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## On the impact of renewable energy support schemes on power prices

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# On the impact of renewable energy support schemes on power prices

Sven Bode

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# On the impact of renewable energy support schemes on power prices

Sven Bode

## Abstract

Power production from renewable energies is supported through special support schemes in almost all industrialised countries. This is because they are generally not competitive today although their use offers a number of benefits that are not considered by energy markets. These support schemes need to be financed, though. Two main options can be observed: Either support through the general public budget or through a renewable energy mark-up that is charged to final power consumers. As this mark-up increases power costs for consumers, the support schemes have been criticised, especially by power intensive industries. It argues that it loses competitiveness on the world market with higher electricity costs due to the mark-up. However, this argument is short-sighted as it only reflects one side of the medal, namely the mark-up. The increased use of renewable energies may also have an influence on the power price on the whole sale market. Based on the analysis of a specific case in Germany the present paper analyses this impact on the whole market more generally. Assuming a simple power market, I show that the power costs for consumers may decrease due to the support scheme. If and to what extent power costs decrease depends on the specific characteristics of the market and the value attached to the “greenness” of power from renewable energies.

**Keywords:** Renewable energy support schemes

**JEL classification:** H 23, L 94, Q 28, Q 41

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## Introduction

As full costs of power production from renewable energies (in the following also RE) are generally higher than those of thermal power plants, their market share is currently rather low. However, there are a number of benefits associated with renewable energies which are generally not reflected by markets. This is why they are supported through different scheme in a number of countries. The benefits of power production from renewable energies are manifold. The EU Directive on the promotion of the electricity produced from renewable sources for example, states that it aims at the contribution to sustainable development, the reduction of GHG emissions, the creation of local employment, the increase of energy security and the increase of energy diversification (EU 2001, p. L283/33). It goes without saying that the support schemes imply additional costs. They can be dealt with differently. For example, they can be taken from the general budget as has been done for example with direct subsidies in Germany in the early nineties. They can also be passed onto power consumers as in the case of the current feed-in tariff in Germany in recent years.<sup>1</sup>

In the case that the costs from the support scheme are passed onto consumers through a RE mark-up (or RE premium), power consumers may complain. Indeed, especially the power intensive industry in Germany has been complaining that power prices increase due the RE mark-up and that its competitiveness is consequently reduced considerably (E&M 2005, Gammelmin 2005, VEA 2006). As a consequence it managed to get a special RE mark-up which is limited and fixed in absolute terms, i.e. 0.05 ct. / kWh (Bundesrat 2006). The mark-up charged to private households on the other hand, is variable. With increasing RE production their mark-up increases, too.

When talking about “the power price” one must be accurate as different power prices exist, most importantly:

- the power price on the whole sale market and
- the power price on the retail market, referred to as power costs for the consumers in this paper.

The power costs for the consumers comprise the power price from the whole sale market and, depending on the country studied, other fees, tariffs for grid use, taxes, possible RE mark-ups etc. Thus, if the whole sale price changes, the power costs for consumers change, too.

Bode et al. (2006) analyse the impact of the German RE feed-in law (Erneuerbare-Energien-Gesetz, EEG) on the whole sale market and show that the price decreases as a function of RE produced. An artificial power market consisting of 199 thermal plants and one RE installation is used. Subsequently, they study the net impact on power costs, which include the RE mark-up, too, for large industrial consumers. These consumers pay a fixed limited mark-up of 0.05 ct/kWh. Depending on the quantity of RE produced and the price decrease respectively, the cost to the large power consumers may thus decrease, too.

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<sup>1</sup> More information is provided below. For a more detailed presentation of the development of RE support in Germany see Wüstenhagen et al. 2006.

In the following, two elements of the power costs for the consumers are studied in broader perspective: 1) the focus is on RE support scheme in general, not only on the German feed-in tariff - and 2) the limitations on mark-ups for large industrial consumers are dropped. The paper is structured as follows: the next section provides a brief overview on the costs of power production. The differences in production costs motivate the introduction of RE schemes. Section 3 qualitatively describes the impact of RE support schemes on the whole sale power price. An analytical analysis follows in Section 4, which in turn is followed by a numerical example in Section 5. The final section concludes.

## Costs of electricity generation - motivation for RE support schemes

The calculation of full costs of power production is rather straightforward; however, a number of assumptions on different parameters are necessary as for example on fuel costs, operation time, discount rate etc. (Pfaffenberger et al. 2004). Table 1 provides an overview on possible ranges for different production technologies.

Table 1: Ranges for power production costs depending on fuel <sup>\*)</sup>

	Coal	Gas	Wind
Investment Costs (USD/MWh)	ca. 8-21	ca. 4-15	ca. 21-77
O&M (USD/MWh)	ca. 4-15	ca. 1-8.5	ca. 6-37
Fuel (USD/MWh)	ca. 1-35	ca. 22-44	0
Total (USD/MWh) <sup>**)</sup>	ca. 13-55	ca. 38-60	ca. 35-90

<sup>\*)</sup> Source: IEA 2005; <sup>\*\*)</sup> taken from source, i. e. no addition of figures for different types of costs given above.

Although power production from wind might be more economically attractive in some case, one can state that it is in general more expensive than power production from thermal plants (based on full costs). This is why different support schemes have been introduced in the past. Examples are given in Table 2.

Table 2: Overview on important instruments to promote renewable energies (based on Meyer 2003)<sup>\*)</sup>

<b>Name</b>	<b>Description</b>	<b>Exemplary countries where Instrument has been implemented</b>
Feed-in tariff	Long-term minimum price is guaranteed for electricity or heat from renewable sources	Germany
RE-Quota	Certain market participants (e.g. supplier, consumer) are required to supply or consume a minimum quantity of electricity or heat from renewable sources <sup>**)</sup>	Italy, The Netherlands
RE-Tender	A national authority puts a certain quantity of electricity or heat from renewable sources to tender. Winners of the tender get a fixed price for the length of the contract	United Kingdom
Direct subsidies	(Parts of) capital costs are borne by a national authority	Germany (1991-1992), India (1997-1999)

<sup>\*)</sup> For a description of instruments and a detailed analysis on current policies in OECD countries see also IEA (2004, p. 85-96)

<sup>\*\*)</sup> Note that a green certificate trading scheme allows meeting these targets cost-efficiently. Trading itself does not promote RE.

An important question is, how the RE support scheme is financed. Two basic options exist.

1. Costs incurred due to the introduction of the scheme are paid from the public budget.
2. Costs incurred are passed onto the final power consumers via a RE mark-up.

In the first case, the impact of the RE support scheme on the whole sale price is most important for power consumers. In the second case with the existence of an RE mark-up, however, the question of how this mark-up is calculated is also important as the total effect on power costs is constituted by the two individual effects, namely the impact on the whole sale market and the RE mark-up. For the following analysis, I distinguish two different options for the mark-up:

- a) The regulator only organises the purchase of the environmental benefit (“the greenness”) through the RE-support scheme at a fixed price. In this case operators of renewable energy devices have to sale the electricity produced directly on the power market and would thus receive two different income flows: one from the sale of the environmental benefit (via the regulator) to all final consumers and another one from

the electricity sale. This implies that the RE operators bear the price risk of the power sale.<sup>2</sup> The mark-up can be calculated as follows:

$$RE \text{ markup} = \frac{\text{specific remuneration for environmental benefits} * RE \text{ production}}{\text{total production}}$$

what is equivalent to

$$RE \text{ markup} = \text{specific remuneration for environmental benefits} * RE \text{ share}$$

- b) The regulator sets up a scheme, where the green power, i. e. power and environmental benefit, is bought from the RE-operators at a fixed rate. RE-operators thus receive a single revenue stream. However, allocating the aggregated remuneration paid to the RE-operators to the final consumers would neglect the fact that the energy produced by the RE devices has already been paid for. The mark-up under the German feed-in tariff, where RE operators receive such a fixed fee for both environmental benefit and power, is calculated as follows:

$$RE \text{ markup} = (\text{specific remuneration for RE} - \text{power price}) * RE \text{ share}$$

Thus, a double burden for the final consumers in Germany is avoided.<sup>3</sup> However, it should be mentioned that the determination of the relevant power price is not straightforward. For example baseload and peakload, spot market or forward markets etc. exist (for more details on this issue IfnE 2006). Under such an approach RE operators do not bear any risk regarding the power price as they receive the fixed remuneration. This has been one explanation for the success of RE penetration in Germany.

Both options will be considered during the analysis below.

## Price formation in competitive power markets

The power market has some characteristics which differentiate it from other markets. Most importantly, power cannot be stored (in large quantities at reasonable costs). Thus supply is almost instantaneously consumed. Consumption (also called “load” in the case of electricity) varies over the day with higher demand at day time and lower demand during the night. Thus quite different market equilibria in terms of quantity and price exist. Demand also changes considerably over the year.

For a single hour of a day we can describe a competitive market in industrialised countries as follows: The aggregated supply curve consists of a large number of different plants that use different fuels and combustion technologies. According to microeconomic theory, suppliers offer at marginal costs in the short-term market. It is thus important to only consider the

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<sup>2</sup> This could be done, for example, by green certificate schemes, such as RECS (see [www.recs.org](http://www.recs.org)). See also country description of Belgium in IEA (2004, p. 161)

<sup>3</sup> For large industrial consumers there are additional rules that limit the RE mark-up in order not to diminish competitiveness too much (see § 16 Erneuerbare-Energien-Gesetz, German feed-in law)



marginal costs of the different types of power plants. Keeping in mind that RE do not face any fuel costs<sup>4</sup> we can construct the supply curve - also referred to as merit-order-curve for the short term market as depicted in Figure 1. While the solid line reflects the general magnitude of marginal costs as a function of the fuel used (see also Table 1), the dashed line represents a schematic supply curve for the power market.

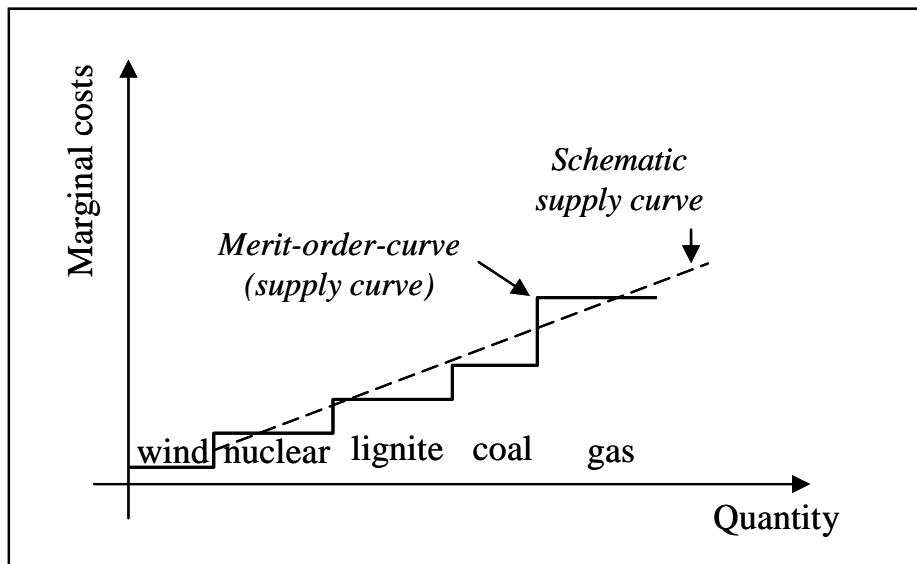


Figure 1: Supply curves for the short term power market

Figure 2 depicts the power market. Demand is represented by the falling linear curve. The intersection of supply and demand curve represents the equilibrium with equilibrium quantity and price. Bode and Groscurth (2006, p. 12-13) now argue that with an increased power production from renewable energies, which is induced by the additional capacity from the RE support scheme, the market equilibrium changes. More precisely they say that the whole power price decreases and the quantity increases (see shift of the dashed supply curve supply<sup>w/o</sup> to the dotted curve supply<sup>RE</sup> by the quantity of produced from RE in Figure 2.<sup>5</sup> As the whole sale price is part of the retail price the latter may also decrease. If and to what extent the whole sale price decreases depends on the magnitude of the RE mark-up. For existing capacities this price decreasing effect has been shown for different wind offer. With higher wind speed power whole sale prices at the Leipzig Energy Exchange decrease (Neubarth et al. 2006). In the next section, this price decreasing effect and the role of the RE mark-up is analysed analytically.

<sup>4</sup> Or costs for CO<sub>2</sub> as installations under European emissions trading scheme do.

<sup>5</sup> Additional costs that might occur from greater RE capacities such as back-up power plants for times with low RE supply, improvements of grid capacities are not considered.

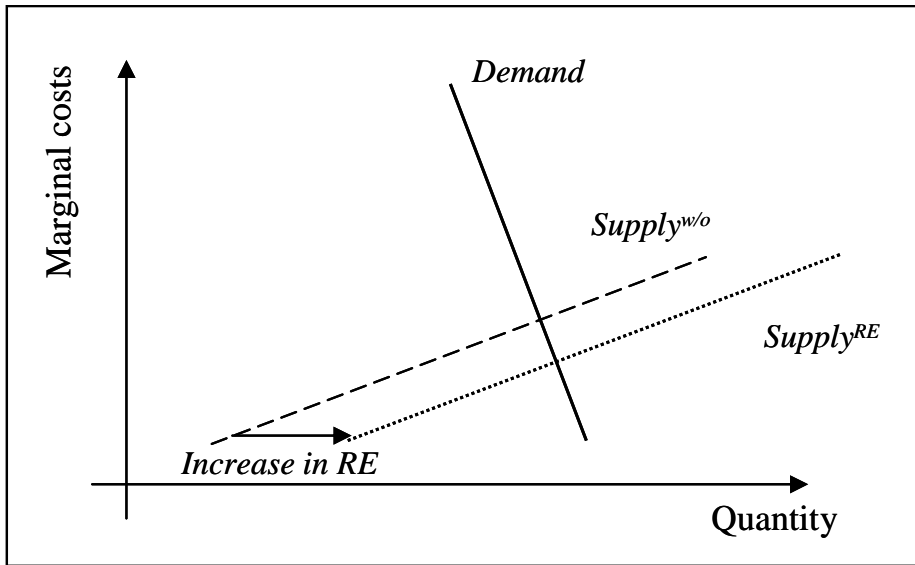


Figure 2: Change for market equilibrium in a short term power market due to increased power production from renewable energies.

## Impact of RE-support schemes on power costs for customers – analytical analysis

After discussing the effect of RE-support schemes on the whole sale power price and on power costs for consumers qualitatively, this section provides an analytical analysis assuming a simple competitive power market.

The analysis is divided into three steps:

- 1) Impact on the wholesale power price
- 2) Renewable energy mark-up
- 3) Net effect

### Ad 1) Impact on the wholesale power price

During the analysis of the impact of the RE scheme on the wholesale power price I assume a competitive market.

Let us assume a linear aggregated supply curve of the form

$$P^S = aq + b \quad (1)$$

where  $P^S$  = price for suppliers, a and b = parameters, q = quantity

and a linear aggregated demand curve

$$P^D = -cq + d \quad (2)$$

where  $P^D$  = price, c and d = parameters, q = quantity

equating supply and demand curve and solving for  $q$  gives the price in the market equilibrium

$$q^* = \frac{d-b}{a+c} \quad (3)$$

which in turn allows to calculate the equilibrium price as follows:

$$p^* = a \frac{d-b}{a+c} + b \quad (4)$$

As shown above, the support of renewable energies results in a shift of the supply curve. If we denote the aggregate power production from renewable energy devices by  $Q_R$ , the new supply curve results as:

$$P_R^S = aq + b - aQ_R \quad (5)$$

With the demand curve being unchanged we obtain the new equilibrium quantity as follows:

$$q_R^* = \frac{d-b+aQ_R}{a+c} \quad (6)$$

As we can see, the quantity increases with increasing RE production.

Inserting (6) for  $q$  in (5) gives the new equilibrium price

$$p_R^* = a \frac{d-b+aQ_R}{a+c} + b - aQ_R \quad (7a)$$

$$\Leftrightarrow = \frac{ad+bc-acQ_R}{a+c} \quad (7b)$$

As one would expect the new price decreases with increasing RE production.

In order to see to what extent the price is decreased due to the support of renewable energies we deduct the new price (6) from the reference price (4), i.e.:

$$p^* - p_R^* = \Delta p_R = \frac{ad+bc}{a+c} - \frac{ad+bc-acQ_R}{a+c} = \frac{ac}{a+c} Q_R \quad (8)$$

As we can see in equation (8) the change of the price depends on the slope of the demand and the supply curve respectively as well as on the quantity of power from renewable energies.

With standard assumptions on the slopes of the supply and demand curve, i.e.  $a, b > 0$ , the price will always decrease.

## Ad 2) Renewable energy mark-up

As mentioned, I assume that the financial means for the RE-support scheme are not taken from the public budget but rather from the final consumers through a renewable energy mark-up which is added to each kWh consumed. With regard to the RE mark-up the two options introduced above are studied.

- a) *Fixed remuneration for environmental benefit only*
- b) *Fixed remuneration for both environmental benefit and electricity*

I elaborate on the mark-up for the two options first before analysing the net effect for power costs below.

### a) *Remuneration for environmental benefit only*

Let us assume that the support of RE is realised through a fixed remuneration per kWh produced, which honours the environmental benefit only (see option a above). The aggregated remuneration from the RE support is equally allocated to the total production. The RE mark-up  $m^e$  to be borne by consumers can be calculated as follows:

$$m^e = r \frac{Q_R}{q^*} \quad (9)$$

where  $m^e$  = renewable energy mark- allocated to total consumption in the case of environmental benefit only remuneration (ct/kWh),  $r$  = average specific remuneration for RE produced (ct/kWh);  $q^*$  = final electricity consumption (kWh)

The quotient on the right hand side ( $Q_R/q^*$ ) can also be interpreted as the share of RE of total energy production.

As  $q^*$  in Equation (9) is a function of  $Q_R$  we insert (6) in (9) and obtain for the mark-up:

$$m^e = \frac{r(a+c)}{d-b+aQ_R} Q_R \quad (10)$$

### b) *Remuneration for both environmental benefit and electricity*

For the second option where environmental benefit and electricity are bought through the RE-support scheme one can calculate the mark-up as follows:

$$m^E = (R - p^*) \frac{Q_R}{q^*} \quad (11)$$

where  $m^E$  = renewable energy mark-allocated to total consumption in the case of environmental benefit and electricity remuneration (ct/kWh),  $R$  = average specific remuneration for RE produced (ct/kWh);  $p^*$  = power price ;  $q^*$  = final electricity consumption (kWh)

With both  $p^*$  and  $q^*$  being a function of  $Q_R$  we insert (6) and (7) in (11) and obtain the mark-up as follows:

$$m^E = \frac{((a + c)R - ad - bc)Q_R + acQ_R^2}{d - b + aQ_R} \quad (12)$$

### Ad 3) Net effect

In order to analyse the net effect of the counter-acting power price decrease and the RE mark-up on the electricity costs for the consumers, the price decrease on the whole sale market must be deducted from the RE mark-up which differs depending on the design of the RE support scheme.

#### a) Remuneration for environmental benefit only

In the case of remuneration for environmental benefit only the net effect is as follows:

$$n^e = m^e - \Delta p_R = \left( \frac{r(a + c)}{d - b + aQ_R} - \frac{ac}{a + c} \right) Q_R \quad (13)$$

where  $n^e$  = net effect of RE support scheme with remuneration for environmental benefit only (c/kWh)

Whether or not the power price decreases depends on whether the subtrahend in Equation (13) is smaller or greater than the minuend. Thus, it depends on the specific supply and demand curve characteristics and the RE remuneration.

#### b) Remuneration for both environmental benefit and electricity

In the case of remuneration for environmental benefit and electricity we obtain the net effect as follows:

$$n^E = \left( \frac{(a + c)R - ad - bc + acQ_R}{d - b + aQ_R} - \frac{ac}{a + c} \right) Q_R \quad (14)$$

As for the case with remuneration for environmental benefit only we see in Equation (14) that the net-effect in the present case also depends on the specific market characteristics. Some examples are studied in the next section.

## Numerical analysis

This section provides a numerical analysis of the above presented findings. Bode et al. analyse a synthetically but close to reality power market (Bode et al. 2006, p. 15-16). I base on this analysis and assume the following supply and demand curves as the initial situation:

$$P^S = 0.0005q + 15$$

$$P^D = -0.05q + 3000$$

With no RE production under the support scheme, the power price in the equilibrium results as 44.6 Euro / MWh, the quantity results to about 59100 MWh. Supply side elasticity is |1.5| and thus rather elastic whereas demand side elasticity is |0.015| and therefore rather inelastic.

With these assumptions I analyse the impact of RE support schemes on the power price and on the power costs. I build some scenarios around the initial situation and focus on changes on the supply side only.

As in the previous section the analysis is structured as follows:

- 1) Impact on the wholesale power price
- 2) Renewable energy mark-up
- 3) Net effect

### Ad 1) Impact on the wholesale power price

Table 3 shows the impact on additional RE production on the power price with different slopes of the supply curve (see Equation 8). As one could expect, we can see that the steeper the slope the higher the price decrease both in absolute and in relative terms. For example, with a slope of 0.0001, the price decreases from 20.96 by one Euro or 4.76 percent to 19.96 Euro/MWh with an increase of RE production from zero to 10,000MWh. With a slope of 0.001, the price decreases from 73.53 by 9.80 Euro or 13.33 percent to 63.73 Euro/MWh for the same increase in RE production. One can also see that the equilibrium price without any RE production increases with greater slopes. We shall keep this in mind for the discussion below. At the same time, the quantity in the equilibrium increases with increasing RE production correspondingly.

Table 3: Change of equilibrium price and quantity with different RE production  $Q_R$  and different slope of the supply curve  $a$

RE Production $Q_R$ (MWh)	Slope of the supply curve $a$					
	0.0001		0.0005		0.001	
	Price <sup>*)</sup> (€/MWh)	Quantity <sup>*)</sup> (MWh)	Price (€/MWh)	Quantity (MWh)	Price (€/MWh)	Quantity (MWh)
0	20.96	59,581	44.55	59,109	73.53	58,529
1,000	20.86	59,583	44.06	59,119	72.55	58,549
2,000	20.76	59,585	43.56	59,129	71.57	58,569
3,000	20.66	59,587	43.07	59,139	70.59	58,588
4,000	20.56	59,589	42.57	59,149	69.61	58,608
5,000	20.46	59,591	42.08	59,158	68.63	58,627
6,000	20.36	59,593	41.58	59,168	67.65	58,647
7,000	20.26	59,595	41.09	59,178	66.67	58,667
8,000	20.16	59,597	40.59	59,188	65.69	58,686
9,000	20.06	59,599	40.10	59,198	64.71	58,706
10,000	19.96	59,601	39.60	59,208	63.73	58,725

<sup>\*)</sup> Market equilibrium

For relative RE targets, as for example given in the EU directive 2001/77/EC the increasing quantity in the market equilibrium implies that the absolute capacity of RE installations must also increase compared to the situation without the RE support scheme.

## Ad 2) Renewable energy mark-up

Again, I distinguish the two different remuneration schemes.

### *a) Remuneration for environmental benefit only*

Based on Equation (10) the RE mark-up with remuneration for environmental benefit only can be quantified. As one can see in Table 4, with a constant remuneration for RE production of 50 Euro/MWh the impact of the slope of the supply curve on the RE mark-up is rather negligible. However, as one can see in Figure 3 the magnitude of the specific remuneration for RE (see  $r$  in Equation 10) is quite important. The higher the remuneration the higher the RE mark-up.

Table 4: RE mark-up  $m^e$  (Euro/MWh) as a function of RE  $Q_R$  produced and slope of the supply curve  $a$  (Remuneration  $r = 50$  Euro/MWh)

RE- production $Q_R$ (MWh)	Slope of the supply curve $a$				
	0,0001	0,00025	0,0005	0,00075	0,001
0	0	0	0	0	0
1,000	0.84	0.84	0.85	0.85	0.85
2,000	1.68	1.68	1.69	1.70	1.71
3,000	2.52	2.52	2.54	2.55	2.56
4,000	3.36	3.37	3.38	3.40	3.41
5,000	4.20	4.21	4.23	4.25	4.26
6,000	5.03	5.05	5.07	5.09	5.12
7,000	5.87	5.89	5.91	5.94	5.97
8,000	6.71	6.73	6.76	6.79	6.82
9,000	7.55	7.57	7.60	7.63	7.67
10,000	8.39	8.41	8.44	8.48	8.51

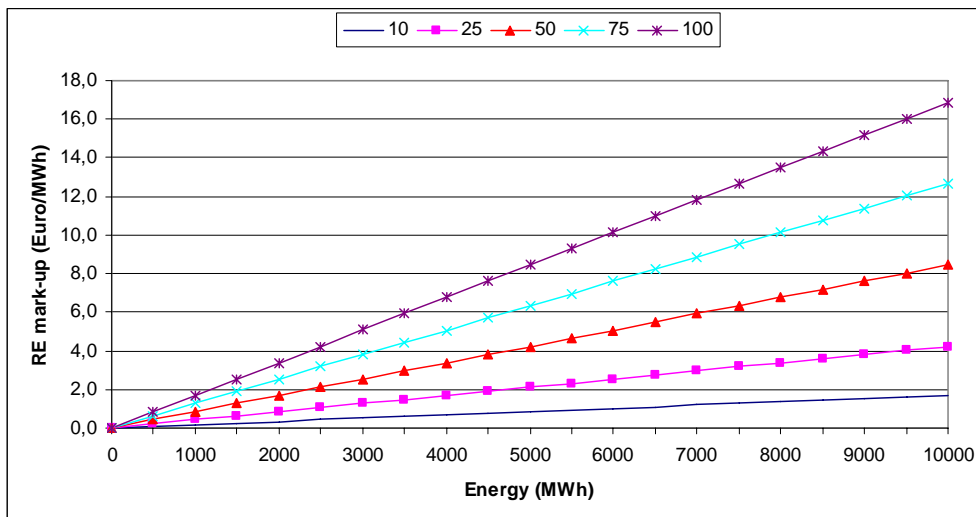


Figure 3: RE mark-up  $m^e$  as a function of RE production  $Q_R$  and specific RE remuneration  $r$  (Euro/MWh);  $a = 0.0005$

*b) Remuneration for both environmental benefit and electricity*

With a joint remuneration for environmental benefit and electricity we can calculate the RE mark-up using Equation (11). Table 5 shows the results for different slopes of the supply curve and different RE production. The RE remuneration  $R$  is greater than in the previous case (90 instead of 50 Euro/MWh) as a remuneration for the power now is included. It remains, however, constant.<sup>6</sup> The analysis is, however, somewhat biased: as mentioned above with increasing slope of the supply curve the equilibrium price increases, too. Thus, referring

<sup>6</sup> See German feed-in tariff;



to Equation (11), a higher price is deducted from the constant remuneration  $R$  what in turn results in the lower mark-up for greater slopes.

The value of the environmental benefit under this approach is not constant as under option a). It is rather a function of the power price. The figures must thus be interpreted correspondingly.

With regard to RE production, the RE mark-up increases with increasing production for all slopes of the supply curve.

Table 5: RE mark-up  $m^E$  (Euro/MWh) as a function of RE produced  $Q_R$  and slope of the supply curve  $a$  (Remuneration  $R = 90$  Euro/MWh)

	slope of the supply curve $a$				
RE- production $Q_R$ (MWh)	0.0001	0.00025	0.0005	0.00075	0.001
0	0	0	0	0	0
1,000	1.16	1.02	0.78	0.54	0.30
2,000	2.32	2.04	1.57	1.10	0.63
3,000	3.49	3.07	2.38	1.69	0.99
4,000	4.66	4.12	3.21	2.30	1.39
5,000	5.83	5.17	4.05	2.94	1.82
6,000	7.01	6.22	4.91	3.60	2.29
7,000	8.19	7.29	5.79	4.28	2.78
8,000	9.38	8.36	6.68	4.99	3.31
9,000	10.56	9.45	7.59	5.73	3.88
10,000	11,75	10,54	8,51	6,49	4,47

Figure 4 shows the RE mark-up as a function of the remuneration  $R$ . The slope is 0.0005 as in the initial situation. The market price in this situation is 44.6 Euro / MWh. This is why the RE mark-up becomes negative for remunerations smaller than the market price. It is of course not reasonable to pay remuneration (for both greenness and power) to RE operators if their full production costs are already lower than the power price. In this case renewable energies would be competitive anyway.

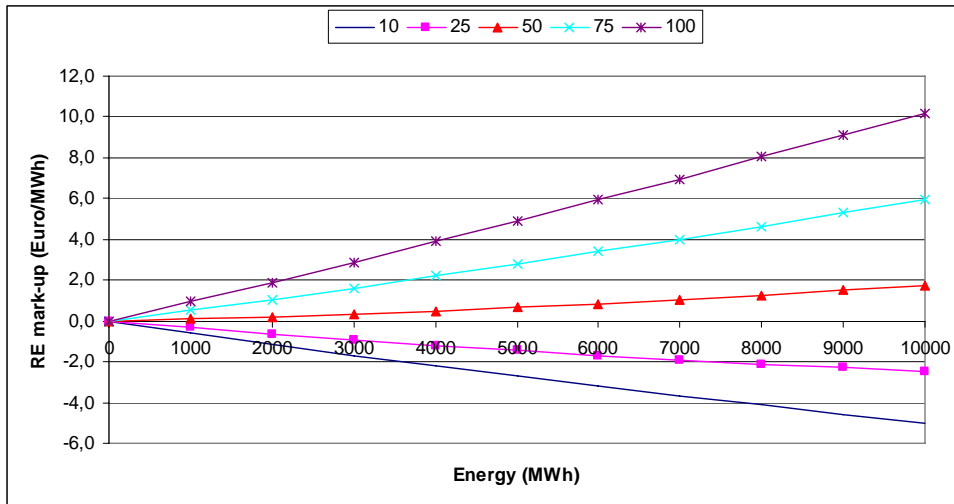


Figure 4: RE mark-up  $m^E$  as a function of RE production  $Q_R$  and specific RE remuneration  $R$  (Euro/MWh);  $a = 0.0005$

### Ad 3) Net-effect

After having discussed the counteracting price decrease on the wholesale market and the prices increase due to the RE mark-up individually, the net effect on the power costs for consumers is studied below.

#### *a) Remuneration for environmental benefits only*

The net effect on the power costs for consumers with the fixed remuneration  $r = 50$  Euro / MWh for environmental benefits only is shown in Figure 5. For most of the slopes studied the net effect is positive, i. e. the power costs for the consumers increase due to the implementation of the RE support scheme. However, with steeper supply curves, the net effect may become negative. In this case the final consumers face reduced power costs due to the RE support scheme. Note that the only the impact on power costs are considered in this figure. Benefits from external effects from renewable energies may be included, too.

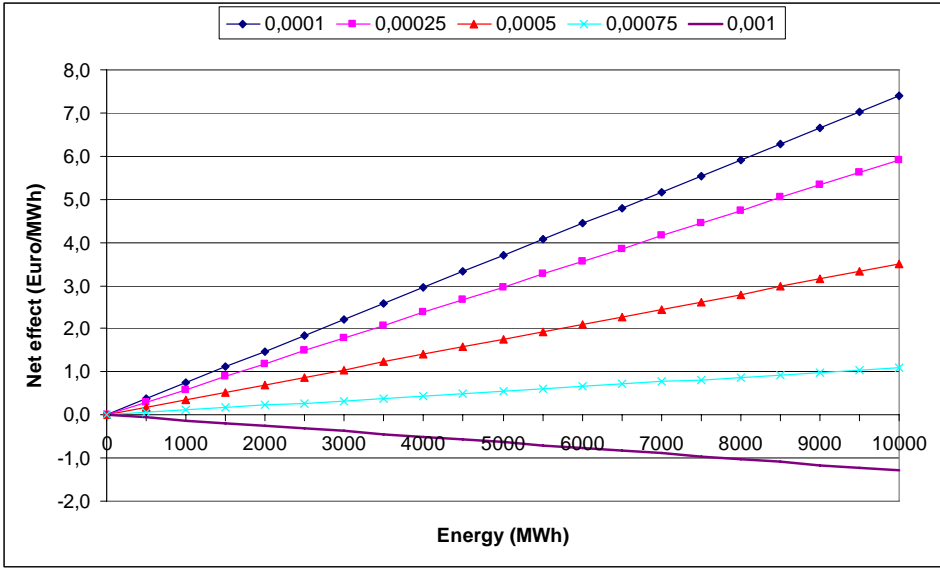


Figure 5: Net effect  $n^e$  as a function of RE production  $Q_R$  and slope of the supply curve  $a$  (positive values indicate price increase);  $r = 50$  Euro / MWh

However, the net effect is not only depending on the slope of the supply curve and RE production but also on the remuneration  $r$  paid for the purchase of the “greenness” of the electricity. This is why different values are analysed in Figure 6. As we can see, with the initial slope  $a = 0.0005$  the net effect may become negative for smaller remunerations for the environmental benefits only.

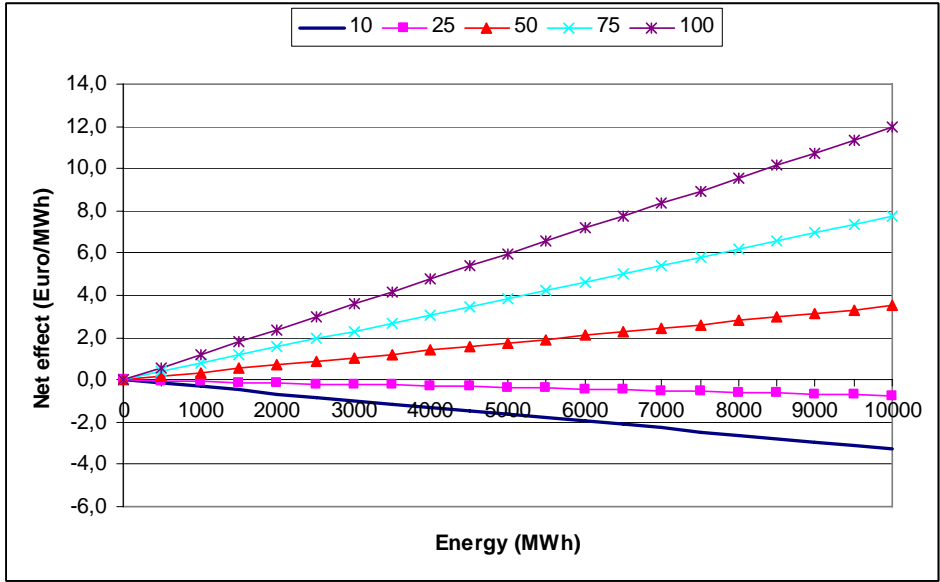


Figure 6: Net effect  $n^e$  on power costs as a function of RE production  $Q_R$  and specific RE remuneration  $r$  (Euro/MWh);  $a = 0.0005$

*b) Remuneration for both environmental benefit and electricity*

Contrary to the analysis of option a), the RE operators receive a full remuneration for both environmental benefit and electricity under option b). Based on Equation (14), Figure 7 provides an idea of the net effect for selected slopes and RE production. Although the remuneration paid to the RE operators is higher than in the previous case, the net effect becomes negative for greater slopes. As discussed above, power prices increase with a greater slope of the supply curve what in turn reduces the mark-up. As mentioned, the approach with the constant remuneration for greenness and electricity (as chosen under the German feed-in tariff) thus implies a decreasing value of the environmental benefit in the case of increasing power prices (see the term in brackets in Equation 11).

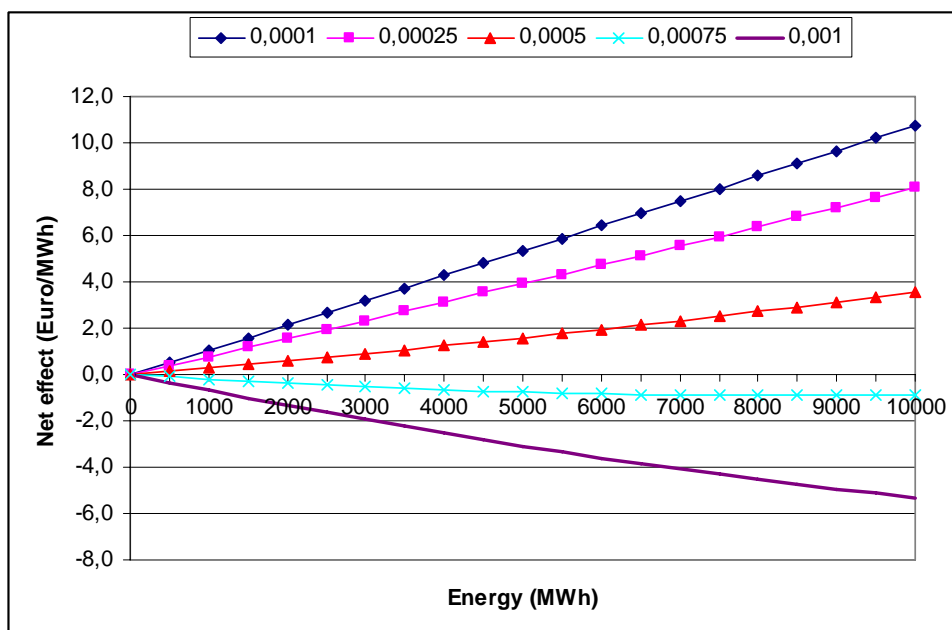


Figure 7: Net effect  $n^E$  as a function of RE production  $Q_R$  and slope of the supply curve  $a$  (positive values indicate price increase);  $R = 90 \text{ Euro} / \text{MWh}$

As discussed during the analysis of the RE mark-up with a full compensation for greenness and power, only remunerations greater than the power price without RE support are reasonable.<sup>7</sup> As we can see in Figure 7, the power costs for consumers may decrease with certain remunerations  $R$ . In these cases RE support schemes introduced by governments may even improve competitiveness of the local heavy industry, which currently generally opposes RE as discussed above.

<sup>7</sup> When we assume that the remuneration reflects the full costs of RE production.

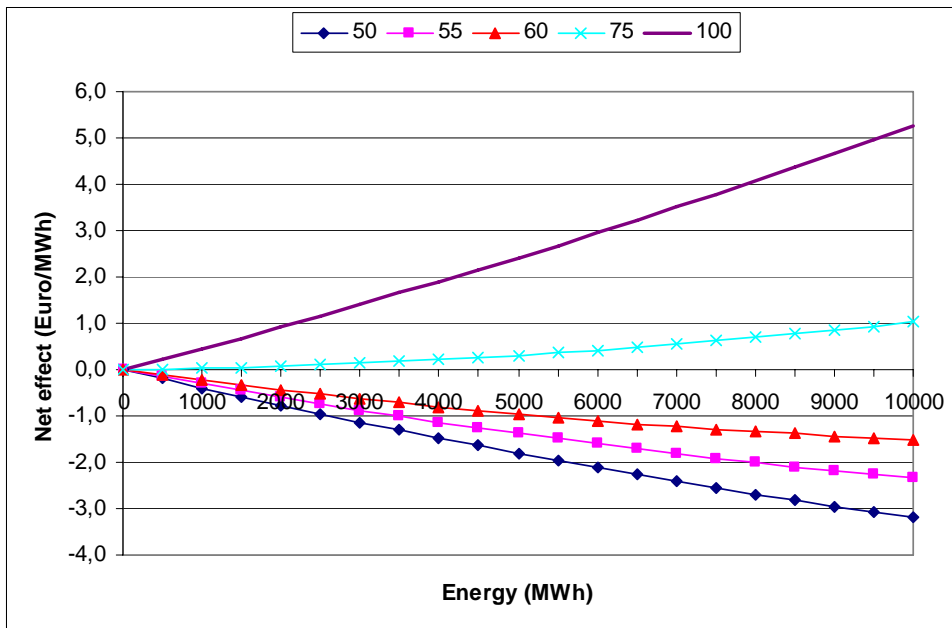


Figure 7: Net effect  $n^E$  as a function of RE production  $Q_R$  and specific RE remuneration  $R$  (Euro/MWh);  $a = 0.0005$

## Conclusion

Power production from renewable energies (RE) is frequently support throughout the world. This is because it is not competitive on a full cost basis and since related environmental benefits are generally not considered by power markets. In the case where these support schemes are financed through the charge of a RE mark-up (or RE premium), consumers - especially power intensive industry - may lobby against such schemes arguing that competitiveness on the international market is reduced. This line of argumentation is, however, only partly correct. It is true that the mark-up increases power costs for the consumers. However, it neglects the fact that RE support reduces whole sale power prices which are part of the power costs of the consumers. The price reduction on the whole sale market can be explained as follows: As marginal costs of RE are considerably lower than those of conventional thermal plants, the latter are driven out of the market with increasing production from RE. Thus, the market equilibrium changes: the price decreases and equilibrium quantity increases. The net effect on power costs to consumers is thus constituted of two counteracting effect. After an analytically discussion of these effects, a numerical analysis provided in this paper shows that the net effect may become positive or negative depending on the assumptions made. In other words, power costs to the consumers may also increase or decrease. A decrease in power costs may motivate the implementation of RE support schemes without any reference to environmental concerns.

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