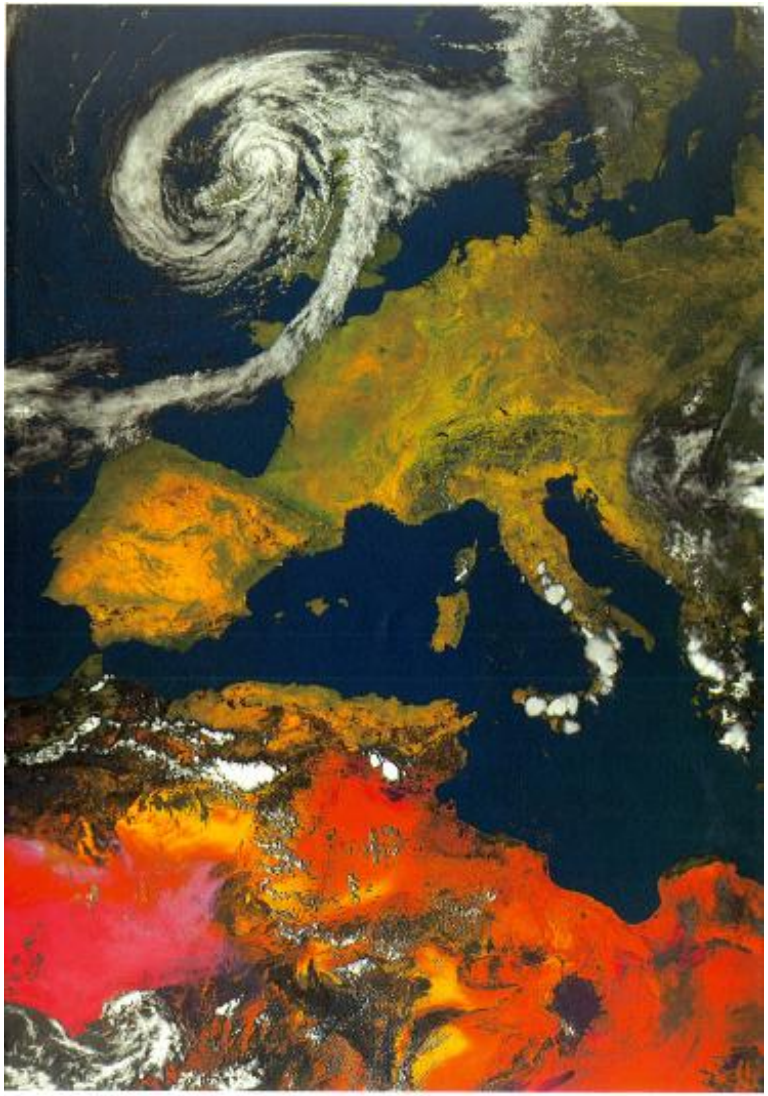


Integrating Wind and Solar – The German Experience

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

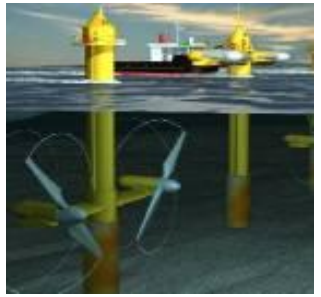
Foundation: 2009

Annual budget: approx. € 35 million

Personal: approx. 500

Electricity grids

Hydro power

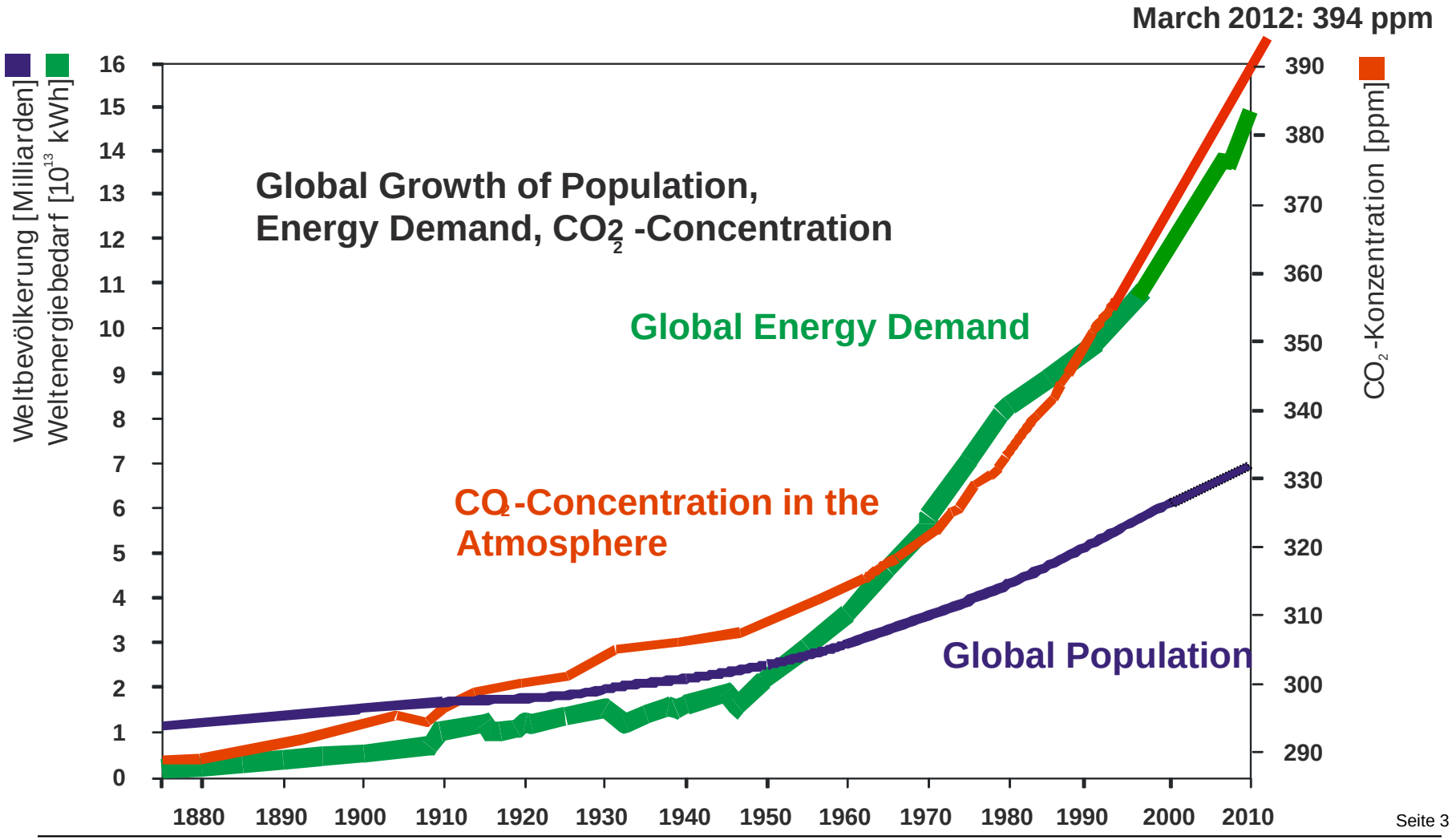


Marine energies

advancing wind energy and energy system technology

Fraunhofer IWES

Global Situation and Future Trends



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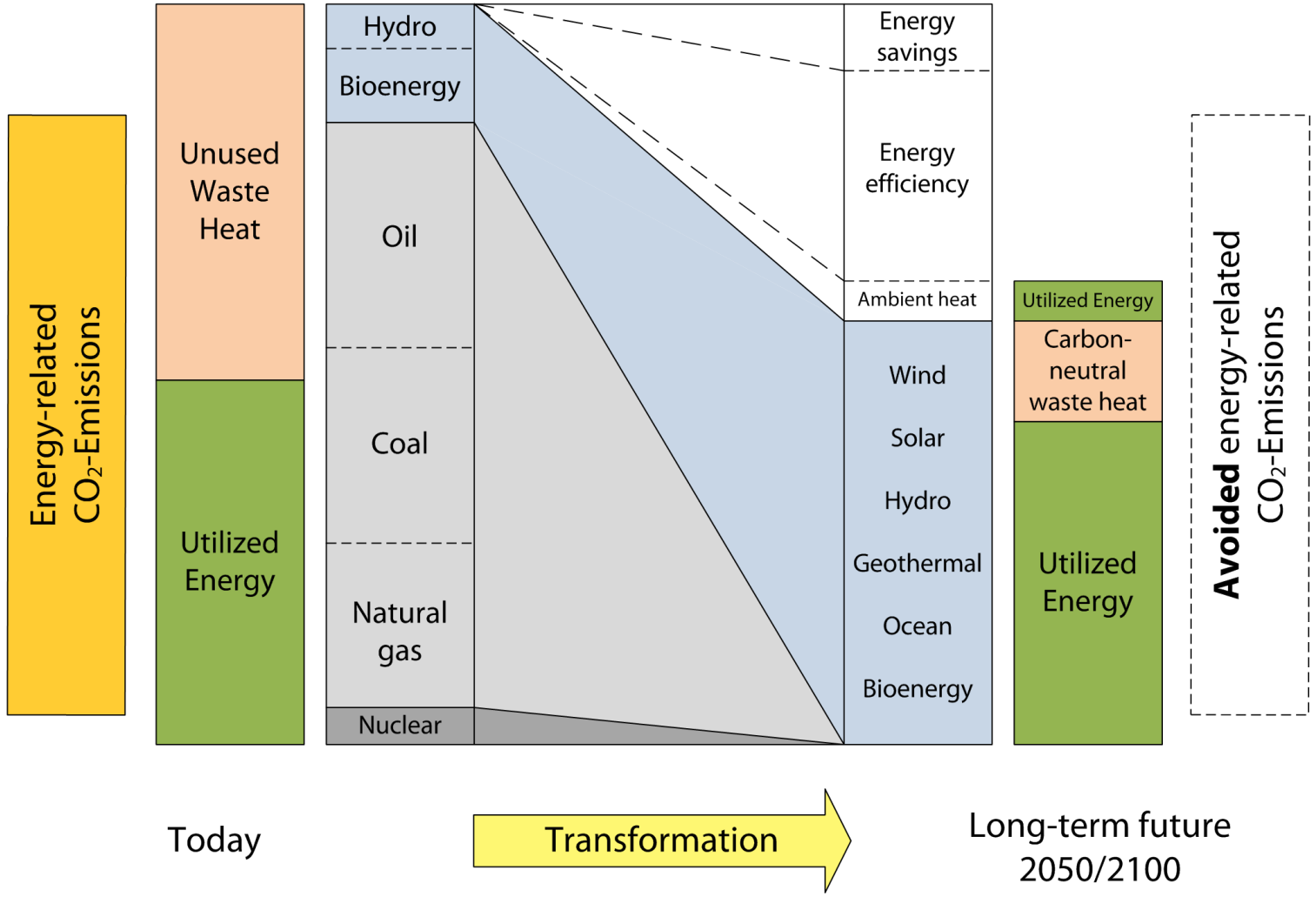
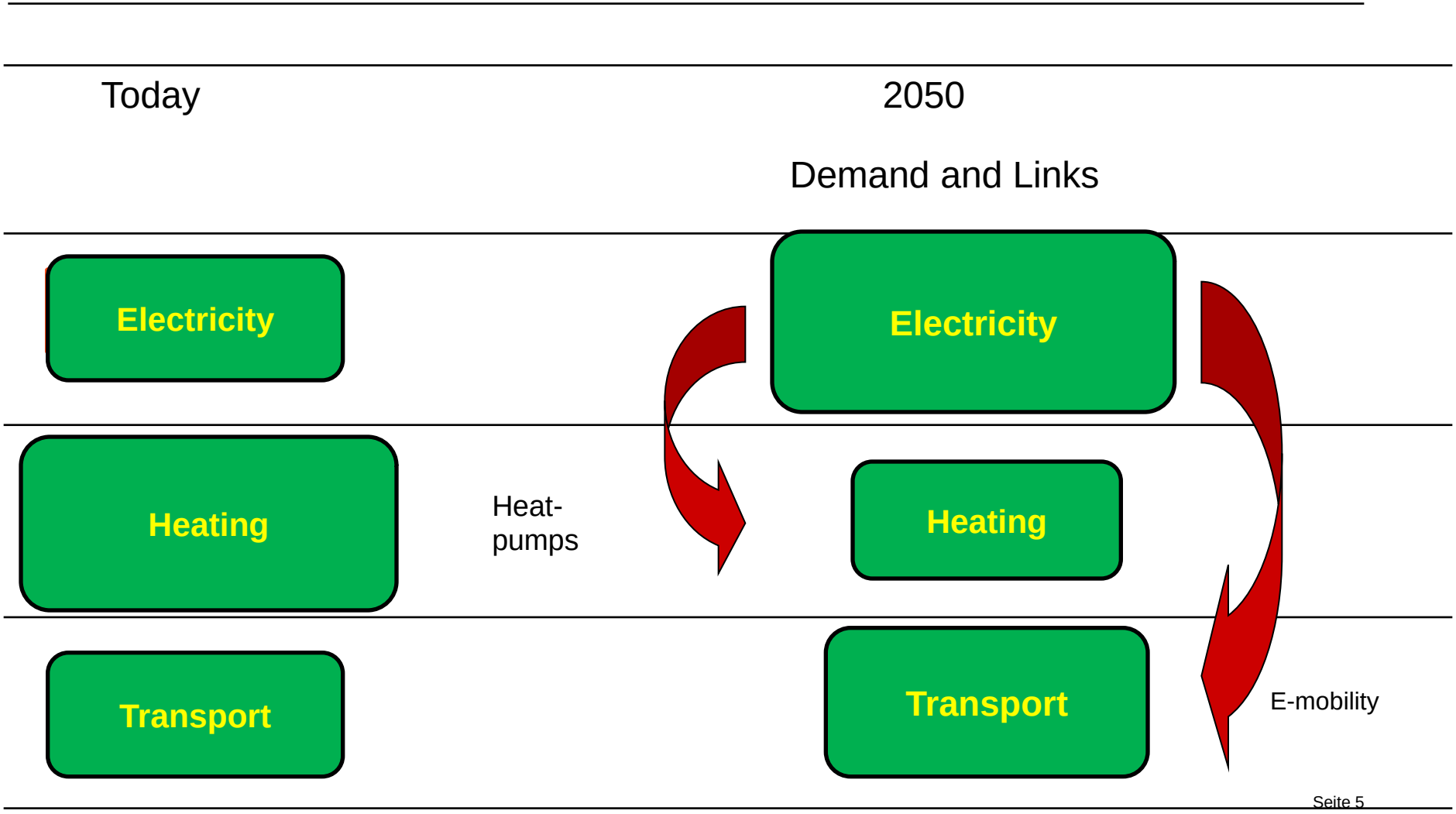
Transformation of Electricity Sector



Fraunhofer IWES

Transformation of Energy Supply System



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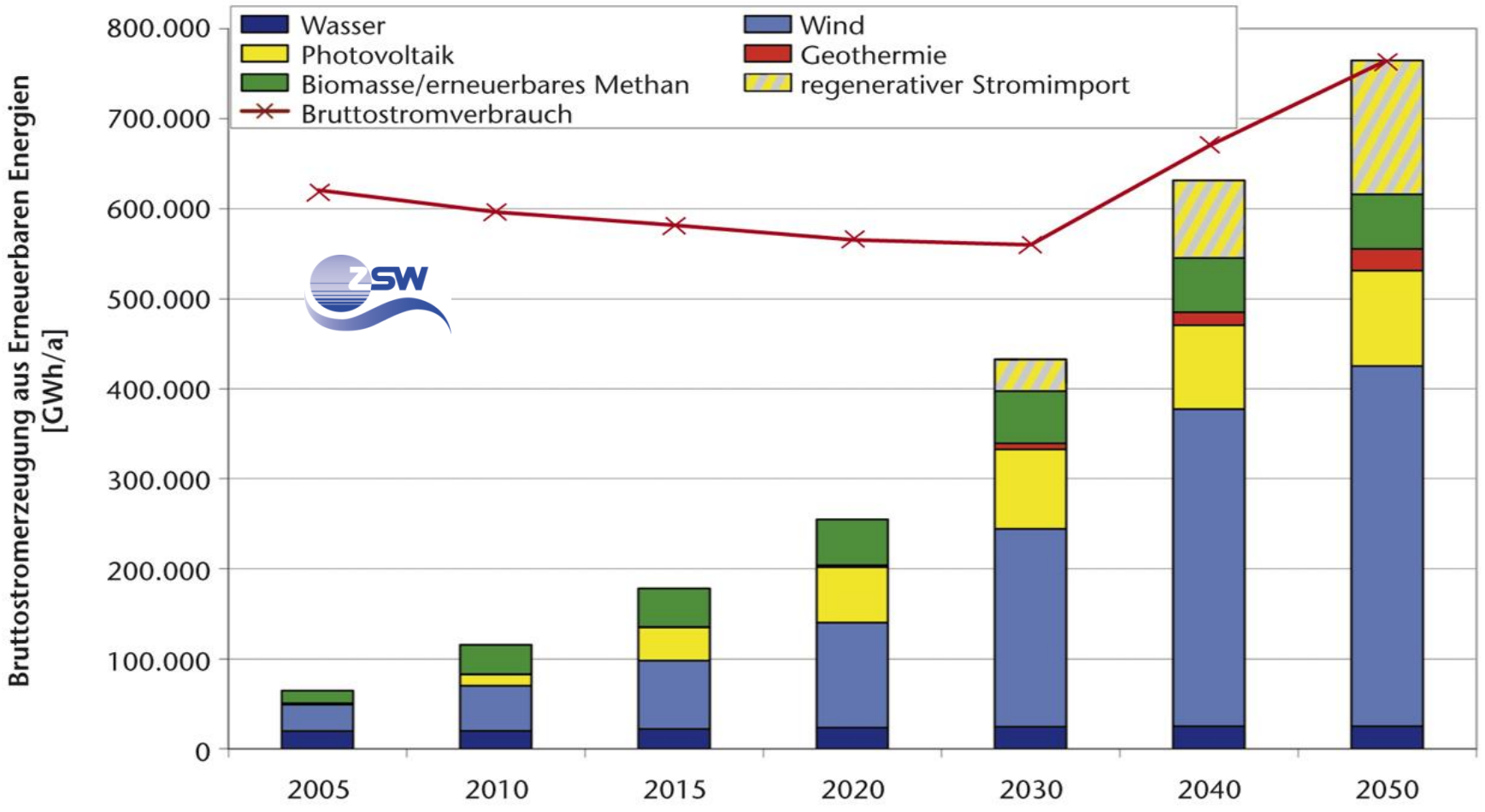
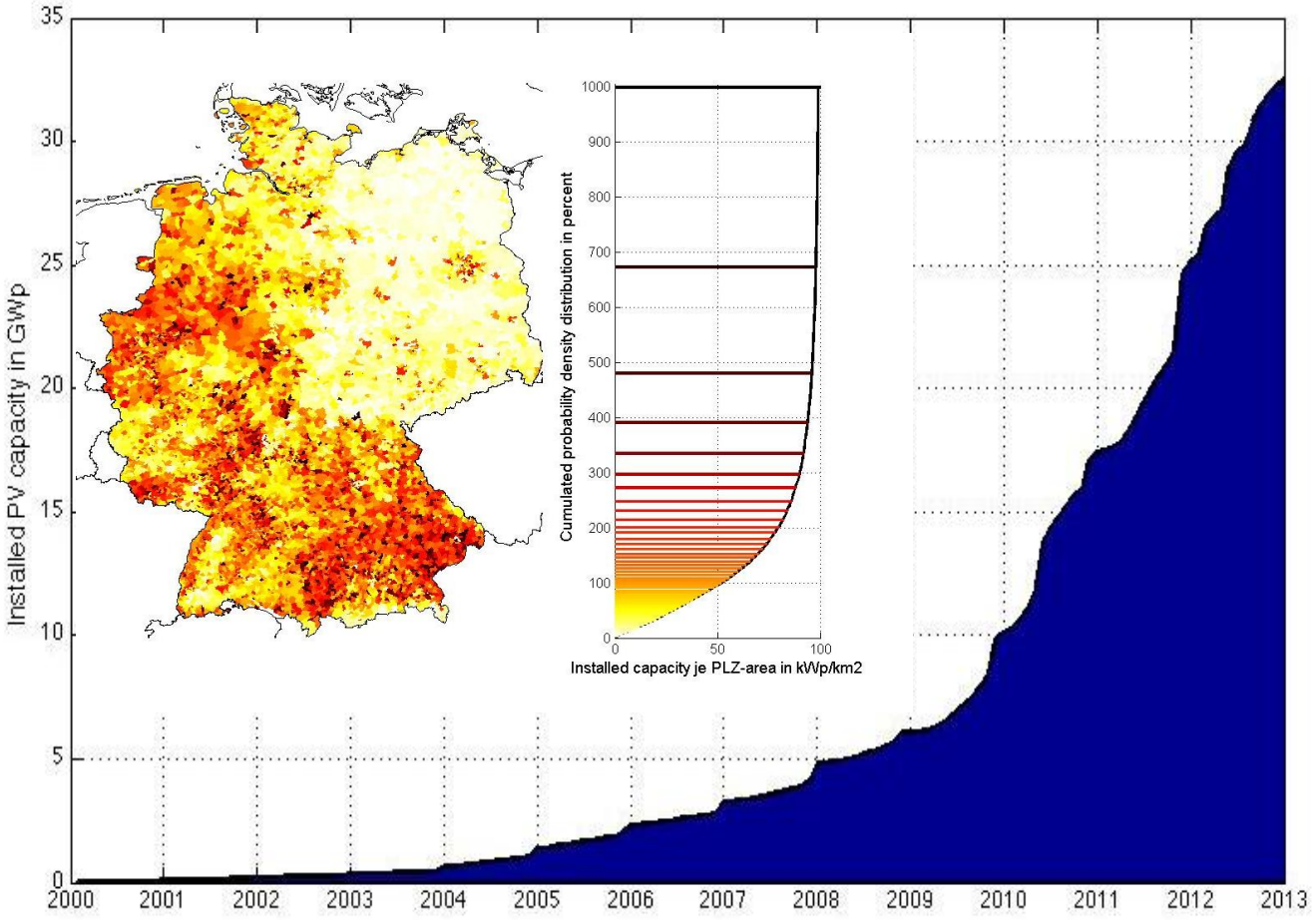
Energiewende Roadmap for the Transfer of the Energy Supply System



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

Fraunhofer IWES

Fast Development of PV-power production in Germany

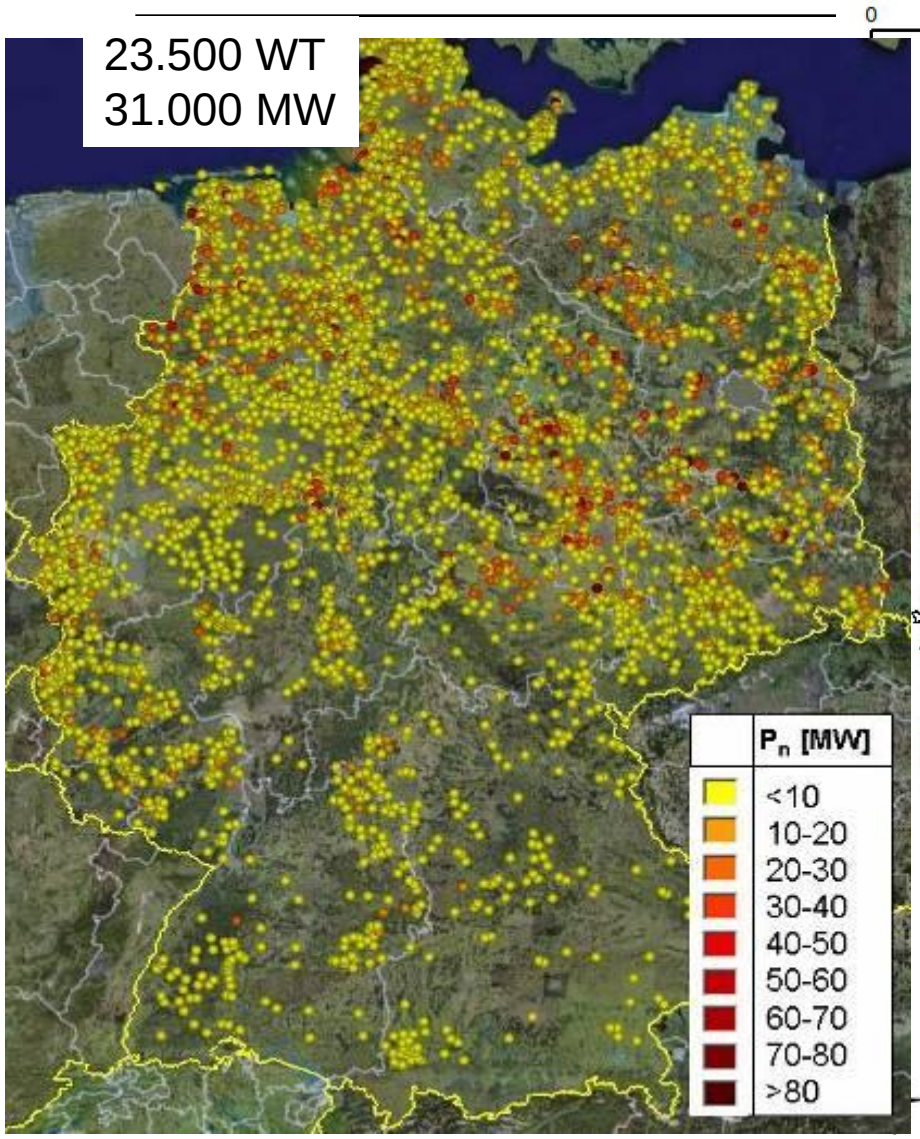


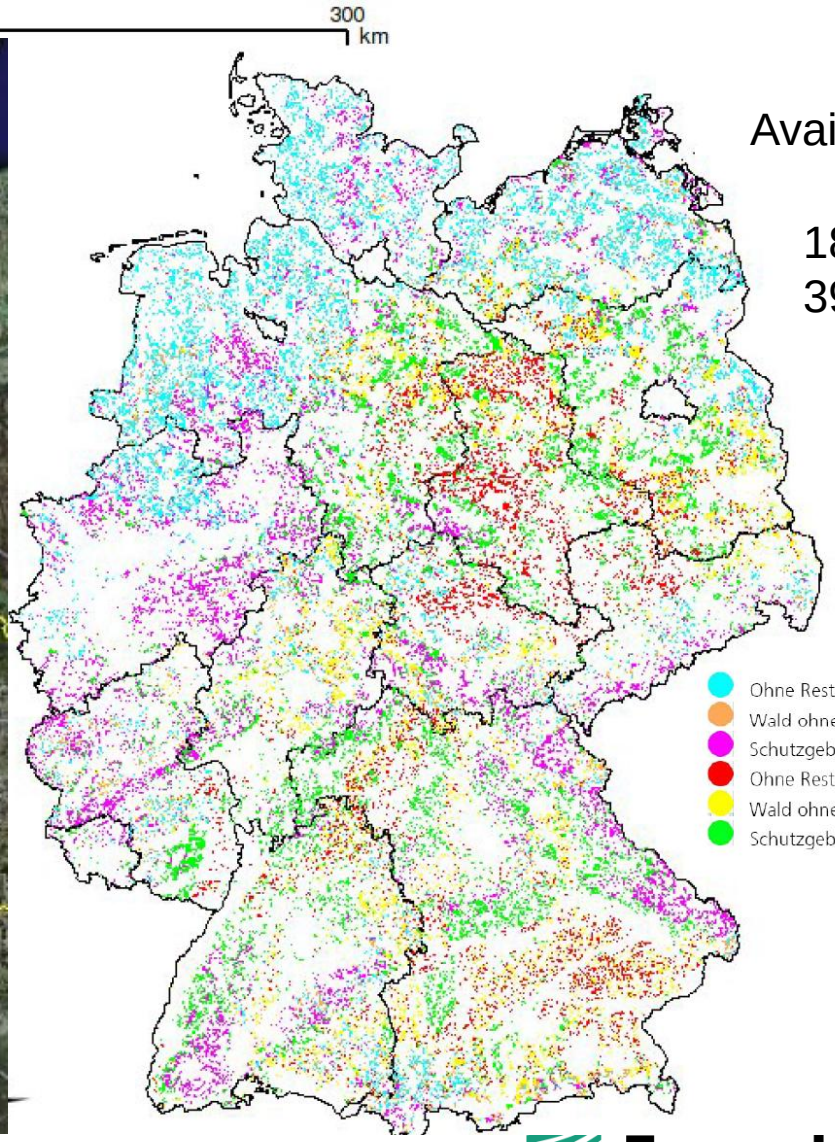
<u>June 2013</u>:

34 024 Gwp installed
1 337 890 PV-plants

Fraunhofer IWES

Wind Energy in Germany – State of the Art and Potential



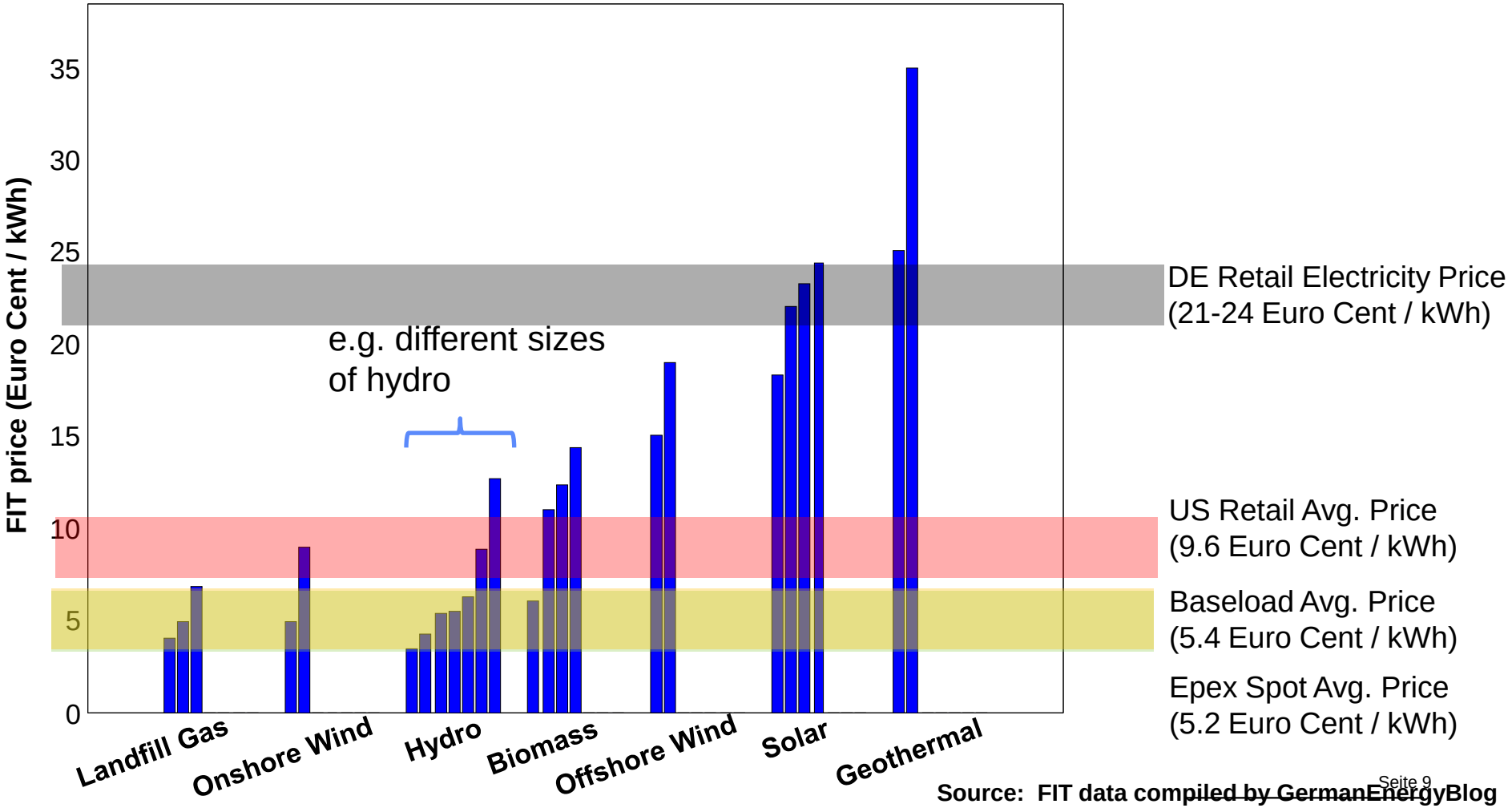


Available Areas

189.000 MW
390 TWh

Fraunhofer
IWES

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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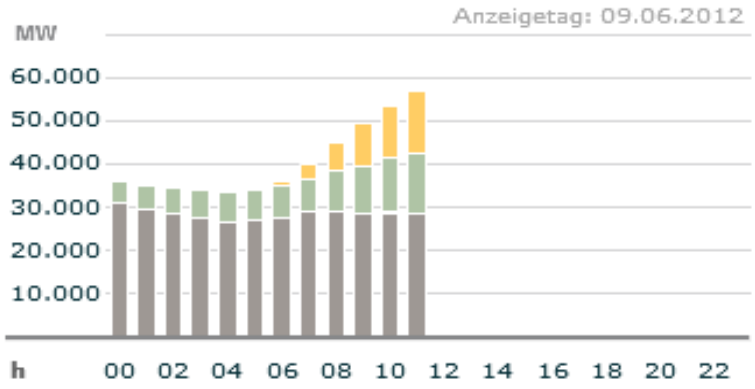
Willkommen auf der EEX-Transparenzplattform

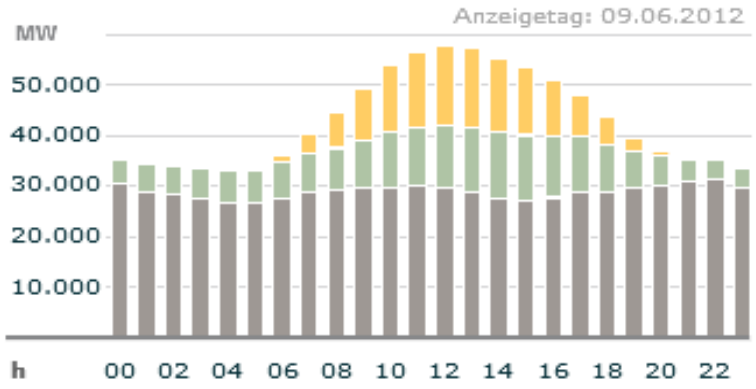
Auf der EEX-Transparenzplattform werden marktnah an zentraler und neutraler Stelle marktrelevante Erzeugungs- und Verbrauchsdaten veröffentlicht, um die Transparenz auf dem Großhandelsmarkt weiter zu erhöhen. Damit werden sowohl gesetzliche Veröffentlichungspflichten als auch freiwillige Selbstverpflichtungen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

DE/AT | **DE** | AT

Tatsächliche Produktion (Strom)



Geplante Produktion (Strom)



Legende: Konventionell Wind Solar

Abdeckungsgrad gesetzliche Veröffentlichungspflichten

DE

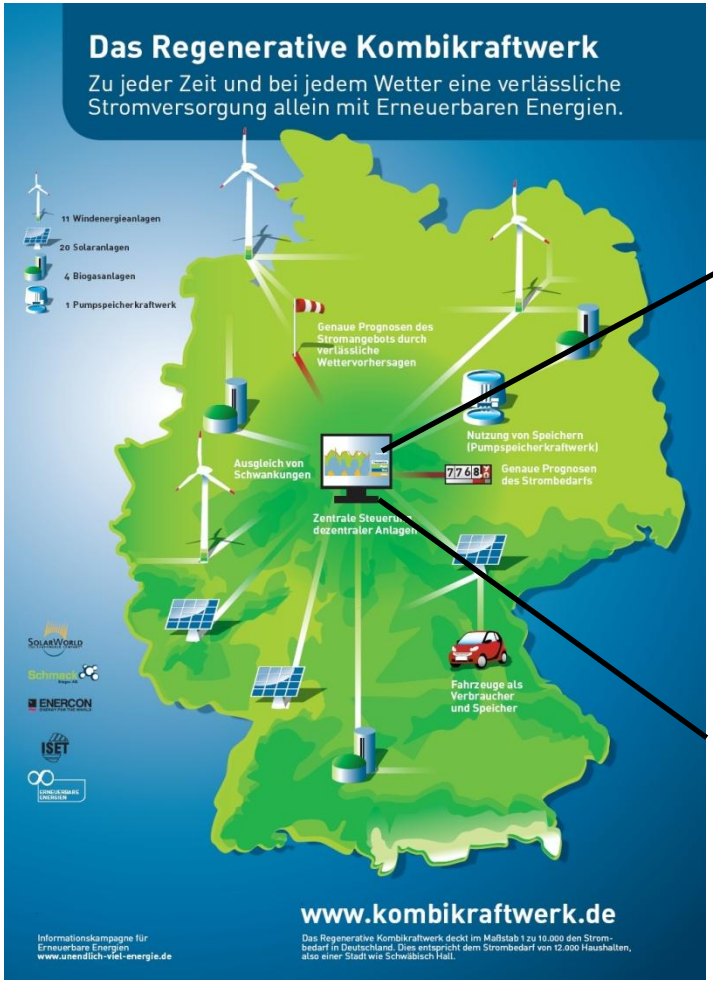
Weitere Info

Marktinformationen

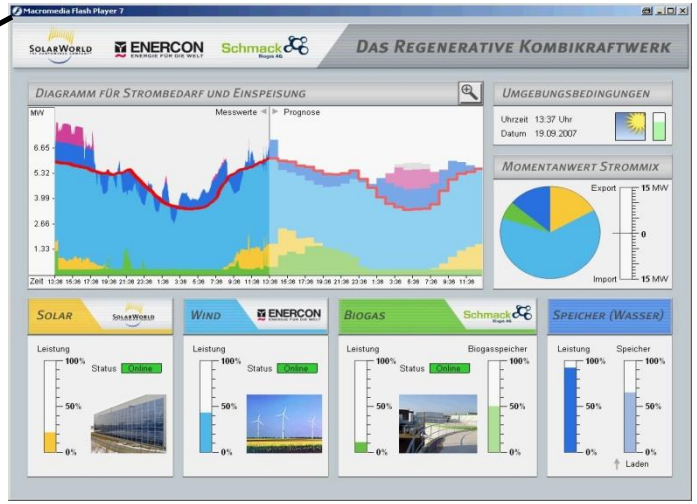
01.06.2012 EEX begrüßt SWB a
Melder: Die swb Erzeugung Gm
hat heute mit der Meldung von
Erzeugungsdaten auf der Tran..
Weiterlesen »

23.05.2012 Aktualisierte Daten u
Neuberechnung der Abdeckung
(QII/2012): Die Übertragungsnet
aus Deutschland und Österreic.
Weiterlesen »

The German RES Power Plant Project



Wind	Solar	Biogas	Hydro	Import/ Export
12,6 MW	**5,5 MW**	**4,0 MW**	**1,0 MW**	**1,0 MW**



Load coverage of German electric power 1/10000 at any time

Operation of real RES power plants

Fraunhofer IWES

Renewable Model Region Harz

REG MOD HARZ
Regenerative Modellregion Harz

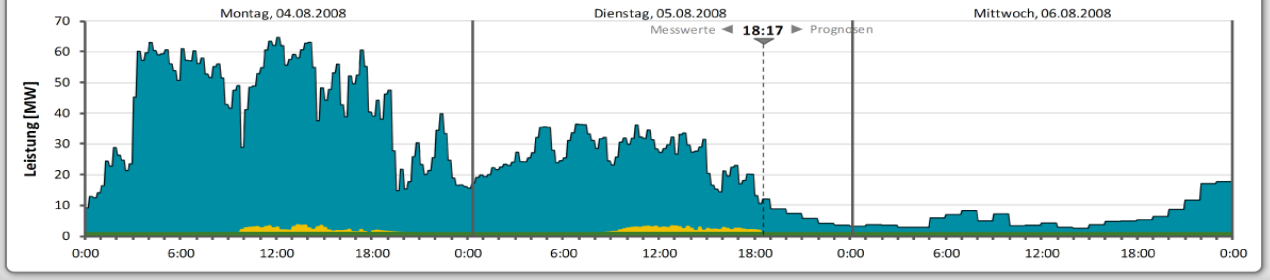
Übersicht | Vermarktung | Topologie | Meldungen

Virtuelles Kraftwerk Leitwarte

REG MOD HARZ
Regenerative Modellregion Harz

Energie

Historie und Prognose des Strommix



Momentane Leistungsbilanz

- 8 MW ..... Nennleistung ..... 86 MW

Momentanleistung 12 MW (14%)

Momentaner Speicherstand

Speicher: 126 MWh

Speicherstand ↑ 23 MW 102 MWh (81%)

Momentaner Stromerzeugungsmix

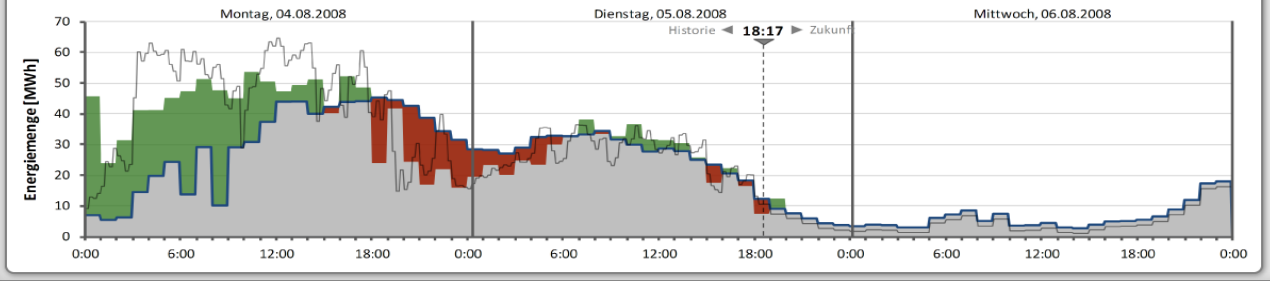
Wind Solar Biogas

72% 16 MW | 8% 4 MW | 20% 12 MW

05.08.2008
18:17
MEZ

Vermarktung

Verlauf der Vermarktung



19:00 - 20:00 Menge / Umsatz Day-Ahead Intraday

- 2,9	13,3	10,4 MWh
- 213,05	683,12	470,07 €

Sa, 01.01.2011 Menge / Umsatz Day-Ahead Intraday

- 7,3	108,8	22,2	123,7 MWh
- 434,52	4.779,74	1.086,31	5.431,53 €

Menge und Umsatz gesamt

Menge 21.371,9 MWh

Umsatz 1.168.401,77 €

EENERGY

Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit

Benutzerkennung: max.mustermann / **Angemeldet seit:** 29.11.2010 09:00

Generation | Loads | Storage

Short-term forecast

Structure of a forecast system for the short-term forecast

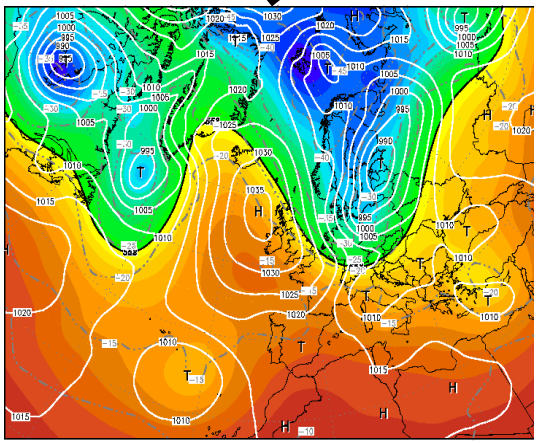
Online power meas. of representative wind farms

Weather forecasts for the locations of rep. wind farms

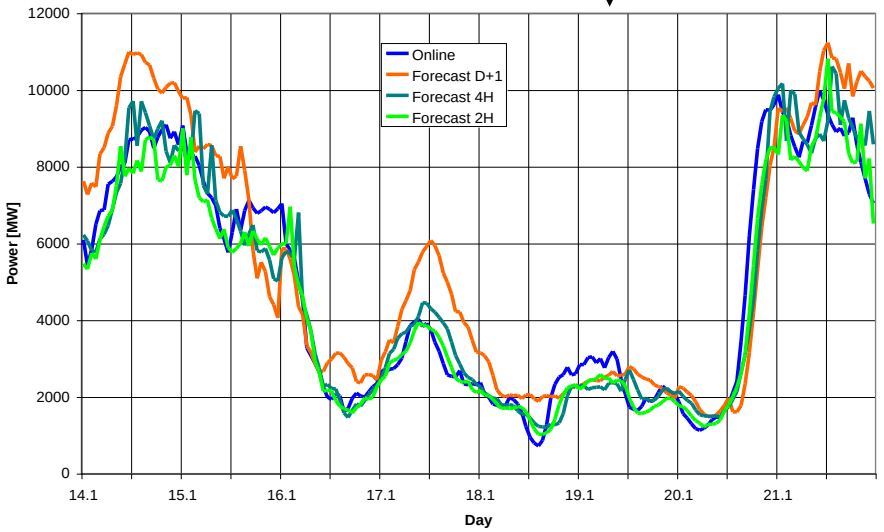
Wind power forecasts for the rep. wind farms

Extrapolation to a control zone

Representative Wind farms



Numerical weather model



Wind power forecast for a control zone

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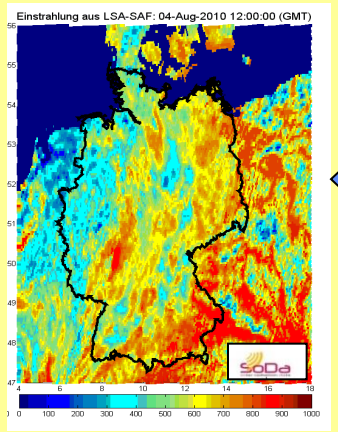
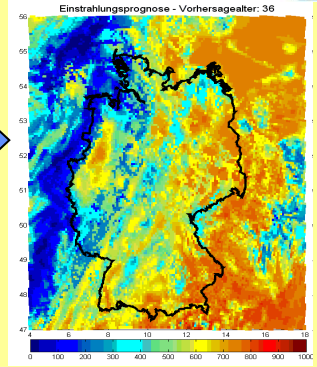
Process of PV Power Forecast

Satellite

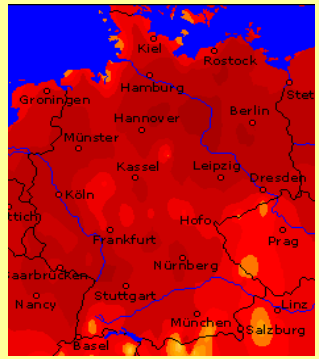


NWP (0 – 78 h) – Cosmo-EU

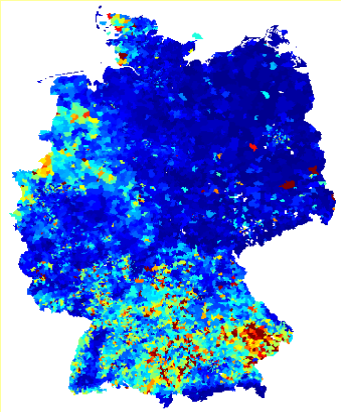
Radiation



Temperature



Installed PV-Capacity



- EEG Database
- PV Database (BNetzA)

Preprocessing

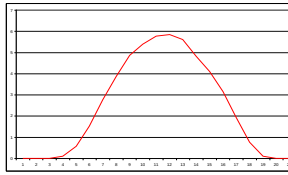
Classification by age, power

Statistical information of :

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

Physical Simulation of all PV plants

MOS NN



PV-forecast

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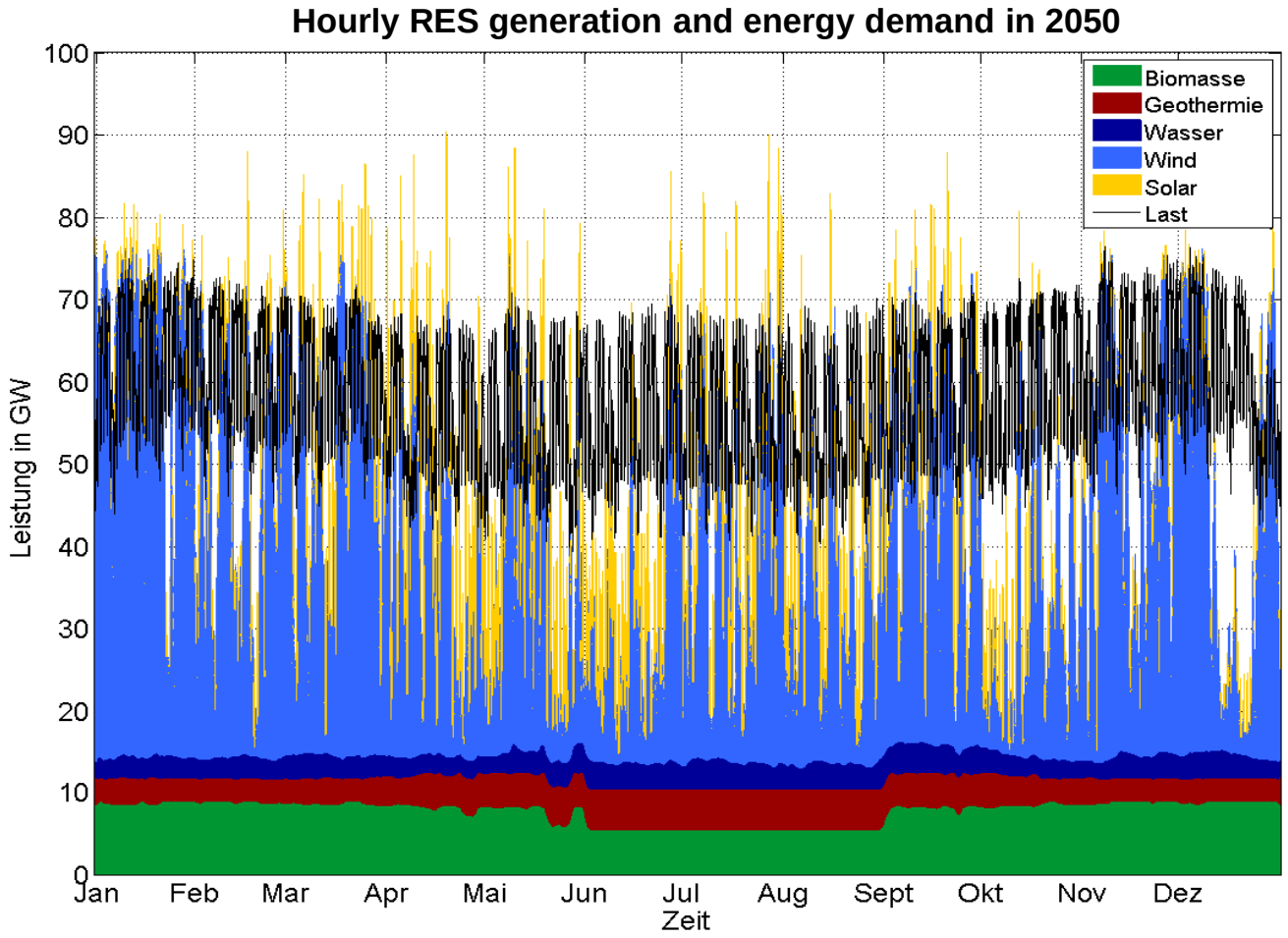
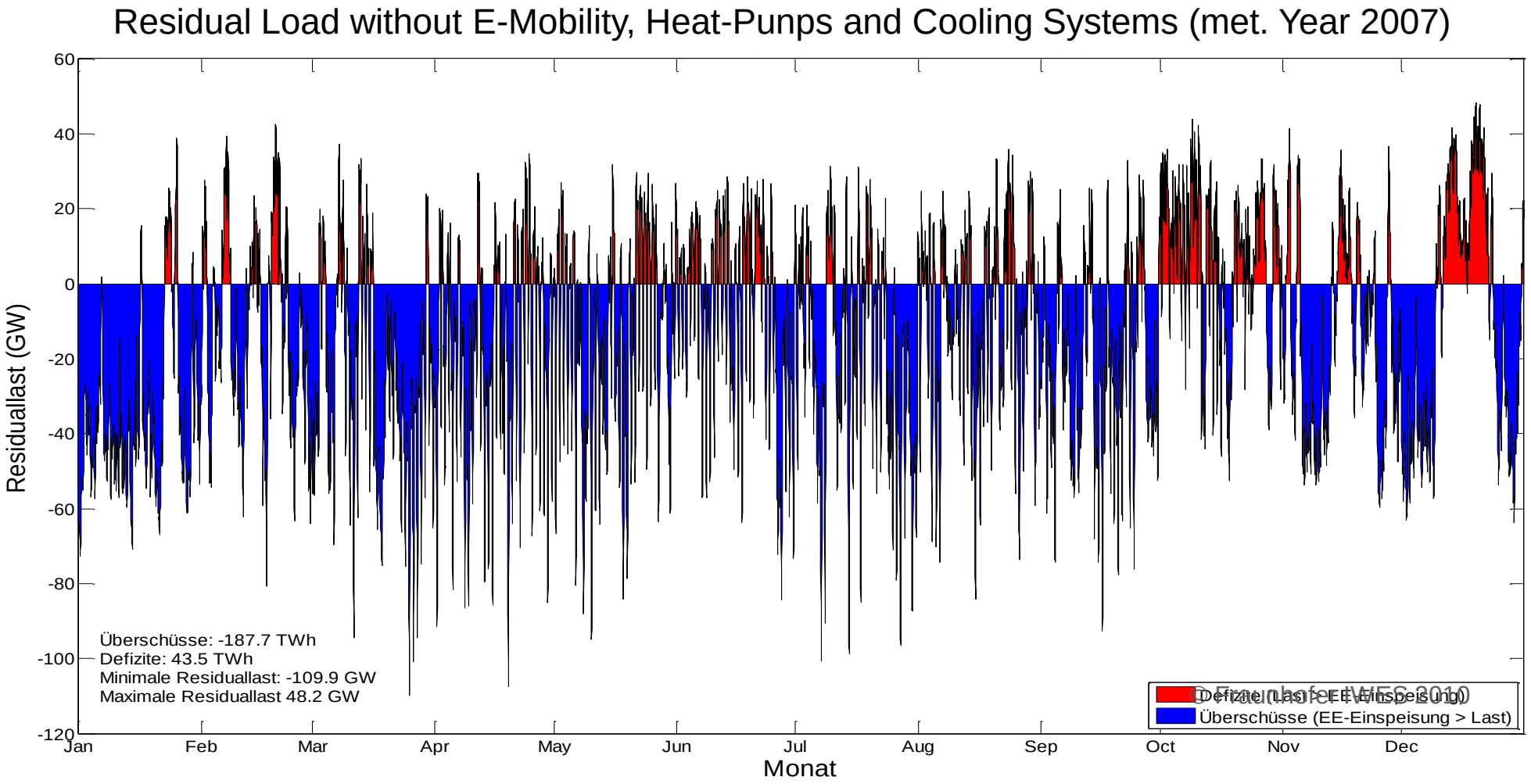
Future Energy Supply Scenarios



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

Fraunhofer IWES

Residual Load: Measure for Balance Efforts



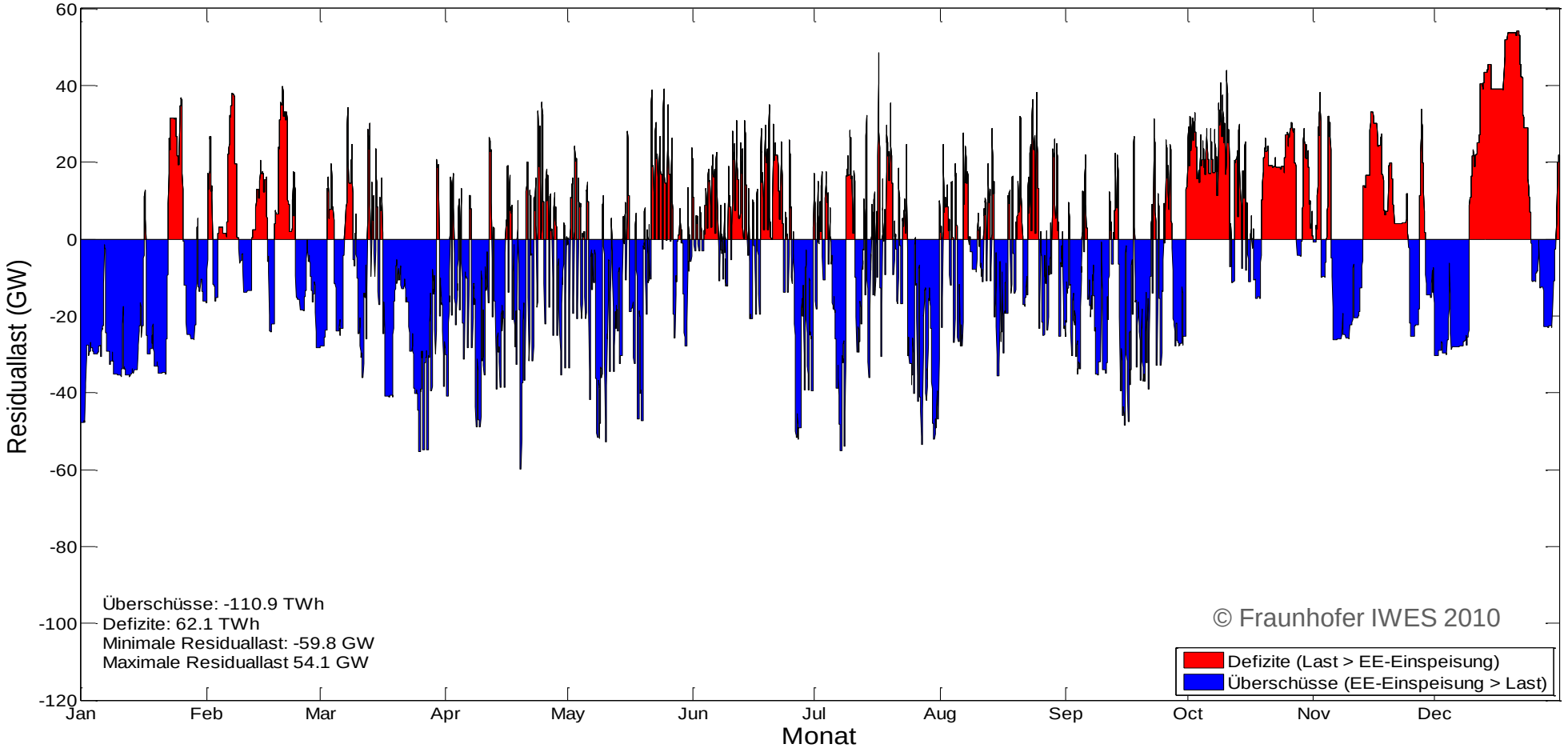
Source: IWES-Calculation for UBA Energy Target 100% Electricity from RES

ZSW

Fraunhofer IWES

Load Management to Reduce Balance Efforts

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

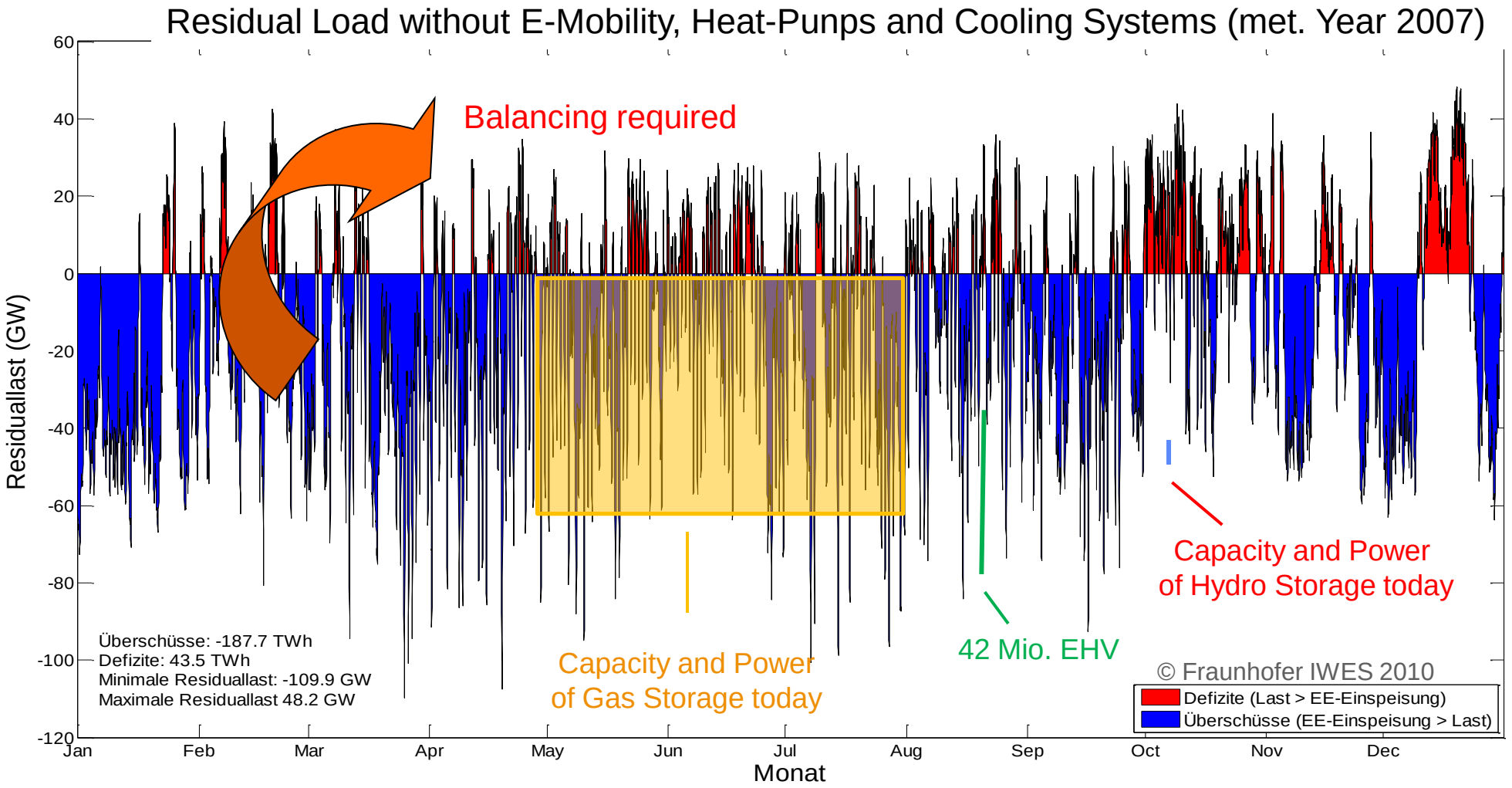


Source: IWES-Calculation for UBA Energy Target 100% Electricity from RES

ZSW

Fraunhofer IWES

Germany has insufficient Storage Capacity



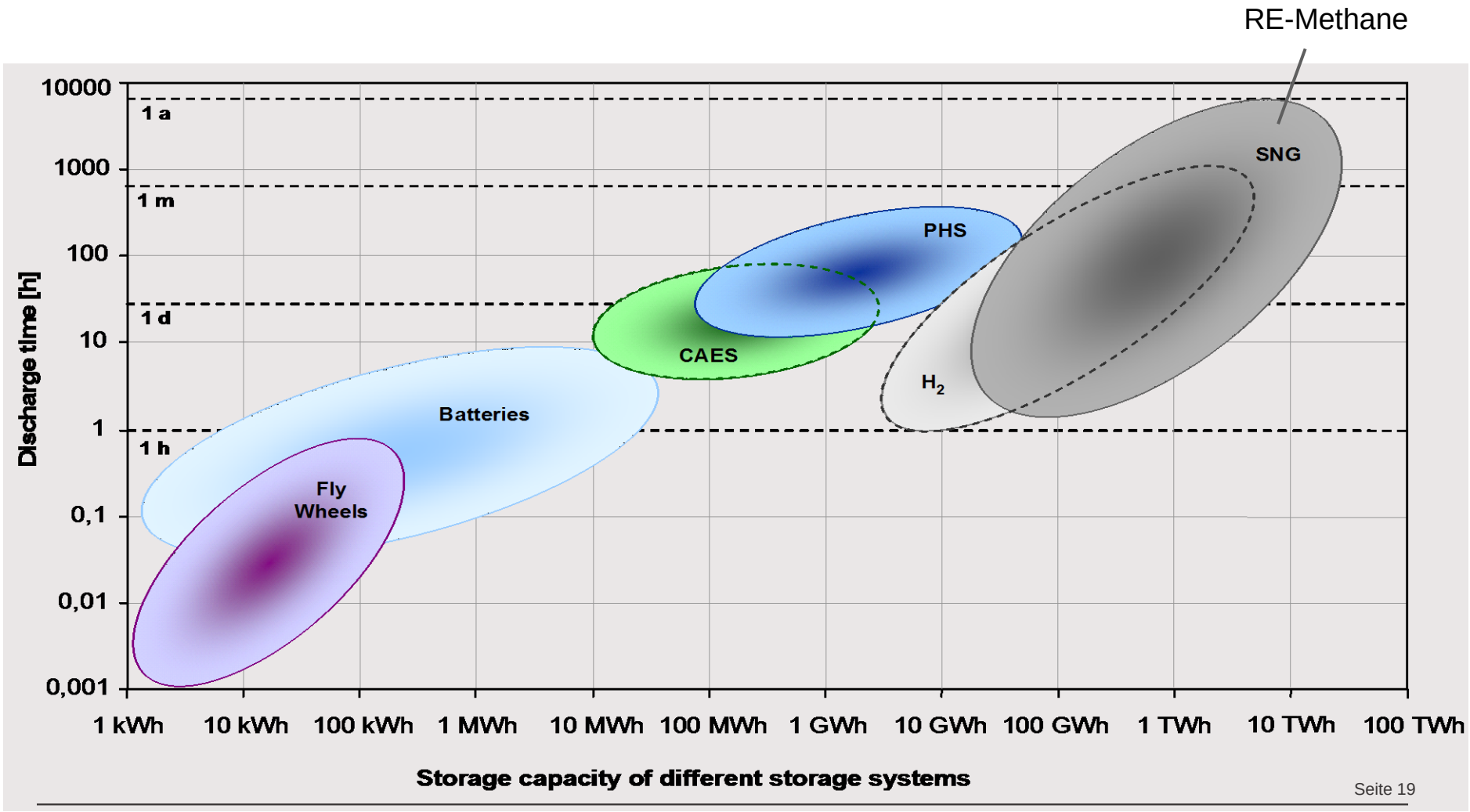
→ Gas storage = 1500 – 3000 x capacity of all hydro storage systems (bei $\eta_{GT,GuD}$ = 28-55%)

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

ZSW

Fraunhofer IWES

Capacity and Discharging Times of different Storage Technologies



Quelle: Specht et al, 2010

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

CH_4

Renewable Power Methane Anlage

Gas Power Stations

Electricity

Heat

GAS DISTRIBUTION

Traffic

Gasspeicher

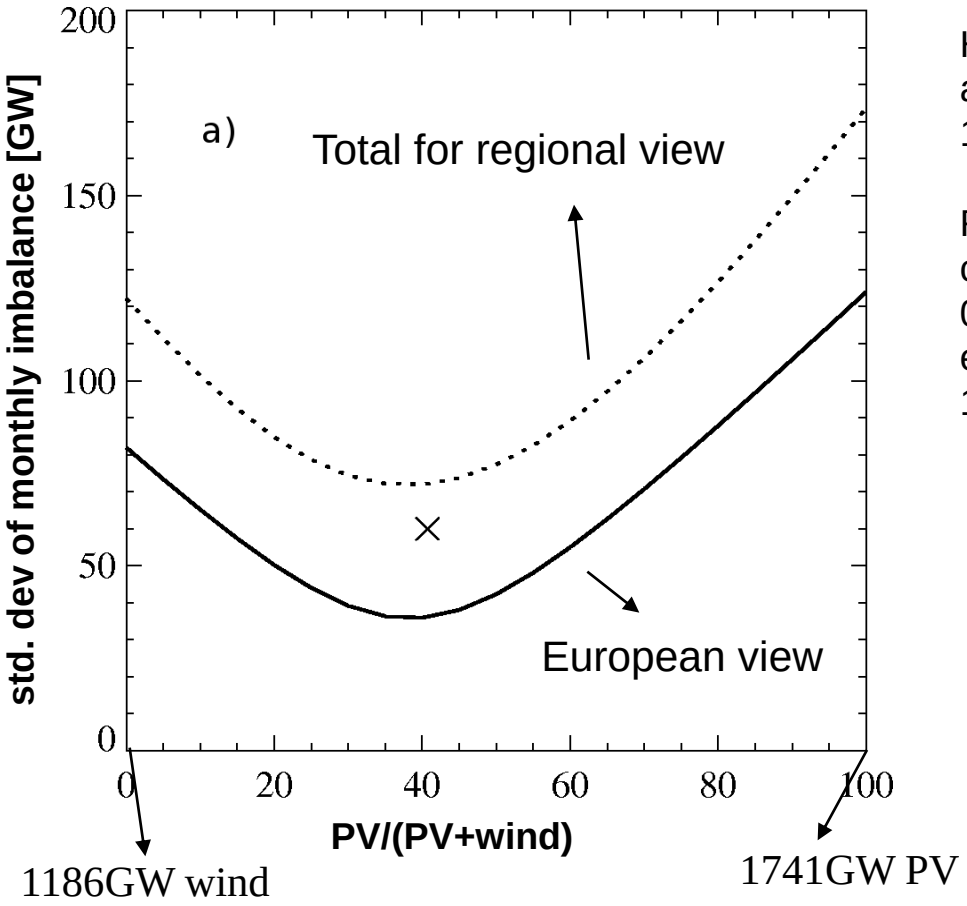
Quelle: Specht et al, 2009
Sterner, 2009

ZSW

Fraunhofer IWES

Optimal Energy Mix and Transport to reduce Balance Efforts

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



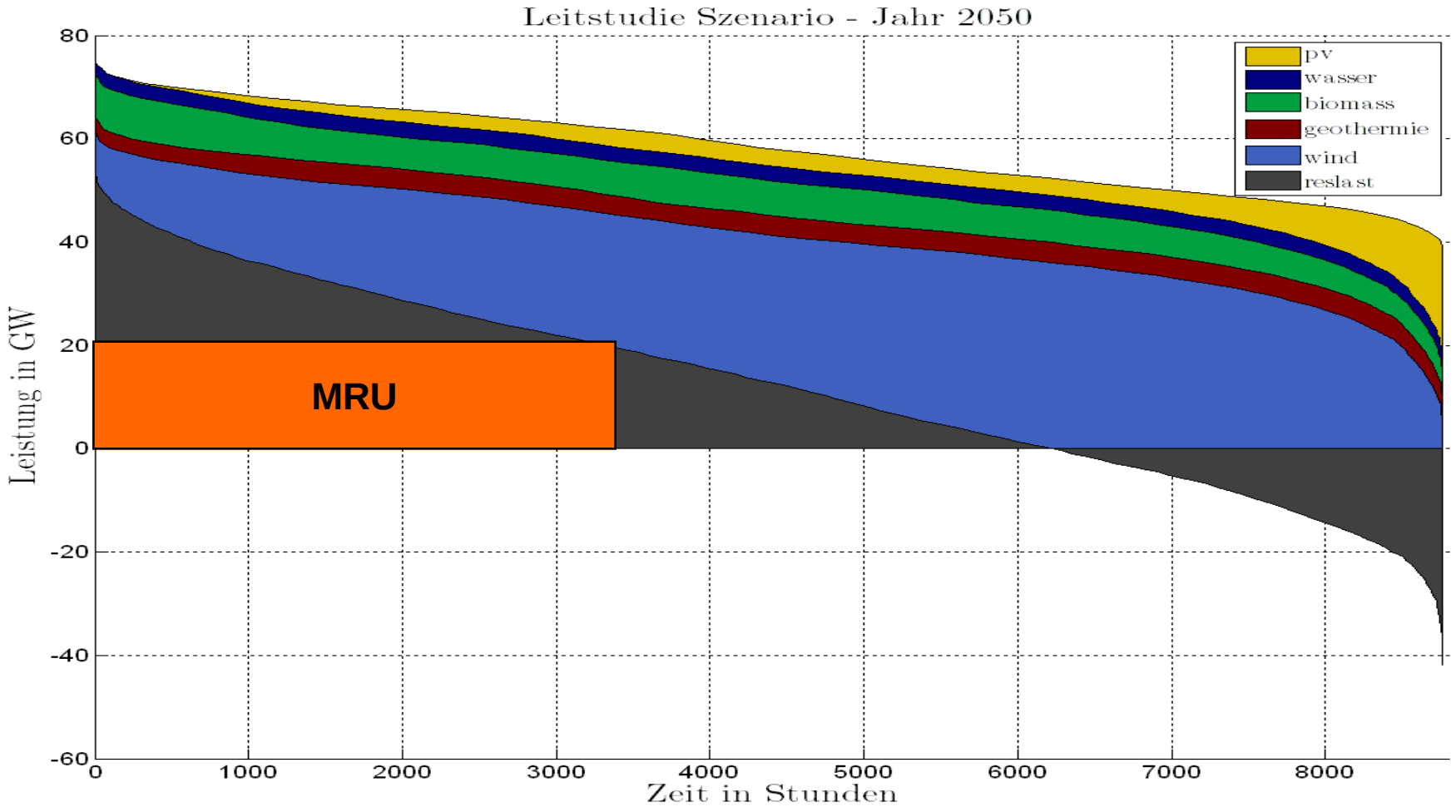
Highest required
average transport capacity
15 GW (in D) – Max. >>>

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

Fraunhofer IWES

Scenario 2050: System Services Required



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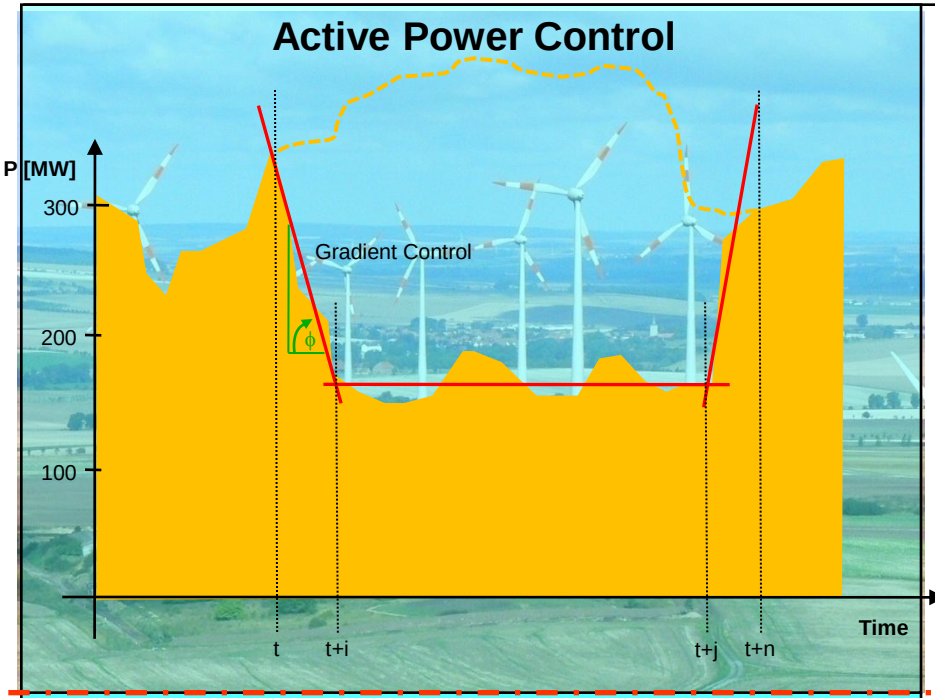
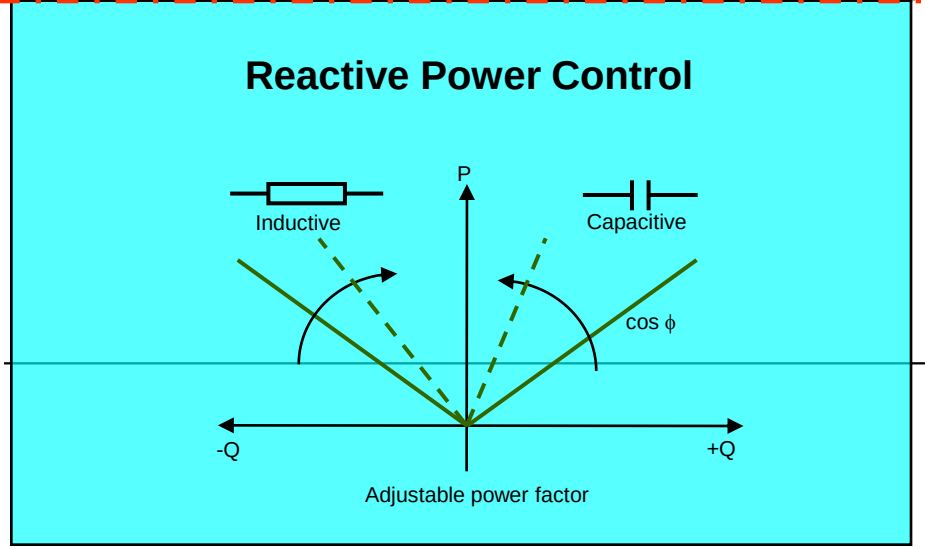
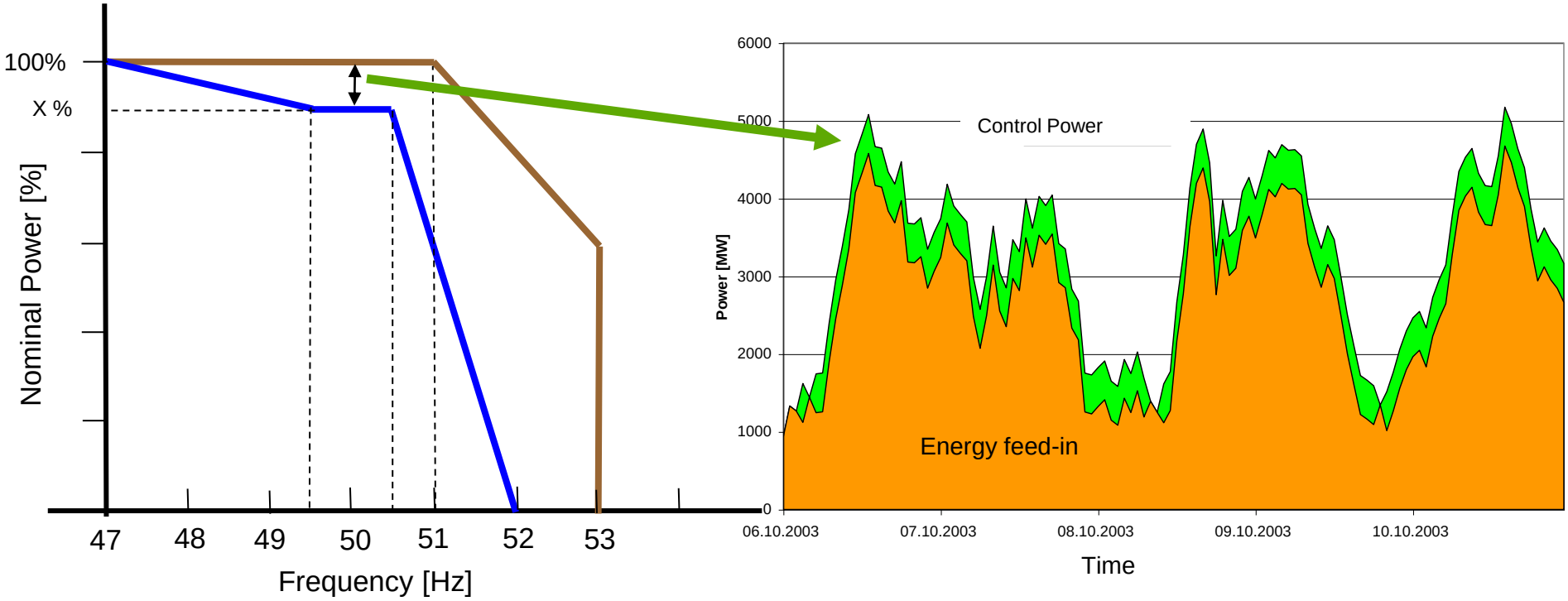
Active Contribution to System Reliability





- 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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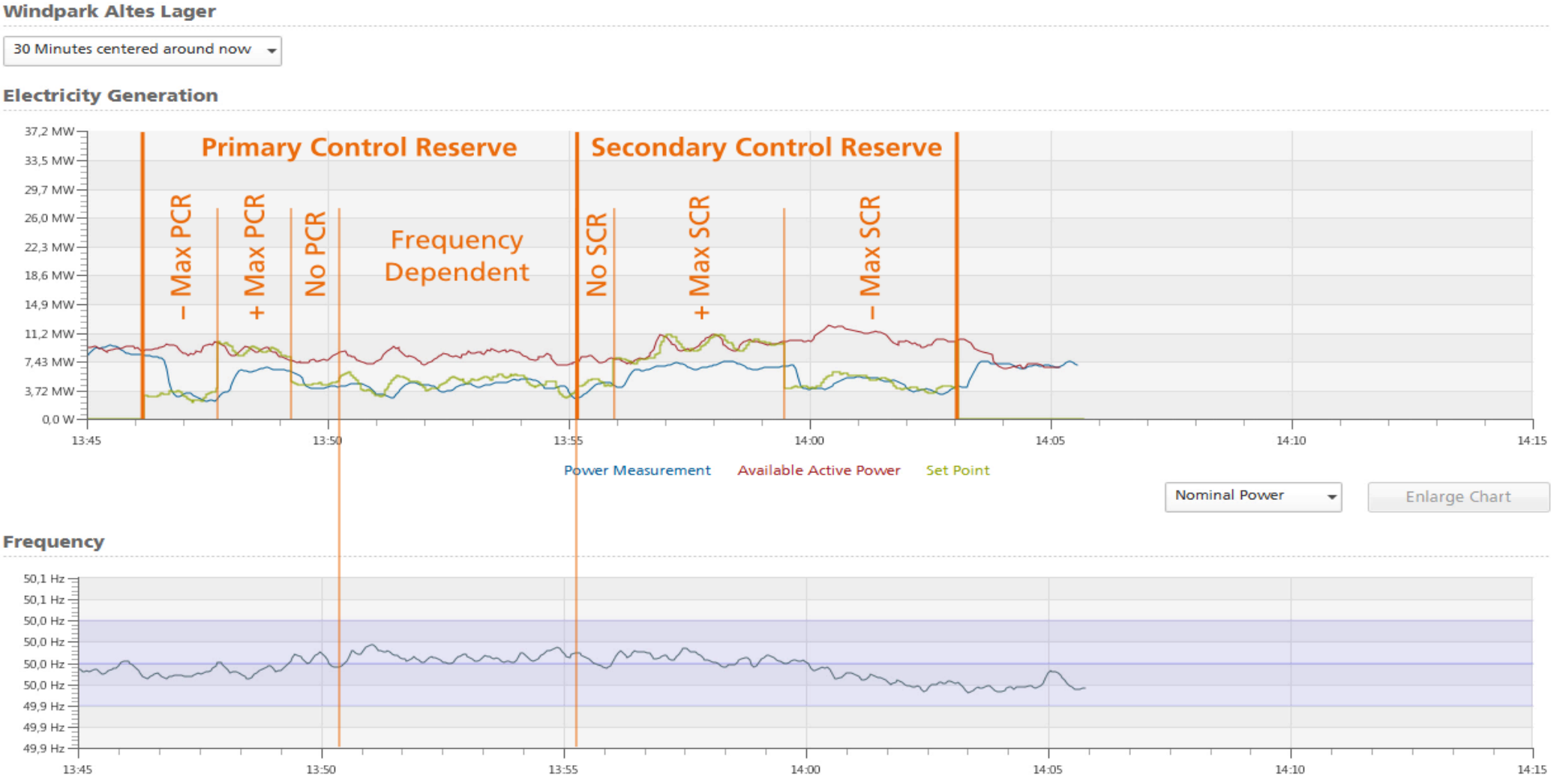
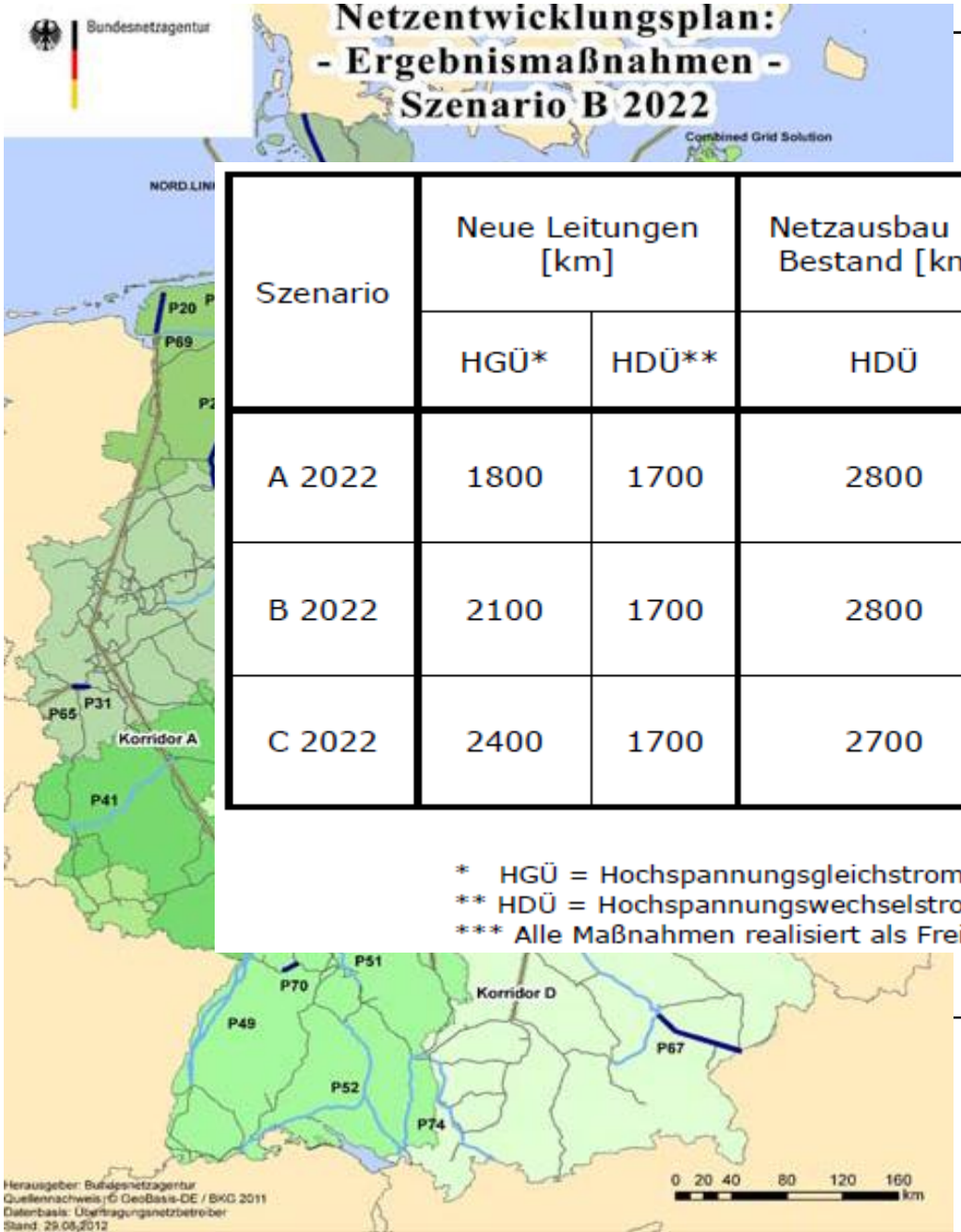
Services based on forecasts and confidence intervals

Frequency Support – Control power provision



IWES

German Grid Development Plan



Szenario	Neue Leitungen [km]		Netzausbau im Bestand [km]	Netzverstärkung im Bestand [km]		Kosten*** [Mrd. €]
	HGÜ*	HDÜ**	HDÜ	HGÜ	HDÜ	
A 2022	1800	1700	2800	300	1400	19
B 2022	2100	1700	2800	300	1300	20
C 2022	2400	1700	2700	300	1200	23

* HGÜ = Hochspannungsgleichstrom
** HDÜ = Hochspannungswechselstrom
*** Alle Maßnahmen realisiert als Freileitungen.

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Supra-Regional Voltage Imbalance

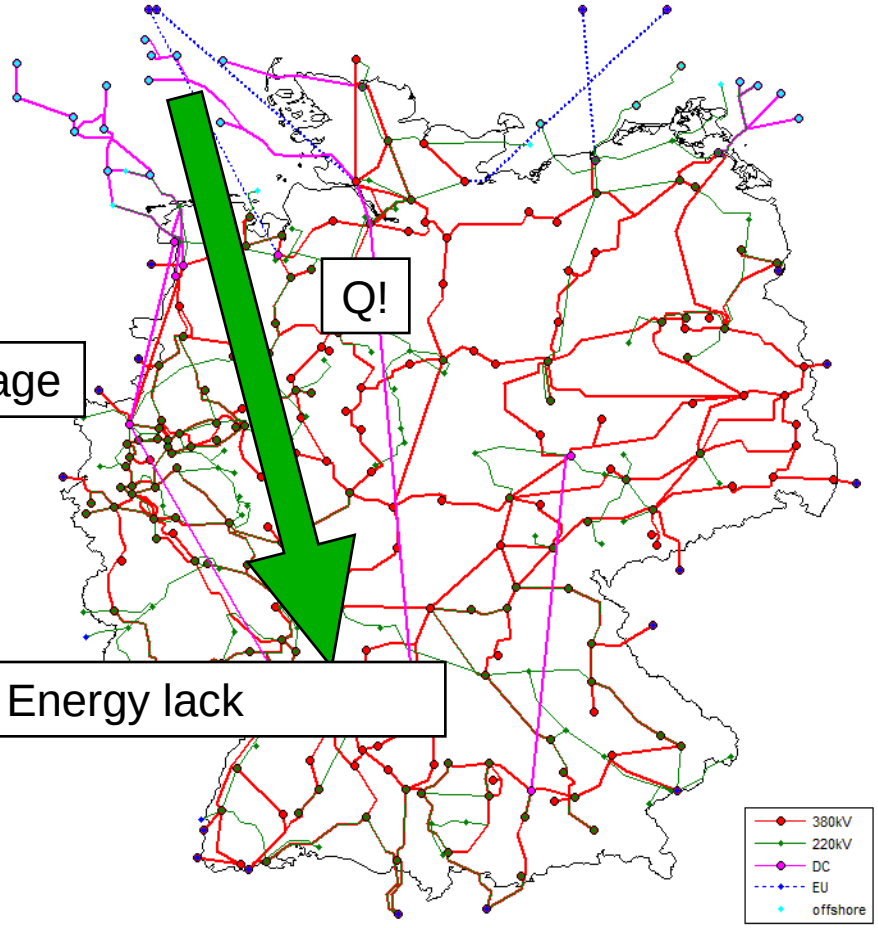
Energy surplus

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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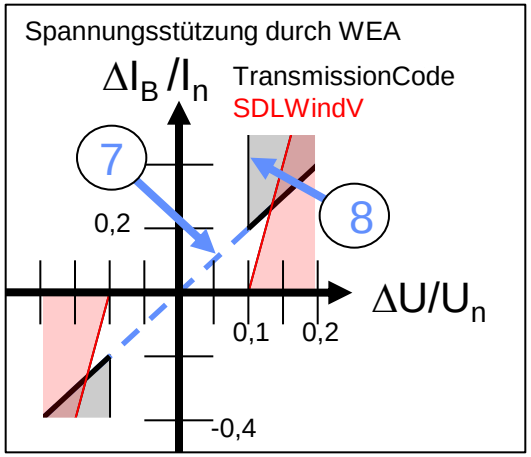
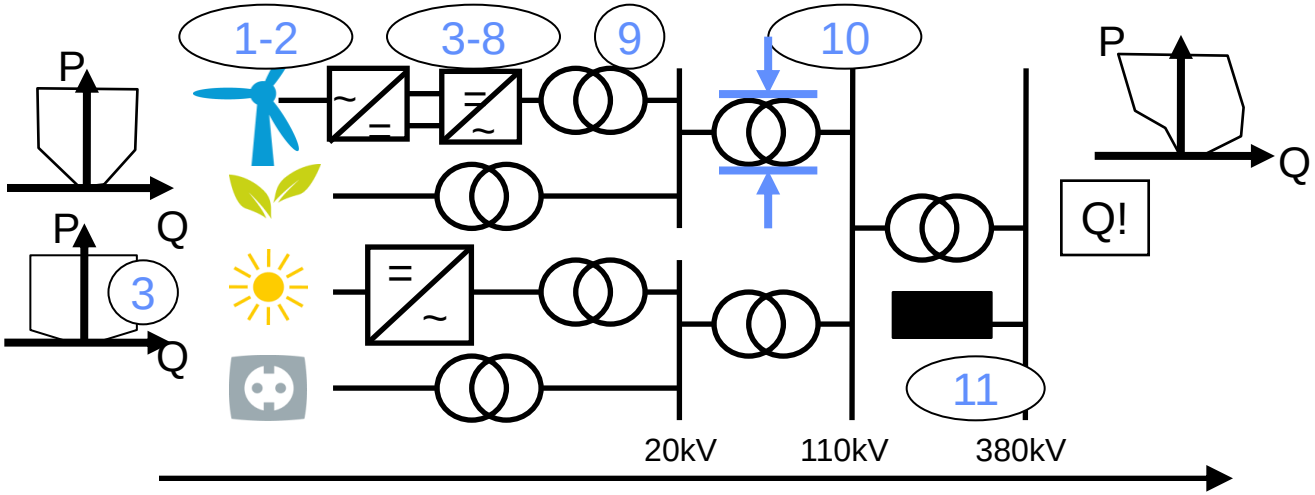
Methods to increase capability of voltage control by RES





Problem: low impact on HV Level

incomplete detection of voltage variation in HV level

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

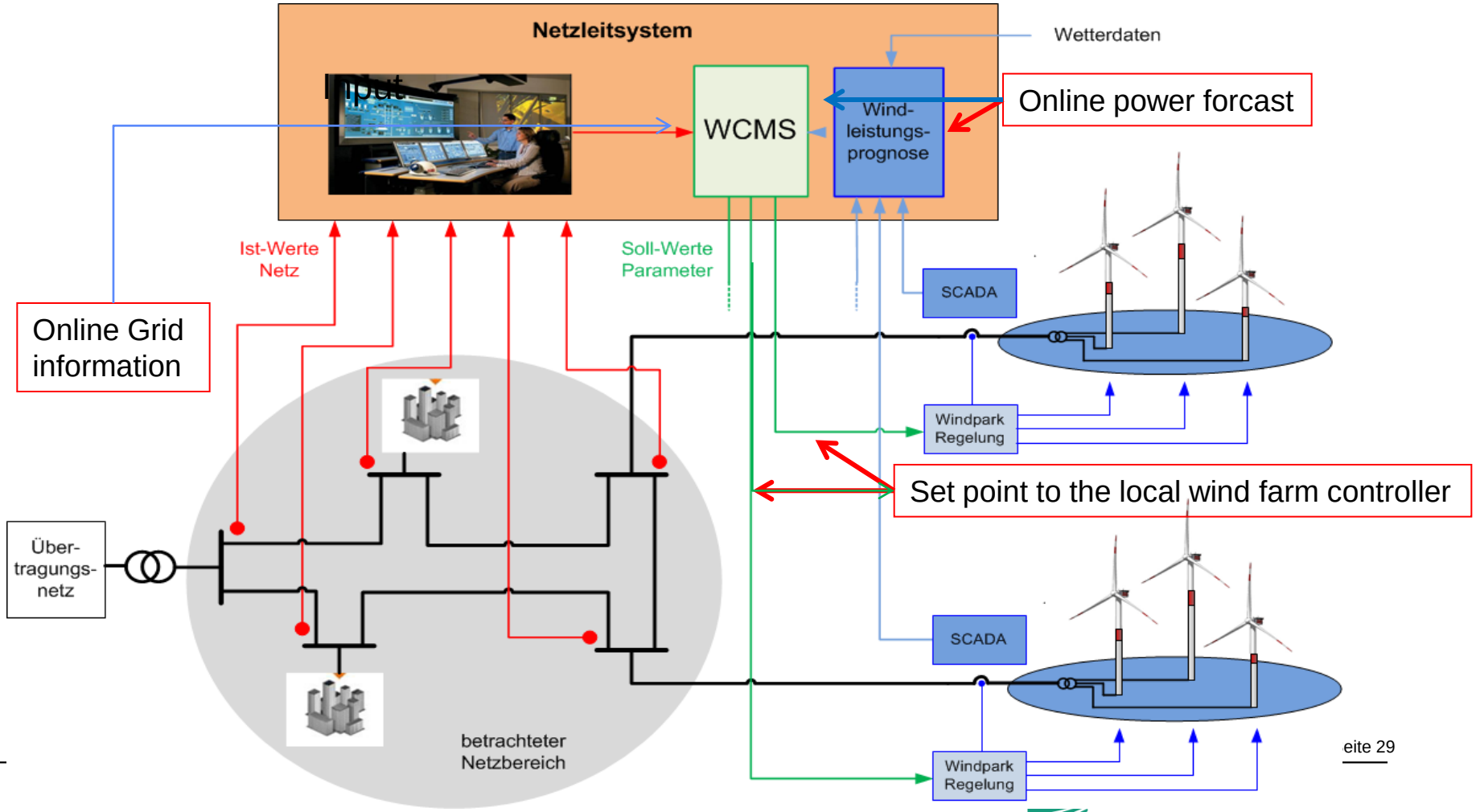
10 Variation of voltage ranges

11 implementation of reactive power compensation

Fraunhofer IWES

Fraunhofer Wind Farm Cluster Management System (WCMS)

Voltage Support



Fraunhofer IWES

Fast Transition form Consumption to Supply Grids

Power flow at 110 kV/ 20 kV Substation

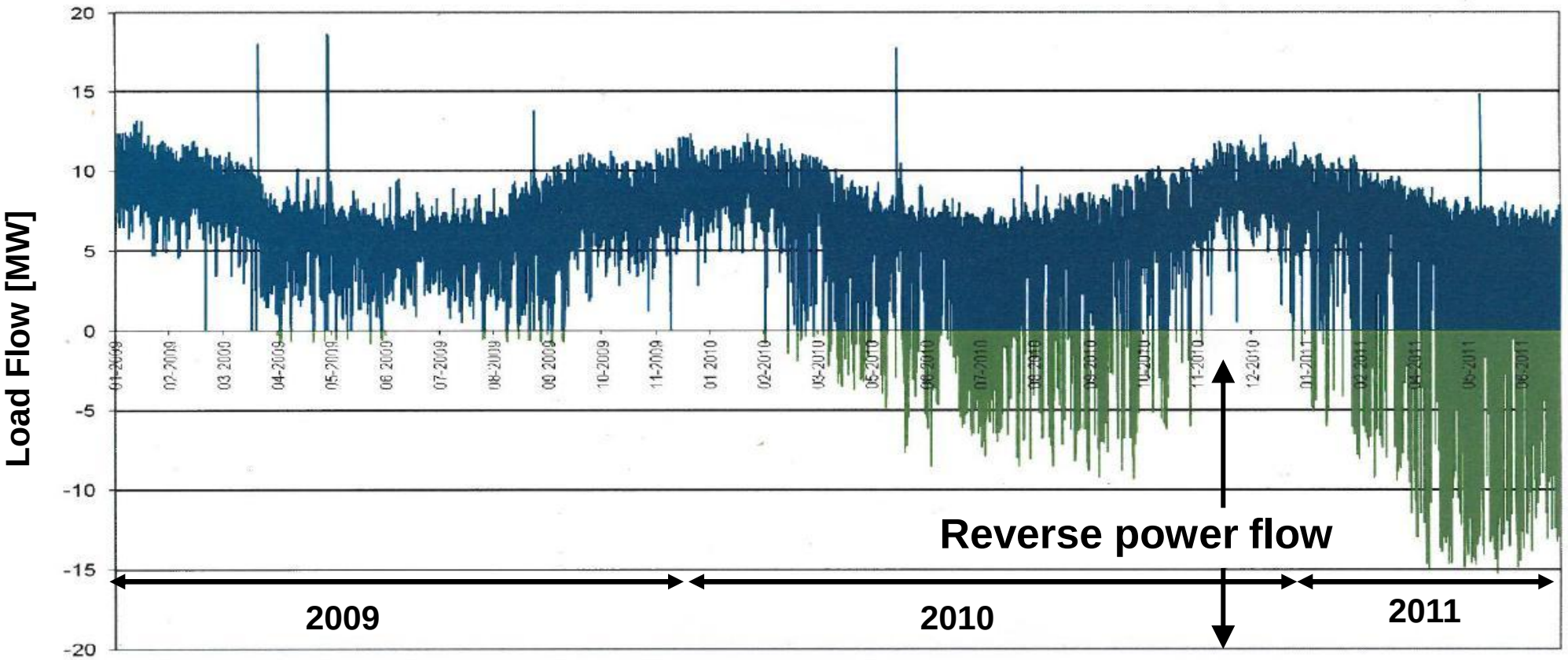


Fig: Courtesy of Bayernwerk AG

Fraunhofer IWES

Distribution Management System

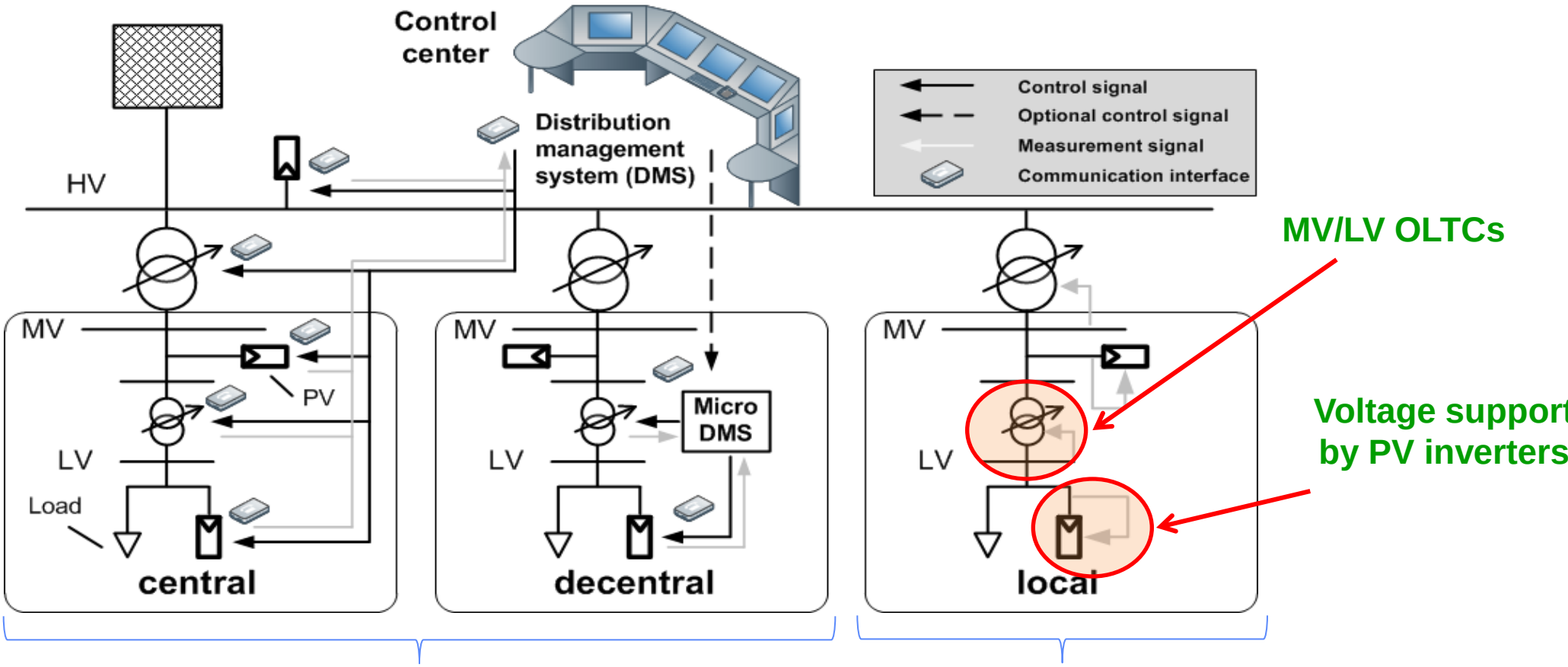
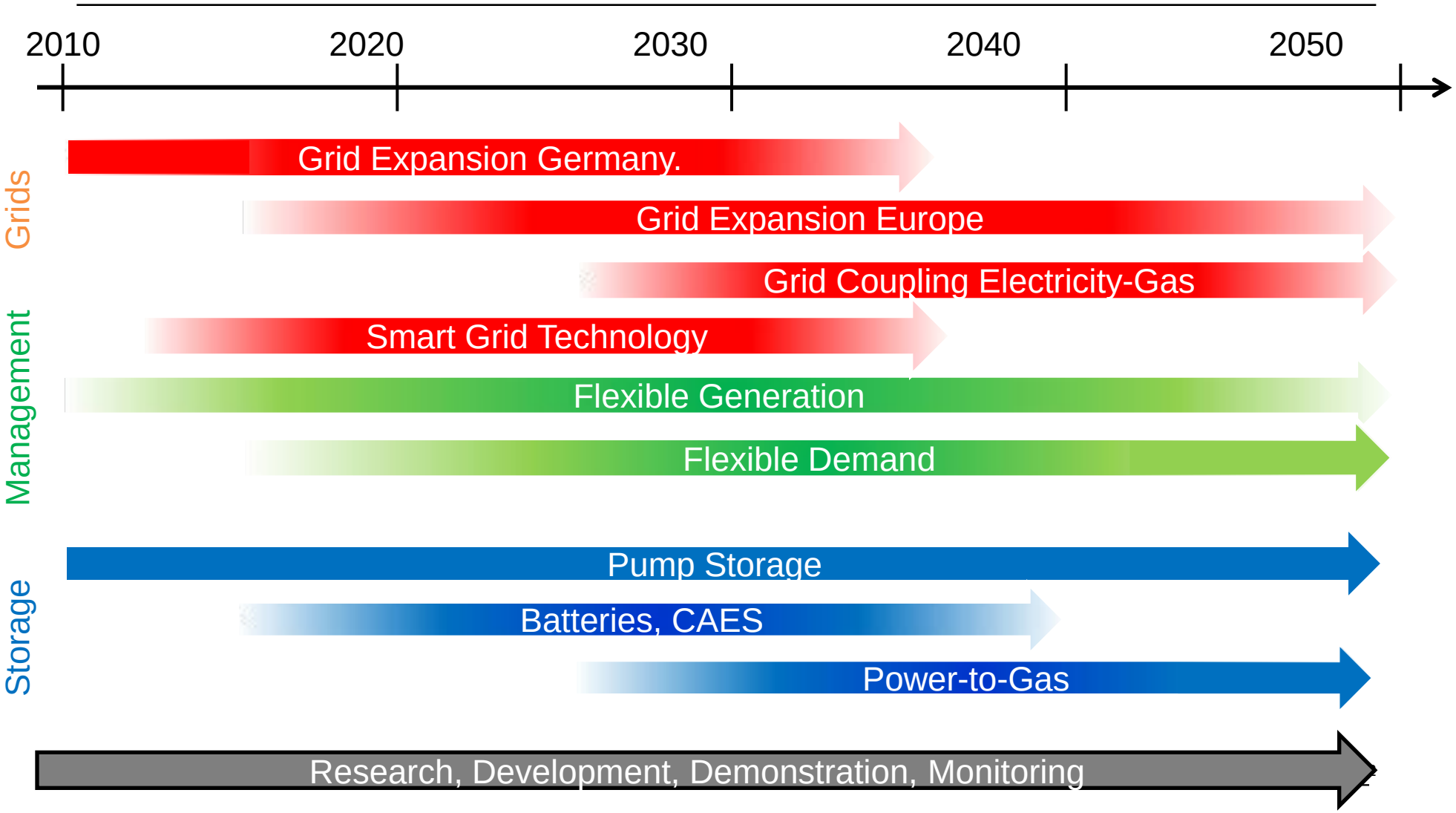


Fig.: J. von Appen et al., „Time in the Sun“, IEEE Power&Energy Magazine, March/April 2013

Fraunhofer IWES

Roadmap Energiewende System Transformation Power Sector



Quelle: IWES, 2011

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Thank You

The Fraunhofer-Gesellschaft in Germany

66 Institutes at 45 locations

2012

Staff 22.000

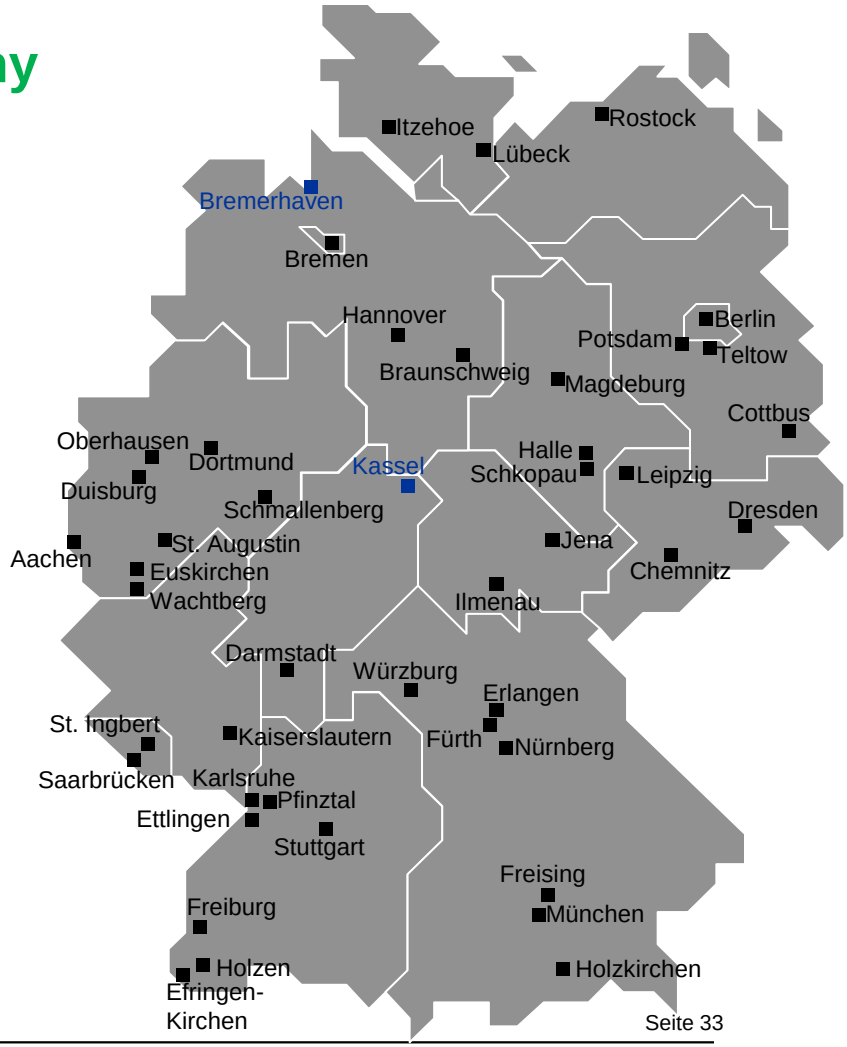
R&D-budget 2.500 Million €

Kurt Rohrig

Fraunhofer Institut für Windenergie und Energiesystemtechnik

Kassel

www.iwes.fraunhofer.de



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