Results from using the Planning Tool

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- Overview of case scenarios
- Value of wind power production
- Price and technical impacts of wind power production
- Impacts of wind power integration measures

Overview of analysed case scenarios (1)

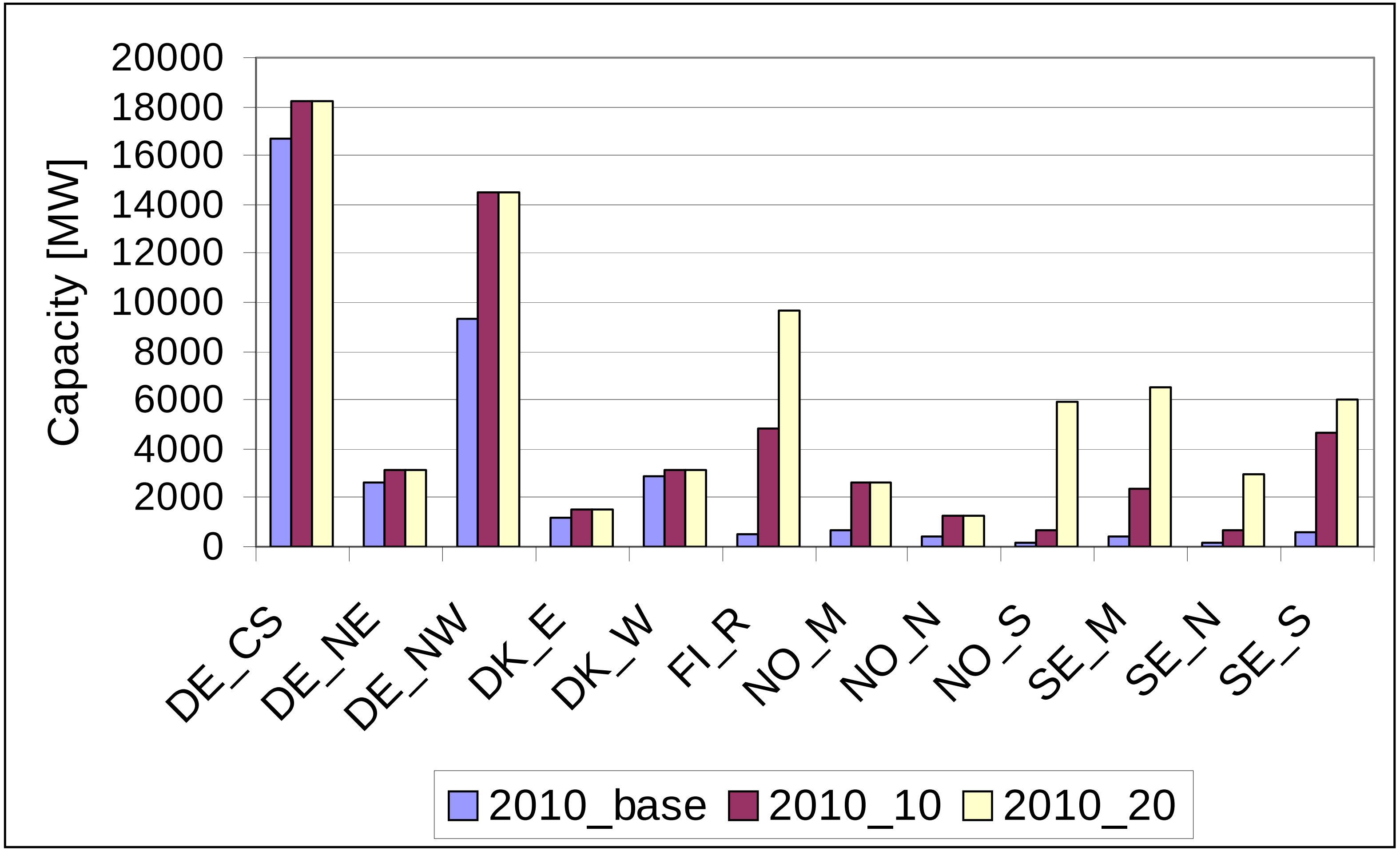
- Consideration of Germany and Scandinavian countries.
- Considered time period from 02.01.2010 – 28.02.2010.
- Time-series are based on the year 2001.
- Comparison of three cases:
  - Year 2010 configuration with base wind (2010_Base)
  - Year 2010 configuration with high wind development (2010_10%)
  - Year 2010 configuration with very high wind development (2010_20%)
- Wind power producers base their bid to the day-ahead market based on the expected wind power production. But the model allows the reduction of these bids.

Overview of analysed case scenarios (2)

- 2010_Base:
  - For all countries, forecasted wind power capacities for 2010 are considered.
- 2010_10 %:
  - For Denmark and Germany: Forecasted wind power capacities for 2015 (equal to cover ca. 11 % and ca. 29 % of the annual electricity demand, respectively).
  - For Finland, Norway and Sweden: Wind power capacities equal to cover 10 % of the annual electricity demand.
- 2010_20 %:
  - For Denmark and Germany: Forecasted wind power capacities for 2015 (equal to cover ca. 11 % and ca. 29 % of the annual electricity demand, respectively).
  - For Finland, Norway and Sweden: Wind power capacities equal to cover 20 % of the annual electricity demand.

Overview of analysed case scenarios (3)

Resulting wind power capacities for the different case scenarios:



Overview of analysed case scenarios (4)

Time period: January and February 2010:

Case Name	Total Prod [TWh]	Wind Prod. [TWh]	Share Wind of Total [%]
2010_Base	180.0	10.4	5.8
2010_10%	180.0	21.2	11.8
2010_20%	180.0	28.1	15.6

Overview of analysed case scenarios – Assumptions (1)

Annual electricity demand (in [TWh]):

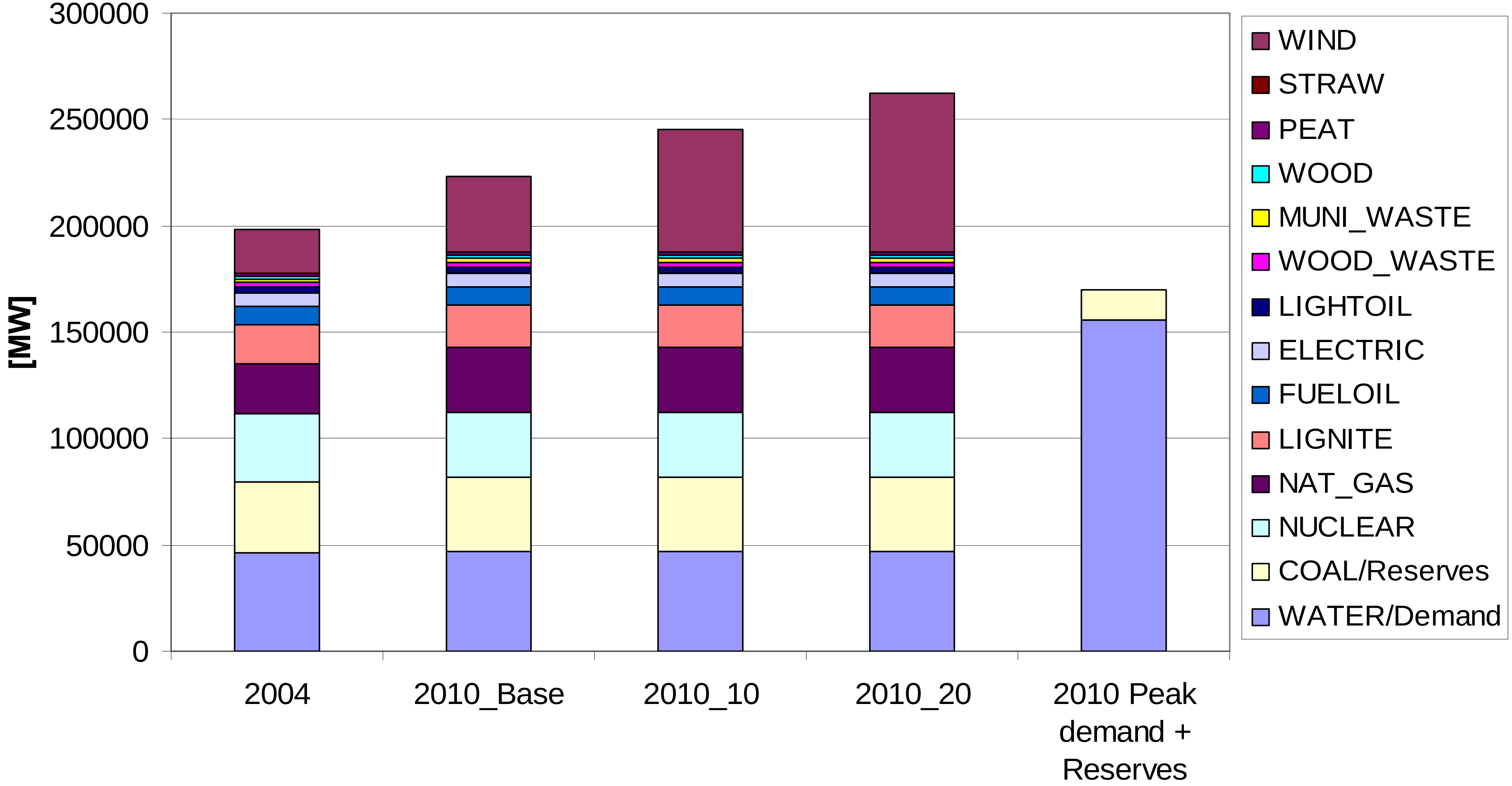
Year	Germany	Denmark	Finland	Norway	Sweden
2001	492.9	35.5	79.1	123.3	147.1
2010	556.9	39.4	94.2	133.3	153.0
Growth	13.0 %	11.0 %	19.1 %	8.0 %	4.0 %

Positive primary and secondary reserve demand (in [MW]):

Country	Positive primary reserve demand	Positive secondary reserve demand
Germany	4037	3379
Denmark	160	1220
Finland	464	1300
Norway	503	1599
Sweden	569	1300

Overview of analysed case scenarios – Assumptions (2)

Capacity development - Available capacity versus demand



Overview of analysed case scenarios – Assumptions (3)

Fuel prices taken from the medium price scenario:

Fuel	Price [Euro2002/GJ]	Fuel	Price [Euro2002/GJ]
Nuclear	1.7	Shale	1.2
Nat_Gas	6.16	Peat	1.5
Coal	2.25	Muni_Waste	0
Lignite	1.05	Straw	4.4
Fueloil	6.16	Wood	4.3
Lightoil	7.19	Wood (Waste)	4
Orimulsion	1.2		

CO_2 emission allowance price for the medium price scenario:

17 Euro2002/MWh

Value of wind power production (1)

- The integration of wind power leads to a change of the total system operation costs, consisting of:
  - Fuel costs
  - Operation and maintenance costs
  - Start-up costs
  - Transmission costs
  - Change in CO_2 emission allowance prices
  - Use of taxes and tariffs
  - The value of changed hydro reservoir levels
- The value of wind power production can be evaluated by the comparison of the use of different system configurations to cover the given demand.

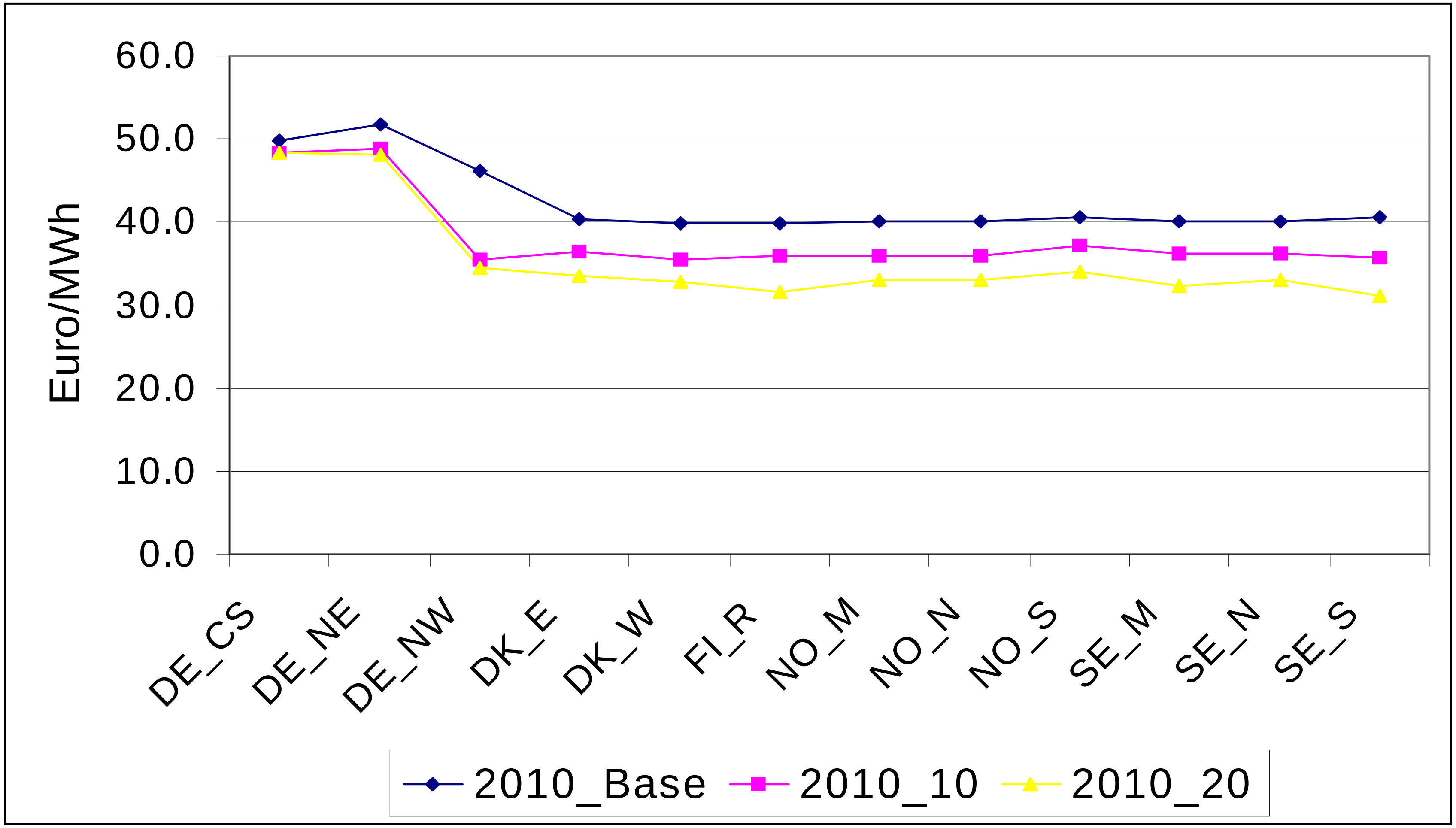
Value of wind power production (2)

Comparison of the change in total system operation costs due to different levels of wind power production:

Case 1 compared with Case 2	**Change Costs** [MEuro]	**Value and amount of saved water** [MEuro] (TWh)	**Change Windpower Production** [TWh]	**Avoided costs per MWh extra wind** [Euro/MWh]
10%/Base	237.3	163.3 (5.0)	10.8	37.2
20%/Base	335.2	294.5 (9.4)	17.7	35.5
20%/10%	97.9	132.3 (4.4)	7.0	33.0

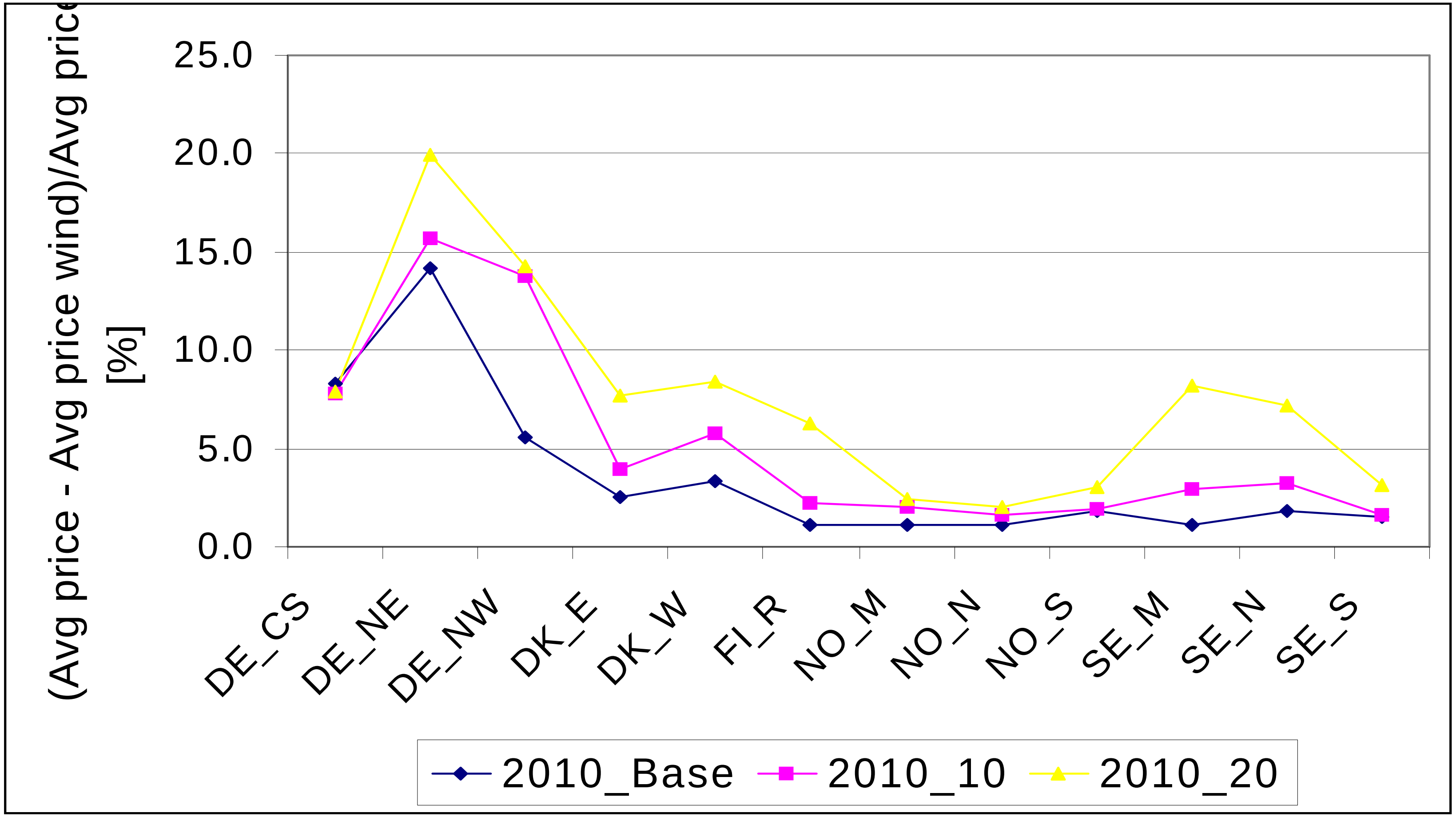
Price impacts of wind power production (1)

Average intraday prices for the time period 02.01.2010 – 28.02.2010:



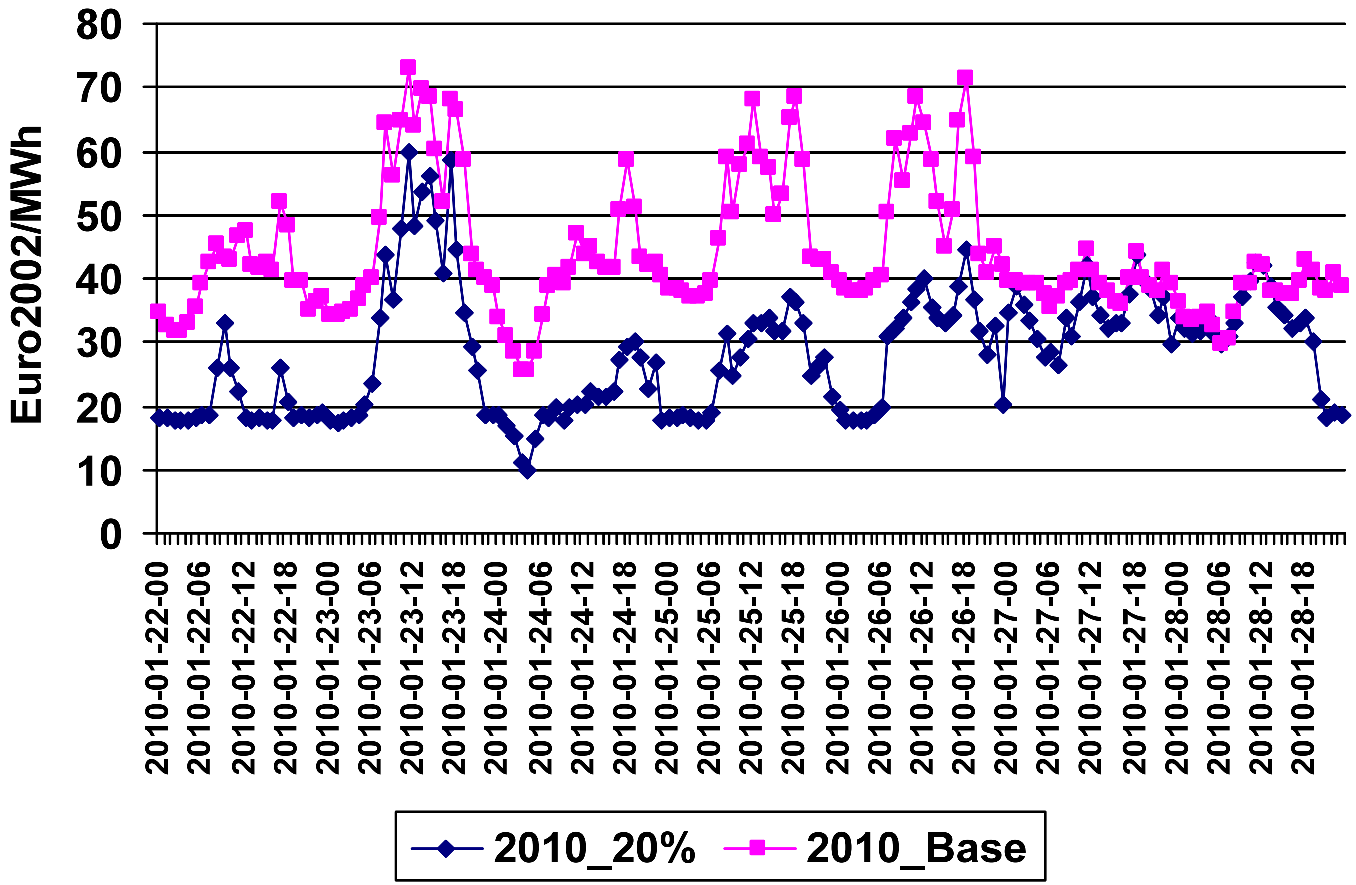
Price impacts of wind power production (2)

Difference between average intraday price obtained by wind power producers and average intraday price obtained by all producers:



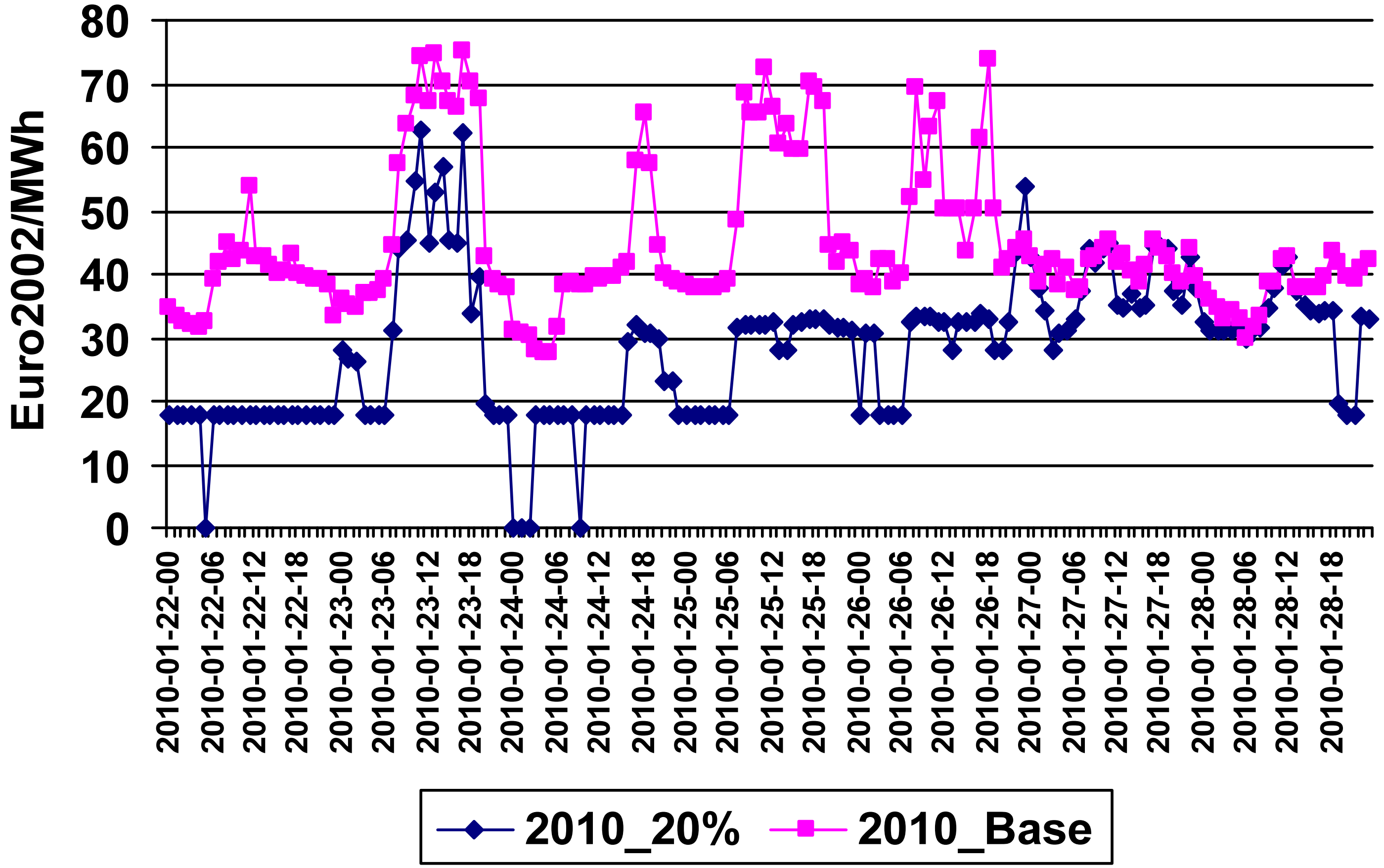
Price impacts of wind power production (3)

Day-ahead prices in northern Germany during the time period 22.01.2010 – 28.01.2010 for the cases 2010_Base and 2010_20%:



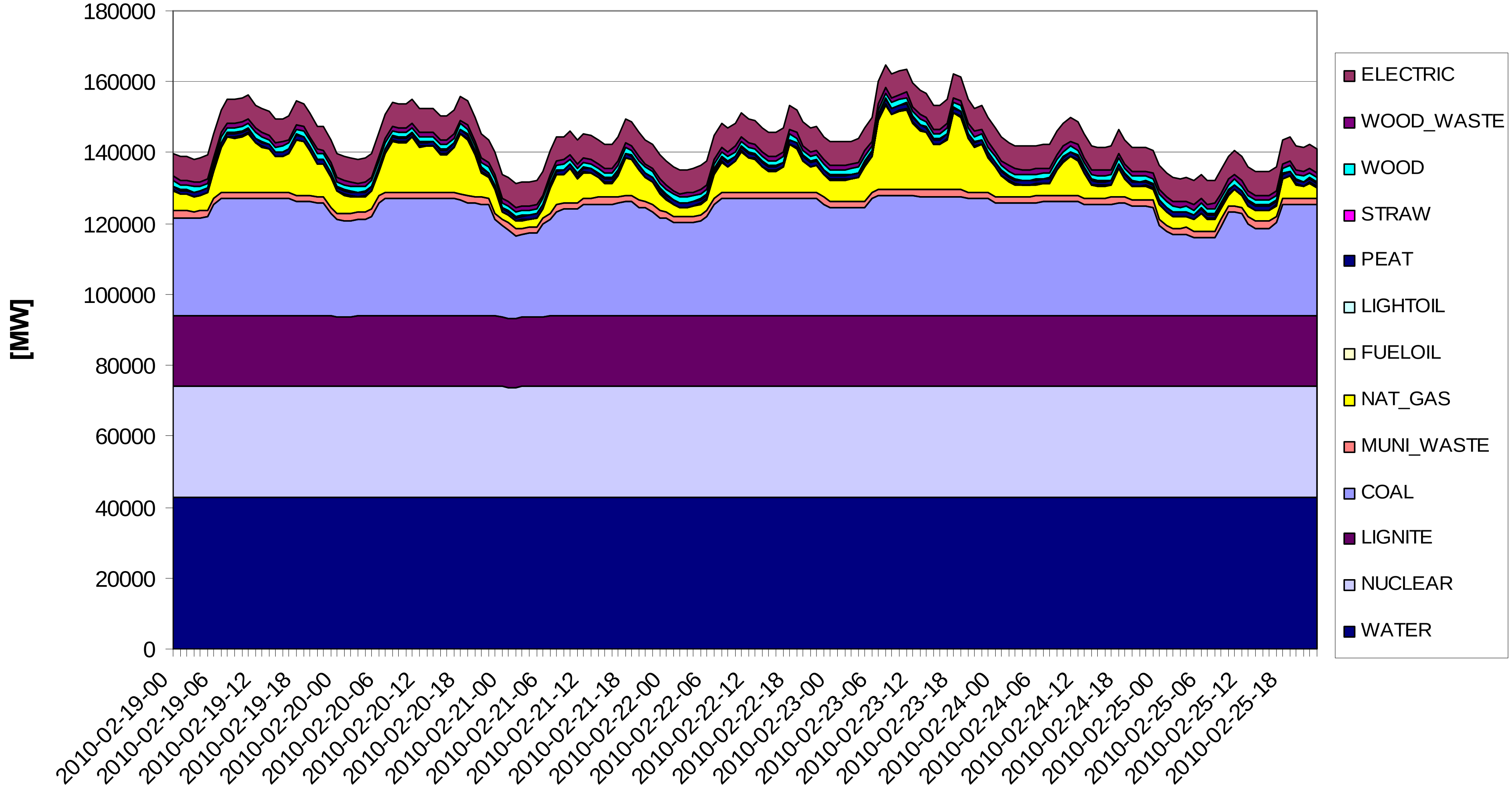
Price impacts of wind power production (4)

Intraday prices in northern Germany during the time period 22.01.2010 – 28.01.2010 for the cases 2010_Base and 2010_20%:



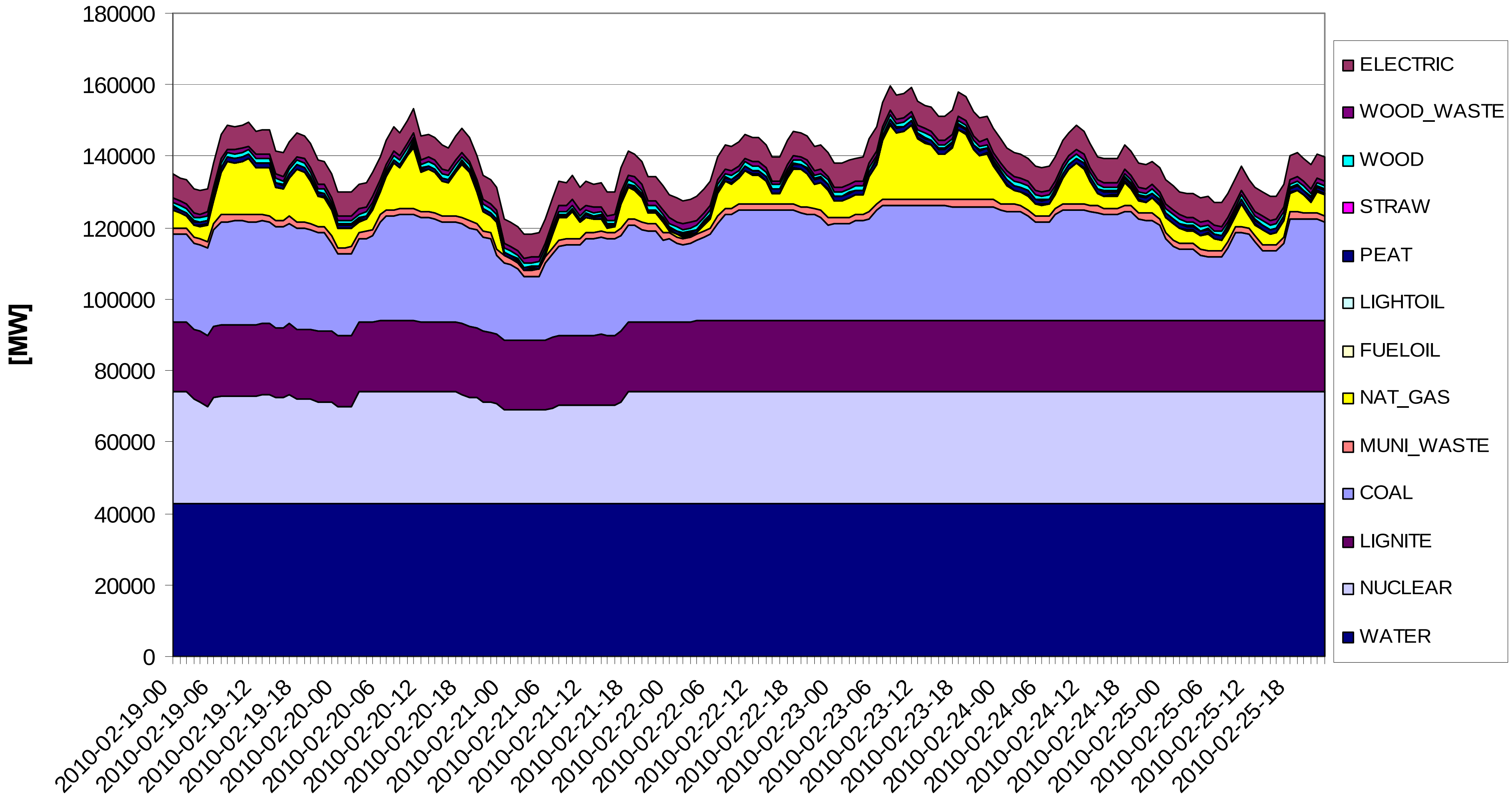
Technical impacts of wind power production (1)

Capacity online for the time period 19.02.2010 – 25.02.2010 and 2010_Base:



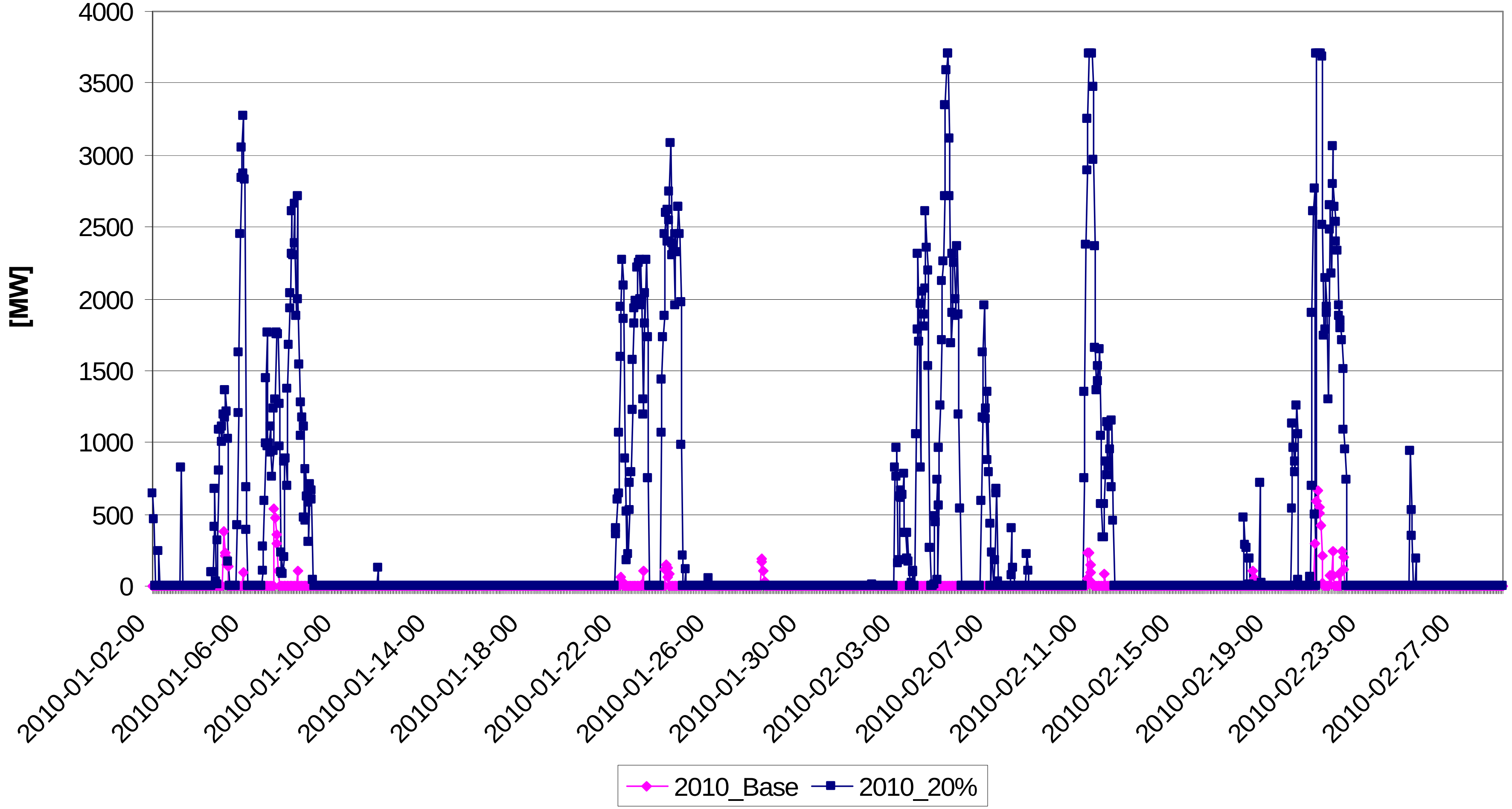
Technical impacts of wind power production (2)

Capacity online for the time period 19.02.2010 – 25.02.2010 and 2010_20%:



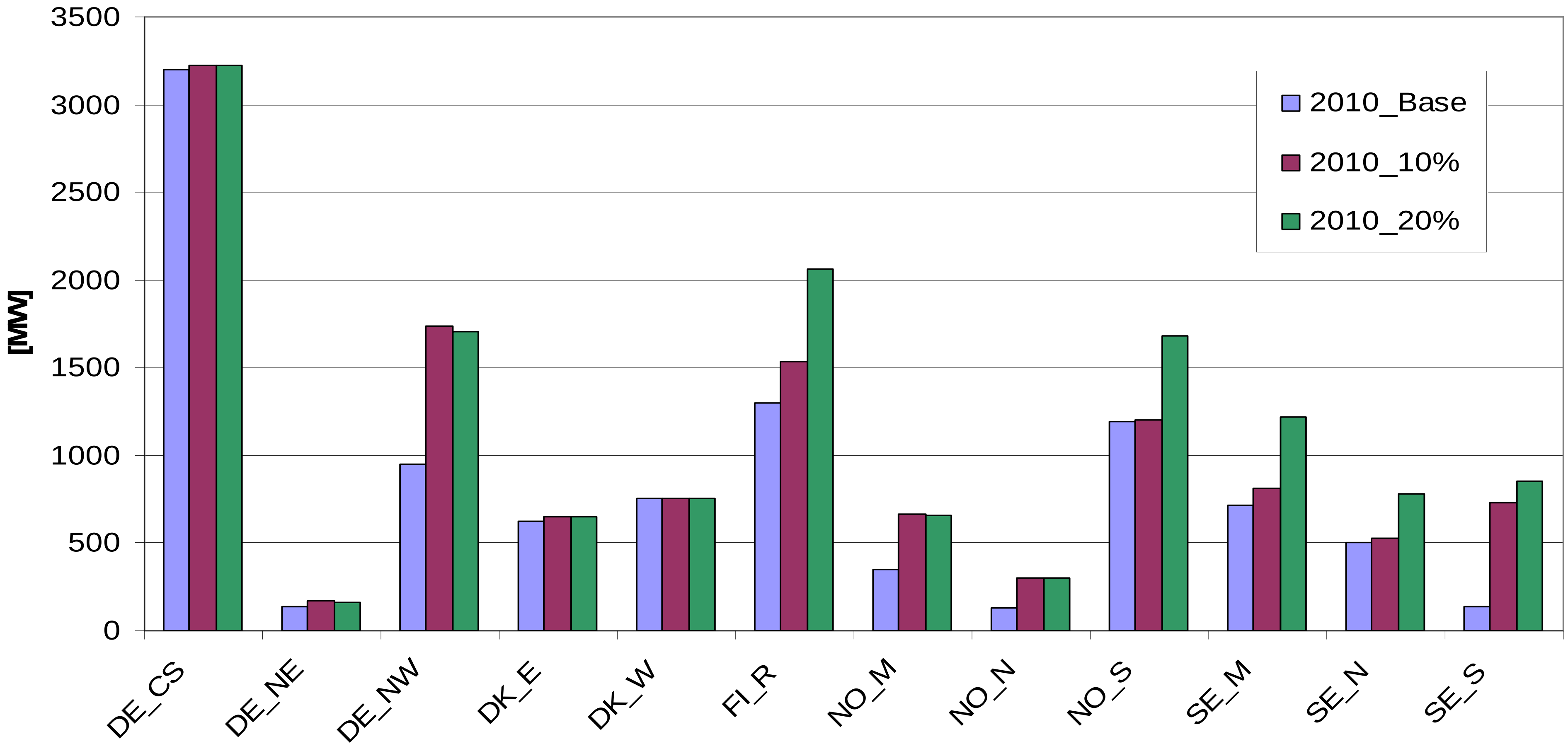
Technical impacts of wind power production (3)

Electricity export from SE_S to SE_M during the time period 02.01.2010 – 28.02.2010 for the cases 2010_Base and 2010_20%:



Technical impacts of wind power production (4)

Average demand for secondary reserves (including the N-1 criterion and wind power fluctuations) for the time period 02.01.2010 – 28.02.2010:



Average prices achieved and penalties paid due to wind power forecast errors for wind power producers:

	Average Price DayAhead [Euro/MWh Wind]	Average Penalty Up regulation [Euro/MWh forecast error]	Average Penalty Down Regulation [Euro/MWh forecast error]
2010_Base	42.5	1.7	1.0
2010_10	34.8	2.4	3.0
2010_20	31.7	2.9	2.6

Earnings of wind power producers and penalties paid due to forecast errors (1)

	All values in MEuro						
	Revenue DayAhead	Sold Intraday	Bought Intraday	Total Revenue	Up regulation penalty	Down regulation penalty	Penalty/ Revenue
2010_ Base	465.4	50.7	76.0	440.1	2.9	1.1	0.9%
2010_ 10	758.0	94.1	127.3	724.8	7.7	7.9	2.2%
2010_ 20	918.5	124.1	166.3	876.3	13.5	10.0	2.7%

Earnings of wind power producers and penalties paid due to forecast errors (2)

•Conclusions:

- Average prices paid to wind power producers decrease due to:
    - More wind power production decrease prices.
    - Imbalance penalties increase.
- Average Up and down regulation penalties are of the same size

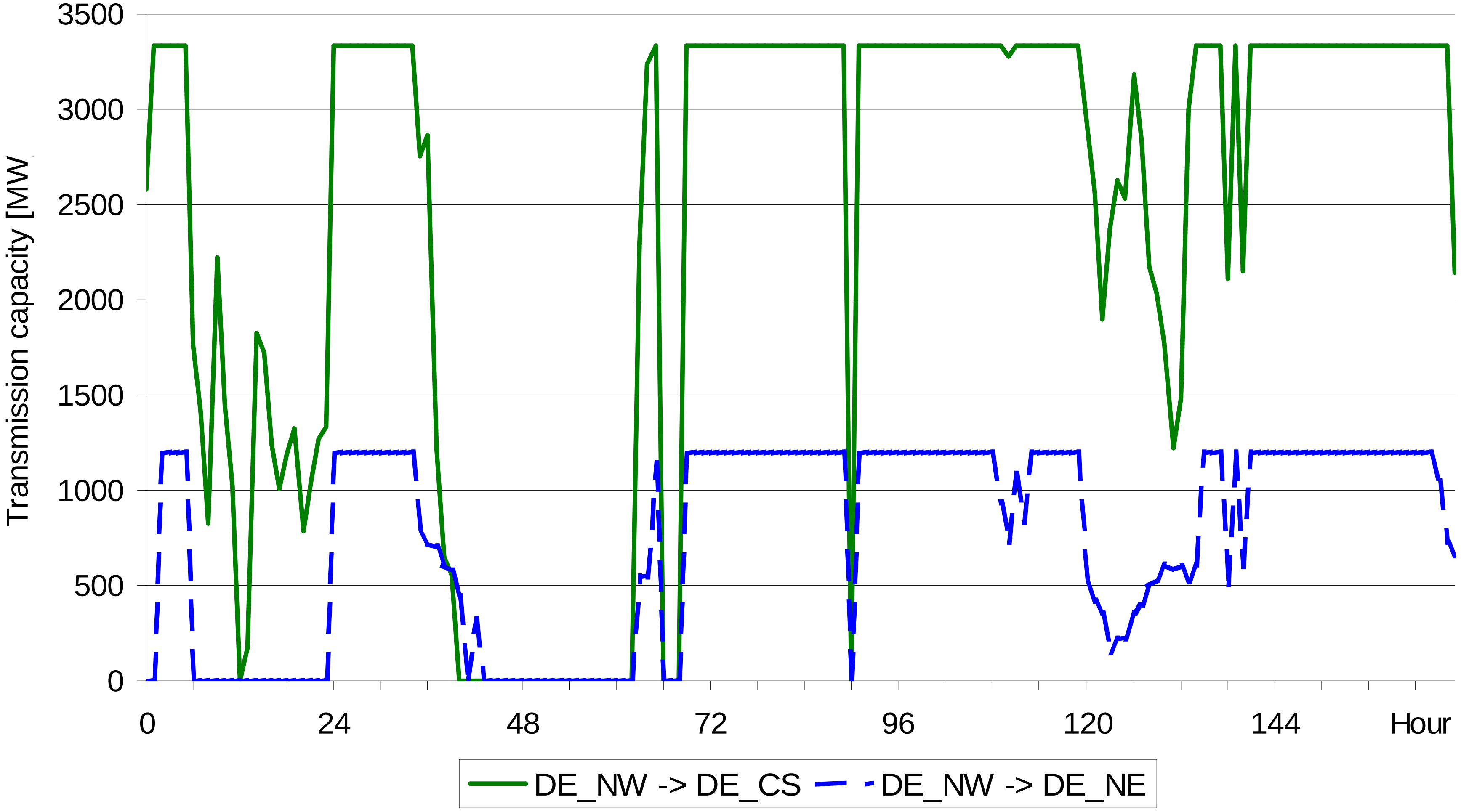
Wind power integration measures – Transmission and storages

Impact of extended transmission and storage capacities on electricity prices in Germany:

- Background of the case studies (will be published in IJGEI):
  - Forecasts for 2020 indicate about 50 GW of wind power capacity in Germany.
  - These wind power extensions are mainly planned in the North of Germany as offshore wind power in the North and Baltic Sea (DE_NW and DE_NE). By contrast the main consumption areas are in the midland.
  - Bottlenecks in the transmission network and therefore system stability problems and price deviations between the individual regions may occur.
- Analysis of:
  - Utilisation of the transmission grid, price deviations and total system costs of an exemplarily week in 2020 with the existing transmission grid, with an extended grid and with extension of storage devices (CAES) in DE_NW within the German system.

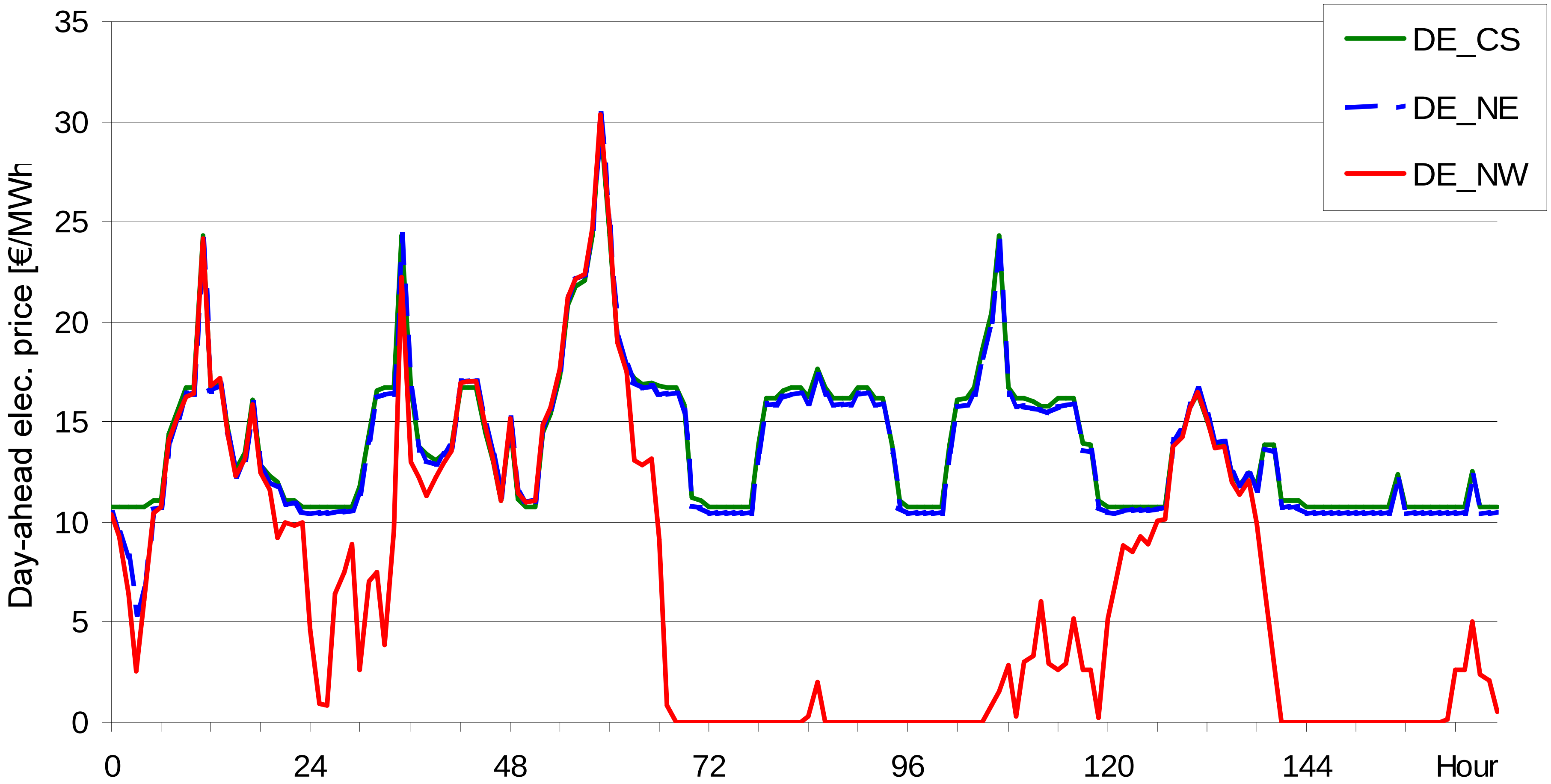
Results for the existing transmission grid (1)

Utilisation of the transmission grid between DE_NW and the other regions:



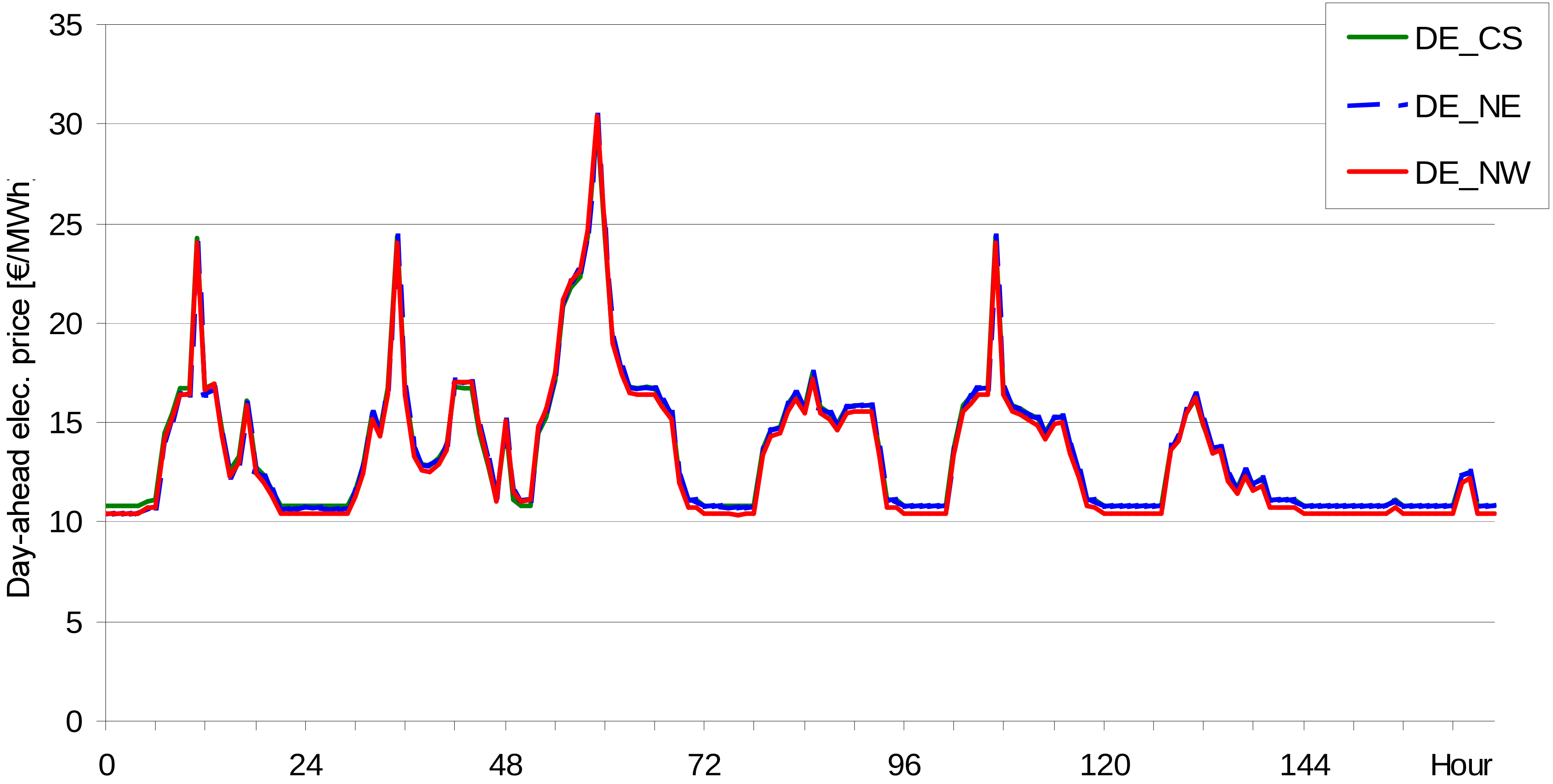
Results for the existing transmission grid (2)

Resulting day-ahead prices:



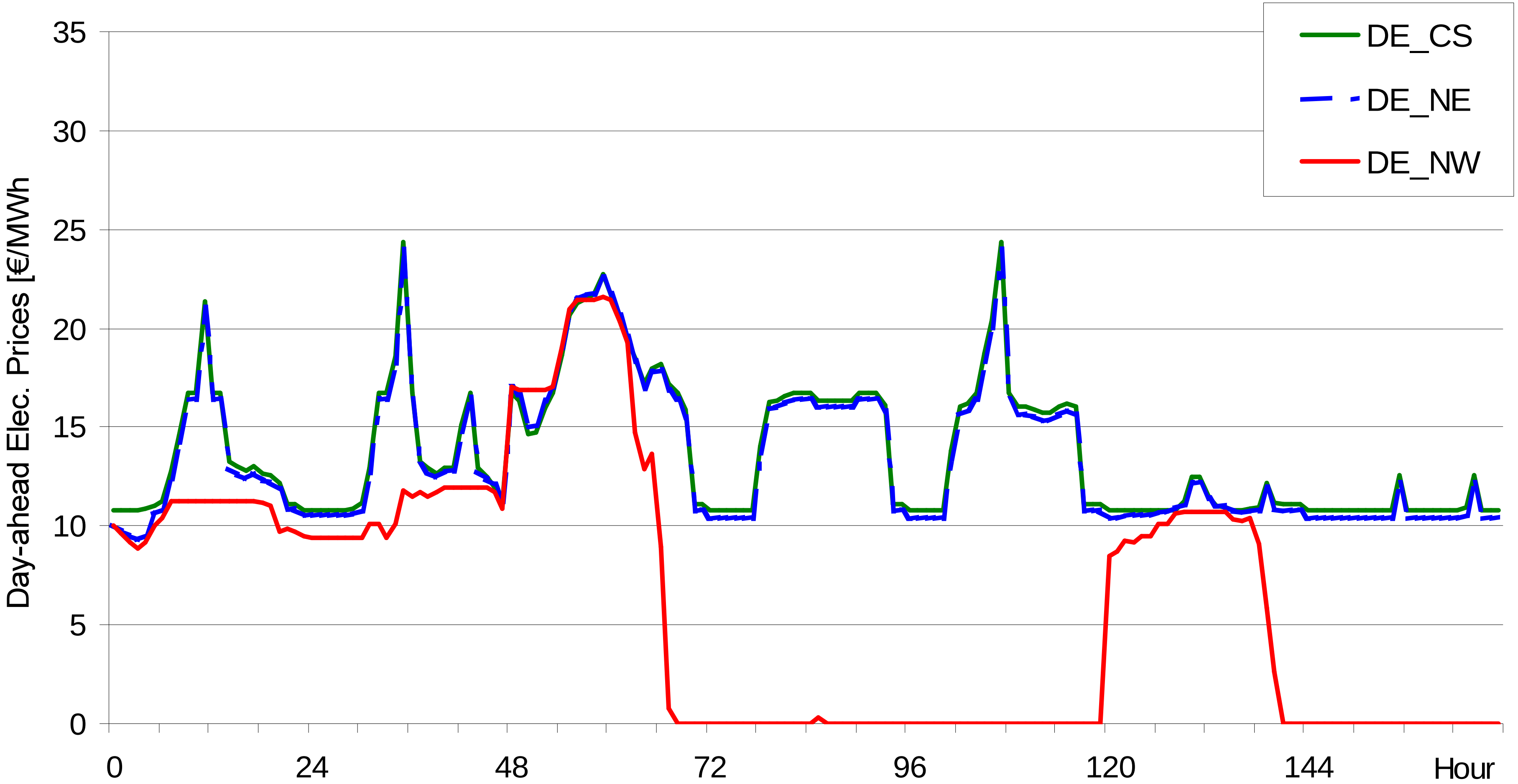
Results for the extended transmission grid

Resulting day-ahead prices for the extended transmission grid between DE_CS and DE_NW:

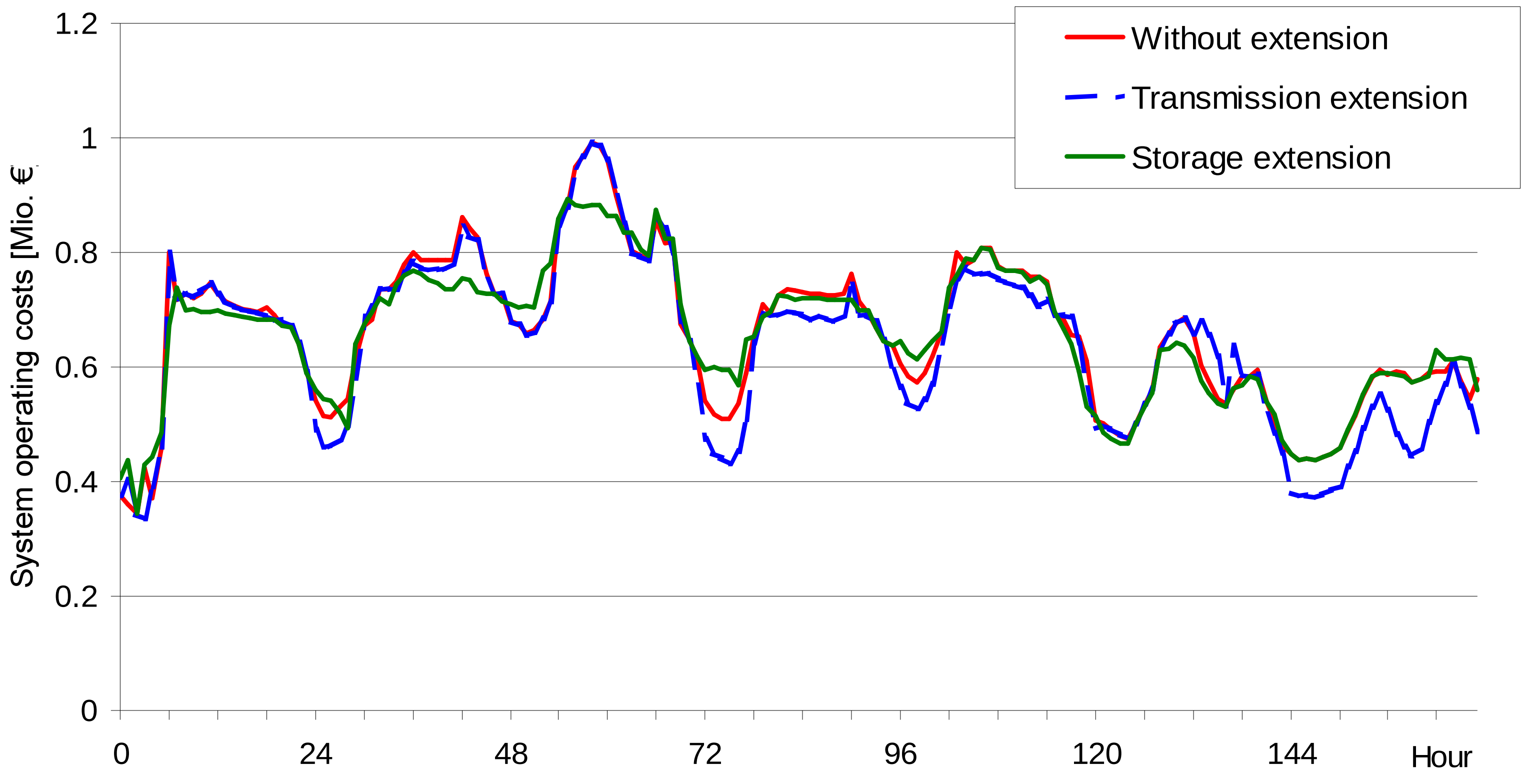


Results for extended storage capacity

Resulting day-ahead prices for the extended storage capacity in DE_NW:



Comparison of total system costs of the analysed week



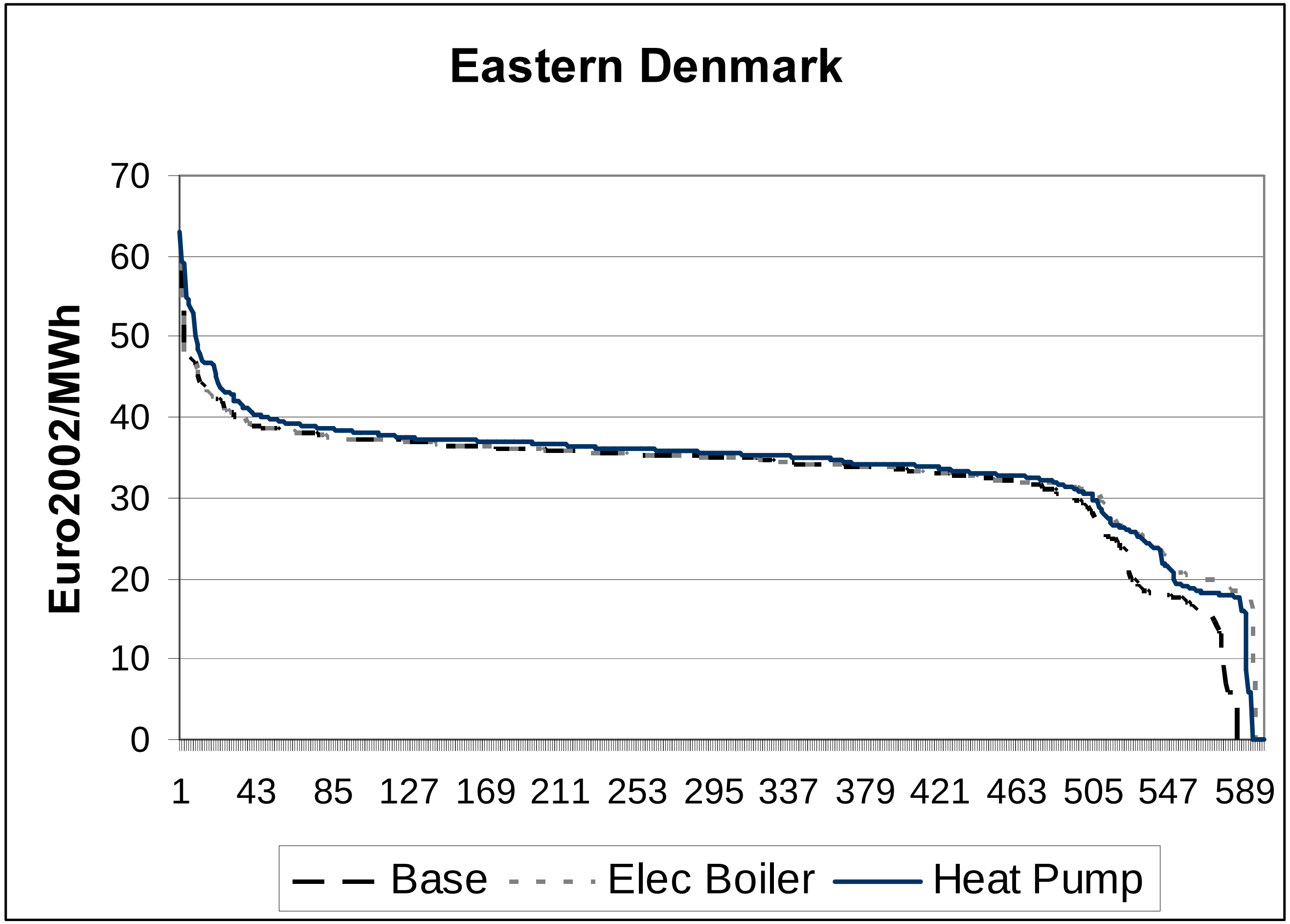
Analysed case	Total system operation costs [Mio. €]
Without transmission or storage extension	110.5
With transmission extension	107.2
With storage extension	109.8

Value of electrical heat boilers and heat pumps for wind power integration

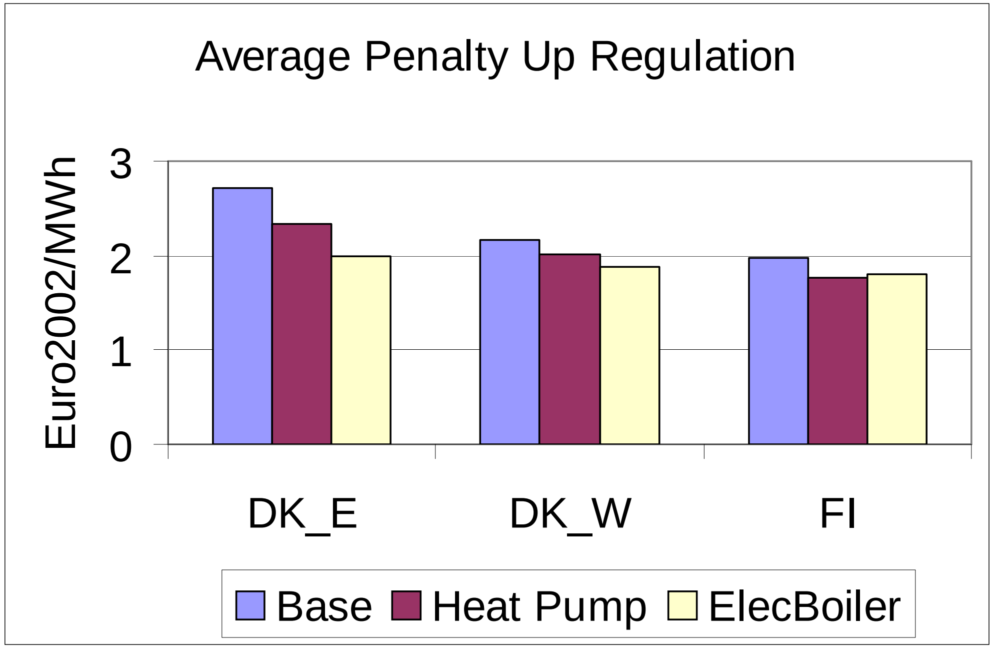
- Recent study with the Planning tool to be presented at EWEC 2006
- Introducing either heat boilers or heat pumps in three heat areas: Odense (DK_W), Copenhagen (DK_E) and Helsinki (FI)
- Analysing three cases during February:
  - 2010_20% as reference case
  - 2010_20% with heat boilers
  - 2010_20% with heat pumps
- In each heat area:
  - Electrical heat boilers and heat pumps have same heat production capacity.
  - This heat production capacity is equal to half of the heat production capacity of CHP plants in the heat area.
- Electricity consumption capacity of heat measures:
  - heat pumps: 736 MW, electrical heat boilers: 2002 MW

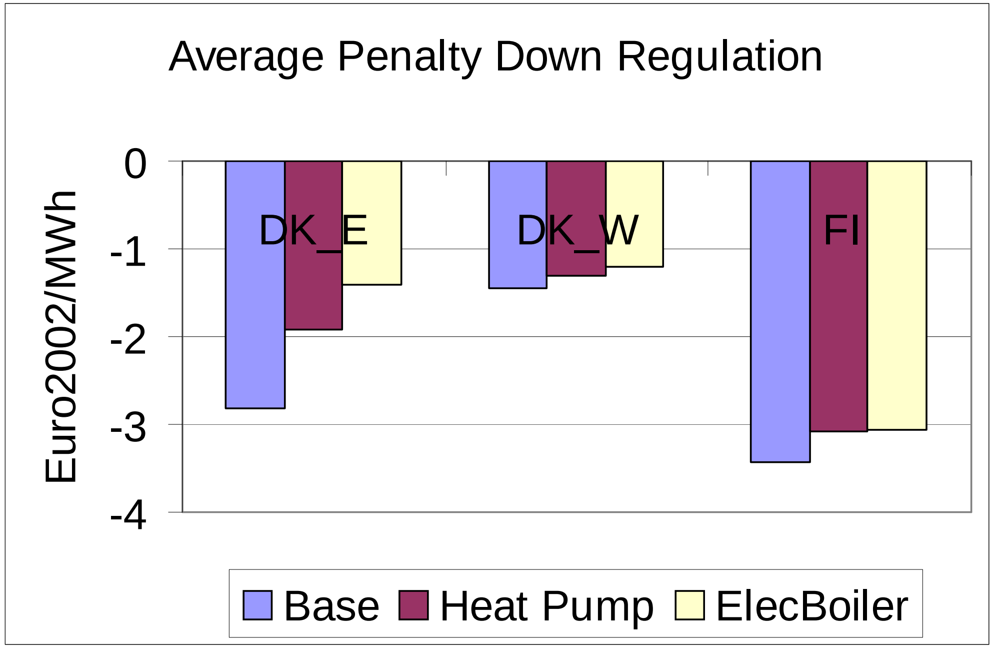
Value of electrical heat boilers and heat pumps for wind power integration – Resulting intraday prices

Duration curve of intraday prices:



Value of electrical heat boilers and heat pumps for wind power integration – Resulting penalty payments





Value of electrical heat boilers and heat pumps for wind power integration

- Conclusions of the study:
  - Heat measures replace production on heat boilers using fuel oil and CHP plants using different fuels.
  - Heat pumps are used more than electrical heat boilers.
  - Heat measures are beneficial for wind power producers in that:
    - Heat measures use electricity to produce heat when power prices are low thereby increasing low power prices.
    - Heat measures provide regulating power thereby decreasing the penalties connected to wind power production forecast errors.
  - The revenue of wind power producers is increased from 381.0 MEuro in the base case to 388.7 MEuro (2.0%) in the case of electrical boilers and to 390.8 MEuro (2.6%) in the case of heat pumps.
  - Heat measures decrease the operational costs of the power system.
  - The reduction in operational costs is probably enough to cover the annualised investment costs of heat pumps in DK_E, i.e. this measure increase social welfare, but extension of analysis to a full year is needed.