Flexibility options for integrating variable renewables in power systems

Experience from Germany and the EU

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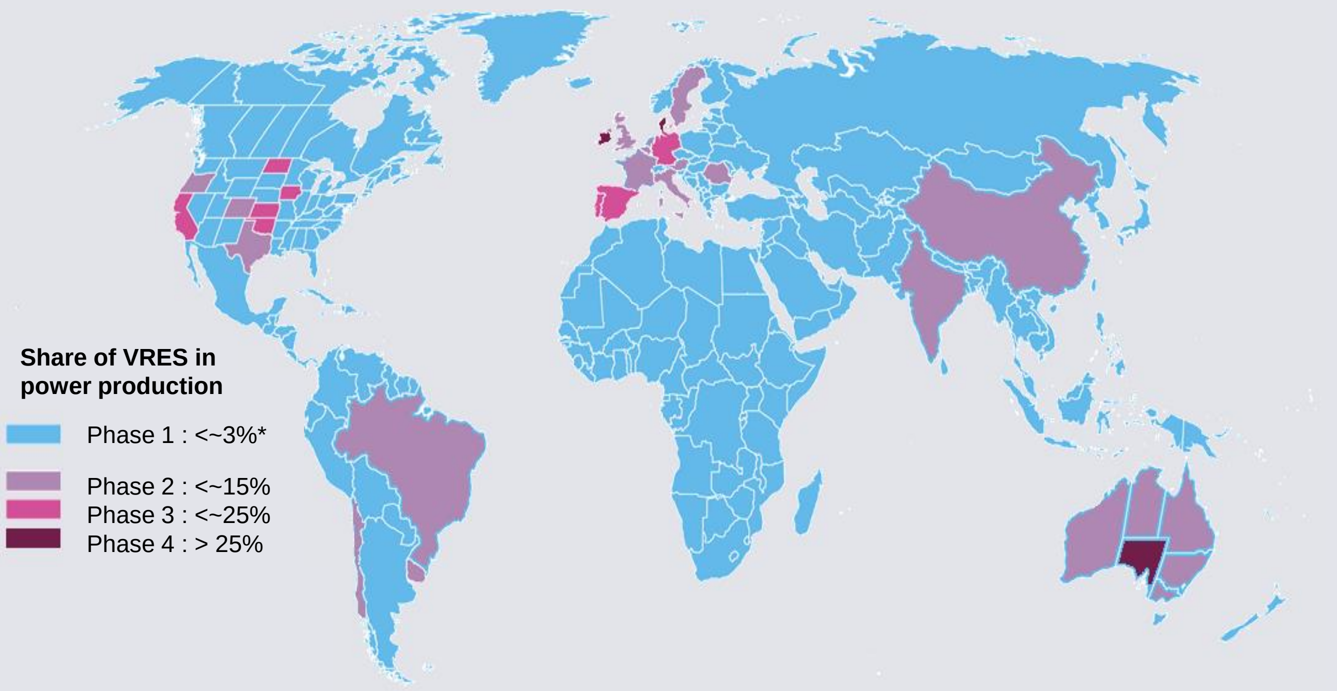
Integrating wind and solar energy poses different challenges depending on the system and the share of renewables

Different phases of power system transformation depending on the share of VRES



Own illustration based on World Energy Council, IEA, EIA.

1st phase*: the impact of variable renewables is insignificant at system level, but can be a local challenge. **Priority** : regulatory, financial, technical framework supportive for RES development

2nd phase: impact of RES starts to be perceived by operators. **Priority:** moving operational practices closer to real-time ; integrated resource/grid planning and clever incentives to support RES.

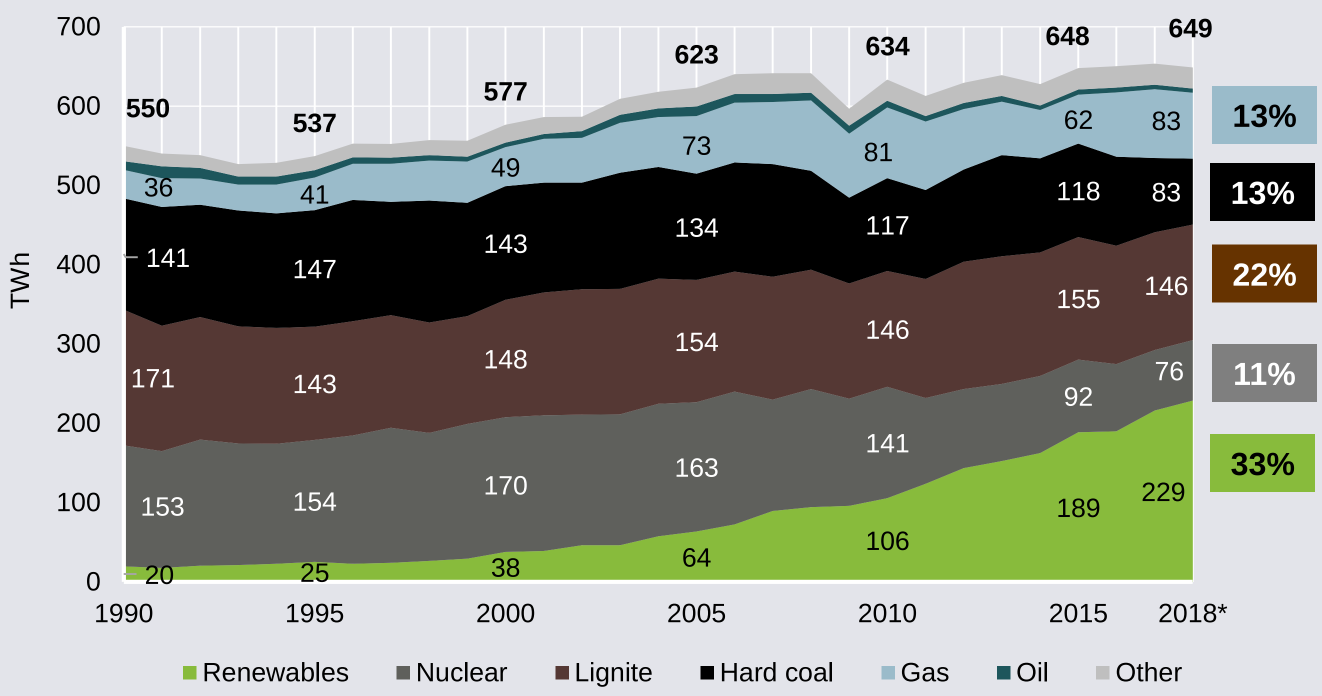
3rd phase: flexibility is the new paradigm. Short-term (and locational) values of power guide investment and operation practices. **Priority**: Abating inflexibility in regulation, market design and planning

4th phase: power system stability can become critical (especially in island systems). Sector integration becomes a key flexibility (and decarbonization!) option. **Priority**: innovation and technological development

*The threshold values between phases are indicative. They depend on the specificities of each system!

In Germany, renewables have grown significantly and cover 33% of power production in 2018

Gross power generation by type 1990 – 2018

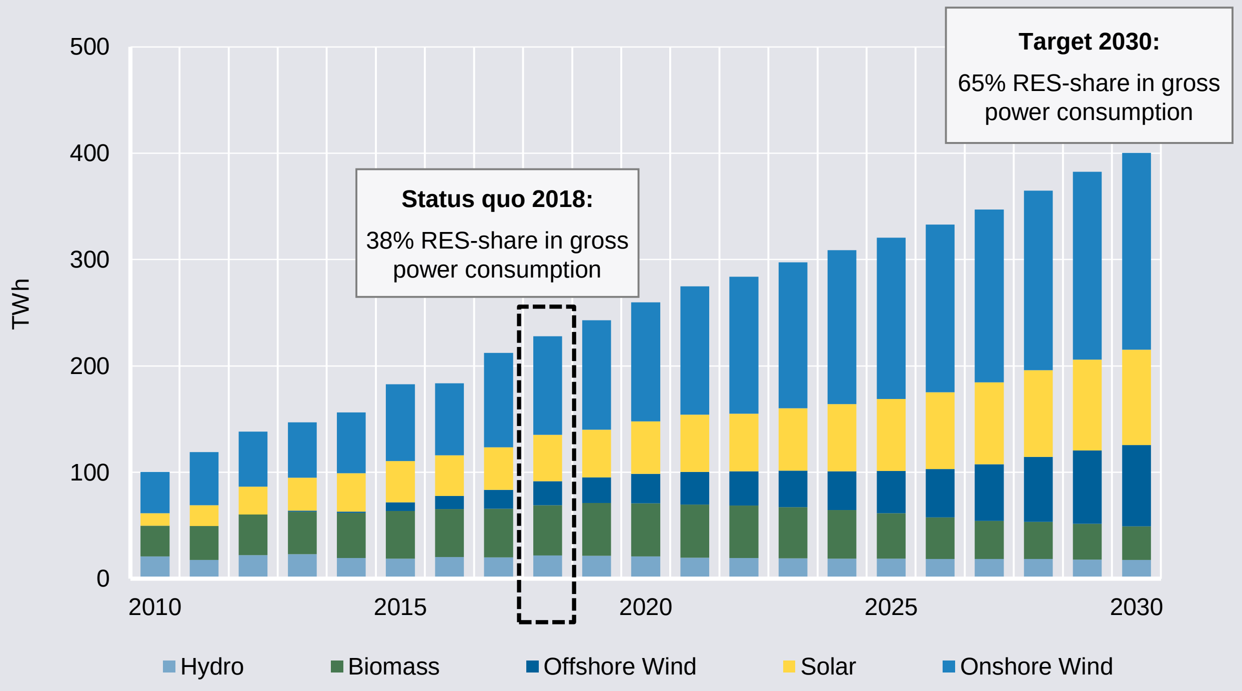


AG Energiebilanzen (2018a), *preliminary data

- Wind and solar energy alone cover 24% of power production in 2018.
- Renewables development has been driven by a supportive investment framework that has been continuously adapted to foster system and market integration.
- As of today, wind and solar energy are cost competitive with new conventional electricity generation sources.

The key insight for the German Energy Transition: It's all about wind and solar!

Gross power generation from renewables, 2015 - 2030

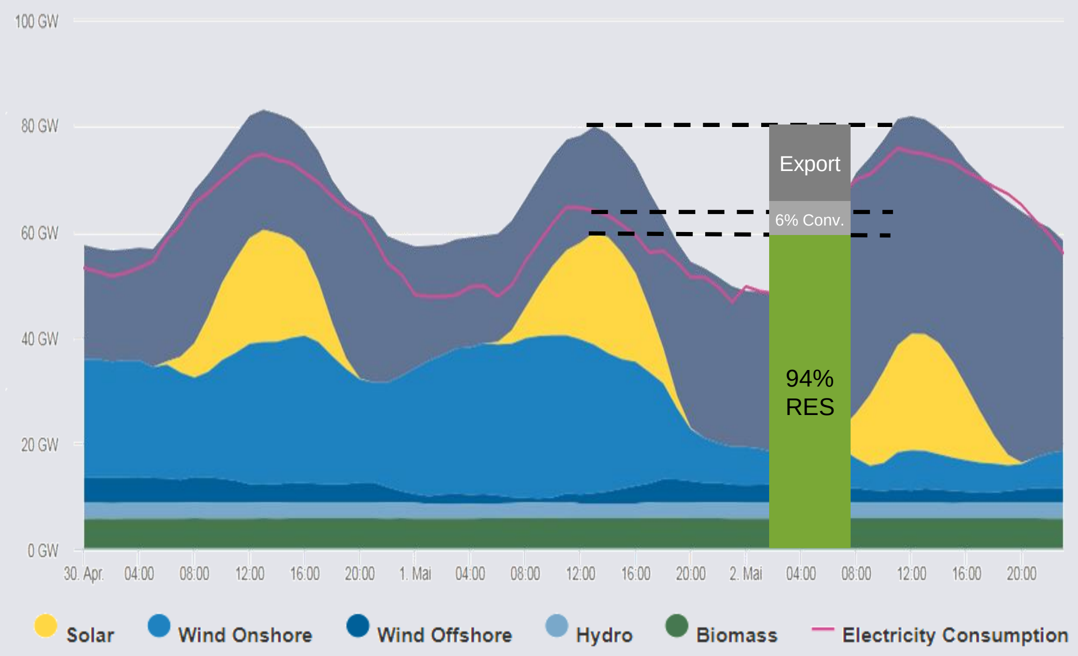


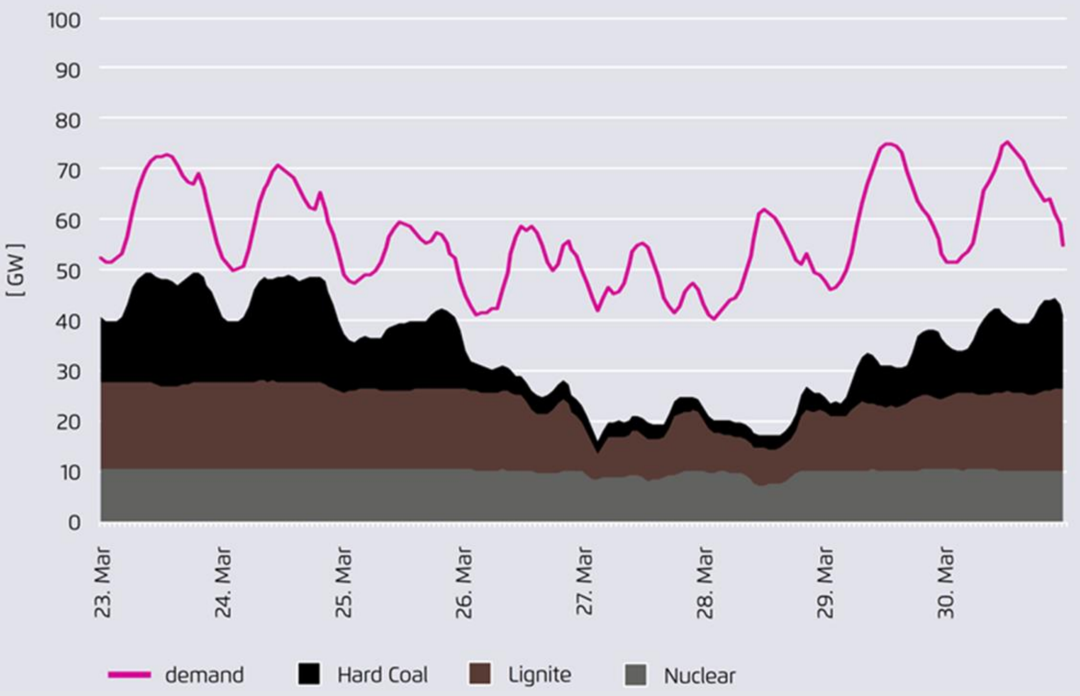
AGEB, own calculations based on Öko-Institut

- → According to the government plan, the share of RES in in the gross power consumption shall increase to 65% till 2030 against 38% in 2018.
- → In 2018, the cumulative installed capacity of variable renewables reached 120 GW (for a max peak demand around 82 GW):
  - 54 GW onshore wind (+3 GW since 2017)
  - 6.3 GW offshore wind (+1 GW since 2017)
  - 46 GW PV (+3 GW since 2017)
- → Primarily wind and PV shall be expanded, because the latter are the least-cost options in Germany and the potentials for other RES is constrained:

Flexibility has become the new paradigm. Baseload is an obsolete concept!

Electricity generation in Germany 30.4-2.05.2018 (links); Power generation from nuclear, hard coal and lignite power plants and demand in Germany, 29.04-06.04.2018;(right)

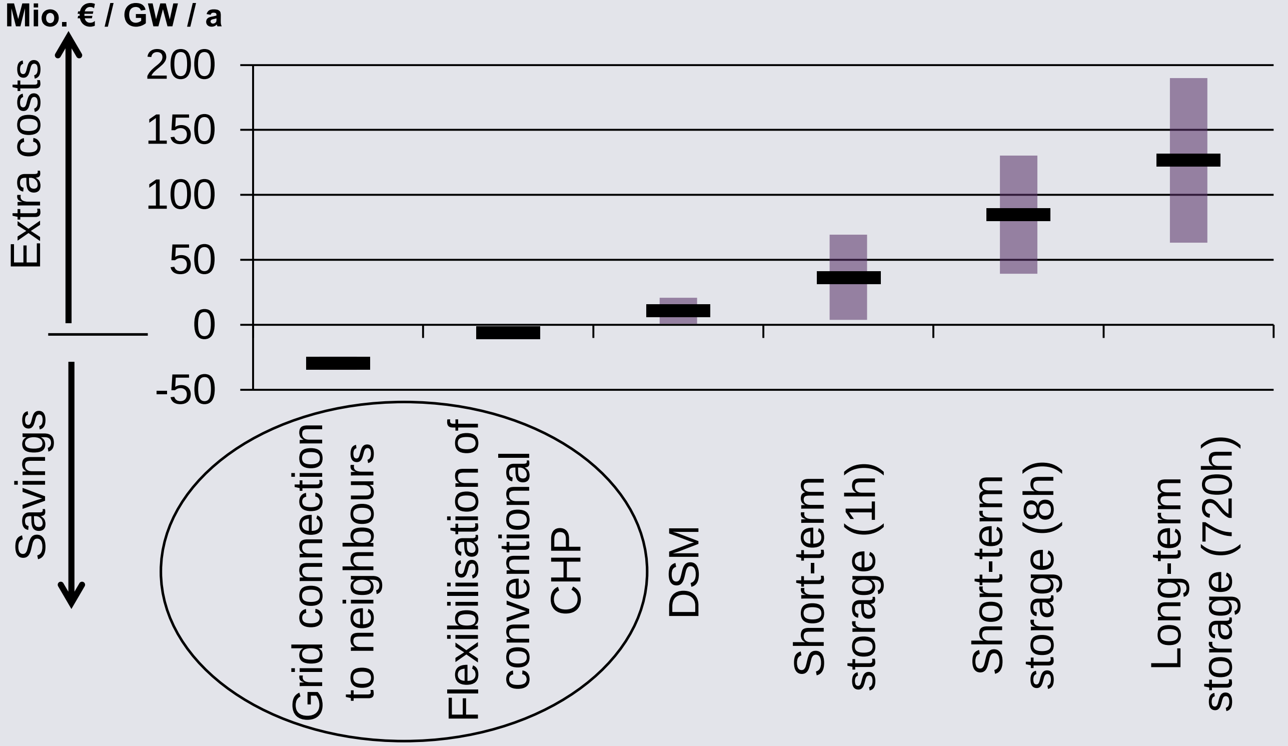




Agorameter - Agora Energiewende (2018)

Various technologies can provides flexibility. A cost-benefit analysis of flexibility option provides the basis for better planning and better regulation

Costs/savings of one GW of flexibility in Germany (43% renewable scenario)

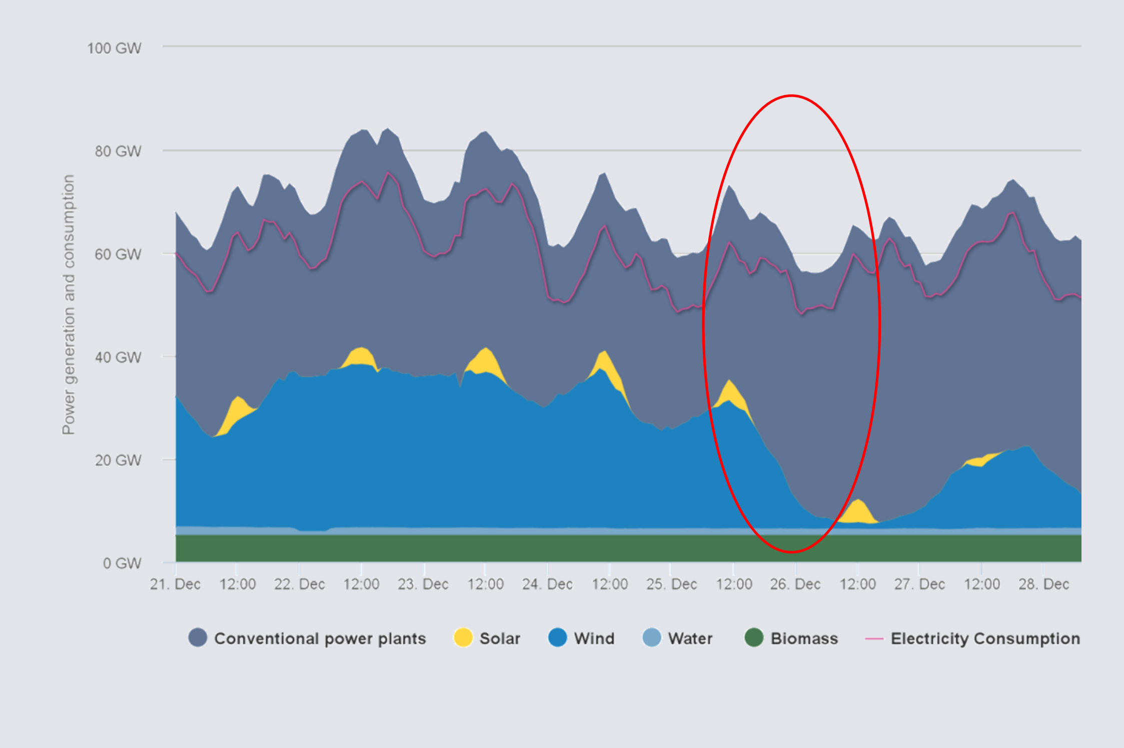


Agora Energiewende

- Grids, flexibilization of conventional generation, demand side management (DSM) are the cheapest flexibility options in Germany.
- In Germany, the flexibility needs are so far nearly mostly met by flexible power plants and interconnectors with neighbours
- From an overall system perspective, new storage is required only at very high shares of renewable energies.
- But short-term storage can today deliver several ancillary services at competitive costs. Furthermore, they can help avoiding distribution grid expansion.

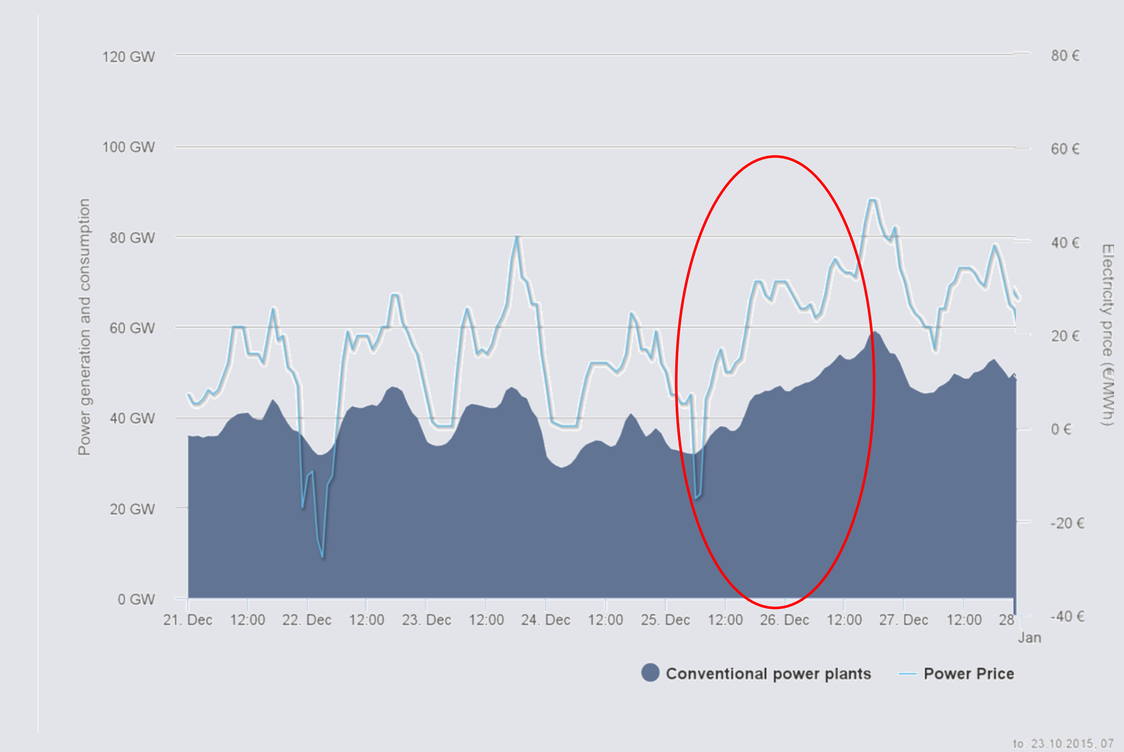
We need a flexible power system to manage steeper ramps and to provide backup capacity for longer periods with little vRES in-feed

Demand and power production on December 21-27, 2014



Agorameter (Agora, 2015)

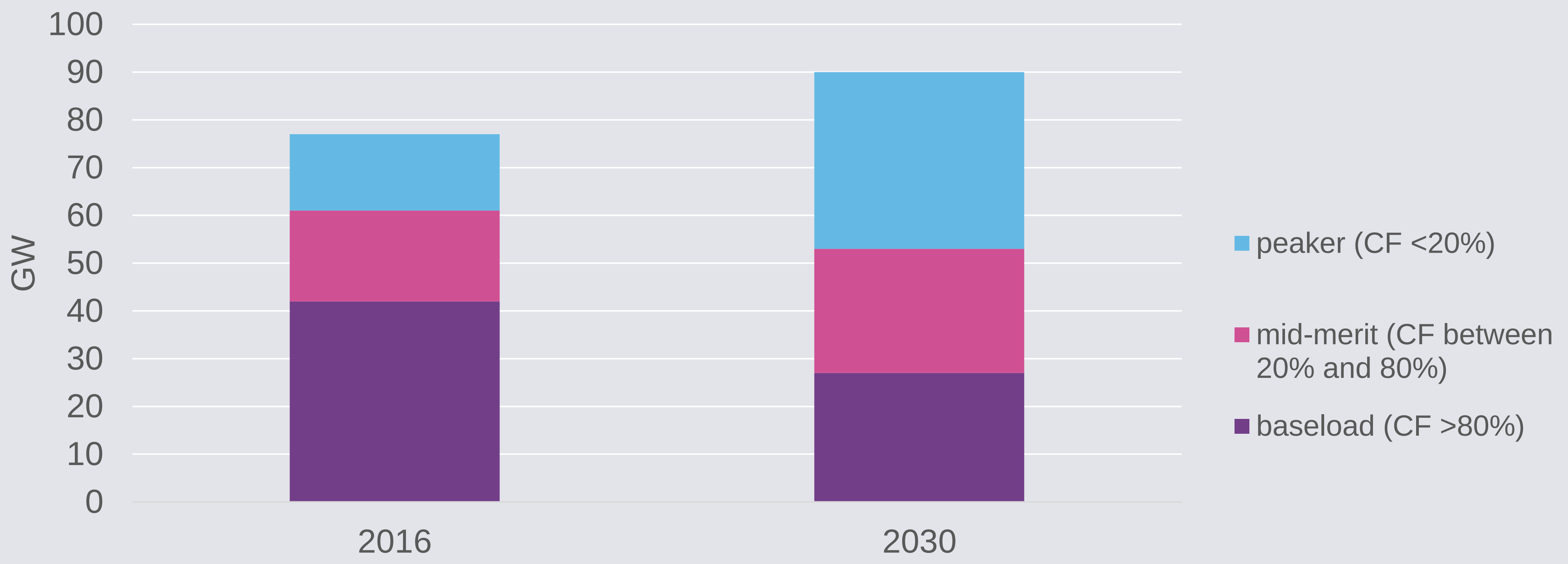
Conventional power and spot market price on Dec 21-27, 2014



Agorameter (Agora, 2015)

The variability of renewables shifts the cost-optimal structure of the portfolio of conventional power plants

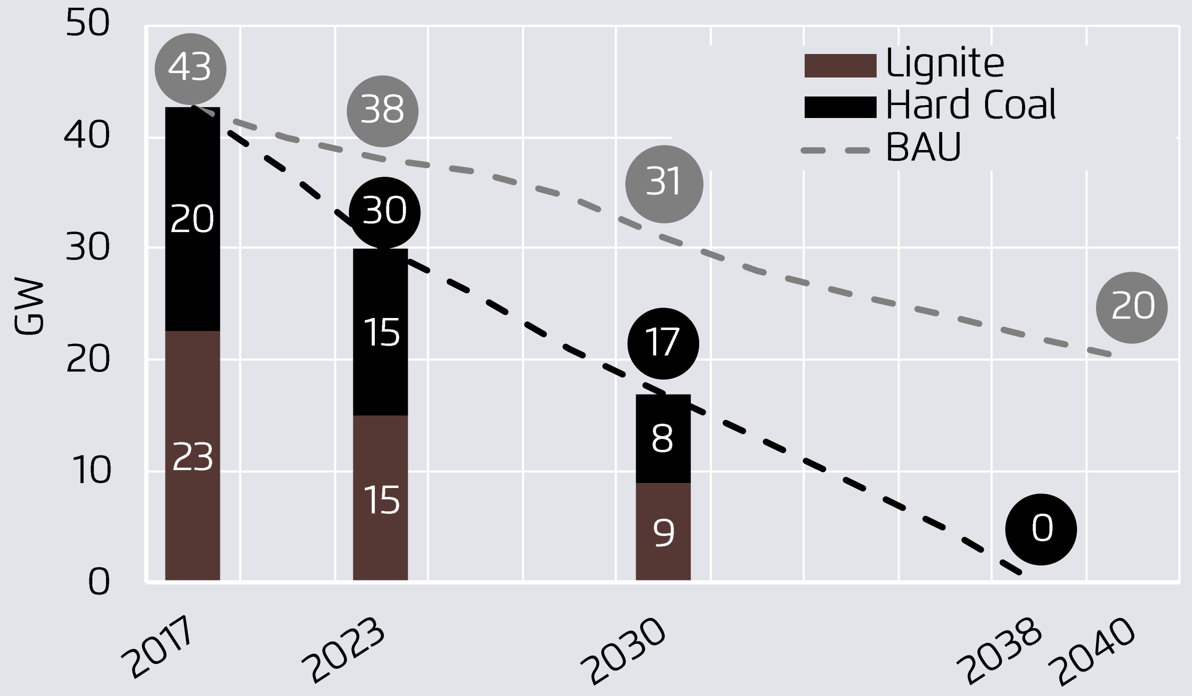
Structure* of the residual power plant park in Germany in 2016 and 2030 (65% renewables).



Agora Energiewende, Artelys Crystal Super Grid. *The structure is derived from assumed capacity factor (CF) values: Plants with a capacity factor of 80% or larger (>7000 full load hours), a capacity factor between 20% and 80% (1750-7000 full load hours) and a capacity factor smaller than 20% (<1750 full load hours) are shown.

Legacy investments in lignite and hard coal power plants are stumbling blocks of the energy transition

Installed capacity vs. peak demand EU (left) Installed capacity in a German coal consensus path (right)

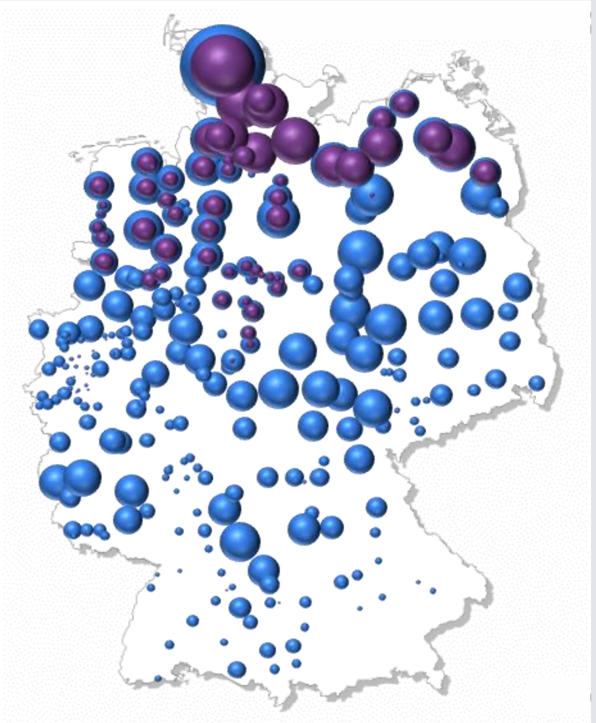


Agora Energiwende (2016)

- Increasing share of flexible resources and decreasing share of inflexible resources should go hand in hand with a growing share of variable renewables
- National managed retirement of old, high-carbon, inflexible capacity ("coal phase out") prerequisite for successful market integration of renewables & to support shift to a more flexible mix of conventional generation
- In January 2019, the Commission "Growth, Structure Change and Employment" agreed upon a coal phase-out plan for Germany with comprehensive measures for the coal region

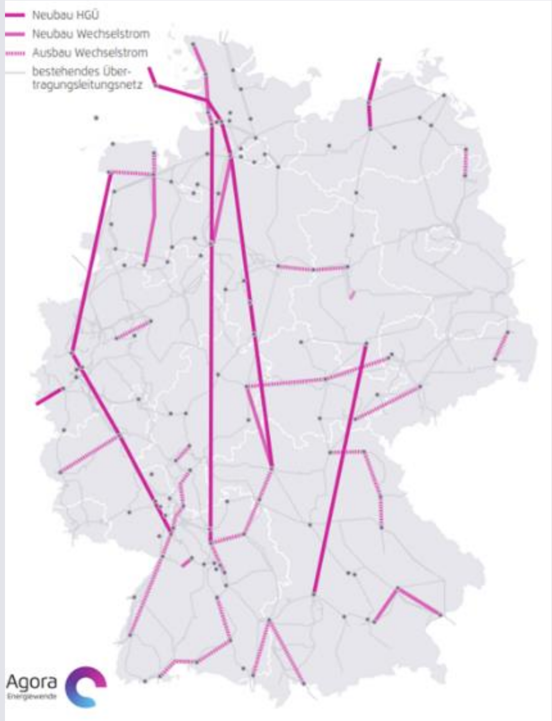
Integrated grid and resource planning is key to provide necessary AND sufficient grid capacity

Installed wind capacity (103 GW, Scenario „Best Sites“) 2033



Fraunhofer IWES (2013)

Planned transmission grid extensions until 2022



Bundesbedarfsplangesetz (2013)

Wind and solar generation tends to be located where resources are best, rather than where demand is → grid expansion needed to transport electricity to load centers

Innovations to better align VRES and grids:

- → RE peak shaving (up to 3% of energy output) in grid planning: This reduce the need to over-dimension new lines
- → “Grid-friendly” placement of new VRES (zoning in RES auctions, locational pricing,…).

Which optimum between central and decentral?

With declining RES costs, decentralized generation, close to the load centers can be cheaper than centralized generation + grid.

Cross border system integration is key for minimizing flexibility challenges and ensuring security of supply at lowest cost

Time series of onshore wind generation in May 2030 at different levels of aggregation

Fraunhofer IWES (2015) * One pixel is equivalent to an area of 2.8 x 2.8 km; PLEF are the countries AT, BE, CH, DE, FR, LU, NL

The EU power system is already highly meshed. By 2030, the EU target a 15% interconnector share (of peak load) in each Member state.

Grids mitigates the flexibility needs through power system integration:

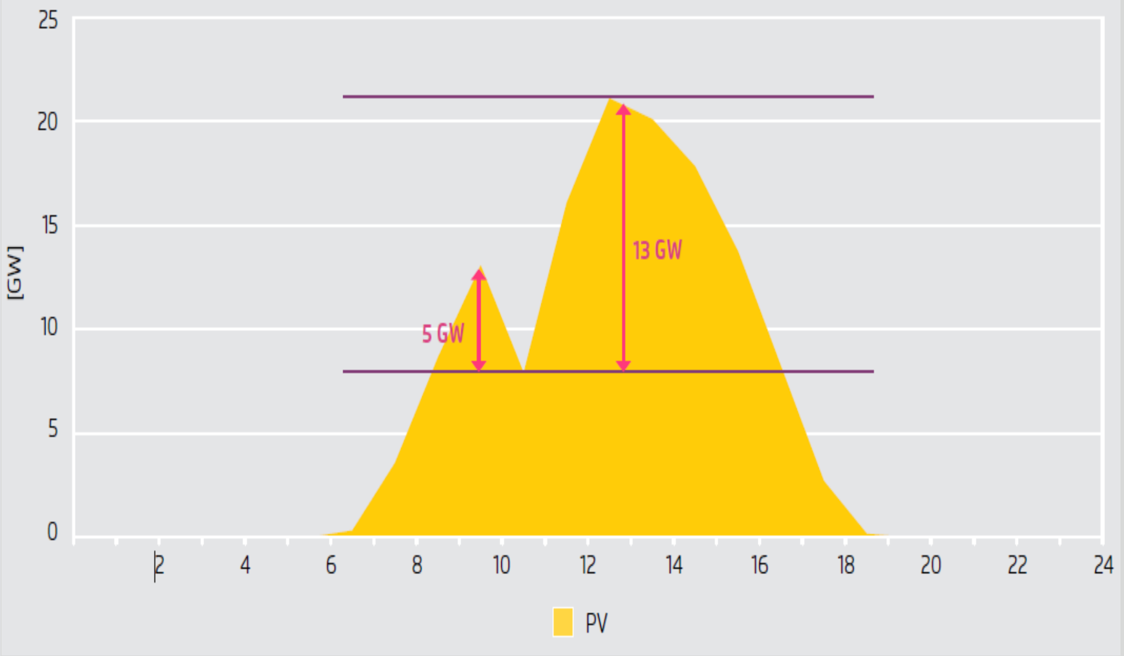
- VRES output and load are less volatile at higher aggregation levels (regional, EU)
- reduced residual load gradients
- reduced balancing requirements;
- less renewables curtailment.

Infrastructure, regulation and policy challenges:

- grid interconnection
- cooperation in system operations,
- alignment of market/regulatory designs.

Don‘t be afraid of the flexbility challenge!
Short-term markets help coping with the flexibility challenge
Example of partial solar eclipse in March 2015

Solar power production on March 20, 2015



Due to the solar eclipse, electricity production from solar PV ramped down 5 GW within 65 minutes, and ramped up again roughly 13 GW within 75 minutes

Such ramps will occur more and more often with growing shares of vRES.

System remained stable during the eclipse. Flexibility was traded in the intraday market.

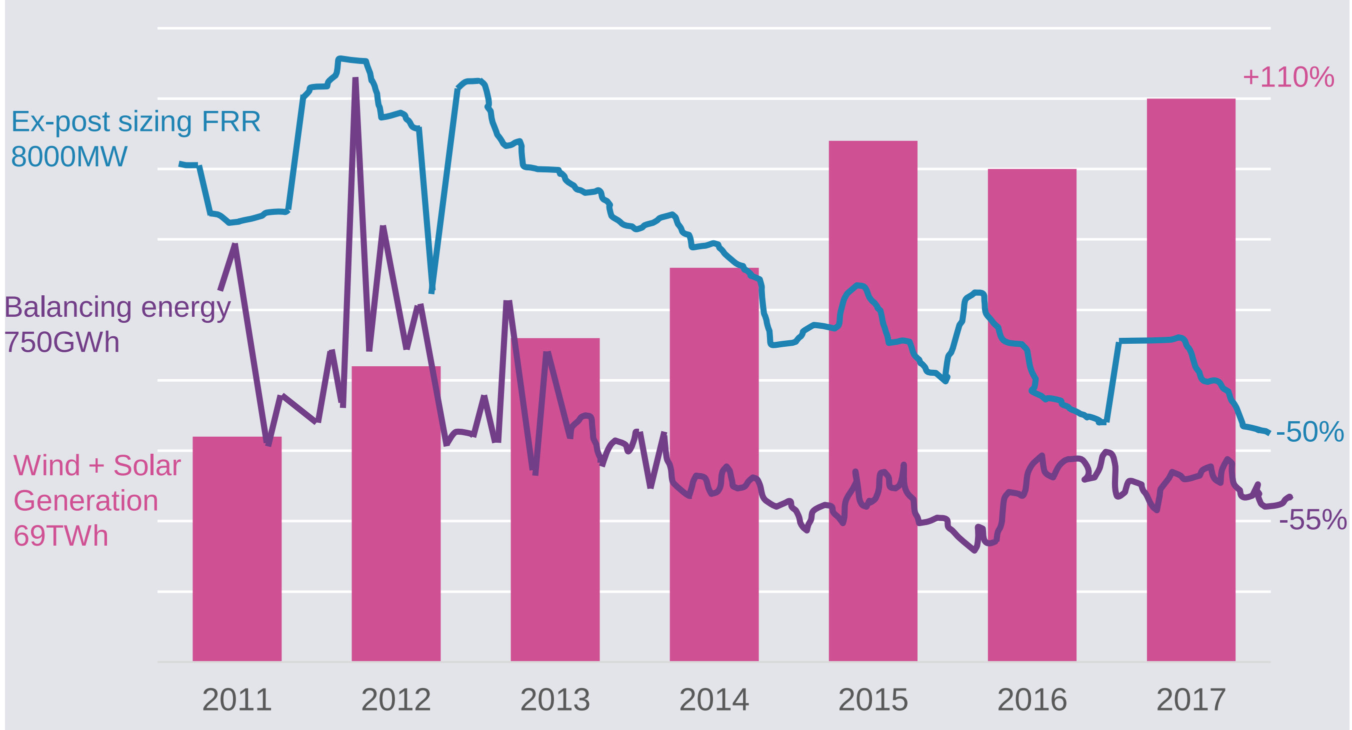
Prices traded on the Intraday market, March 20, 2015

Agora Energiewende (2018): A word on flexibility

www.epexspot.com

Improving balancing markets can outweigh the impact of increasing renewables

Balancing reserve and cost development in Germany since 2008



Adapted from Hirth et al. (2015)

Balancing costs have decreased by 50% between 2011-2017, while vRES capacity has been multiplied by two.

Reasons:

- TSO cooperation (larger geographies)
- competitive balancing power markets
- Improvement of forecasts
- More liquid spot markets

Managing the flexibility challenge: main takeaways

- Wind energy and solar PV are reshaping power systems in Europe (share ~30% in 2030). Hence, it is crucial to increase **system flexibility**
- **Various flexibility solutions exist** already today for coping with the fluctuating output of wind and solar energy
- **In Germany, the flexibility needs are so far nearly solely met by flexible power plants.** The good news : thermal power plants can provide much of the required flexibilty !
- **Power system integration at regional and European level** mitigates flexibility needs due to smoothing effects
- The **power market** can effectively **manage** the **flexibility challenge**, through **price signals** that incentivize generators and consumers to adjust their generation and consumption
- Still, a **more flexible power system is required.** The structure and operation of the conventional power plant park must change towards **less baseload, more mid-merit and peak-load plants**
- **Storage solutions are required only at very high RES levels** (>50-60%). However, new markets for battery storage and power to gas technologies are expected to emerge, especially in the transport and chemical sector

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Questions or Comments? Feel free to contact me

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