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Publication date:
2003

Document Version
Publisher's PDF, also known as Version of record

Linking promotion strategies for RES-E and CO_2 reduction in a liberalised power market: Is a simultaneous policy necessary?

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Abstract

Three important issues with respect to the integration of different renewable energy sources into the liberalised European electricity market and the international condition of GHG-reduction will be investigated in this paper.
First, it will be analysed how most important promotion schemes (feed-in tariffs, quota systems) for different renewable energy sources for electricity generation (RES-E) interact with the liberalised market.
Second, the influence of the restriction of the greenhouse gas emissions on the electricity generation and the international electricity market price will be discussed.
Third, the interaction of RES-E, conventional electricity generation and GHG-reduction with the three markets, for physical power, green certificates and emission trading will be analysis, i.e. it will be evaluated how new environmental markets, such as tradable emission allowances may affect or overlap with the promotion of RES.
Special focus will be given on the effect of national GHG-reduction as well as on the effects for the producer and consumer, respectively.
A number of policy recommendations in relation to the integration of the three markets and trade-offs between technologies and promotion schemes will be made.

1 Introduction

The power market within the European Union and other countries around the world is, currently, in high transition. The reason is threefold, namely:

First, due to the liberalisation process of the mostly restrict regulated conventional electricity market in the past. According to the European Commission (EC, 1997a) the driving forces of this process, which started during the last decade, is the goal to maximise the efficiency of the electricity supply sector and to reduce consumer prices.

Second, increasing the share of renewable energy sources for electricity generation (RES-E) has a high priority in the energy strategies of the European Commission (and other countries). The 'White Paper on Renewable Sources of Energy' (EC, 1997b) as well as the 'RES-E Directive' (European Parliament and Council, 2001), set essential goals to double the share of renewables in the electricity generation mix of EU countries by 2010. For example, the EU-directive including a proposal on the share of renewable in the individual member states in 2010, based on the percentage of each country's consumption of electricity. Although not binding it seems that these indicative targets by now are accepted by the EU member states. As the EU-directive fails to indicate, which promotion schemes should be used to reach these goals, different strategies have to be derived; see e.g. Haas et at (2001) or Huber et at (2001a). Most promising instruments are guaranteed feed-in tariffs for electricity produced from RES and a quota system for RES-E generation. To facilitate the fulfilment of the quota obligation and to increase the cost efficiency of this instrument tradable green certificates (TGC) should be connected to the quota. This means, that the quota is the regulation instrument, whereas the TGC are used by the market actors to fulfil the quota.

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Third, most industrial countries have consented to reduce its greenhouse gas (GHG) emissions under the Kyoto protocol. The European Union has agreed on a common GHG reduction of 8% in the period 2008-2012 compared to the emission level of 1990. According to the agreed burden sharing within the European Union this overall EU-target is converted into national GHG reduction-targets for each of the member states. Thus, some of the member states will have to reduce their GHG-emissions significantly in the above-mentioned time-period, while others are allowed to increase their emissions, mostly on account of a required economic development. In this way the EU bubble is translated into a set of national commitments, calling for country specific strategies to comply with their Kyoto commitment. In parallel with national emission reduction initiatives, however, common EU policies for GHG emission reductions are considered. In December 2002 it has been decided to introduce an EU-wide GHG allowance trading scheme for the power industry and other energy intensive industries (EC, 2001). The core idea of such a system is to ensure that GHG reductions in the included sectors are undertaken in the most cost-efficient manner. This means that actual GHG-reductions will mainly take place in those countries with the highest reduction potentials and the lowest costs. In this way the tradable emission allowances (TEAs) will help ensuring that the EU member countries achieve the Kyoto greenhouse gas reduction targets as cheap as possible.

Hence, summing up, the EU has three parallel core goals, namely:

- to bring down consumer prices
- to promote RES-E generation
- to reduce greenhouse-gas emissions.

In setting efficient framework conditions in order to fulfil the different goals, it is necessary to consider interactions between the contributing markets and thus the effects of different goals. For example a rise in the share of RES-E generation results in lower conventional power production. This leads to a decrease in the total amount of GHG-emissions. Therefore, RES-E promotion schemes have the positive effect of lower emissions and, hence, serve as GHG instrument too. Similar, an introduction of a GHG emission target favours RES-E technologies, because production costs from conventional fossil power plants raises due to the scarcity of emissions allowances. As a result, the market share assigned to RES-E generation increases. In addition, while a higher share of RES-E leads to a break down in the conventional spot market price[3], a GHG-target drives the spot market price upwards. How these schemes and the corresponding markets interact with each other is not a trivial matter.

This paper analyse these interactions, and tries to give the reader an understanding of how markets interact. In more detail three important issues with respect to the integration of different renewable energy sources into the liberalised conventional electricity market and the international condition of GHG-reduction will be investigated.

First, it will be analysed how most important promotion schemes for different renewable energy technologies for electricity generation – namely feed-in tariffs and quota systems with tradable green certificates - interact with the liberalised conventional electricity market.

Second, the linkage of different CO_2-targets with and the effects of the allocation of the corresponding tradable emission allowances on the liberalised power market will be investigated.

[3] Note the total effect of RES-E promotion strategies is, however, ambiguous, i.e. the total costs for the consumer (both conventional electricity and RES-E) could be either higher or lower than without a RES-E policy. For more details see Jensen and Skytte (2003)

Third, the interactions of RES-E, conventional electricity generation and GHG-reduction with the three markets, for physical power, tradable green certificates and GHG emission allowances will be investigated, i.e. it will be evaluated how new environmental markets, such as an international market for GHG emission allowances may affect or overlap with the promotion of RES-E.

In the analysis special concern is given in working out the consequences for the national GHG-reduction policy as well as the costs for the consumer pursuing the achievement of the goals. To facilitate the understanding, the investigation will be illustrated by a four countries / utilities example.

2 Model assumptions and conditions set in the numerical example

Before the interactions of different policies can be investigated, the main assumptions of the model are described. It is assumed that the following three general conditions are fulfilled.

- All considered countries have entrance to the same physical electricity market. In addition, there are no barriers for export/import of electricity between the countries.
- In the case of import / export of electricity GHG-emission adjustments are taken place.
- Electricity consumption is assumed to be constant and do not depend on the price level, i.e. the price-elasticity is zero.[4]

Table 1: Model specifications in the numerical four country example

	Country 1			Country 2			Country 3			Country 4		
	Demand: 110 TWh			Demand: 110 TWh			Demand: 40 TWh			Demand: 40 TWh		
	Generation costs	Potential	Specific CO_2-emissions	Generation costs	Potential	Specific CO_2-emissions	Generation costs	Potential	Specific CO_2-emissions	Generation costs	Potential	Specific CO_2-emissions
	€/MWh	TWh	tCO_2/MWh	€/MWh	TWh	tCO_2/MWh	€/MWh	TWh	tCO_2/MWh	€/MWh	TWh	tCO_2/MWh
Conv. 1	25,0	20	0,80	28,0	60	1,00	28,0	10	0,90	28,0	22	0,90
Conv. 2	28,0	30	1,00	31,0	38	0,40	29,0	14	0,85	32,5	22	0,38
Conv. 3	32,0	40	0,50	37,0	62	0,60	31,5	8	0,40	36,0	4	0,65
Conv. total		90			160			32			48	
RES-E 1	15,0	24	0,00	65,0	5	0,00	10,0	14	0,00	55,0	7	0,00
RES-E 2	65,0	24	0,00	70,0	6	0,00	68,0	22	0,00	69,0	14	0,00
RES-E 3	100,0	42	0,00	98,0	9	0,00	95,0	12	0,00	90,0	11	0,00
RES-E total		90			20			48			32	

As already mentioned above, a numerical example considering four countries will be used to illustrate the consequences of a certain policy on both national and international level.[5] Used specifications with respect to the generation costs and the specific CO_2-emissions are summarised in Table 1. It is assumed that two big countries (country 1 and 2) and two small ones exist. For each country three options to generate electricity by conventional fossil power plants and three options to generate electricity by RES-E are available. In addition, it is assumed that one big (country 1) and one small country (country 3) possesses a high(er) RES-

[4] In reality, small negative price elasticity can be observed.

[5] Consider: By replacing the name 'country 1' by 'utility 1', etc, the influence of different policy schemes on regional and national level, respectively, can be show.

E potential. Note that all data used in the numerical example are constructed, but especially with respect to cost curves caution is taken to make these ‘relatively’ close to the observed reality.

National conventional electricity market

Assuming, first, that the four countries are not connected by an international grid or import / export of electricity is (via political constraints) not possible.[6] Hence, each country has to fulfil the electricity demand by them. Obviously, depending on the national electricity supply structure, different national market prices occur. The average weighed electricity price is 33,83 €/MWh, see Table 2.

Table 2: National conventional electricity market

			Country 1	Country 2	Country 3	Country 4	Total
targets	electricity demand	[TWh]	110,0	110,0	40,0	40,0	300,0
electricity generation	conventional electricity	[TWh]	86,0	110,0	26,0	40,0	262,0
	RES-generation	[TWh]	24,0	0,0	14,0	0,0	**38,0**
	Import / Export (+/-)	[TWh]	0,0	0,0	0,0	0,0	0,0
	CO_2-emission	[Mt-CO_2]	64,0	82,4	21,7	26,6	**194,7**
market price	spot market price	[€/MWh]	32,00	37,00	31,50	32,50	
generation costs	conventional electricity	[M€]	2.492	3.302	749	1.201	7.744
	RES-E	[M€]	360	0	140	0	500
	generation costs	[M€]	2.852	3.302	889	1.201	**8.244**
effects on producer / consumer	producer surplus	[M€]	668	768	371	99	**1.906**
	consumer costs	[M€]	3.520	4.070	1.260	1.300	10.150
	consumer costs	[€/MWh]	32,00	37,00	31,50	32,50	**33,83**

Liberalised conventional electricity market

Allow international electricity trade between the suppliers among the different countries one of the major energy goals of the EC can be pursued, namely the reduction of consumer prices. The consequence of an international market is that **total generation costs in the considered countries can be reduced**, due to a higher (and cheaper) available portfolio of generation units. Neglecting any existing import / export barriers electricity generation costs can be minimised.[7]

Table 3: Liberalised conventional electricity market

			Country 1	Country 2	Country 3	Country 4	Total
targets	electricity demand	[TWh]	110,0	110,0	40,0	40,0	300,0
electricity generation	conventional electricity	[TWh]	90,0	98,0	32,0	42,0	262,0
	RES-generation	[TWh]	24,0	0,0	14,0	0,0	**38,0**
	Import / Export (+/-)	[TWh]	-4,0	12,0	-6,0	-2,0	0,0
	CO_2-emission	[Mt-CO_2]	66,0	75,2	24,1	27,4	**192,7**
market price	spot market price	[€/MWh]	32,50				
generation costs	conventional electricity	[M€]	2.620	2.858	938	1.266	7.682
	RES-E	[M€]	360	0	140	0	500
	generation costs	[M€]	2.980	2.858	1.078	1.266	**8.182**
effects on producer / consumer	producer surplus	[M€]	725	327	417	99	**1.568**
	consumer costs	[M€]	3.575	3.575	1.300	1.300	9.750
	consumer costs	[€/MWh]	32,50	32,50	32,50	32,50	**32,50**

In most cases the market extension leads to a cost reduction for the consumer too. This constrain, however, is not automatically guaranteed. While consumer in countries with an expensive generation bases and, hence, high prices gains from the liberalisation, customers in

[6] This case should be served as reference case.

[7] In the real world economic inefficiencies exists, due to insufficient grid extension among the countries.

countries with a cheap electricity production structure must expect that the electricity prices raises. Obviously, the total CO_2-emissions changes too, due to the different portfolio. In which direction - increasing or decreasing - however, depends only on specific CO_2-emissions of the operating plants, i.e. a **liberalisation of the electricity market must not automatically lead to a reduction on GHG emissions**! The results of the numerical example are summarised in Table 3.

3 Interactions between RES-E generation and liberalised conventional electricity market

In this sector it should be assumed that the government promotes RES-E generation to reduce (beside other goals) their national CO_2-emissions. More precisely, it will be discussed how most important promotion schemes for different RES-E technologies, i.e. a feed-in tariff scheme and quota systems with tradable green certificates, interact with the liberalised conventional electricity market.[8] Special attention will be given to the reduction of the national CO_2-emissions as well as the costs associated with the different policies.

3.1 Feed-in tariff [9]

Non-harmonised feed-in tariff and liberalised conventional electricity market

First, it should be assumed that the national governments introducing national-specific feed-in tariffs to increase their national RES-E production.[10] This means that each country offers different, non harmonised guaranteed prices for their RES-E generation. The results of these strategies are summarised in see Table 4. Totally, the RES-E production increases from 38 TWh to 140 TWh.

Table 4: Effects of a guaranteed price for RES -E in a liberalised conventional electricity market to reach a 'relative' unit share of RES -E generation related to the national consumption

			Country 1	Country 2	Country 3	Country 4	Total
targets	electricity demand	[TWh]	110,0	110,0	40,0	40,0	300,0
electricity generation	conventional electricity	[TWh]	50,0	64,0	24,0	22,0	160,0
	RES-generation	[TWh]	72,6	20,0	26,4	21,0	**140,0**
	Import / Export (+/-)	[TWh]	-12,6	26,0	-10,4	-3,0	0,0
	CO_2-emission	[Mt-CO_2]	46,0	61,6	20,9	19,8	**148,3**
market price	spot market price	[€/MWh]			31,00		
	feed-in tariff for RES-E	[€/MWh]	100,00	98,00	68,00	69,00	
generation costs	conventional electricity	[M€]	1.340	1.804	686	616	4.446
	RES-E	[M€]	4.380	1.627	983	1.351	8.341
	generation costs	[M€]	5.720	3.431	1.669	1.967	**12.787**
effects on producer / consumer	producer surplus	[M€]	3.090	513	870	164	**4.637**
	consumer costs	[M€]	8.419	4.750	2.217	2.038	17.424
	consumer costs	[€/MWh]	76,54	43,18	55,42	50,95	**58,08**

[8] Interactions between the different RES-E policies are described in detail in Huber et at (2001b).

[9] To be able to compare the numerical results of with those of the other sections (140 TWh RES-E generation), it is assumed that the amount, which can receive a guaranteed feed-in tariff is restricted. Note, this assumption is only necessary due to the constant cost curve for the single technologies in the numerical example. In practice, observing continuously increasing costs this condition is unnecessary.

[10] Feed-in tariffs permit RES-E producers to feed their electricity into the grid and to receive therefore a minimum price (the feed-in tariff), usually for specific period of time. Note: Similar results occur applying other price-driven promotion schemes like investment subsidies or tax-relief.

Assuming that total demand is constant, any additional RES-E generation will substitute conventional electricity generation.[11] The reason is that a market separation of RES-E and conventional electricity takes place, due to the introduction of such a RES-E strategies. Consequently, **an active RES-E policy leads to lower CO_2-emissions and to a lower spot market price for electricity**.[12]

A lower conventional electricity price, however, does not mean that the consumer automatically gains from the introduction of a RES-E promotion scheme. The reason is that they have to bear the additional costs from subsidising RES-E generation. Jensen and Skytte (2003) show that it is ambiguous whether the additional cost is larger than the saved cost. Therefore, **the consumer costs can either increase or decrease, as a result of introducing a promotion scheme.** In practise, considering that the cost curve for conventional electricity is flat, an increase of the consumer prices can be expected.[13] The electricity prices in the single countries, however, differ significantly. Note that the electricity price level do not explicitly depend on the level of the feed-in tariff (compare country 1 and country 2) but also on the actual share of RES-E production. Premium costs are high in countries with a large share of RES-E and low in countries with a restricted RES-E generation. Summing up, **a feed-in tariff set individually and uncoordinated by the national governments leads to distortions among the consumers in the countries**.

Due to the higher share of RES-E production, total cost efficiency of the electricity supply drops, i.e. **total generation costs raises**.[14]

The situation for the producer is similar to those for the consumer. They can either win or lose from the introduction of a RES-E policy. Under the assumption that RES-E cost curve is step and conventional marginal generation cost curve is flat –as observable in practise – producer surplus will rise, too, compare Table 3 and Table 4.

In parallel with the change of the production structure, the import / export balances of the countries alter too. The distribution of the national conventional electricity reduction is independent from the total national RES-E generation. The reason is that the national conventional electricity production depends only from the conditions on the international spot market (marginal generation plant). [15] As CO_2-emissions are related to the power generation the same conclusion is valid for the national CO_2-reduction: **How the total increase in RES-E generation by itself is distributed upon the countries has no influence upon the realised CO_2-reduction in each of the countries**. This is totally determined by the marginal cost conditions at the spot market and the specific CO_2-emissions of the substituted electricity (Morthorst, 2003).[16]

Thus, the main result with respect to national climate change policy is: **Within a liberalised electricity market the deployment of RES-E generation as an important instrument for**

[11] In the case of price elasticity the occurring substitution rate is a bit lower.

[12] In the numerical model CO_2-emissions drops from 192,5 Mt-CO_2 to 148,3 Mt-CO_2 or 23%. The spot market price decreases from 32,5 €/MWh to 31 €/MWh.

[13] In the four country example average consumer prices rises from 32,5 €/MWh to 58,08 €/MWh.

[14] In the model, generation costs rise by approximately 56% to 12.787 Mio. €.

[15] E.g.: the conventional electricity generation in country 1 drops from 95 TWh to 50 TWh due to the lower demand for conventional electricity.

[16] A comparison of country 2 and 3 in the numerical example illustrates this fact. While an increase of the RES-E generation by 12,4 TWh in country 3 leads to a CO_2 reduction of only 3,2 Mt-CO_2, a rise in country 2 by 20,0 TWh results in a CO_2 reduction of 13,6 Mt-CO_2.
Note: In contrast to an international power market, separated non-opened national conventional electricity markets would lead to an appropriate domestic CO_2-reduction. However, under this condition a higher and non-harmonised power price occur.

obtaining significantly national CO_2-reductions cannot be recommended by itself. In general, this result stems from the fact that national reduction targets for CO_2-emissions do not go well together with a liberalised power market.

The remaining question arises is: Can a harmonised promotion scheme improve the unsatisfactory situation for both distortions among the consumer costs and the actual national CO_2-reduction.

Harmonised feed-in tariff and liberalised conventional electricity market

Now the situation will be investigated that all countries agree to harmonise their guaranteed feed-in price for RES-E. Assuming that the same quantity of RES-E electricity will be generated – otherwise the cases can not be compared - no change in both, the total and the national CO_2-emissions occurs. This means, **despite a harmonised promotion scheme for RES-E no homogenous (national) CO_2-reduction benefits among the countries can be expected, too**. The only certain **advantage of a harmonisation of the promotion system on the global level is that total generation costs are minimised**.[17] The reason is that all RES-E technologies in all countries receive the same subsidy, so – similar to a trading scheme - only most 'efficient' technologies are used.

Table 5: Effects of a harmonised guaranteed price for RES-E / minimum guaranteed price for RES-E minimising generation costs in a liberalised conventional electricity market

			Country 1	Country 2	Country 3	Country 4	Total
targets	electricity demand	[TWh]	110,0	110,0	40,0	40,0	300,0
electricity generation	conventional electricity	[TWh]	50,0	64,0	24,0	22,0	160,0
	RES-generation	[TWh]	48,0	12,0	48,0	32,0	**140,0**
	Import / Export (+/-)	[TWh]	12,0	34,0	-32,0	-14,0	0,0
	CO_2-emission	[Mt-CO_2]	46,0	61,6	20,9	19,8	**148,3**
market price	spot market price	[€/MWh]	31,00				
	feed-in tariff for RES-E	[€/MWh]	98,00	98,00	98,00	98,00	
generation costs	conventional electricity	[M€]	1.340	1.804	686	616	4.446
	RES-E	[M€]	1.920	843	2.776	2.341	7.880
	generation costs	[M€]	3.260	2.647	3.462	2.957	**12.326**
effects on producer / consumer	producer surplus	[M€]	2.994	513	1.986	861	**6.354**
	consumer costs	[M€]	6.626	4.214	4.456	3.384	18.680
	consumer costs	[€/MWh]	60,24	38,31	111,4	84,60	**62,27**

The consequences for the producer are ambiguous. While producer in countries with increasing feed-in tariff gains compared to the non-harmonised case before, producer with a lower harmonised tariff loss.[18] The impact of a harmonisation for the consumer is contrary to them for the producer. Here consumer in countries with a reduction of the guaranteed feed-in tariff gains.[19] Note that a **homogeneous promotion scheme among the countries must not necessarily lead to fewer distortions among the consumer costs in the different countries**. High costs for the customers occur in those states with a high share of actual RES-E generation, i.e. in countries with large cheap RES-E potential.

Summing up, it can be concluded that - independently if the price driven RES-E promotion strategies are harmonised or not internationally - distortions in the RES-E generation and in the national CO_2-reduction occurs. In the following section it will be analysed if a market instrument, a quota system for RES-E generation in combination with TGCs, fits better in a liberalised electricity market reducing national CO_2-emissions.

[17] In the numerical example, generation costs can be reduced by 3,6%.

[18] In our example producer in country 3 and country 4 win significantly.

[19] In practice, this situation will lead to conflicts pushing or hindering a harmonisation between producers and consumers.

3.2 Quota system

Assuming that a quota system with TGCs will be implemented, the following additional model conditions are made:

- free international TGC trade is possible, i.e. it is assumed that all countries have accepted the same rules for TGC trading
- no GHG-credits are attached to the green certificates, i.e. no tradable GHG emission allowances (TEA) must be provided with the TGCs.

The introduction of a quota system leads – similar to a feed-in tariff, where the electricity will be feet into the grid at a guaranteed price and is, therefore, not available for the conventional power market - to a market separation between conventional electricity production and RES-E generation.[20] While the demand for the RES-E market is determined by the total quota obligation for RES-E, the demand for conventional electricity yields by the difference between total demand and the total quota for RES-E. Hence, how the substitution of conventional electricity is split upon the single countries is determined by two factors, firstly, the total RES-E quota and, secondly, the marginal cost conditions at the spot market. This means, **how the total RES-E quota by itself is distributed upon the countries has no influence upon the realised substitution of conventional electricity, which depends totally on the marginal cost conditions at the spot market**. As the TGC-systems allow international trade of RES-E generation, the actual RES-E development within a country depends on the international TGC market price. In other words, **the RES-E deployment in one country is fully determined by the total (aggregated) quota for all countries**, i.e. it is independent from the national quota obligation. In addition, the joint TGC-market guarantees that only cost efficient RES-E technologies will be used.

Table 6: Effects of a non-unit and a unit quota system per consumption for RES-E generation in a liberalised conventional electricity market

			Country 1	Country 2	Country 3	Country 4	Total
targets	electricity demand	[TWh]	110,0	110,0	40,0	40,0	300,0
	RES-E target	[%]	46,7 / 60,0	46,7 / 36,4	46,7 / 75,0	46,7 / 10,0	46,7 / 46,7
electricity generation	conventional electricity	[TWh]	50,0	64,0	24,0	22,0	160,0
	RES-generation	[TWh]	48,0	12,0	48,0	32,0	**140,0**
	Import / Export (+/-)	[TWh]	12,0	34,0	-32,0	-14,0	0,0
	CO_2-emission	[Mt-CO_2]	46,0	61,6	20,9	19,8	**148,3**
market price	spot market price	[€/MWh]			31,00		
	TGC price	[€/MWh]			67,00		
generation costs	conventional electricity	[M€]	1.340	1.804	686	616	4.446
	RES-E	[M€]	1.920	843	2.776	2.341	7.880
	generation costs	[M€]	3.260	2.647	3.462	2.957	**12.326**
effects on producer / consumer	producer surplus	[M€]	2.994	513	1.986	861	**6.354**
	consumer costs	[M€]	6.849 / 7.832	6.849 / 6.090	2.491 / 3.250	2.491 / 1.508	18.680 / 18.680
	consumer costs	[€/MWh]	62,27 / 71,20	62,27 / 55,36	62,27 / 81,25	62,27 / 37,70	**62,27 / 62,27**

Most important results of the numerical example are summarised in Table 6 for two cases:

- country specific obligations, i.e. countries, more ambitious in promoting RES-E (and reducing national CO_2-emissions) impose a higher quota than more modest countries.

[20] In the case of investment subsides, tax relief or guaranteed premium prices for RES-E generation (= premium feed-in tariff system as implemented e.g. in Spain) no market separation takes place. Due to the subsidy, however, marginal generation costs for RES-E technologies will be reduced by this amount. RES-E must compete with conventional power generation at a joint electricity market. In principle, however, the same generation structures and costs occur than implementing a feed-in tariff.

- unit quota obligation per electricity demand in all countries[21]

Independently how the quota allocation looks like, the same generation structure and the same CO_2-emissions occurs as implementing a harmonised feed-in tariff, if the guaranteed price is set equal to the spot market price plus the TGC price. In the case that each country should fulfil the same RES-E target per consumption, distortions between the electricity consumers in the single countries can be avoided.[22] Observe that **the quota allocation has no influence on the producer surplus of the RES-E producer in the countries**. The reason is that the quota allocation does not influence the actual RES-E generation in the countries.

As already mentioned, independently of the national quota allocation – observe that just the total quota for all countries is relevant – both conventional and RES-E generation are determined by their marginal cost conditions at their single market (spot price market and TGC market). This means that **the amount of RES-E generation, the conventional power production and the national CO_2-emissions in one country are independent of the RES-E quota allocation in this country**. Even in the case that one country increases the internationally agreed total quota autonomously, i.e. the total RES-E quota will be extended, only a certain share of both RES-E generation and national CO_2- reduction can be gained by this country. Thus, the main result of the ambitious RES-E quota setting in one country is that they have to share the actual additional RES-E generation as well as the achieved CO_2-reduction with the less ambitious countries.

Summing up, **from the perspective of a national CO_2-reduction policy, a separate introduction of an international green certificate system into a liberalised electricity market cannot be recommended either, if the TGC-market is expected to contribute to achieving the national CO_2-reduction targets.** But of course the development of RES-E production in general does contribute to overall international GHG reductions.

Figure 1 compares the national CO_2 reductions, the additional national RES-E generation and the resulting specific national CO_2 reduction factors due to the substitution of conventional power for three cases:

- non-harmonised feed-in tariff plus national electricity trade [23](left bars)
- non-harmonised feed-in tariff plus international electricity trade (bars in the middle)
- international quota system (or equivalent harmonised feed-in tariff) plus international trade (right bars)

It can be seen that, allowing international electricity trade, no distinctions between a feed-in tariff and a quota system on a global level exist with respect to both the global CO_2-emissions

[21] Observe to be able to compare the results, it is assumed that the total RES-E quota remains unchanged in the two sub-cases.

[22] Note: According to the 'RES-E' directive (European Parliament and Council 2001) a EU-target of 22,1% must be fulfilled by 2010. The indicative targets for the single EU member countries are set, however, very different. This means, that - assuming an international TGC trading system will be introduced– the consumer in the countries are imposed with quite different addition costs for the fulfilment of the national targets. A simulation with the model **El*Green*** (Huber 2001a) show that the premium price varies between 3,6 €/MWh in Belgium and 53,9 €/MWh in Austria. Assuming a unit quota allocation between the countries (each country has to fulfil a quota of 22,1%) the additional costs would be 15,0 €/MWh.

[23] This case is added to illustrate the interactions between the international electricity market and the countries. It assumes that a non-harmonised feed-in tariff (as described in the section before) will be granted. Due to the national market restriction all additional RES-E generation substitutes national conventional electricity production. Note that the turn back of the liberalisation process of the conventional electricity market is currently not realistic.

and the specific CO_2-substitition factor; see bracket total in Figure 1. Observe that they are lower in this (specific) example compared to pure national electricity markets.[24] With respect to the country specific emissions huge differences occur. For example, country 2 gains significantly due to the additional RES-E generation in the other countries as indicated by the high country-specific CO_2-reduction factor.

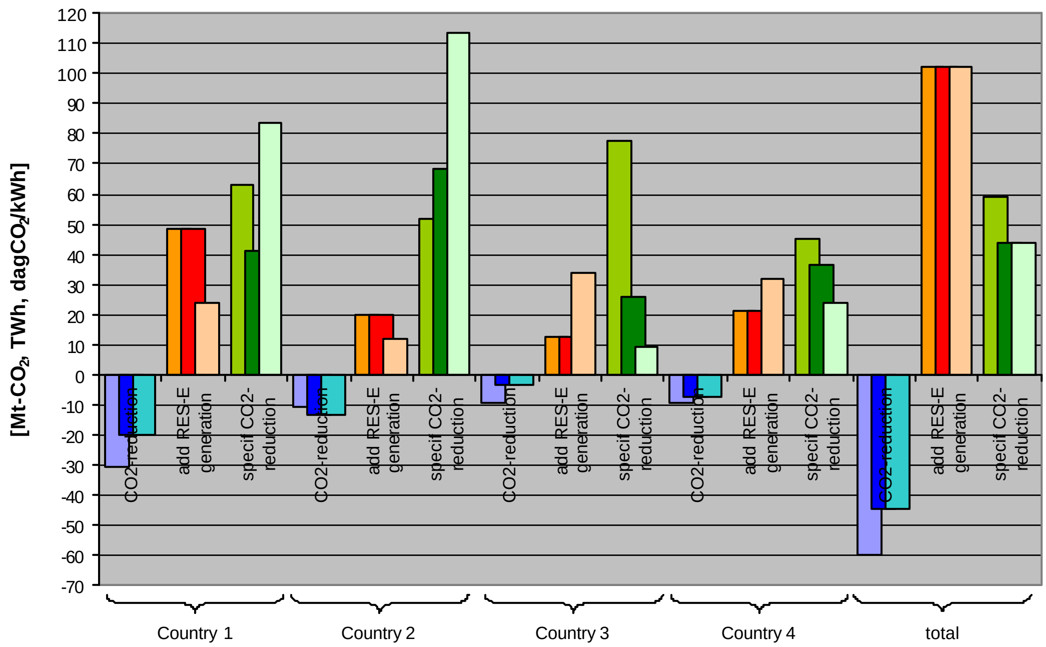

Figure 1: Comparison of national CO_2-reduction, additional national RES-E generation and specific CO_2-reductions for the cases no electricity trade and non-harmonised FIT (left), electricity trade and non-harmonised FIT (middle), and electricity trade and international quota system with TGC (right)

4 Interactions between a CO_2 target and the liberalised conventional electricity market

In the previous section it has been analysis that a RES-E strategies – both price-driven promotion schemes and a quota system with TGC – can not be adequately contribute to reduce national GHG-emissions. Thus a general remedy has to be found. One solution is to introduce tradable GHG emission allowance (TEA)-scheme as recently implemented by the European Commission (EC, 2001). The idea of a TEA-scheme is to achieve reductions in GHG-emissions from the power industry and other energy intensive industries by establishing a set of national quotas (allowances) that can be traded both nationally and internationally. Hence, GHG-reductions are carried out where it is least costly, because the TEA-system will secure a cost-effective utilisation of GHG-reducing options within the industries covered by the scheme.

To simplify the analyses the following additional assumptions are introduced:

- the TEA-scheme relates only to CO_2-emissions

[24] Note: This is, however, not generally valid.

- the TEA-scheme covers only the power industry, i.e. other energy intensive industries are not included[25]
- free international TEA trade is possible, i.e. it is assumed that all countries have accepted the same rules for TEA trading, e.g. consenting the rules developed in the EU trading scheme
- competitive market conditions, i.e. no distortions due to strategic behaviour of single players and / or allocations occur

The TEA-system is characterised by two important framework conditions, namely

- the distribution of the total CO_2-cap among the single countries, i.e. unit versus non-unit CO_2-target per electricity consumption
- the allocation of the TEA to the single companies, i.e. free allocation of TEA (grand-fathering) versus sell of the TEA via an auction

In the following the effects of these conditions on GHG emissions, the producer and consumer will be discussed.[26]

Country specific, non-harmonised national CO_2-target setting

It is assumed that each country oblige a national-specific CO_2-targets, not relating to the actual electricity demand. More precisely, countries with a very ambitious environmental policy choose a low (harsh) CO_2-target, and countries with a modest interest agree to reduce their emission level less (high CO_2-target).[27] The consequences of this non-harmonised policy are summarised in Table 7 for two sub-cases - TEA are allocated sold (via an auction) and given for free (grandfathering system), respectively.

Table 7: Effects of a GHG-target (CO_2 emissions < 148,3 Mt-CO_2; non-equal GHG-target per electricity consumption; TEA allocation via an auction / grandfathering system) for RES-E and conventional electricity generation in a liberalised conventional electricity market

			Country 1	Country 2	Country 3	Country 4	Total
targets	electricity demand	[TWh]	110,0	110,0	40,0	40,0	300,0
	GHG target	[Mt-CO_2]	30,0	80,0	14,0	24,3	148,3
	free allocation of TEA	[%]	0,0 / 100,0	0,0 / 100,0	0,0 / 100,0	0,0 / 100,0	0,0 / 100,0
electricity generation	conventional electricity	[TWh]	65,0	100,0	32,0	48,0	245,0
	RES-generation	[TWh]	34,0	0,0	14,0	7,0	**55,0**
	Import / Export (+/-)	[TWh]	11,0	10,0	-6,0	-15,0	0,0
	CO_2-emission	[Mt-CO_2]	41,0	52,4	24,1	30,8	**148,3**
market price	spot market price	[€/MWh]	65,00				
	TEA price	[€/t-CO_2]	37,00				
generation costs	conventional electricity	[M€]	1.921	3.472	938	1.475	7.806
	RES-E	[M€]	1.007	0	140	385	1.532
	generation costs	[M€]	2.929	3.472	1.078	1.860	**9.339**
effects on producer / consumer	producer surplus	[M€]	1.988 / 3.098	1.089 / 4.049	1.020 / 1.538	577 / 1.476	**4.674 / 10.161**
	consumer costs	[M€]	6.040 / 7.150	4.190 / 7.150	2.082 / 2.600	1.701 / 2.600	14.013 / 19.500
	consumer costs	[€/MWh]	54,91 / 65,00	38,09 / 65,00	52,05 / 65,00	42,52 / 65,00	**46,71 / 65,00**

[25] Assuming that the power industry is dominant in terms of CO_2-emissions, the inclusion of other industries will not change results significantly.

[26] To illustrate the interactions of a TEA-system with the liberalised electricity market again the numerical four country example is used. To be able to compare the results gained in the previous sections, it is assumed that the same total CO_2-emissions should be reached, i.e. the maximum CO_2 emission of all four countries is restricted by 148,3 Mt-CO_2.

[27] In the numerical example total CO_2-emissions should be reduced by 23% compared to a liberalised power market without any environmental restrictions, compare Table 3. In the numerical example the country specific distribution is very ambiguous: Country 1 agrees to reduce their emission by 54%, country 3 by 42%, country 4 by 11%, and country 2 increases their initial emission level by 6%.

Contrary to the cases investigated above, a CO_2-target leads to no market separation of conventional electricity production and RES-E generation. This means that the total demand must be covered by one single market, including both conventional power plants and RES-E technologies. However, the marginal generation costs for fossil plants are influences by the CO_2-restriction. The additional costs, characterised by the TEA-price, are high for plants with high specific CO_2-emissions (e.g. coal) and low for technologies with low specific CO_2-emissions (e.g. gas). As the emissions refer to the electricity output, the energy efficiency of the plants is of importance too. Due to the consideration of the addition CO_2-costs **the spot market price for electricity raises**.[28]

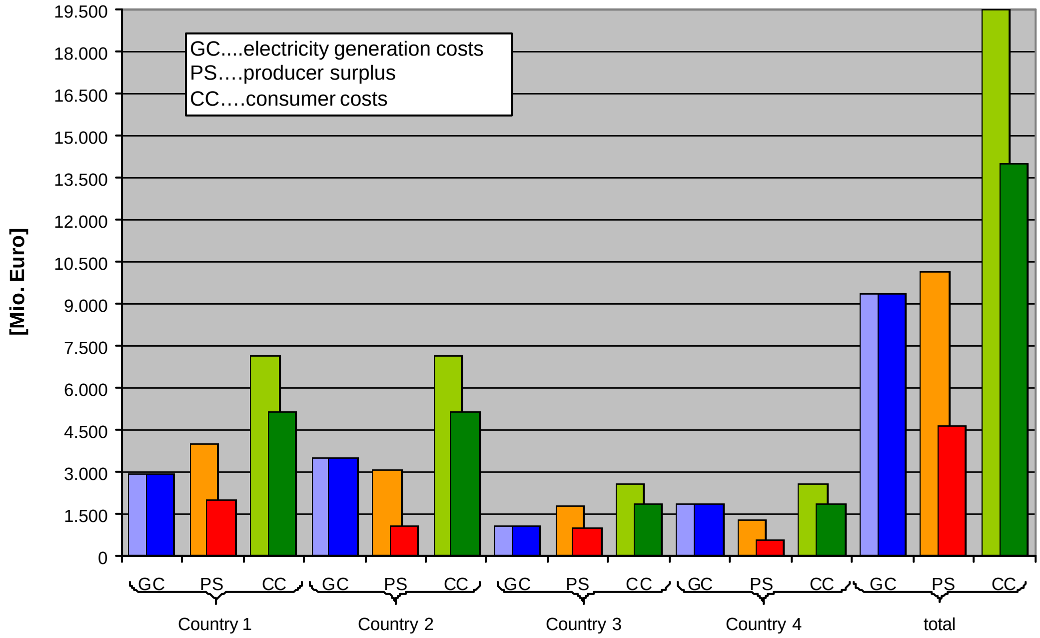

Figure 2: Effects of a non-equivalent GHG-target per electricity consumption assuming that TEA are allocated by grandfathering (left) and auction (right)

The total costs the consumers, however, actually have to pay, depend on the allocation of the TEAs; see Figure 2.

Firstly, assuming that the allowances are allocated for free to the producer – as suggested at least for 90% of the TEA in the EU-trading scheme – consumers have to pay the spot market price for their electricity.[29] As the market price is internationally given, the consumers in all countries are confronted with the same electricity price. Hence, no distortions between the consumers in the different countries occur. Observe that this kind of TEA allocation, however, influences the producer surpluses in single countries. For more details see next sub-section.

Secondly, supposing that the producers have to purchase the TEA via an auction system the state receives high revenue.[30] Assume that these revenues will be reimbursed to the

[28] In the illustrative example (with a high CO_2-restriction) spot market price increases from 32,5 to 65 €/MWh.

[29] In the example consumer have to pay 65 €/MWh, which is more than using a RES-E system to reduce CO_2-emissions!

[30] In the numerical example in total 5487 Mio. € must be paid for the TEAs. This is equivalent to 58% of the total electricity generation costs.

customers, the electricity price can be reduced. The amount of the reduction depends on the national CO_2-target. Countries with a harsh emission goal receive less money from the sell of the TEAs, because the national amount of TEAs is low. Hence the benefit for the customers in these countries is lower compared to customers in countries with a weak CO_2-target.[31]

Due to the CO_2-restriction, total generation costs increases compared with the case of a pure liberalised market and no 'environmental' restrictions. **The increase of total electricity production costs, however, is in ever lower than it would be by reaching the same CO_2-target via applying a RES-E strategy.** The reason is that all available options to reduce CO_2-emissions in the electricity supply sector can be used.[32] Normally, a certain increase of RES-E generation is part of the portfolio of CO_2-measures actually carried out. The level of the additional RES-E production indicates the efficiency of this kind of measure compared with the other CO2-reduction options. If this amount is high, the substitution of conventional electricity by RES-E is also an efficiency strategy reducing CO_2-emissions.

Harmonised CO_2-target setting

Now it is assumed that a joint CO_2-target – again 148,3 Mt-CO_2 in the numerical example – should be reached. The total CO_2-goal is broken down on the single country level according to the national electricity consumption.[33] Most important results are summarised in Table 8.

The **distribution of the national CO_2-target has no influence on the actual national CO_2-emissions if the total CO_2-cap**. In addition, again the marginal conditions at the spot market determine how the electricity generation – and hence the CO_2 emissions - is distributed among the countries. The **distribution** of the national CO_2-targets **influences only the gains for the produces and consumers**, respectively – see Figure 3.

Table 8: Effects of a GHG-target (CO_2 emissions < 148,3 Mt-CO_2; equal GHG-target per electricity consumption; TEA allocation via an auction / grandfathering system) for RES-E and conventional electricity generation in a liberalised conventional electricity market

			Country 1	Country 2	Country 3	Country 4	Total
targets	electricity demand	[TWh]	110,0	110,0	40,0	40,0	300,0
	GHG target	[Mt-CO_2]	54,4	54,4	19,8	19,8	148,3
	free allocation of TEA	[%]	0,0 / 100,0	0,0 / 100,0	0,0 / 100,0	0,0 / 100,0	0,0 / 100,0
electricity generation	conventional electricity	[TWh]	65,0	100,0	32,0	48,0	245,0
	RES-generation	[TWh]	34,0	0,0	14,0	7,0	**55,0**
	Import / Export (+/-)	[TWh]	11,0	10,0	-6,0	-15,0	0,0
	CO_2-emission	[Mt-CO_2]	41,0	52,4	24,1	30,8	**148,3**
market price	spot market price	[€/MWh]	65,00				
	TEA price	[€/t-CO_2]	37,00				
generation costs	conventional electricity	[M€]	1.921	3.472	938	1.475	7.806
	RES-E	[M€]	1.007	0	140	385	1.532
	generation costs	[M€]	2.929	3.472	1.078	1.860	**9.339**
effects on producer / consumer	producer surplus	[M€]	1.988 / 4.000	1.089 / 3.101	1.020 / 1.752	577 / 1.308	**4.674 / 10.161**
	consumer costs	[M€]	5.138 / 7.150	5.138 / 7.150	1.868 / 2.600	1.868 / 2.600	14.013 / 19.500
	consumer costs	[€/MWh]	**46,71 / 65,00**				

[31] The electricity price in country 1 is 54,9 €/MWh compared to 38,1 €/MWh in country 2.

[32] In more detail, these are: (i) energy efficiency improvements of conventional power plants, (ii) fuel switching to primary energy carrier with lower CO_2-content per energy output, e.g. a switch from hard coal to gas, and (iii) substitution of conventional electricity production by RES-E generation.

[33] Note: Setting the country targets according to the historical CO_2-emissions, as negotiated in international agreements, will not lead to a harmonised CO_2-burden for all consumers!

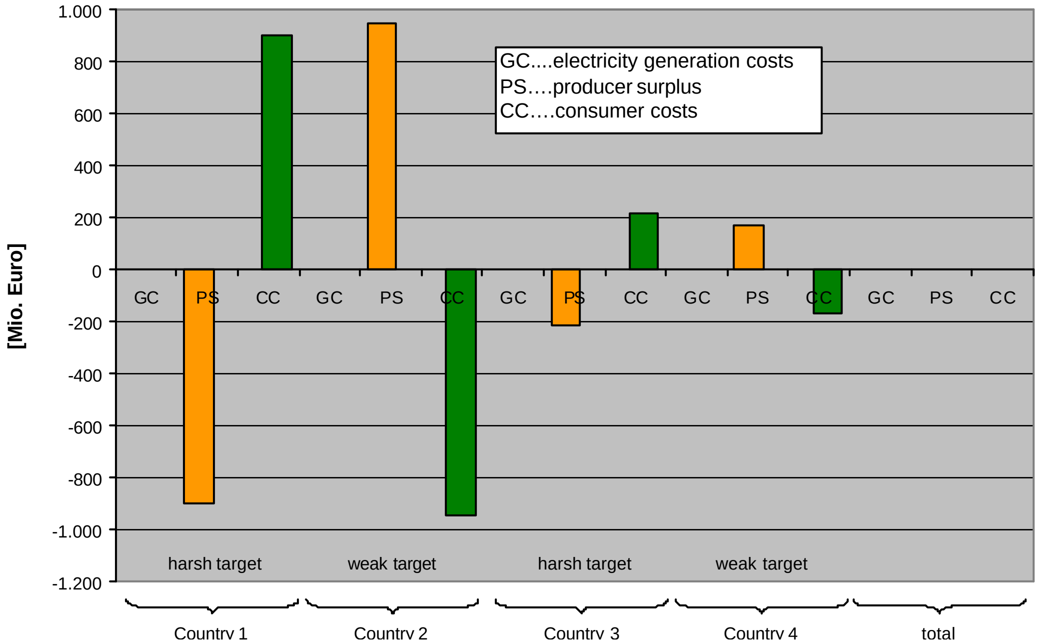

Figure 3: Comparison of non-unit and unit CO_2-target per electricity consumption assuming that the TEA are allocated for free (grandfathering – orange bars) and auction system (green bars)

With respect to the allocation of TEA the following conclusion can be derived:

- The allocation of the TEA is important with respect to a harmonisation of international economic conditions for both producers and consumers.
- A free allocation (grandfathering system) of tradable GHG emission permits has no influence on the consumer costs, but leading to (large) advantages for electricity producers (in countries) with less restricted GHG targets compared to generators (in countries) with a more restrictive environmental goal. Hence competitive distortions in the electricity sector occur implementing a grandfathering system.
- Applying an auction-system total electricity costs are low for consumers in countries with a weak CO_2-target compared to consumers in countries with a more restrictive goal. The reason is that in the first case more revenues received from selling tradable GHG emission permits can be reimbursed (from the state) to the consumer. Hence, economic distortions between the consumers in different countries occur, which is of especially importance for the competitiveness of the industry. However, in contrast to a grandfathering system, an auction has no influence on the competitive situation in the electricity generator, because the additional costs due to the GHG restrictions are already included in the (rising) conventional electricity price. This means the agreed quota of each country leads to no distortions within the electricity supply industry.

5 Interactions between a RES-E market, a tradable GHG allowance market and a liberalised power market

In the section the effects of a simultaneously use of two policy instruments, a RES-E quota and a GHG-target, both in combination with tradable certificate, i.e. TGCs for RES-E and TEA for GHG-reduction, on the reduction of CO_2-emissions will be investigated.[34] To be able

[34] Similar results arise implementing a feed-in tariff scheme instead of a RES-E quota.

to compare the results with those derived in the previous sections, the same model assumptions are used with respect to the liberalised electricity market, TGC-scheme and TEA-system, respectively. The cases described in the previous sections - i.e. applying a pure RES-E and a pure CO_2-target - can be understood as the border or corner solutions of the coincide use of the two instruments. Table 9 summarises the results of a inner solution imposing a total RES-E quota of 80 TWh and a GHG-target of 148,3 Mt-CO_2.[35]

Table 9: Effects of a RES-E quota (unit share per consumption, Q1 = 29,33 TWh, Q2 = 29,33 TWh, Q 3 = 10,67 TWh, Q 4 = 10,67 TWh) and a GHG-target (CO_2 emissions < 148,3 Mt- CO_2; equal GHG-target per electricity consumption; TEA are allocation via auction / grandfathering system) for RES-E and conventional electricity generation in a liberalised conventional electricity market

			Country 1	Country 2	Country 3	Country 4	Total
targets	electricity demand	[TWh]	110,0	110,0	40,0	40,0	300,0
	RES-E target	[%]	26,7	26,7	26,7	26,7	26,7
	GHG target	[Mt-CO_2]	54,4	54,4	19,8	19,8	148,3
	free allocation of TEA	[%]	0,0 / 100,0	0,0 / 100,0	0,0 / 100,0	0,0 / 100,0	0,0 / 100,0
electricity generation	conventional electricity	[TWh]	60,0	84,0	32,0	44,0	220,0
	RES-generation	[TWh]	48,0	5,0	20,0	7,0	**80,0**
	Import / Export (+/-)	[TWh]	2,0	21,0	-12,0	-11,0	0,0
	CO_2-emission	[Mt-CO_2]	36,0	60,0	24,1	28,2	**148,3**
market price	spot market price	[€/MWh]	50,50				
	TGC price	[€/MWh]	17,50				
	TEA price	[€/t-CO_2]	22,50				
generation costs	conventional electricity	[M€]	1.780	2.492	938	1.331	6.541
	RES-E	[M€]	1.920	325	548	385	3.178
	generation costs	[M€]	3.700	2.817	1.486	1.716	**9.719**
effects on producer / consumer	producer surplus	[M€]	1.784 / 3.007	414 / 1.637	948 / 1.393	348 / 793	**3.494 / 6.831**
	consumer costs	[M€]	4.845 / 6.068	4.845 / 6.068	1.762 / 2.207	1.762 / 2.207	13.213 / 16.550
	consumer costs	[€/MWh]	**44,04 / 55,17**				

Due to the RES-E quota obligation, total demand must be separated into two parts: Firstly, demand for RES-E generation, connected to the TGC-market, and, secondly, demand for conventional power, linked to the spot market. Equivalent to the case of a pure TEA-system, the additional CO_2-costs must be considered in the marginal supply curve for the conventional electricity. Now these costs depend on the RES-E obligation too. Generally, **the additional CO_2-costs for conventional power decrease with an increasing RES-E quota obligation**. The reason is that a higher share of conventional electricity is substituted by CO_2-free electricity production from RES-E. As the CO_2-target is independent from the RES-E quota[36], the fossil electricity production to cover the (lower) power demand can have higher average specific CO_2-emissions. In other words, the marginal generation costs for conventional electricity generation are a function of the RES-E quota.

A less ambiguous RES-E policy favours plants with low specific CO_2-emissions. As the TEA price indicates the scarcity of the good CO_2, the TEA market price is high under this assumption. Furthermore, as the marginal conventional electricity generation costs (including additional CO_2-costs) determine the spot market price, the spot market power price is high too. The reverse holds if the RES-E obligation is high, i.e. the TEA price and the spot market price are low. Figure 4 shows the progress of the TEA, the conventional power price as well as the TGC market price in dependency of the RES-E quota. Obviously, the TGC-price depends of the RES-E quota. The market price for TGCs rises with the (mandatory) RES-E demand for two reasons. First, a higher demand corresponds with higher marginal RES-E

[35] Furthermore in the example it is assumed that the total RES-E quota is distributes homogenously among the countries per national electricity consumption The effects of a non-uniform distribution are described in the section 3 and are in principle valid in this case.

[36] In the numerical example the maximum CO_2-level is still 148,3 Mt-CO_2.

generation costs and, second, the TGC-price increases due to the reduction of the conventional electricity price; see Figure 4.[37]

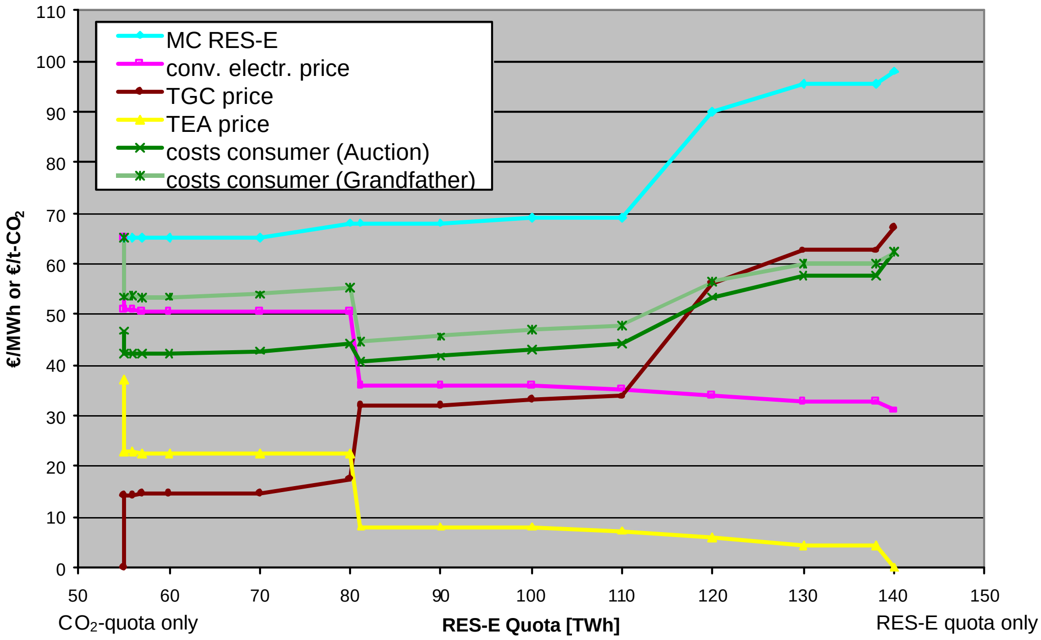

Figure 4: Development of the market prices for conventional electricity, TGC and TEA, the total end-user price (costs for consumer), and the marginal production costs of RES-E in dependency of the RES-E quota

The costs for the consumer consist of the conventional electricity price and the additional costs due to the RES-E obligation. One the one hand the conventional electricity price decrease with a higher share of RES-E. On the other hand the additional costs for the customers rise proportional with the increase of the national RES-E obligation.[38] Hence, **it is a priori not clear at which share of RES-E the total cost for the consumer reach a minimum**.[39] The TEAs do not directly affect the consumer costs. **The CO_2-restriction, however, is internalised in a higher conventional electricity price**. In addition, the allocation of the TEA influences the consumer costs. In the case of an auction system and a cost reimbursed from the sell of the TEAs to the customers, consumer costs are lower compared to a free allocation of TEAs, see Figure 4 and Figure 5. With respect to the allocation of TEAs the reverse holds for the electricity producer. This means, a grandfather system leads to (much) higher surplus compared to an auction.

Total electricity generation costs increases with a higher share of RES-E. The reason is that – considering only the economic CO_2-reduction costs – more efficient options (like efficiency improvement or fuel switching) will not be used adequately, due to the distorting promotion schemes.

[37] Note: TGC-price is given by marginal generation costs minus conventional market price.

[38] Note in the case of a feed-in tariff, a higher national RES-E generation leads to higher consumer costs, too.

[39] In the numerical example the burden for the customers is at the lowest, imposing a RES-E quota of 82 TWh. Observe that the total electricity costs jumps, in dependency of the marginal generation cost conditions at the spot market and the TGC market.

However, beside the cost advantages for the customers that can be occur due to the promotion of RES-E, renewables has other assets too.[40] In addition, in the long-run, RES-E generation may be a better answer to the climate problem and to a sustainable energy system than the adaptation of conventional electricity plants. Hence, to secure the development of RES technologies a separate promotion scheme for RES - beside pure climate change policy – makes sense.

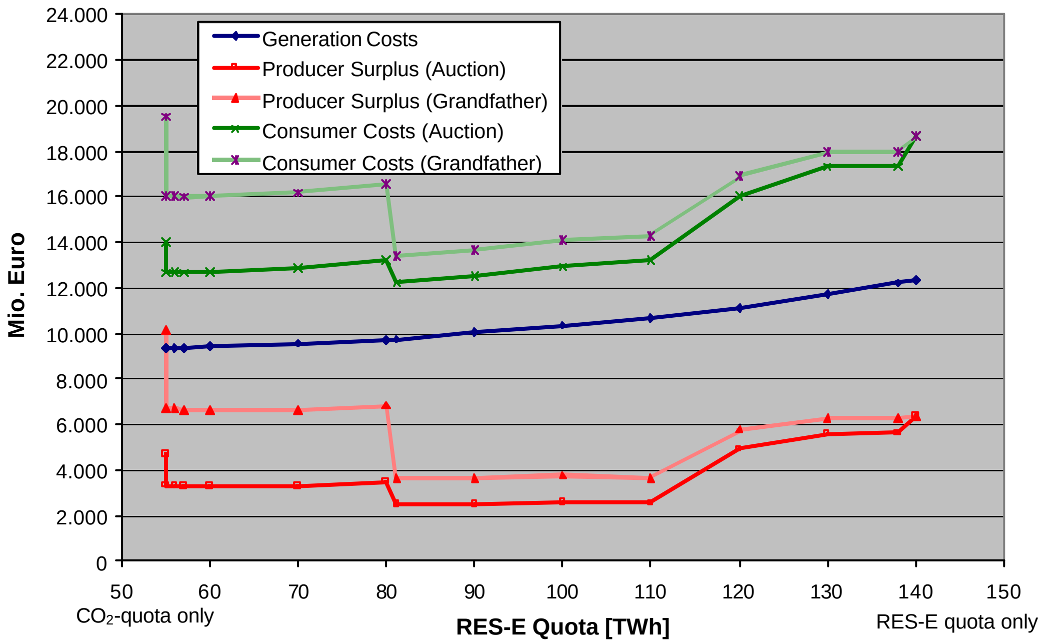

Figure 5: Development of the total generation cost, total producer surplus and total in dependency of the RES-E quota

6 Conclusions

The paper analysis the interactions of three markets, the conventional power market, a market for tradable green certificates (TGCs) and a tradable emissions allowances (TEA)-market in relation with a GHG-target. The investigations are focused on two aspects.

- Reduction of national CO_2-emission
- Cost effects for both producer and consumer

Most important conclusions with respect to national CO_2 emission reductions are:

- independently from the design of the RES-E quota allocation, the same generation structure and the same CO_2-emissions occurs as implementing a harmonised feed-in tariff, if the guaranteed price is set equal to the spot market price plus the TGC price
- if the main objective of the policy-goal is to reduce national CO_2-emission, neither the use of national price-driven RES-E support schemes nor the introduction of a TGC-system into a liberalised power market can be recommended. In contrary to them, ambiguous RES-E policy in separated non-opened national power markets would lead

[40] For example: increased diversity of national power supply, increased security of supply, avoided pollution form “conventional” electricity generation, added value of developing new industries (e.g. new jobs, service skills, diversity of the rural employment, export and manufacturing capacity).

to an appropriate domestic CO_2-reduction. However, under this condition a higher and non-harmonised power price occur.

- countries most ambitious in implementing RES-E technologies will only partly be gaining the CO_2-reduction benefits themselves in an international environment – independently from RES-E the support scheme. This means, the ambitious countries will support the less ambitious ones in achieving their GHG-reduction targets; e.g. in a TGC-system most ambitious countries will have to buy certificates from the less ambitious ones to fulfil their TGC-quotas, although this only contributes to achieving a national target for renewable development, not in reaching their national CO_2 reduction targets.
- a combination of an TEA-market and a TGC-system is seen to be efficient in contributing in achieving the national CO_2 reduction targets if a close co-ordination of the two instruments is undertaken at least at the national level: More precisely, when the RES-E production (of independent producers) is increased, the national CO_2-target (for the conventional power generators) should be decreased correspondingly. Thus, if it is a prerequisite that RES-E generation contributes to achieving national GHG-reduction targets, then the combination of these two markets might be the right solution. It should be mentioned that the achievement of the expected CO_2 reduction, however, might be expensive for the consumer and / or society.

The key conclusions with respect to generation structure, costs for producer and consumer, respectively are:

- a non-harmonised feed-in tariff usually leads to distortions among the additional costs imposed on the electricity customers in the different countries. A harmonisation of the feed-in tariff must, however, not necessarily lead to fewer economic distortions. High costs for the customers occur in states with a high share of actual RES-E generation, i.e. in countries with large cheap RES-E potential. One (certain) advantage of a harmonised promotion system (on global level) is that total RES-E generation costs are minimised;
- the distribution of the total RES-E quota influences the cost for customers. In countries with a high quota consumer are burdened with high additional electricity costs. In the case that each country fulfil the same RES-E target per national electricity consumption, distortions among the electricity consumer can be avoided. The quota allocation, however, has no influence on the producer surplus of the RES-E producer in the countries;
- a support scheme for RES-E can, but must not lead to higher total electricity costs (for the consumer). Due to the market separation the conventional power price drops. If this gain will be overcompensated due to the additional costs for RES-E generation or not depends on the marginal conditions of both conventional power and RES-E; in contrast, a GHG-target ever drives the total consumer costs upwards;
- under the assumption that a certain GHG-level must be reached, total consumer costs can be minimised by setting both a RES-E quota and a CO_2-target. By a simultaneously use of both instruments the market prices for TGCs, TEAs and conventional electricity can be influenced in a way that the producer surplus can be reduced compared to both a pure GHG-reduction scheme target and a pure RES-E policy respectively, leading to lower total consumer costs;
- however, an introduction of a RES-E quota in addition to a given CO_2-restriction is counterproductive with respect to the total electricity generation costs. This means, a

sole CO_2- target, neglecting any certain share of RES-E, minimise production costs for electricity generation. The reason is that by introducing an additional RES-E quota the flexibility in choosing more cost efficient CO_2-reduction measures is restricted;

- the allocation of TEAs - independently if in combination with or without a RES-E promotion scheme - is important with respect to an harmonisation of international economic conditions for both producers and consumers.
  + a free allocation of TEAs has no influence on the consumer costs, but leading to (large) advantages for electricity producers (in countries) with less restricted GHG targets compared to generators (in countries) with a more restrictive environmental goal. Hence competitive distortions in the electricity sector occur;
  + an auction of TEAs has no influence on the competitiveness in the power industry, because the additional costs due to the GHG restrictions are already included in the (rising) conventional electricity price. Under the assumption that the government reimburses the revenue gained from the sell of the TEAs to the consumer, consumer costs can be (significantly) reduced. However, electricity costs are low for consumers in countries with a less restrictive GHG target compared to them in countries with a harsher goal due to higher reimbursements. Hence, economic distortions between the consumers in different countries occur, which is of especially importance for the competitiveness of the industry.

Acknowledgements

The work for this paper was partly funded by the EU 5th framework programme supported by DG Research, the ***Green-X*** project. Although the views expressed are solely the responsibility of the authors, we are grateful for helpful discussions with the ***Green-X*** team.

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