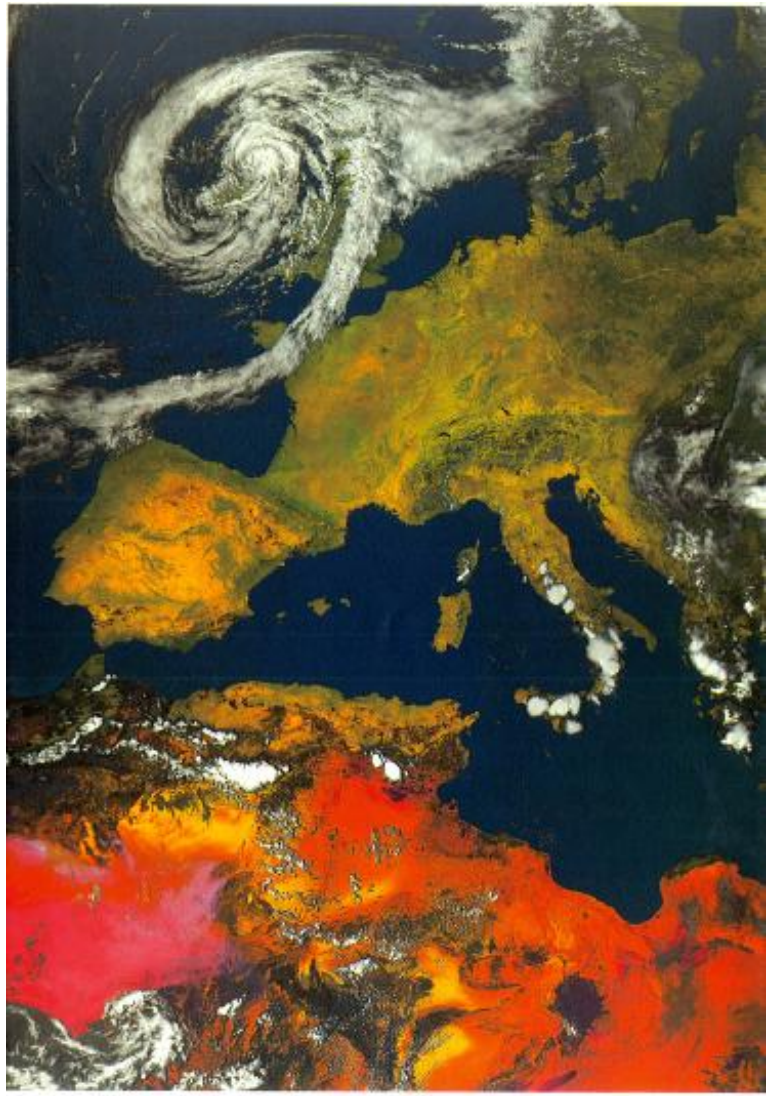


Managing the Grid in Areas with Increasingly Decentralized Power Production

Kurt Rohrig

Fraunhofer Institut für Windenergie und Energiesystemtechnik

Kassel

www.iwes.fraunhofer.de

Fraunhofer IWES

Fraunhofer IWES: Institute Profile

Wind energy

Photovoltaics

Bio energy

Research spectrum:

- Wind energy from material development to grid optimization
- Energy system technology for all renewables

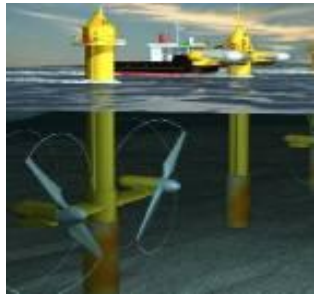
Foundation: 2009

Annual budget: approx. € 35 million

Personal: approx. 500

Electricity grids

Hydro power



Marine energies

advancing wind energy and energy system technology

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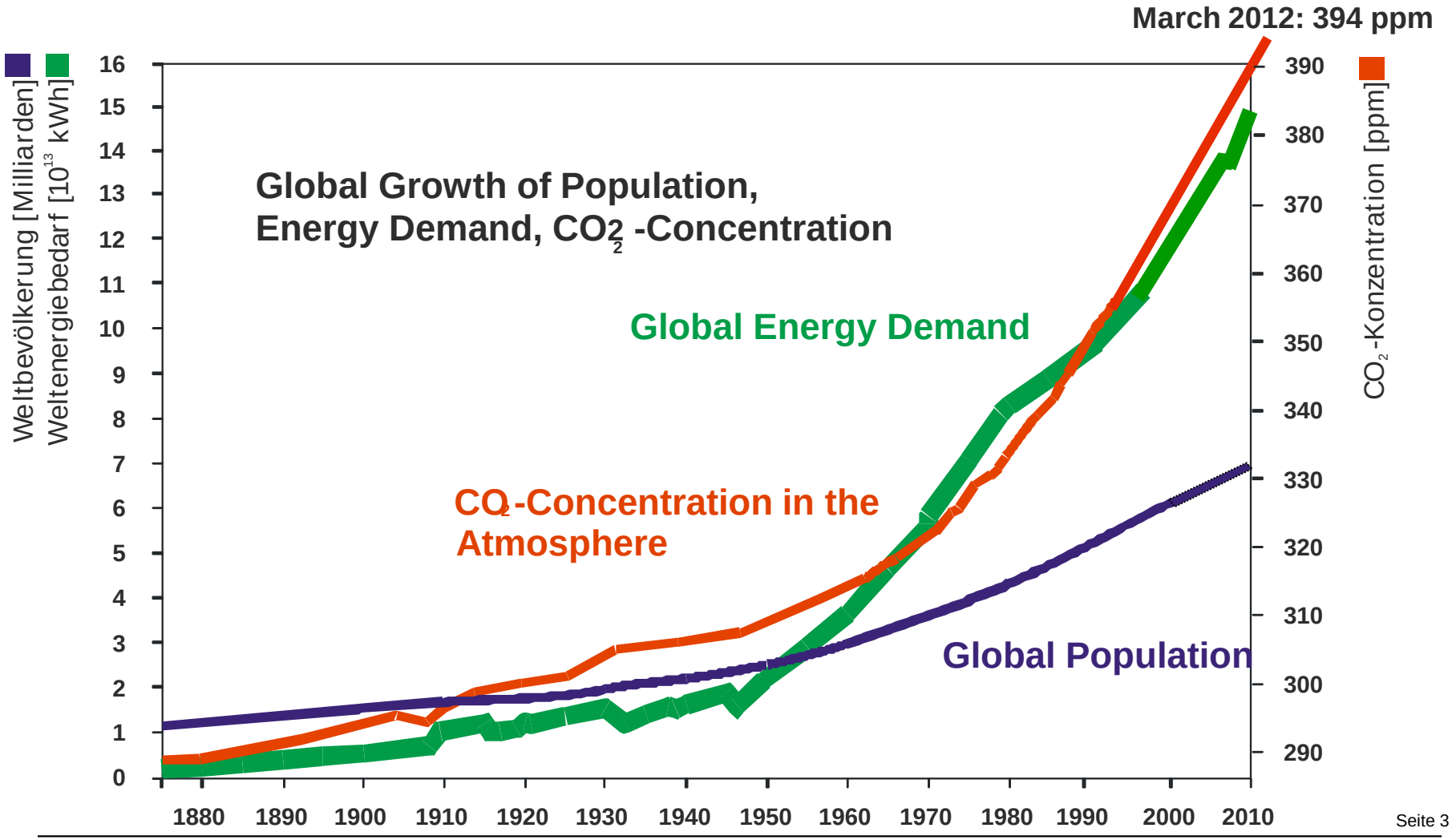
Global Situation and Future Trends



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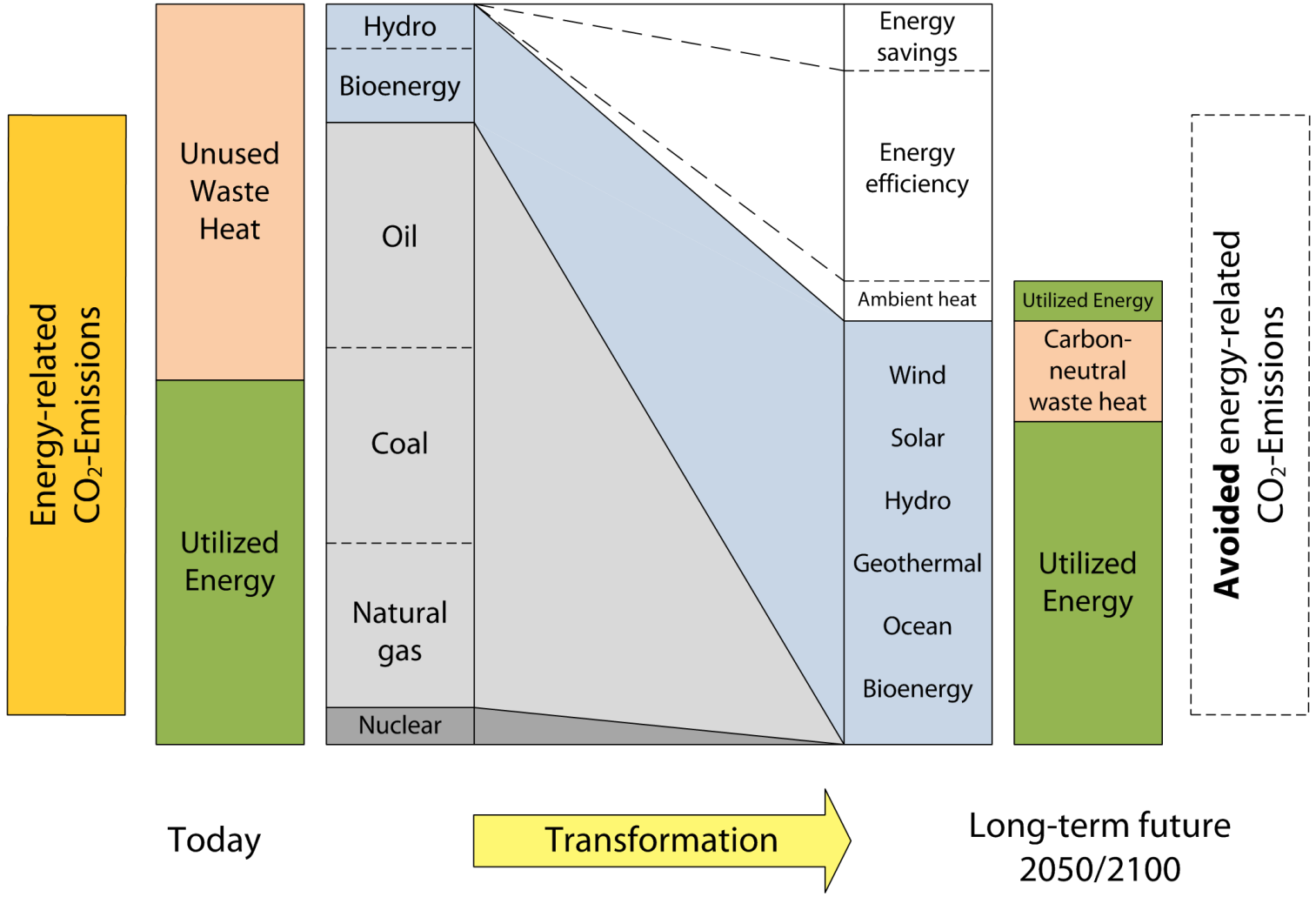
Transformation of Electricity Sector



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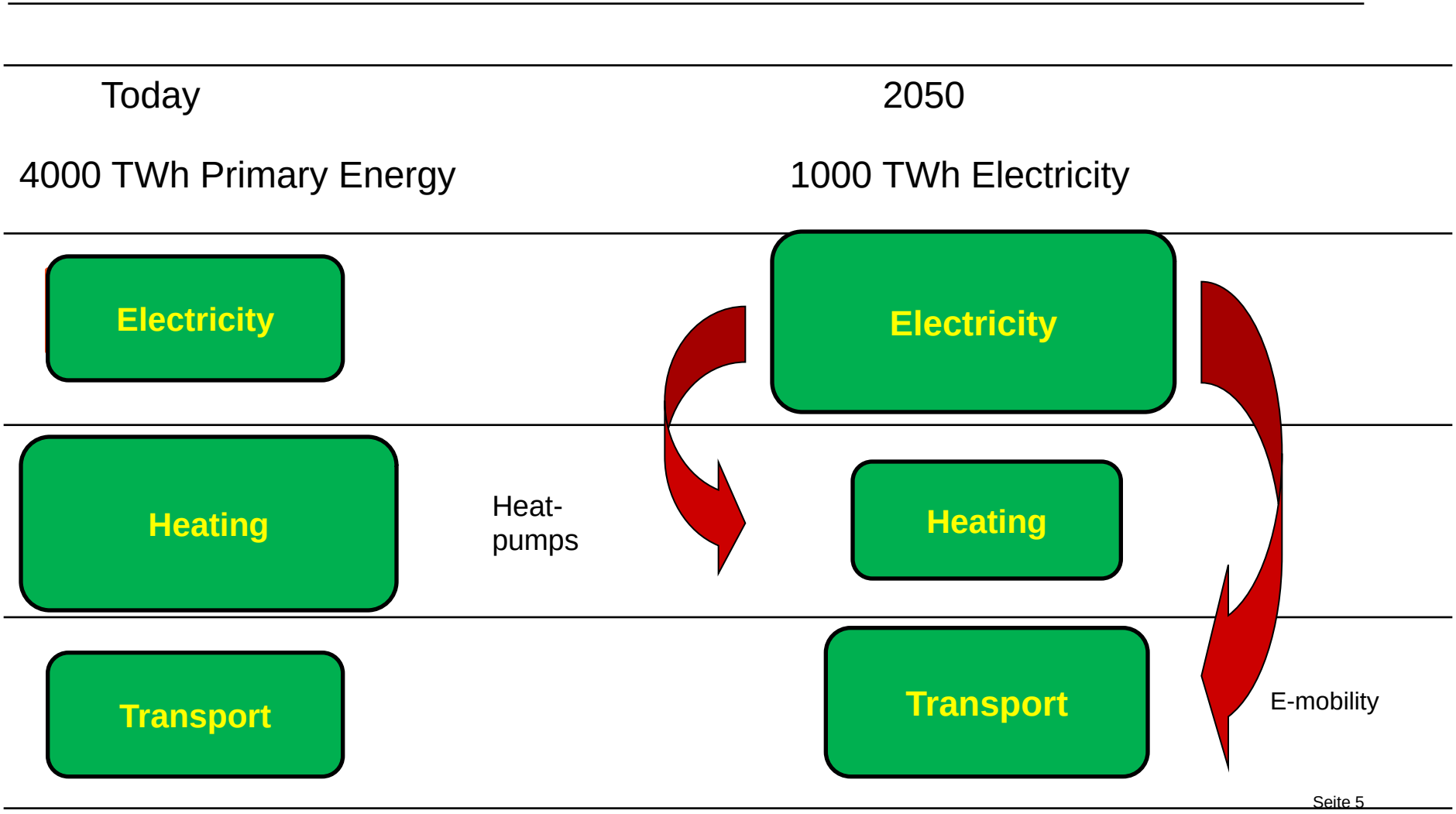
Transformation of Energy Supply System



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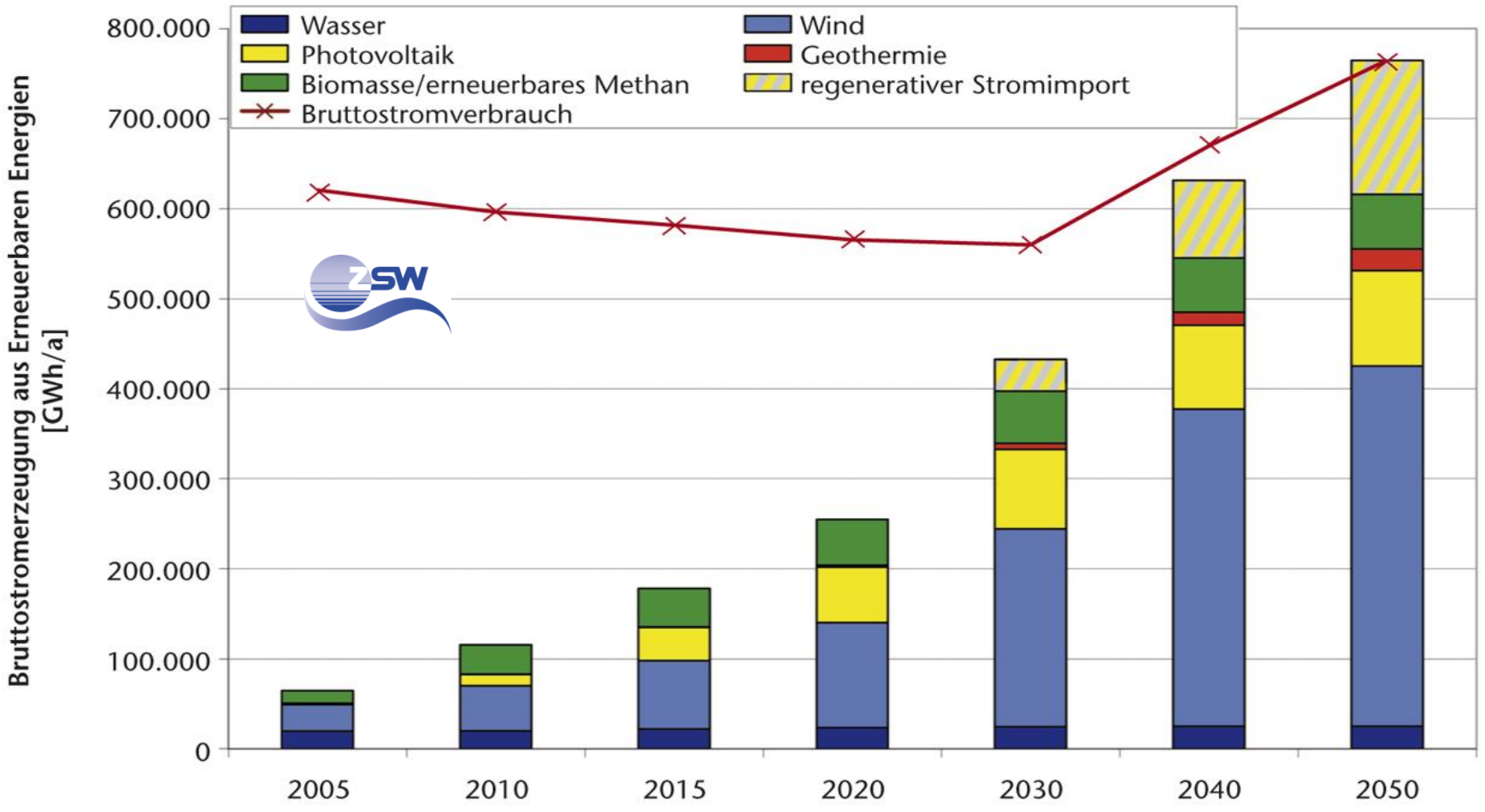
Gross Electricity Generation from RES and Consumption in Germany up to 2050



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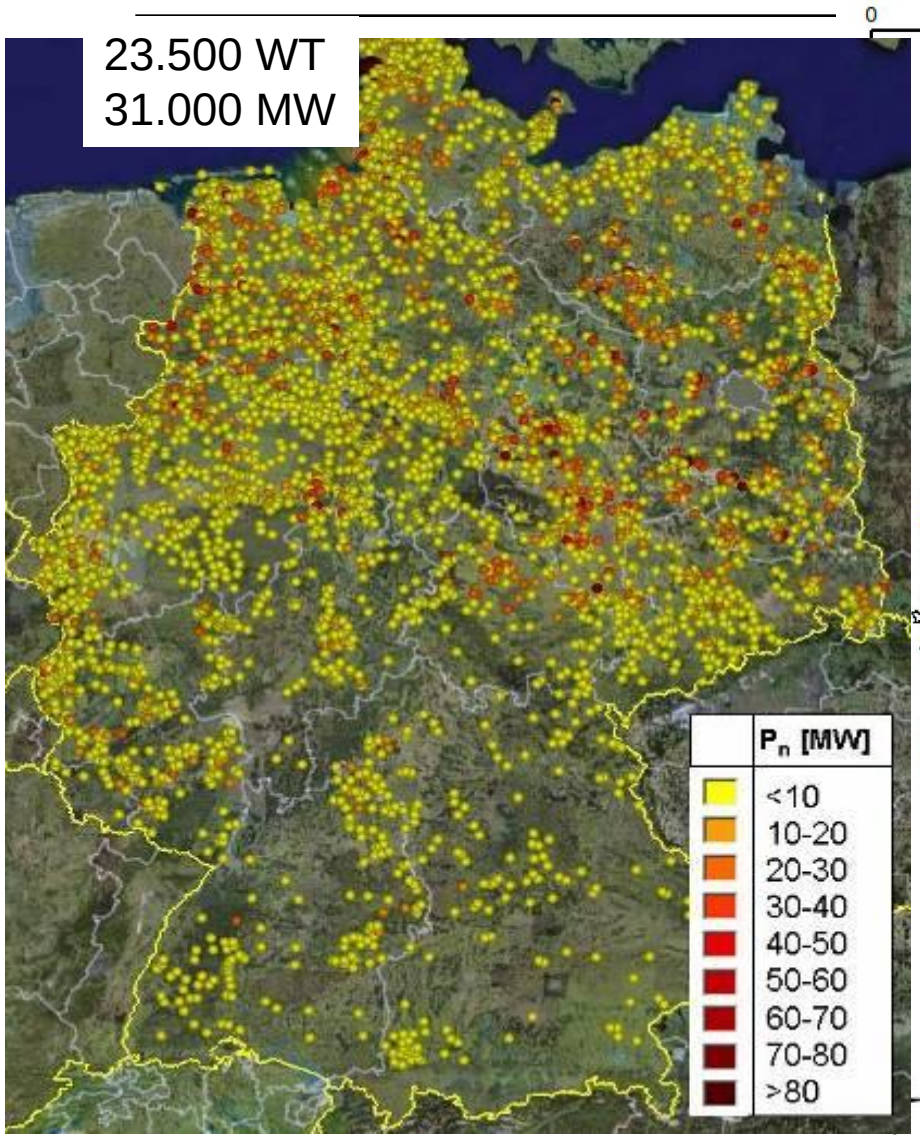
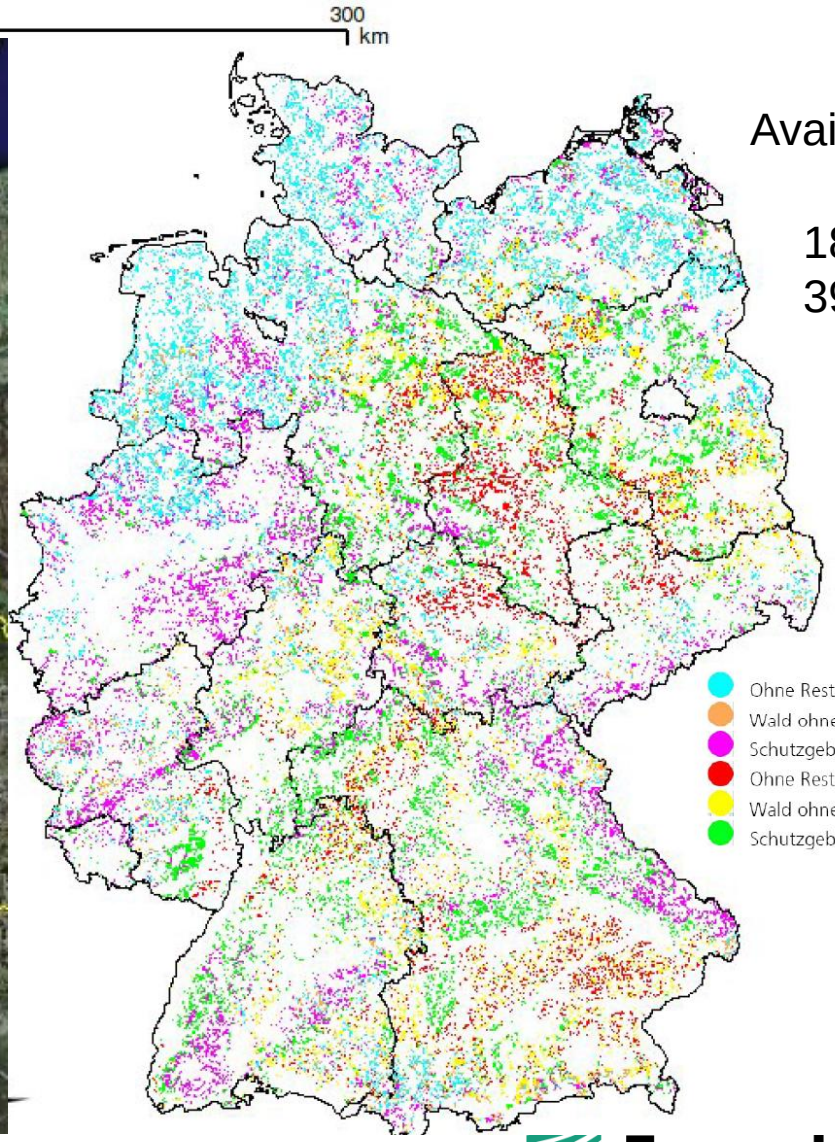
Wind Energy in Germany – State of the Art and Potential



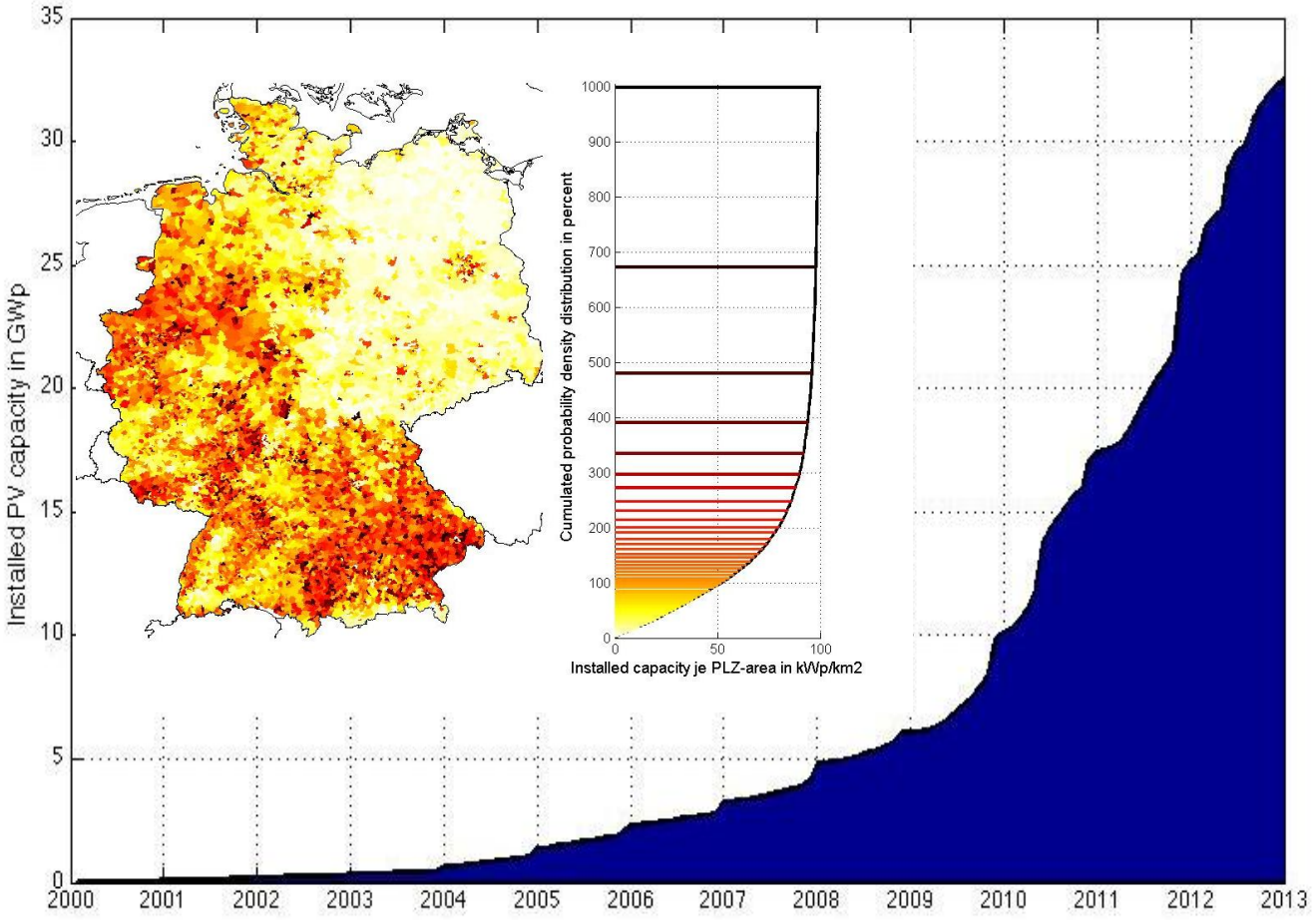


Available Areas

189.000 MW
390 TWh

Fraunhofer
IWES

Impact of the PV-power production on the German power system



2013:

33 Gwp installed

1 337 890 PV-plants

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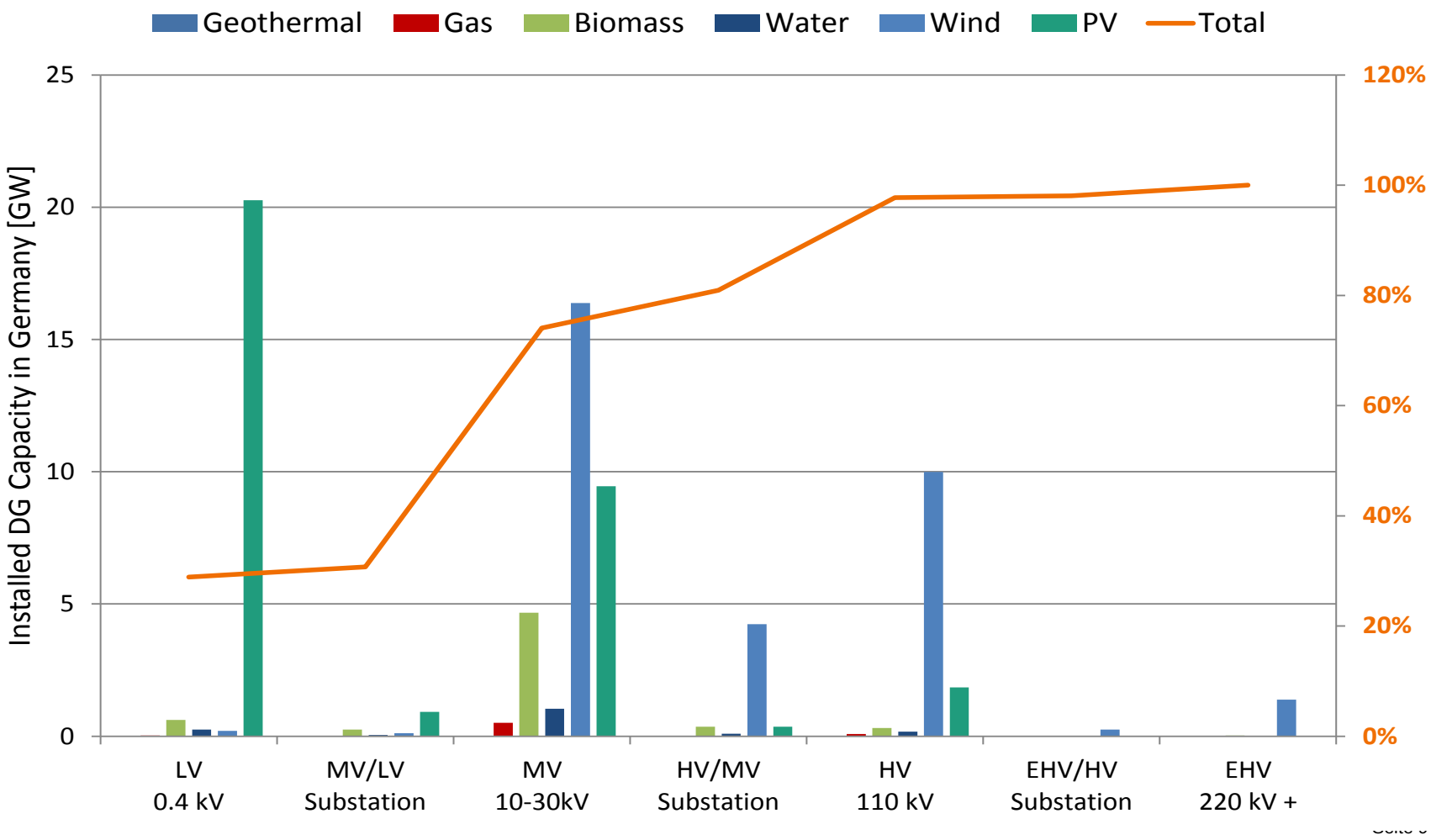
Total installed DG Capacity: 74 GW (33 GWp PV)
Peak Load in Germany: 80 GW



Data Source: DGS, www.energymap.info

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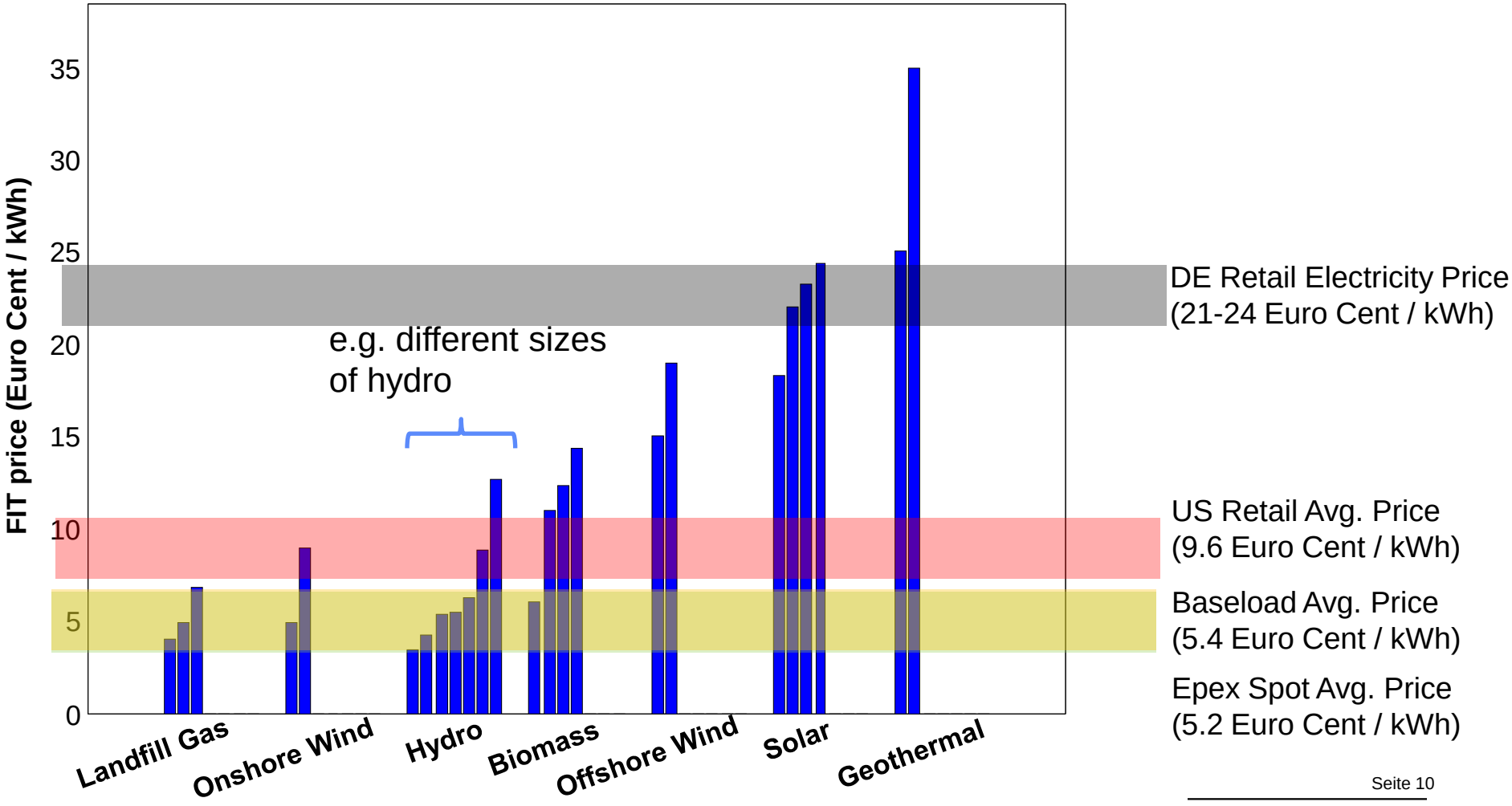
German FIT Prices vs. Technology and Size (2012)



Source: FIT data compiled by GermanEnergyBlog
See notes for other price data sources

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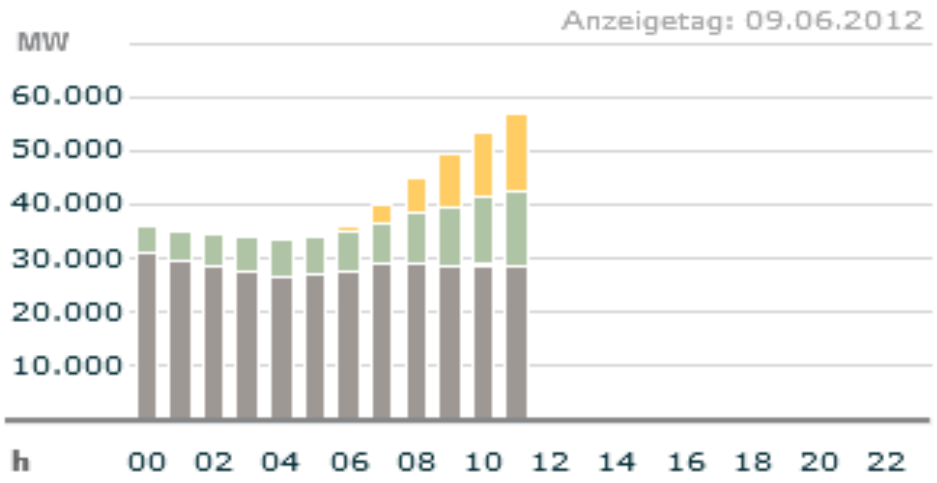
Willkommen auf der EEX-Transparenzplattform

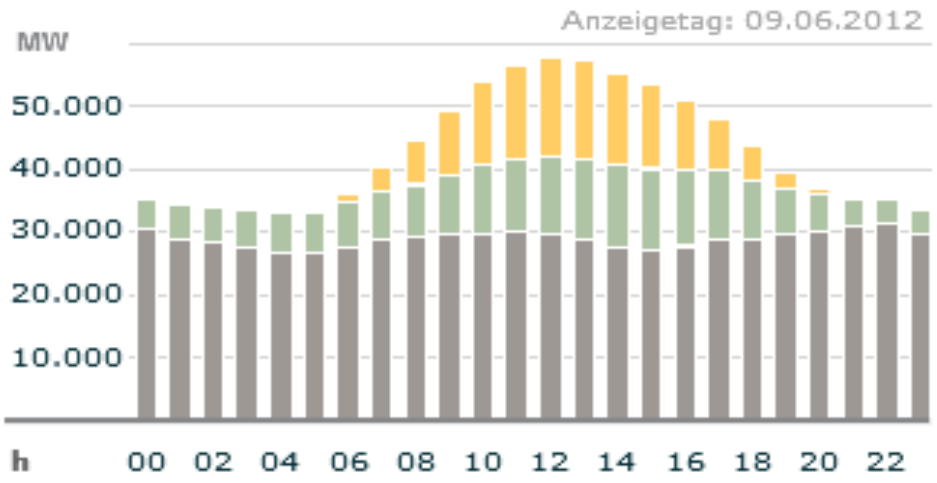
Auf der EEX-Transparenzplattform werden marktnah an zentraler und neutraler Stelle marktrelevante Erzeugungs- und Verbrauchsdaten veröffentlicht, um die Transparenz auf dem Großhandelsmarkt weiter zu erhöhen. Damit werden sowohl gesetzliche Veröffentlichungspflichten als auch freiwillige Selbstverpflichtungen der Branche umgesetzt.

DE/AT | **DE** | AT

Tatsächliche Produktion (Strom)



Geplante Produktion (Strom)



Legende: Konventionell | Wind | Solar

Short-term forecast

Structure of a forecast system for the short-term forecast

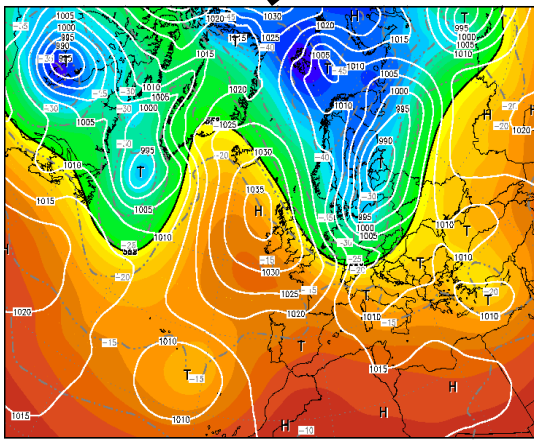
Online power meas. of representative wind farms

Weather forecasts for the locations of rep. wind farms

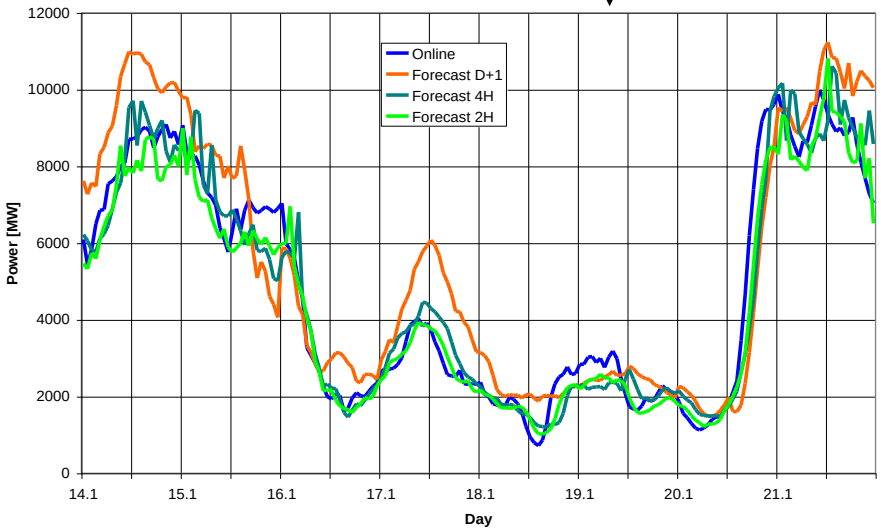
Wind power forecasts for the rep. wind farms

Extrapolation to a control zone

Representative Wind farms



Numerical weather model



Wind power forecast for a control zone

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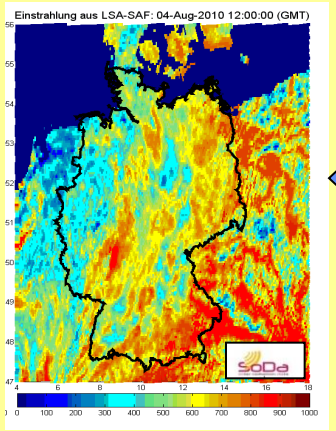
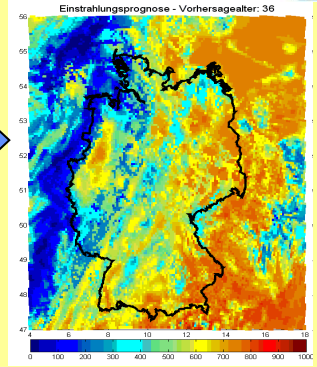
Process of PV Power Forecast

Satellite

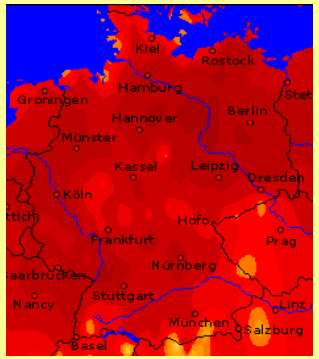


NWP (0 – 78 h) – Cosmo-EU

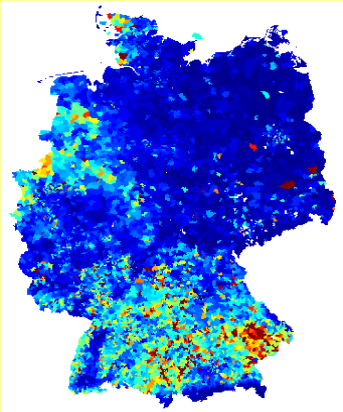
Radiation



Temperature



Installed PV-Capacity



- EEG Database
- PV Database (BNetzA)

Preprocessing

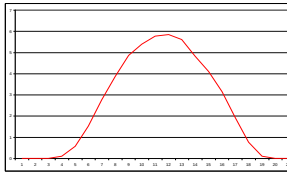
Classification by age, power

Statistical information of :

-inclination, orientation, - WR- und efficiency factor
- losses

Physical Simulation of all PV plants

MOS NN



PV-forecast

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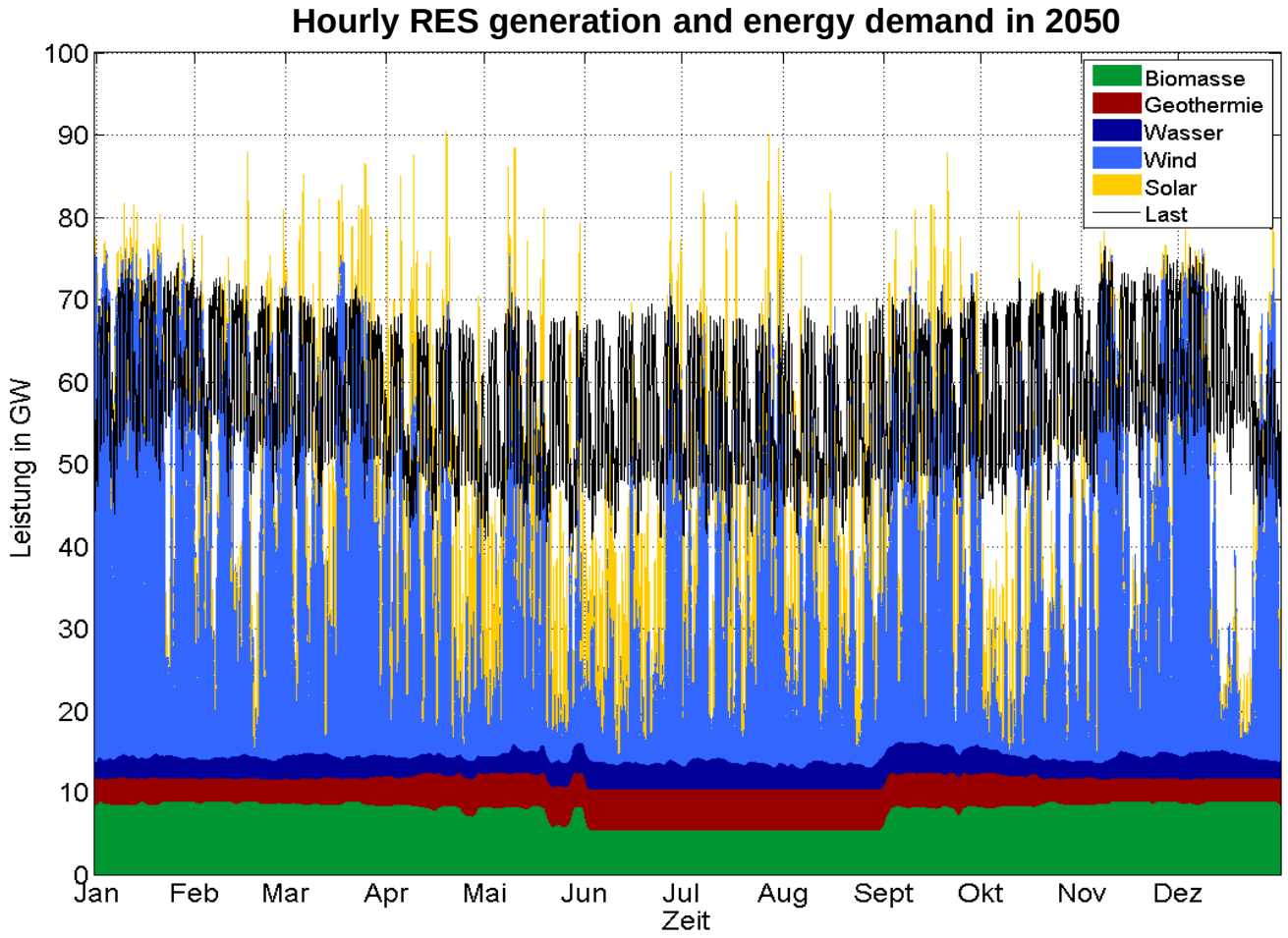
Future Energy Supply Scenarios



German Lead Study 2009 without additional Consumers – 2050
(meteorological basis 2007)

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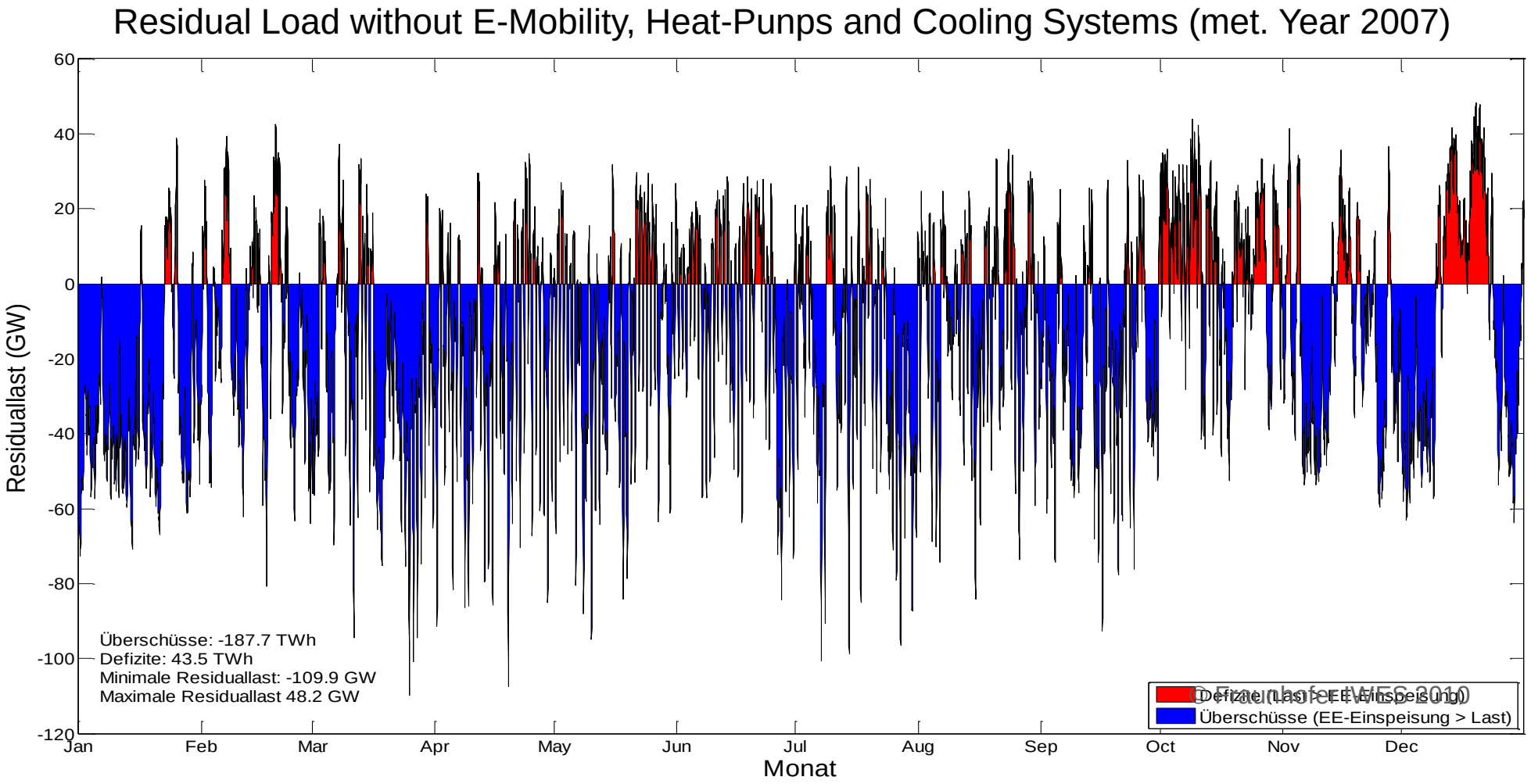
Residual Load: Measure for Balance Efforts



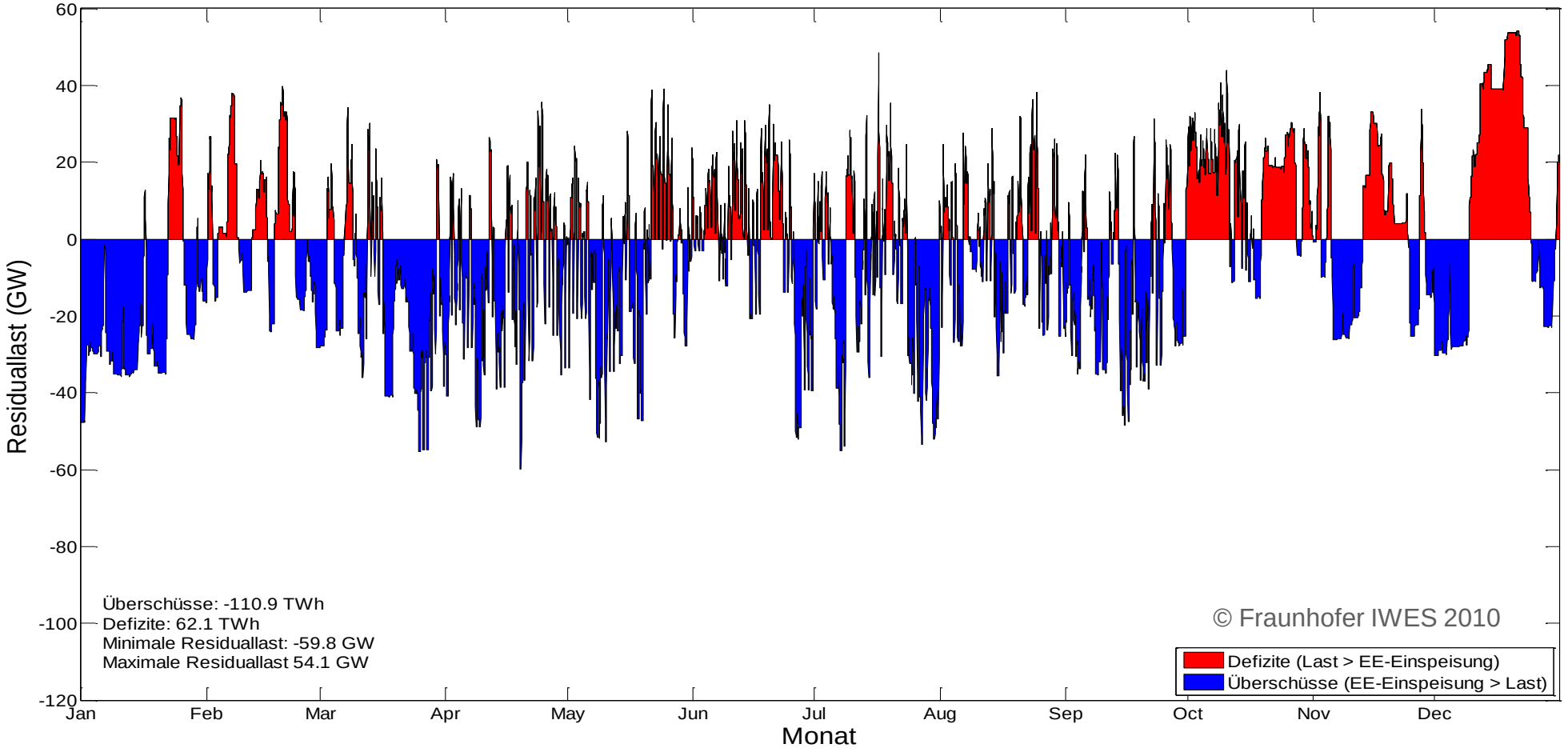
Source: IWES-Calculation for UBA Energy Target 100% Electricity from RES

ZSW

Fraunhofer IWES

Load Management to Reduce Balance Efforts

Residual Load incl. E-Mobility, Heat-Punps, Cooling Systems and Hydro Storage (met. Year 2007



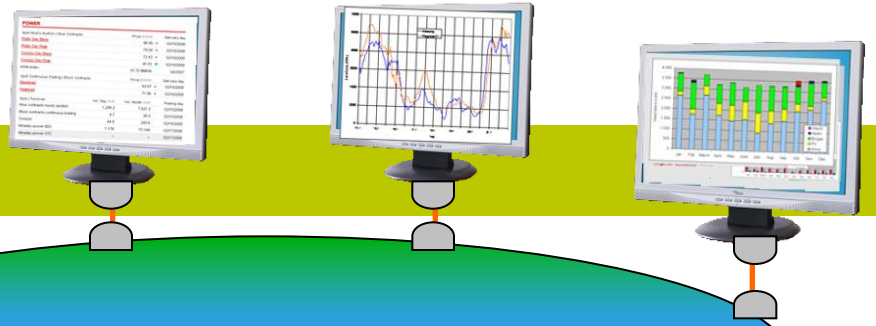
Source: IWES-Calculation for UBA Energy Target 100% Electricity from RES

ZSW

Fraunhofer IWES

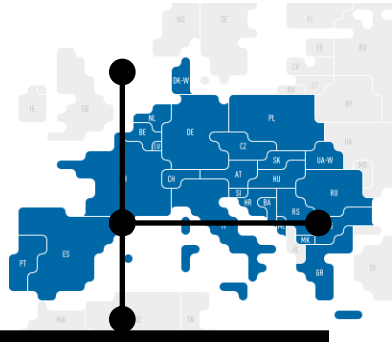
Regional Supply Structures by VPP: Model Region Harz

REGMODHARZ
Regenerative Modellregion Harz



Renewable Power Plant Harz

Device Control
Market Information



Generation

Controlable Loads

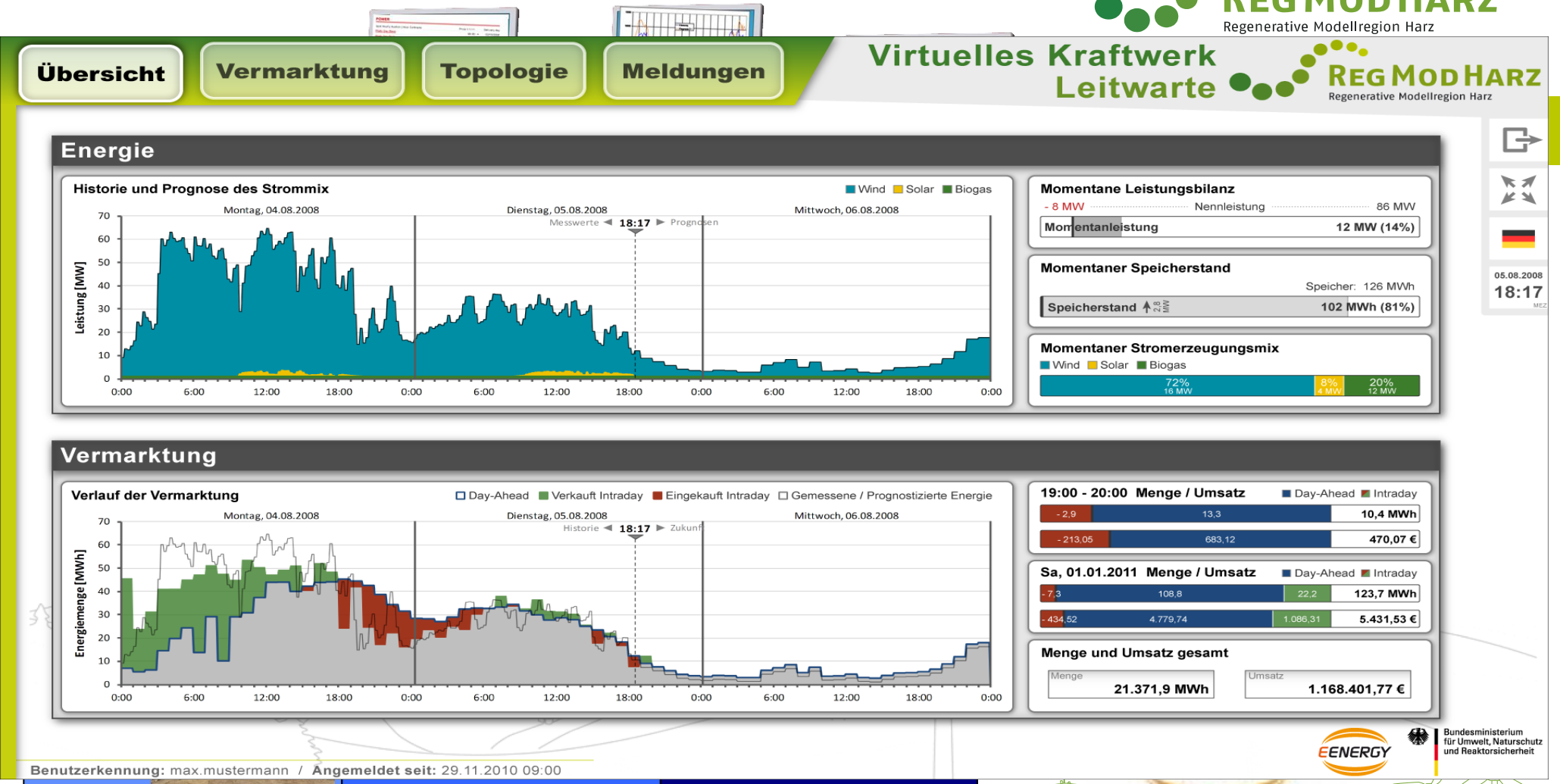
Storage

Harz.EE-mobility

EENERGY

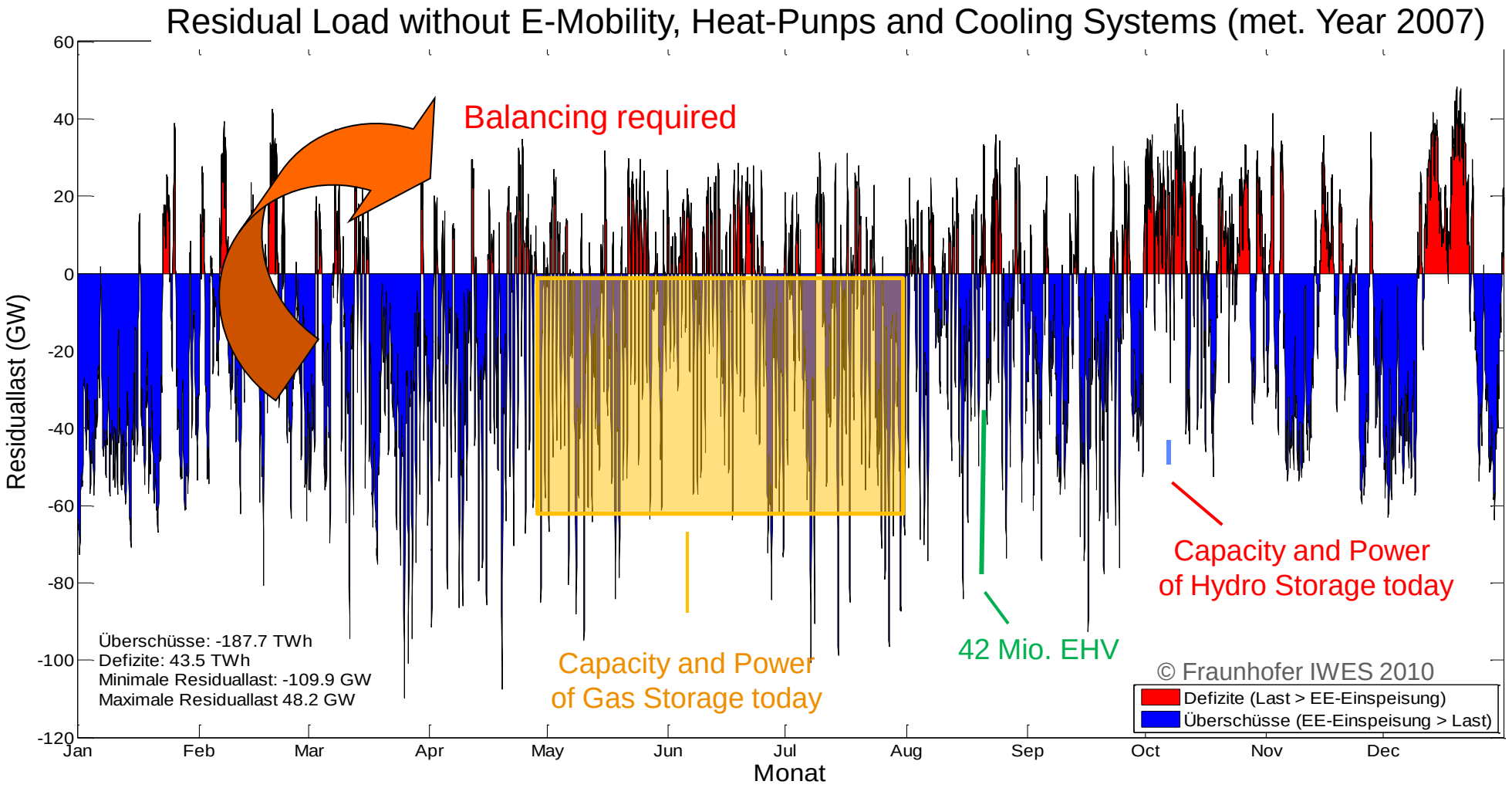
Regional Supply Structures by VPP: Model Region Harz

REGMODHARZ
Regenerative Modellregion Harz



Generation | Loads | Storage

Germany has insufficient Storage Capacity



→ Gas storage = 1500 – 3000 x capacity of all hydro storage systems (bei $\eta_{GT,GuD}$ = 28-55%)

Source: IWES-Calculation for UBA Energy Target 100% Electricity from RES

ZSW

Fraunhofer IWES

Coupling of the Electricity Grid and the Gas Distribution System

SOURCES

STORAGE / TRANSPORT

CONSUMPTION

ELECTRICITY GRID

Balancing

Wind

Sonne

H_2O

CO_2

Atmosphäre
Biomasse, Abfall
(Fossile Brennstoffe)

Electro-lysis

H_2

CO_2

Tank

Methan-isierung

Renewable Power Methane Anlage

CH_4

Gas Power Stations

Electricity

Heat

GAS DISTRIBUTION

Traffic

Gasspeicher

Quelle: Specht et al, 2009
Sterner, 2009

ZSW

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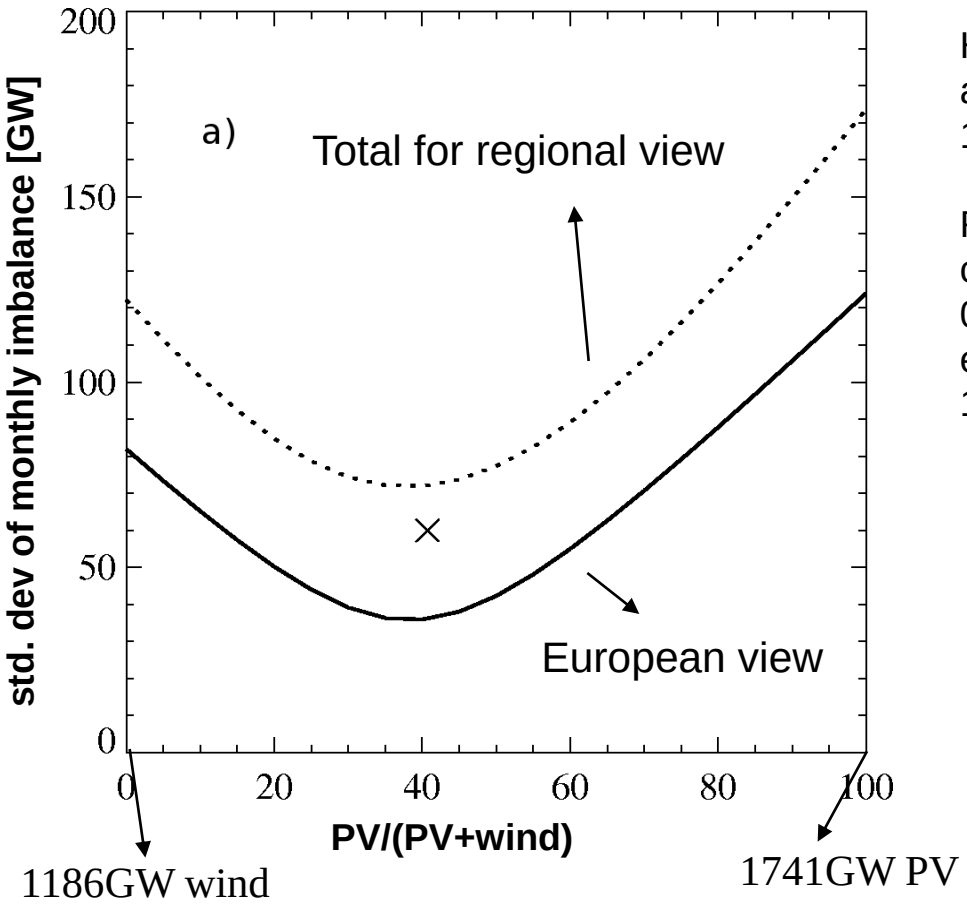
Optimal Energy Mix and Transport to reduce Balance Efforts

➢Fluctuation of monthly residual load (RES-consumption) in a 100% renewables scenario



Highest required
average transport capacity
15 GW (in D) – Max. >>>

Required storage-
capacity
0,5% - 8% of average anual European
electricity consumption
16-260 TWh/a

Optimal ratio between PV and wind power via minimal fluctuations

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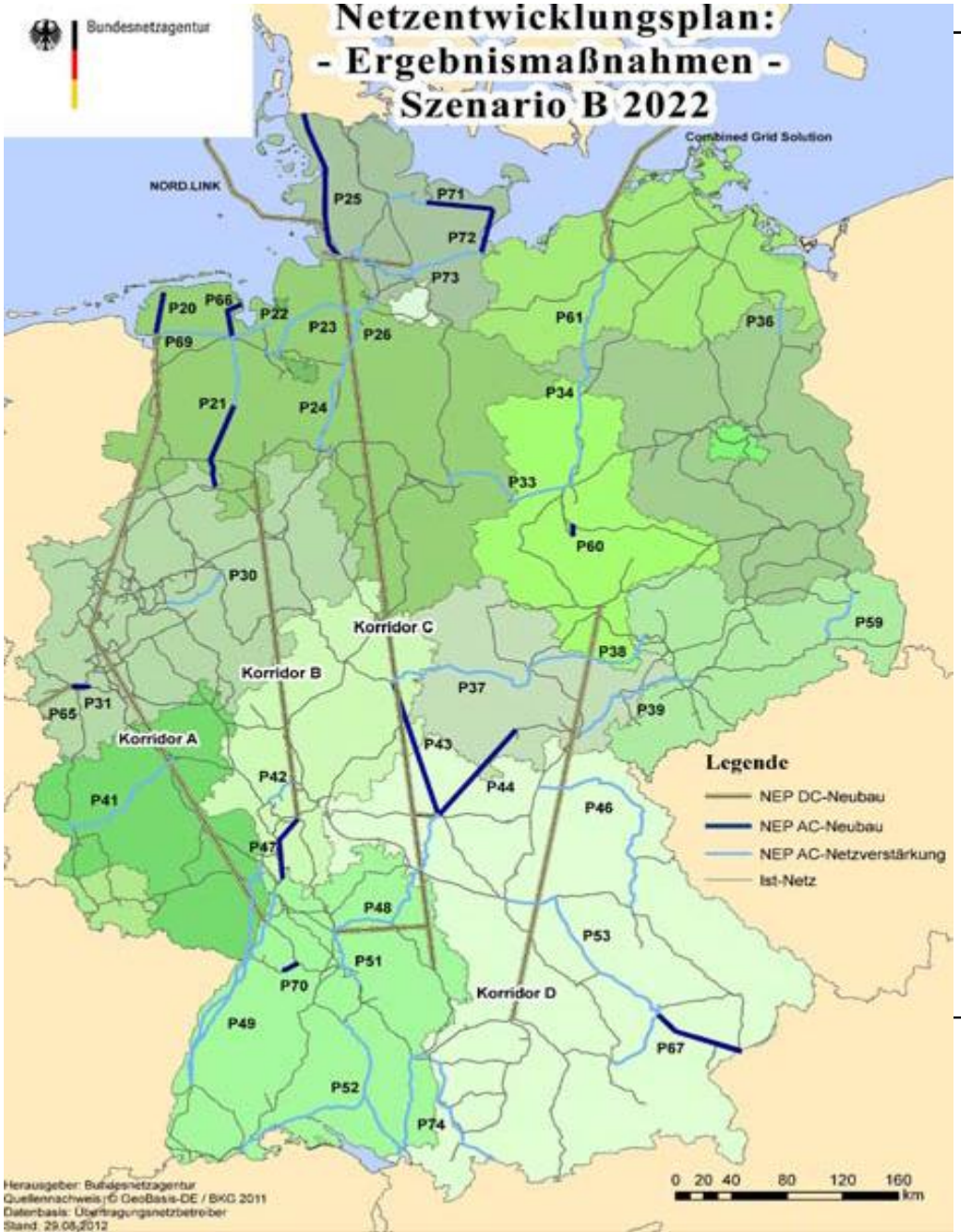
German Grid Development Plan



- Governmental driven
- Planned by R&D institutes and TSO‘s
- Organized by German TSO‘s
- Observed by German Regulator

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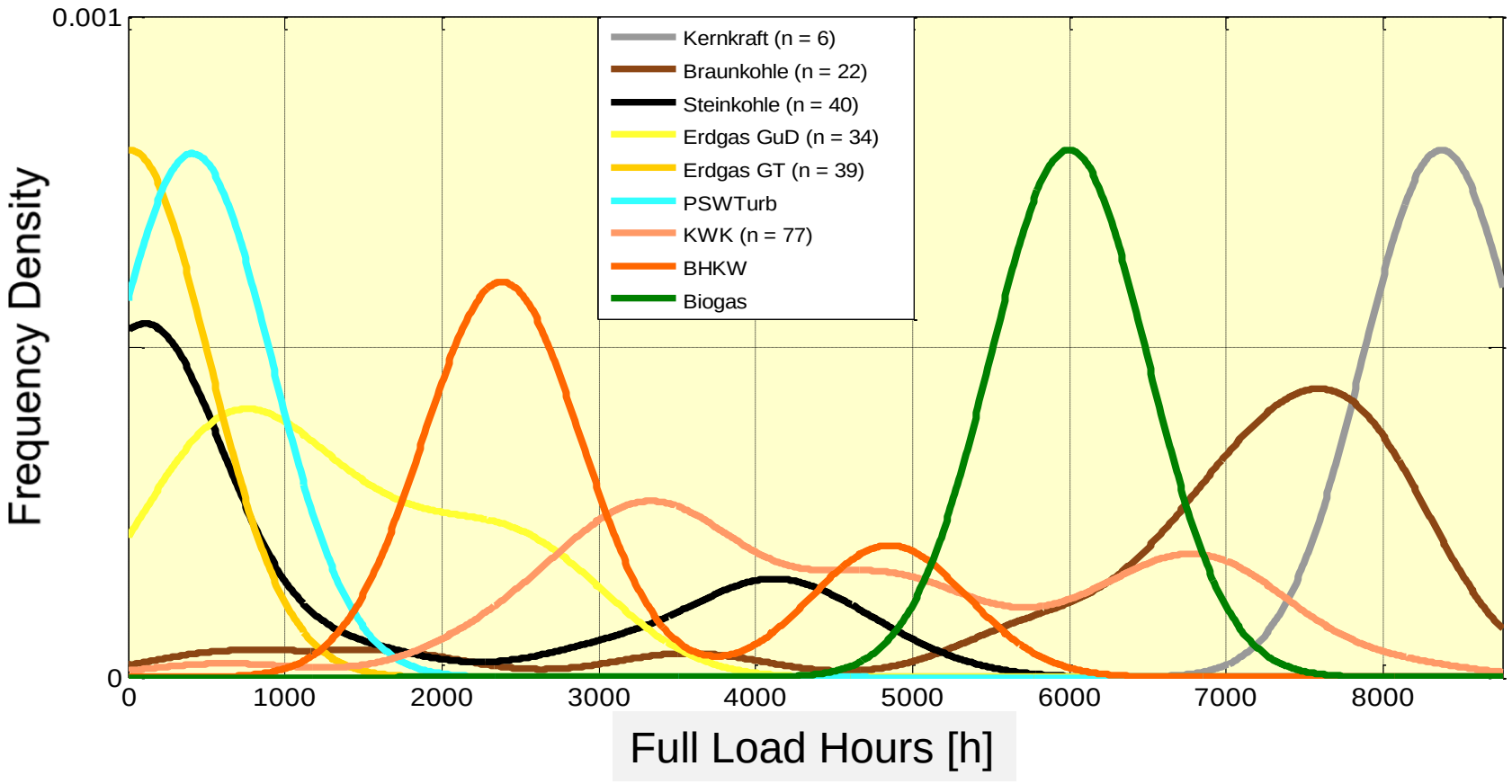
Frequency Distribution of Power Plants 2020



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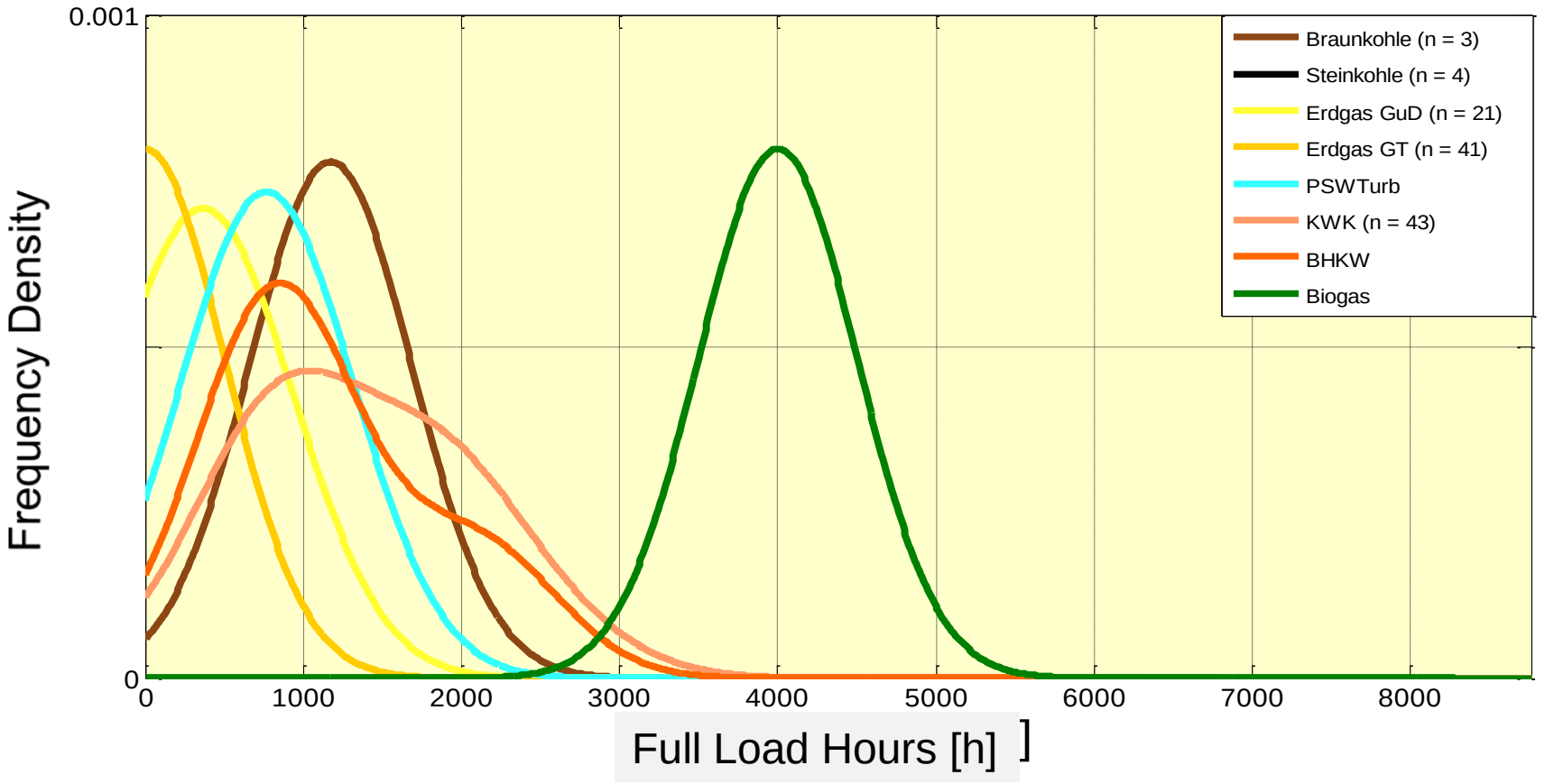
Frequency Distribution of Power Plants 2050



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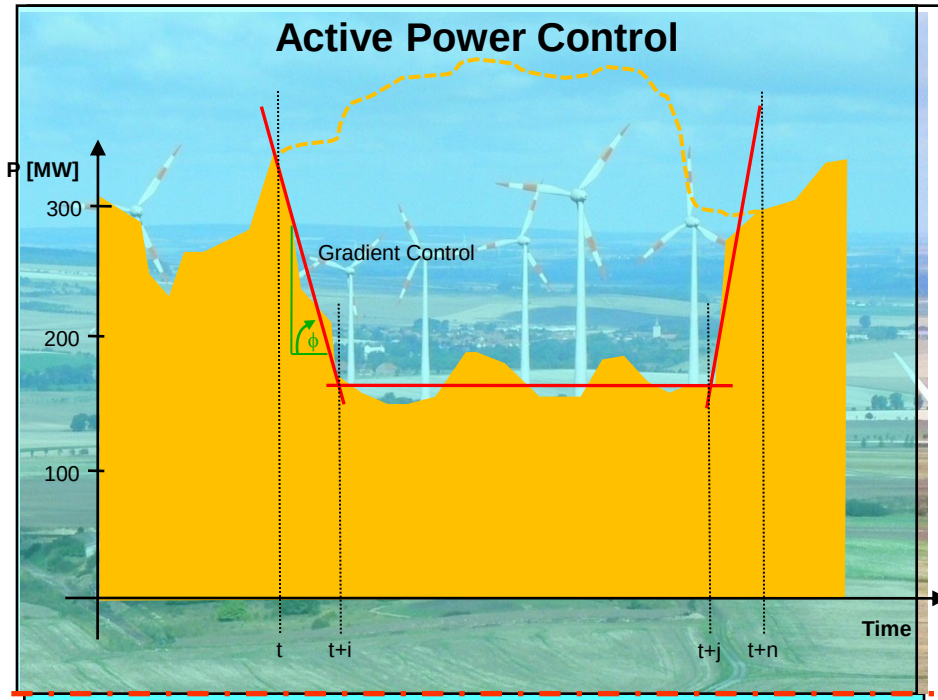
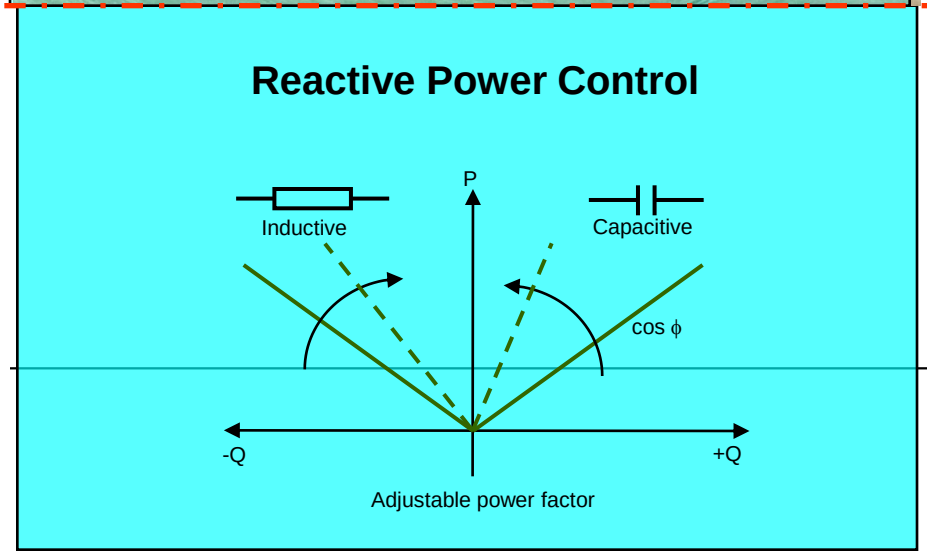
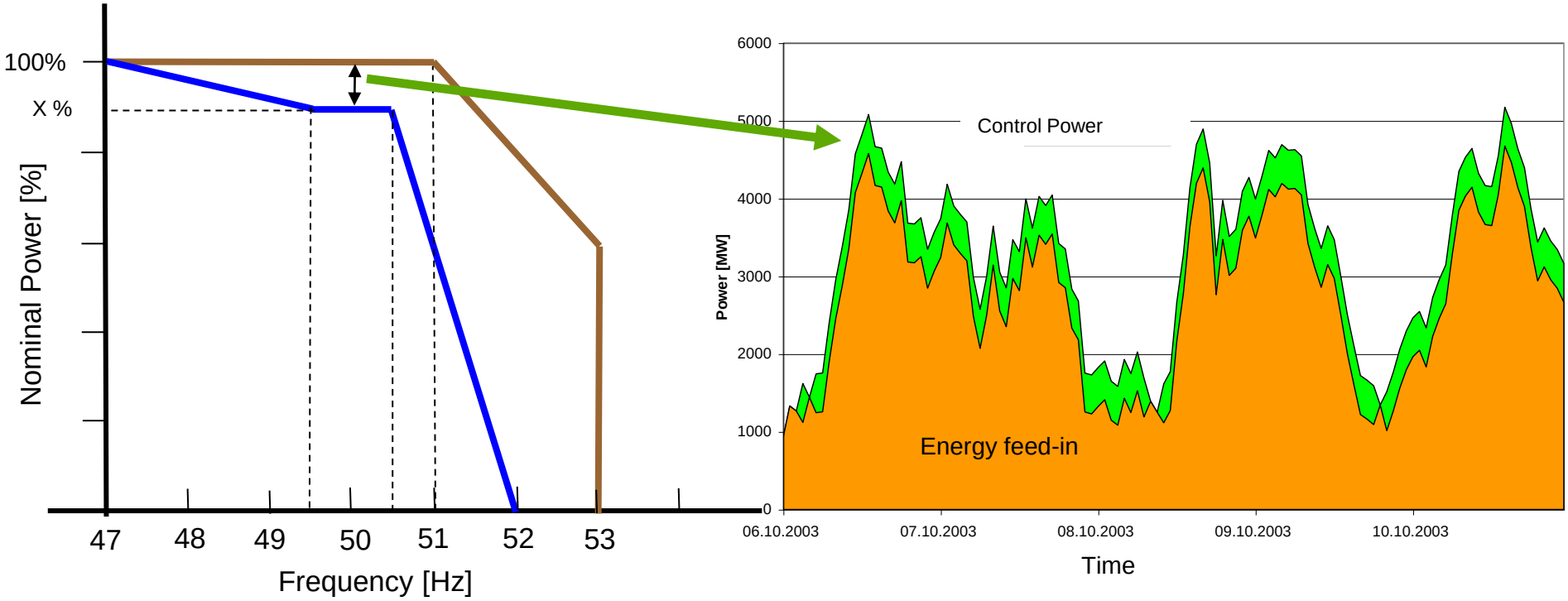
Active Contribution to System Reliability





- Frequency Control
- Wind power reserve
- Congestion management
- Power limitation
- Gradient control
- Reactive power range forecast
- Reactive power control
- Power factor control
- Voltage changes control

Frequency Support / Control Power Provision



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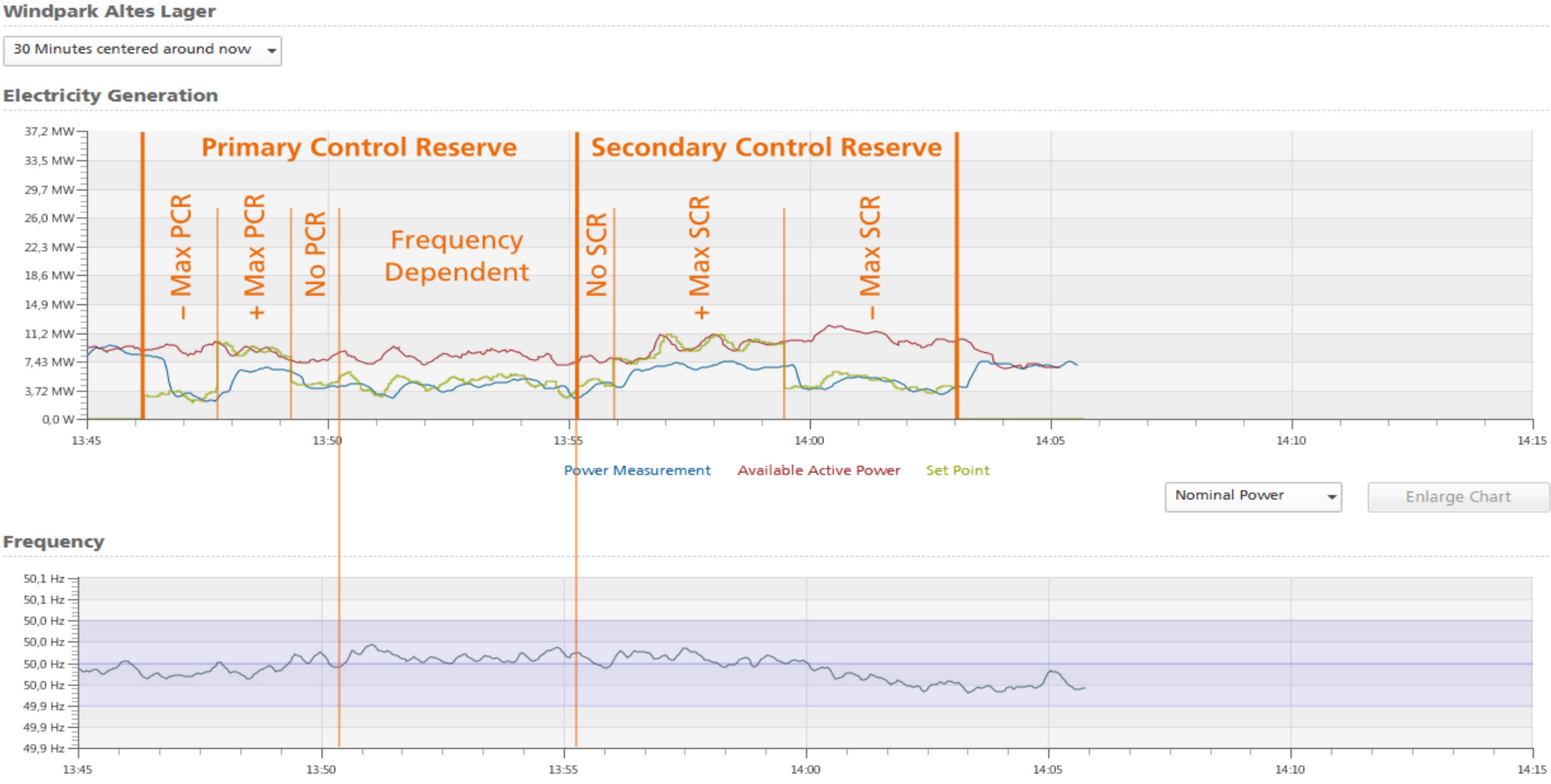
Services based on forecasts and confidence intervals

Frequency Support – Control power provision



IWES

Supra-Regional Voltage Imbalance

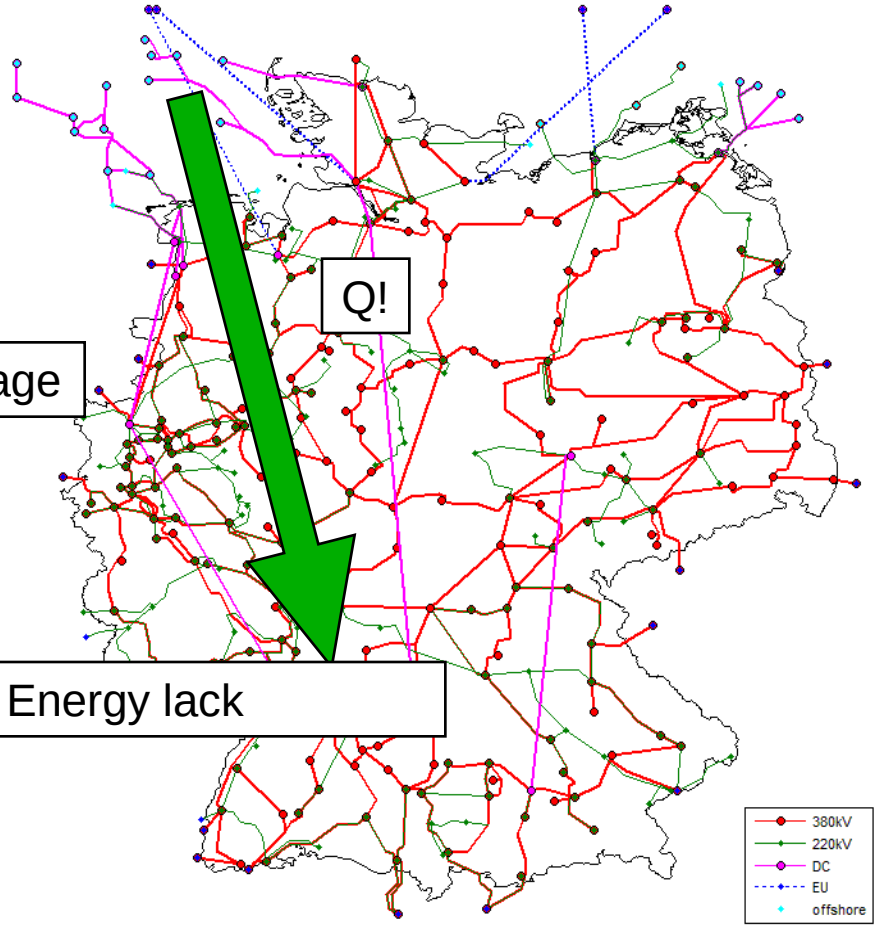
Energy surplus

AC-load flow calculation for HV level
(for HV w.o. conv. Power plants
or reactive power compensation)

→Fall of Voltage

→reactive power demand (Q!) at HV-transformers

(increasement of up to 36000Mvar in 2020)



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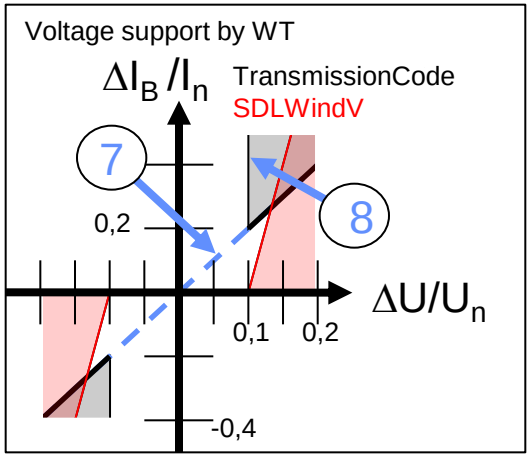
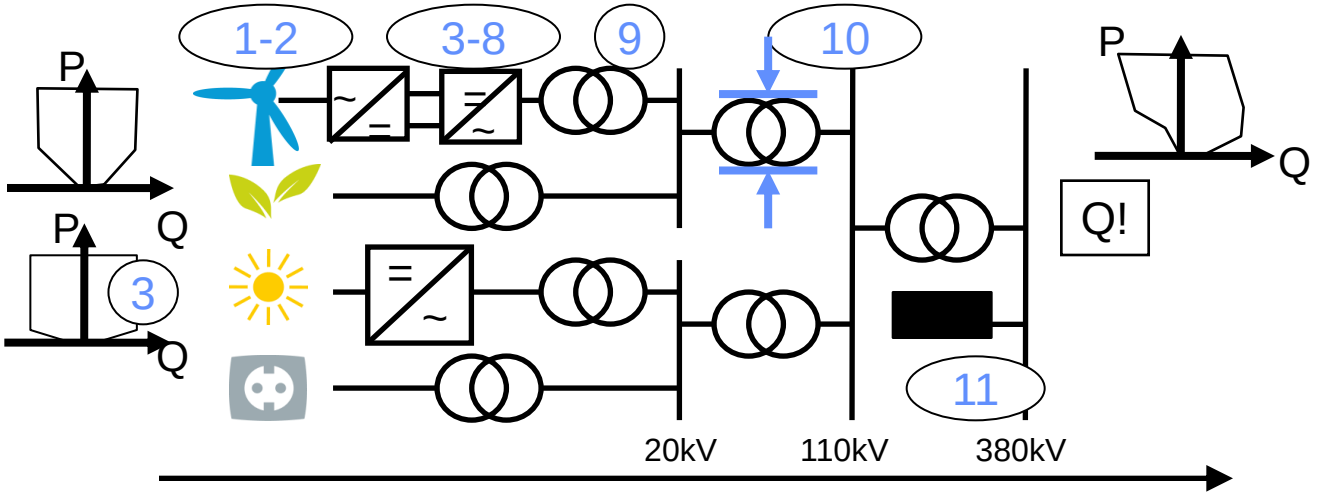
Methods to increase capability of voltage control by RES





Methods to increase capability of Voltage control by RES

1 Direct connected synchron generators

2 Piller-Princip (rotating mass)

3 Variation of P/Q-caracteristics

4 Larger Inverters

5 Reduction of active power in favour of reactive current

6 Use of STATCOM-Function

7 Continuous voltage support

8 Increase amplification factor at voltage regulator

9 Neutral earthing of WT main transformers

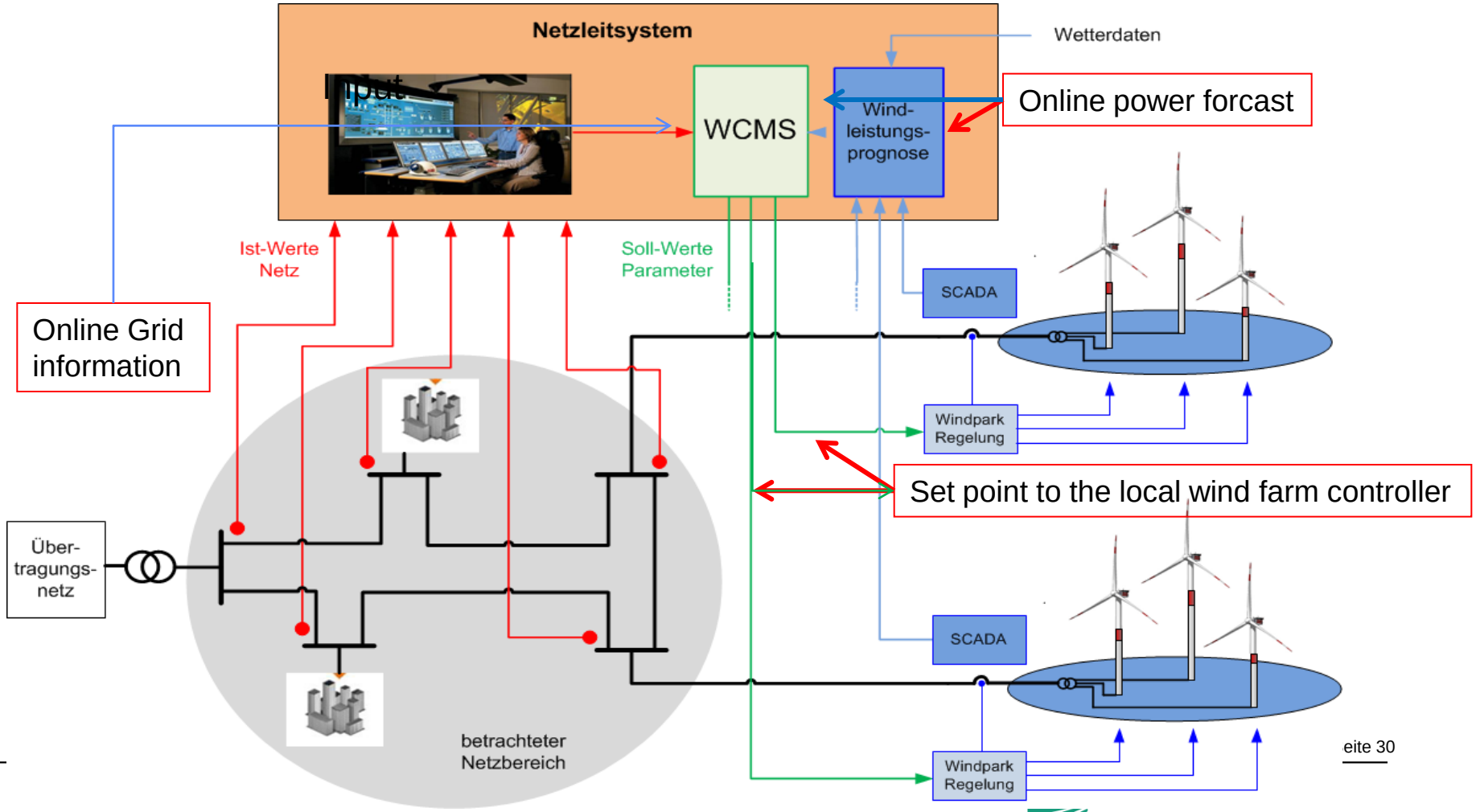
10 Variation of voltage ranges

11 implementation of reactive power compensation

Fraunhofer IWES

Fraunhofer Wind Farm Cluster Management System (WCMS)

Voltage Support



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Fast Transition form Consumption to Supply Grids

Power flow at 110 kV/ 20 kV Substation

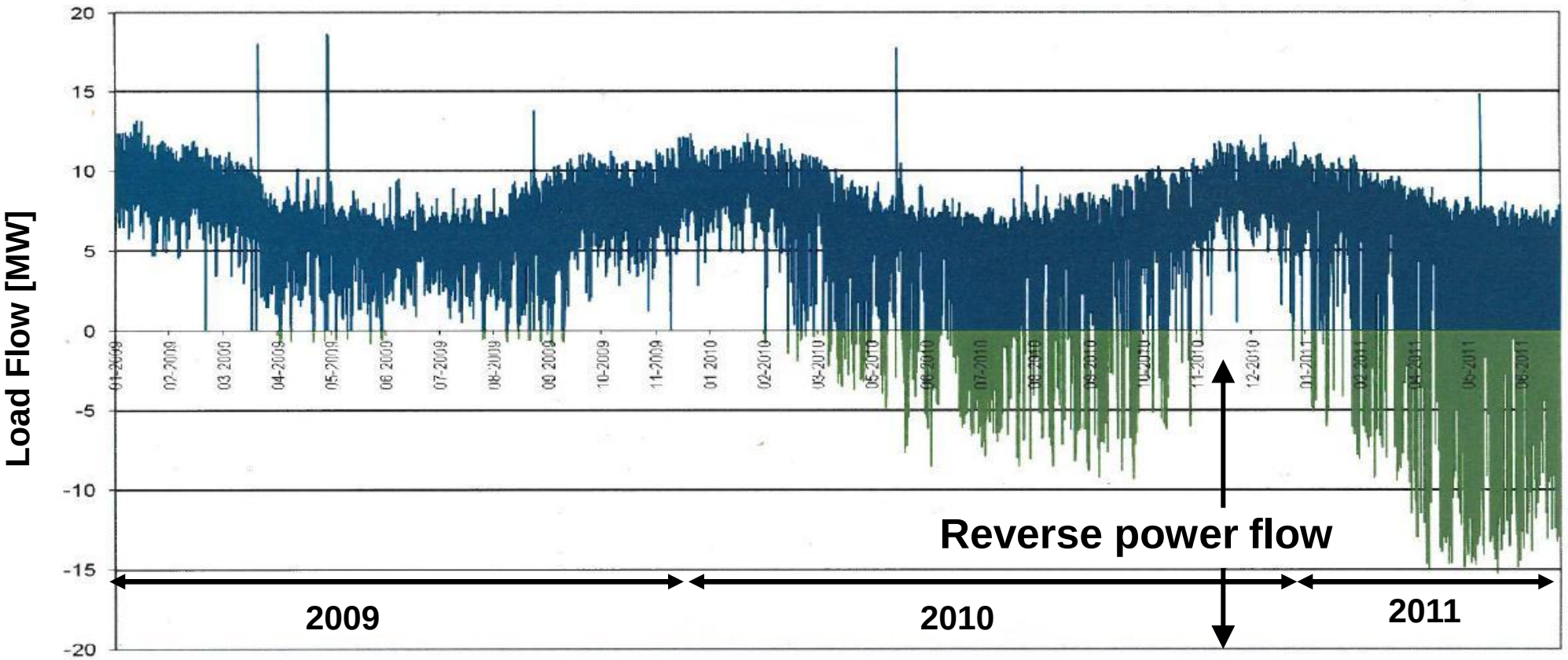

Fig: Courtesy of Bayernwerk AG

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Distribution Management System

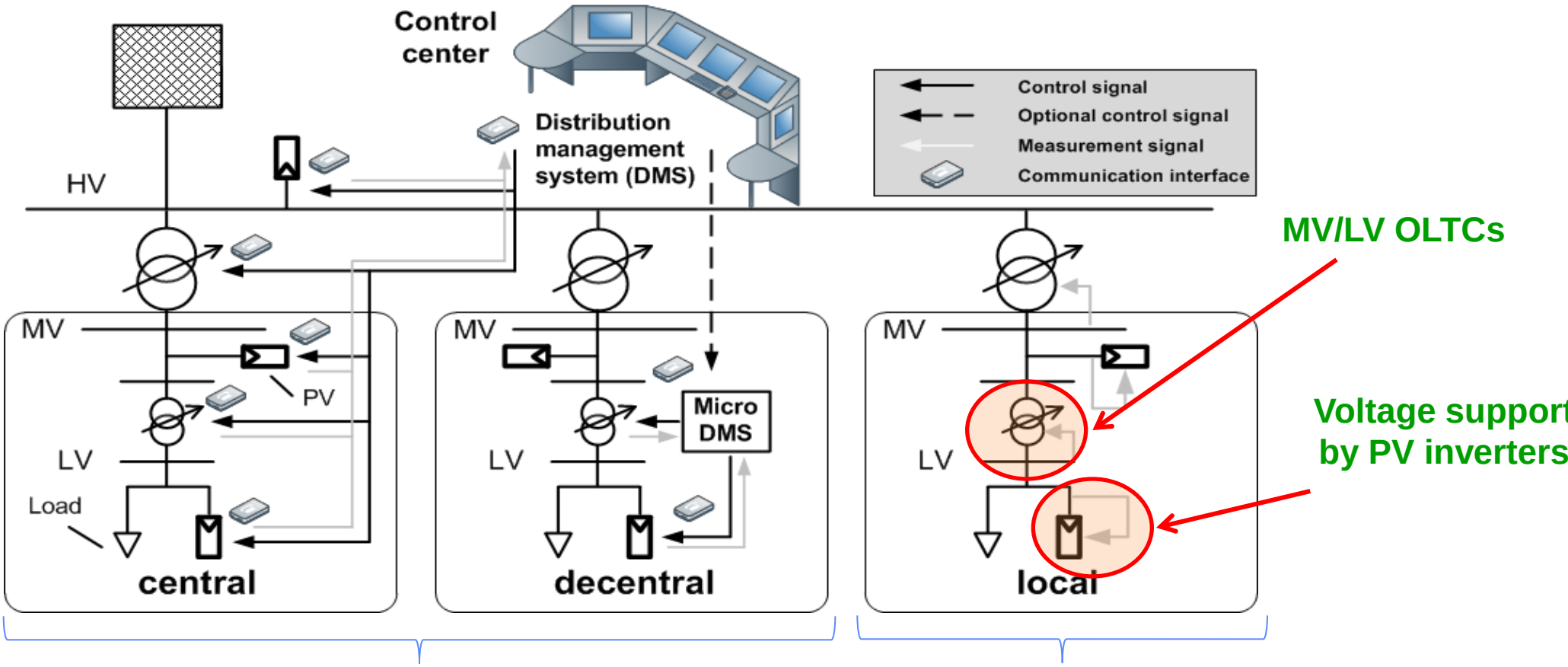

Fig.: J. von Appen et al., „Time in the Sun“, IEEE Power&Energy Magazine, March/April 2013

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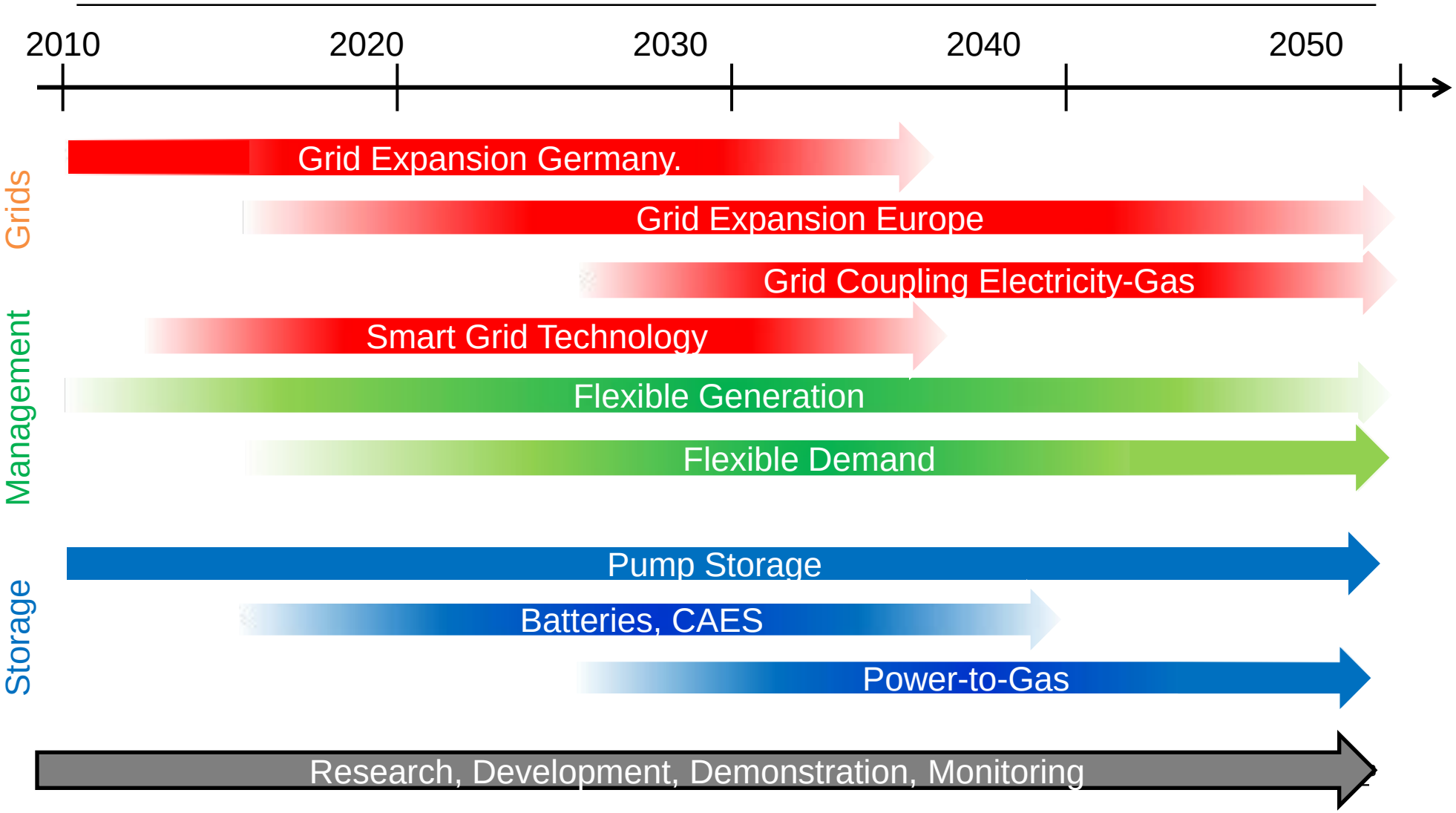
Roadmap Energiewende System Transformation Power Sector



Quelle: IWES, 2011

Fraunhofer IWES

Thank You

The Fraunhofer-Gesellschaft in Germany

66 Institutes at 45 locations

2012

Staff 22.000

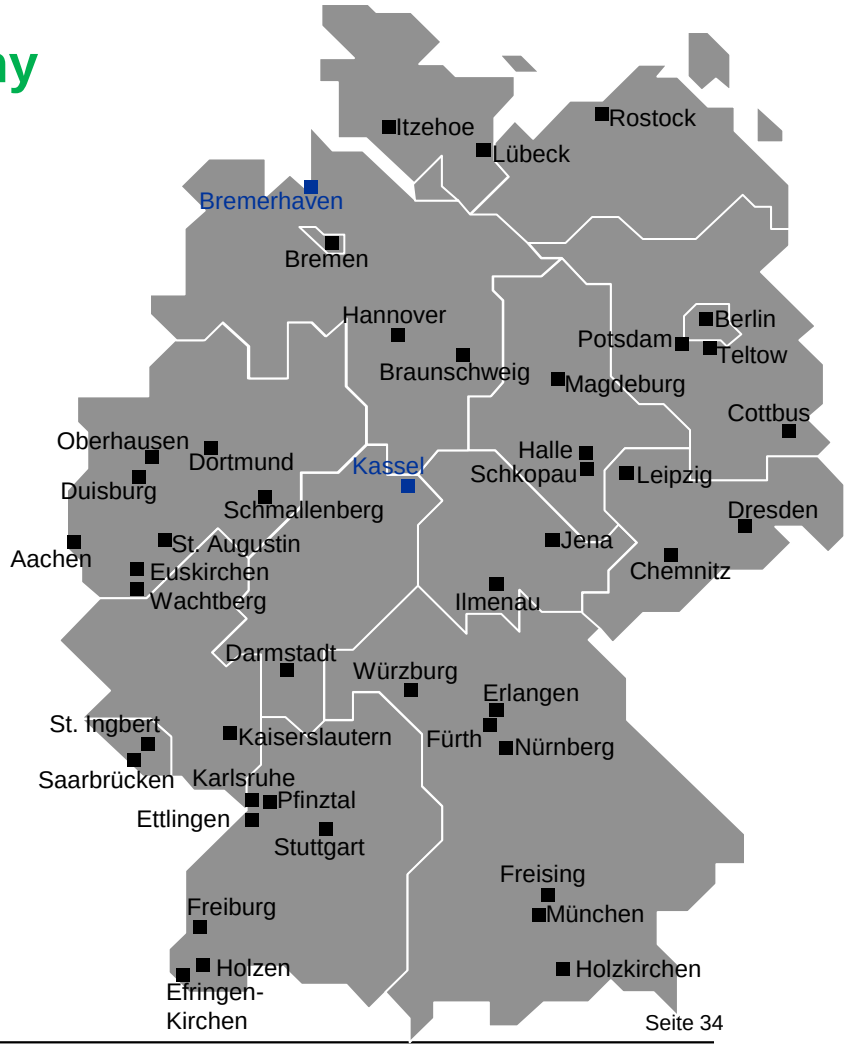
R&D-budget 2.500 Million €

Kurt Rohrig

Fraunhofer Institut für Windenergie und Energiesystemtechnik

Kassel

www.iwes.fraunhofer.de



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