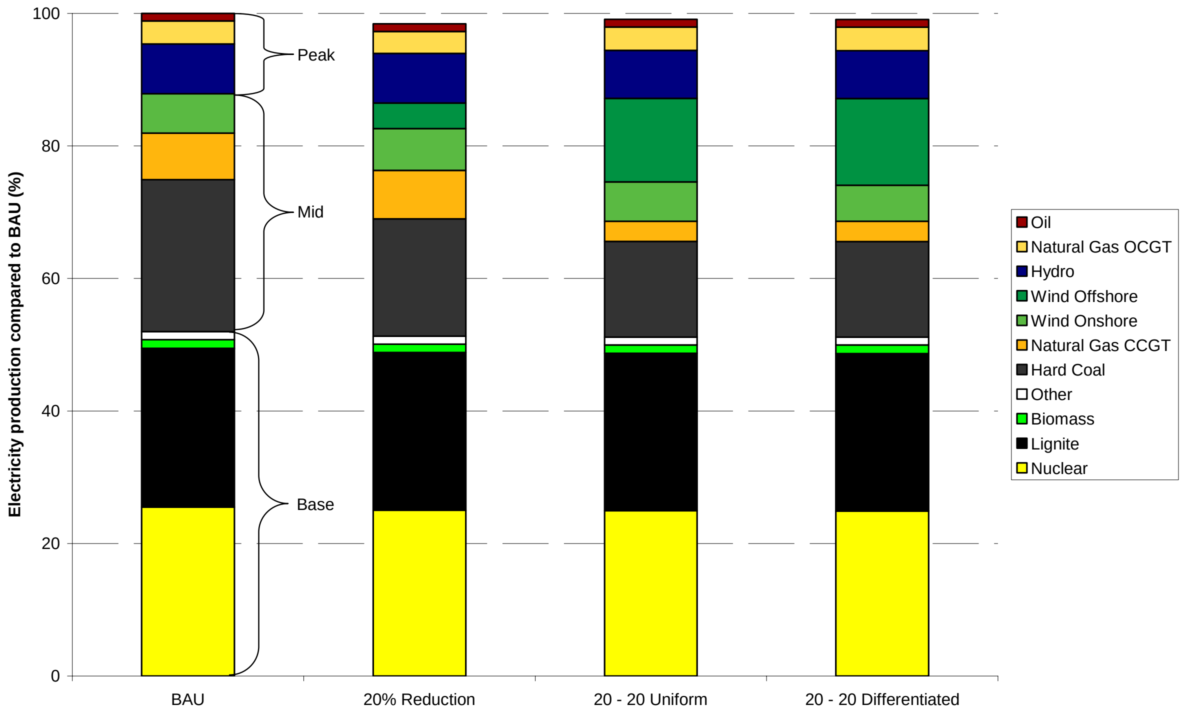
Surprisingly, imposing a renewable quota of 20% in addition to the emission reduction leads to a carbon price of zero. Due to the high share of renewables in electricity generation, the electricity sector already avoids 37% of its emissions. Therefore, the imposed carbon constraint becomes non-binding and the price drops to zero. Put differently, the high target of renewable generation leads to excess supply of emission allowances and, thus, to a zero emission price. Independently whether uniform or differentiated feed-in tariffs are used, the electricity price is decreasing compared to the pure reduction scenario. Accordingly, electricity demand is also increasing leading to a higher electricity supply compared to the 20% reduction scenario. Both renewable policies lead to a higher welfare loss than the pure reduction scenario since electricity producers deviate from their cost minimizing generation portfolio. This effect is only slightly more negative for the case of differentiated feed-inn tariffs.

The reason for the nearly equal performance of the different renewable policies is revealed in Figure 2 and Table 5 in the Appendix. Independent of the instrument used, the renewable quota is fulfilled by using offshore wind energy. Like in the pure reduction scenario, this leads to a decline of generation from hard coal. Even with a high feed-in tariff for PV in the differentiated scenario, this technology does not become competitive. Comparing the technology mix under uniform and differentiated feed-ins shows that slightly more onshore instead of offshore wind energy is used in the case of differentiated feed-ins. This deviation from the cost efficient generation portfolio under a uniform renewable subsidy causes the slightly more negative welfare impact.

Table 3: Carbon Price, Electricity Price, Supply, and Demand

	20% Reduction	20 – 20 Uniform	20 – 20 Differentiated
Carbon Price (€/t CO2)	3.43	0.00	0.00
Electricity Price (% vs BAU)	2.16	1.11	1.12
Electricity Demand (% vs BAU)	-1.08	-0.72	-0.72
Electricity Supply (% vs BAU)	-1.60	-0.99	-1.00
Welfare (HEV % vs BAU)	-0.0019	-0.0209	-0.0213

Figure 2: Electricity Production by Technology Compared to BAU (in %)



5 Conclusion

In this paper, we analyze the interaction of tradable emission permits and different support mechanisms for electricity generation from renewable energy sources, i.e. uniform quota system and differentiated feed-in tariffs. Using a top-down computable general equilibrium model which incorporates bottom-up features for electricity generation, we imposed a 20% emission reduction target for the electricity and energy intensive sector together with a 20% quota for electricity production from renewable energy sources.

From our results we draw two major conclusions: First, supporting renewable energy leads to a decreasing carbon prices and, thus, also decreasing electricity price since the increased share of renewables decreases demand for carbon permits. In the extreme situation shown in this paper, the imposed renewable quota leads to excess supply of carbon permits and, in turn, to a zero carbon permit price. This result has an import implication for policy design: if renewable targets are set too tight, carbon regulation becomes redundant, i.e. the implementation and administrative cost of carbon trading are spent without any benefit. The argument is valid the other way around, too: imposing strict carbon regulation could lead to a renewable share exceeding the proposed renewable quota and, thus, feed-in or tradable green certificates schemes are superfluous. With an eye on the proposed 20-20-20 target of the EU which furthermore includes an improvement of economies' energy efficiency by 20%, this interaction becomes even more important.

Second, imposing a renewable quota on top of an emission trading system, leads to a further welfare loss. In the case of a support scheme differentiated by technologies, the welfare loss becomes even larger. Therefore, an additional renewable quota and the differentiation of the support scheme have to be justified. Learning effects are the standard justification of renewable energy support. Generally, it is agreed that there are learning effects for renewable generation technologies. Therefore, a uniform support scheme for renewable energies points into the right direction. However, differentiating such a system by technologies needs to be justified by different learning rates. However, these rates are generally unknown and hard to estimate. Therefore, an efficient differentiation seems to be impossible. Furthermore, if renewable support schemes are justified on the base of learning effects, then the same argument applies for other emerging technologies which are not renewable but supposed to have learning effects, like CCS technologies.

The obtained results are highly sensitive to the assumptions about the cost-disadvantages of new technologies. Particularly the low allowance prices are a consequence of the large share of offshore wind capacities installed. This large offshore generation is a result of the optimistic assumption of an 20% cost-disadvantage of offshore wind compared to other mid-load technologies. Further analysis is necessary to gain insights on the impact of different assumptions regarding technology.

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Appendix

Figure 3: Production Structure Except Electricity Sector

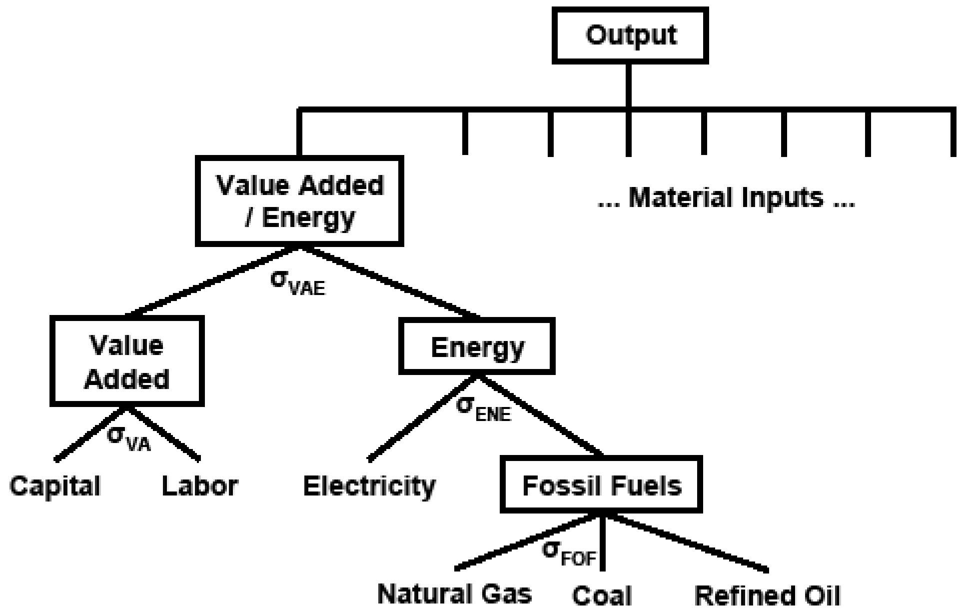

Figure 4: Production Structure Electricity Sector

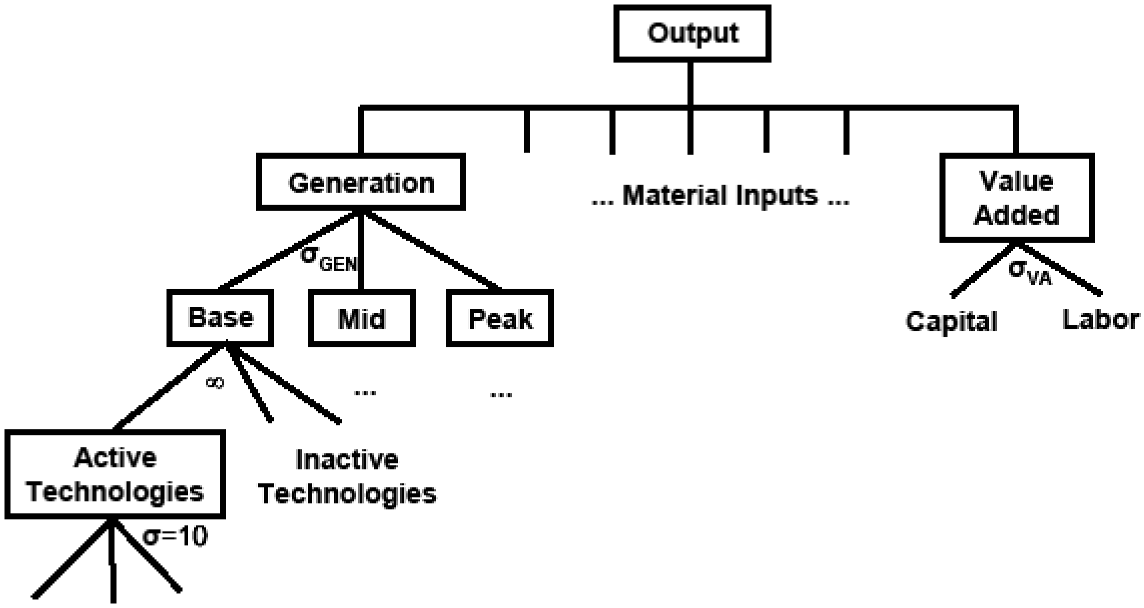

Figure 5: Utility Structure

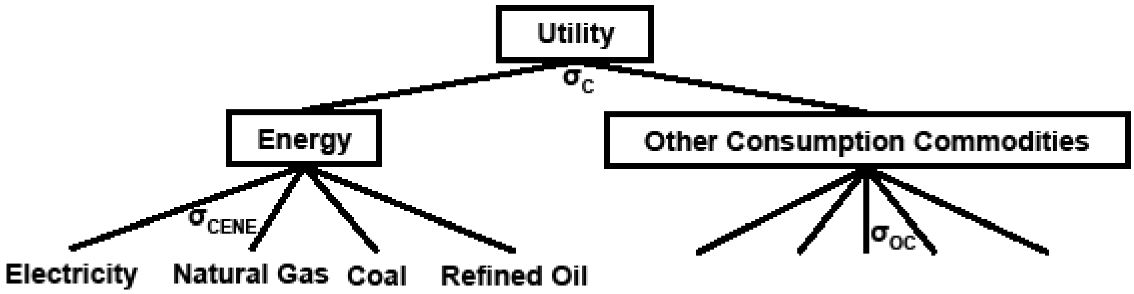

Table 4: Substitution Elasticities

Elasticity	Value	Description
		Production
σ_{VAE}	0.4	Values added and energy aggregate
σ_{VA}	1	Primary factors capital and labor
σ_{ENE}	0.5	Electricity and fossil fuel aggregate
σ_{FOF}	1	Different fossil fuels
σ_{GEN}	0.1	Different load segments in electricity production
		Utility
σ_{C}	0.25	Other and energy consumption
σ_{OC}	0.3	Other consumption commodities
σ_{CENE}	0.4	Energy commodities
		Trade
σ_{DM}	2	Combines domestic and imported commodities (electricity: 0.3)

Table 5: Generation Shares by Technologies (in %)

	BAU	20% Reduction	20 - 20 Uniform	20 - 20 Differentiated
Lignite	24.0	24.2	24.0	24.0
Nuclear	25.5	25.4	25.1	25.2
Biomass	1.3	1.3	1.3	1.3
Other	1.2	1.2	1.2	1.2
Hard Coal	22.9	18.0	14.6	14.6
Natural Gas CCGT	7.0	7.4	3.1	3.1
Wind Onshore	6.0	6.4	5.5	6.0
Wind Offshore	0.0	3.9	13.2	12.7
Hydro	7.5	7.6	7.3	7.3
Natural Gas OCGT	3.5	3.3	3.6	3.6
Oil	1.1	1.2	1.2	1.2