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**On the market value of wind power**

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#### Abstract

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#### Index Terms

Inspec

#### Controlled Indexing

[power generation economics](#) [wind power](#)

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# On the market value of wind power

Carlo Obersteiner and Marcelo Saguan

**Abstract**—In leading European wind power countries wind power generation affects wholesale power prices already today. First investigations indicate that the respective wind power - price relation lowers the market value of wind power relative to the baseload price with increasing penetration. The aim of this paper is to identify parameters that determine this effect based on simulations for the Central European Power Market (CEPM). We model wind power - price interactions and investigate the sensitivity of the market value on a number of wind power and system related parameters. The market value of wind power is sensitive to changes in wind share and variability, wind-demand correlation and the supply characteristics. Results further indicate that for expected wind capacities in 2020 the market value in the CEPM is significantly lower than the baseload price. The market value reducing effect varies among countries and is comparably low for wind power portfolios whose generation is weakly correlated with the overall wind power generation in the respective power market. Hence with rising wind shares it will become increasingly important to take this effect into account when assessing the economics of wind power projects. Future trends in the CEPM that may positively influence the market value are increasing electricity demand, fuel and CO<sub>2</sub> prices, a better geographic distribution of onshore wind within the CEPM and an increasing utilization of offshore wind.

**Index Terms**—Wind power, power markets, market value

## I. INTRODUCTION

IN leading European wind power countries like Germany, Spain and Denmark wind power generation affects power prices already today. As marginal cost of wind power is almost zero, rising amounts of wind power ceteris paribus have a dampening effect on electricity prices for a given power system. This so called merit order effect has already been studied for selected power markets (cf. [1]–[3])<sup>1</sup>.

From the power producers point of view the merit order effect lowers the market value of power generation i.e. the average price for selling power on the wholesale power

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<sup>1</sup> It is important to note that this effect is not wind power specific but might be observed for any power generation technology with low marginal cost of generation that is pushed into the market. In the long-term however increasing wind shares will influence the investment decision for conventional power plants which has to be taken into account to get a complete picture of the influence of wind power on power prices.

market. In contrast to a baseload generation technology i.e. a technology that produces a fixed quantity constantly, for a variable generation technology like wind power there is a correlation between power generation and electricity prices which is inherent to the system: For a power system that is specified by a certain supply structure and a fixed demand we might observe “low” electricity prices when wind power generation is high because residual demand can be met with less costly conventional generation and vice versa.

While the effect of wind power on power prices has already been analyzed, studies investigating implications of the above mentioned system immanent wind power - price correlation on the market value of wind power are rare. Within an investigation of the long-term system value of intermittent power generation technologies [4] finds that the market value of wind power decreases with increasing wind shares relative to the average system baseload price and explains this effect by the decrease in covariance between wind power generation and power price.

This paper aims to go one step further and investigates in more detail the impact of fundamental wind and system related parameters on the market value of wind power based on simulations. We model wind power - price interactions using a simplistic representation of the Central European Power Market (CEPM)<sup>2</sup> and analyze the sensitivity of the market value of wind power on parameter variations. Both implications on market as well as country level are looked at. Finally, based on simulation results, a qualitative assessment of impacts of future trends in the CEPM on the market value of wind power is realized.

To get insight in mechanisms affecting the market value of wind power is of importance for both investors and policy makers. For the first the market value determines the economics of their investment unless wind power support is uncoupled from power markets<sup>3</sup>. Knowledge about the market value helps latter to optimize support schemes and estimate support needs. From an international perspective the market value (together with the quality of wind sites) determines where most cost efficient potentials can be realized.

The paper is organized as follows. In Section II, main

<sup>2</sup> The CEPM includes Austria, Czech Republic, France, Germany and Switzerland. After the introduction of market coupling between France, Belgium and the Netherlands wholesale power prices in the two Benelux countries tend to converge towards the price level in above mentioned countries (see [5]).

<sup>3</sup> In Europe we can observe a trend from the classical feed-in tariff schemes which remunerate renewable electricity at a fixed tariff (independent of the wholesale price) to feed-in premium schemes that provide a premium on top of revenues from selling power on the markets. Currently the German regulation is adapted in this direction.

parameters influencing the market value of wind power are discussed. Section III explains the modeling and simulation framework. Simulation results on both CEPM and country level are presented in Section IV. Section V discusses future trends in the CEPM and their qualitative impact on the market value of wind power. Section VI concludes and gives an outlook for future work.

## II. MAIN PARAMETERS INFLUENCING THE MARKET VALUE OF WIND POWER

The aim of this section is to identify main parameters influencing the market value of wind power. We define the market value of wind power as the sum of revenues by unit of energy if all wind power production were sold in the power exchange. When assessing the market value as interpreted within this paper for a specific generation technology it is important to note that there is no single but a broad range of market values depending on the supposed trading strategy. For instance, wind power might be sold on the long-term market i.e. bilaterally or in form of baseload futures and additionally short-term deviations based on wind power forecasts may be settled on the day-ahead market. Finally deviations between trading schedules and actual generation are settled with imbalance clearing prices within the balancing mechanism. The market value finally results in the sum of revenues (and cost) from several trading activities as illustrated in [6]. As it is not the aim of this paper to analyze trading strategies and imbalance cost, forecast uncertainties are neglected and a single stage of market clearing is assumed when modeling the CEPM.

The starting point for the identification of influencing parameters is the key analytical finding of [4] that the market value of wind power can be split up in two components: i) a “baseload” power price component and ii) a component related to the covariance between power price and wind power production:

$$MV_W = \frac{\sum_{h=1}^H \pi_{PX,h} \cdot Q_{W,h}}{\sum_{h=1}^H Q_{W,h}} = \bar{\pi}_{PX} + \frac{\text{cov}(\pi_{PX}, Q_W)}{\bar{Q}_W} \quad (1)$$

where  $MV_W$  is the market value of wind power,  $\pi_{PX,h}$  is the power price at the power exchange in hour  $h$ ,  $Q_{W,h}$  is the wind power generation in hour  $h$ ,  $\pi_{PX}$  is the power price vector,  $\bar{\pi}_{PX}$  is the average baseload price and  $Q_W$  is the wind power generation vector.

Thus the market value of wind power is determined by both parameters influencing the baseload price and those affecting the covariance between wind power and power price. As this paper specifically aims to investigate the relation between market value and baseload price, the analysis focuses on latter parameters.

In a competitive power market, the wholesale price<sup>4</sup> is

<sup>4</sup> Wholesale electricity markets are mainly composed by organized (day-ahead) power market transactions and over the counter (OTC) transactions. Theoretically, the presence of traders that arbitrage opportunities between

determined by the generation costs of the marginal technology i.e. the short run marginal cost of the most expensive unit which is needed to satisfy demand. Therefore power price variations may originate from variations in generation costs of the marginal technologies, from variations in the availability of power generation and from variations in demand. In a non-competitive setting, prices may additionally be affected by strategic behavior of market actors.

As gas and coal power plants represent the marginal technologies in the CEPM, variations in generation cost are mainly related to the evolution of the gas, coal and CO<sub>2</sub>-certificate prices. Depending on the correlation with wind power generation fuel and CO<sub>2</sub> price shocks might significantly influence the market value of wind power relative to the baseload price in a specific period of consideration. However, if the observed period is long enough, we expect no significant impact, as there is no evidence for a long-term correlation of these shocks with wind power generation.

Wind power, supply and demand variations are translated into price variations. The resulting wind power-price correlation depends on the shape of the supply curve and on the correlation of corresponding parameters with wind generation. The correlation between wind power and demand as well as other variable renewable generation is mainly determined by meteorological interactions. A correlation between wind generation and the availability of thermal capacities might result from weather depending cooling restrictions and a maintenance planning that takes into account the seasonal availability of wind power. The wind power-price correlation further depends on the wind share as found in [4] and may also be affected by the variability of wind power.

Effects of strategic behavior on the market value of wind power are investigated in [7]. They conclude that intermittent generation benefits less from abuse of market power than conventional generation.

Within this paper we analyze the following abovementioned parameters affecting the wind power-price covariance: wind power share and variance, wind-demand correlation and the supply characteristics.

## III. MODELING WIND POWER-PRICE INTERACTIONS

### A. The power system model

The characteristics of power supply in the CEPM is represented by a function  $s$  – the supply curve – that describes the relation between the quantity of supply  $Q_S$  and the marginal cost  $MC$  at which this quantity may be produced:

$$MC = s(Q_S) \quad (2)$$

The CEPM is modeled as an isolated market i.e. exchanges with neighboring systems are not reflected.

In order to account for the variability of wind power the model has a time resolution of 1 hour. Wind power generation

these two market places ensures that power exchange prices should be equivalent to OTC prices. Supposing that this free arbitrage assumption holds in reality, only power exchange prices are considered in this paper.

$Q_{W,h}$  in hour  $h$  is reflected within the residual system demand  $Q_{D,res,h}$  which has to be met by remaining power generation technologies in the form

$$Q_{D,res,h} = Q_{D,h} - Q_{W,h} \quad (3)$$

where  $Q_{D,h}$  represents system gross demand in hour  $h$  i.e. electricity demand including power losses.

Note that supply and residual demand curves corresponding to each country are aggregated to a unique curve representing the integrated CEPM. This implies the assumption of perfect (copper plate) integration of national electricity markets.

Then, if we assume perfect competition, the power price  $\pi_h$  results as

$$\pi_h = s(Q_{D,res,h}). \quad (4)$$

The baseload price<sup>5</sup>  $\pi_{base}$  is calculated as the average of elements  $\pi_h$  of the resulting price vector

$$\pi_{base} = \frac{1}{H} \sum_{h=1}^H \pi_h \quad (5)$$

while the market value of wind power  $MV_W$  is calculated as the volume weighted average price:

$$MV_W = \frac{\sum_{h=1}^H Q_{W,h} \cdot \pi_h}{\sum_{h=1}^H Q_{W,h}} \quad (6)$$

### B. Data base

The supply curve represents the average available capacity of all generation technologies in the CEPM except from wind power and is assumed to be fixed. Marginal costs of generation are calculated assuming average prices for fossil fuels and CO<sub>2</sub> certificates and efficiencies differentiated by fuel type and decade of commissioning. All parameters refer to the year 2006 (see below Table 1 for price assumptions). Hourly wind power and demand time series also refer to the year 2006. For Austria, Germany and France measured wind power data is used while for Czech Republic and Switzerland wind power time series modeled within the Tradewind project based on numerical weather data are applied (cf. [8], [9]). Hourly demand data stem from UCTE.

### C. Implementation of parameter variations

In order to derive the sensitivity of the market value of wind power we vary single above mentioned parameters within simulations while several other parameters are kept constant.

Parameter variations are implemented as follows:

Increased wind shares are modeled by simply scaling wind power time series for 2006. We investigate different deployment scenarios for 2020 based on simulations with the Green-X model (cf. [10]) for countries of the CEPM: i) Current support policies are retained in the future (2020 BAU), ii) Strengthened national policies in line with 20% target (2020 20%), iii) A case with wind deployment on CEPM level according to the 2020 20 % scenario and

<sup>5</sup> Baseload price represents the revenue per unit of energy if power is produced in a constant manner over the studied period.

distribution among countries as in 2006.

Wind power demand correlation: We use copulas to generate samples with distributions equal to historic wind power and demand in the CEPM and varying correlation. For a detailed description of the methodology see [11].

Historic wind power time series represent a certain distribution and variability and are therefore not suited to reflect different scenarios of wind power variability. We simulate a set of samples with varying wind power variance and representative distributions according to the following procedure:

- 1) Generation of uncorrelated with Rayleigh distributed samples for wind speed with defined mean.
- 2) Application of samples to a normalized power curve<sup>6</sup>. Summing up of different numbers of uncorrelated wind power samples.
- 3) Scaling of resulting samples to the reference mean wind power generation

Again copulas are used to simulate corresponding samples of wind power and gross demand with reference correlation observed for 2006 data (for details see [11]).

Varying supply characteristics are represented by scenarios for fuel prices for gas and oil and the CO<sub>2</sub> certificate price as indicated in the table below. It is important to note, that in contrast to [4], we do not model the optimal energy mix for given wind shares but focus on sensitivities for given system configurations. Our simulations are “static” meaning that changes in parameters are not endogenous. We do not study the impact of the future development of the supply structure.

Table 1. Assumptions for investigated price scenarios

	Gas [€/MWh]	Oil [€/MWh]	CO <sub>2</sub> [€/tCO <sub>2</sub> ]
<b>2006 prices</b>	21.4	32.5	17
<b>High fuel</b>	27.9	41.3	17
<b>High CO<sub>2</sub></b>	21.4	32.5	50
<b>High fuel&amp;CO<sub>2</sub></b>	27.9	41.3	50

Sources: BAFA (2006 prices for gas and oil), EEX (CO<sub>2</sub> certificates), [12] (high fuel prices).

## IV. SIMULATION RESULTS

### A. Sensitivity analysis for the CEPM

In this section, simulation results on the sensitivity of the relative price difference between market value and baseload price on changes of aforementioned parameters are presented<sup>7</sup>.

As sensitivities depend on the point of reference, two wind deployment scenarios are investigated: i) the reference case (2006 wind deployment), ii) the 2020 20% wind scenario.

<sup>6</sup> The used power curves have been developed within the TradeWind project and reflects the characteristics of regionally distributed wind farms in lowland areas (cf. [9])

<sup>7</sup> It is important to note that the market values indicated here refer to total wind power generation on country and CEPM level respectively and therefore represent the revenue for a single actor managing the whole portfolio. A particular wind farm however will have a specific market value that will depend on the specific correlation between its production and market price.

For the reference case, that reflects wind power and system characteristics of the year 2006, the baseload price is 51.4 €/MWh in the CEPM while the market value of the overall wind power portfolio is 51.2 €/MWh<sup>8</sup>. For a wind share of 2.8 % of gross demand the relative price difference is therefore still minor with -0.4 % of the baseload price.

The sensitivity of the price difference is significant for all indicated parameters (see Fig. 1). While an increase of wind share and variance reduces the market value of wind power cet. par. an increased wind-demand correlation is beneficial for the economics of wind power. It can be seen that for specific parameter settings the market value can even exceed the baseload price. The highest sensitivity is observed for variations of the wind power share. A doubling results in a price difference of -3.3 % while for a reduction to half of the generation the market value is 1.2 % higher than the baseload price. The market value equals the baseload price when reducing the variance of wind power by 25 % of the reference value or when increasing the wind-demand correlation by 25 %.

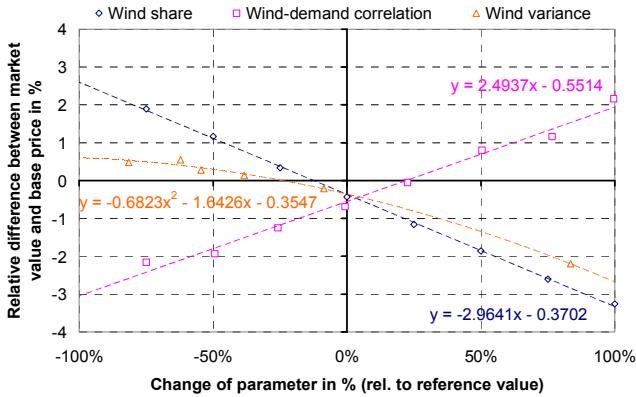


Fig. 1. Reference scenario – sensitivity of the relative price difference between market value and baseload price on selected parameters. Assumptions: CEPM, supply, demand and wind power data from 2006

For a wind generation scenario which is in line with the 20% renewables target in 2020, sensitivities show the same qualitative behavior. As a result of the increased wind share of 16.3 % the baseload price is reduced to 41.7 €/MWh (cet. par.). For this level of penetration the relative price difference is already considerable with 10.8 %. The sensitivity of the price difference on wind share variation is still highest. A 10 % increase of wind share results in a 1.3 % decrease of market value. The sensitivity on the variance of wind power is in a comparable range. It can be seen that for the investigated level of wind penetration the price difference diminishes only in the case of smooth wind power production. The sensitivity on wind-demand correlation variations is comparable low. An increase of 10 % results in a increase of the market value of about 0.2 % of baseload price (see Fig. 2).

<sup>8</sup> In 2006 the average price of day-ahead auctions on the major power exchange in the CEPM – the European Energy Exchange (EEX) – was 50.9 €/MWh.

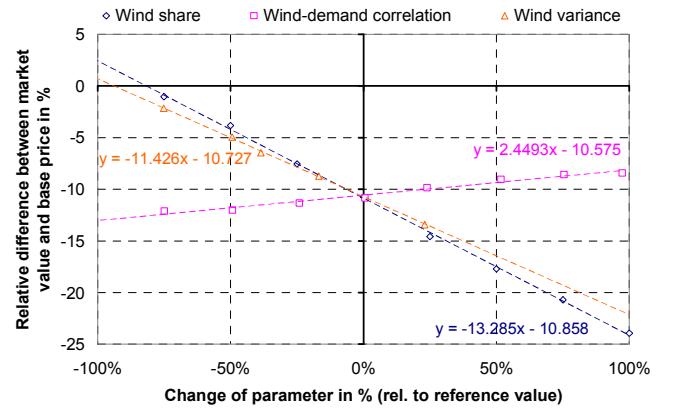


Fig. 2. 2020 20 % target scenario – sensitivity of the relative price difference between market value and baseload price on selected parameters. Assumptions: CEPM, supply and demand from 2006, wind power generation according to 2020 20% scenario

Analyses for stylized, continuous supply curves in [11] indicate that the market value of wind power declines with increasing convexities. The interpretation of this finding for changes in the supply characteristics of real systems is not clear given the complex structure of real supply curves including both linear and convex sections as well as jump discontinuities.

For our supply representation of the CEPM we do not observe remarkable changes of the relative price difference for investigated fuel and CO<sub>2</sub> price scenarios compared to the reference case for 2006 wind generation. However for the 2020 20% wind scenario all alternative price scenarios result in a higher price difference (12.4 %) than in the reference case (10.6 %). As a consequence of differing baseload prices the difference between market value and base price varies between 5.5 €/MWh in the high fuel price scenario and 8.5 €/MWh in the high fuel&CO<sub>2</sub> price scenario (see Fig. 3).

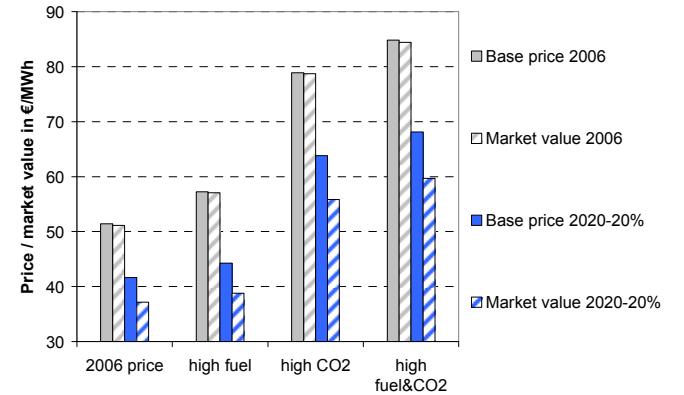


Fig. 3. Comparison of baseload price and market value of wind power for investigated price and wind scenarios. Assumptions: fuel and CO<sub>2</sub> prices according to Table 1

### B. The price difference on country level

The difference between the market value of wind power and the baseload price on country level is assessed for wind deployment scenarios indicated in section III-C. As illustrated

in Fig. 4, the price difference becomes significant for increased wind shares.

Interestingly, the effect is quite different on country level – for the 2020-20% scenario the price difference varies between 4% in Austria and 16% in Germany. This might be explained by differing resulting correlations between wind generations on country level and overall residual demand in the CEPM. Another remarkable fact is that the increase of the price difference for Austria is significantly lower than for other countries. Austrian wind power obviously profits from comparable low correlation with overall wind power generation in the CEPM (see Table 2). When comparing the 2020-20% scenario with the case of wind power distribution of 2006 we can identify a significant benefit of the better geographical distribution of wind capacities on CEPM level<sup>9</sup>. Austrian, German and Czech wind power profit from the increased share of French wind power while the market value is reduced in France and Switzerland. This might be again explained by the wind-wind correlation coefficients drawn in Table 2. For first countries wind power generation is more correlated with German than with French wind power while for the latter the situation is inverse.

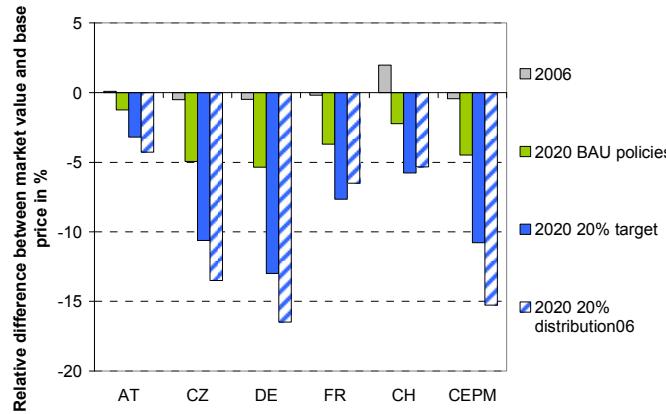


Fig. 4. Relative difference between market value and baseload price for investigated wind penetration scenarios.

Table 2. Correlation between wind power generations in countries of the CEPM. Assumption: 2020 20% wind scenario

	AT	CZ	DE	FR	CH	CEPM
AT	1.00	0.44	0.20	0.12	0.18	0.23
CZ	0.44	1.00	0.73	0.32	0.39	0.69
DE	0.20	0.73	1.00	0.51	0.38	0.95
FR	0.12	0.32	0.51	1.00	0.57	0.75
CH	0.18	0.39	0.38	0.57	1.00	0.51
CEPM	0.23	0.69	0.95	0.75	0.51	1.00

## V. FUTURE TRENDS AND THEIR IMPLICATIONS ON THE MARKET VALUE OF WIND POWER

In this chapter we firstly discuss how investigated

<sup>9</sup> In 2006 wind power generation in the CEPM is highly dominated by German wind (89%) while in the 2020-20% scenario wind power is dominated by both German (59%) and French (36%) wind power resulting in a lower variability of overall wind power.

parameters may evolve in the CEPM in the future and then assess the qualitative impact of future trends based on presented simulation results.

### A. Wind share

Wind deployment scenarios investigated in [10] indicate an increase of overall wind power generation from 34 TWh in 2006 to 196 TWh for the CEPM in 2020 for a 20 % renewables target on EU-level. Remarkable trends are an increased share of French wind power (from 6 to 36 %) and offshore wind (from 0 to 48%). The wind share obviously also depends on the development of demand. A constant increase of 2% annually up to 2020 would result in demand increase compared to 2006 of more than 30%. Depending on the development of fundamental parameters and the effectiveness of energy efficiency measures this increase might also be considerably lower.

### B. Wind power variability

The major parameter affecting the variability of wind power is the geographic distribution of wind sites as correlation between wind power generation decreases with increasing distance between sites. While we can expect that the distribution of onshore wind will not change dramatically within investigated countries, onshore wind in future will be better distributed within the CEPM according to the scenario cited above, resulting in a lower overall variability. Besides that an increased utilization of offshore wind will further dampen the variability of resulting wind power generation as shown in [13] for the case of Germany.

### C. Wind-demand correlation

In 2006 wind and demand in the CEPM are weekly positive correlated (0.13). Among countries correlation with CEPM demand varies between 0.05 and 0.14. For the 2020 20% scenario there is no significant change in correlation. It is not clear if and in which direction a higher wind offshore share will influence this parameter. Increased storage capacities in form of pumped hydro or compressed air storage can positively influence the correlation between wind and demand if they are operated in a way to arbitrage price variations induced by wind power.

### D. Supply characteristics

In the short to medium term fuel and CO<sub>2</sub> price shocks influence the supply characteristics. In a longer term perspective the supply mix changes depending on expectations of the future development of these parameters. Further influencing parameters include the development of demand and renewable electricity of which most important wind power. Volatile prices and policy uncertainty involve a broad bandwidth of future supply scenarios.

### E. Qualitative assessment

Finally based on simulation results presented in Chapter IV the implication of discussed future trends in the CEPM on the market value of wind power and its difference to the baseload price are assessed qualitatively (see Table 3). All indications

follow the logic of a *ceteris paribus* consideration i.e. all parameters except for the investigated parameter are kept constant.

Table 3. Qualitative assessment of the impact of parameter changes in the CEPM on the market value of wind power

Effect of parameter increase on	baseload price	MV of wind power	price difference base - MV
<b>Demand</b>	+	++	↓
<b>Storage capacity</b>	- <sup>1)</sup>	o <sup>2)</sup>	↓
<b>Wind capacity</b>	-	--	↑
<b>Wind offshore share</b>	o	+	↓
<b>Geographic wind power distribution in CEPM</b>	o	+	↓
<b>Fuel price</b>	++	+	↑
<b>CO<sub>2</sub> certificate price</b>	++	+	↑

<sup>1)</sup> under assumption of a convex supply curve

<sup>2)</sup> simulation results indicate a slight decrease for both base price and price difference

## VI. CONCLUSIONS

The impact of the system immanent wind power-price correlation on the market value of wind power in the CEPM is negligible in 2006 but will become significant for expected wind capacities in 2020. The baseload price then does not constitute any longer a reliable indicator for the market value of wind power.

Simulations show that price differences will vary considerably among countries in the CEPM. For increased wind shares the economics of wind power will not only depend on the potential energy yield but increasingly also on specific wind characteristics; there are incentives to utilize second best potentials that are less correlated with overall generation in the relevant market.

The market value of wind power can benefit from increasing electricity demand, increasing fuel and CO<sub>2</sub> prices, a better geographic distribution of onshore wind within the CEPM and an increasing utilization of offshore wind.

For two reasons quantitative results have to be interpreted with care:

- 1) The data base for a single year might not reflect the long term characteristics of wind power and demand and their relation accordingly.
- 2) The simplified representation of the CEPM neglects important aspects like operational constraints of power plants, interconnections with neighboring markets and congestions within the CEPM.

Further research should focus on both an improved data base and representation of the CEPM in order to derive more reliable qualitative results that may then be confronted with empirical analysis.

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## REFERENCES

- [1] G. de Miera, P. del Rio Gonzalez, I. Vizcaino, *Analysing the impact of renewable electricity support schemes on power prices: The case of wind electricity in Spain*, Energy Policy, 36 (9), pp.3345-3359, Sep 2008
- [2] F. Sensfuss, M. Ragwitz, M. Genoese, *The merit-order effect: A detailed analysis of the price effect of renewable electricity generation on spot market*, Energy Policy, 36 (8), pp.3086-3094, Aug 2008
- [3] J. Munksgaard, P. E. Morthorst, Wind power in the Danish liberalized power market – Policy measures, price impact and investor incentives, Energy Policy, 36 (2008), pp. 3940-3947
- [4] A. D. Lamont, *Assessing the long-term system value of intermittent electric generation technologies*, Energy Economics, Volume 30, Issue 3, May 2008, pp. 1208-1231
- [5] R. Haas, C. Redl, H. Auer, *Mid-term Perspectives for the Western/Central European Electricity Market*, Newsletter of the International Association of Energy Economics (IAEE), Q1 2008
- [6] C. Obersteiner, L. von Bremen, *On the Influence of Market Rules on the Economic Value of Wind Power – An Austrian Case Study*, International Journal of Environment and Pollution, to be published
- [7] P. Twomey, K. Neuhoff, Wind Power and Market Power in Competitive Markets, Proceedings of Workshop on “Wind power and market design”, 6-7 June 2008, Fontenay aux Roses, France
- [8] J. R. McLean, Characteristic Wind Speed Time Series, Report of the Tradewind project, July 2008, [www.trade-wind.eu/](http://www.trade-wind.eu/)
- [9] J. R. McLean, *Equivalent Wind Power Curves*, Report of the Tradewind project, April 2007, [www.trade-wind.eu/](http://www.trade-wind.eu/)
- [10] G. Resch, T. Faber, A. Held, C. Panzer, R. Haas, *20% RES by 2020 – a balanced scenario to meet Europe’s renewable energy target*, Report of the Futures-e project, Vienna, Austria, Feb 2008, [www.futures-e.org/](http://www.futures-e.org/)
- [11] C. Obersteiner, M. Saguan, H. Auer, C. Hiroux, *On the relation between wind power generation, electricity prices and the market value of wind power*, Proceedings of the 31st IAEE International Conference, 18-20 June 2008, Istanbul, Turkey
- [12] L. Mantzos, P. Capros, European energy and transport – Scenarios on high oil and gas prices, Report for the European Commission, Athena, Greece, Sep 2006
- [13] L. von Bremen, N. Saleck, U. Gräwe, J. Tambke, D. Heinemann, Meteorological models for prediction and simulation of wind power, Proceedings of the FVS Workshop, 2 November 2006, Berlin, Germany