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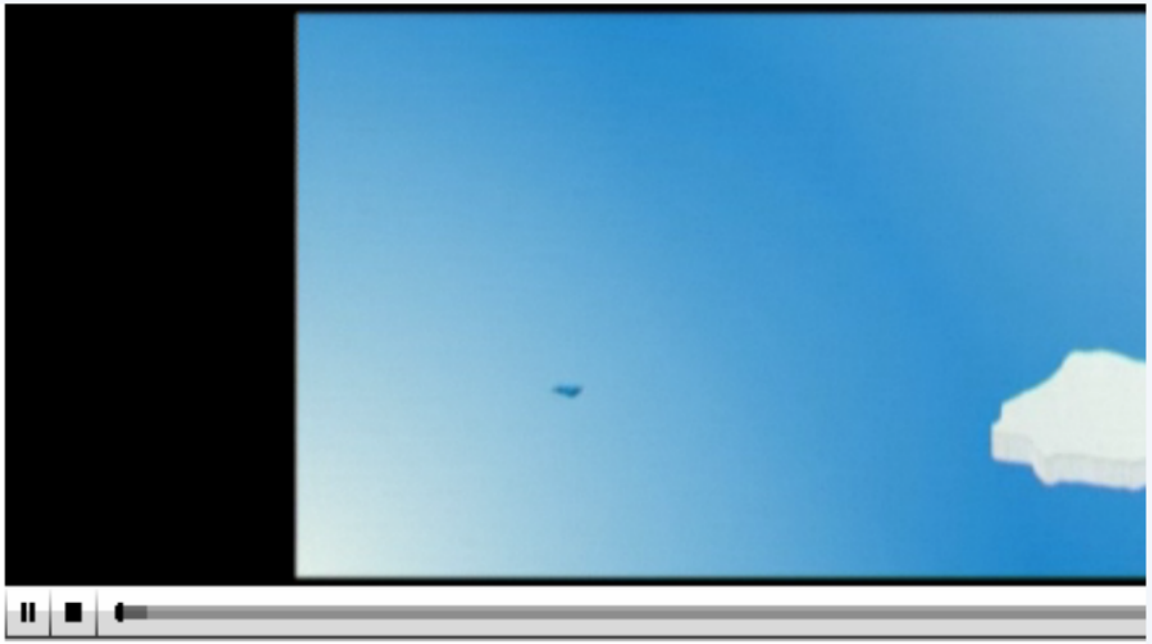

Full Opening Session

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European Wind Energy Conference
Marseille, France
16-19 March 2009

On the market value of wind power

How much money flows when the wind blows?

Carlo Obersteiner
Energy Economics Group (EEG), Vienna University of Technology
obersteiner@eeg.tuwien.ac.at

Marcelo Saguan
Department of Power and Energy Systems, SUPELEC
and
GRJM, Faculté Jean Monnet, University of Paris XI
marcelo.saguan@u-psud.fr

Outline

1. **Introduction**
   - *Motivation*
   - *Parameters influencing the market value of wind power*
2. **Methodology**
   - *Approach*
   - *Modelling wind power price interactions*
3. **Model results**
   - *Sensitivities of market value on analysed parameters*
   - *Country analyses*
4. **Future Trends in the CEPM**
5. **Conclusions, Outlook**

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Motivation

- **Wind power affects power markets (prices) already today**

- **Literature:** *De Miera et al. (2008), Sensfuß et al. (2008), Munksgaard and Morthorst (2008)*

Findings

(1) Wind power replaces more expensive generation → lowers power price

(2) High wind generation coincides with low power prices and vice versa

Question:

- **What are the implications of (2) on the market value of wind power?**

Literature

Lamont (2008) 'Assessing the long-term system value of intermittent electric generation technologies'

– **Key analytical finding: market value of wind power can be split up in two components**

$$mv = \frac{\sum_{h=1}^{H}(p_{PX,h} \cdot P_{Wind,h})}{\sum_{h=1}^{H}(P_{Wind,h})} \quad \Rightarrow \quad mv = \overline{p_{PX}} + \frac{\mathrm{cov}(p_{PX}, P_{Wind})}{\overline{P_{Wind}}}$$

with

mv	*market value of wind power*
$p_{PX,h}$	*hourly power price at power exchange*
$P_{Wind,h}$	*hourly wind power generation*
p_{PX}	*power price vector*
P_{Wind}	*wind power generation vector*
$\overline{p_{PX}}$	*base load price*
$\overline{P_{Wind}}$	*mean wind power*

Literature

Lamont A. D. (2008) 'Assessing the long-term system value of intermittent electric generation technologies'

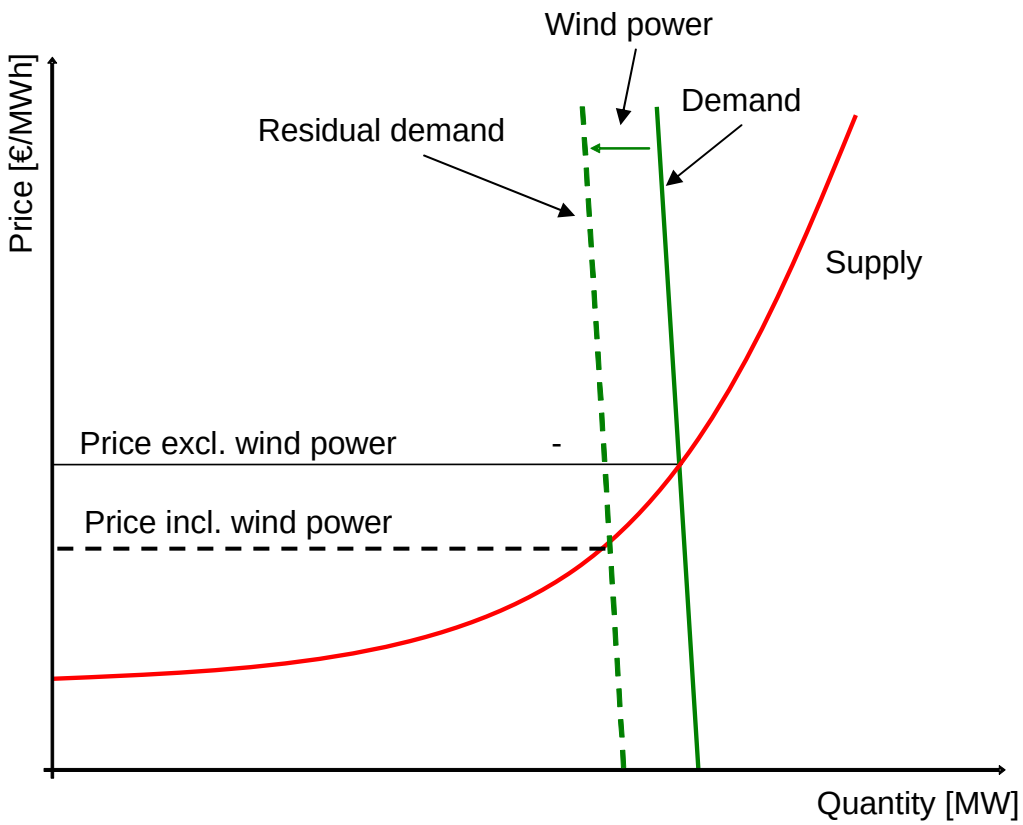
Further findings related to market value:

- **Market value decreases with increasing wind share relative to base load price**
- **Explanation: Decreasing wind power - price covariance**

Questions:

1. **Which parameters are affecting the covariance between wind power and power price?**
2. **Relevance of effect for Central European Power Market (CEPM)?**

Key influencing parameters



System immanent correlation

- Wind power share
- Supply characteristics
- Wind power-demand, -supply correlation
- Variance of wind power and demand

Further parameters

- SRMC of price setting technologies (gas, coal, CO2-certificate price)
- Abuse of market power (mark up on SRMC, withhold capacity)

→ *no long term correlation with wind power generation*

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Approach

- **Model based analysis**
- **Focus on difference between market value and baseload price**

i. Sensitivity on parameter changes for CEPM

- wind share
- wind demand correlation
- wind variability
- supply characteristics

ii. Country analysis for future wind deployment scenarios

iii. Qualitative assessment of impact of future trends

Modelling wind power - price interactions

Representation of the power market

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

with

π_h	*hourly power price*
$Q_{D,res,h}$	*Hourly residual demand (= demand – wind power)*
s	*Supply function*

Assumptions

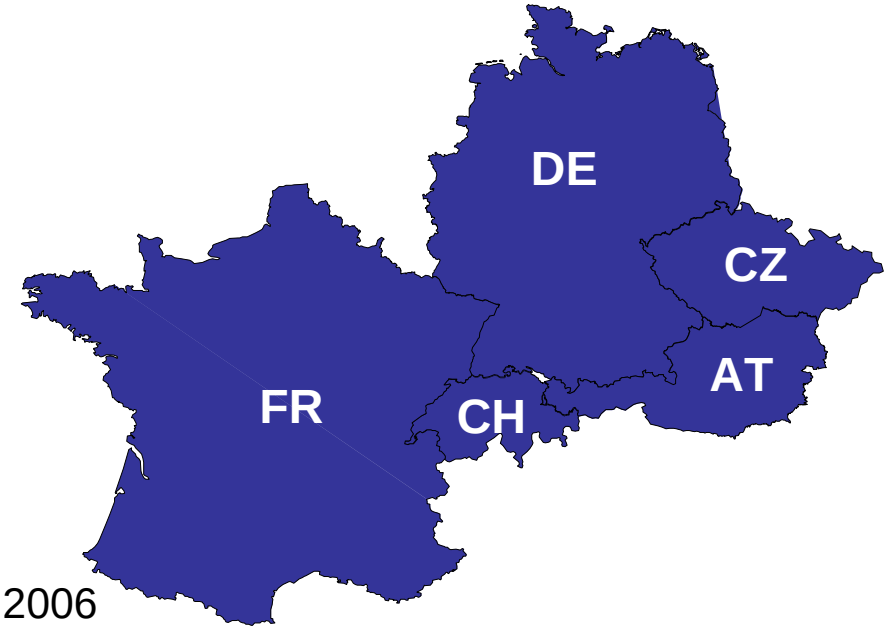
- Static consideration
- Isolated power market
- Perfect competition
- No power plant operation constraints
- No internal congestions

Market value

Baseload technology: $mv_{base} = \overline{\pi_h}$

Wind power: $mv_{Wind} = \overline{\pi_h} + \frac{\mathrm{cov}(\pi, P_{Wind})}{\overline{P_{Wind}}}$

Framework, Data



System boarders

– Central European Power Market (CEPM)

Reference year

– 2006

Wind power generation (per country)

– Measured/simulated hourly time series for 2006

Demand (per country)

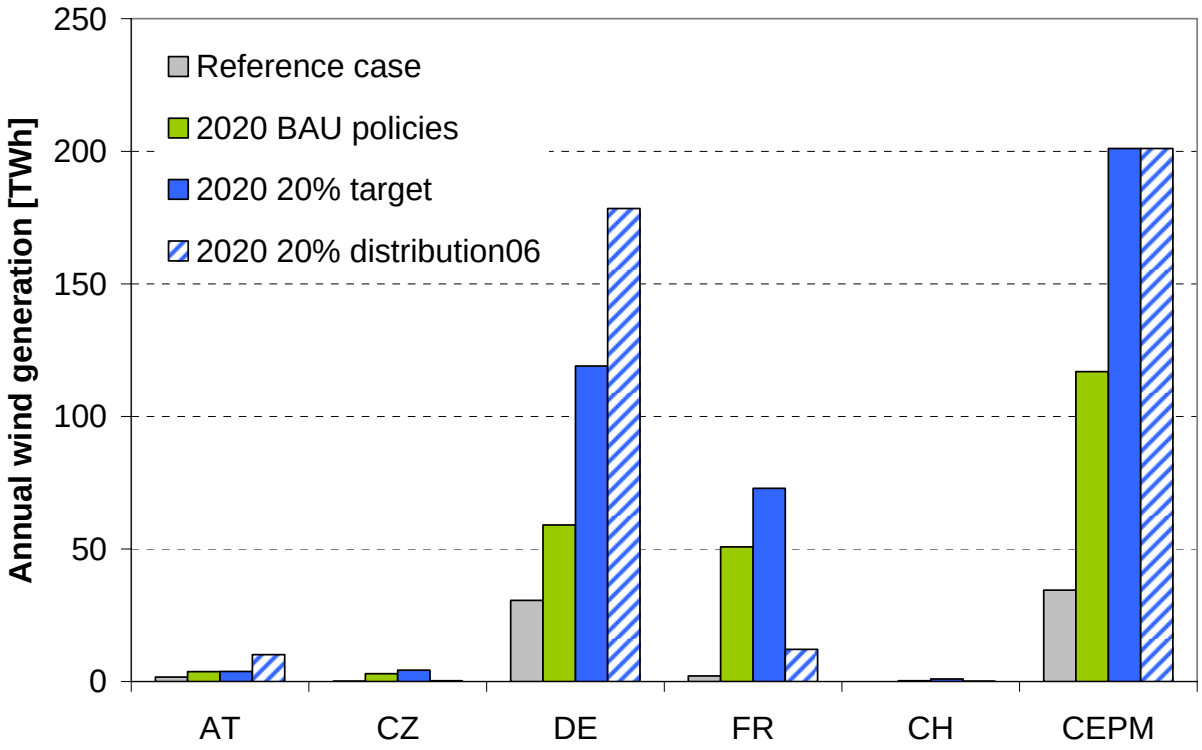
– Hourly time series from UCTE

Supply (for CEPM)

– Average available capacity
– SRMC
  - Efficiencies per fuel type and decade of commissioning
  - Average prices for fuel, CO2-certificates

Investigated wind scenarios

i. Reference case: 2006 data
ii. 2020 BAU: Current support policies retained until 2020
iii. 2020 20% target: Support policies in line with 20% RE target
iv. 2020 20% distribution06: deployment as for iii) but distribution according to i)



Source:
own scenarios based on Green-X model (cf. Resch et al., 2008)

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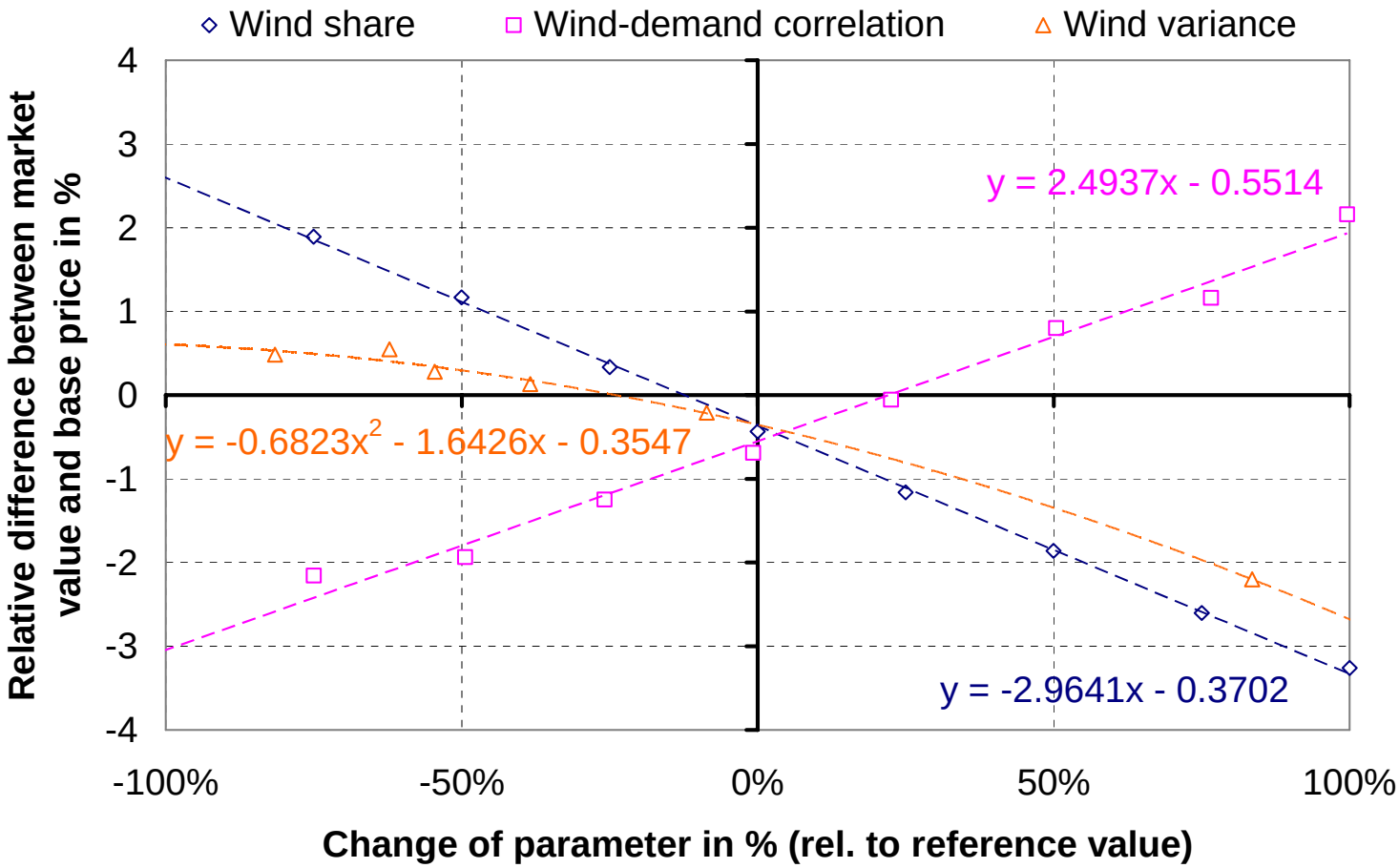
Sensitivity analysis for CEPM (1)

Reference case (2006)

Sensitivity of relative price difference on parameter variations



Sensitivity analysis for CEPM (3)

Fuel and CO2-certificate price

Investigated scenarios	**Gas [€/MWh]**	**Oil [€/MWh]**	**CO2 [€/tCO2]**
2006 prices	21.4	32.5	17
High fuel	27.9	41.3	17
High CO2	21.4	32.5	50
High fuel&CO2	27.9	41.3	50

Sources: EEX, BAFA, DG TREN

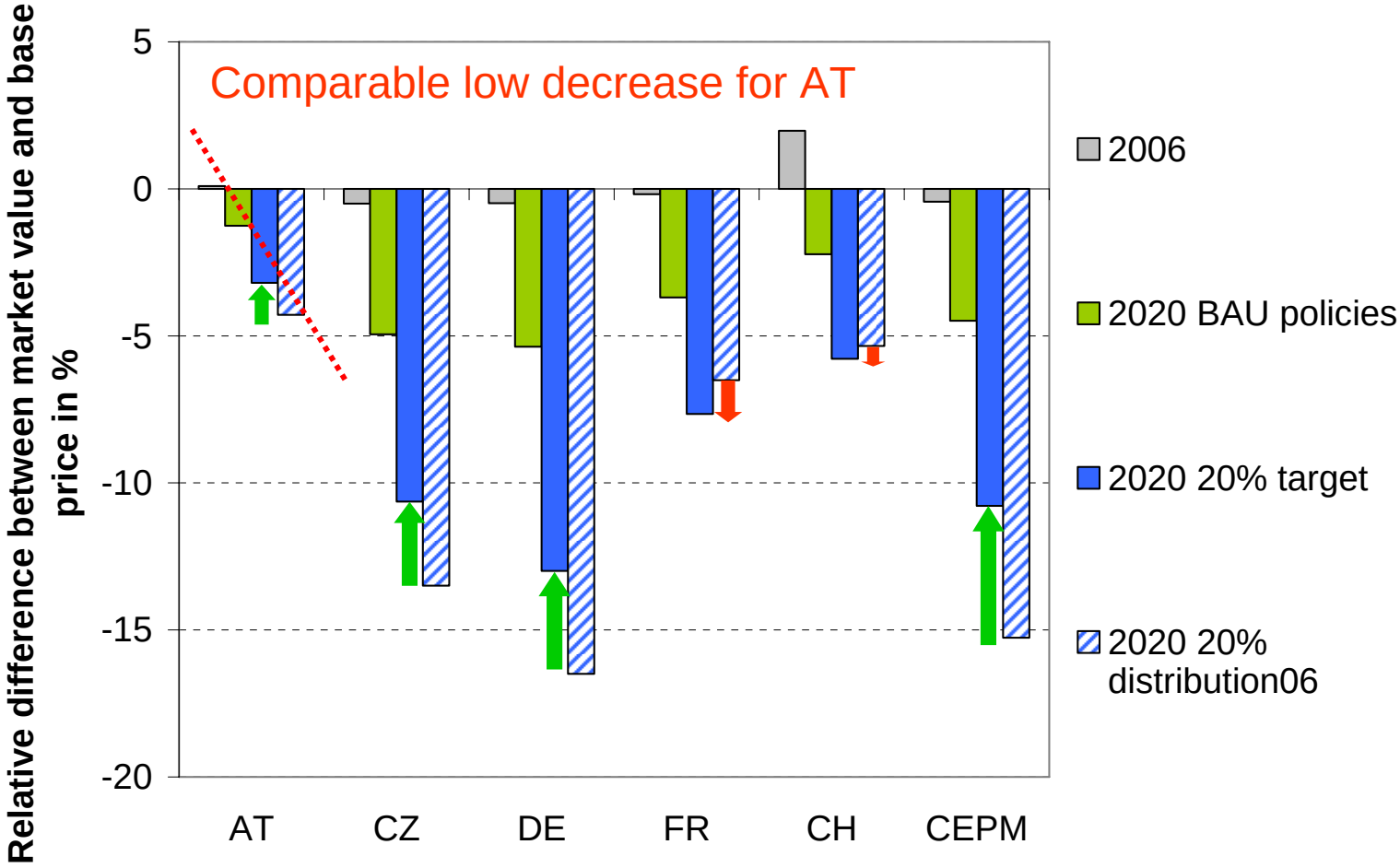
Results

- **2006:** no significant sensitivity
- **2020 20% target:** relative price difference increases from 10.6 to 12.3% for all high price scenarios

Country analysis (1)

Wind scenarios on country level

Relative price difference for different wind scenarios



Country analysis (2)

1. **Low decrease for Austria**

2. **Impact of increased dominance of French wind power (and lower dominance of German wind power)**

Wind scenario 2020 20% target

Linear correlation between wind generation

	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*

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Qualitative assessment of future trends

Effect of parameter increase on	base load price	MV of wind power	price difference base - MV
Demand	+	++	↓
Storage capacity	– [1])	o[2])	↓
Wind capacity	–	- -	↑
Wind offshore share	o	+	↓
Geographic wind power distribution in CEPM	o	+	↓
Fuel price	++	+	↑
CO2 certificate price	++	+	↑

1) under assumption of a convex supply curve
2) simulation results indicate a slight decrease for both base price and price difference

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General conclusions

- **Base load price no proper indicator of market value for significant wind shares**
- **Market value will vary considerably between countries**
- **Modify Feed-In Tariff schemes in order to reflect the market value of wind power**
- **Increasing incentive to utilise second best potentials having low correlation with overall wind power generation**

Specific conclusions

- **Market value of wind power in CEPM benefits from**
  - increasing electricity demand
  - increasing fuel and CO2 prices
  - better geographic distribution of onshore wind
  - and increased offshore share

- **Quantitative results to be interpreted with care**
  - limited sample (one year only)
  - simplified representation of CEPM

Outlook

Future work necessary to increase reliability of quantitative results:

- **Improvement of data base**
- **Improvement of model representation of CEPM**

Thank you for your attention

Further information / questions:

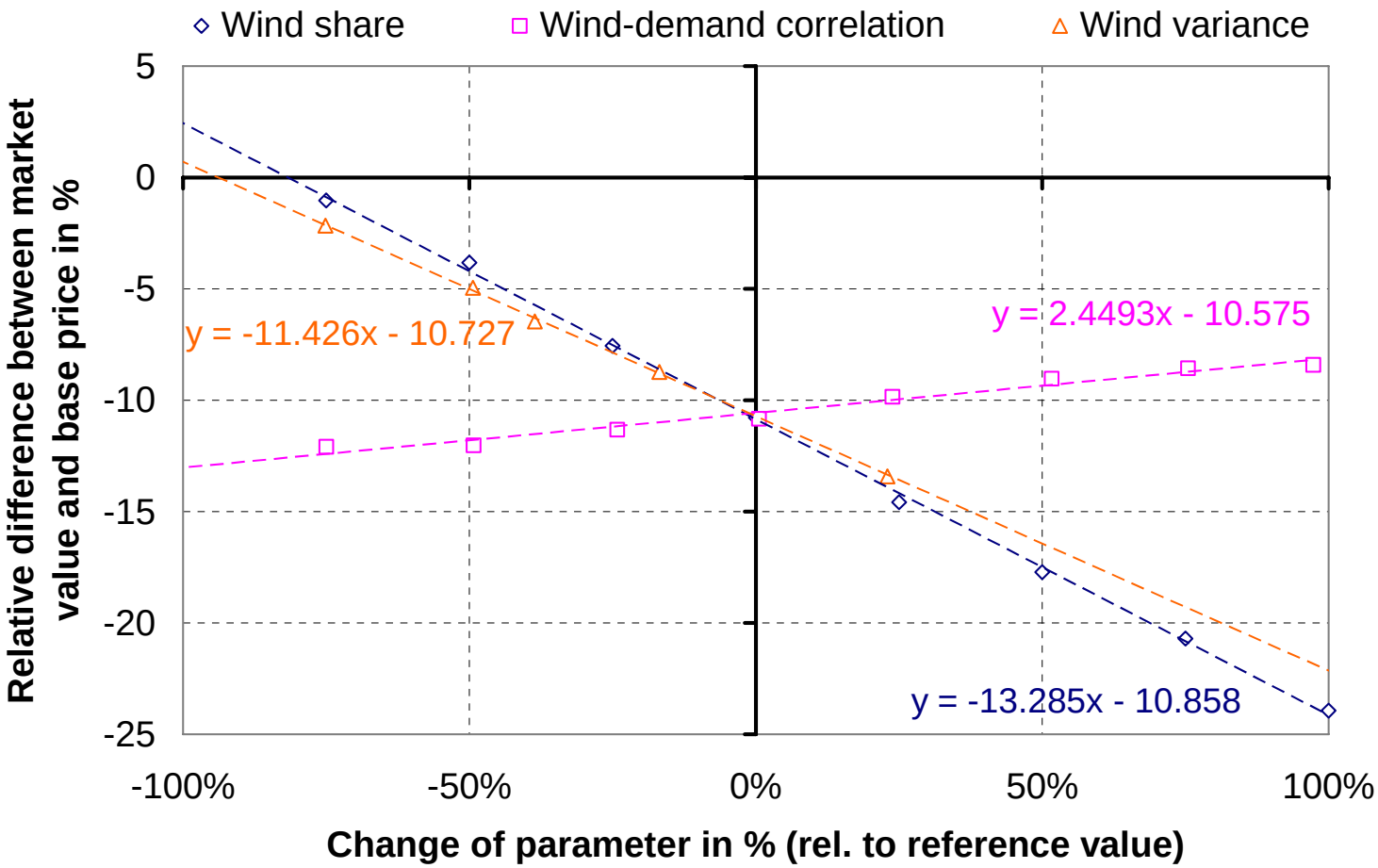
Carlo Obersteiner
Energy Economics Group
Tel.: +43 1 58801 37367
Fax: +43 1 58801 37397
Email: obersteiner@eeg.tuwien.ac.at

Web: www.eeg.tuwien.ac.at

Sensitivity analysis for CEPM (2)

Wind scenario 2020 20% target

Sensitivity of relative price difference on parameter variations



Future trends of analysed parameters (1)

1. **Wind share**
   - Significant increase of wind generation:
     20% RE scenario in 2020 (Resch et al., 2008): appr. 200 TWh
   - Increase of electricity demand:
     Up to 30% for 2020 depending on efficiency improvement

   Expected trend: increasing wind share

2. **Wind power variability**
   - Better geographic distribution of onshore wind sites within CEPM
   - Increased offshore share (Bremen et al., 2006)

   Expected trend: decreasing variability

Future trends of analysed parameters (2)

3. Wind power - demand correlation

- 2006: low and positive (0.05-0.14)
- 2020: no significant change for CEPM
- Increased storage capacity?

Expected trend: depends storage capacity and operation

4. Supply characteristics

- Short term: price developments (fuel, CO2)
- Medium to long term: Change of supply mix

Expected trend: broad bandwidth of future scenarios