



FFF Conference: What is the Future of Fossil Fuels  
in Times of Greenhouse Gas Neutrality?

# Electricity storage and the renewable energy transition

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**Introduction**  
The transition to renewable energy sources is a main strategy for energy decarbonization in many countries, the potential of dispatchable renewables such as hydro power, geothermal or biomass are limited. The renewable energy transition is thus often driven by wind power and solar

photovoltaics (PV), wind and their associated features that become increasingly relevant with growing penetration. In particular, their generation patterns are temporally variable, and the spatial distribution of good wind and solar resources does not necessarily coincide with the historical grid layout. Different technological options are available for integrating increasing shares of variable renewable energy sources, often referred to as flexibility options. These include, but are not limited to, various electricity storage technologies.

There are many different applications for electricity storage. A major problem application is bulk electricity storage, also referred to as energy arbitrage. It allows increasing the use of generators with low variable costs by shifting their production from periods with low electricity demand (and low prices) to such with higher demand (and higher prices), which becomes increasingly relevant with growing renewable penetration.

Apart from energy arbitrage, there are many other uses of electricity storage, which storage facilities may also be able to contribute to operation. These include, but are not limited to, reduced energy of other generators, the provision of different types of ancillary services, in particular balancing power, the provision of firm capacity, the deferral of investments in distribution infrastructure investments and various industrial applications, including power quality and PV self-consumption. Many of these energy applications can become increasingly relevant in the context of variable renewable energy integration.

**Electricity Storage Technologies, Applications, and Coupling Flexibility Options**  
Many different electricity storage technologies are available. Electricity storage is usually defined as any technology that allows taking up electrical energy at one point in time and releasing electrical energy again at a later point in time ("Power-to-Power"). Technologies are available at various

\* Power-to-Flexibility: Distributed management, in particular temporal shifting of conventional electric

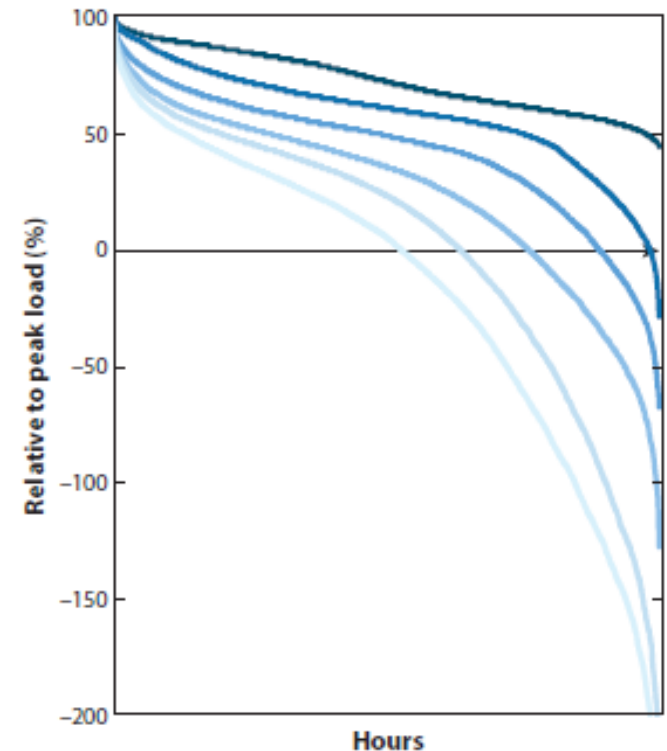
## Commentary published in *Joule*

- Brief summary of three strands of storage research literature
- Illustration how storage use changes with increasing renewables and sector coupling, i.e. with a fossil phase-out

## Residual load duration curves (RLDC)

- RL: electric load – potential renewable generation
- RLDC: Hourly RL values, sorted in decreasing order
- Generated with stylized version of DIETER, calibrated to Germany
- Zenodo: <https://doi.org/10.5281/zenodo.3935702>

<https://doi.org/10.1016/j.joule.2020.07.022>



## Various technologies

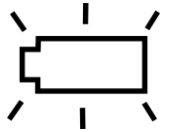
- Always: „Power-to-Power“
- Differences in roundtrip efficiency and costs related to energy and power  
→ different typical E/P ratios

## Many different applications

- Focus here: bulk electricity storage (energy arbitrage)
- Other applications: ancillary services, transmission or distribution grid relief, ...

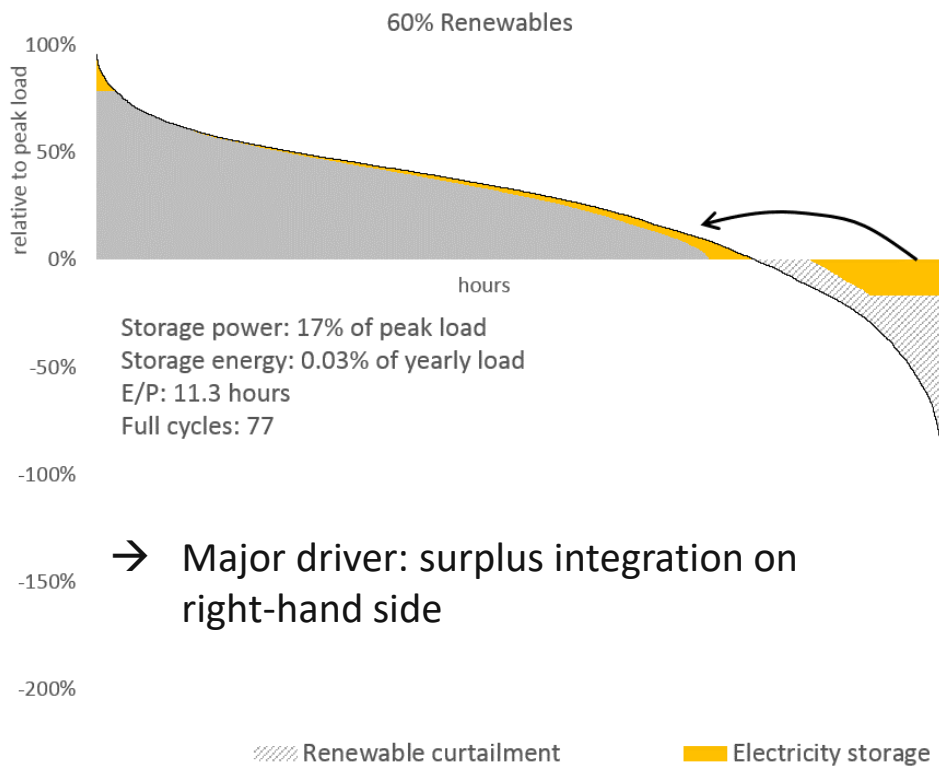
## Competing flexibility options

- Power-to-Power: e.g. demand-side management of existing load
- X-to-Power: Flexible operation of dispatchable plants
- Power-to-X: New and flexible loads related to sector coupling, e.g. Power-to-Heat
- Geographical balancing



## Common findings in the literature

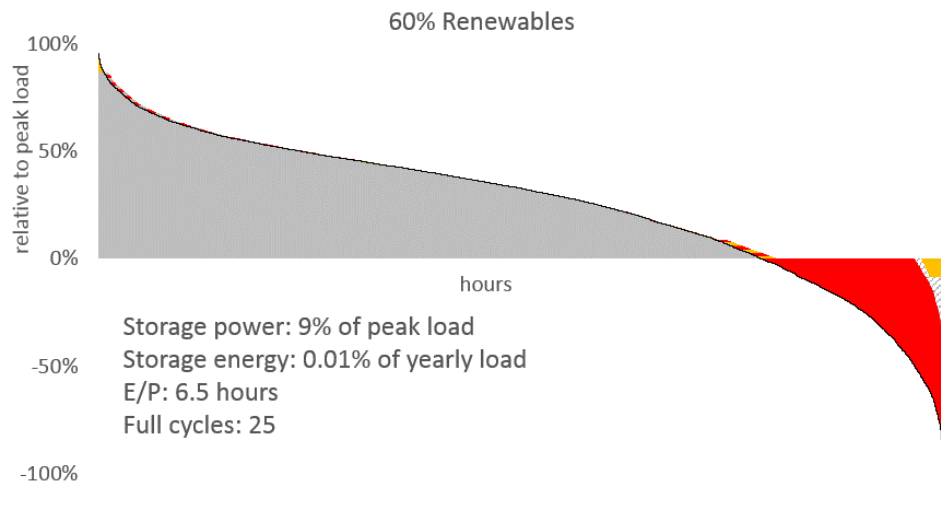
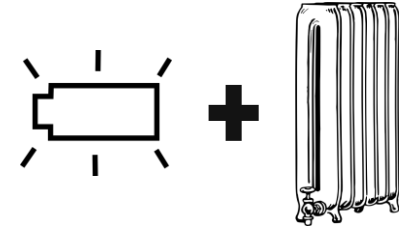
- Optimal storage deployment remain moderate until ~80% RES
- Increases substantially towards 100% renewable, also storage duration
- Depends on other sources of power sector flexibility



→ Driver for storage deployment shifts to left-hand side (residual load coverage)

## Intuition on Power-to-X

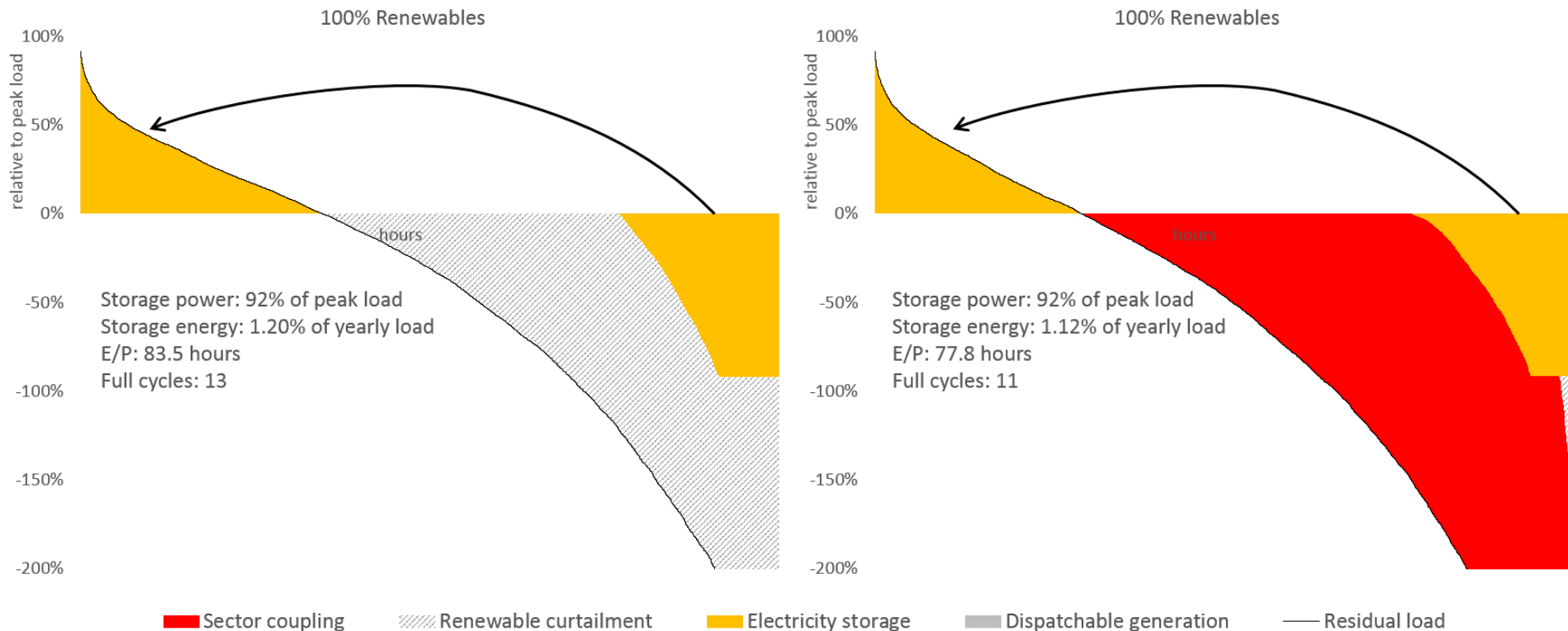
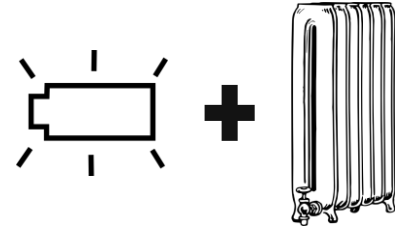
- New loads can increase the demand-side flexibility of the system
- E.g. Power-to-heat, electric vehicle batteries, green hydrogen
- This can mitigate storage needs for lower RES shares



→ Sector coupling substitutes electricity storage and curtailment

## 100% renewables

- Storage needs strongly increase vs. 90%
- Even massive sector coupling hardly changes optimal storage deployment  
→ Again, left-hand side of RLDC
- If sector coupling is less flexible, additional electricity storage may be required...



### Policy conclusions

- Electricity storage concerns currently no reason to slow down renewable deployment
- Long-duration storage becomes key for high VRE shares
  - Focus for R&D
  - Incentives for market uptake to scale up, foster learning, and develop supply chains
- Enable sector coupling to become temporally flexible
  - Sufficient investment in heat and hydrogen storage
  - Non-distortive charges and tariffs

### Conclusions for energy system research

- Research on „power sector only“ is over
- Put flexibility aspects of sector coupling in the focus
- Special case: Battery-electric vehicles → sector coupling with reconversion

Thank you for listening

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# Backup: less flexible storage

## Inflexible sector coupling increases electricity storage needs

