Experience in Wind Power Integration at the German TSO Amprion

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WIF – WIND INTEGRATION FORUM

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- Consequences of a massive Infeed from Renewables
- Forecasting of renewable Energies
- Conclusion

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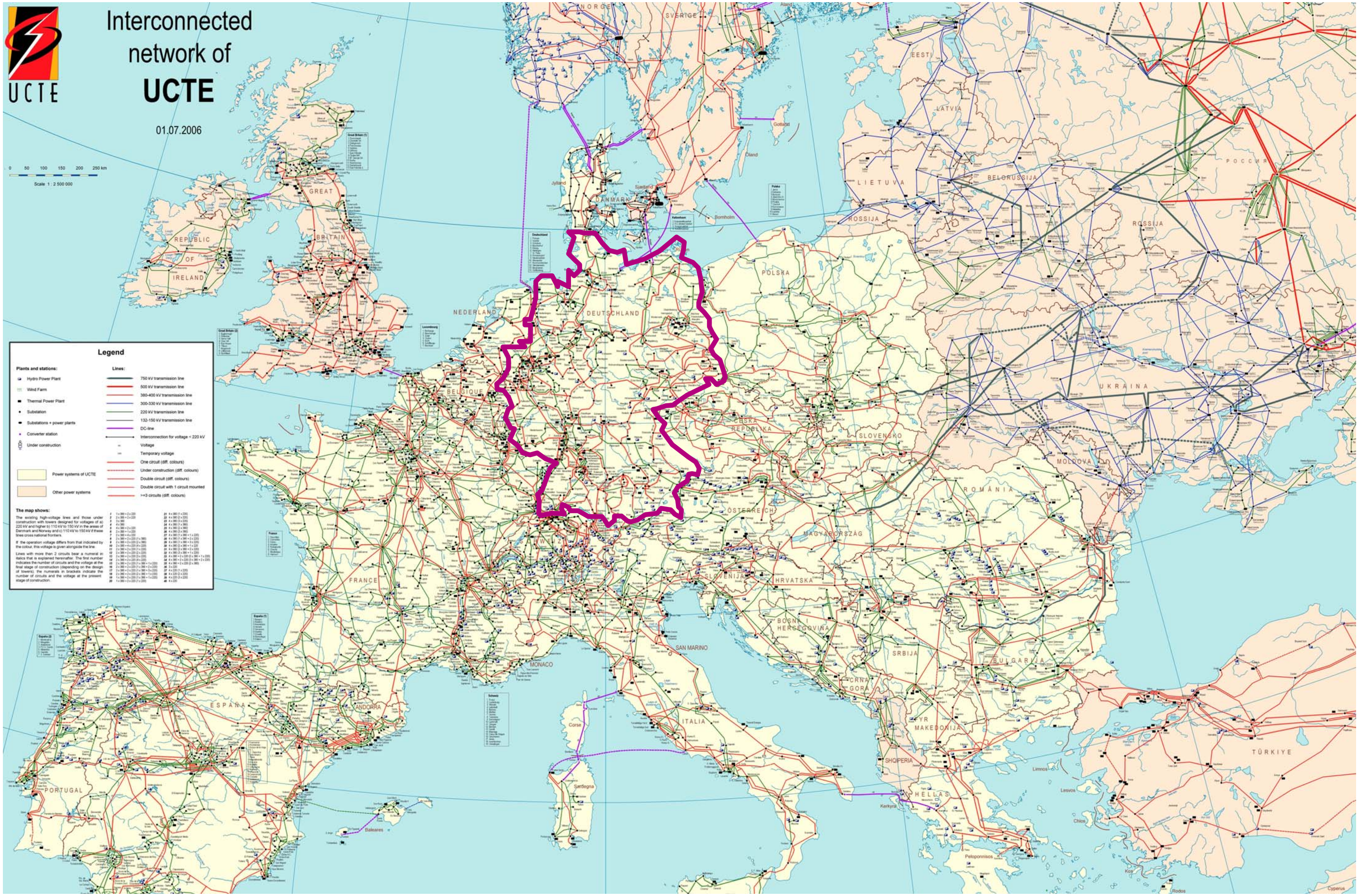
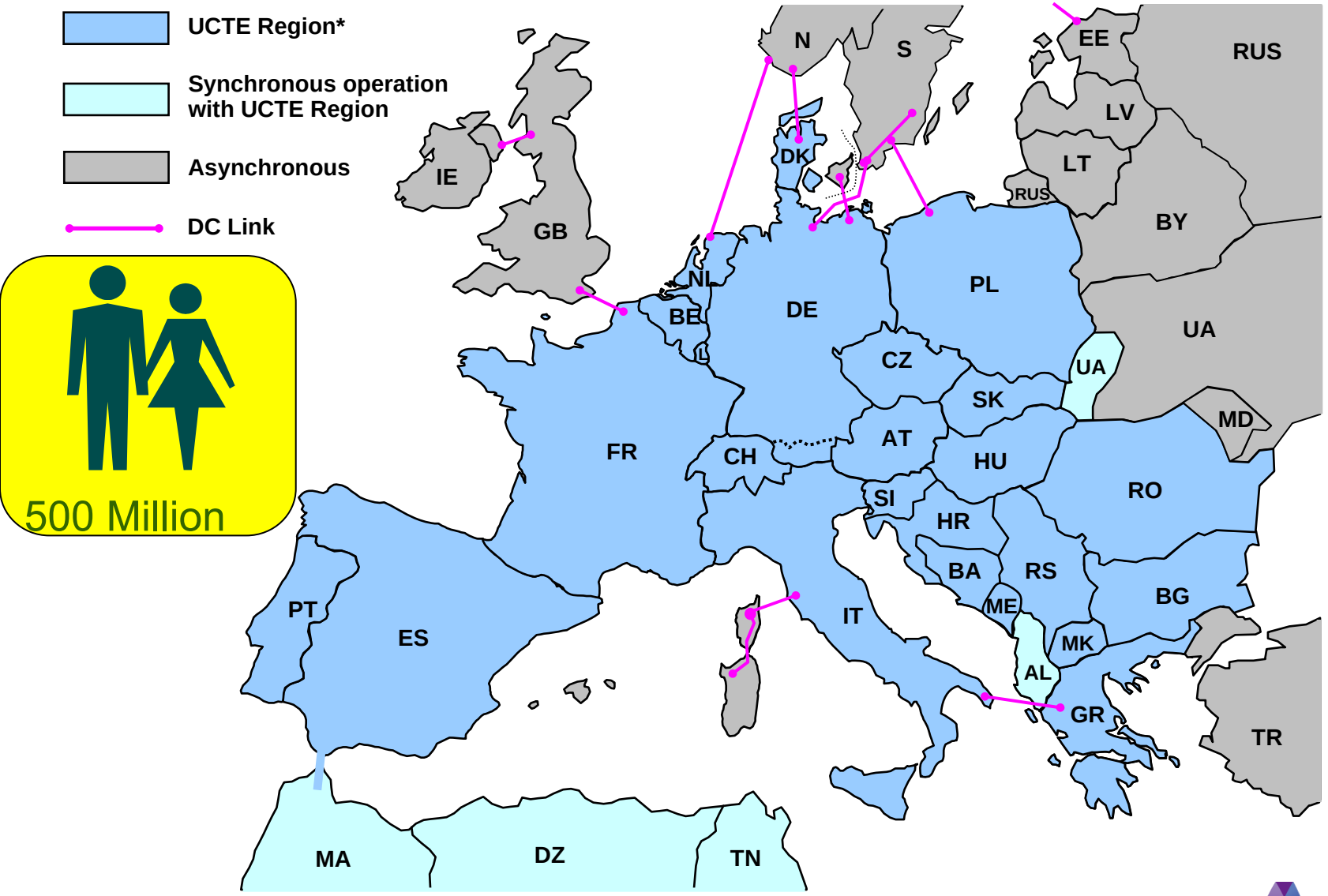

UCTE
Interconnected network of UCTE
01.07.2006
Scale 1 : 2 500 000
Legend
Plants and stations:
Lines:
NORGE
SVERIGE
EESTI
LATVIA
LIETUVA
BELORUSSIJA
ROSSIJA
POLSKA
DEUTSCHLAND
NEDERLAND
BELGIQUE
DANMARK
GREAT BRITAIN
REPUBLIC OF IRELAND
FRANCE
ESPAÑA
PORTUGAL
ANDORRA
ITALIA
SAN MARINO
MONACO
ÖSTERREICH
SLOVENSKO
MAGYARORSZÁG
SLOVENIJA
HRVATSKA
BOSNA I HERCEGOVINA
SRBIJA
CRNA GORA
SHQIPERIA
HELLAS
BULGARIA
ROMÂNIA
MOLDOVA
UKRAINA
TÜRKIYE
Corse
Sardegna
Baleares
Gotland
Öland
Bornholm
Jylland
Kerkyra
Peloponnisos
Limnos
Lesvos
Chios
Rodos
Cyprus

European Interconnected System



*ENTSO-E RG Continental Europe

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Grid Area of Amprion

Main Control Centre of Amprion at Brauweiler nearby Cologne

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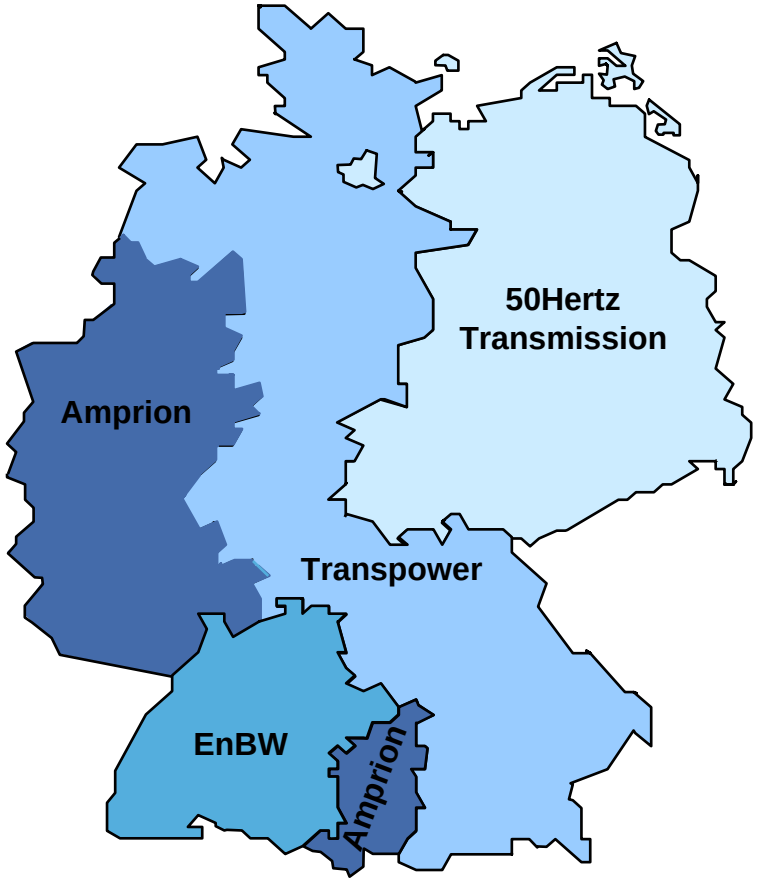
Operational areas of German transmission system operators



	Amprion	Transpower	50Hertz	EnBW
Network length [km] (380 kV)	5.200	5.400	6.700	1.936
Network length [km] (220 kV)	6.100	5.300	2.865	1.721
Served area [km²]*	73.100	139.400	109.000	34.600
Annual transmission [TWh]	175	138	85	76
Share load [%]**	38	30	19	13

* in Germany
** Renewable Energy Act load compensation

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Background of Renewable Energies

- Germany and the EU aim to strongly increase their use of renewable energies.
- Germany: Increase the share of renewable energy sources in electricity supply to at least 30 percent by the year 2020 and continuously increase that share thereafter.
- Generating structure and generating performance different from conventional generating facilities; generation from renewables: dispersed, volatile, far from consumers
- Creation of a legal basis, regulatory rules and technical guidelines

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Current Status of Renewable Energies in Germany (April 2010)

	Capacity [MW]	Production [TWh]
Hydropower	4.760	19 *
Biomass	5.889	30,52
Photovoltaics	9.800	6,2
Windpower	25.704	37,8
Pump Storage	7.479	

*) without share of Pump Storage

~33% of the German peak load

Source: BMU, internal

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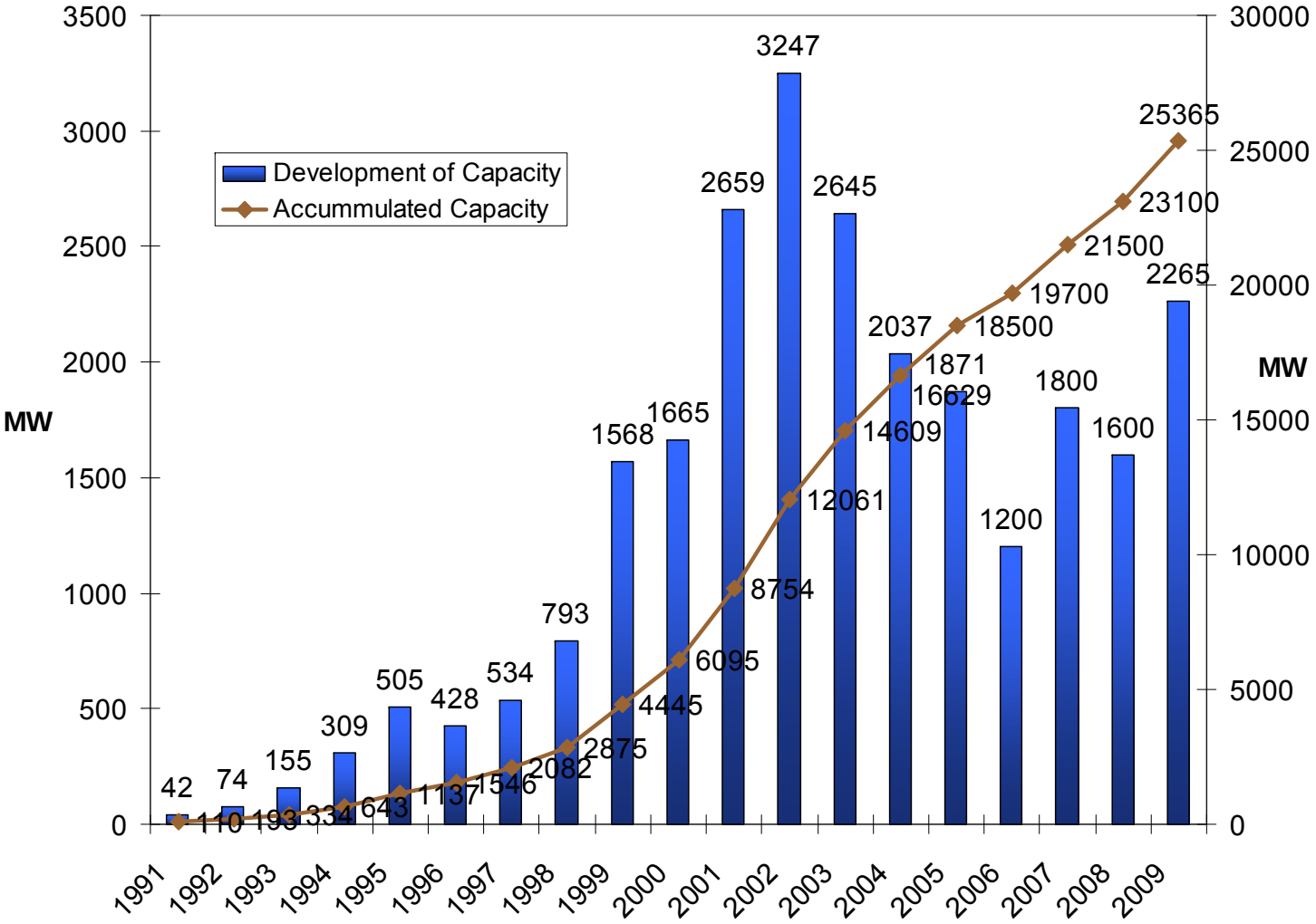
Wind Power Development in Germany



12/2009; Source: ISET, IWET

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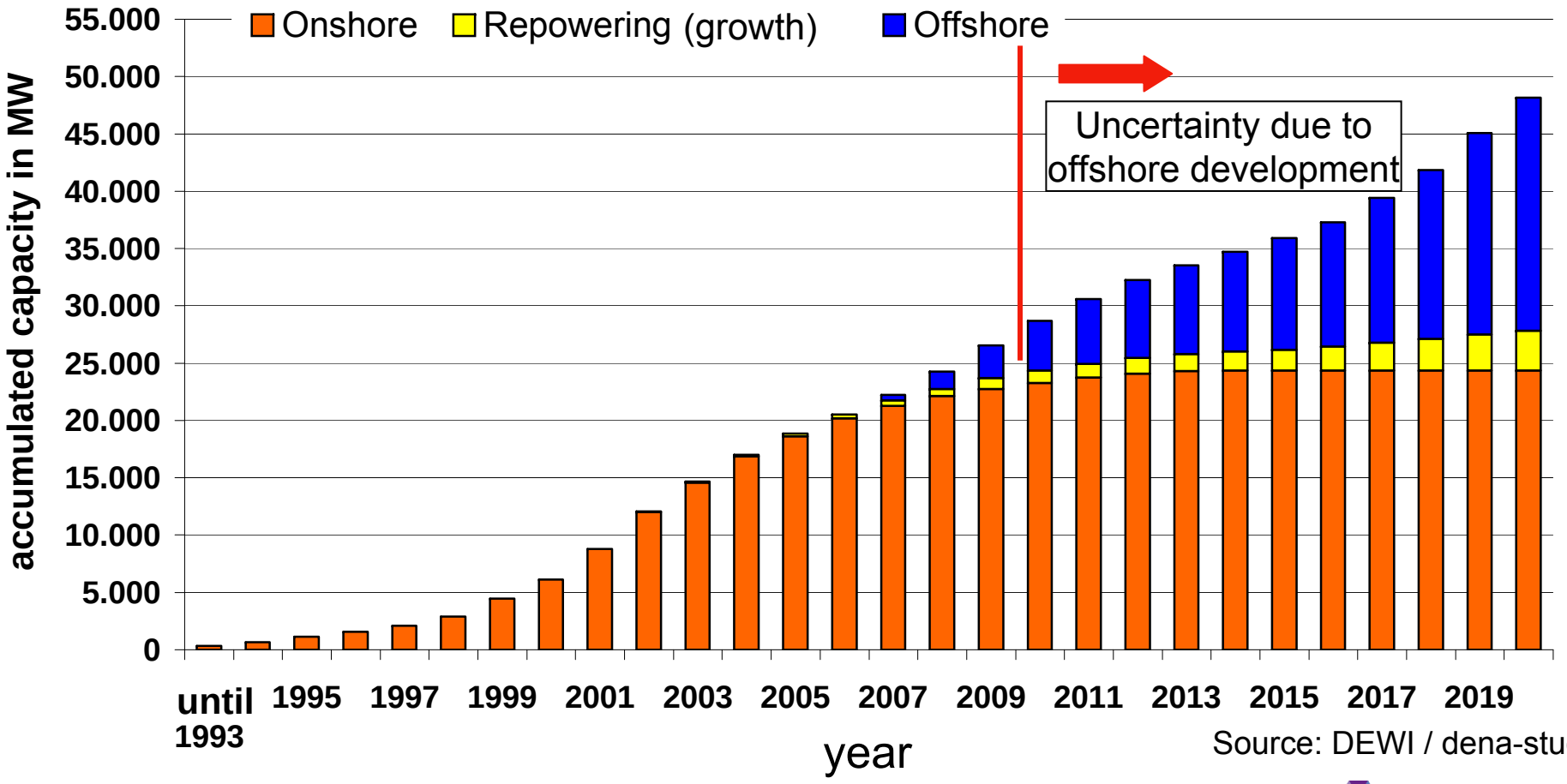
Installed Generation Capacity of Wind Power

Forecast of development until 2020



Source: DEWI / dena-study

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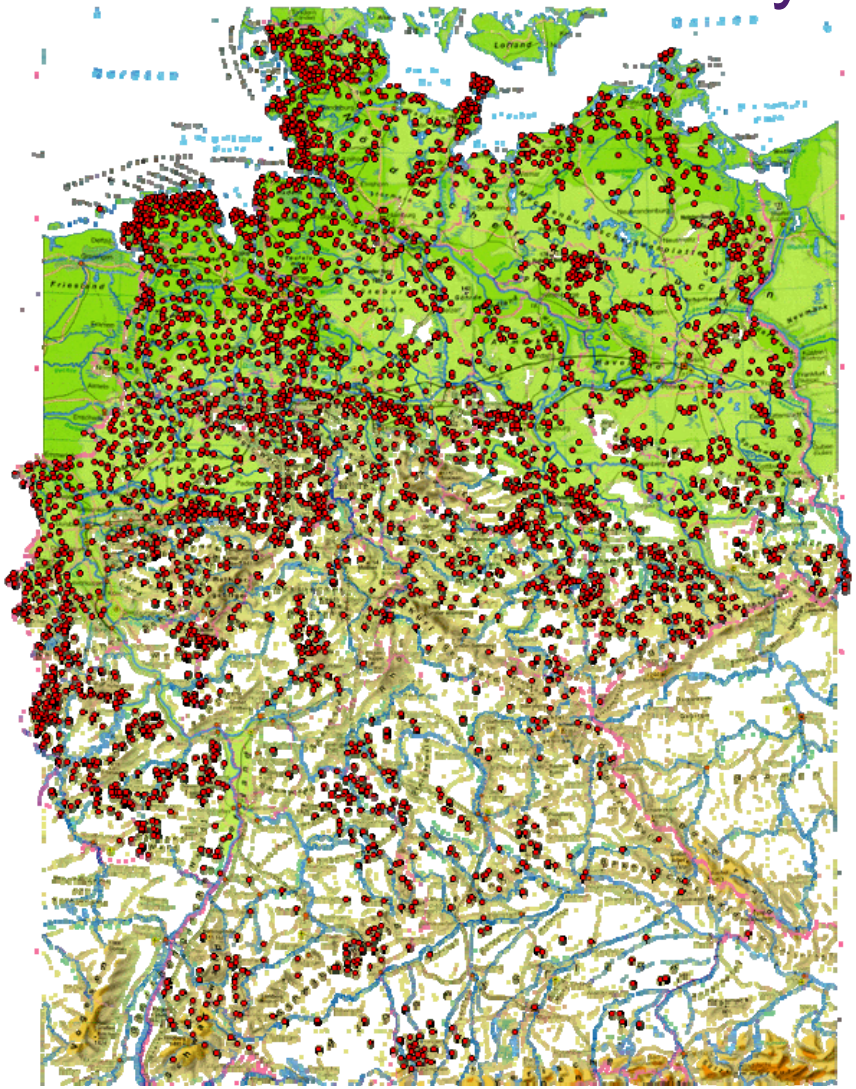
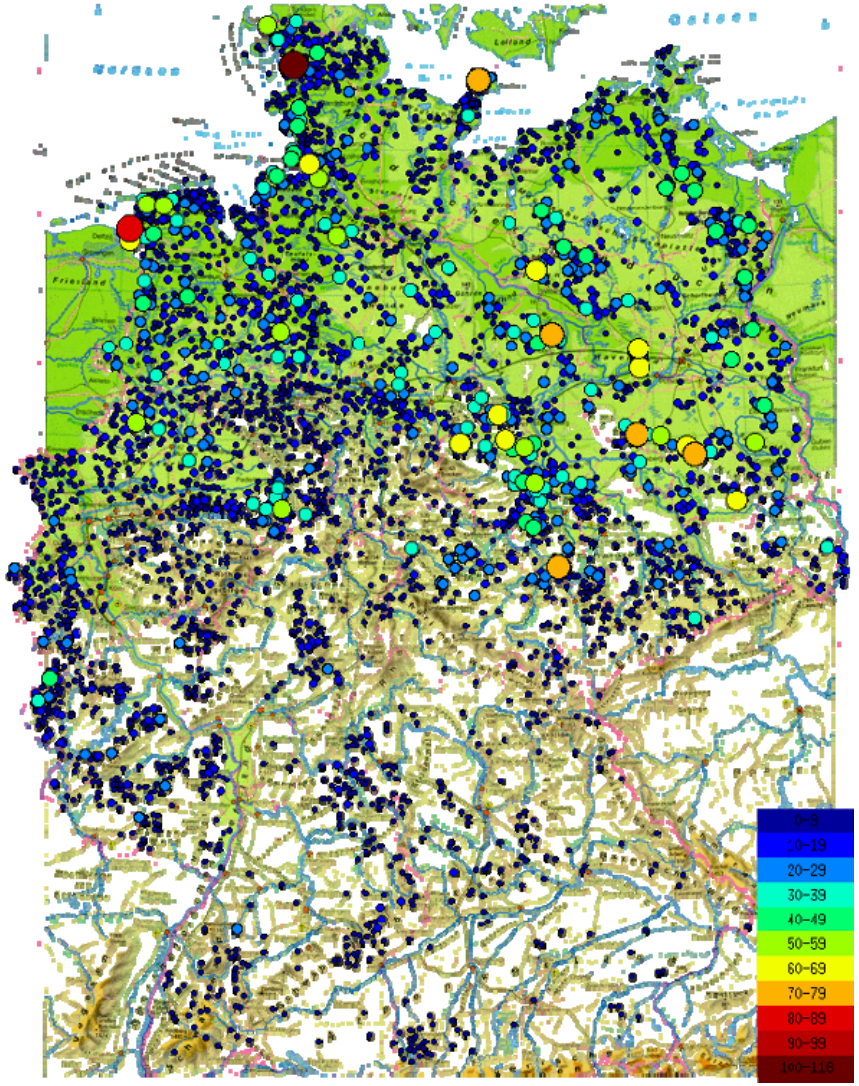
Wind Power in Germany

Data source: ISET, IWET



location of installed wind turbines



capacity per area

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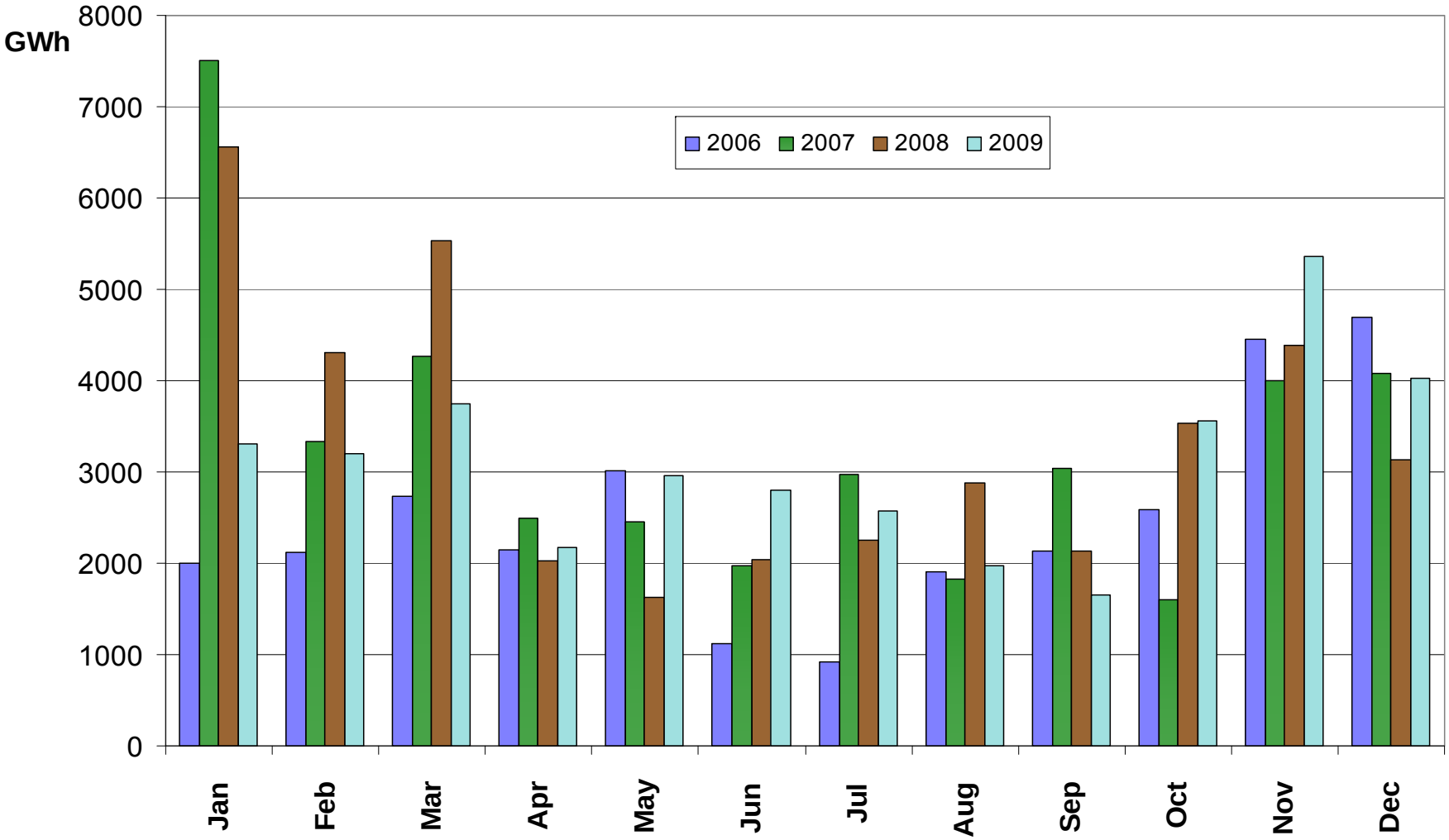
Monthly Production of Wind Energy in Germany

2006 to 2009



Source: Online Extrapolation German TSO

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General Conditions of Grid Integration of Renewable Energies

- **Legal Basis**
  - Renewable Energy Source Act: Came into force on 1 January 2009, replaces the previous act of 2004
- **Regulatory Background**
  - Equalisation Scheme ordinance: Entered into force on 17 July 2009
  - Equalisation Scheme Execution Ordinance: Entered into force on 27 February 2010
- **Grid Code**
  - Transmission Code 2007: Network and System Rules of the German Transmission System Operators
  - Guidelines: Renewables-based generating facilities on the HV and EHV grid

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Renewable Energy Sources Act (1)

- **Connection and purchase, transmission & distribution**
  - Obligation of the grid system operators to connect the installation to the nearest connection point of their grid
  - Grid connection costs are generally to be paid by the installation operator; excepted Offshore installations (RESA §13, Energy Industry Act § 17 (2a))
  - Obligation also applies if the purchase of the electricity is only made possible by optimising, boosting or expanding the grid system
  - Obligation of the grid system operators to purchase, transmit and distribute the entire available quantity of electricity from renewables
  - Grid system operator is not obliged if capacity expansion economically unreasonable

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Renewable Energy Sources Act (2)

- **Capacity expansion and feed-in management**
  - Installations with a capacity of over 100 kilowatts to be provided with remote control of the infeed power
  - Grid system operator is allowed to take technical control over installations over 100 kW in case of system overloading
  - Ancillary services bonus for a period of five years by 0.7 cents for wind turbines in operation before 2014 (behaviour in case of faults, delivery of reactive power, maintaining frequency)

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Renewable Energy Sources Act (3)

- **Payment claims, Direct selling & Tariffs**
  - Obligation of grid system operators to pay installation operators tariffs according to the “special provisions regarding tariffs“
  - Direct selling of the electricity by the installation operators to third parties on a monthly agreement with the grid system operator
  - Various tariffs for the different kinds of renewable energy sources, i. e.
    - Hydropower
    - Biogas
    - Geothermal energy
    - **Wind energy, onshore**
    - **Wind energy, offshore**
    - Solar radiation

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Renewable Energy Sources Act (4)

- **Equalisation scheme**
  - Nationwide equalisation scheme
    - Delivery to transmission system operator
    - Tariffs paid by transmission system operator
    - Equalisation amongst transmission system operators
  - ➢ Ordinance on the Further Development of the Nationwide Equalisation Scheme – Equalisation Scheme Ordinance

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Ordinance on the Further Development of the Nationwide Equalisation Scheme

Equalisation Scheme Ordinance – AusglMechV

- **Basic principles:**

1. The transmission system operators are not obliged to transmit the electricity to downstream utility companies.
2. The utility companies are not obliged to purchase and pay tariffs for electricity from their regular transmission system operators.

➢ The electricity generated by renewable energy is fully integrated in the electricity delivery in total

3. The transmission system operators are obliged to market the electricity
4. The transmission system operators can claim reimbursement from the utility companies for delivering electricity to final consumers
   → *Renewable Energy Act surcharge*

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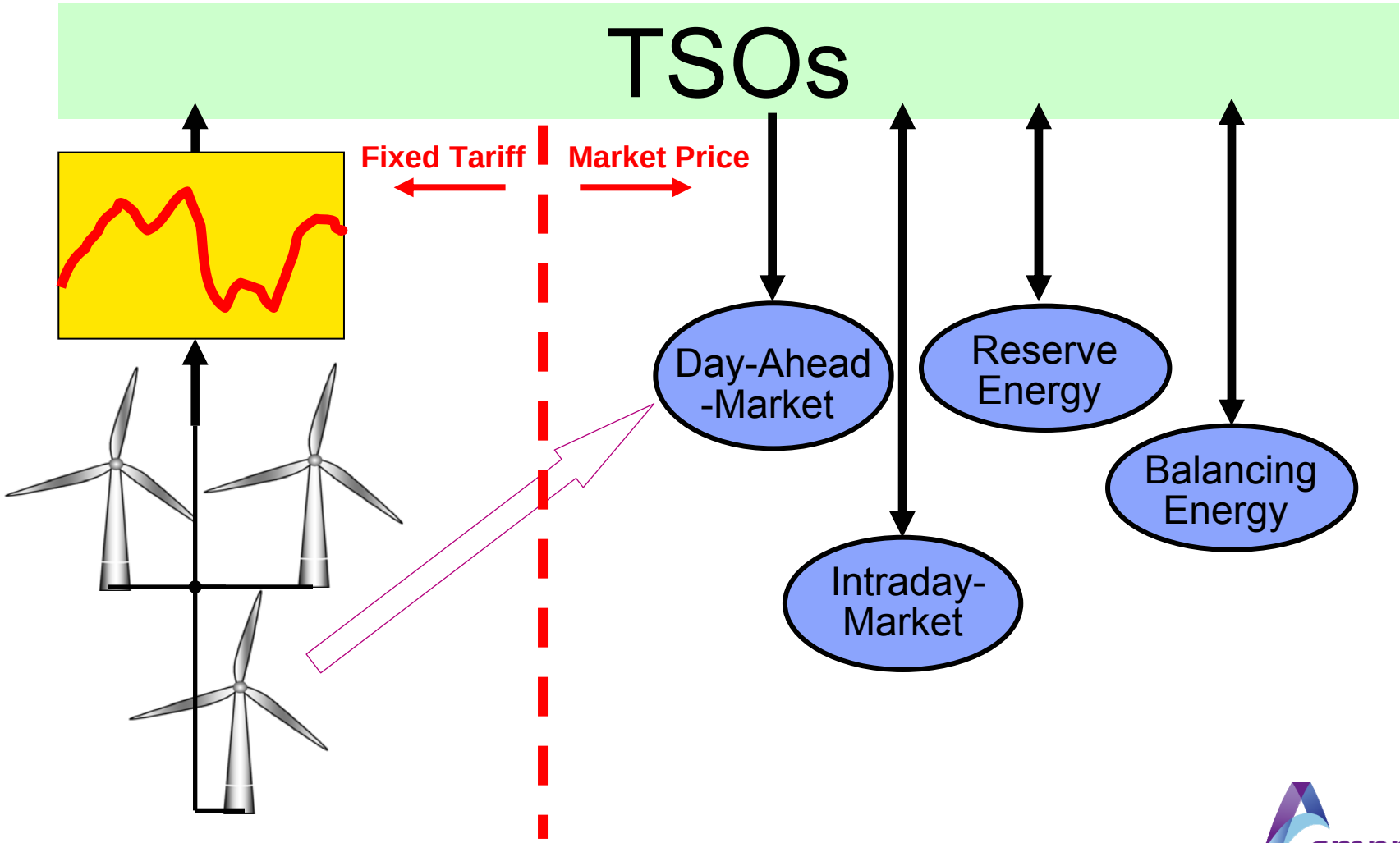
Role of the TSOs in Germany

TSOs are obliged to take off the energy, bring it to market and balance the infeed



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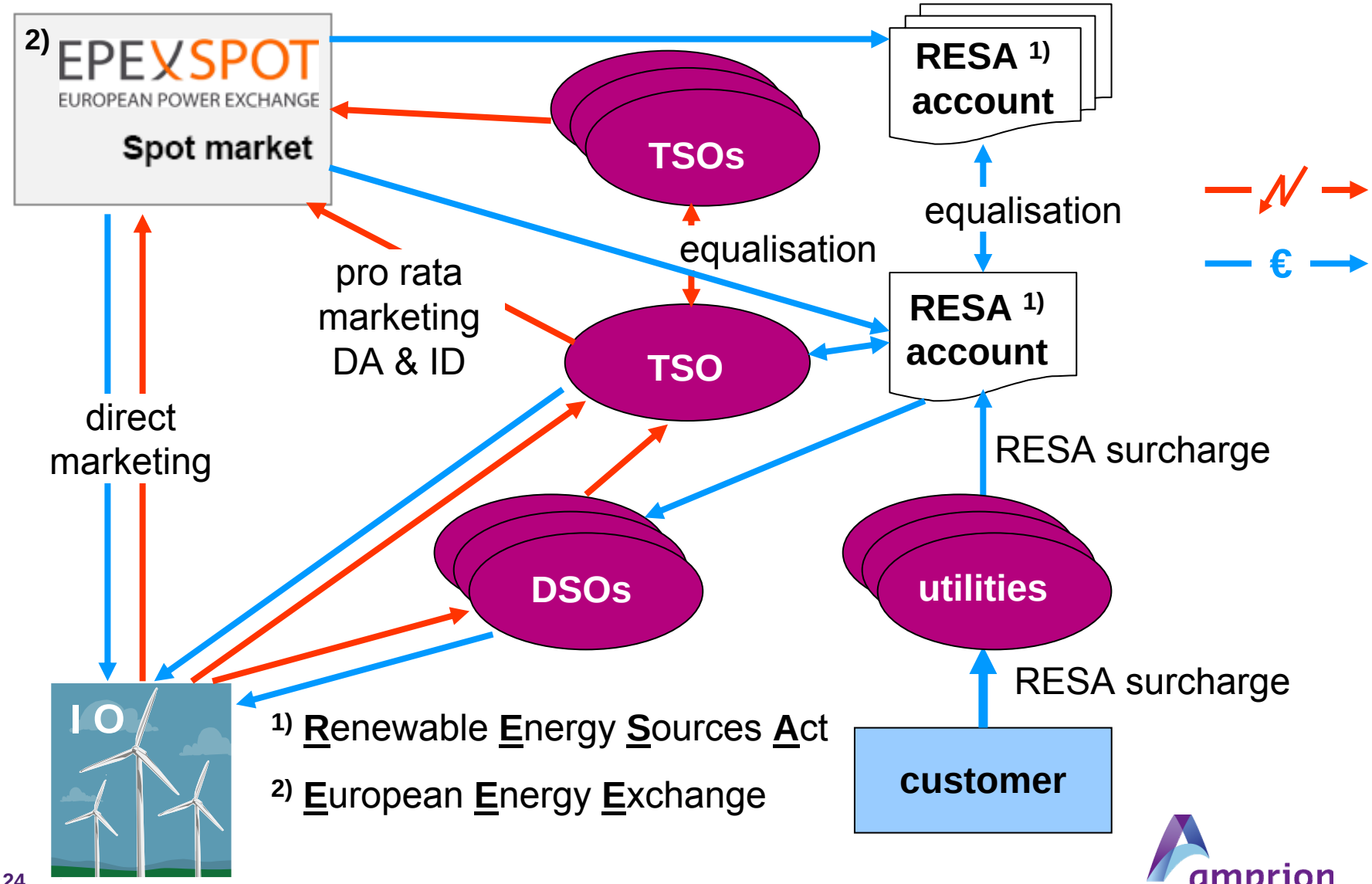
Equalisation Scheme started in 2010



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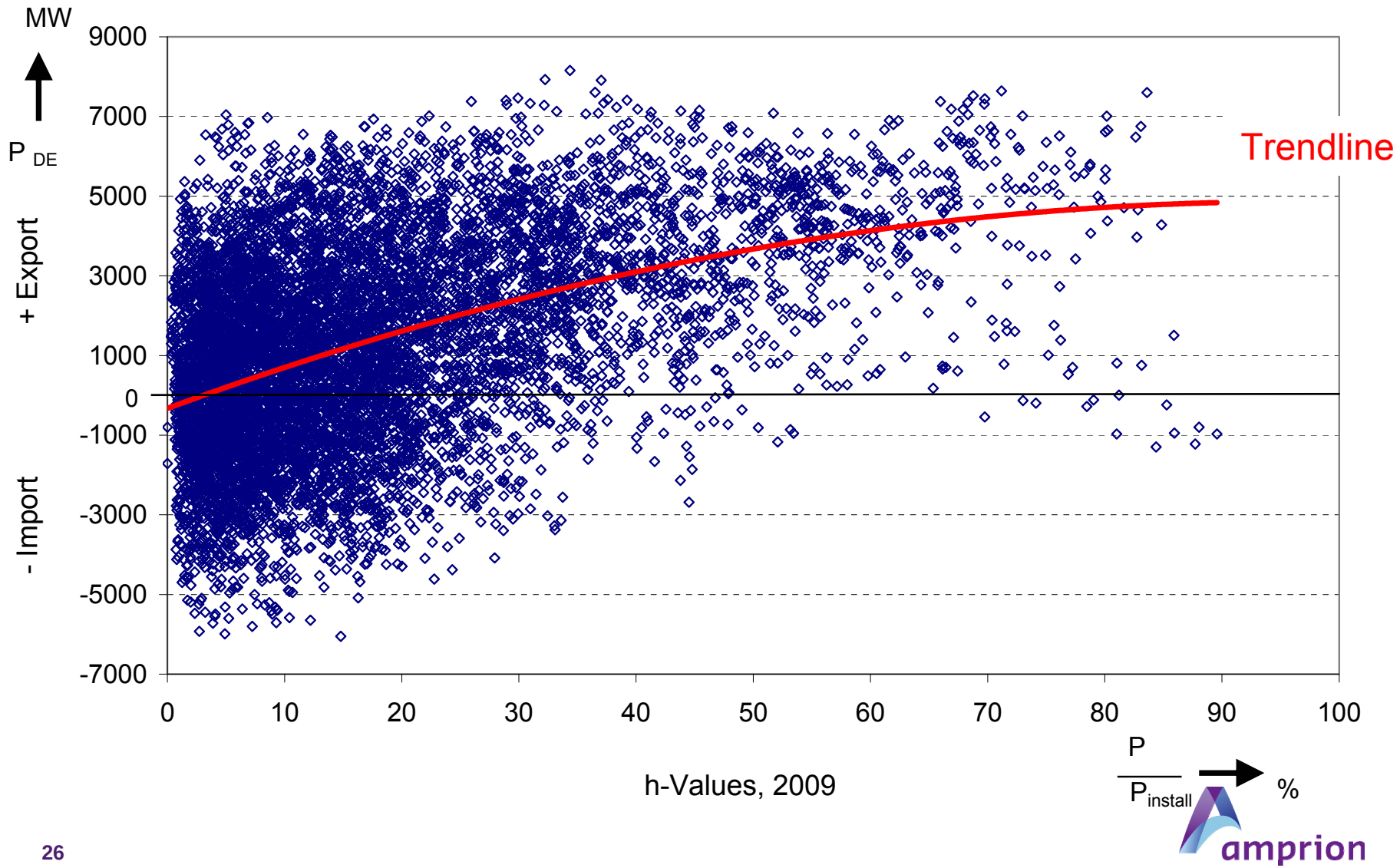
Correlation

Wind Energy Production ↔ Control Program DE



Source: Amprion GmbH

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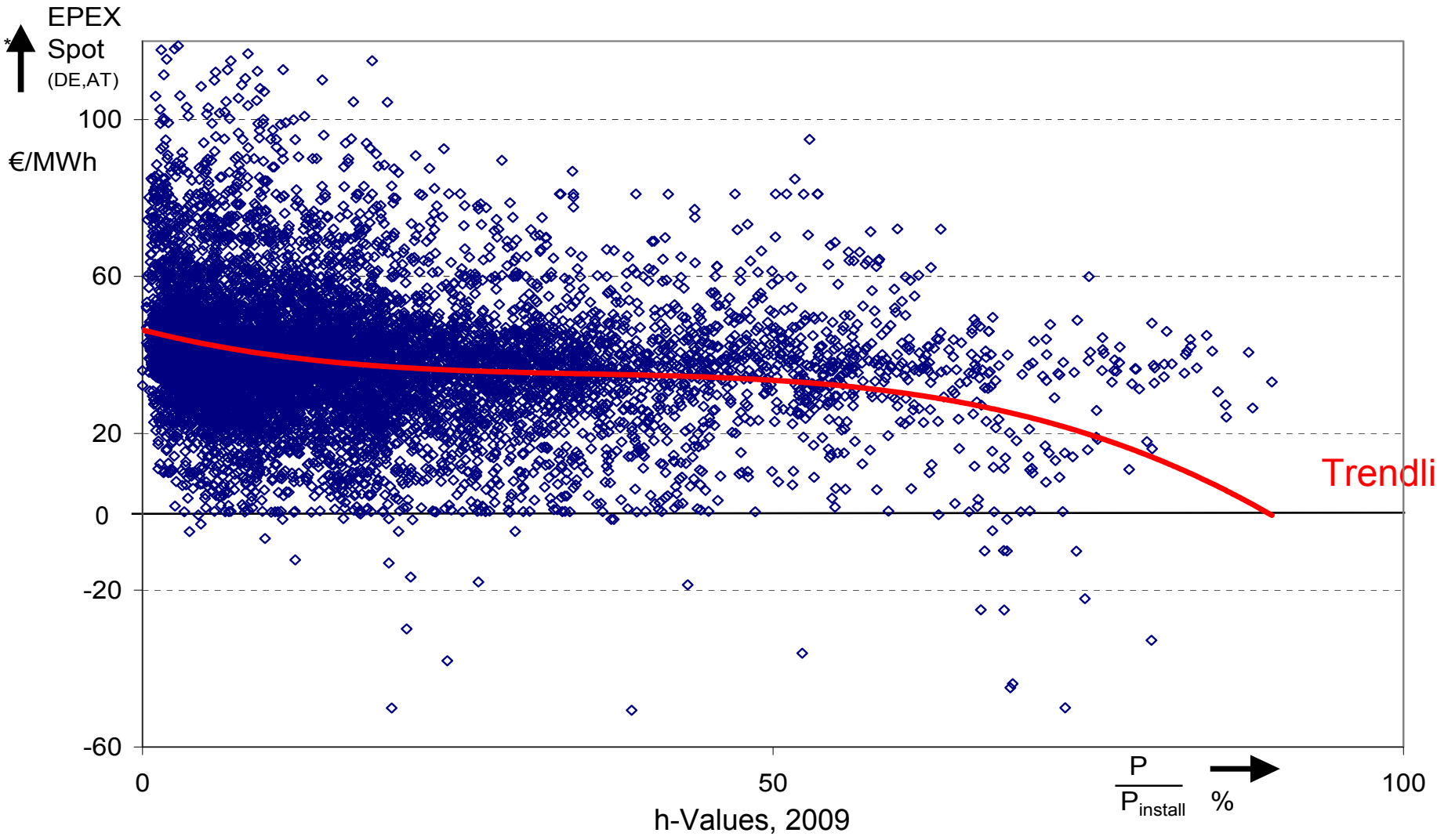
Correlation

Wind Energy Production ↔ Day-ahead Price EPEX



Source: Amprion GmbH

October 2009: day-ahead -500 € / MWh, intra-day: -1.500 € / MWh !!!

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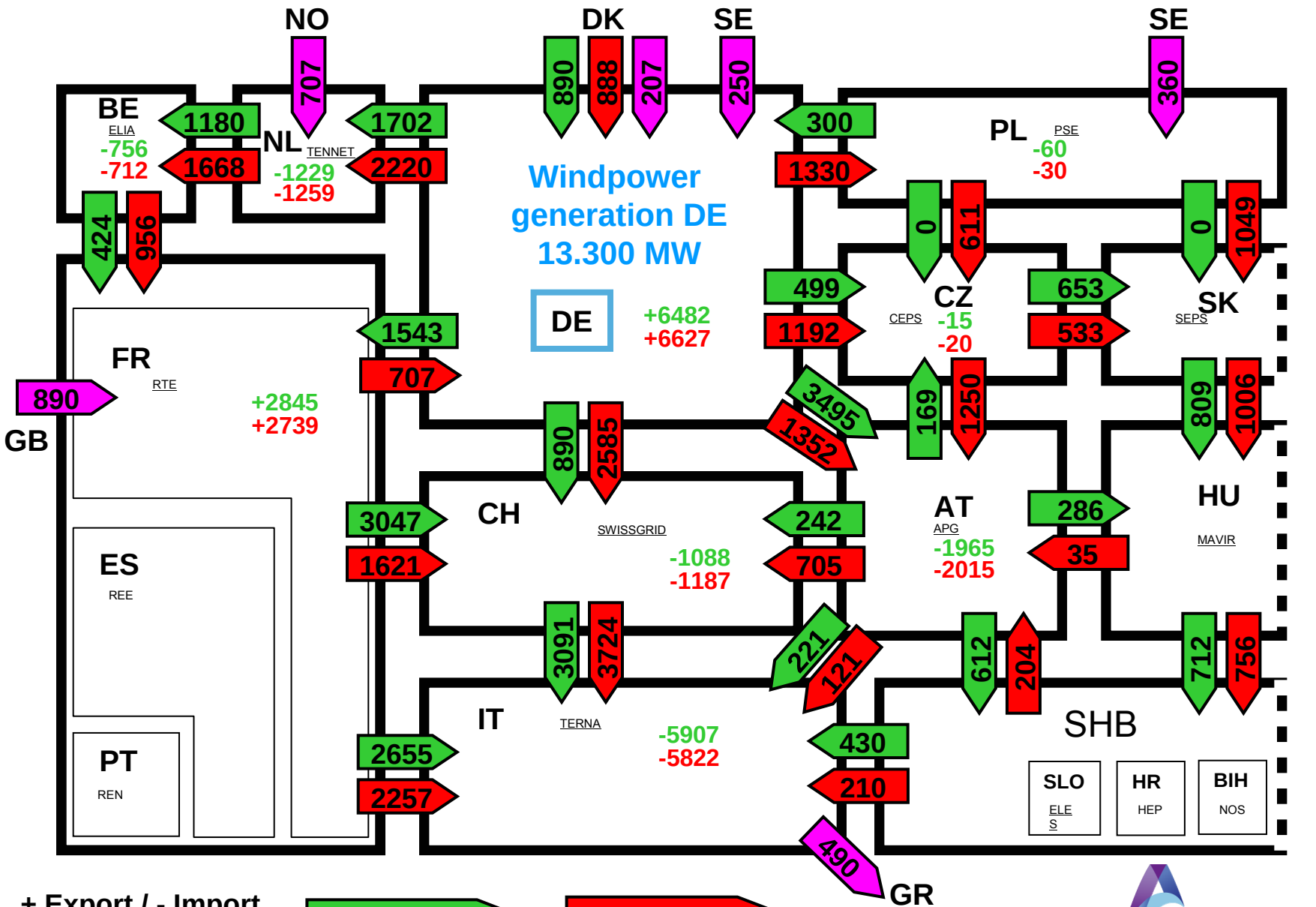
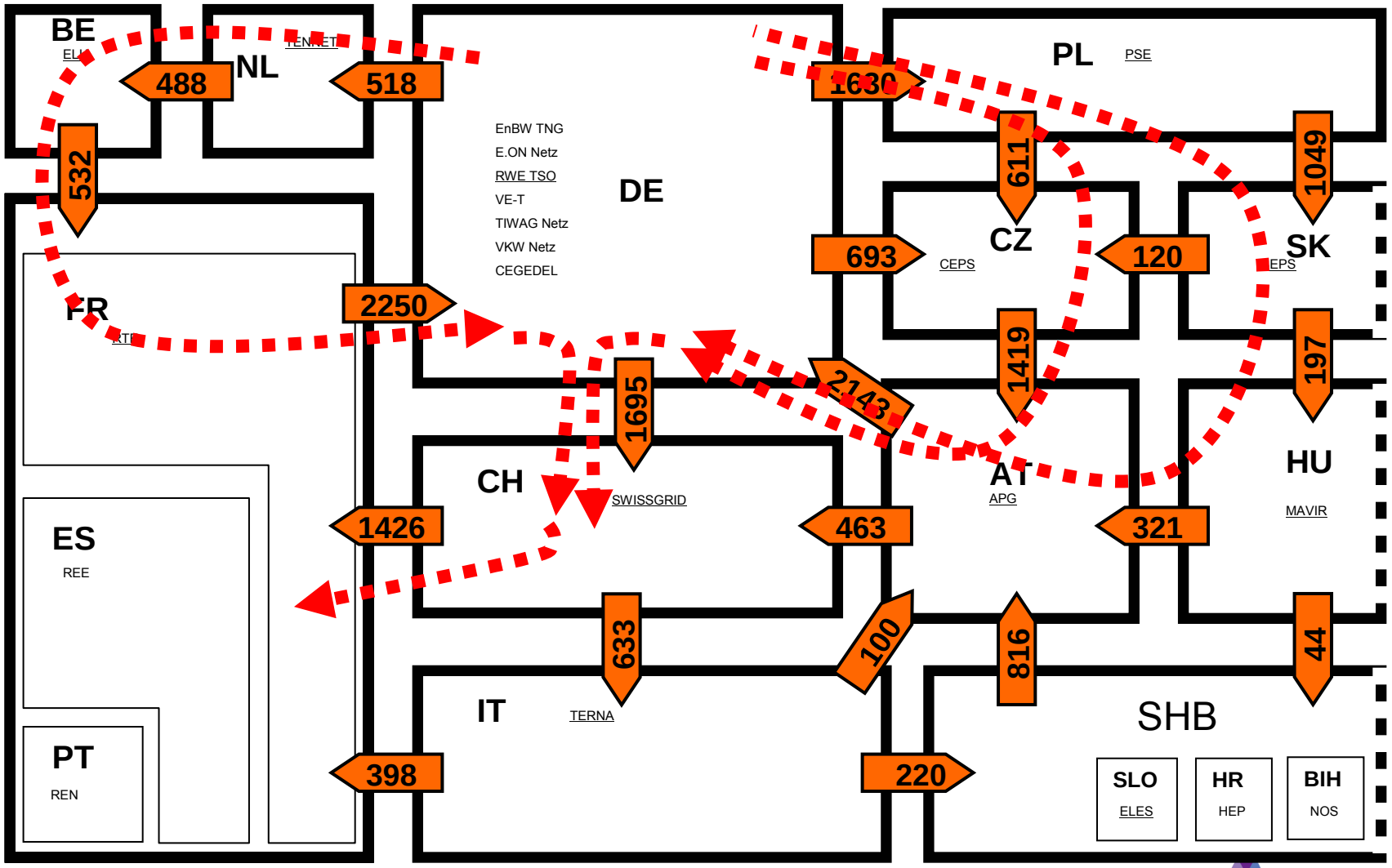
Commercial vs. physical flows in Europe (19-11-2008, 13h30)



Loop flows in Europe (19-11-2008 at 13h30)

Loop flow = physical flow – commercial flow

all values in MW



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Wind Power Prediction

Size of the Forecast Area

Root mean square error (rmse) of a single day ahead forecast model for wind power (% of installed capacity):

- Single Wind Farm: **10%** to **20%**
- Single Control Area (400 km x 400 km): **7.5%** to **10%**
- All German Control Areas (800 km x 1000 km): **5%** to **7%**
- With Combination of Forecasts: **4,2%** (2009)

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Wind Power Prediction

Day ahead prediction - combining different weather models

- Wind power prediction systems commonly use only one single numerical weather prediction model (NWP)
- But the NWP models have strengths and weaknesses in different weather situations

  e.g.: convection is over-estimated by one model, which leads to increase in the predicted wind speed

Approach

- Combine different deterministic NWP models to minimize the error of wind power forecasts. The wind power forecast is calculated as the optimal combination of several single forecasts for the specific weather situation.

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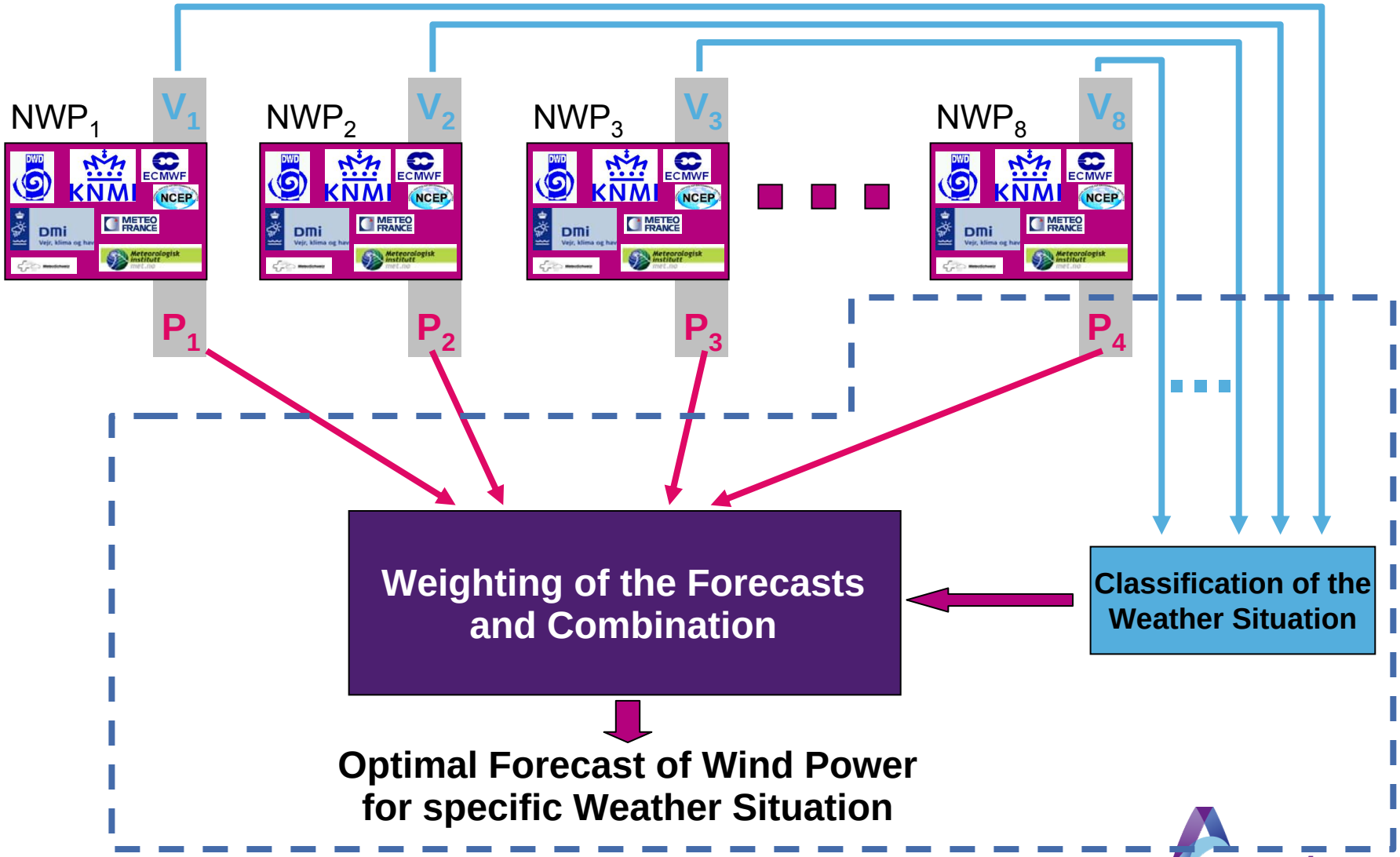
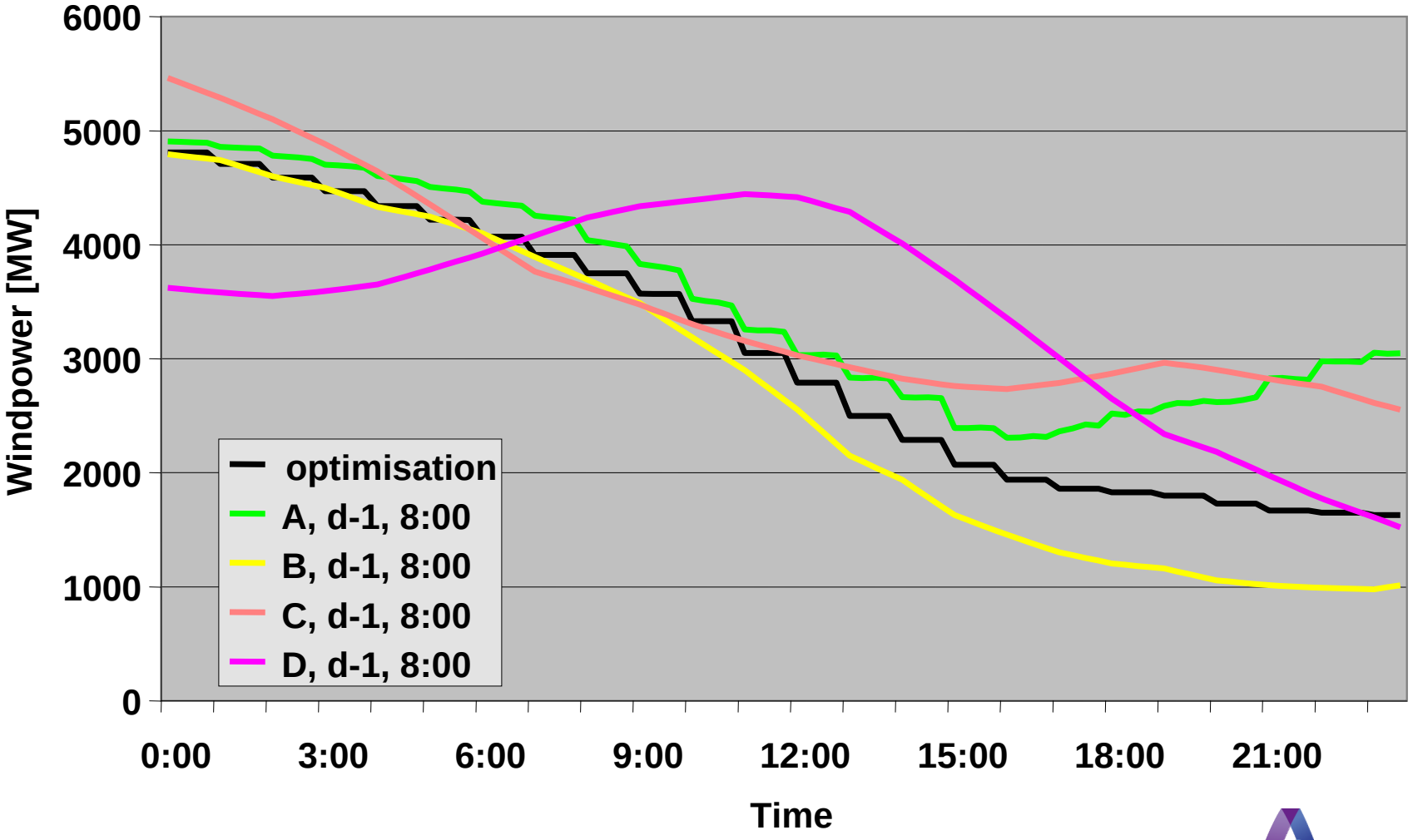
Wind Power Prediction

What the Combination Tool does



Optimisation of wind power forecast process (1)

Predictions, Amprion Share, Day Ahead, 8:00



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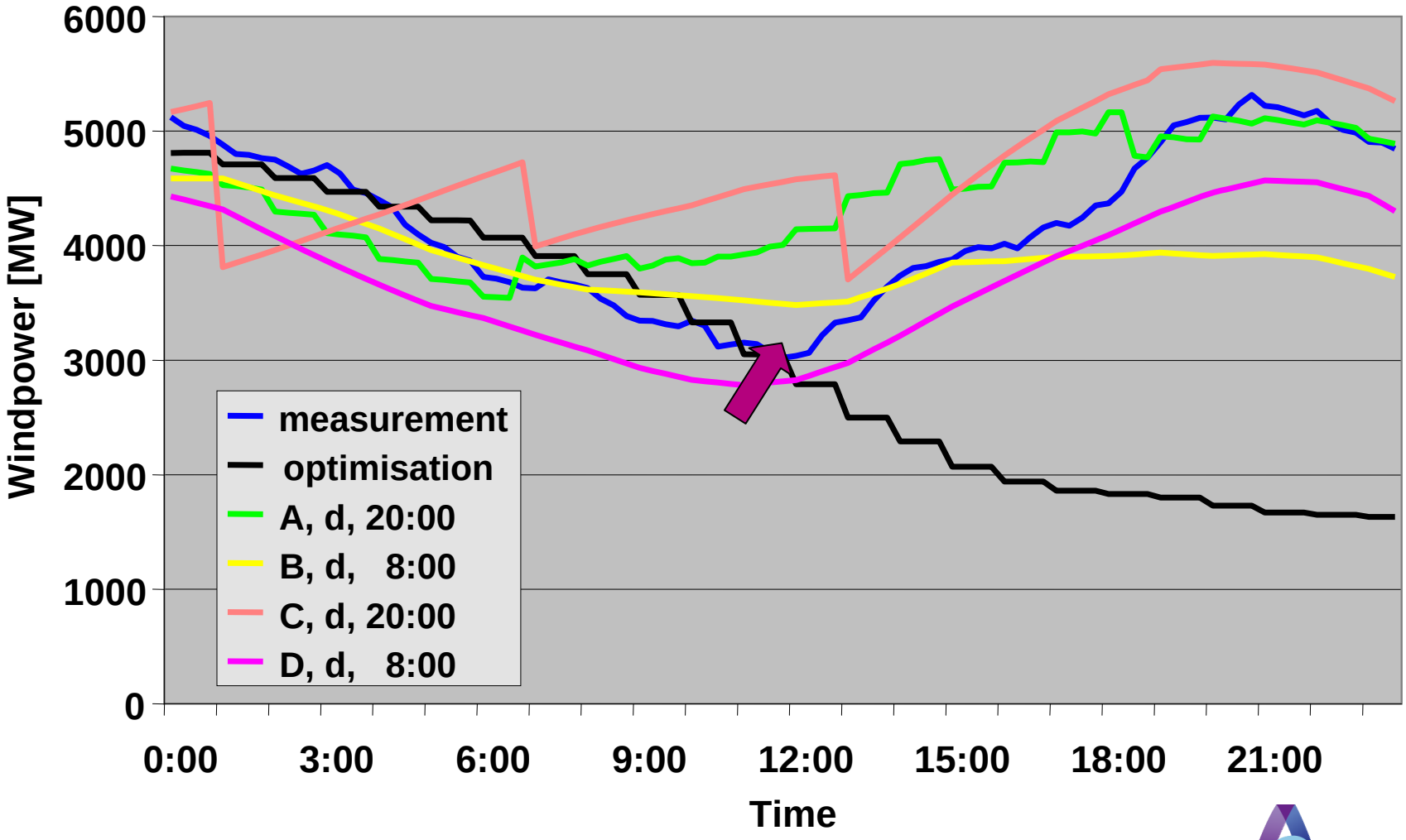
Optimisation of wind power forecast process (2)

Predictions & Measurement, Amprion Share, Actual Day, 24:00



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Conclusion

- The ambitious plans of the EU and the German government lead to a very high amount of renewables in Germany, wind energy takes a dominant part (26 GW).
- The “Renewable Energy Source Act“ is the legal basis for the integration of renewables. It defines the grid connection and purchase, transmission & distribution, capacity expansion and feed-in management, direct selling & tariffs.
- The TSO plays an important role. He has to purchase the energy from renewables at fixed tariffs and has to market the energy on the spot market.
- The massive infeed from renewables has a big impact on the energy market and on the load flows in Germany and the surrounding countries.
- A good wind power forecast is of great importance for the TSO. By combining different forecast models a higher forecast quality can be achieved.

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Thank you for your attention.

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