The current and future role of storage

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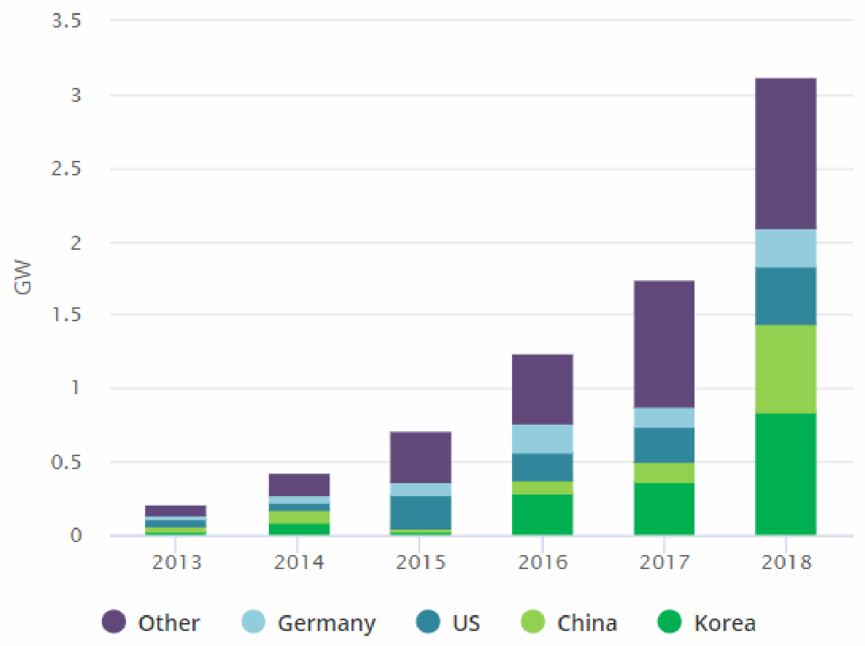
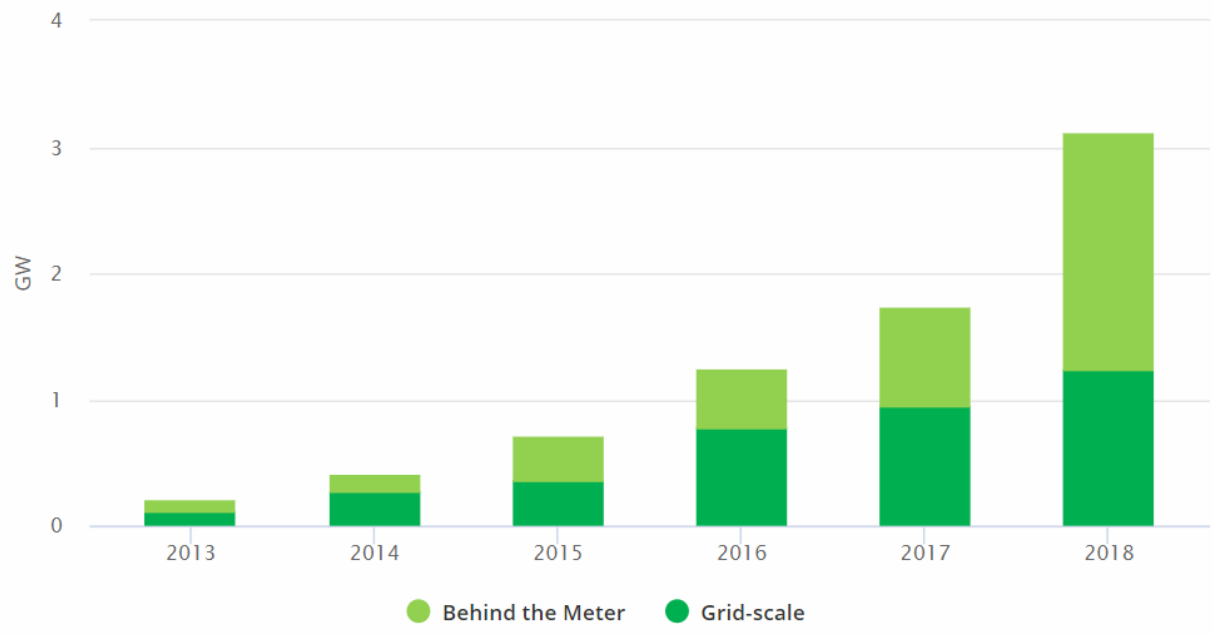
SINGAPORE, 31 OCTOBER 2019

Global energy storage deployment reached a record level in 2018, nearly doubling from 2017

Korea, China, the US and Germany have been leading countries in storage deployment



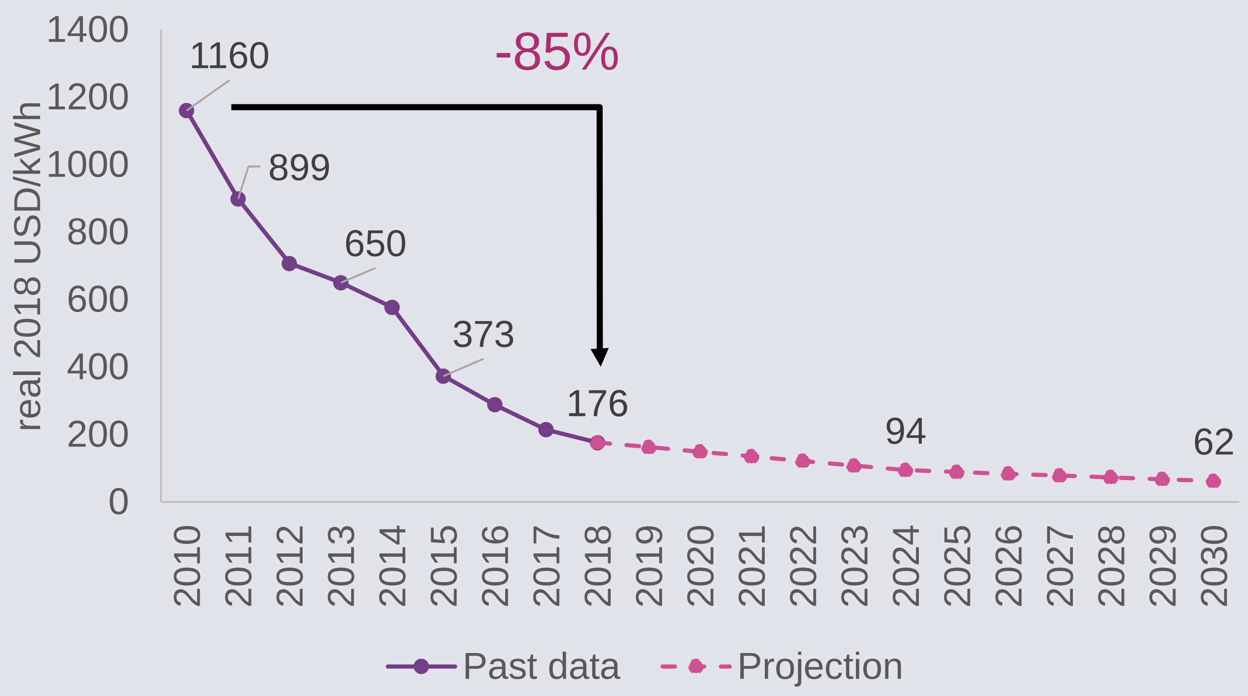
Behind the meter storage deployment nearly tripled 2017 capacity



Source: IEA TCEP, 2019

Battery prices decreased by 85% from 2010 to 2018 - and are projected to continue falling

Li-ion Battery price – past and outlook



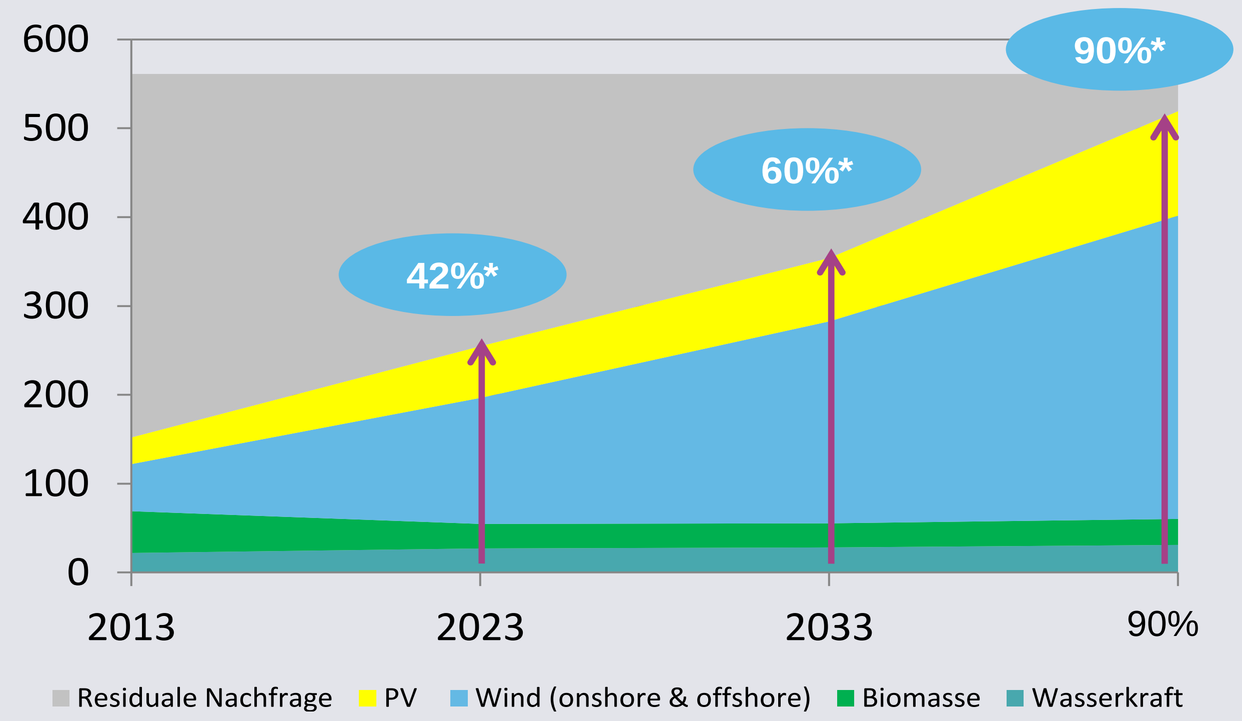
Source: BNEF 2019

- → The price* of Lithium-ion battery decreased by 85% between 2010-2018
- → Further price decrease expected from 176 USD/kWh in 2018 to 62 USD/KWh in 2030
- → Actual development will depend on economies of scale and the cumulative manufacturing experience gained globally.
- → Main driver: battery EV development

*the price is volume weighted average battery price and result of the ninth Battery Price Survey by BNEF

In 2014, Agora assessed storage needs for the German Power System at 40%, 60% and 90% Renewables shares

Electricity Generation and Demand in Germany, in TWh



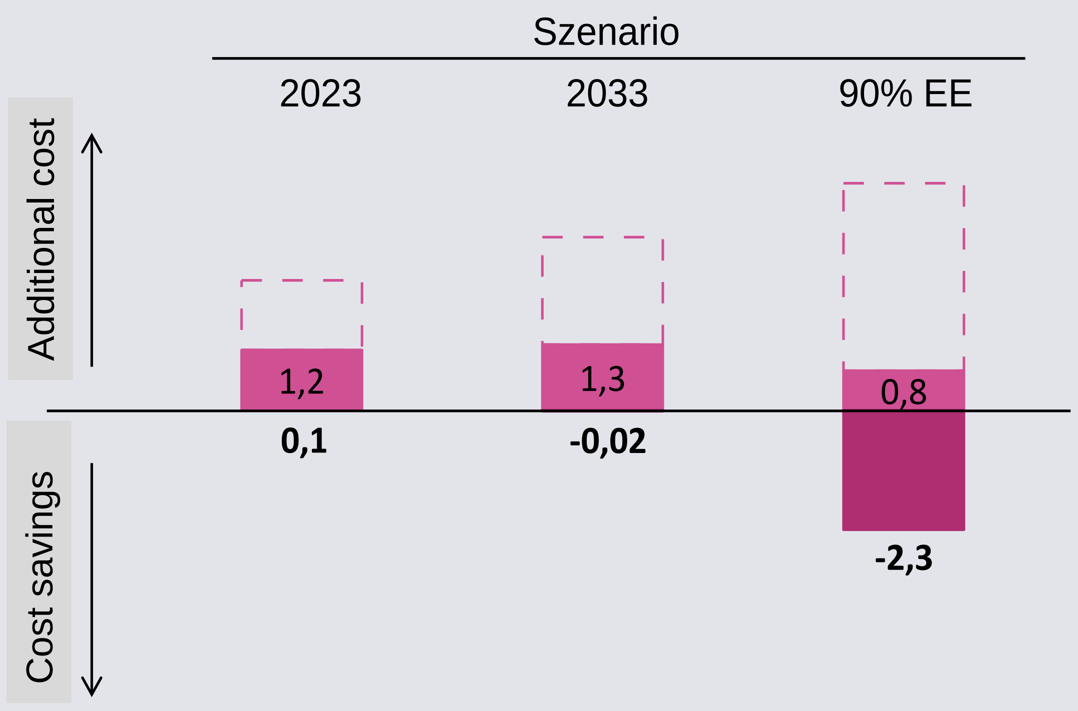
FENES et al. 2014

Use cases considered

- → Storage in the power sector to **balance generation and demand** (at the transmission level)
- → Storage at the **distribution level** to defer network investment
- → Storage for **ancillary services**
- → **Future markets** for new storage technologies

Main finding: Investment in storage makes sense economically only at very high RE shares

Savings and cost increases by additional storage, in bn EUR per year*



FENES et al. 2014; bandwidth of results: different combinations of storage tech.

→ **2023**: benefit of new storage to balance generation and demand is insignificant, resulting in cost increase

→ **2033**: a small amount of new storage can lead to cost reductions in the best case

→ **90%-Scenario**: new storage leads to cost reductions. Highest savings at
  - 16 GW long term storage
  - 7 GW short term storage

- Results are broadly confirmed by series of similar studies in Germany
- Main reason: more efficient flexibility options available

Some ancillary services can already be provided at competitive cost today

Qualitative Analysis: Storage for ancillary services (Summary)

Primary Response	• Battery storage very competitive • Long term demand remains small (~0,6 GW)
Secondary Response	• Storage well suited, competitiveness unclear • In the future strong competition from renewables and DSM
Adequacy	• Storage can provide secured capacity in principle

FENES et al. 2014

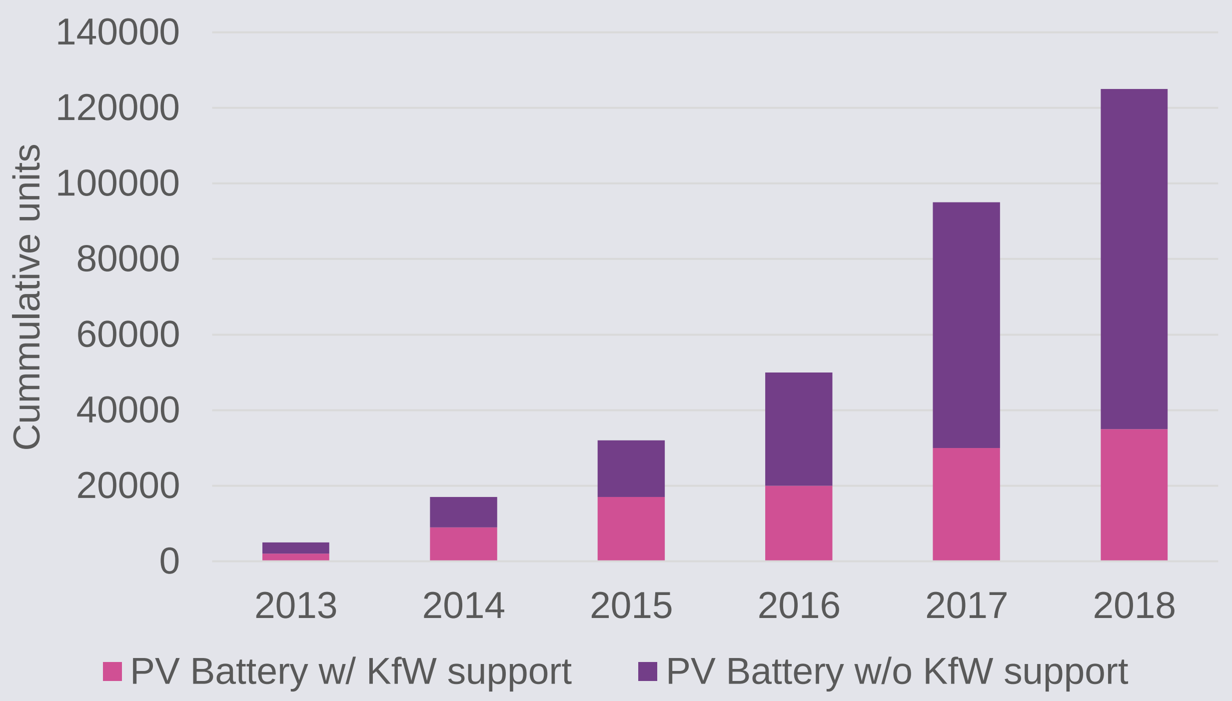
- **Primary response**
  Germany: 0,6 GW
  Rest-EU: 2,4 GW
  Total: 3 GW

- **Secondary response**
  Germany: +2,5 / -2,8 GW

→ Flexibility markets such as balancing markets or future capacity markets should be set up technology-neutral

Germany: Storage investment driven by PV plus storage

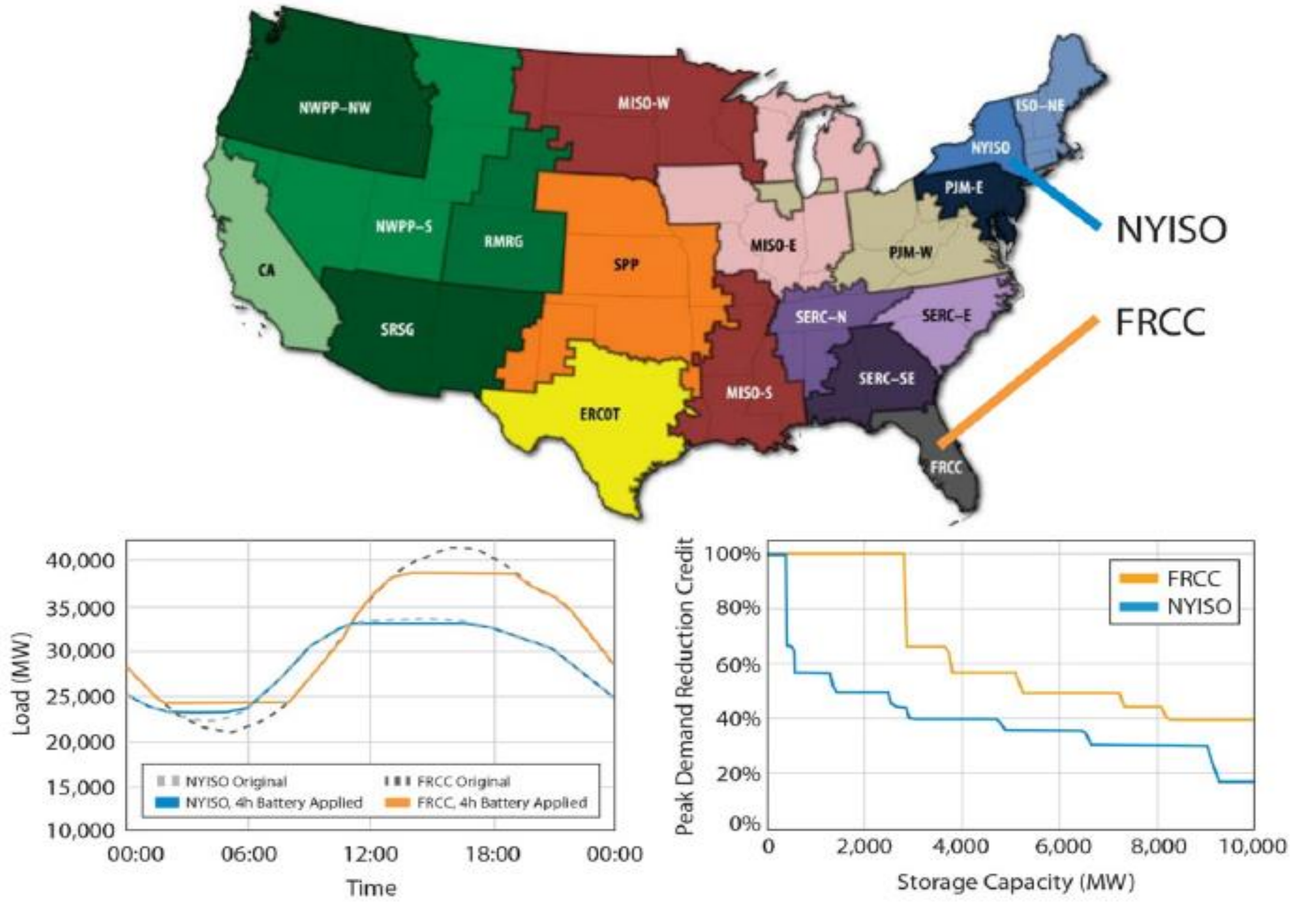
Cummulative installed capacity of home battery system



iSEA, RWTH Aachen

- → New installation in 2018 ~40.000 units
  - Financed through KfW ~5% (down from ~55% in 2013-2015
  - Retrofit.~10% of home battery system
- → One out of two new PV rooftop installation comes with storage
- → Motivation, however, not mainly driven by system needs, rather:
  - Wish to increase consumption ofself generation (from 35% to >60%)
  - Contributing to energy transition,
  - Preference for Innovation

US trend: Storage to compete with gas plants for peak demand coverage

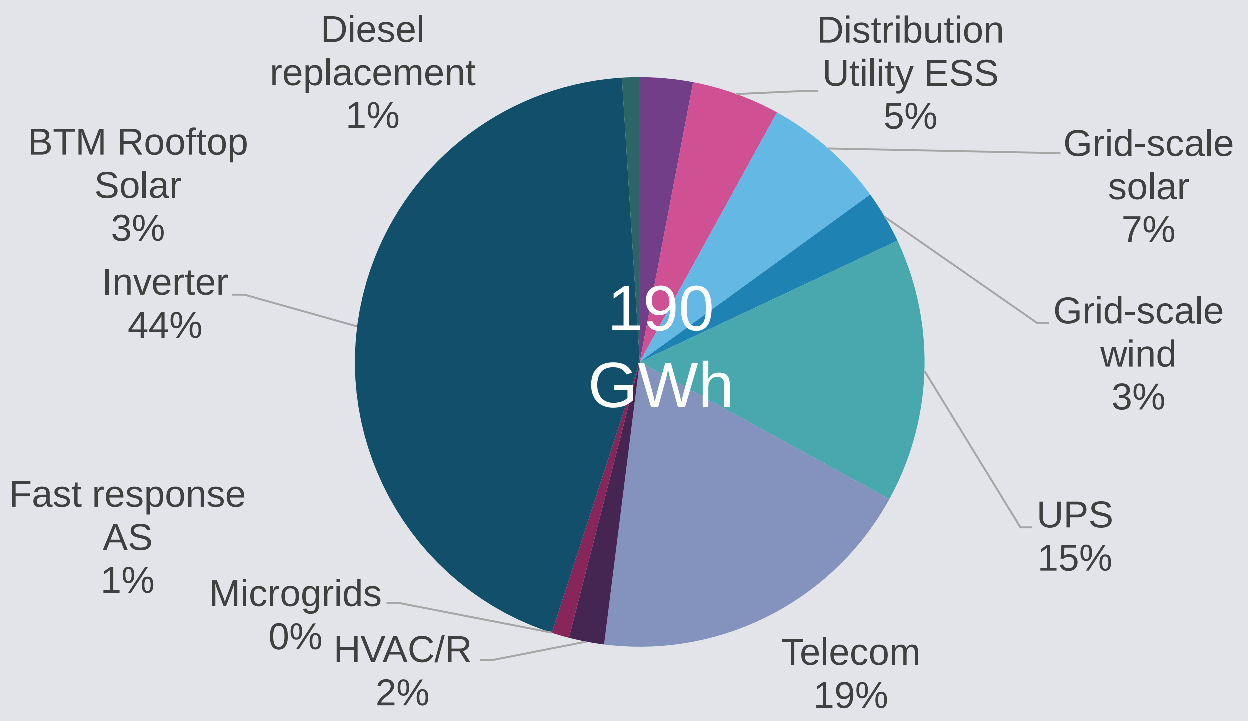


- Recent NREL analysis calculates 28 GW of potential for 4-hour storage providing peaking capacity
- Could help decrease storage costs and may provide additional benefits, such as a sink for low- or zero-value PV generation during non-peak periods.
- This in turn can enable greater PV deployment, which then increases the potential of 4-hour storage, potentially to up to 50 GW (at US PV share of 10%)
- **But: Storage will need to compete with demand response options!**

NREL (2019)

India: 190 GWh of storage requirement projected by storage association, driven by variety of use cases

Projection of India Storage Requirement (2019 – 2025)



CES Analysis, India Energy Storage Alliance

→ From 190 GWh of storage requirement projected by 2025, only 17% of energy storage is likely to be deployed at grid scale.

→ Majority of the deployment at grid scale will be driven by
- RE integration,
- Fast Response Ancillary Service (FRAS) market,
- and T&D deferral.

→ Electric vehicle industry is forecasted to consume over 110 GWh of batteries during 2019 - 2025. Some of these can be used through V2G (Vehicle to Grid) technology to meet flexibility needs of the distribution grid.

BTM: behind the meter; UPS: uninterrupted power supply; HVAC: heating, ventilation, air con; AS: Ancillary services

Depending on the system, there is a variety of potential use cases for storage as enabler for the Energy transition

System perspective

- **Off grid** in rural areas, contributing to electrification / substituting diesel engines with PV + storage
- Element of „virtual power plants“ in **micro- or mini grids**
- **Transmission / distribution deferral** (more efficient use of energy at local level)
- **Grid support**: voltage control, frequency control, black start capability
- **Peak reduction** (substituting gas / oil peakers)
- **System adequacy** during longer periods of low RE feed-in

Consumer perspective

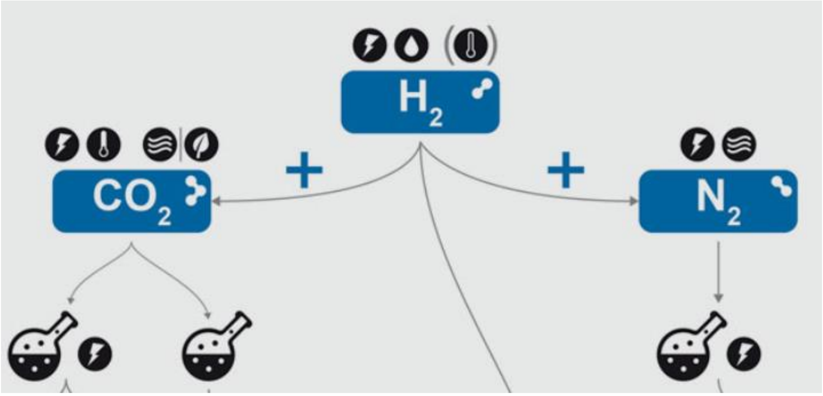
- **Energy arbitrage**: Short term energy shifts to benefit from price differentials
- Increase **own consumption**, in particular industrial/commercial users with high energy prices

Different storage technologies suitable for different storage needs

→ Very short term (milliseconds to seconds): e.g. **flywheels**

→ Minutes to hours: **batteries** (mostly Li-Ion)

→ Days to weeks or even months: **pumped hydro, hydrogen, power-to-gas / power-to-heat**)



How to determine the most efficient size, technology and configuration of storage for the energy transition?

Market-based systems	State-dominated systems
→ Improve market framework for short term markets and ancillary service markets: • allowing for high prices in particular in short term and in ancillary service markets • strengthening the role of aggregators that can market packages of batteries, including V2G services from car batteries • Allowing for fair competition among different flexibility options, rewarding e.g. very short term reaction of fly wheels and partly batteries	→ Sophisticated cost-benefit assessment required, involving all flexibility options needed, to avoid inefficient investment → Comparing scenarios with/without storage, keeping demand profiles and power quality (frequency voltage, …) at the same level → Include alternative options such as smart grids, demand response → When location, sizing are defined, either:, ▪ Procurement by system operator / DSO or ▪ Investment by transmission system owners

Key Findings

1	Role of storage is often overrated when variable Renewables enter power systems, as often cheaper flexibility options are available
2	Price decrease in batteries in particular may make very short to short term storage, for grid services and peak shaving attractive in SEA countries even at lower RE shares
3	Well-designed markets provide efficient investment signals. In state-dominated systems, sound and well defined analysis required in order to avoid inefficient investment

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Questions or Comments? Feel free to contact me:

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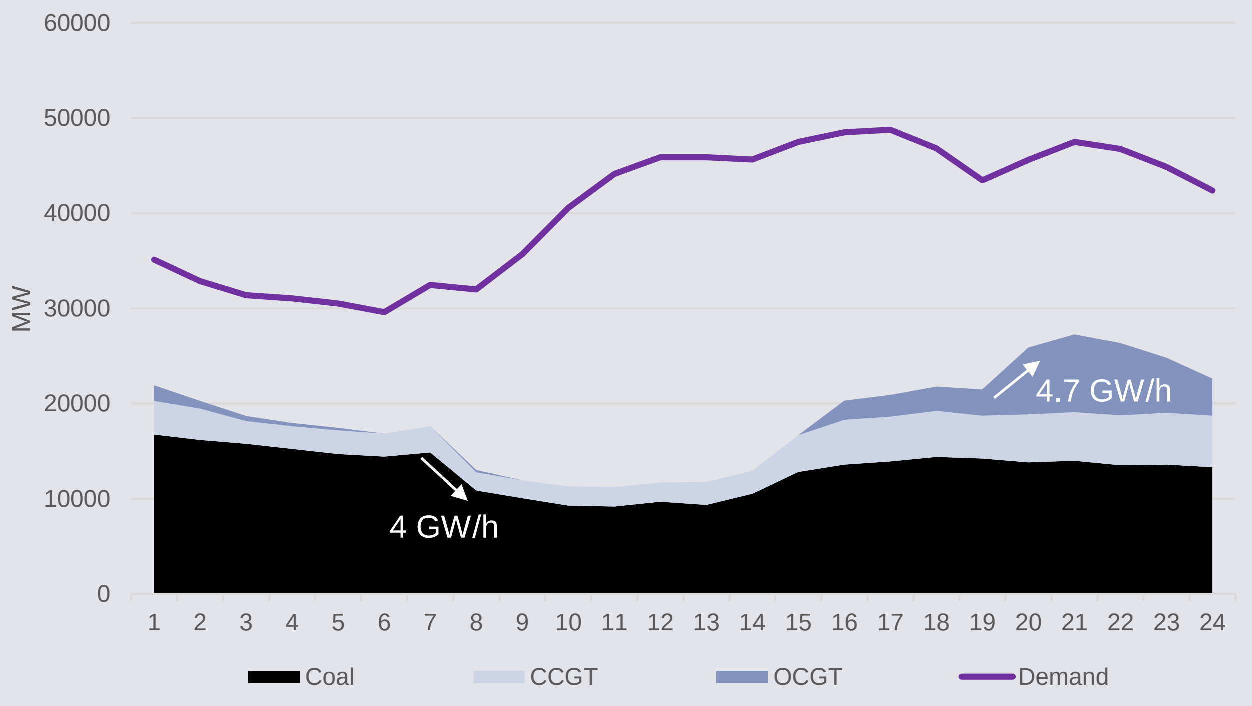
Agora Energiewende is a joint initiative of the Mercator Foundation and the European Climate Foundation.

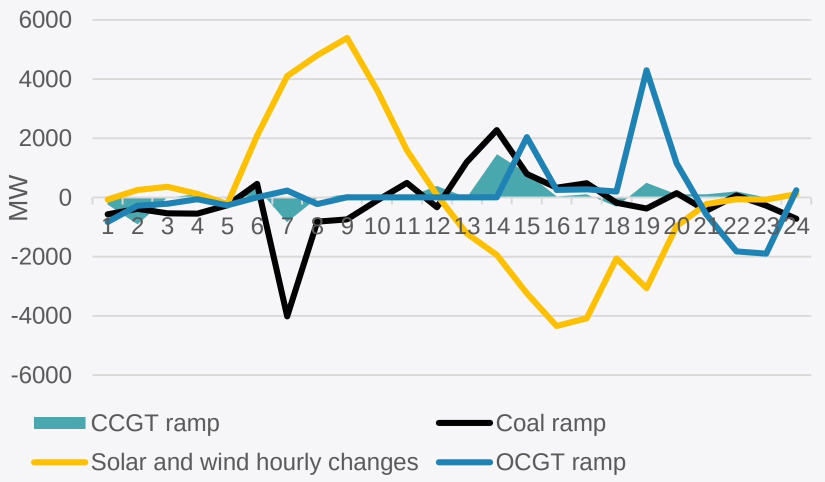
Installed coal and gas power plant are able to ramp up and down to accomodate high share of Renewables

Residual generation and ramp rate in high renewables scenario



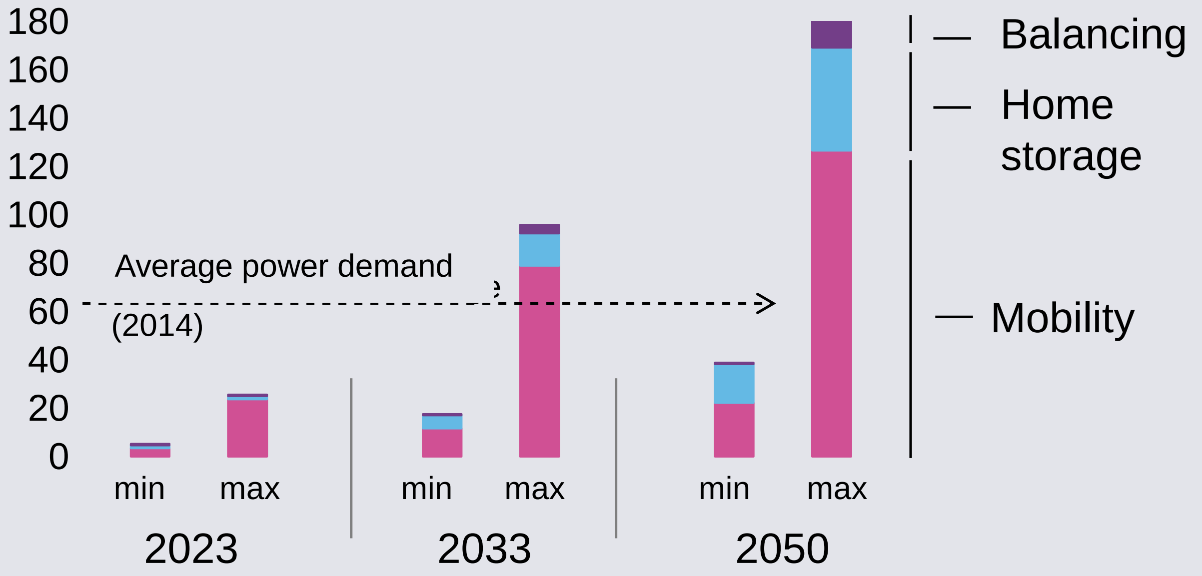
IESR, Agora, Monash (2019)

- → Ramp rate of the coal power plant fleet maximum 4 GW/h (or 0.5 – 1% of nameplate capacity/min)
- → Ramp rate of the CCGT power plant fleet maximum 5 GW/h (1.5-2%/min)
- → Maximum hourly change of residual load: 5GW



Future markets for battery systems may have different size – depending on regulation and the demand for electric vehicles

Estimation of future markets for Power-to-Gas in Germany (in GW)



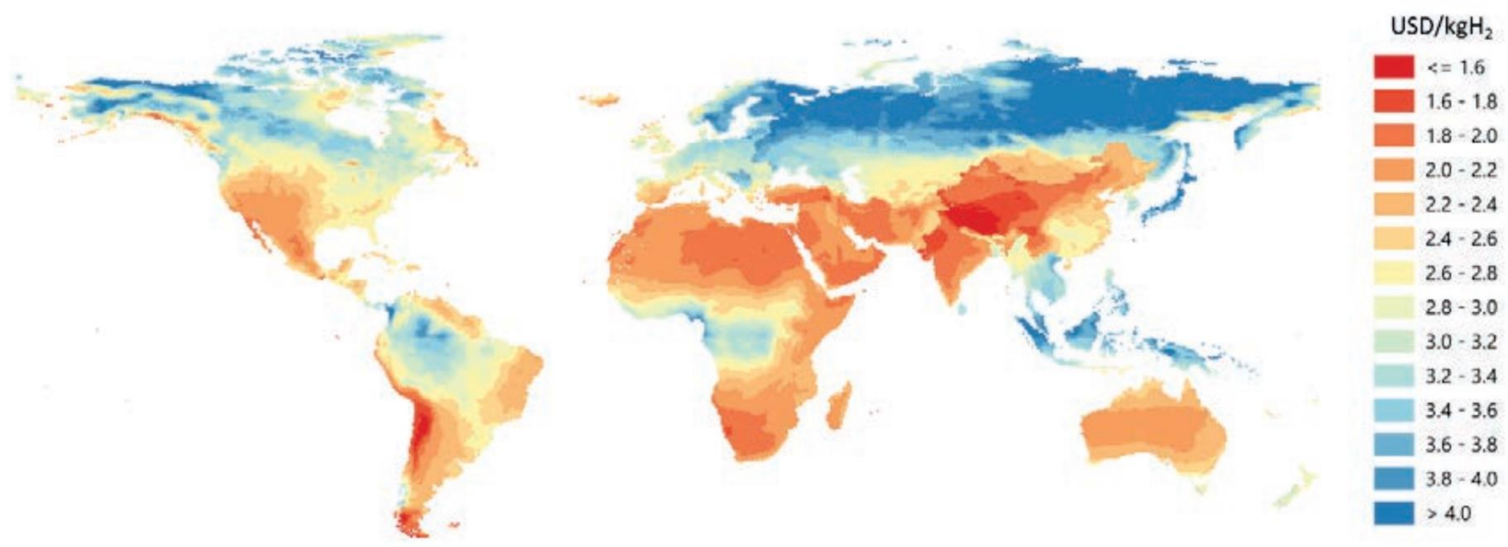
FENES et al. 2014

- **Balancing market volume** remains small
- For home storage system, regulation is key: Economics depend on the question how much consumption from the grid can be substituted by own consumption
- **Electric vehicles** have the largest potential. Used battery storage may also play a role as second life applications

** Siehe dazu auch unsere aktuelle Diskussion und Analyse zum Thema „Ausreichende Belegung von Dachflächen mit PV".*

Assuming electrolyser CAPEX of USD 450/kW, solar PV and wind could be a low-cost source for hydrogen production in regions with favourable resource conditions.

Hydrogen costs from hybrid solar PV and onshore wind systems in the long term



Notes: This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area. Electrolyser CAPEX = USD 450/kW_e, efficiency (LHV) = 74%; solar PV CAPEX and onshore wind CAPEX = between USD 400–1 000/kW and USD 900–2 500/kW depending on the region; discount rate = 8%.

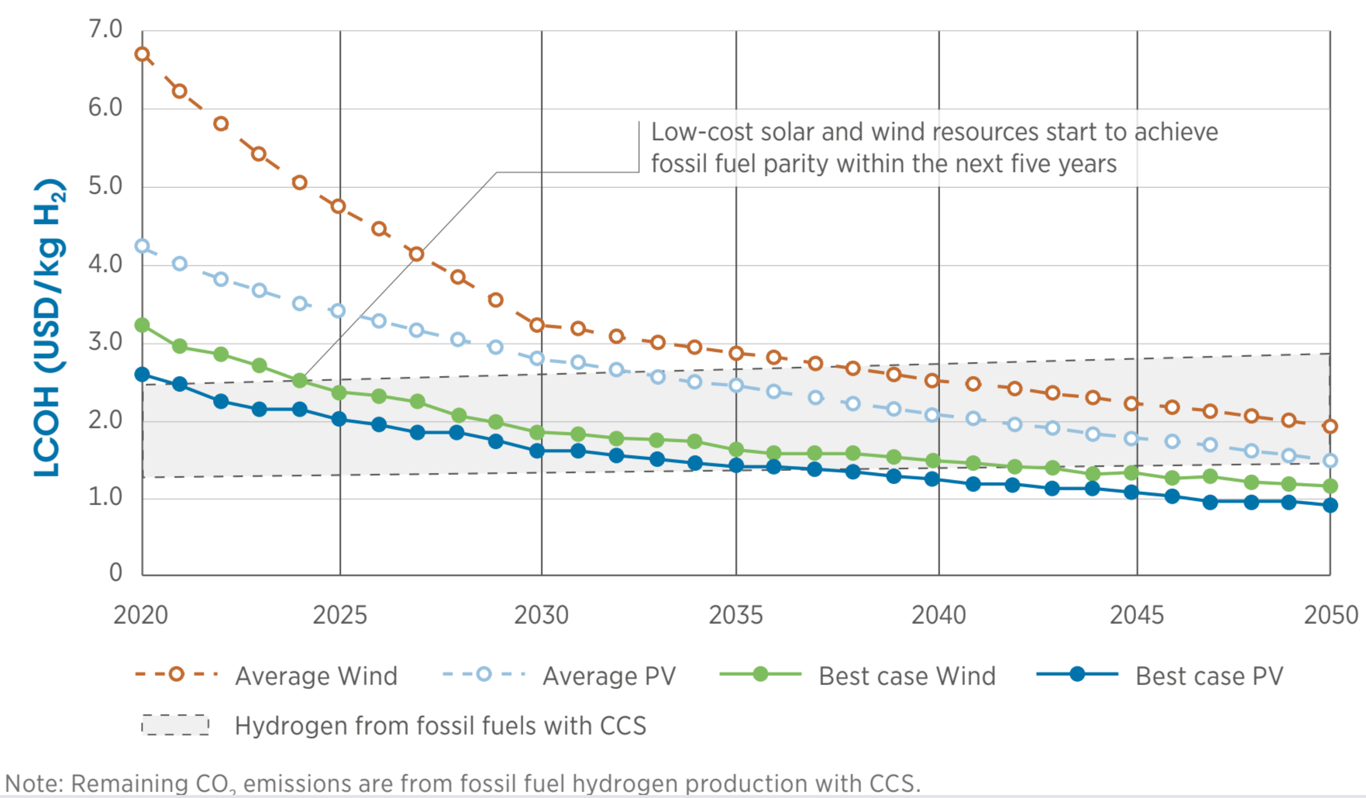
IEA (2019): The future of hydrogen

Promising areas include:

- Patagonia,
- New Zealand,
- Northern Africa,
- the Middle East,
- Mongolia,
- most of Australia,
- parts of China
- parts of the United States

IRENA: Future costs of green H_2 will be below those for blue H_2.

Hydrogen production costs from solar and wind vs. fossil fuels with CCS



- By 2035, **average-cost green H_2** also starts to become competitive.
- **Pricing of CO_2** emissions further improves the competitiveness of green hydrogen.
- In the **best locations**, green H_2 is competitive in the next 3-5 years compared to blue H_2.

For comparison, BNEF on green H_2 cost:

- USD 1.5/kg by 2030
- USD 0.8/kg by 2050

IRENA (2019): Hydrogen: A renewable energy perspective;
BNEF (2019): http://taiyangnews.info/business/sharp-drop-in-costs-for-re-powered-hydrogen-by-2050/