EUROPEAN PERSPECTIVE ON HYBRID POWER SYSTEMS – A JOURNEY OF DECARBONIZATION

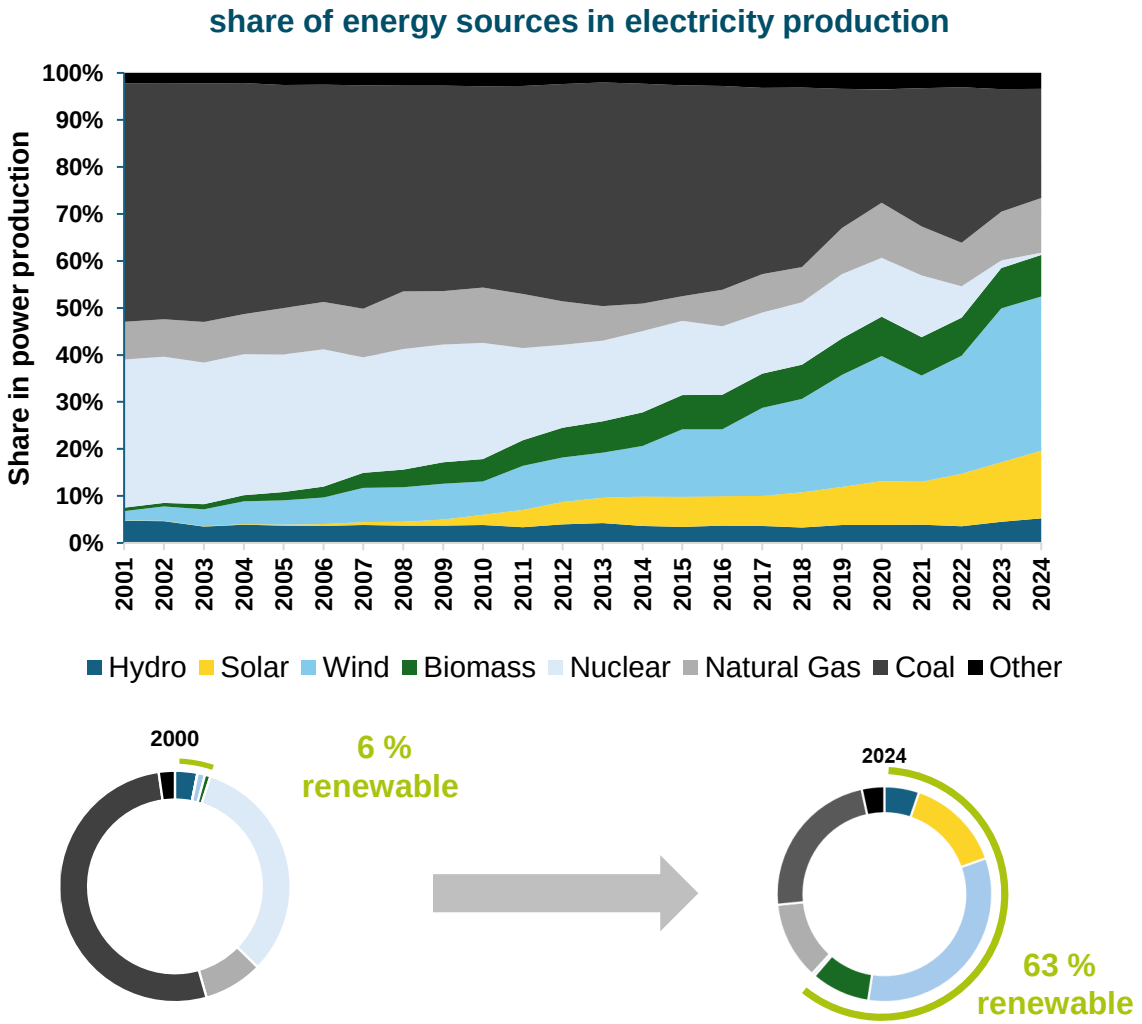
ef.Ruhr GmbH

Germany‘s Growth of Renewable Electricity Production until 2024

- In 2000, about 94% of electricity generation relied on fossil fuels and nuclear energy.
- Renewable energy was minimal, making up just 6% of electricity generation
- Renewable energies act came into force in 2000, subsidizing bio, wind and PV energy
- Since then, the share of renewable energies in electricity production has been increased to 63% in 2024
- Parallel phase-out of nuclear power plants
- Phase-out of coal-based power production planned until 2038

➢ Reduction of green house gas emissions were a great success so far

➢ But greater challenges lay ahead



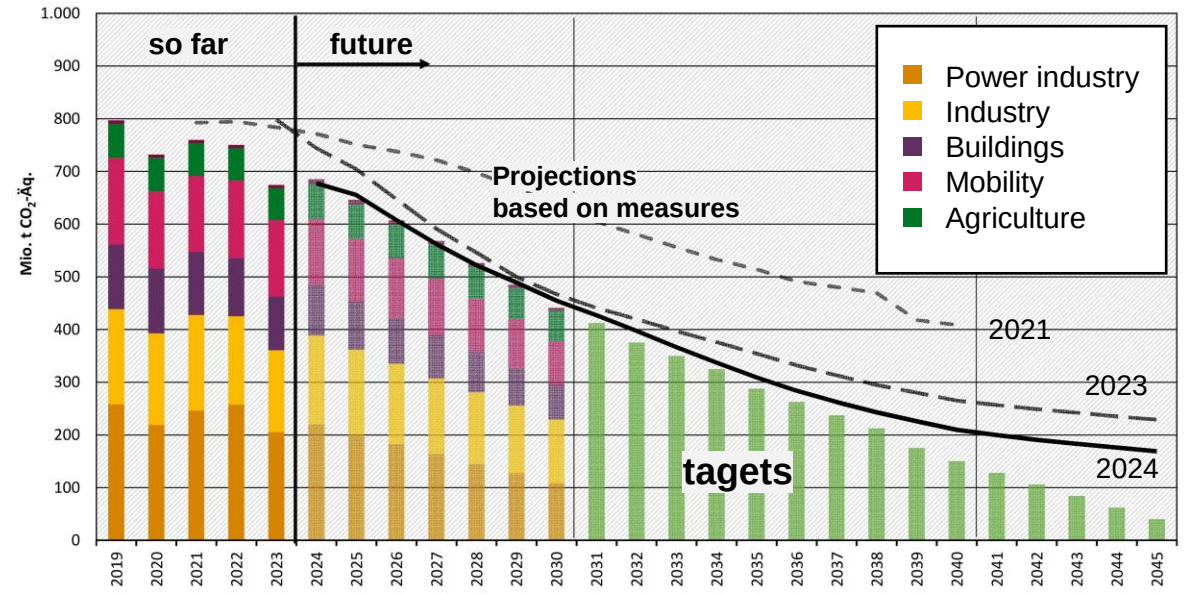
… and the further emission reduction targets

- Power industry is responsible for around a third of greenhouse gas emissions
- Emission reduction of all other sectors will heavily depend on electrification
  - Electric vehicles and trucks
  - Heat pumps
  - Industry processes and materials
  - Hydrogen production / electrolyzer

➢ Power sector will not only have to switch to renewables energies, but also

➢ Redouble electricity production until 2045

Projections of greenhouse gas emissions based on current measures



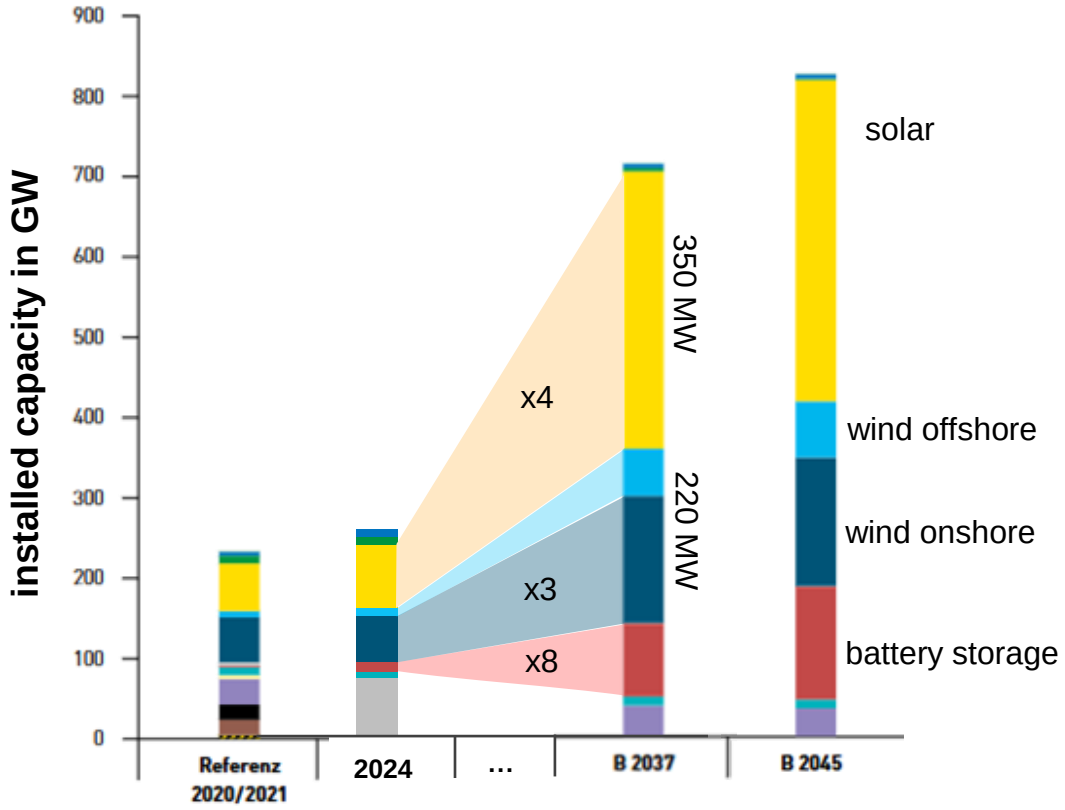
Source: Umweltbundesamt, Öko-Institut

Projections of German Power Production until 2045

- Emission Reduction Targets will require massive investments in renewable energies
  - Solar power x 4
  - Wind power x 3
  - Battery Storage x 8

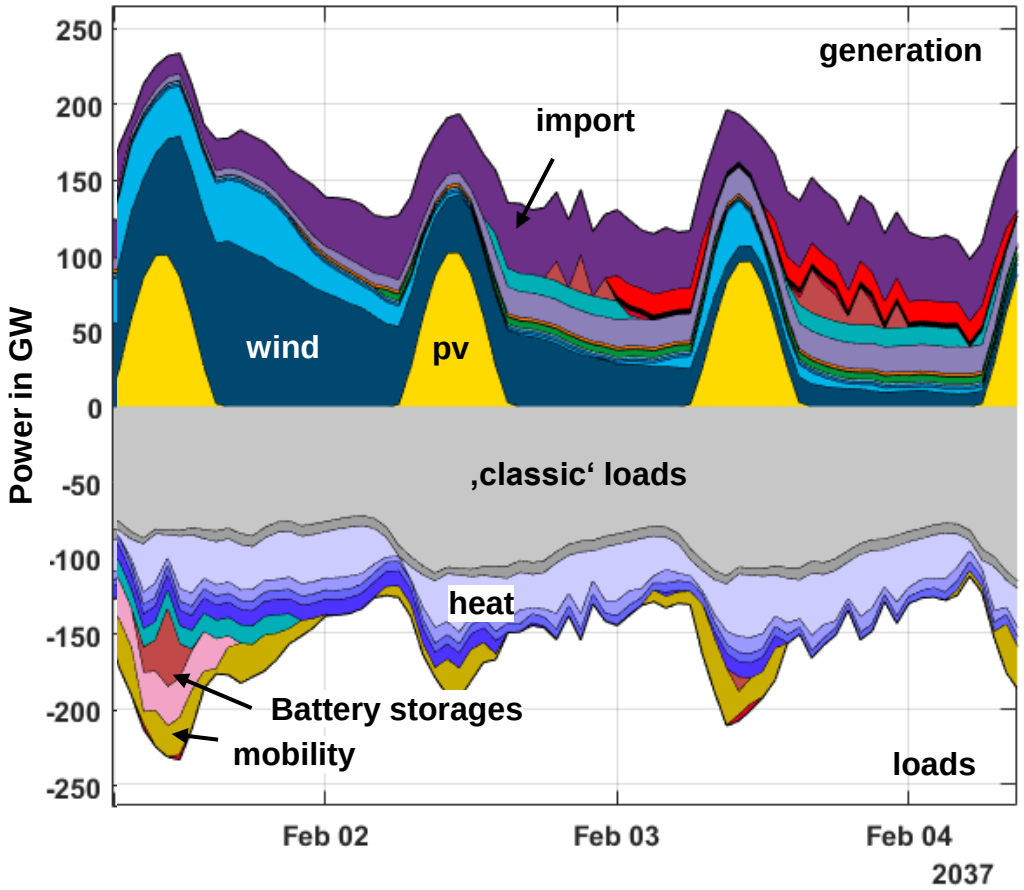
➢ Future power production will heavily depend on the weather situation

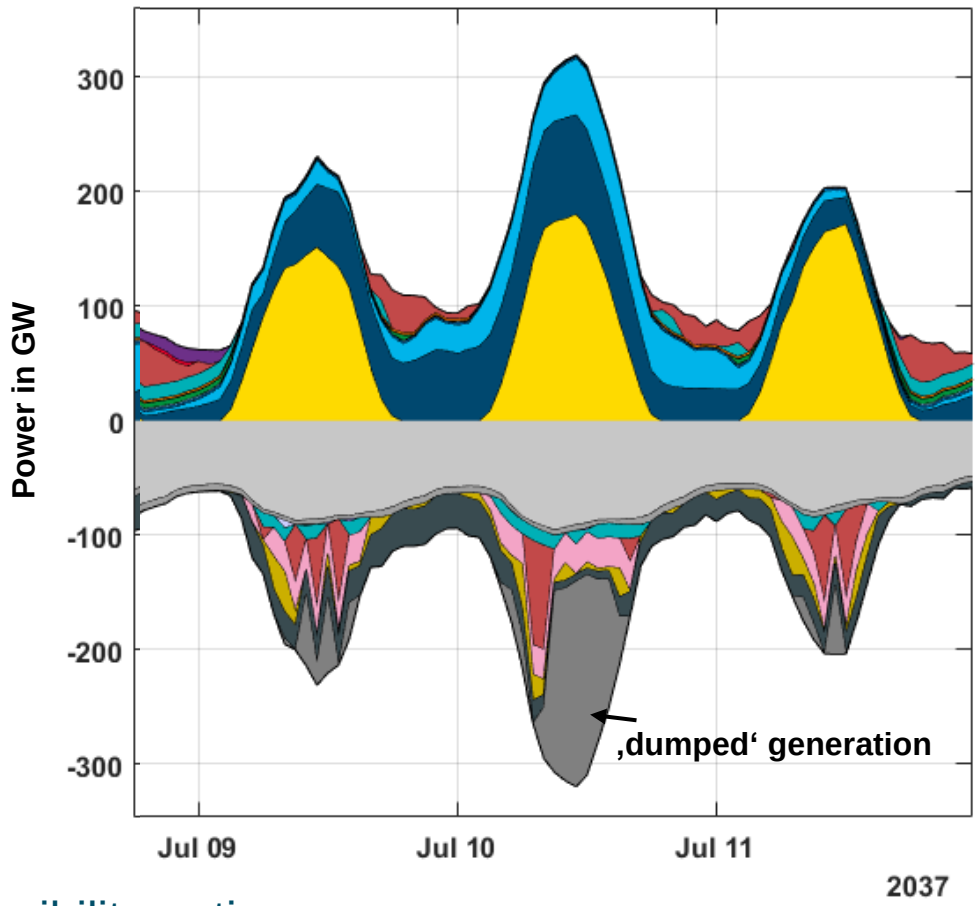
➢ Demand for battery storages (and other sources of flexibility) will increase massively



Source: Netzentwicklungsplan 2037/2045 (2023)

What some days in 2037 might look like





- Complex interplay between fluctuating renewables and flexibility options
- New challenges for the power grid infrastructure

(Some) Future Key Challenges

- The transformation of the energy system requires ongoing and far-reaching adjustments in the power system (and other sectors)

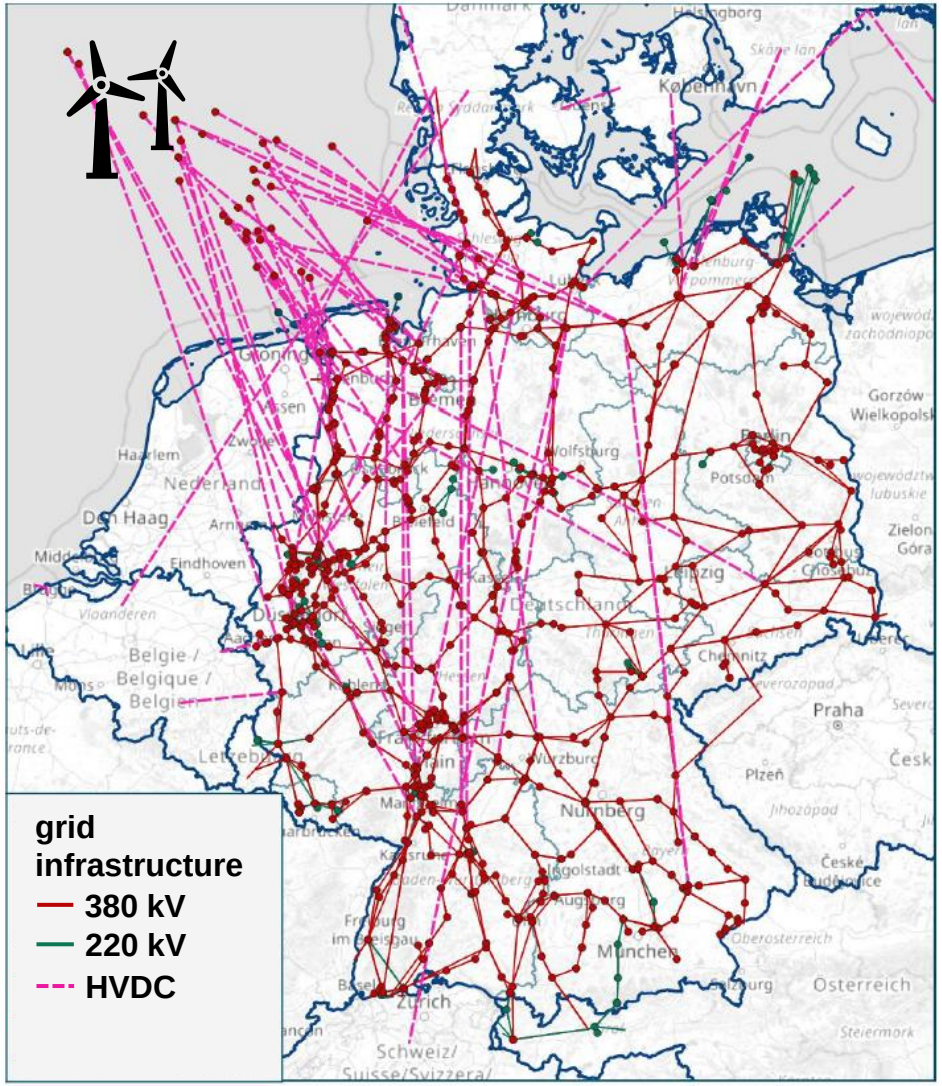
- Some of these challenges are
  - Expansion of transmission grids
  - Ensuring grid connectivity in distribution grids
  - Ensuring reasonable energy prices
  - Ensuring system stability

➢ **Challenges are manifold**

➢ **Battery storage systems offer increasingly attractive solutions**

- Expansion of Transmission Grids
- Guaranteeing System Stability
- Ensuring reasonable energy prices
- Grid Connectivity in Distribution Grids
- Reduction of dumped PV energy
- Reliable Provision of Renewables Power (PPAs)
- …

Expansion of Transmission Grid

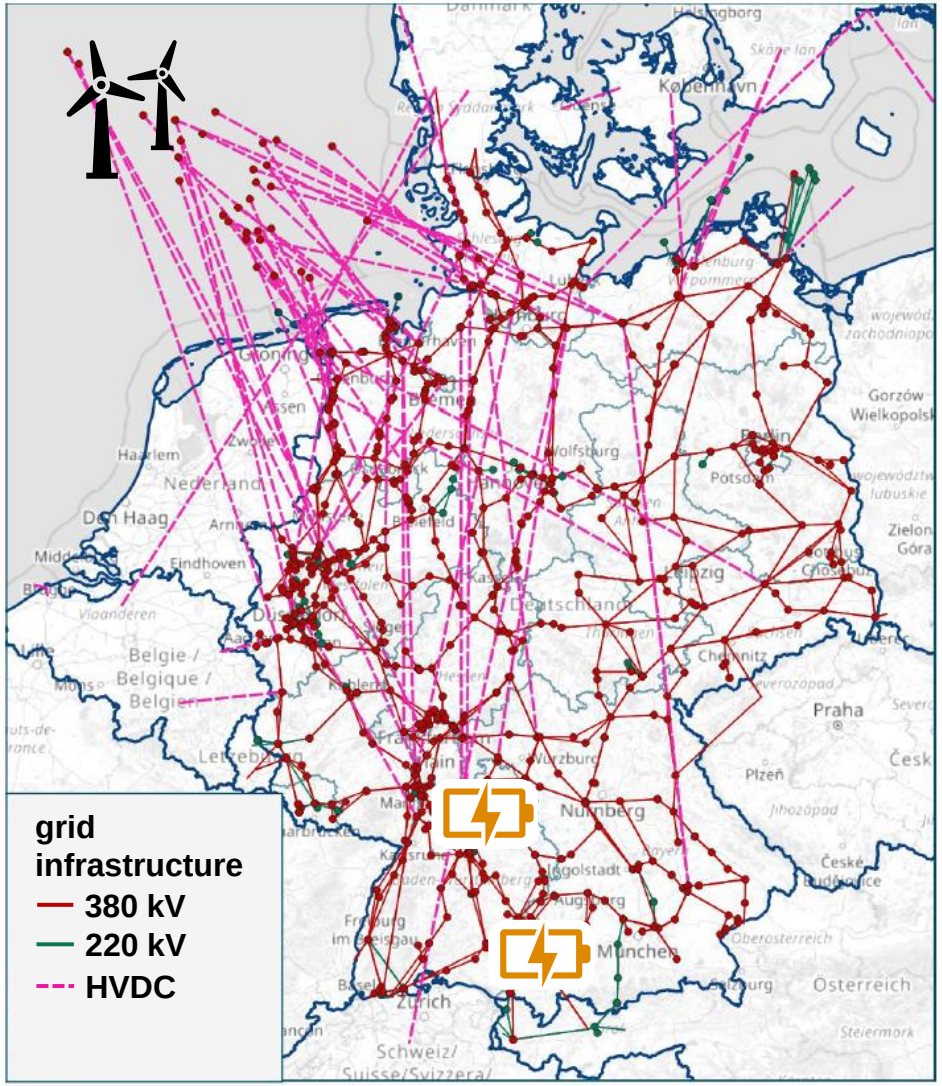


Expansion of Transmission Grids

- Development of HVDC overlay grid
  - Point-to-point connections
- Currently 29 approved projects. Of that…
  - 12 national DC corridors
  - 10 offshore grid connections for wind energy
  - 7 DC-interconnectors to European neighbors
- Additionally, 99 approved project in AC grid
- Estimated spendings of ~300 bn. € / $

Source: BMWK

Expansion of Transmission Grid



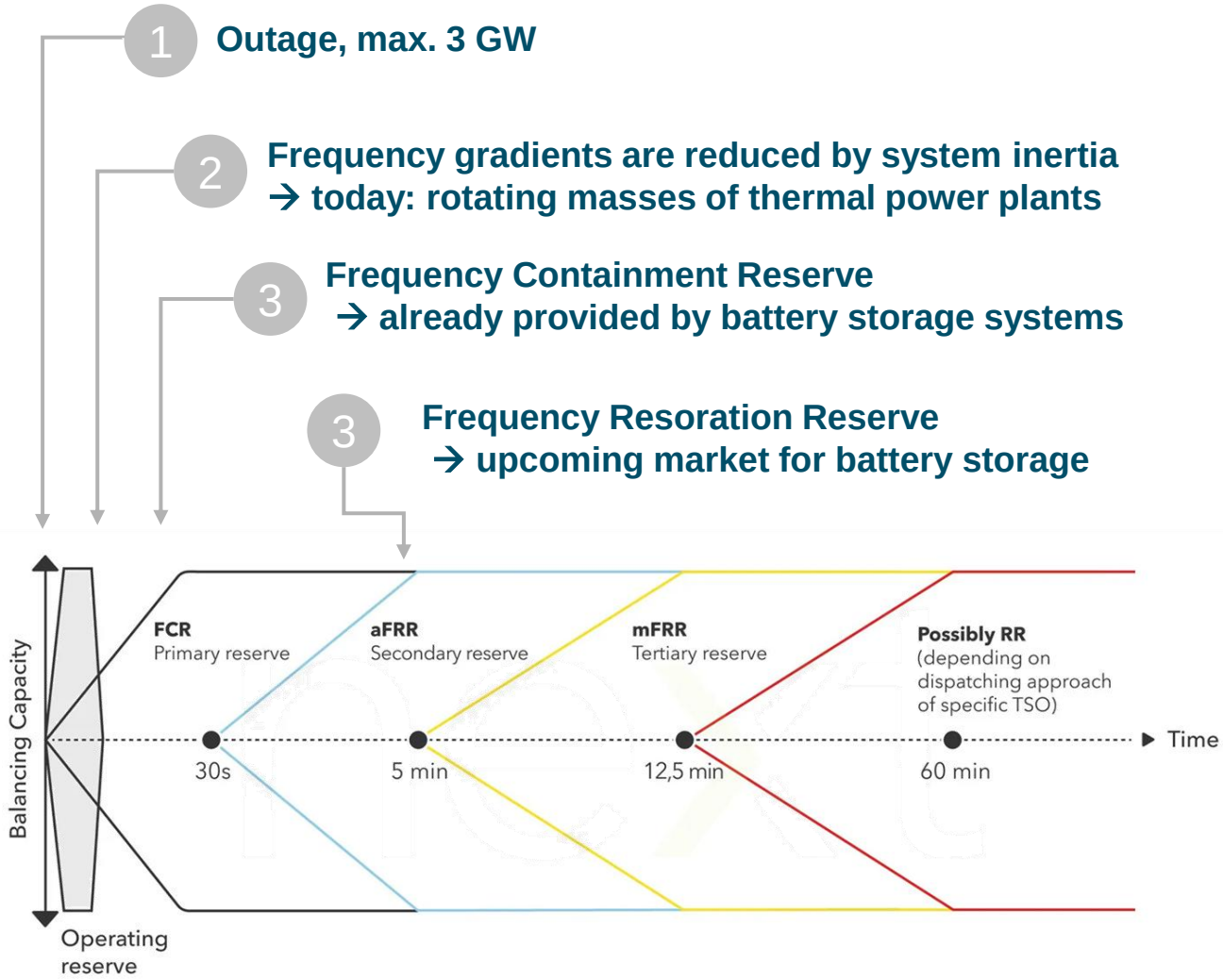
Expansion of Transmission Grids

Contribution of batter storage systems

- Use of **grid boosters** to reduce expansion demand
  - Grid boosters react on outages of AC or DC infrastructure (within milliseconds)
  - Grid boosters allow additional loading of transmission grid and thus
  - Reduction of grid expansion and redispatch demand

➢ Two projects with a battery power of 250 and 350 MW approved

Guaranteeing System stability



Challenges

- Today, system stability is provided in large parts by thermal power plants
- In close future, system stability must be provided by use of power inverters
- “Roadmap system stability” accounts for more than 50 fields of action for guaranteeing system stability
  - Frequency stability
  - Voltage Control
  - Short Circuit Power
  - Black start concepts
  - And others…

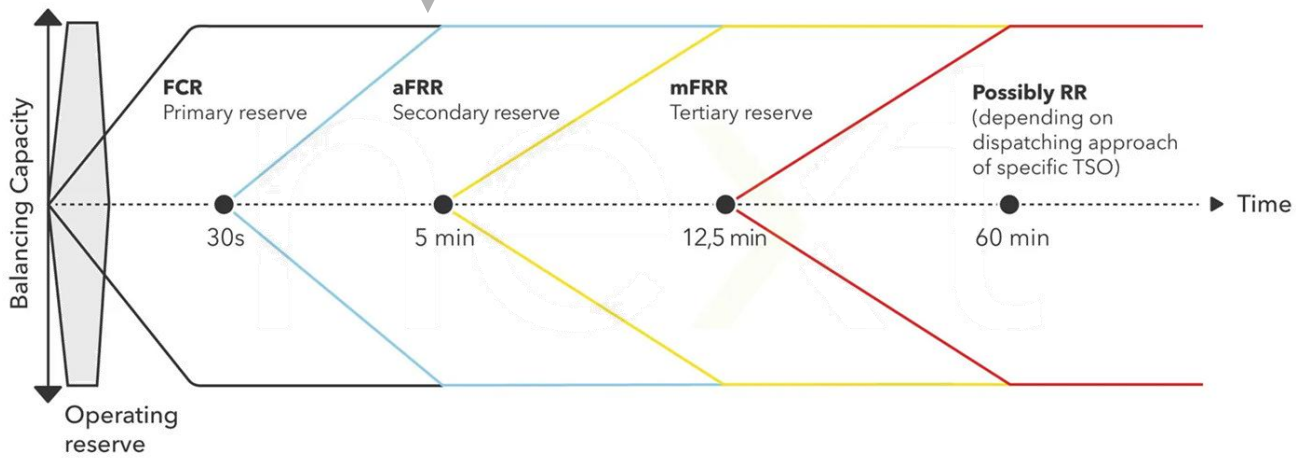
Guaranteeing System stability

1 **Outage, max. 3 GW**

2 **Frequency gradients are reduced by system inertia**
→ today: rotating masses of thermal power plants

3 **Frequency Containment Reserve**
→ already provided by battery storage systems

4 **Frequency Resoration Reserve**
→ upcoming market for battery storage



Contributions of battery storage systems

- Already today
  - Provision of balancing services without use of must-run thermal generation
- Upcoming
  - Long-term balancing reserves
  - Increasing system inertia via novel inverter designs
  - Support of distribution grids
  - Grid Boosters
  - Pooling of small-scale storages to provide better adaption to power system demands

Conclusion

- European power system is in the middle of a substantial transition towards green-house gas reduction
- Despite progress, the decarbonization journey is far from complete – a lot is achieved, but significant challenges remain
- Fluctuation renewables and inverter-based power production demands extensive changes in planning and operation of power systems
- Battery Storage Systems offer increasingly attractive solutions for many of the upcoming challenges

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