

Renewable Energies in Germany

2nd ELECON – Workshop

28.10.-29.10.2014

Otto-von-Guericke-University Magdeburg

M.Sc. Philipp Kühne



FAKULTÄT FÜR
ELEKTROTECHNIK UND
INFORMATIONSTECHNIK



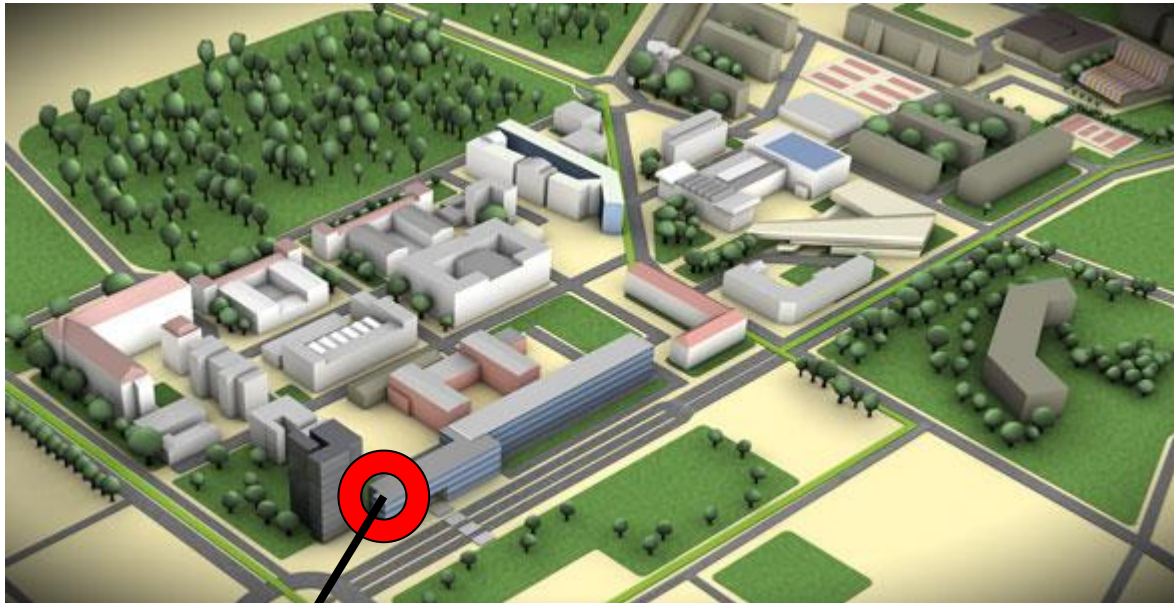
Magdeburg

- Capital of Saxony-Anhalt
- Over 1200 years old
- Population: 230.000



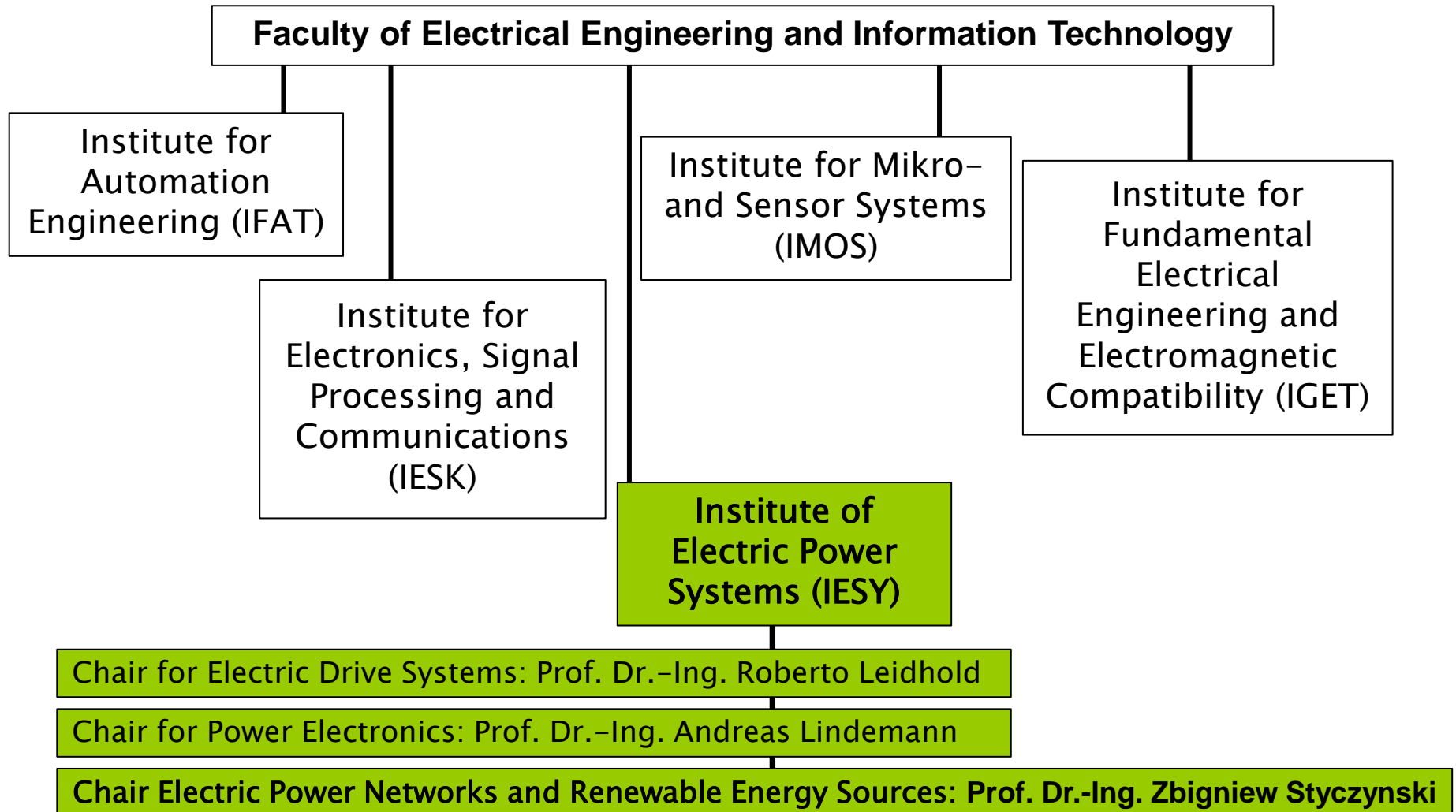
- Otto-von-Guericke 1602 – 1686
- Politician, lawyer, physicist and inventor
- Proved that vacuum exists and that air has a weight





- Founded in 1993
- 14 000 students
- 2500 employers
- 246 professors
- 9 faculties

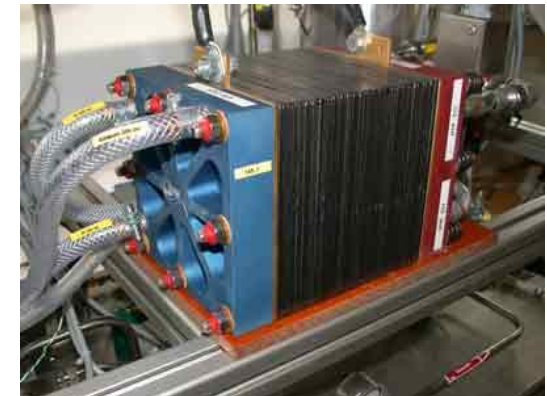
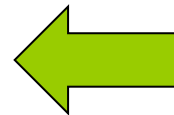






Research Topics:

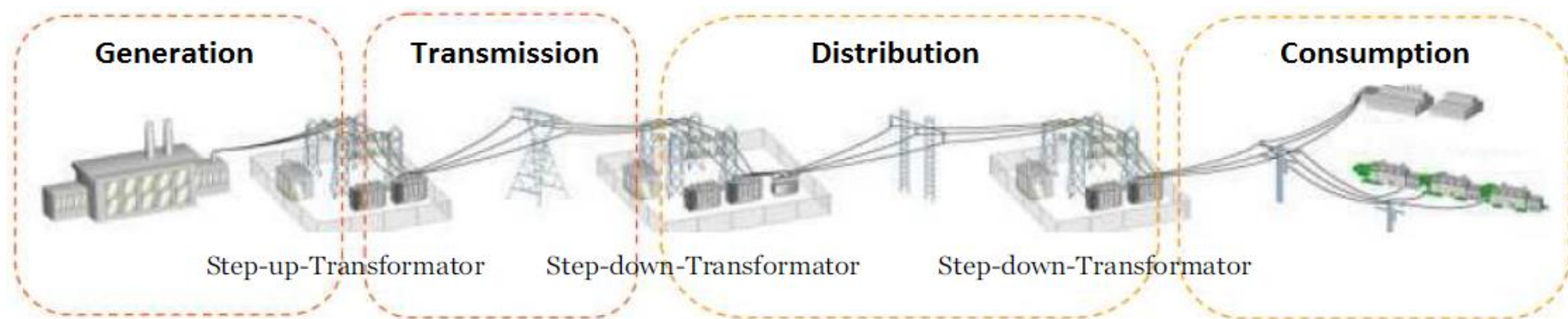
- Renewable Energies
- Power quality
- Network Planning
- HVDC Transmission
- E-mobility
- Fuel Cells



Agenda

- 1. Electrical grid in Germany**
- 2. Development of renewables in Germany**
- 3. Future plans of the government**
- 4. Conclusion**

Source: www.vde.org

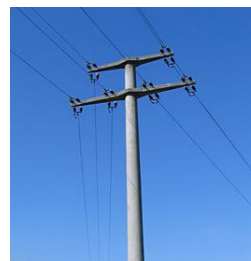
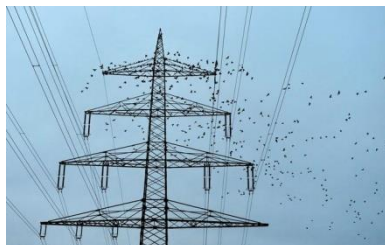


Generate
alternating current
@ 50 Hz

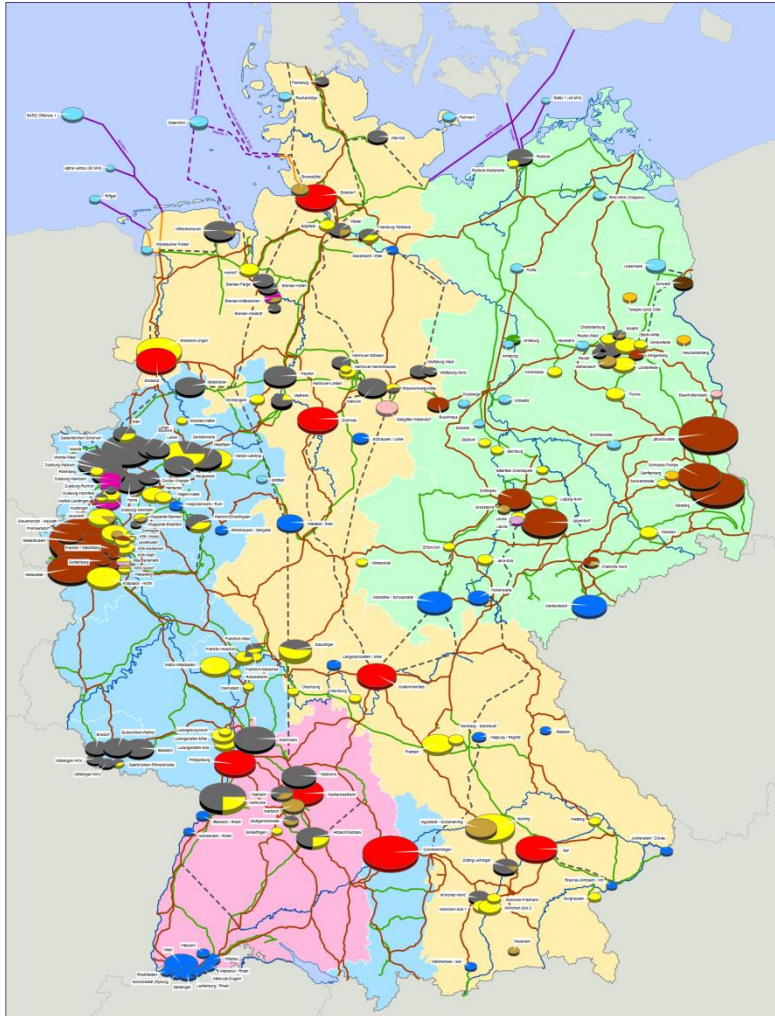
(extra-) High voltage
110 kV – 380 kV
75.000 km cable

Medium voltage
~ 20 kV
490.000 km cable

Low voltage
230 V – 400 V
>1 mil km cable



Power plants > 100 MW

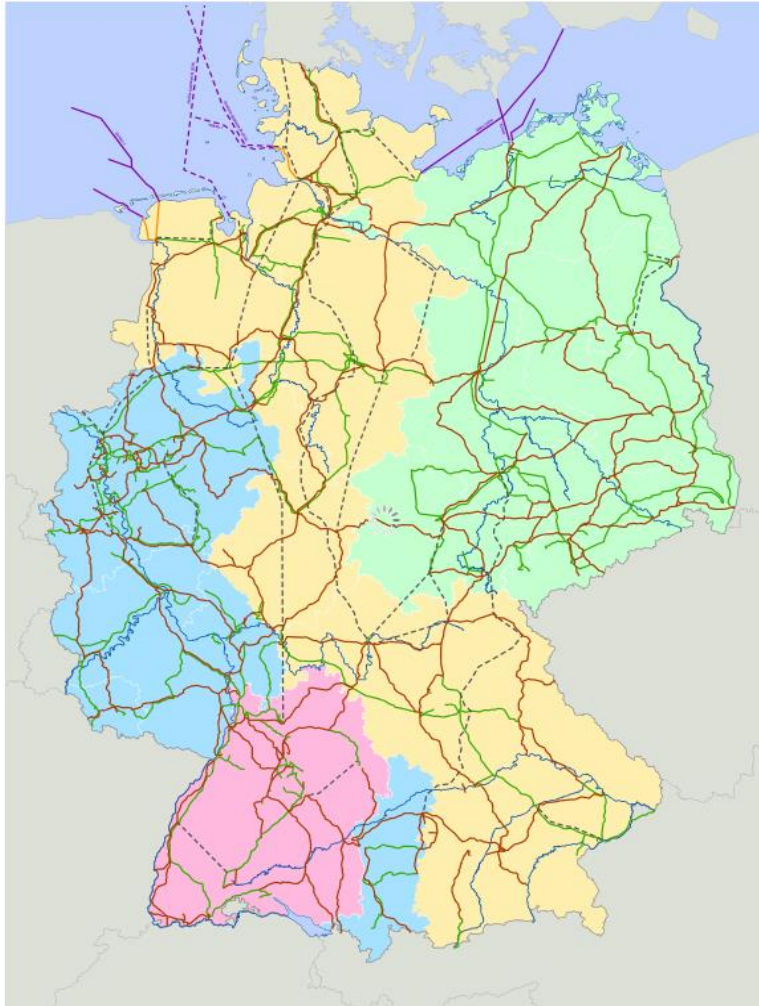


nuclear energy	red square	water	blue square
hard coal	grey square	wind	light blue square
lignite	brown square	natural gas	yellow square
oil	tan square	photovoltaic	orange square

Country area:	357.121 km ²
Population:	80,4 mil

- Installed capacity: 183,4 GW
- load between 30 GW and 80 GW
- 51% renewable energy (19 % wind, 20 % photovoltaic, 8 % water, 4 % biomass)

Source: www.bundesnetzagentur.de



Amprion
TenneT
50 Hertz
TransnetBW



Sea cable
380-kV-line
380-kV-line (planned)
220-kV-line
155-kV-line

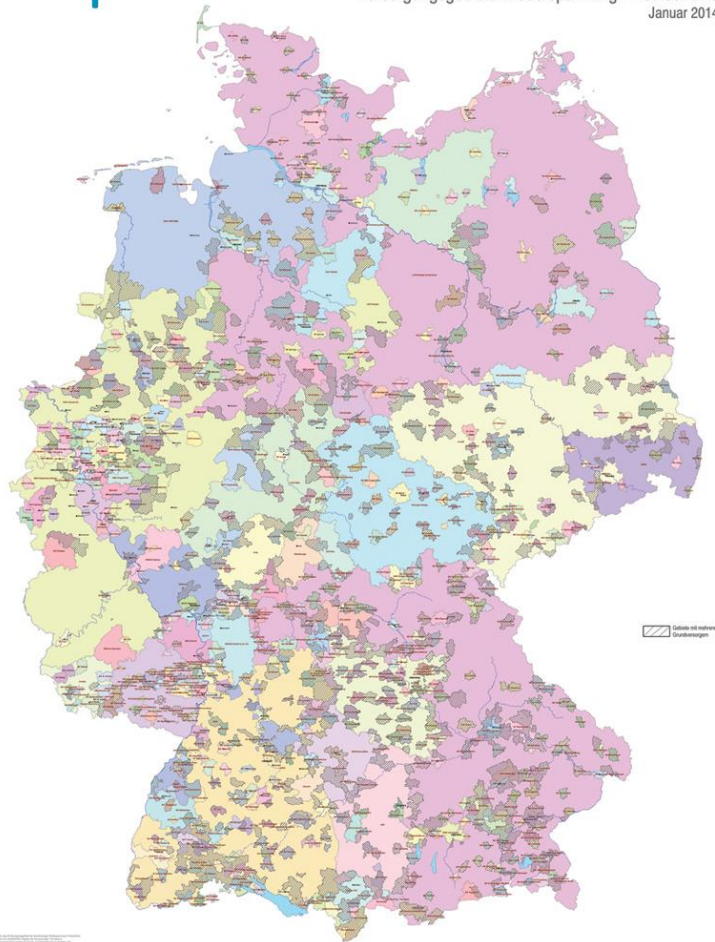


- About 75.000 km of transmission lines
- 4 TSO operating the grid:
 - Maintenance, operation and dimensioning of electrical energy transmission
 - Non-discriminatory access for all Distribution System Operators
 - Subject to government supervision since 2005

Source: www.bundesnetzagentur.de

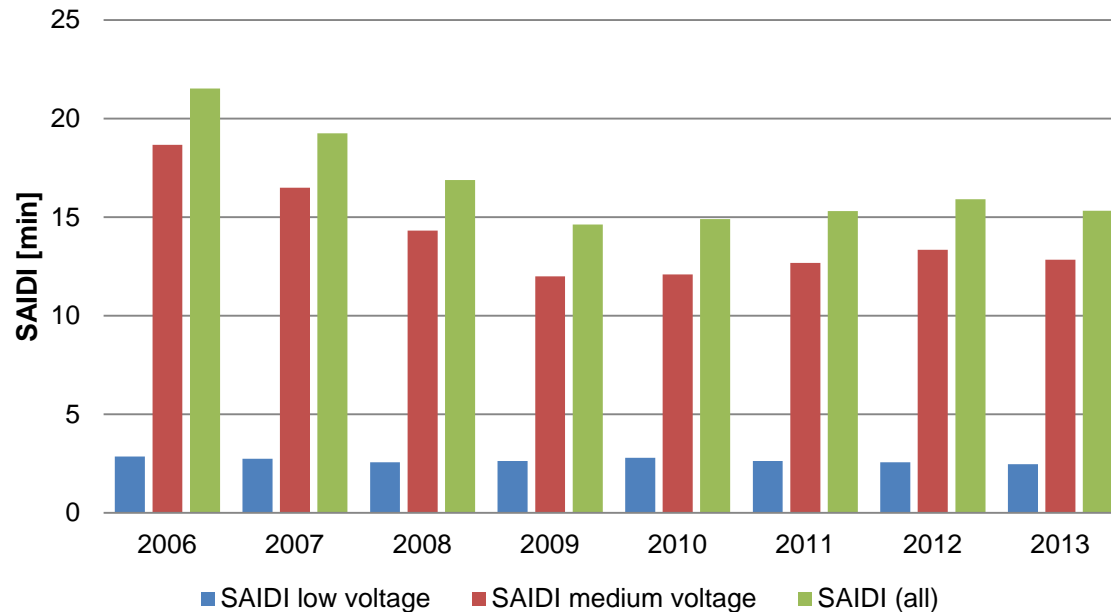


Karte der Grundversorger Strom
Versorgungsgebiete Niederspannung - Deutschland
Januar 2014



- Distribution of the electrical energy to the consumer
- Since liberalization of the market in 1998 → over 900 companies
- End-Users are not bound to the local supplier

SAIDI in Germany



- End-users: 49,5 mil (2013)
- Frequency control to balance generation and consumption
- Regulation power provided in Germany:
 - positive 7000 MW (generation)
 - negative 5500 MW (load)
- SAIDI in 2013: 15.2 min (brasil: 18 h)

SAIDI → Interruption time per end-user that was not planned and last longer than 3 minutes

source: bundesnetzagentur 2013

Overhead line network (standard in Germany)

- Capacities of twice 1800 – 2500 MW @ 380 kV
- Much experience in installation and operation
- Low costs, high operation time



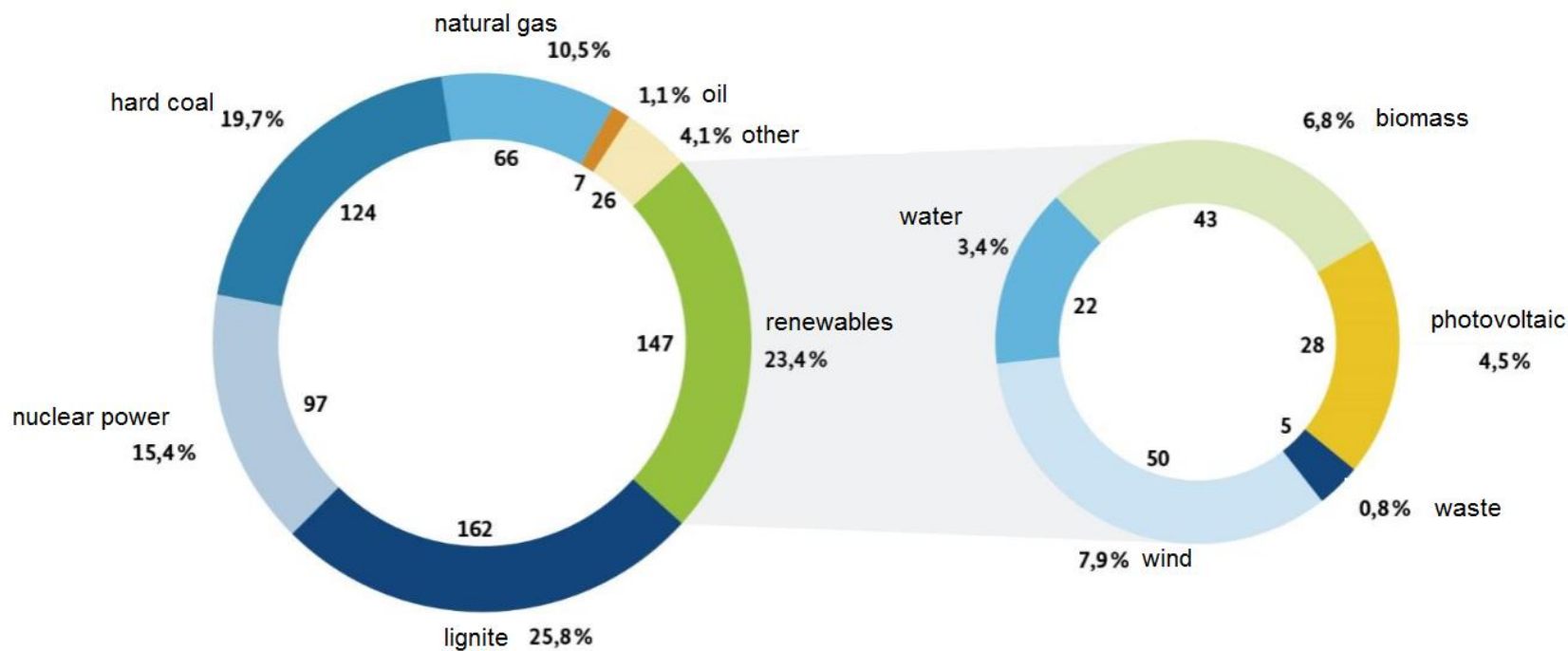
Buried cable system

- Reduced visibility
- Lower transmission capacity up to 1000 MW
- Only built for special applications
- Distinctly higher costs compared to overhead lines
- Only used for distribution in urban areas or in low voltage level

Agenda

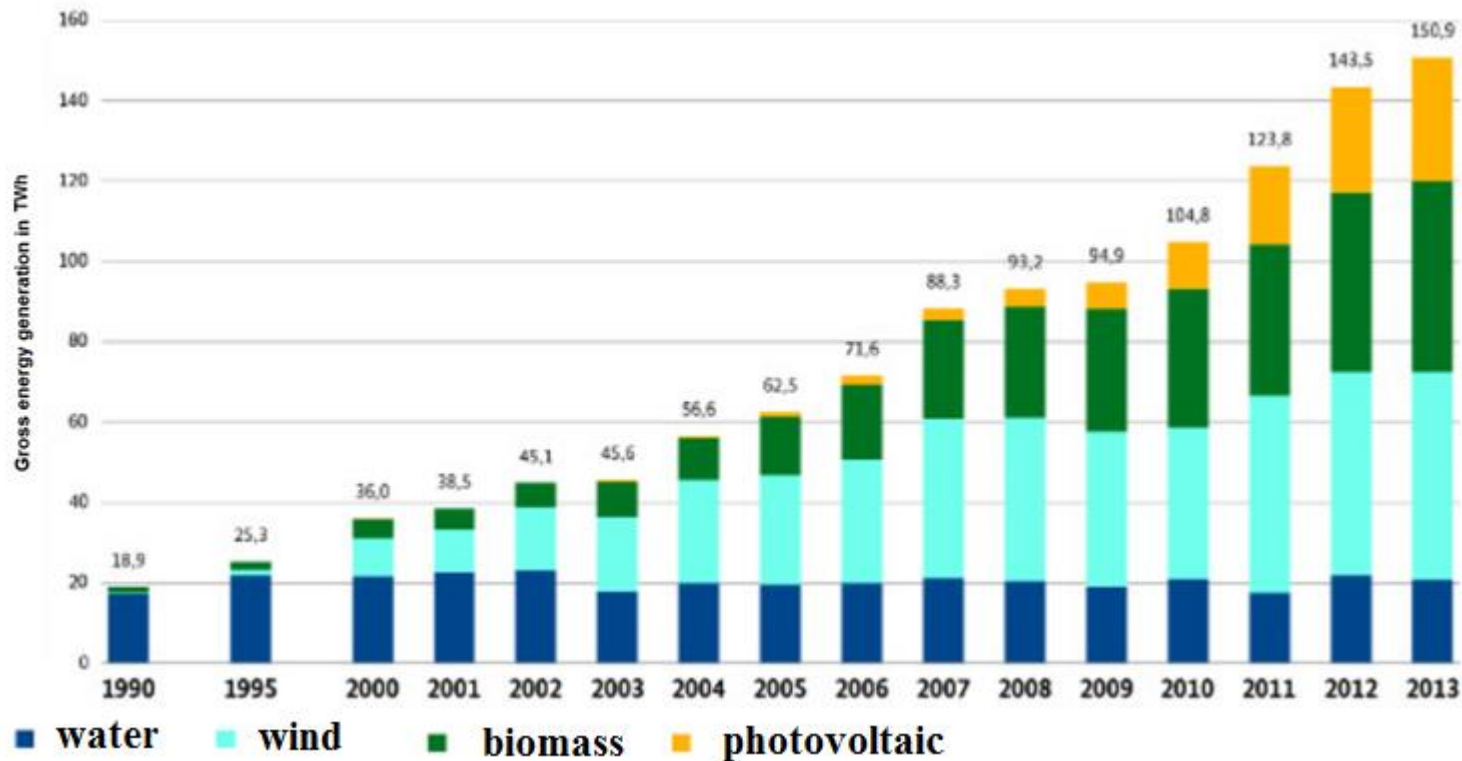
- 1. Electrical grid in Germany**
- 2. Development of renewables in Germany**
- 3. Future plans of the government**
- 4. Conclusion**

Gross electricity generation in Germany 2013



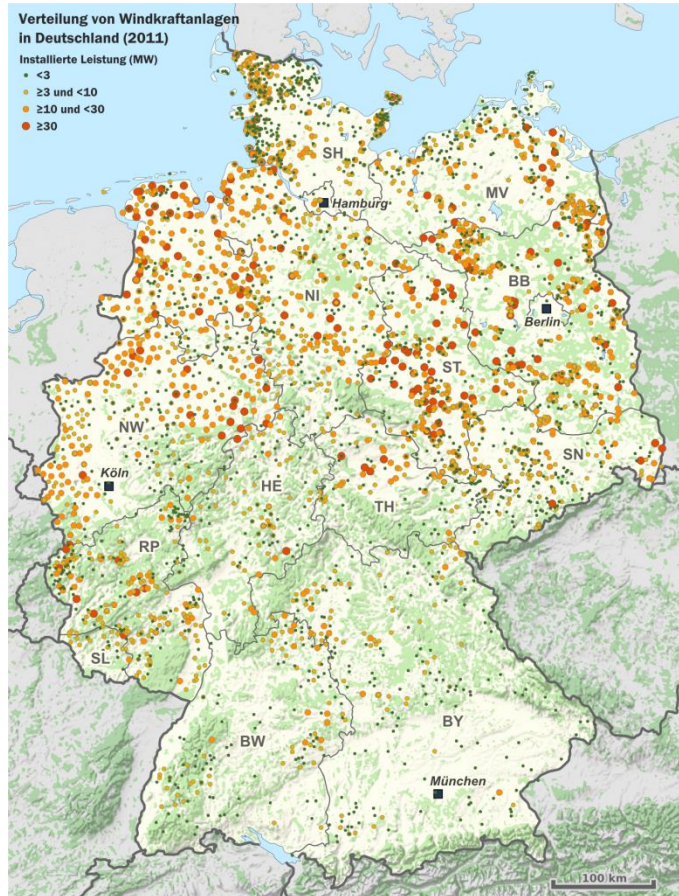
- 629 TWh generated in 2013 (brutto)
- 150,9 TWh generated by renewable energy sources

Source: www.bmwi.de



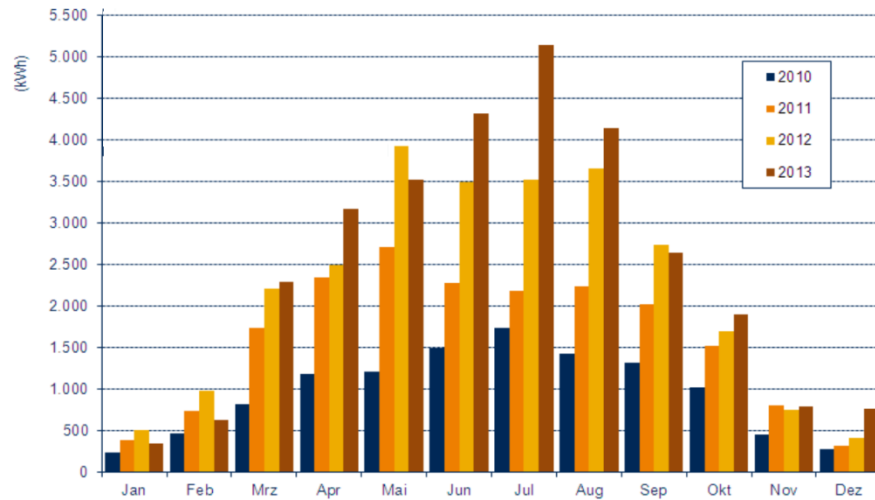
- Since 1990 high increase renewables
- With the renewable energy law in 2000 wind, photovoltaic and biomass increased significantly
- Water power remains stable because the potential is near its end

Source: www.bmwi.de

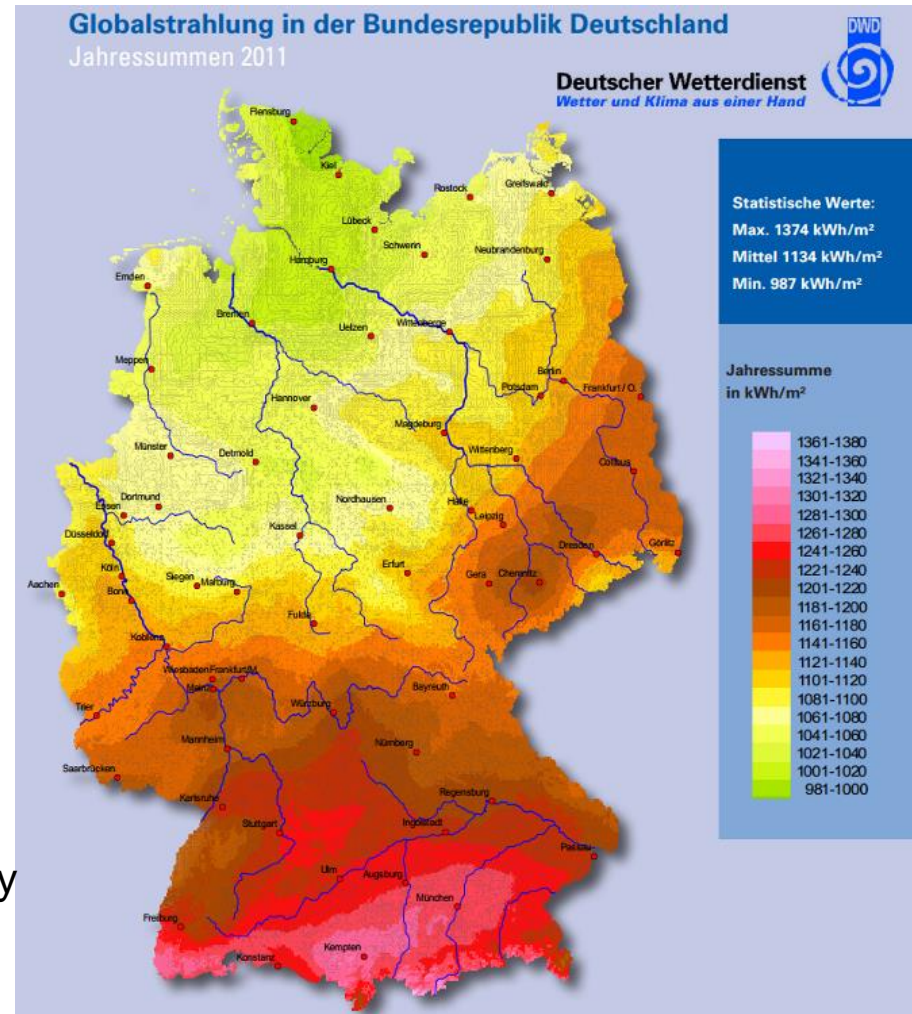


- 33,7 GW installed wind power (19 %)
- 50 TWh in 2013 generated electrical energy (8 %)
- About 24.000 wind power plants
- High density of wind power plants in the north of Germany
- Low consumption in the north leads to a big need of transmission of energy

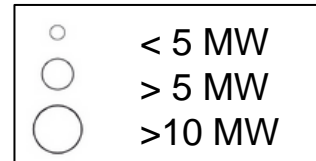
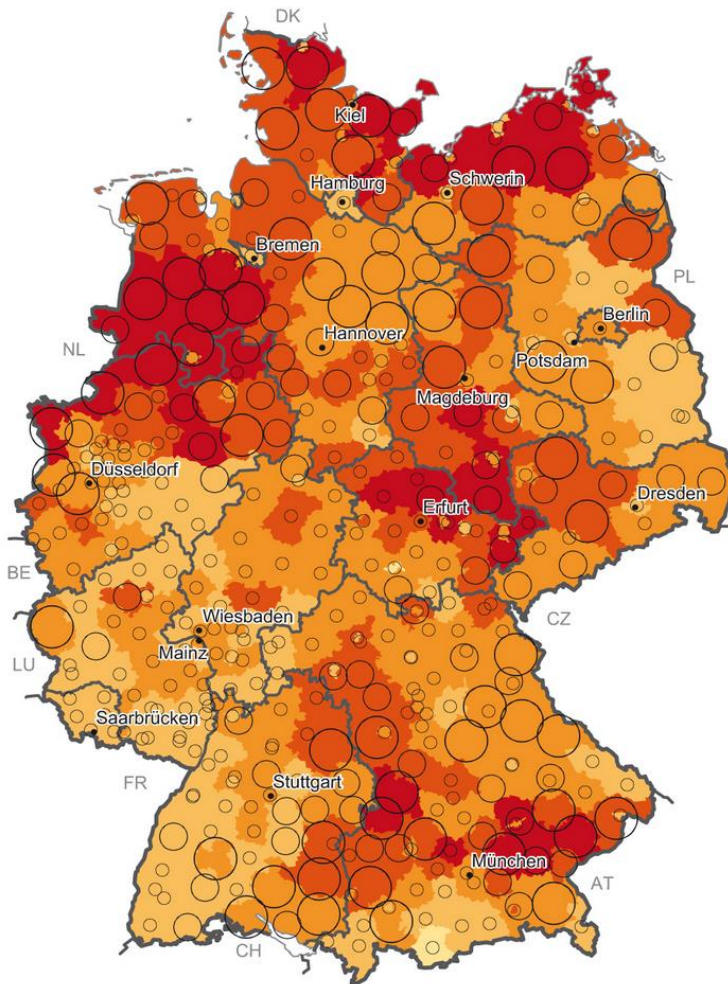
Source: www.bmwi.de



- 37,2 GW installed solar power (21 %)
- 29,7 TWh generated electrical energy (4.8 %)
- About 1.4 mil photovoltaic plants
- Most of them small private plants
- High radiation density in the south of Germany



Source: Deutscher Wetterdienst



- 8,1 GW installed power (4 %)
- 43,9 TWh generated electrical energy (7.1 %)
- Suitable to for base load
- Small plants near agriculture and big central plants
- Because of regulations and laws, the capacity of biomass is near its end

source: www.bbr.bund.de

The renewable energy law is responsible for the fast implementation of sustainable energies in Germany

1991 – Feed-in-law for electricity from renewables

2000 – Renewable energy law

2004

- Regulated Payment for wind, photovoltaic and biomass

2009

- Payment for combined heat and power
- New regulations according to the size of power plants

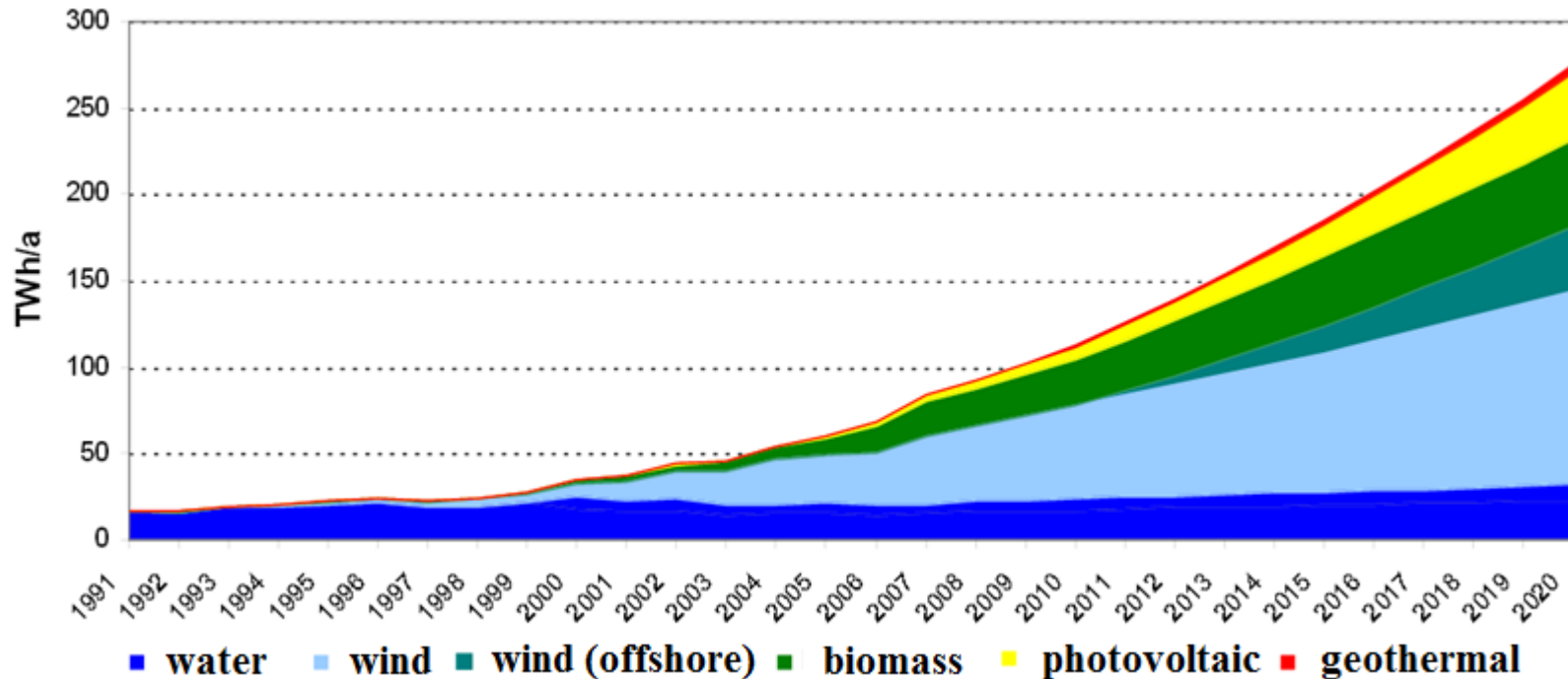
2012

- Pricing models for direct marketing
- Remote control capability

2014

- Limited new capacities for wind, biomass and photovoltaics
- Increased remote control capability





- Windpower as the main energy source (>50 % in 2020)
- Renewable energy at least 35 % of gross electrical energy in 2020

Quelle: www.energieeffizient-sanieren.org

Agenda

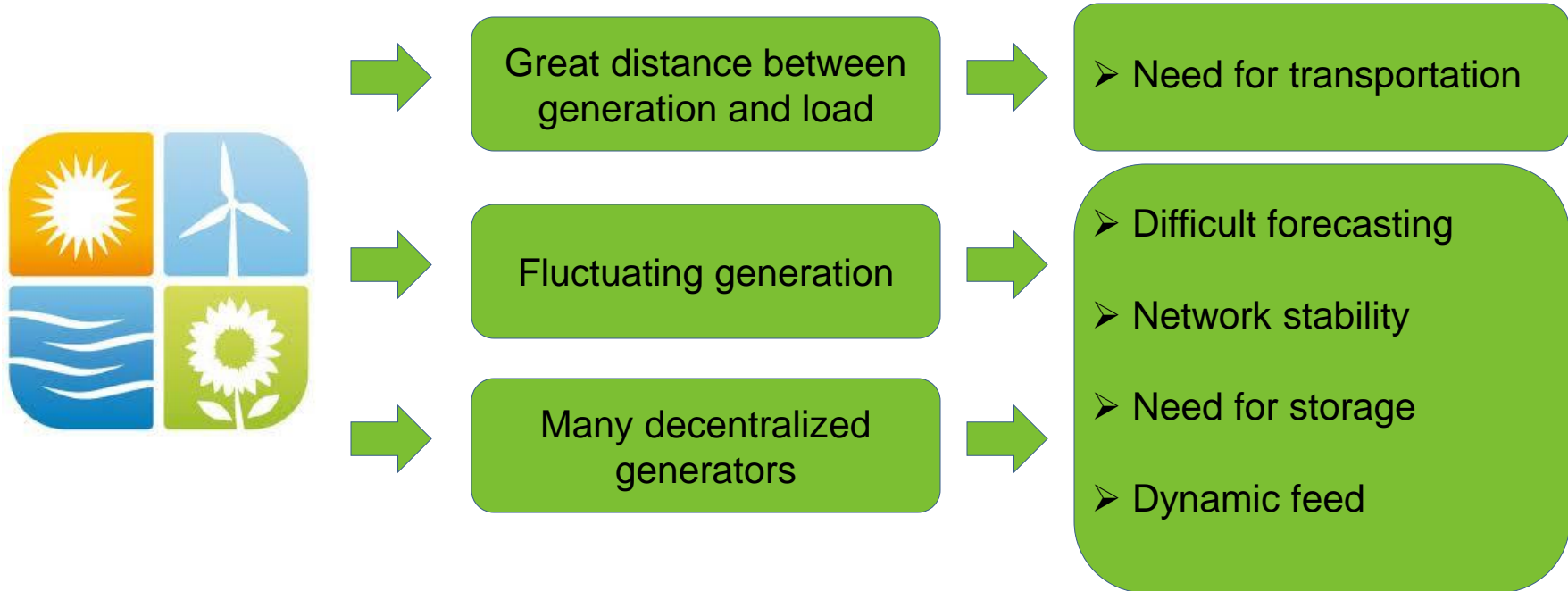
- 1. Electrical grid in Germany**
- 2. Development of renewables in Germany**
- 3. Future plans of the government**
- 4. Conclusion**

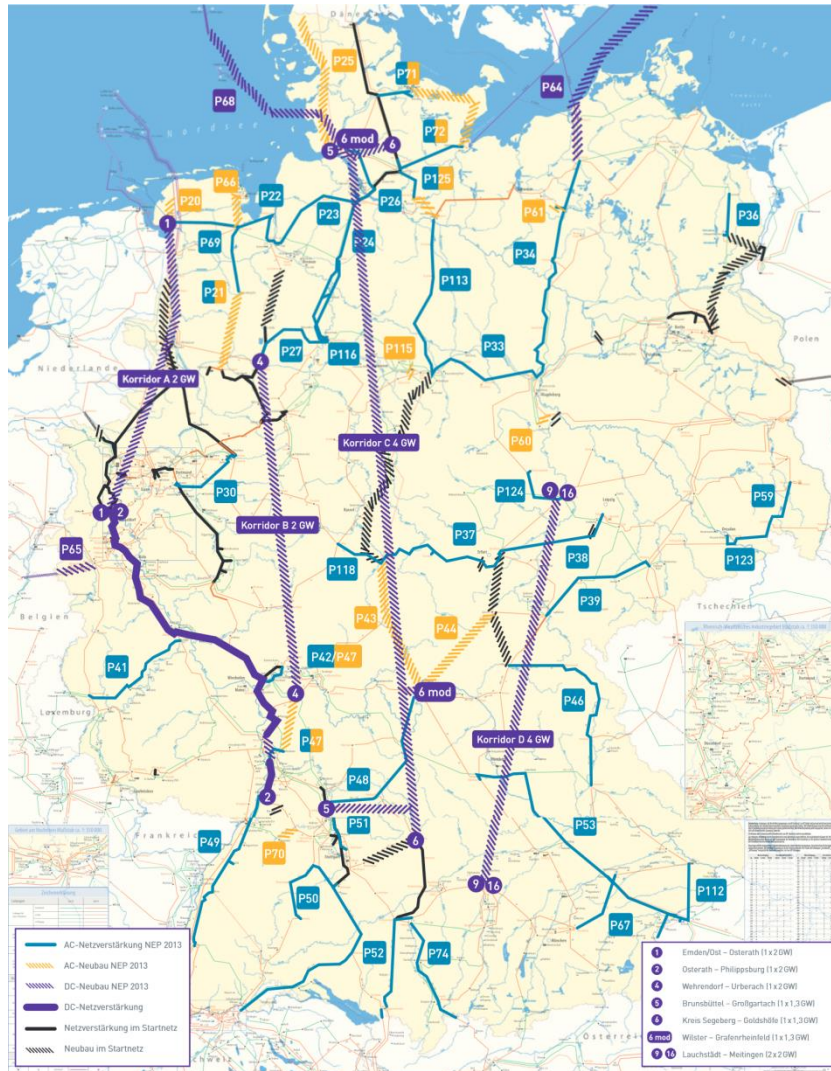
"Energiewende" in Germany



Goals:

- Reduction of CO₂ emissions about 95 % until 2050
- Phase-out of nuclear energy until 2022
- Increase share of renewable electrical energy up to 80% until 2050

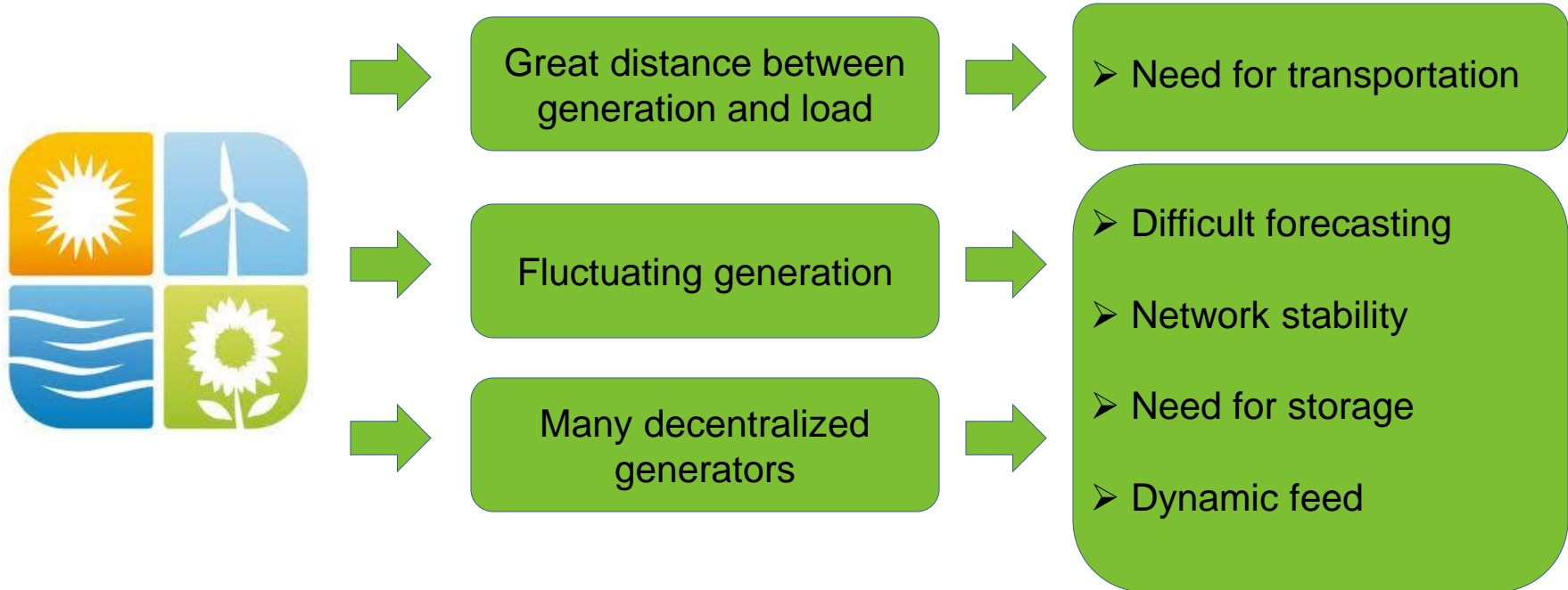


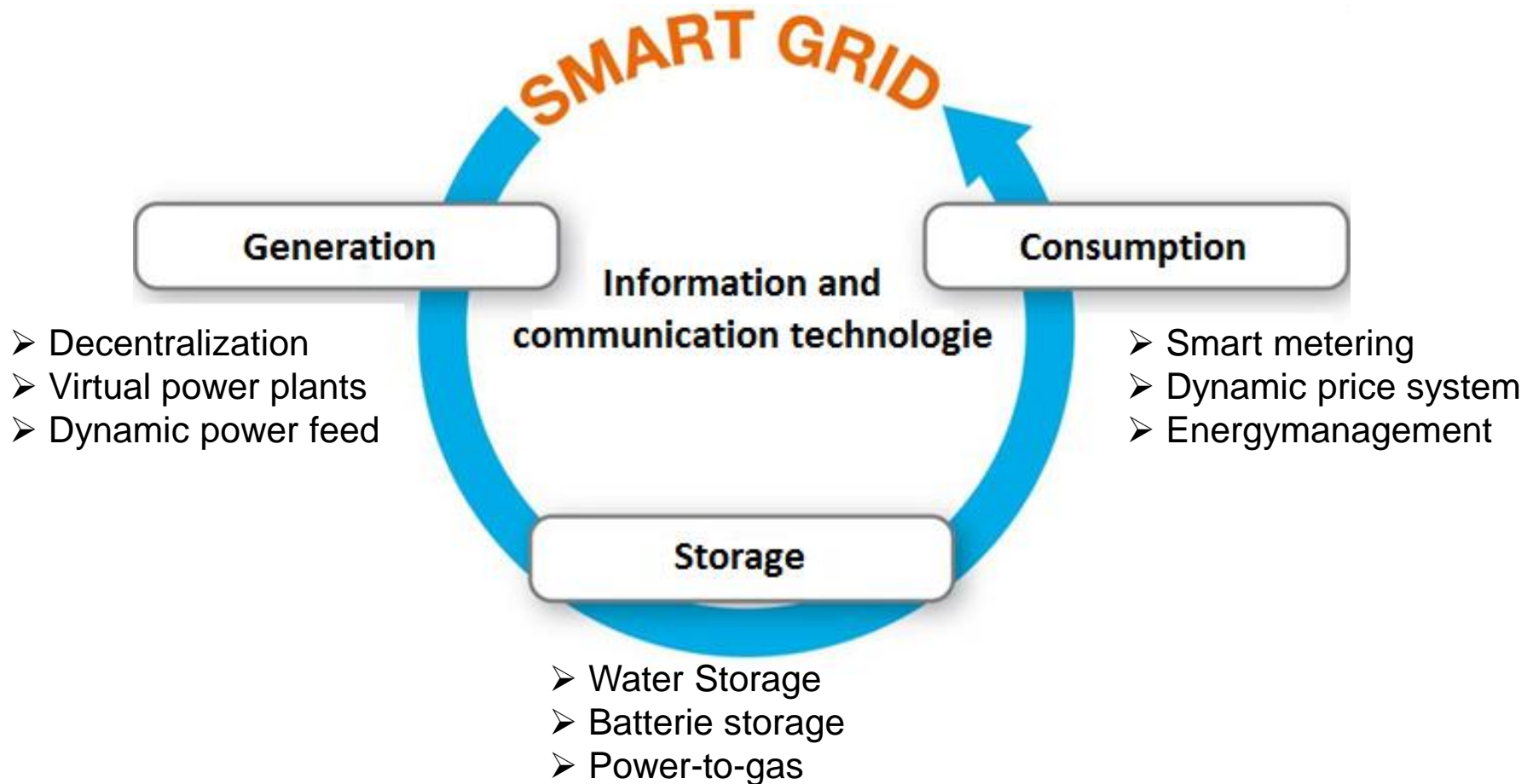


- „Netzentwicklungsplan 2013“
- 3800 km additional power lines
- 2100 km HVDC (12 GW)/ 1700 km AC
- 4400 km revised for the new requirements
- Estimated cost: 21 billion euro
- Completion: 2023



Source: www.netzentwicklungsplan.de 2013





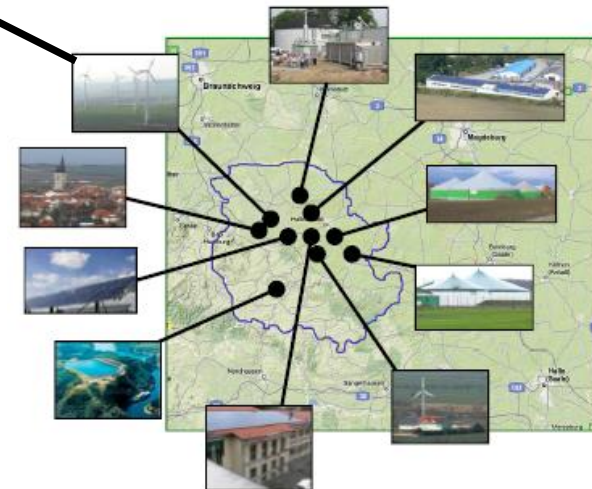
Source: www.hitachi.com



➤ Population: 241017 Area: 2104 km²

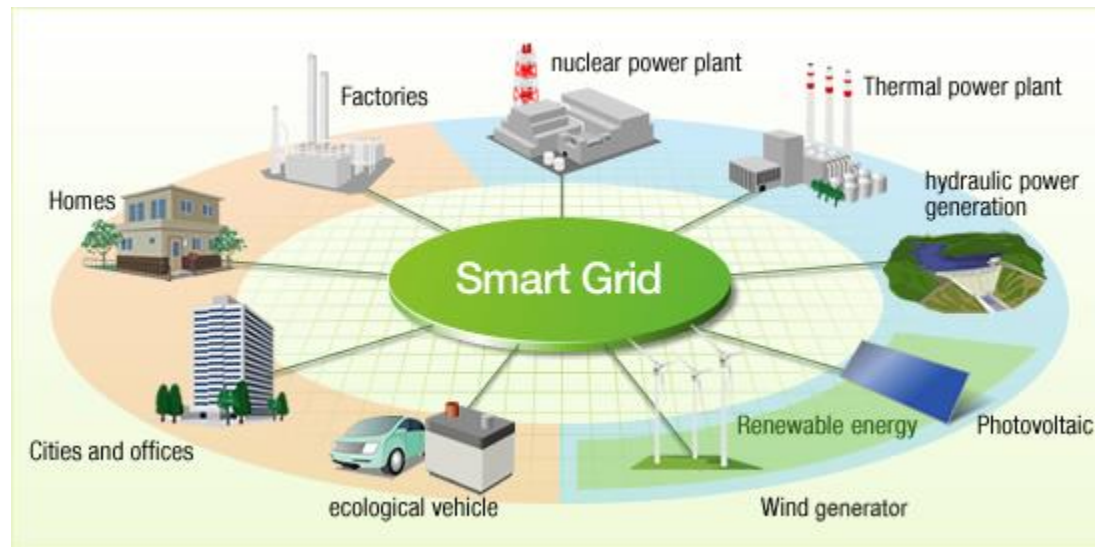
➤ Wind-parks, photovoltaic-parks, biomass, hydrostorage powerplant

- ✓ Control centre to manage renewables
- ✓ Testing of marketing system
- ✓ Measuring units for system monitoring



Challenges for the future

- The share of renewable energy sources will grow and will become the most important part in electrical energy generation in Germany
- The existing transmission network needs to be expanded to meet future requirements
- Smart grids and virtual power plants have a central role in the future energy system



Thank you for your attention!

2nd ELECON – Workshop

28.10.-29.10.2014

Otto-von-Guericke-University Magdeburg

M.Sc. Philipp Kühne

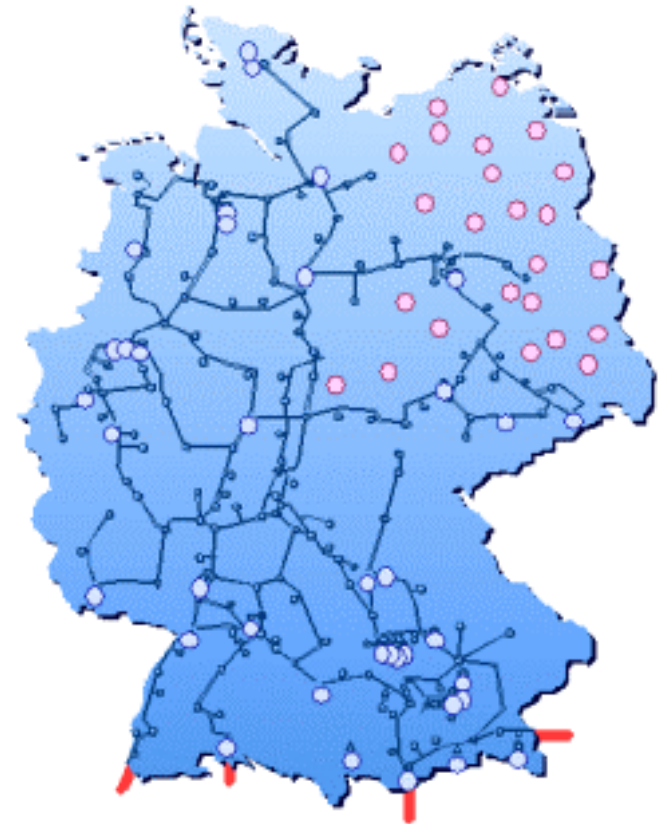


FAKULTÄT FÜR
ELEKTROTECHNIK UND
INFORMATIONSTECHNIK

The DB-network

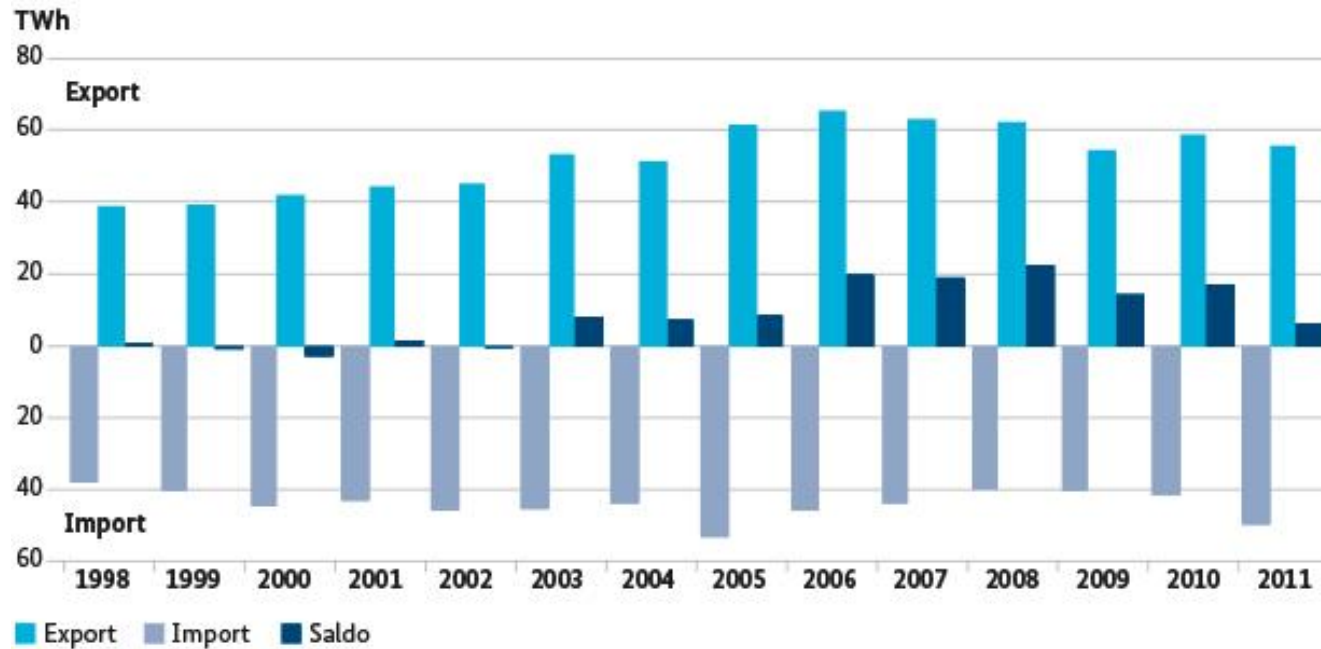


- Operated by Deutsche Bahn Energy
- 7.600 km overhead network (AC, 110 kV, 16,7 Hz)
- Biggest coherent 110 kV network in Germany



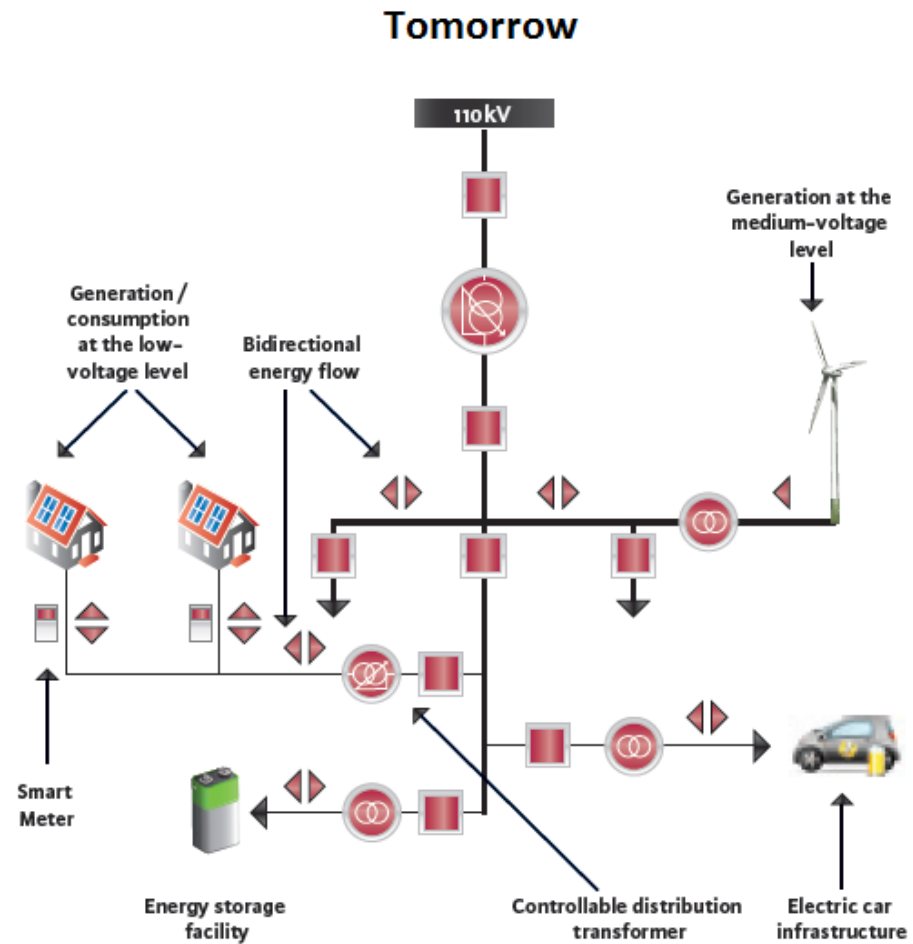
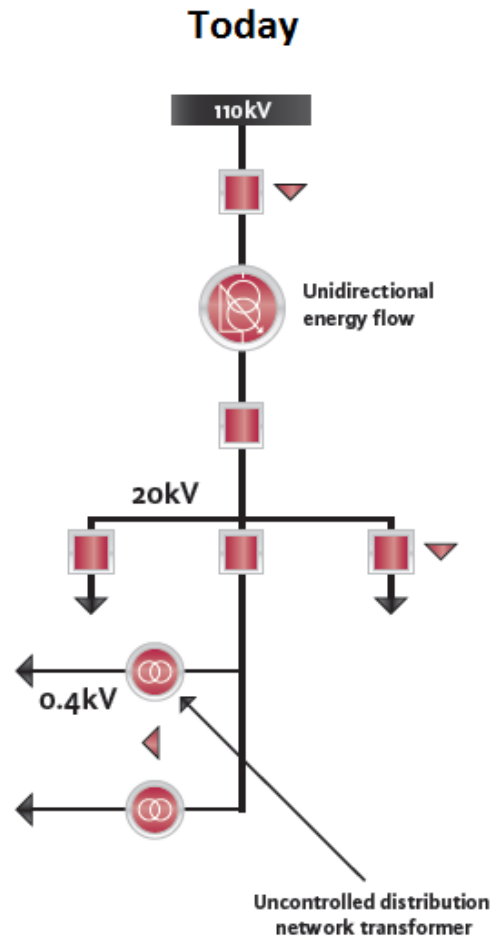
Source: www.energie-chronik.de

Electricity exchange with neighboring countries



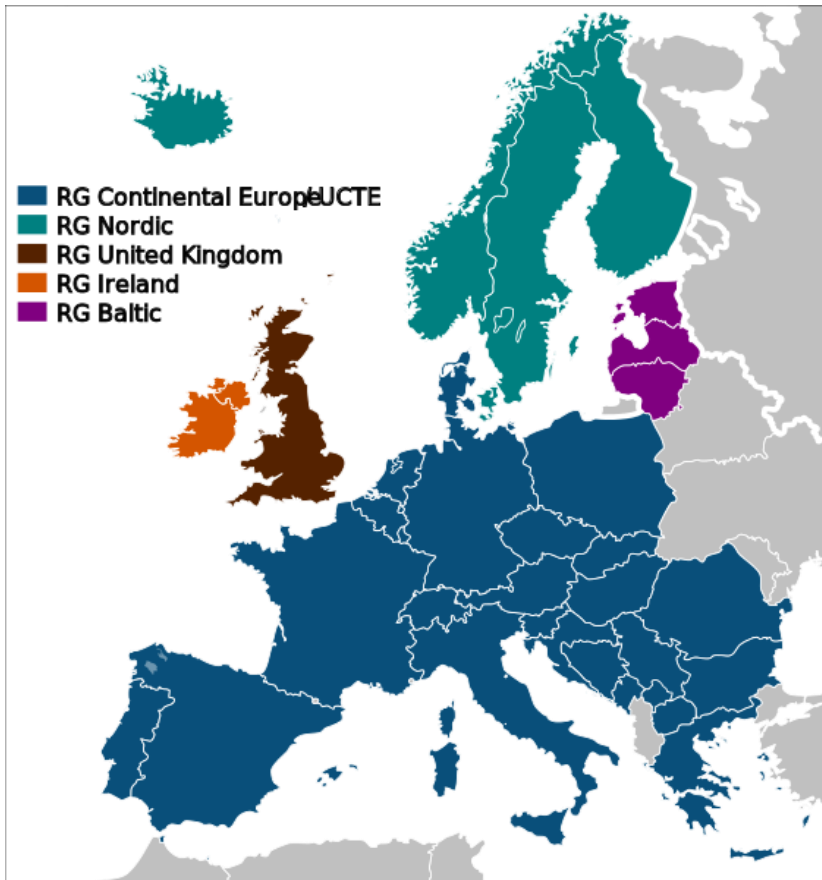
Source: www.bmwi.de

Change of the power system



Source: www.vde.org

Powertransmission in Europe

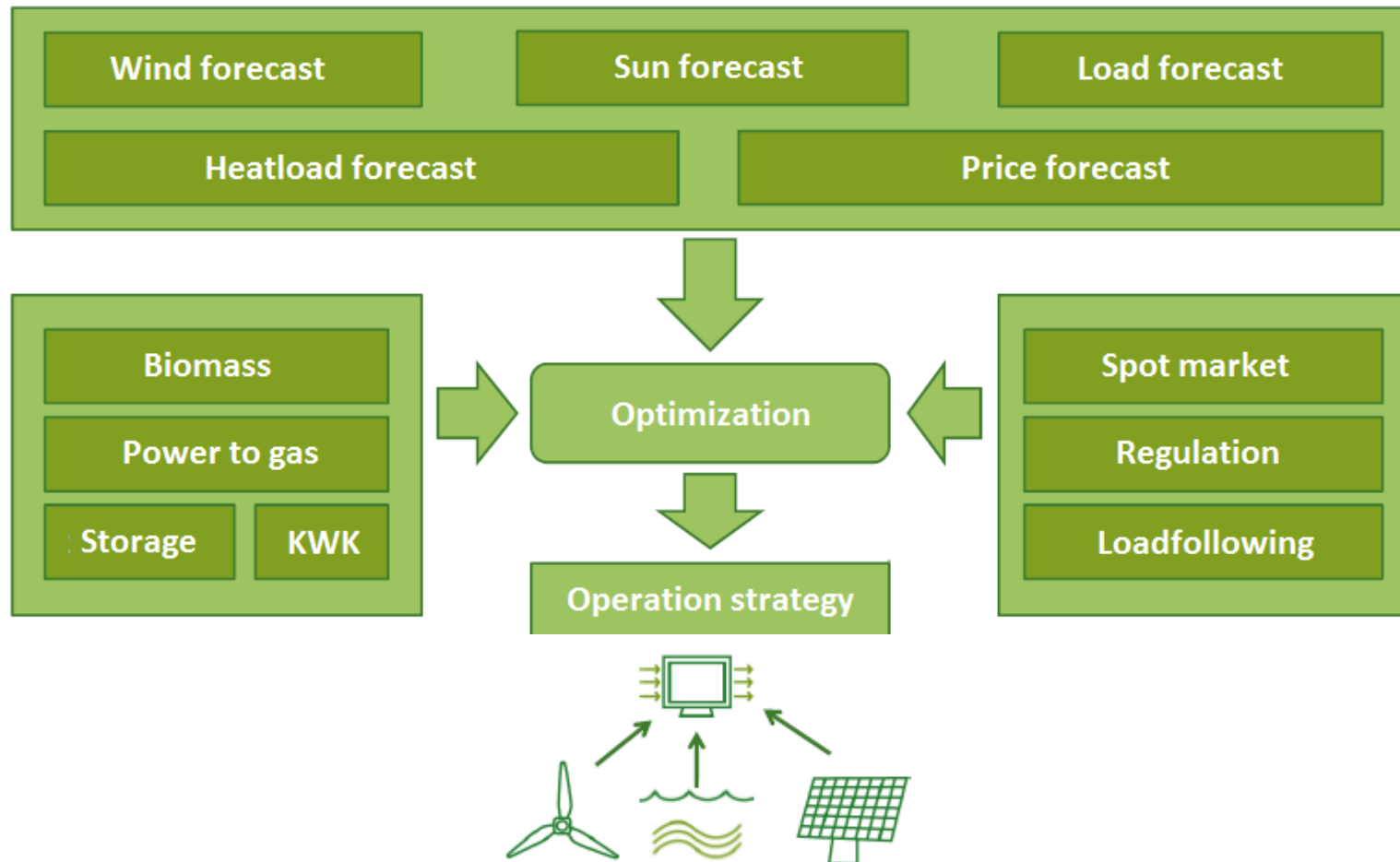


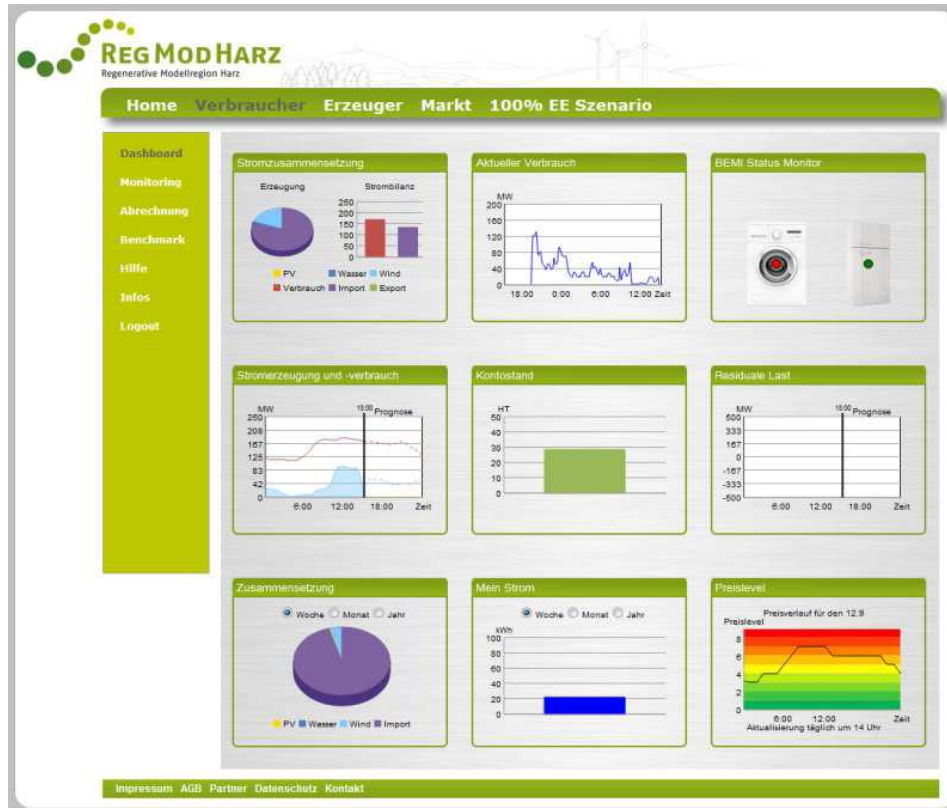
ENTSO-E

- Former UCTE
- 450 million people
- Lines 220/400 kV – 220.100 km
- Max – 391 GW
- Min - 190 GW

Source: UCTE 2006

Structure of the energy management system

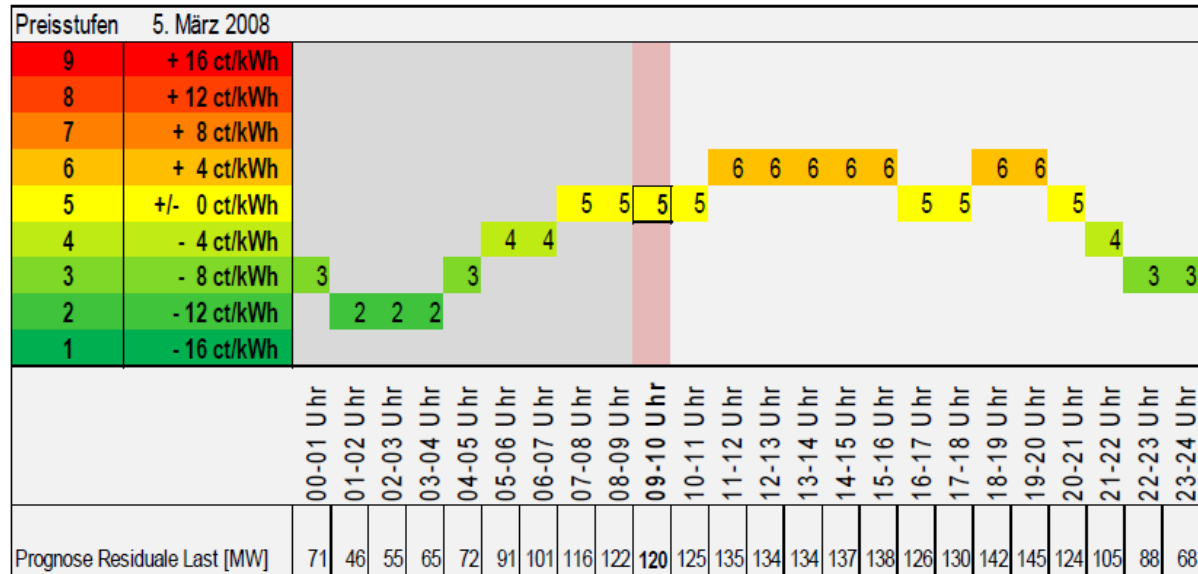




- Informations about the energy management
- Optimize the consumption behavior
- Market situation and prices
- Smart household appliances



Marketing system

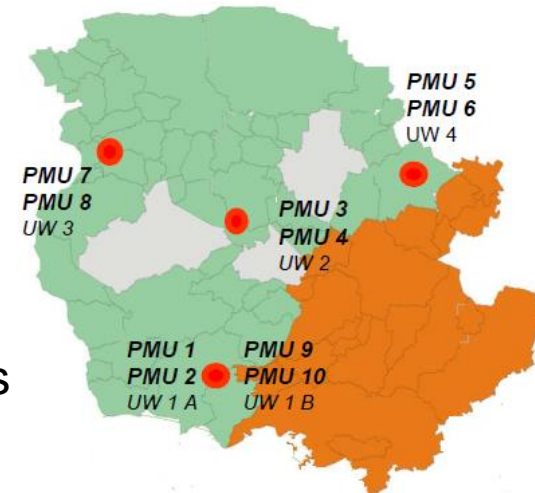
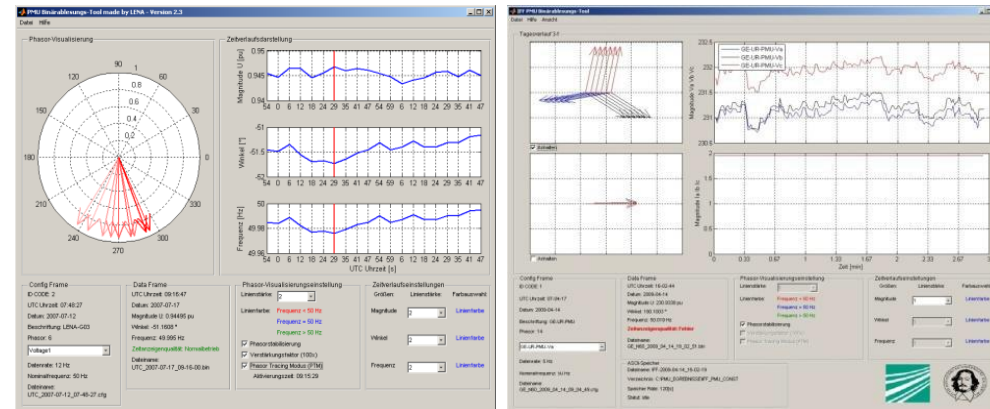


- Variable price model
- Peak load reduction about 10 % is possible

Measuring and monitoring

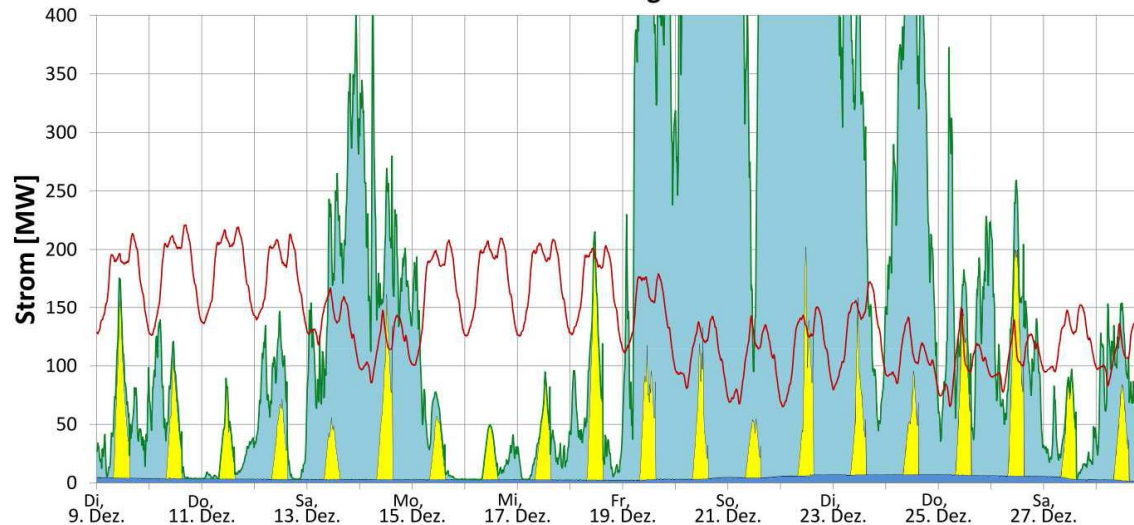
System state monitoring with phasor measuring units

- High precision time synchronization via GPS
- Sampling rate: 25/sec
- Standardized data collection (IEEE C37.118)
- Located by an optimization algorithm
- Disturbance tracing by Post-Disturbance-Analysis



Results

100 % - Erneuerbare Energien - Szenario



100% EE	[MW]
Installiert Wind	625
Installiert PV	708

- Required network extension without management system – ca. 1000 MW
- Required network extension with management system – ca. 500 MW

Source: www.e-energy.de