Kombikraftwerk 2 - Renewable Power Plant Germany: ancillary services with 100% Renewable Energy

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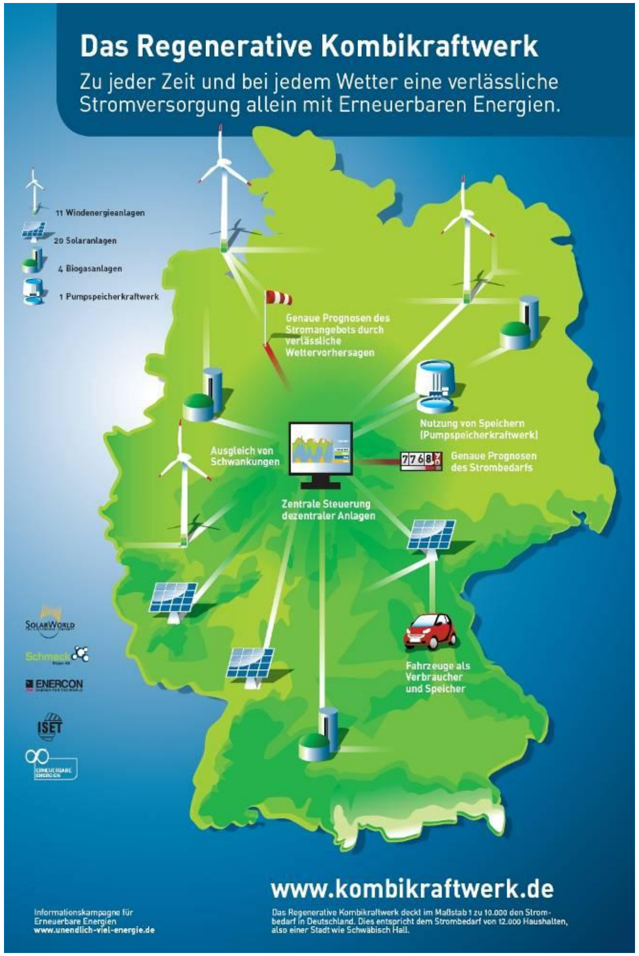
Kombikraftwerk 2

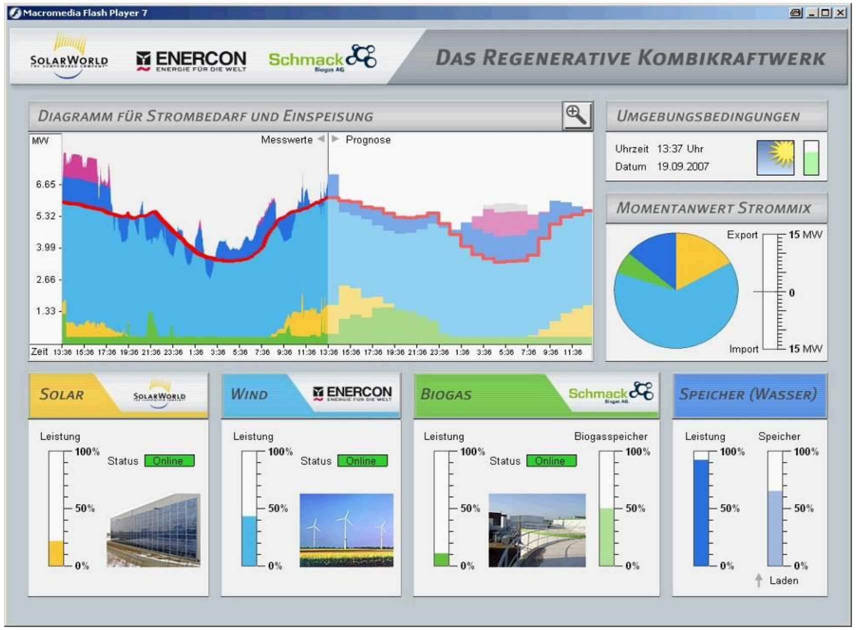
Retrospective "Kombikraftwerk 1"



- **Conclusion:** October 2007
- **Goal:** Proof of feasibility of a 100% renewable power supply
- **Approach:** Communication connection of renewable systems to a virtual power plant

  System conditions in accordance with estates of potentials

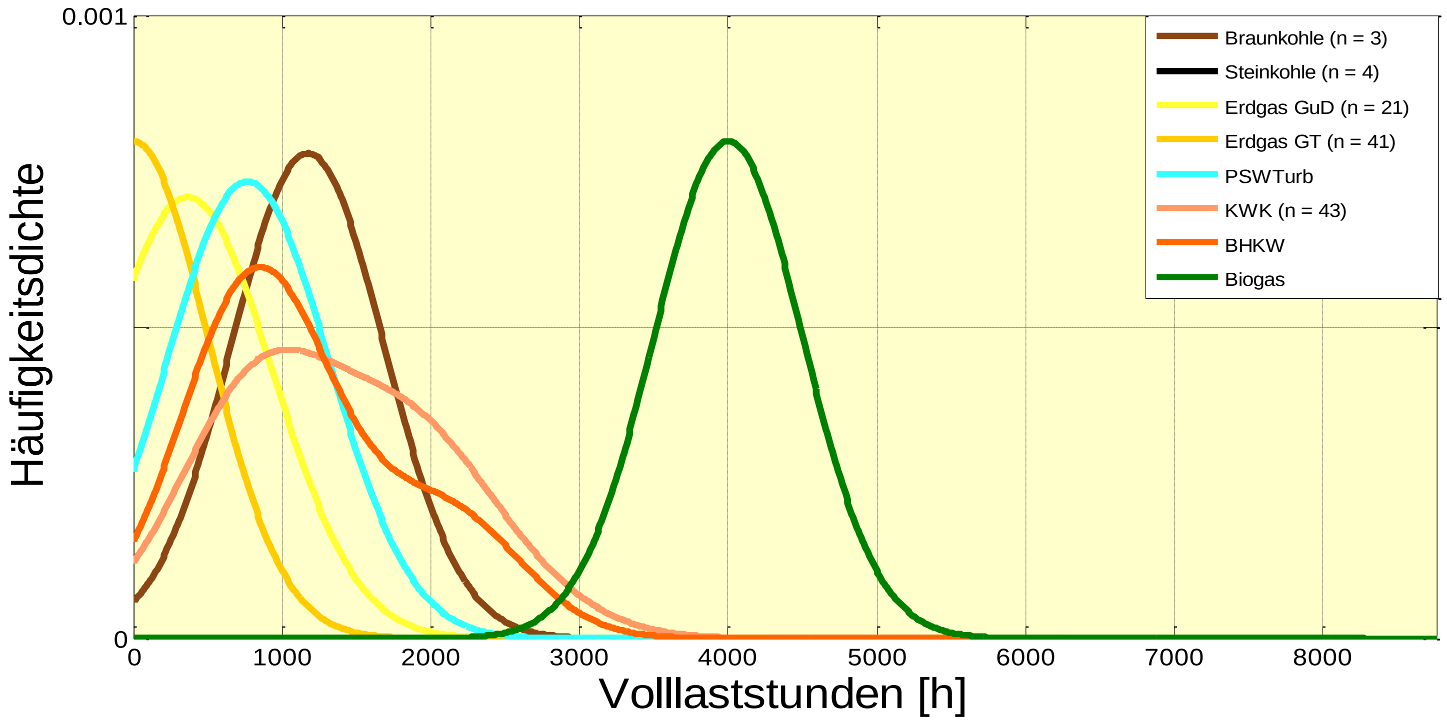
Retrospective "Kombikraftwerk 1"



- **Demonstration:** Coverage of 1/10,000 of the German electricity consumption at any time.
- **Result:** Germany's electricity consumption can be met completely by domestic renewable energy sources at any time.
- ➢ Supply reliability!
- **Open question**: Is a 100% renewable power supply also technically reliable/stable?
- ➢ Supply quality?

  (Quality of voltage and frequency, grid stability)

Development of existing power stations in Germany



Source: BMU Leitstudie 2011 (2020/2050)

The follow-on project "Kombikraftwerk 2"

Kombikraftwerk 2

Gefördert durch:

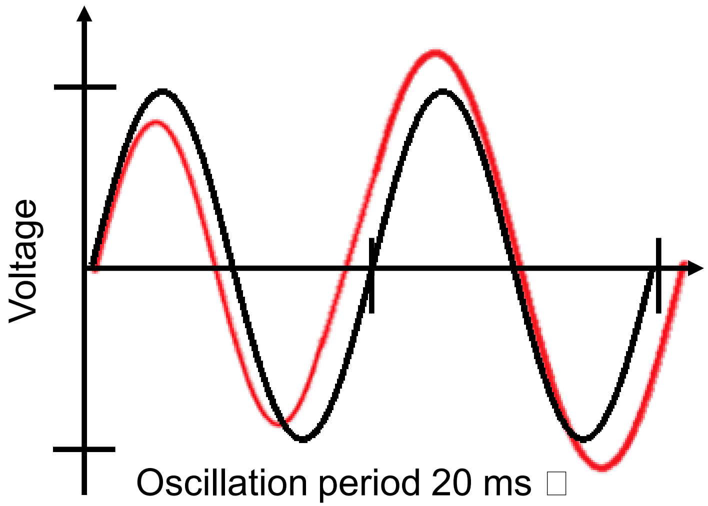
Bundesministerium
für Umwelt, Naturschutz
und Reaktorsicherheit

aufgrund eines Beschlusses
des Deutschen Bundestages

- **Goal:** Examination of the stability of a power supply in Germany consisting 100% of renewable energy

  (the heat and transportation energy sectors, as well as economic questions were not examined)
- **Sponsor:** The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU)
- **Project volume:** 3.053 million euros
- **Total funding:** 1.810 million euros
- **Project term:** 3 years
- **End of the project:** December 2013
- **Parties involved:** 10 project partners from science, industry and services
- **www.kombikraftwerk.de**

Explanations on grid stability



Oscillation period 20 ms
Frequency (50 Hz)

- Frequency and voltage must be within the tolerance range
- ➢ Ancillary services "frequency and voltage control"
- Frequency represents the balance between generation and consumption in the overall system
- By contrast, voltage differs locally and depends on the grid
- ➢ Grid stability analyses require a geographically precise representation of the electricity generators and consumers including the grid structure

Simulation of the future electricity generation with RE

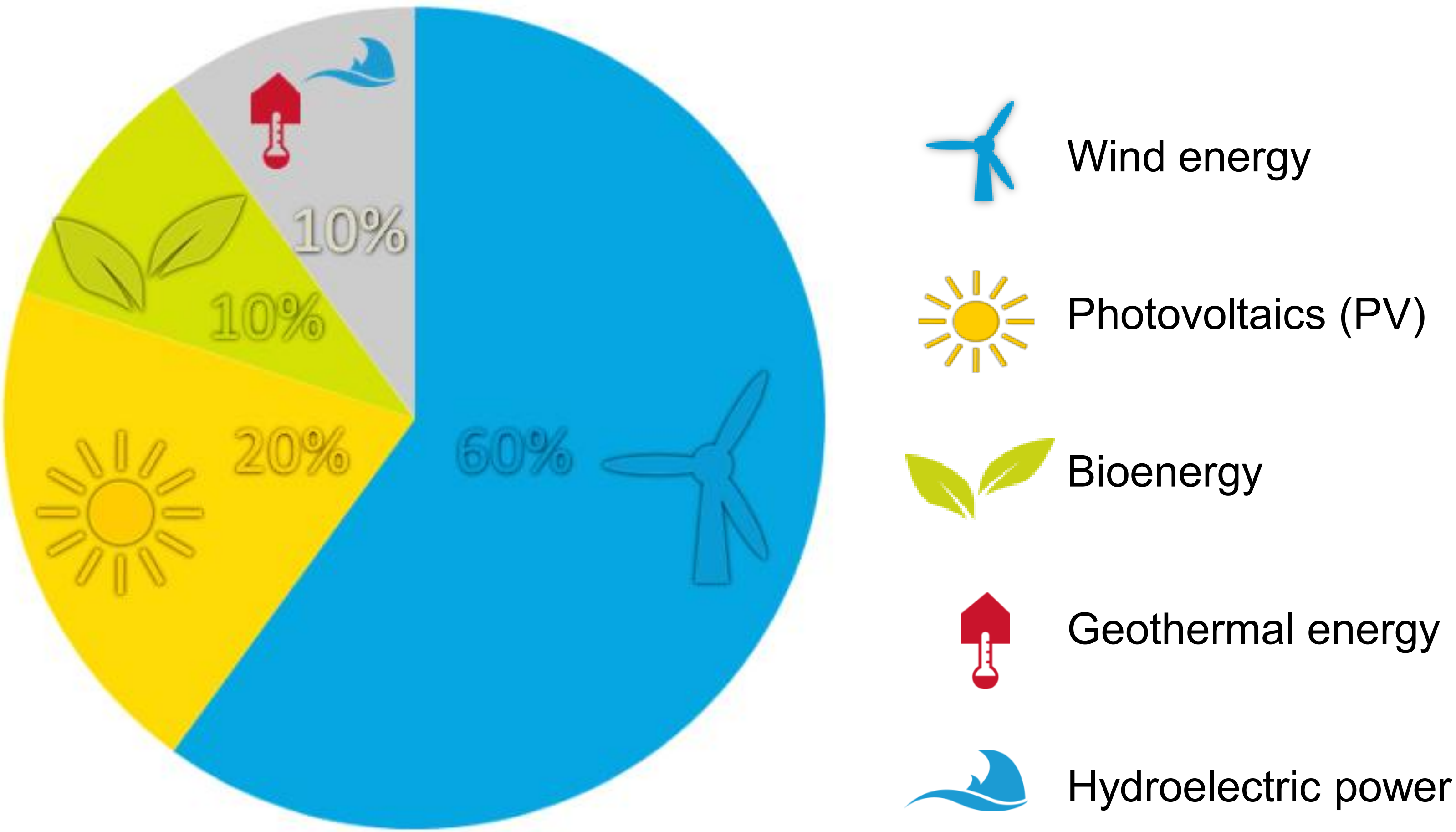
<u>Development of a consistent, geographically high-resolution scenario</u>

- Energy mix approach
- Detailed modelling of the future power station network
- Determination of the storage demand
- Determination of generation peaks, excesses and deficits
- Where and when do extreme frequency and voltage situations occur in the future system?

<u>Examination of the system stability</u>

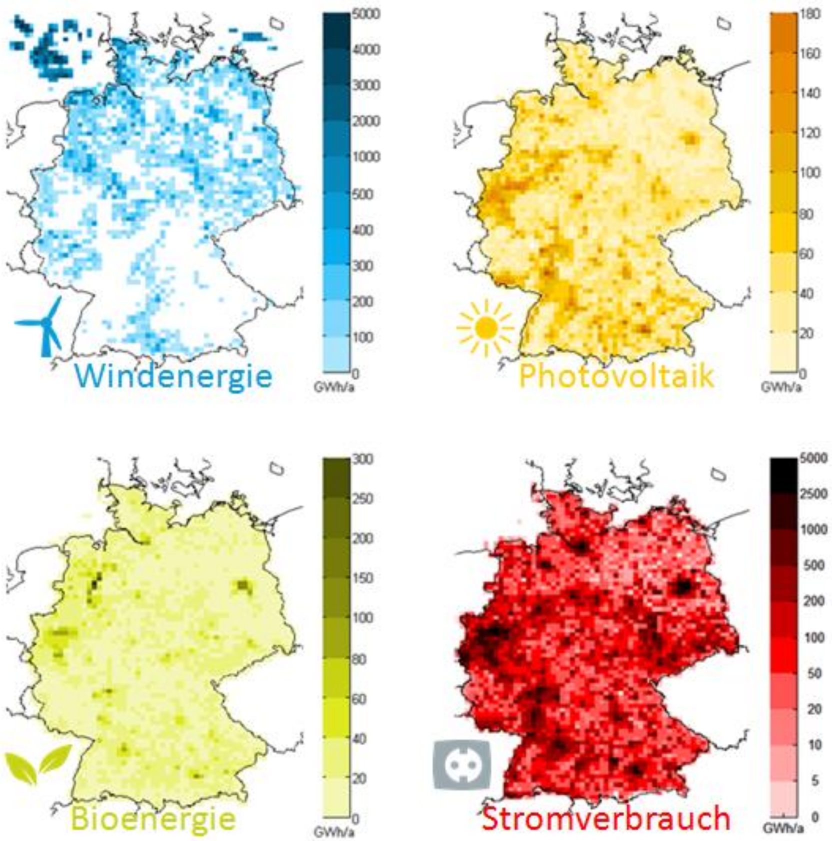
- What is the demand for balancing energy and reactive power in the system?
- Can all required ancillary services in the system be provided?

Energy mix used to meet the electricity consumption



Primary energy generation

Modelling the geographic distribution

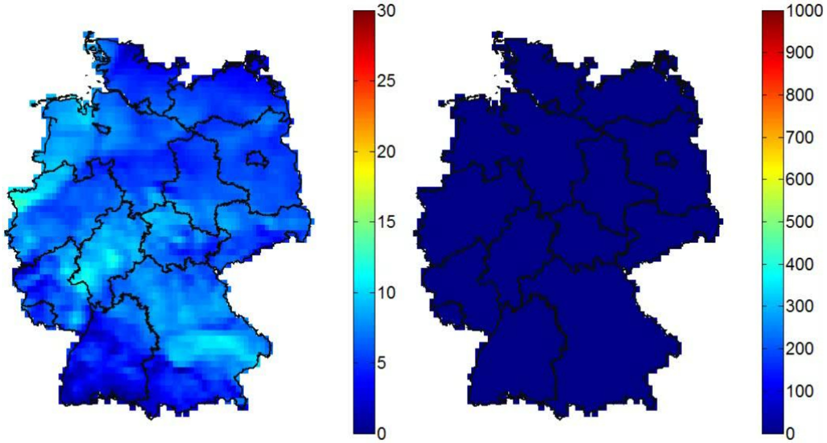


- High variety of technology:
  - ✓ 5 wind turbine classes
  - ✓ 5 PV system types
  - ✓ 10 bioenergy types
  - ✓ Geothermal power
  - ✓ Hydroelectric power
  - ✓ Methane power stations
  - ✓ 4 energy storage types
  - ✓ 7 electricity consumption areas
  - ✓ Imports and exports
- Incorporation of potential sites, present distribution and weather conditions
- Uniquely high geographic resolution (pinpoint accuracy or 100 m x 100 m)

➢ Interactive scenario map

Chronological properties of the power supply system

Wind speed [m/s] Solar irradiation [W/m²]



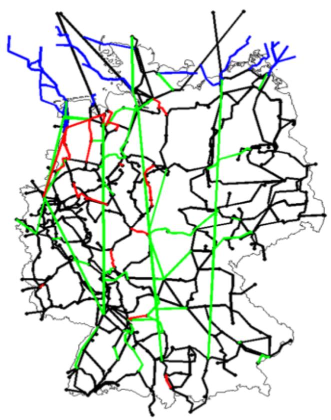
Transmission grid model

Present grid

+ Offshore connection

+ dena1 + GDP2012

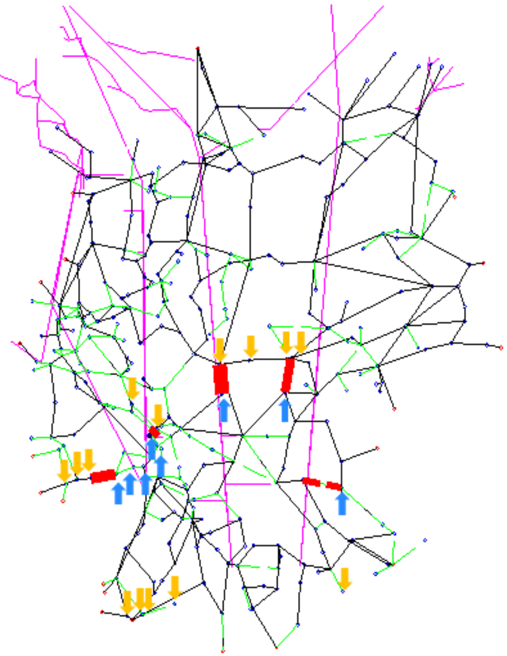
+ Own additional construction

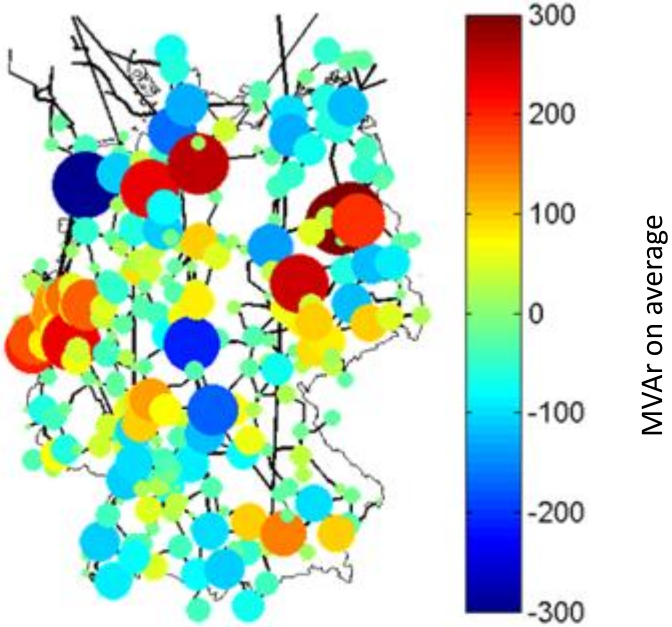


- Weather-dependent generators
  - High-resolution historic weather model data from the German Weather Service (DWD)
  - Physical models. E.g. system characteristics, mutual shading effects (wind), orientations, pitch angles (PV)
- Consumption
  - Historic load time series
  - Standard load profiles
  - Load management strategies
- Compensating system (bioenergy, storages, methane power stations)
  - Determination of the capacity and localisation via cost-optimising use and design calculations

➢ Power flow animation

Grid-specific stability calculations

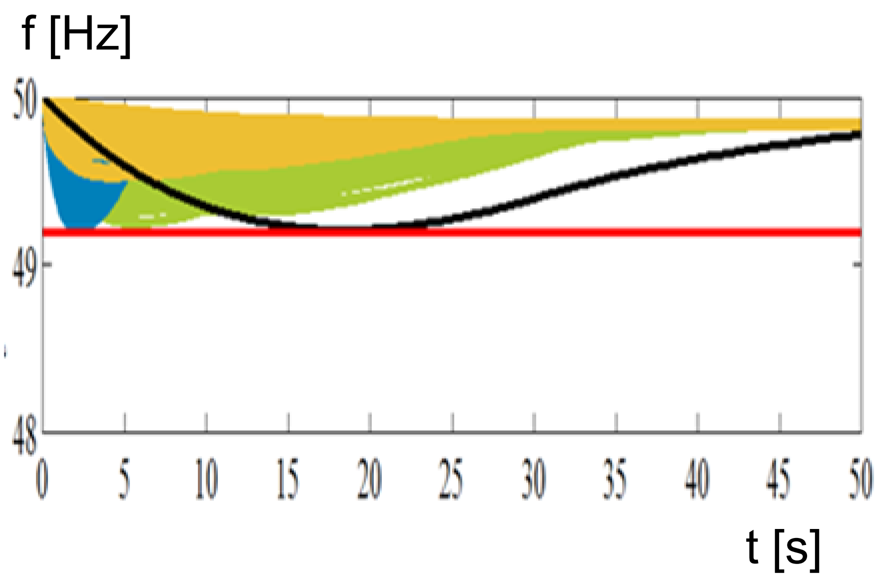


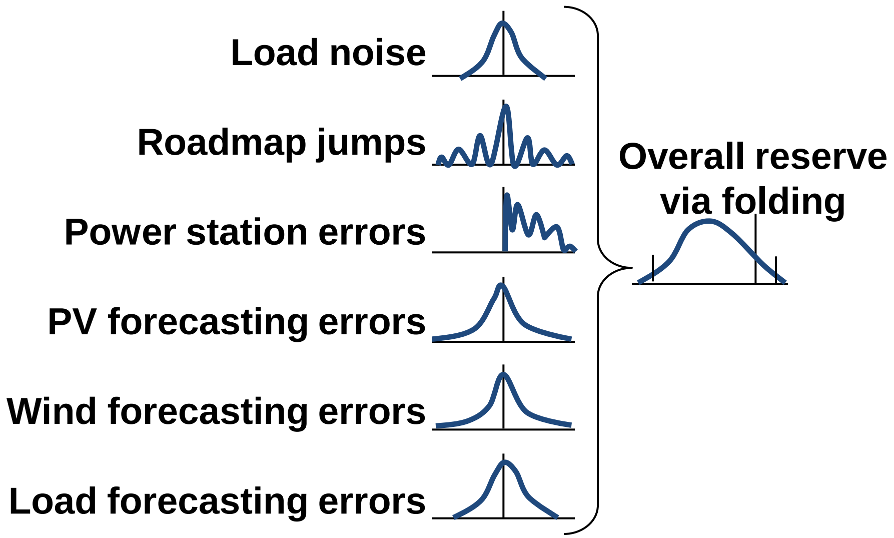


- **Grid bottlenecks** due to n-1 security considerations
- **Grid bottleneck management** via a variety of decentralised generators

- **Reactive power requirement** via AC load flow calculations
- **Reactive power provision** based on estimates of the influence of the connected generators

Frequency stability calculations



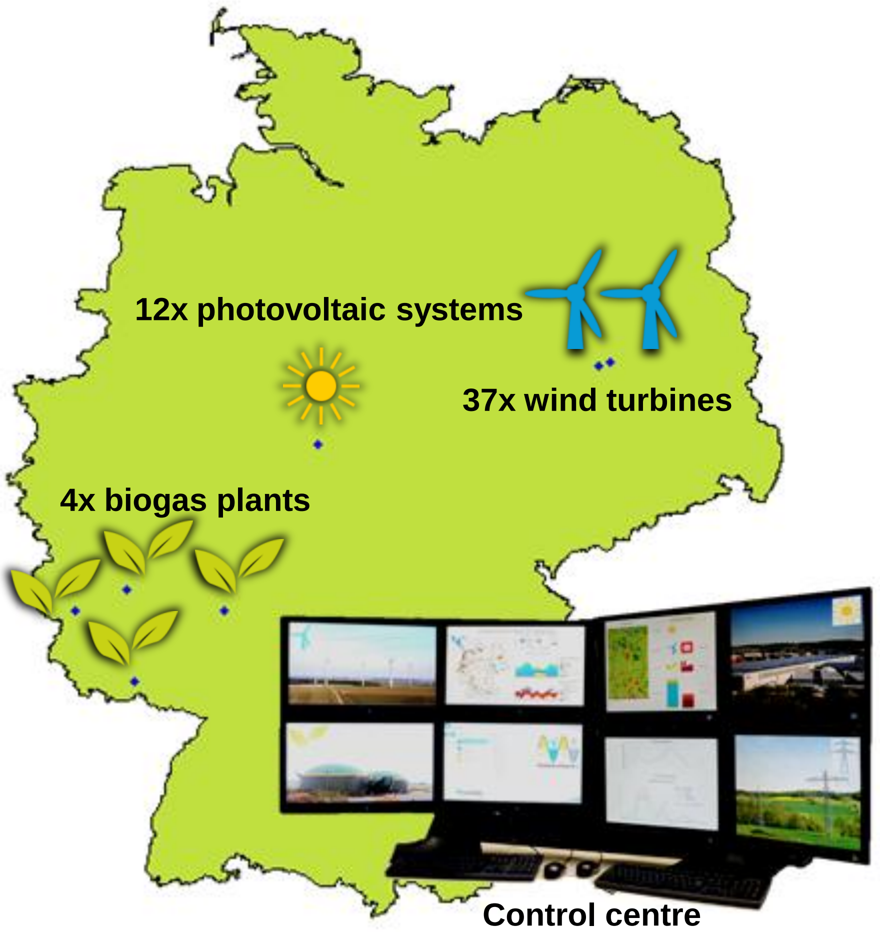


- **Dynamic frequency drop** after generation failure
- **Dynamic frequency rise** via increased control speed of the REs

- **Control reserve requirement** via dynamic process
- **Provision of control reserve** via economic optimisation with energy dispatch planning

Control reserve demonstration

- First demonstration of the provision of balancing energy via a combination of wind, solar and bioenergy systems
- Active & intelligent power management of the extensive combined system with split-second accuracy
- Innovative control concept:
  - Probabilistic power forecasts on the basis of current weather forecasts
  - Determination of the possible feed-in for solar energy systems & wind turbines for implementation and verification of the balancing energy provision



Project Results

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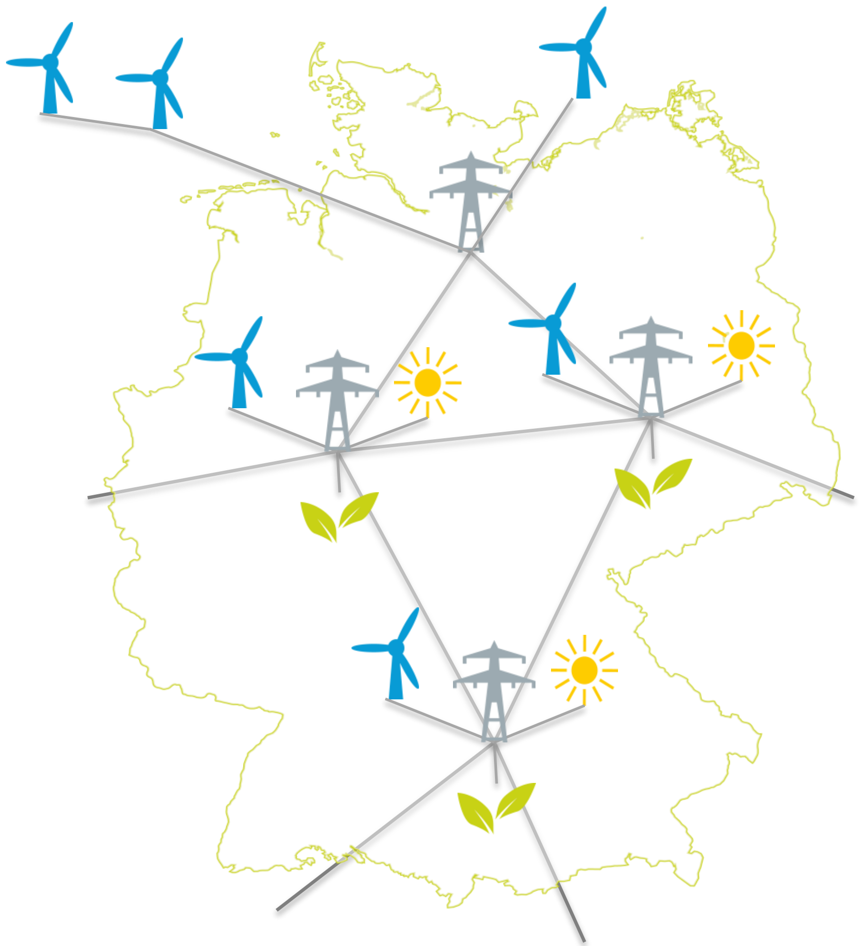
The calculations show:

A reliable and stable electricity supply for Germany from 100% renewable sources is technically possible in the future

if renewable generation, storage and backup power stations interact intelligently with renewable gas.



The model experiment showed:

Renewable energy sources can already technically provide important ancillary services today.

The framework conditions for market and system integration must be adapted for this.

In order to guarantee grid reliability, decentralised renewable energy systems must also be monitored and managed with secure and powerful communication standards.

Linking them in virtual power plants increases the scope for action.

Thank you very much for your attention

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