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The Merit-order effect: A detailed analysis of the price effect of renewable electricity generation on spot market prices in Germany

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Abstract

The German feed-in support of electricity generation from renewable energy sources has led to high growth rates of the supported technologies. Critics state that the costs for consumers are too high. An important aspect to be considered in the discussion is the price effect created by renewable electricity generation. This paper seeks to analyse the impact of privileged renewable electricity generation on the electricity market in Germany. The central aspect to be analysed is the impact of renewable electricity generation on spot market prices. The results generated by an agent-based simulation platform indicate that the financial volume of the price reduction is considerable. In the short run, this gives rise to a distributional effect which creates savings for the demand side by reducing generator profits. In the case of the year 2006, the volume of the merit-order effect exceeds the volume of the net support payments for renewable electricity generation which have to be paid by consumers.

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1 Introduction

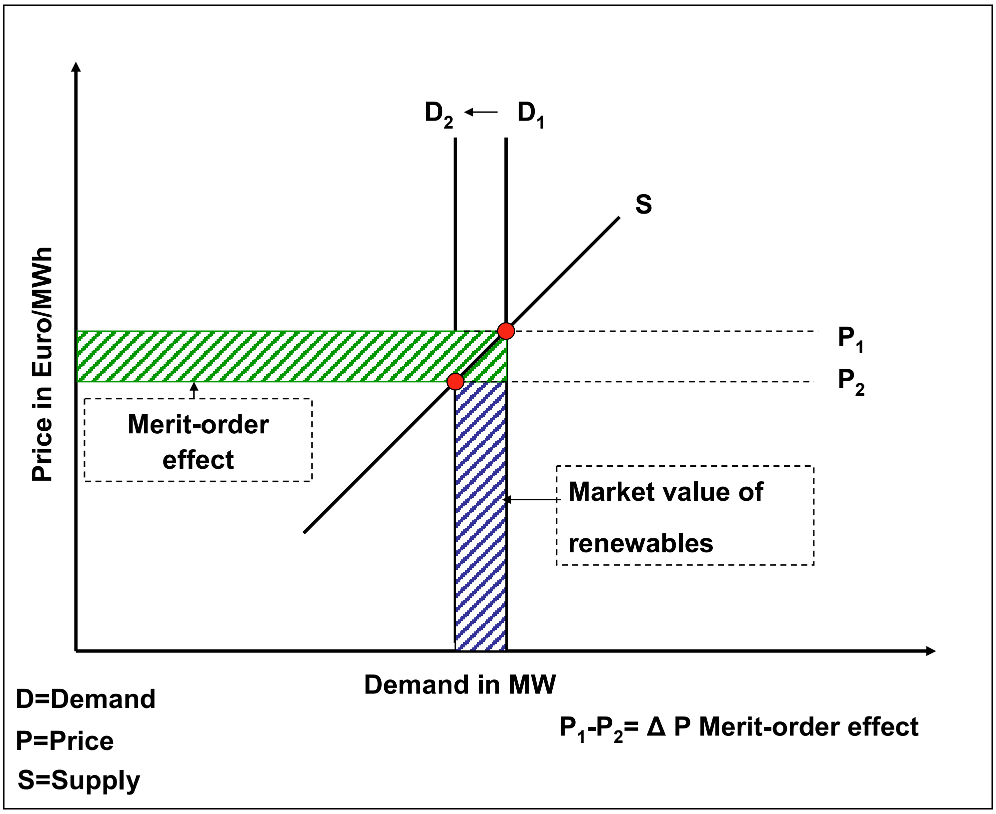
The development of renewable electricity generation in Germany has been characterized by considerable growth rates throughout the past 15 years. This development is mainly driven by a guaranteed feed-in-tariff which has been in place since 1991. The actual conditions of the German support scheme were revised in 1998, 2000 and 2004 (see also Laubner, Metz, 2004; Wustenhagen, Bilharz, 2006). Since 2000 the Renewable Energy Sources Act is in place. According to the law the German grid operators have to buy electricity generated by specified renewable energy sources at a guaranteed feed-in-tariff. In a second step the electricity is sold to the electricity suppliers according to their market-share. The additional cost for the feed-in-tariff has to be paid by the consumers in the end. There is a considerable debate on the efficiency and the cost of the renewable support scheme. Publications on international level on the analysis of cost and efficiency of different support schemes on the European level (Ragwitz et al., 2007; Huber et al., 2004) and the United States (Palmer, Burtraw, 2005) show that this discussion is not only a German phenomenon. As a consequence of the continuous growth of supported renewable electricity generation in Germany from 18.1 TWh to ca. 52 TWh per year in the period of 2001-2006 the payments for the feed-in-tariff rose according to the association of German grid operators from 1.6 billion Euro to 5.6 billion per year (Verband der Netzbetreiber [VDN], 2007). Additional aspects are necessary extensions of the grid and the increased demand for system services. However, recent studies show that the additional cost for these aspects are within the range of 1-10 Euro per MWh of renewable electricity generation which equals ca. 52-520 million Euro in the year 2006. (Auer et al., 2006; Klobasa, Ragwitz, 2006). But the electricity generated by renewable energy sources also has a value which has to be taken into account in the current discussion. Leaving minor aspects like necessary grid extensions and the increased demand for system services (Deutsche Energie-Agentur [DENA], 2005) aside the additional costs of the support from a consumer perspective could be defined by the feed-in-tariff minus the market value of the renewable electricity. An estimation of the market value of the renewable electricity generation can be calculated by multiplying the electricity production by the spot market price. Based on the market prices and the volume of the renewable electricity generation the market value of the generated renewable electricity can be estimated to ca. 2.5 billion Euro, almost 45% of the support payments. In another recent study which takes electricity trades on future markets into account the market value of renewable electricity generation is estimated to 44 Euro/MWh (Wenzel, Diekmann, 2006) or 2.3

billion Euro. The rising fuel prices and the introduction of the European emission trading system have lead to an heavy increase electricity prices was not foreseen in the future markets (European Energy Exchange [EEX], 2007a). This aspect leads to slight differences for the estimation of the market value.

In addition the electricity generated by renewable energy sources also has an impact on the market prices itself. The central contribution of this paper to the current discussion of renewable support schemes is the analysis of this interaction. A stylized overview of the discussed effects of renewable electricity generation for a single hour is given in Figure 1. Thereby it is assumed that the electricity demand is inelastic in the short-term perspective of a day-ahead market. Since the electricity generated by renewable energy sources has to be bought by supply companies in advance the remaining demand load that has to be purchased on the electricity markets is reduced correspondingly. Therefore the guaranteed feed-in of electricity generated by renewable energy sources has the effect of a reduction in the electricity demand. In the picture the German merit-order-curve, which is a step function of single plant units in the real world, is simplified as a linear supply-curve. As long as this supply curve has a positive slope the reduced demand on the markets leads to lower prices. As this effect shifts market prices along the German merit-order of power plants this effect is called merit-order-effect in this paper. A central goal of this paper is to assess the actual value of the merit-effect of German renewable electricity generation in the period 2001-2006. Another important interaction of renewable electricity generation is the interaction with the European emission trading system. A discussion of the interrelation of the German feed-in-support for renewable electricity generation and the European emission trading system can be found in recent publications (Rathmann, 2007; Walz, 2005). Future work will have to take this aspect into account.

In addition to the value of the electricity generated by renewable energy sources the supported electricity generation also has an impact on the market price itself. The main goal of this section is the analysis of this interaction. An overview of the discussed effects of renewable electricity generation is given in Figure 1 for a single hour. It is assumed that the electricity demand is inelastic in the short-term perspective of a day-ahead market. Since the electricity generated by renewable energy sources has to be bought by supply companies in advance, the remaining demand load that has to be purchased on the electricity markets is reduced correspondingly. Therefore, the guaranteed feed-in of electricity generated by renewable energy sources have the effect of a reduced electricity demand. In the diagram the German merit-order curve is depicted as a step function. As long as this supply curve has a positive slope, the reduced demand on the markets leads to lower prices. As this effect shifts market prices along the German merit-order of power plants, this effect is called the "merit-order effect" in this paper. A central goal of this section is to assess the actual value of the merit-order effect of German renewable electricity generation in the year 2006.

Figure 1: Merit-order effect of renewable electricity generation



Source: own illustration

Since electricity demand and renewable electricity generation vary on an hourly basis, an estimation of the actual value of the merit-order effect is far more complex than the estimation of the market value. Therefore the analysis is carried out using the PowerACE Cluster System which is able to simulate hourly spot market prices.

2 Methodology

In order to determine the impact of renewable electricity generation the calibrated PowerACE model is used to simulate electricity market prices in the years 2001 and 2004-2006. A detailed description of the PowerACE model can be found in (Sensfuß, 2007, Genoese et al., 2007). The model provides a detailed representation of the German electricity sector. The model simulates reserve markets and the spot market. The spot market prices are calculated on hourly level for an entire year. Based on a price prognosis power plants and pump storage plants are bid into reserve markets and the spot market. For the given simulation the bid price for power plants is based on variable cost and start up cost. Demand and renewable load are bid with price inelastic bids into the market.

Thereby it is assumed that the entire electricity demand is traded at the simulated spot market. This assumption deviates form the real world situation in two ways:

1. In the real world situation only ca. 89 TWh or 16.5 % of the electricity demand were traded on the spot market in 2006 European Energy Exchange [EEX], 2007b. It can be assumed that an important amount of electricity is traded in bilateral contracts which are likely to be less volatile than the spot market.
2. The simulated spot market prices are based on fundamental data. Therefore prices are less volatile than real world market prices. It is not likely that peak prices of several hundred Euro/MWh at the real spot market represent a good price signal for the entire electricity demand in a given hour. Under the given assumption that the entire electricity demand is traded at the resulting market prices it seems to be adequate to base the analysis on the more conservative price development of the simulated market prices.

In case of renewable electricity generation the electricity generation is calculated based on given hourly load profiles. The resulting electricity production may differ from published production data due to the fact that the capacity available at the end of the year is assumed to be producing for the entire year according to the technology specific utilization.

All other parameters are held constant. In order to determine the impact of renewable electricity generation on the electricity market the simulation is run 50 times. The resulting time series is calculated as average of the simulation runs in order to level out variations caused by the random generator used to simulate power plant outages. In a second step the same procedure is applied to 50 simulation runs without renewable electricity production supported by the feed-in tariff. Since the development of large hydro plants has not yet been affected by the renewable support scheme, electricity production of large hydro plants is taken into account in both simulation settings. The following analysis compares both time series.

3 Results

A comparison of a selected day in October 2006 is given in Figure 3. The figure shows the impact of renewable electricity generation supported by the EEG on the remaining system load that has to be covered by conventional power plants. The load of renewable electricity generation in the selected period varies between 4.4 GW and 14.7 GW. But its impact on prices varies even more. During hours of low load the reduction of the market price is 0 Euro/MWh while it reaches up to 36 Euro/MWh in hours of peak demand. This difference in the impact on market prices is caused by the different slope or step size of the German merit-order curve in different load segments of the electricity demand. The slope of the German merit-order is higher in cases of high demand. This effect is illustrated in a stylized way in Figure 2.

Figure 2: The impact of renewable generation on market prices in different segments on electricity demand

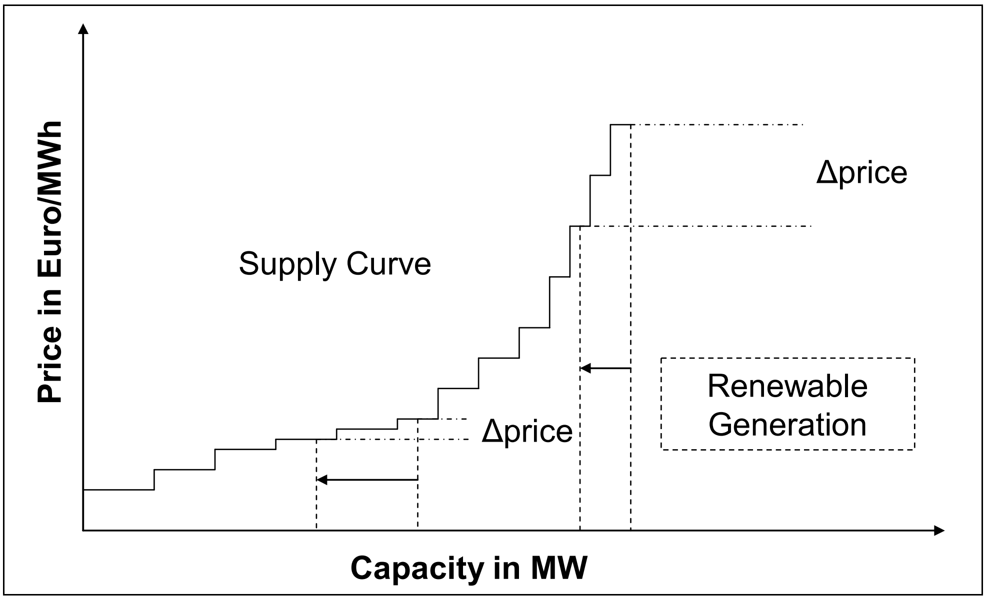


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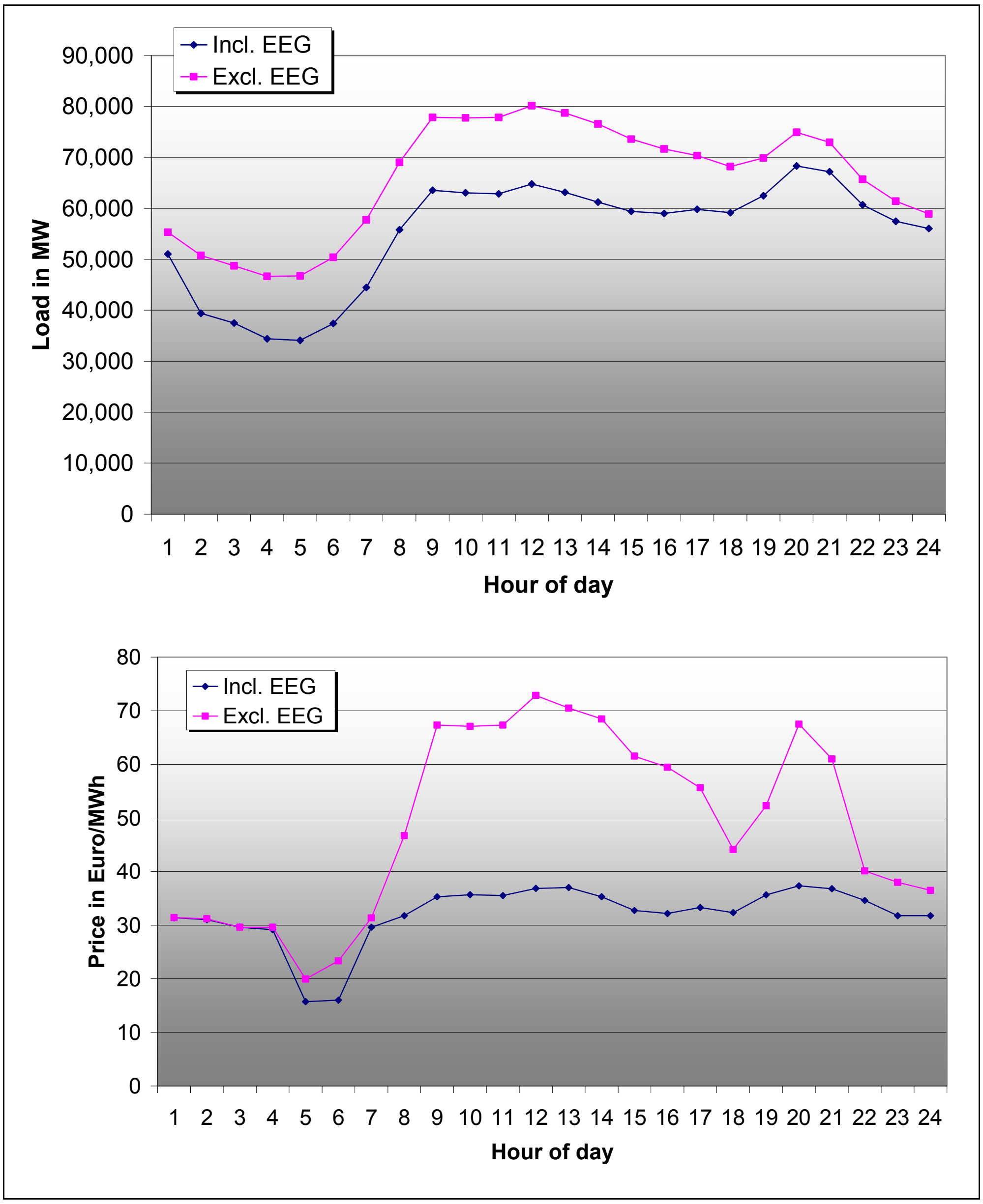
Figure 3: Comparison of load and prices for one simulated day in October 2006 (two scenarios: one including EEG-Renewables, the other excluding EEG-Renewables)



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Based on the assumption that the entire electricity demand of a single hour is purchased at the corresponding spot market price the volume of the merit-order effect can be calculated. If the difference is summed up according to Formula 3-1, the absolute volume of the merit-order effect can be estimated.

The results for the years 2001, 2004, 2005 and 2006 are presented in Table 1. The results indicate a considerable reduction of the average market price of

7.83 Euro/MWh in the year 2006. In total the volume of the merit-order effect reaches its highest value in the year 2006 with about 4.98 billion Euro. Another interesting indicator for the discussion of the actual cost of renewable electricity support from the consumer perspective is the ratio of the merit-order effect and the electricity generated by renewable energy sources (Formula 3-2). This indicator allows a comparison to the average specific tariff for renewable electricity of 109 Euro/MWh in 2006 (Verband der Netzbetreiber [VDN], 2007). This indicator reaches 95.4 Euro/MWh in the year 2006.

Formula 3-1: Calculation of the annual financial volume of the „merit-order effect“

$$v = \sum_{h=1}^{h=8760} (x_h - p_h) \cdot d_h$$

Legend:

Variables			**Unit**	**Indices**		
d	=	Total electricity demand	[MWh]	h	=	Hour
p	=	Price including renewable generation	[Euro/MWh]			
x	=	Price excluding renewable generation	[Euro/MWh]			
v	=	Total volume of the merit-order effect	[Euro]			

Formula 3-2: Calculation of the specific value of the merit-order effect

$$s = \frac{v}{r}$$

Legend:

Variables			**Unit**	**Indices**
r	=	Renewable electricity generation	[MWh]	
s	=	Specific value of the merit-order effect	[Euro/MWh]	
v	=	Volume of the merit-order effect	[Euro]	

Table 1: Price-effect and total volume of the merit-order effect[1]

Year	**Simulated renewable generation** TWh	**Average price reduction** €/MWh	**Volume merit-order effect** Billion €	**Merit-order effect per renewable MWh** €/MWh	**Average feed-in tariff** €/MWh
2001	24.3	1.7	1.07	44	86.9
2004	41.5	2.5	1.65	40	92.9
2005	45.5	4.25	2.78	61	99.5
2006	52.2	7.83	4.98	95	109

1 The volume of the renewable electricity generation deviates slightly from the published data (see also Verband der Netzbetreiber [VDN], 2007). This effect is caused by the fact that the model settings assume that the renewable electricity generation capacity at the end of a year is available for the entire year.

4 Sensitivity analysis

An analysis of the development of the volume of the merit-order effect shows that the effect is not only influenced by the growth of renewable electricity generation. The main driving factors for the level of the merit-order effect are the installed capacity of renewable electricity generation, the development of fuel prices and the CO_2 price. In total 42 scenarios with 50 simulation runs are carried out for the sensitivity analysis of the year 2006. The total amount of 2100 simulation runs leads to extensive requirements in terms of computing power, data handling and data storage since the produced data for this analysis amounts to ca. 20 GB.

4.1 Fuel prices

In order to analyse the impact of changes to the fuel prices, the merit-order effect is determined for simulation runs with different fuel prices. Thereby simulations are run with a price increase and decrease of 20 % for each fuel the results are shown in Table 2.

Table 2: Sensitivity Analysis for the year 2006

2006	Fuel prices			Relative change merit-order effect	
	low €/MWh	**normal** €/MWh	**high** €/MWh	**low** %	**high** %
Nuclear	2.99	3.75	4.49	0	0
Hard coal	6.37	7.98	9.55	11	-9
Lignite	3.03	3.79	4.55	2	-1
Oil	25.65	32.15	38.48	-2	1
Gas	17.30	21.69	25.95	-30	26

The sensitivity analysis for the year 2006 shows that the fuel prices for lignite and nuclear power plants only have a very low impact on the value of the merit-order effect. Despite the spread of +/- 20 % in the fuel cost the fuel price only influences the value of the merit-order effect by a maximum of 2 %. This result is not surprising as the base load power plants are largely unaffected by the development of renewable electricity generation up to 2006 due to the fact that they are rarely replaced by renewable electricity generation.

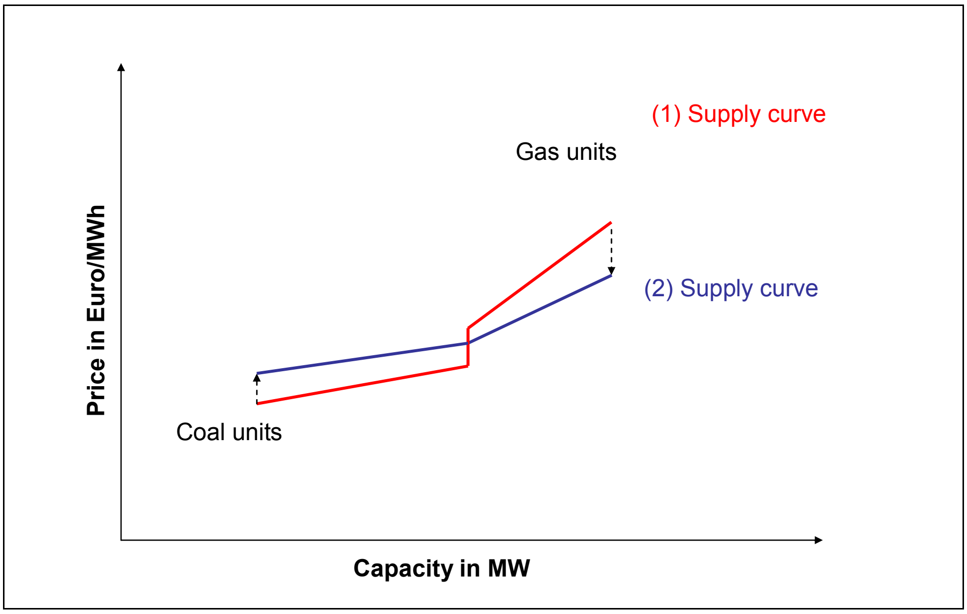
In case of fuel oil the sensitivity analysis for fuel oil shows only a very low impact on the value of the merit-order effect. A 20 % lower fuel price decreases the value of the merit-order effect by 2 % while the higher oil price increases the merit-order effect by 1 %. The low sensitivity can be explained by the low importance of oil fired power plants in the German electricity supply. Since the number of plants is low, they only set the market price in rare cases.

The analysis of the variation of the gas price shows the highest impact on the result. A reduction of the gas price by 20 % leads to a reduction change of the merit-order effect of ca. 30 %. The disproportionately high effect of a variation of the gas price on the volume of the merit-order effect can be explained by the impact of the gas price on the generation cost. The gas turbines for peak demand have a lower efficiency, which makes the generation cost more sensitive towards higher fuel prices. Since gas fired units set the prices in most hours of peak demand, the effect is not levelled out by scheduling another generation technology.

Another important factor with an influence on the result is the hard coal price. A 20 % variation of the fuel price leads to an opposite effect of 9 % and 11 % on the volume of the merit-order effect. At first sight this result is striking, but the analysis shows that the result is not only influenced by a single fuel price or the general price level of fuel prices. An important factor influencing the results is the ratio of gas and coal prices.

The strong dependency of the effect to the ratio gas and coal prices can be explained by the German merit-order curve. Price setting units are mostly coal and gas power plants. In hours of lower electricity demand the price is set by hard coal units and in hours of high demand the price is set by gas units. Therefore higher hard coal prices reduce the slope of the merit-order curve, thus reducing the merit-order effect. Very high coal prices and lower gas prices decrease the slope of the supply as depicted in Figure 4.

Figure 4: The impact of coal and gas prices on the supply curve



Source: own illustration

4.2 Capacity

In addition to the fuel prices the factor that has an obvious impact on the volume of the merit-order effect is the amount of electricity generated by renewable energy sources. In order to determine the impact of this factor all parameters of the simulation run for the year 2006 are held constant while the supported renewable electricity generation capacity is varied in steps of 20 %. The results presented in Table 3 show that the merit-order effect grows almost in line with renewable electricity generation. While the supported renewable electricity generation grows by 40 % from 52.2 TWh to 73.1 TWh in the analysed simulation, the volume of the merit-order effect grows by 31 %. In the given setting there is a tendency that the growth rates of the merit-order effect decrease slightly with increasing renewable electricity generation. This is again caused by the slope of the German merit-order curve which decreases with lower load. Thereby it has to be taken into account that the sensitivity analysis of fuel prices presented above shows that the actual slope of the German merit-order curve is influenced heavily by fuel prices, which again influences the sensitivity of the simulation results towards the volume of renewable electricity generation.

Table 3: Impact of growing renewable electricity generation on the merit-order effect

Renewable Generation TWh	RES-Generation Comparison to 2006	Effect Comparison to 2006
31.3	60 %	66 %
41.8	80 %	86 %
52.2	100 %	100 %
62.6	120 %	118 %
73.1	140 %	131 %

4.3 Scarcity mark-up

Another factor which has an impact on the result of the merit-order effect is the scarcity mark-up. Since market prices tend to be very high in the peak load segment, an additional mark-up can be added to the bid price within the simulation. The size of the mark-up is depending on the expected ratio of load to be covered and available generation capacity. An overview is given in Table 4.

In case of the years 2005 and 2006 the scarcity mark-up can be added to the bid price. As renewable electricity generation also affects the scarcity of generation capacity in a given hour, the merit-order effect is also influenced by the scarcity mark-up.

Table 4: Impact of growing renewable electricity generation on the merit-order effect

Ratio Available generation capacity / demand	Mark-up in Euro/MWh
2	1.54
1.8	4.92
1.2	6.15
1	12.29
73.1	140 %

In order to determine the impact of the scarcity mark-up the calculation of the merit-order effect is carried out with activated and deactivated mark-up for the years 2005 and 2006. The results presented inTable 5 show that the mark-up increases the merit-order effect by ca. 0.6 and 0.7 billion Euro for the years 2005 and 2006. As the impact of the scarcity mark-up is considerable, this aspect clearly needs further investigation. But as there is no broad empirical validation available, it is not applied for the analysis carried out in this paper.

Table 5: Sensitivity analysis of the scarcity mark-up

Year	Simulated renewable generation TWh	Volume merit-order effect no mark-up Billion €	Volume merit-order effect incl. mark-up Billion €	Difference Billion €	Relative Change %
2005	45.5	2.78	3.41	0.63	23
2006	52.2	4.98	5.69	0.71	14

4.4 CO_2 prices

Another important parameter is the CO_2 price. In order to calculate the sensitivity of the results to the CO_2 price the merit-order effect is simulated with the PowerACE Cluster System with varying CO_2 prices. The CO_2 prices are varied between 0 Euro/t and 40 Euro/t in steps of 10 Euro/t. The results are presented in Table 6. The results indicate that the volume of the merit-order effect decreases slightly with increasing CO_2 price. A rise of the daily CO_2 price from 0 to 40 Euro/t leads to a reduction of the merit-order effect by ca. 16 %.

Table 6: Impact of CO_2 prices on the merit-order effect

CO_2 prices (€/t)	**Relative change** (%)
0	0
10	-4
20	-8
30	-12
40	-16

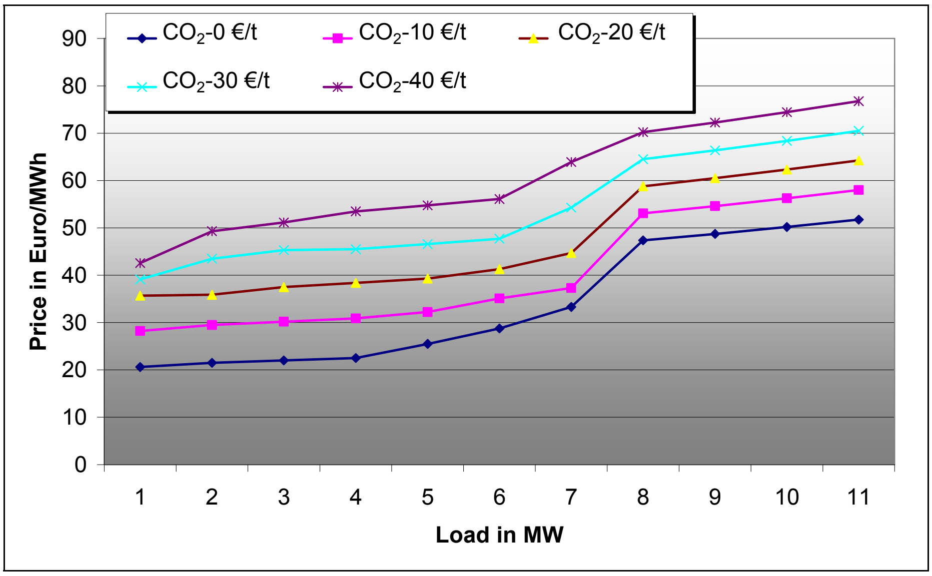
At first sight this result is rather surprising. In order to illustrate the effects caused by rising CO_2 prices the merit-order curve of a small power plant portfolio is created for illustration purposes. The plant portfolio consists of eleven hard coal and gas fired power plants with different efficiencies. The characteristics and the merit-order curve of this simplified power system for different CO_2 prices are given inTable 7 and Figure 5.

Table 7: Simplified power plant portfolio

Fuel	Capacity MW	Efficiency %	Fuel Price €/MWh	Variable cost €/MWh	Generation cost €/MWh
Hard coal	1	44	8.4	1.5	20.6
Hard coal	1	42	8.4	1.5	21.5
Hard coal	1	41	8.4	1.5	22.0
Hard coal	1	40	8.4	1.5	22.5
Hard coal	1	35	8.4	1.5	25.5
Gas	1	58	16.4	0.5	28.8
Gas	1	50	16.4	0.5	33.3
Gas	1	35	16.4	0.5	47.4
Gas	1	34	16.4	0.5	48.7
Gas	1	33	16.4	0.5	50.2
Gas	1	32	16.4	0.5	51.8

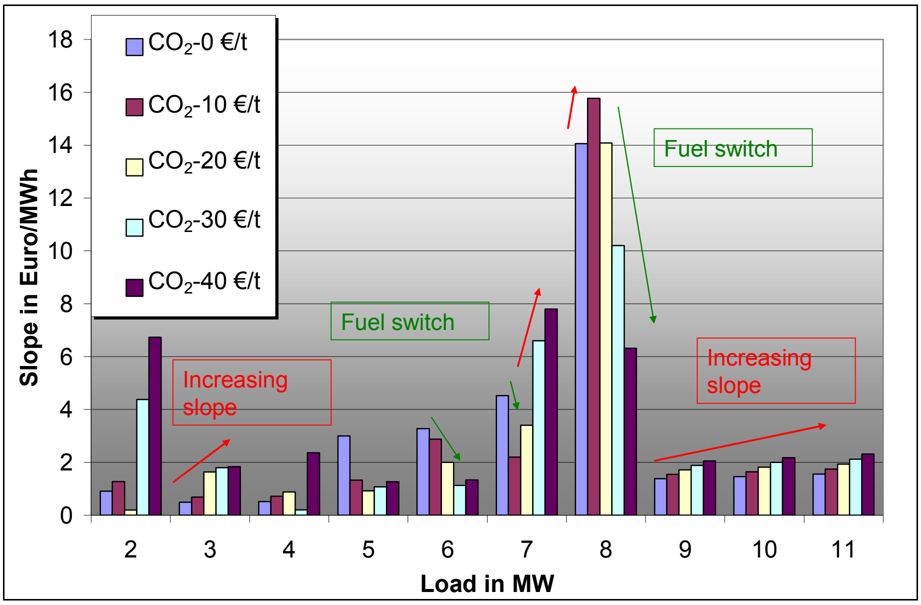
Figure 5 shows increasing prices with increasing CO_2 prices and differences in the slope of the merit-order curve. Since the slope of the merit-order curve is the most important parameter that determines the volume of the merit-order effect, another figure is added which analyses the slope of the merit-order curve in different segments with varying CO_2 prices. The result is presented in Figure 6. The figure shows that there are two different effects changing the slope of the merit-order curve. Within a certain technology group like gas turbines the increasing CO_2 prices increase the slope of the merit-order curve since the impact of efficiencies on generation cost increases. This effect should increase the merit-order effect of renewable electricity generation. Another important aspect which seems to have a stronger impact is the fuel switch effect. Higher CO_2 prices move hard coal power plants up within the merit-order curve, thereby decreasing the slope of the shoulder and peak load segment. As the result the volume of the merit-order effect decreases. The actual size of both effects heavily depends on the position within the merit-order curve which is determined by the hourly renewable electricity generation and the total electricity demand. In addition it has to be stated that the actual size of both effects heavily depends on the relation of gas and coal prices and the CO_2 price. In summary this simplified analysis shows the complexity of the effects determining the impact of CO_2 prices on the merit-order effect. Thereby the detailed PowerACE simulation helps to determine the volume of the discussed effects which are almost impossible to estimate at first sight.

Figure 5: Merit-order curve of the simplified power system



Source: own illustration

Figure 6: Slope of the merit-order curve



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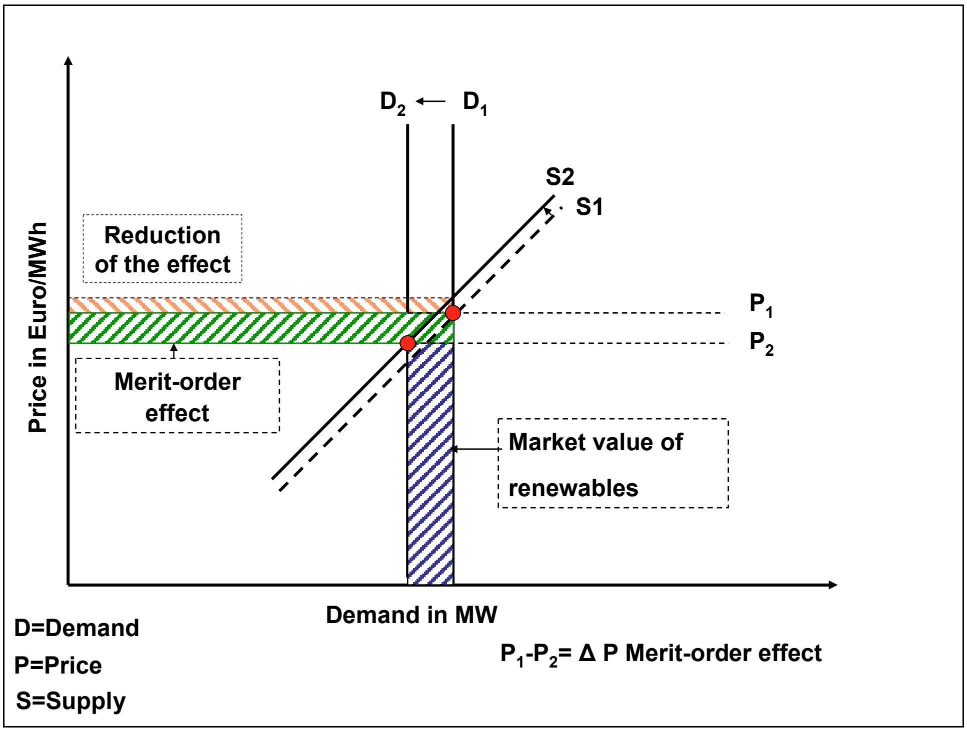
4.5 The impact of the power plant portfolio

Another factor which can have an important impact on the volume of the merit-order effect is the development of the power plant portfolio. Some authors state that the development of renewable electricity generation could have had and impact on the development of the power plant portfolio (Wissen, Nicolosi, 2007). In this case the merit-order curve could have a different shape in the scenario without renewable electricity generation. As a result the merit-order effect is reduced. The structure of this aspect is shown in Figure 7.

Figure 7: The effect of a dynamic power plant portfolio on the merit-order effect



Since the introduction of the electricity feed-in law the power plant portfolio could have been influenced in the following ways. The growing renewable electricity generation could have:

- Reduced the investments into new generation capacity
- Increased cold reserve (mothballed capacity)
- Increased decommissioning of power plants.

These aspects will be analysed in the next sections.

4.5.1 Investments into new generation capacity

It can be safely stated that the development of renewable electricity generation has had no major impact on investments into new generation capacity up to the year 2006. One reason is that the period after the liberalization of the electricity market was characterized by excess capacity and a following decommissioning of power plants. Another important aspect is the development of market prices. Up to the year 2004 market prices were too low to create incentives for the investment into new power plants. The calculated merit-order effect for the year 2004 shows that this situation has not been changed by the development of renewable electricity generation. Considering that the planning and construction of new power plants requires a period of several years it is not likely that the higher prices of the year 2005 could have lead to new generation capacity in 2006. These considerations show that is unlikely the supported renewable electricity generation has had a major impact on the investments so far. This assessment is also shared by various scientists (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, 2007).

4.5.2 Impact of renewable growth on decommissioned and mothballed capacity

Another important question is whether the development of renewable electricity generation has lead to an increase of mothballed or decommissioned capacity. In a recent paper (Wissen, Nicolosi, 2007) the decommissioned capacity for the years 2001-2005 and the mothballed capacity for the years 2005-2006 is published. It is very likely that most the decommissioned capacity was decommissioned for economic reasons such as low efficiency of the plant need for repairs or inefficient use of expensive fuels such as oil and gas. This assessment is also supported by discussions with the electricity industry. In particular the total mothballed capacity decreases from 2005 to 2006, which gives a further indication that stronger renewable energy deployment is not the key driver behind mothballing capacity. Nevertheless Wissen and Nicolosi state that some capacities might be still in operation if there was no growth in renewable electricity generation. In order to assess the uncertainty that is connected with this issue the merit-order effect is determined in a new scenario with the existing power plant portfolio for the runs with renewable electricity generation and a varied power plant portfolio for the runs without renewable electricity generation reflecting the decommissioned capacity.

Table 8: Mothballed capacity

	2005	2006
	MW	MW
Hard coal	1195	1195
Gas	750	300
Oil	1134	1134
Total	3079	2629

Source (Wissen, Nicolosi, 2007)

Table 9: Decommissioned capacity in the period 2001-2005

	Age of power plants			
	≤ 30	>30 ≤ 40	>40	Total
	MW	MW	MW	MW
Lignite	325	242	316	883
Hard coal	77	1307	545	1929
Gas	1558	1212	58	2828
Oil	714	0	0	0
Total	2674	2761	919	6354

Source (Wissen, Nicolosi, 2007)

4.5.3 Simulation results with varied power plant portfolio

In order to assess the possible impact of modified power plant portfolio on the results, additional capacity is added in steps to the scenario runs with deactivated renewable electricity generation and the merit-order effect is calculated. In the first step it is assumed that all decommissioned power plants with a lifetime of less than 30 years have been retired because of the growing renewable electricity generation. In this case the volume of the merit-order effect remains unchanged. In a second step the scope is extended to power plants with an age of up to 40 years. As a result the volume of the merit-order effect is reduced to 3.6 billion Euro. In the very unlikely case that all decommissioned power plants have been retired because of renewable electricity generation the merit-order effect is reduced to 2.8 billion Euro. Even if it is assumed that in addition to the retired capacity all mothballed power plants are mothballed because of the growing renewable electricity generation the merit-order effect stays at a considerable level of 2.1 billion Euro for the year 2006. An overview of the results is given Table 10.

Table 10: Additional capacity

	Additional capacity			
	Step I	**Step II**	**Step III**	**Step IV**
	Retired < 30 a	**Retired ≤ 40 a**	**Retired all**	**Retired and Mothballed**
	MW	MW	MW	MW
Lignite	325	567	883	883
Hard coal	77	1384	1929	3124
Gas	1558	2770	2828	3128
Oil	714	714	714	1848
Total	2674	5435	6354	8983
Merit-Order Effect in Mrd. Euro	5.01	3.6	2.84	2.1

5 Comparison with the literature

There are some studies which have been carried out in order to estimate the effect of renewable electricity generation on German spot market prices. Neubarth et al. (Neubarth et al., 2006) try to assess the value of the trades carried out by the grid operators in order to deal with fluctuating wind energy. They apply statistical methods to the analysis of a time series of spot market prices and day-ahead wind prognoses. The analysed time period is 01.09.2004-31.08.2005. They determine an average price effect on the daily average price of 1.89 Euro/MWh per GW average available wind energy. By scaling this effect to an installed capacity of 18.4 GW for the year 2005 and the corresponding wind conditions a value of 6.08 Euro/MW is reached. However the PowerACE calculations with considerable differences in the results between 2004 and 2005 show that the selected time period for the statistical analysis may not be a good choice. In addition the analysis carried out by Neubarth et al. neglects important factors such as plant outages, CO_2 prices, load and fuel prices. In case of correlation between one of these factors and the wind energy production the estimation could be changed heavily. Another approach is presented by Bode and Groscurth (Bode, Groscurth, 2006). They apply a model based analysis which is in principle similar to the approach of this paper. Based on a rather simple representation of the electricity sector they estimate an average price effect of 2.4 Euro/MWh in case of 36.7 TWh renewable electricity generation and a CO_2 price of 0 Euro/t. In a next step they vary the amount of renewable electricity generation in case of elastic and inelastic demand. As a result an average impact of 0.55 Euro/MWh or 0.61 Euro/MWh per GW available renewable electricity capacity is estimated. The upscaling of this effect to the simulated electricity generation in PowerACE of the year 2005 with an average renewable electricity generation of 45.5 TWh leads to an effect of 3.17 Euro/MWh. In another paper Bode (Bode, 2006) applies the results to the analysis of the price effects of different support schemes. The assumed slope of the supply curve is varied without new empirical analysis. In Table 11 the results of the discussed studies for Germany are compared to the analysis carried out with the PowerACE Cluster System[2].

Table 11: Comparison of the results for the merit-order effect

	Own calculations	**Own calculations**	**Own calculations**	**Bode, Groscurth 2006**	**Neubarth et al. 2006**
Time period	2004	2005	2006	Model period	2004-2005
Approach	PowerACE model	PowerACE model	PowerACE model	Simple model	Statistical approach
Price Effect	2.5 €/MWh	4.25 €/MWh	7.83€/MWh	3.17 €/MWh	6.08 €/MWh

The value published by Bode and Groscurth is considerably lower than the PowerACE results for the year 2005 and a bit higher than the results for the year 2004. The sensitivity analysis carried out in PowerACE shows that the merit-order effect is very sensitive to fuel prices and other assumptions, such as renewable electricity generation and fuel prices. Therefore the differences can be explained by the underlying assumptions. The applied fuel prices of Bode and Groscurth are considerably lower than the import prices of the year 2005.

2 Due to the calibration procedure described in the previous Chapter the settings of the PowerACE Cluster System deviate for the different years with regard to the settings of the CO_2 price factors and the scarcity mark-up. (2004 includes no scarcity mark-up and no CO_2 prices, 2005: CO_2 price factors: Gas 100 %, Hard coal 85 %, Lignite 70 %; 2006 no scarcity mark-up included, CO_2 price factors: Gas 100 %, Hard coal 100 % Lignite 20 %.)

6 Conclusions

This paper analyses the impact of the supported renewable electricity generation on spot market prices in Germany. The analysis is carried out based on the detailed electricity market simulation platform called PowerACE Cluster System. The model-based analysis shows that the renewable electricity generation has a considerable impact on market prices. In the year 2006 the reduction of the unweighted average price reaches 7.8 Euro/MWh. If it is assumed that the entire electricity demand is traded based on the simulated prices the financial volume of the merit-order effect can be calculated. The analysis for selected years in the period 2001-2006 shows that shows a considerable growth of the volume of the merit-order effect from 1 billion Euro in 2001 to 5 billion Euro in 2006. In a sensitivity analysis the driving factors for this development are determined. Besides the growing renewable electricity generation the main driving factor for the strong growth of the merit-order effect is the development of fuel prices. Thereby the gas price is the most important fact with a disproportionately high impact on the result. A considerable increase of gas prices and a moderate development of coal prices have increased the slope of the supply curve (merit-order curve) in the analysed period leading to a higher financial volume of the merit-order effect.

A central assumption for the calculation of the price effect is that the renewable electricity generation had no major impact on the development of the power plant portfolio up to the year 2006. Although this assumption is reasonable additional scenarios are analysed where it is assumed that some of the decommissioned and mothballed capacity are caused by renewable electricity generation. Even in the very unlikely scenario that the entire decommissioning of the period 2001-2005 is caused by renewable electricity generation the volume of the merit-order effect reaches the remarkable value of 2.8 billion Euro in the year 2006.

Another open issue is the impact of renewable electricity generation in Germany on imports and exports of renewable electricity generation. The integration of this aspect requires a detailed simulation of hourly prices on European level which is a demanding task. However, a comparison to recent studies analysing the price effect based on statistical data of real world prices shows that the price effect of renewable electricity generation is comparable to the results presented in this study. In recent studies the impact of wind energy on market prices in Denmark (Morthorst, 2007) and Germany (Neubarth et al., 2006) price reductions of 12-15% are observed.

As a result of the thorough sensitivity analysis and the comparison to the literature it can be stated that the fact the merit-order effect for the year 2006 reaches a considerable volume in the order of magnitude of 3-5 billion Euro is robust.

The considerable value of the merit-order effect shows that the cost for the renewable support that have to be paid by consumers might not be as high as expected (when ignoring this effect) in an electricity system. Thereby the merit-order effect is a distributional effect which shifts profits from generation companies to consumers. If the market value of renewable electricity is taken into account and the potential savings for consumers created by the merit-order effect are taken into account the feed-in support can lead to a net profit for consumers in the short run. Whether the savings created on the wholesale market are passed on to consumers heavily depends on the competitiveness of the consumer market. A central question for future research is how the volume of the merit-order effect can be estimated for future years.

7 Literature

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