# Economic analysis of a hybrid battery storage system providing frequency containment reserve in Germany considering future developments

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PhD-day EERA PhD-day Energy Storage: Techno-economics and Sustainability

DLR Institute of Networked Energy Systems

# Agenda

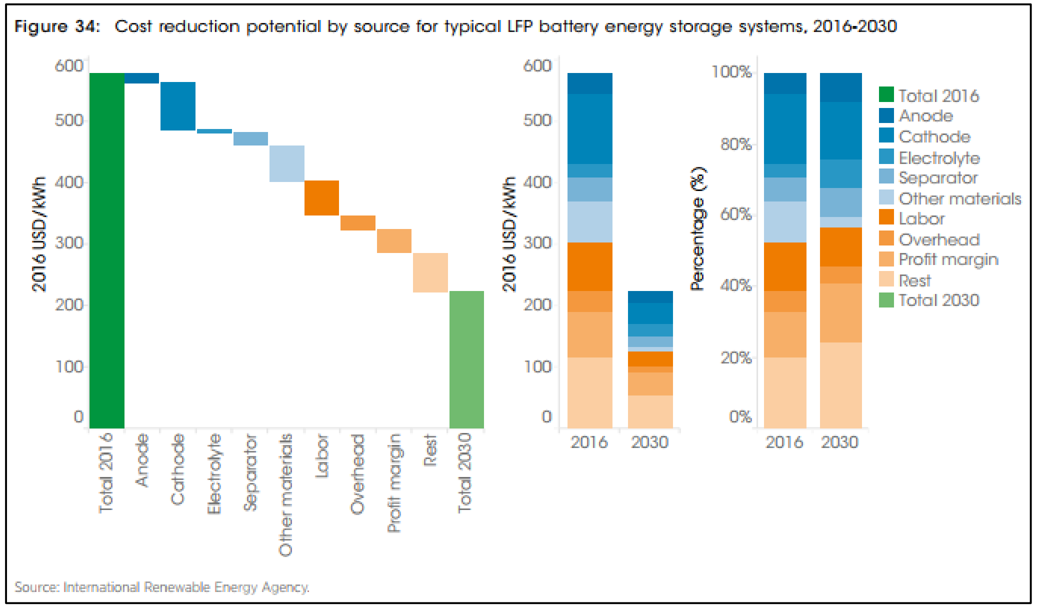
1. Business Cases for hybrid BESS concepts
- Research Project „HyReK 2.0“
- Frequency Containment Reserve and the HyReK-Concept
- Economic Assessment Results
- Conclusion of Project Results

2. Circular Economy for BESS
- First concepts and ideas

Source: DLR VE

# Potential PhD Topic 1
# Business Cases for hybrid battery energy storage system (BESS) concepts

Source: IRENA (2017)




## Starting Point

- BESS are key to the energy transition (e.g. IRENA 2017)
- Strong BESS price decrease expected, offering new opportunities
- Business cases are necessary for the success of innovations (de Medeiros et al. 2013)
- Sector coupling concepts have a high potential

## Possible Research Question

- How can business cases for short-term energy storage systems in combination with sector coupling (e.g. hybrid BESS) be established while supporting the energy transition?

# Why hybrid BESS?

# „HyReK 2.0“: Research Project and Concept

- Project Title: “HyReK – Hybrid Regulating Power Station 2.0” (11/2018 – 10/2021)
- System installed in Bremen, Northwest Germany
  - Li-ion battery storage system (BESS) of 18 MW power and 14.2 MWh capacity
  - PtH-unit (electric boiler) of 18 MW capacity linked to the battery storage and a heat storage
- Project partners: Stadtwerke Bremen (SWB), AEG Power Solutions, DLR Institute of Networked Energy Systems
- Access to high quality data thanks to industry partners

Source: DLR VE

Supported by:
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# Frequency Containment Reserve (FCR) in Germany

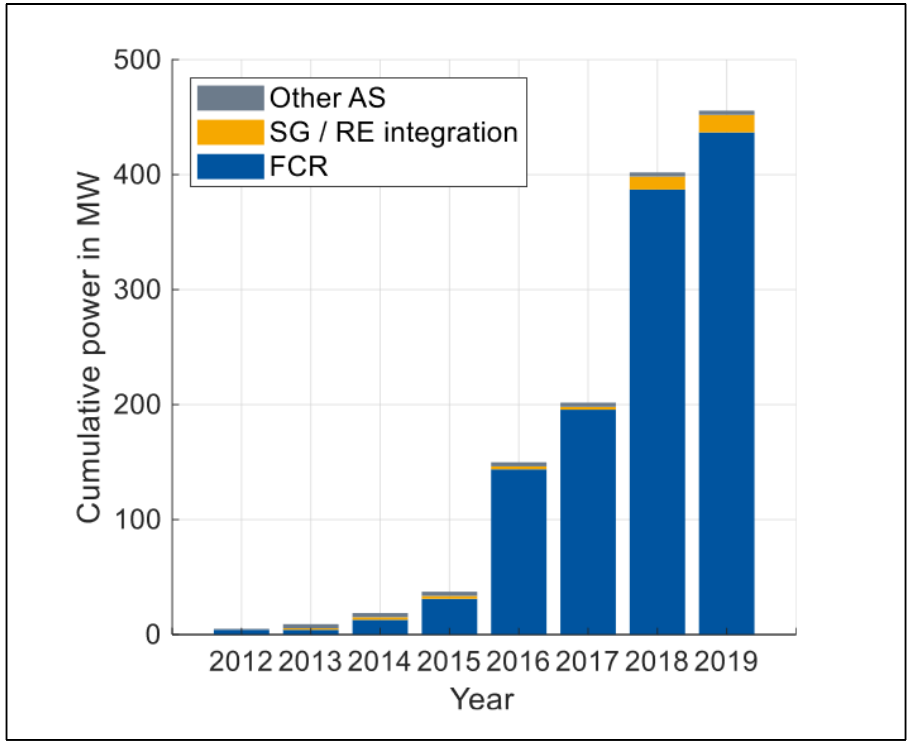
- First (=primary) balancing measure among the ancillary services if the power grid frequency deviates from the nominal value of 50 Hz

- FCR-providing systems have to be able to supply and absorb power

- Market is organized in an auction

- BESS are highly qualified for FCR provision
  - Fast response
  - Power supply and absorption

- More than 400 MW BESS for a total of 573 MW market capacity, prices have been falling since 2015




Source: Figgener et al. (2020)

# Frequency Containment Reserve
# The HyReK-Concept

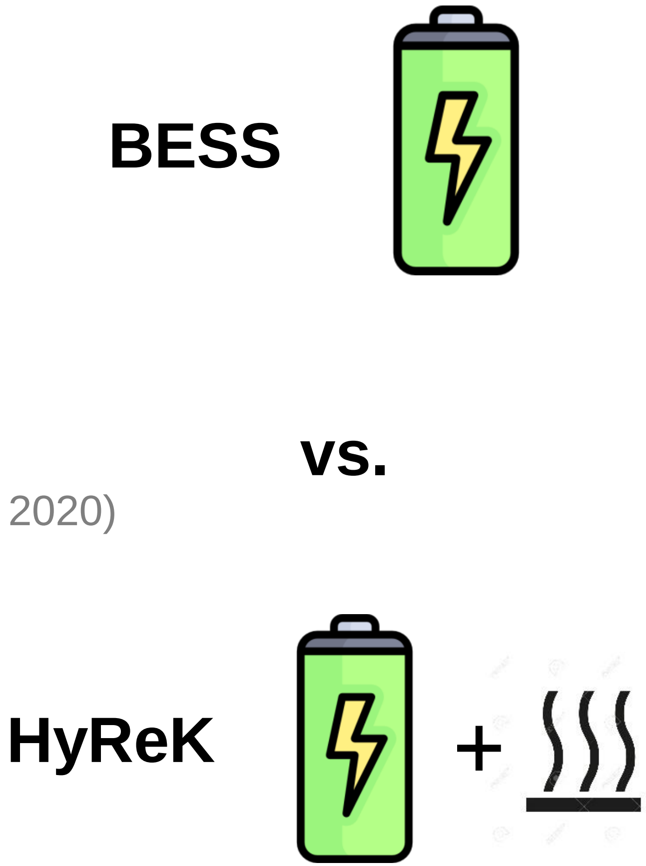
- Hybrid setup allows heat generation if the battery is fully charged
- → PtH unit replaces part of the battery

- In theory, the HyReK has two main advantages compared to BESS

1. Lower battery capacity necessary for same FCR power output
   – BESS require 0.7 MWH and HyReK 0.5 MWh for each MW FCR (Schlachter et al. 2020)
   → Lower initial investment, saving battery resources

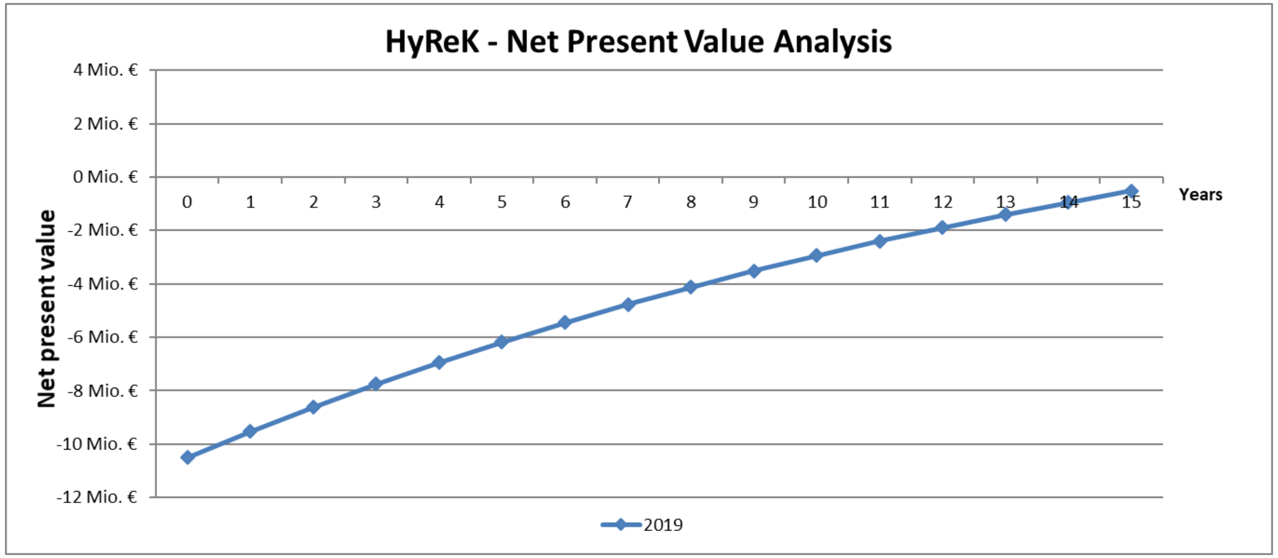
2. Second revenue stream by selling heat
   → Higher revenues

→HyReK is a smart way of using sector coupling for FCR
→Existing system has proven to function well in practice




Icon sources:
123rf.com
Flaticon.com

# Frequency Containment Reserve
# HyReK Economic Assessment




Source: Willenbrock et al (2021)

Base Assumptions

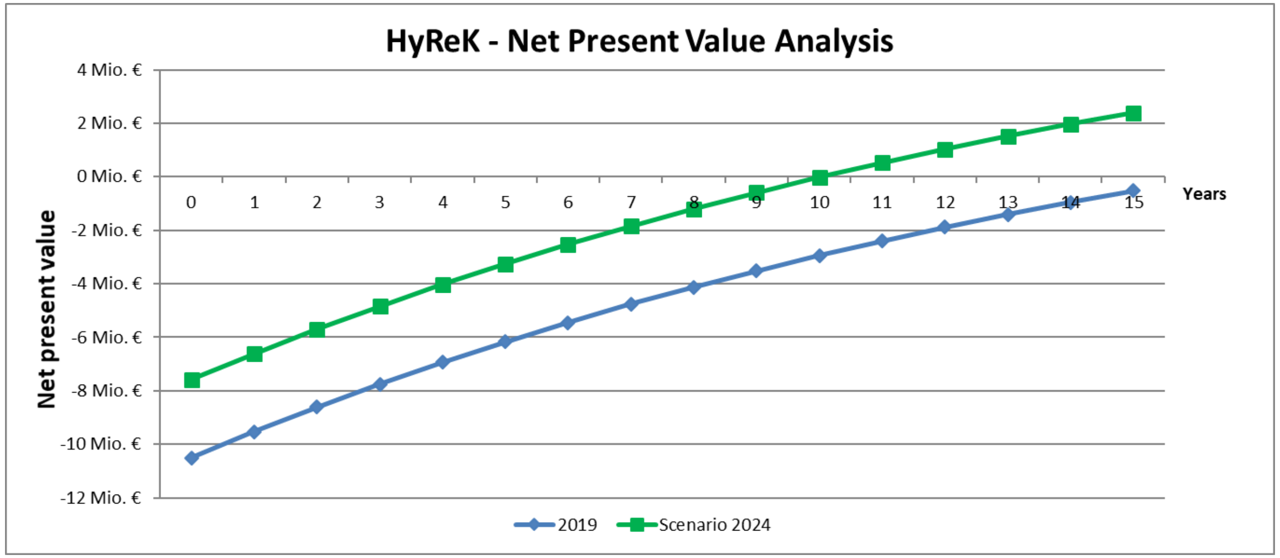
| | |
|---|---|
| • Initial investment costs | 10,5 million € |
| • Price and Frequency data | 2019 |
| • Discount Rate | 6 % |
| • Lifetime | 15 years |
| • Heat revenue | 10 €/MWh |
| • Heat taxes | 157 €/MWh |

- HyReK operational costs are high due to PtH taxes

→ About 13 % (2 million €) of the total costs account for PtH taxes

→<u>The HyReK cannot unfold its full sector coupling potential under the current tax framework</u>

# Frequency Containment Reserve
# HyReK Economic Assessment – Sensitivity Analysis




Only initial investment considered

Source: Willenbrock et al (2021)

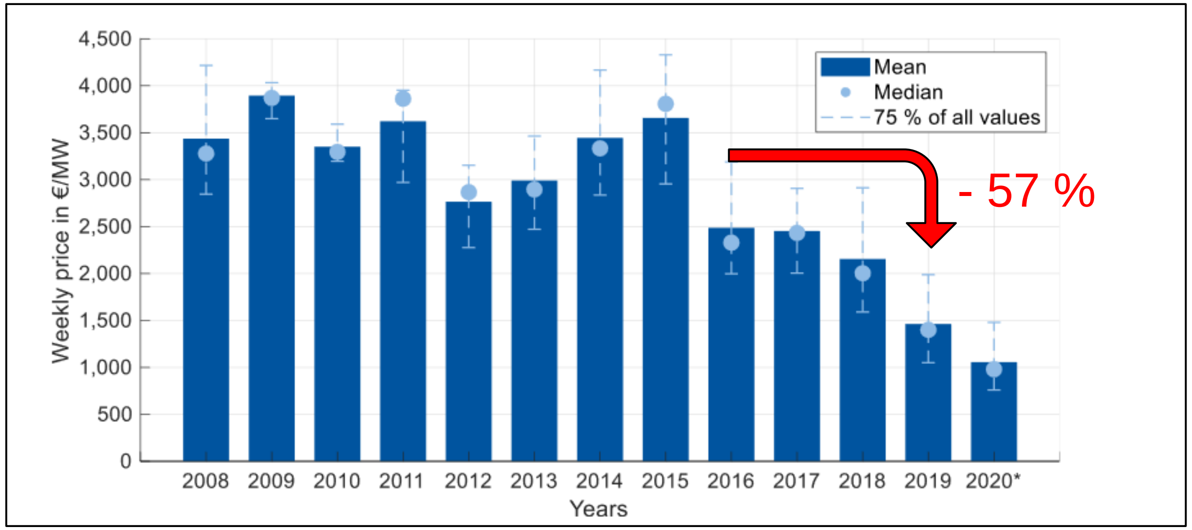
## Base Assumptions

- Initial investment costs — 10,5 million €
  - Optimized Dimensioning (-3.5 MWh)
  - Battery Costs (-44 %) — 7,5 million €
- Price data — 2019
- Discount Rate — 6 %
- Lifetime — 15 years
- Heat revenue — 10 €/MWh
- Heat taxes — 157 €/MWh

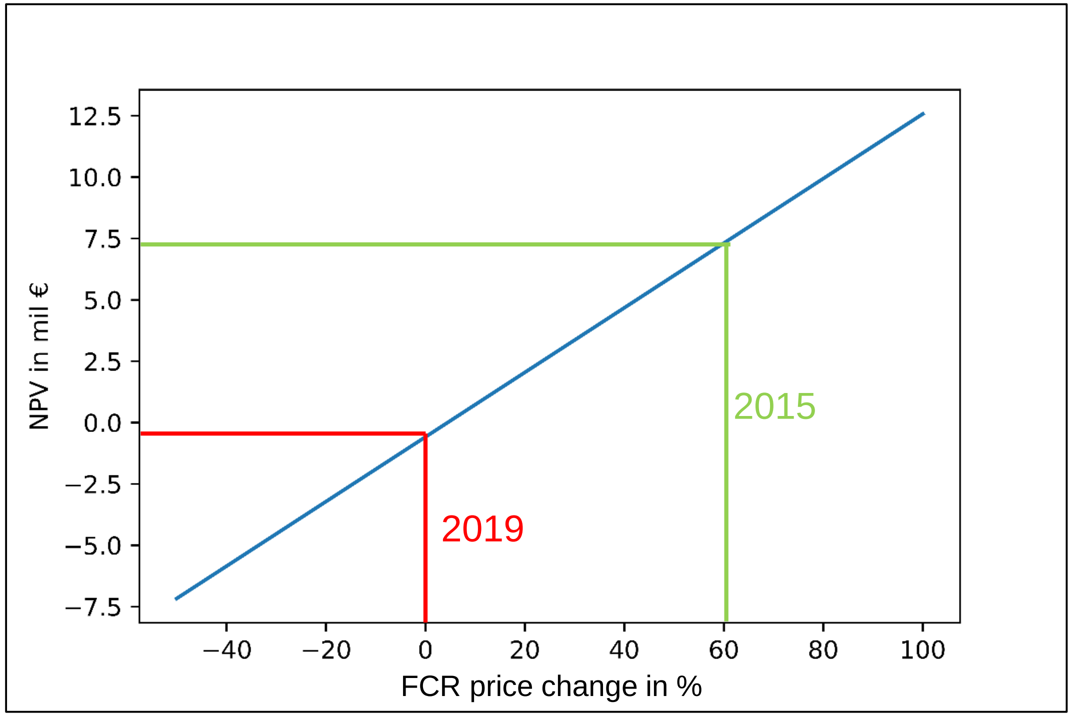
- Battery costs could decrease by 70% until 2030 (IRENA 2017)
- Lower investment costs lead to considerably higher profitability

→ Battery cell cost decrease could heavily influence the profitability of the HyReK within the next years

# Frequency Containment Reserve
# HyReK Economic Assessment – Sensitivity Analyses




Source: Figgener et al. (2020)




Source: Willenbrock et al (2021)

- FCR Price decrease 2015-2019: ~ 57 %
- FCR prices are another main parameter for the economic profitability of HyReK
- Future development hard to predict due to non-transparent market

→ FCR has become a volatile and risky market

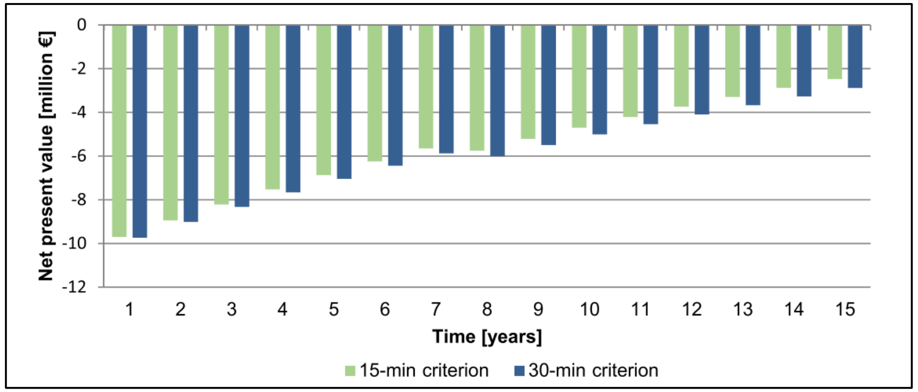
→ New applications/business models

# Further Business Models
# HyReK Economic Assessment

## Arbitrage Trading

= Capitalizing price difference on electricity markets

- Current literature indicates strong battery strain and high degradation
- Revenues are not sufficient to justify the degradation

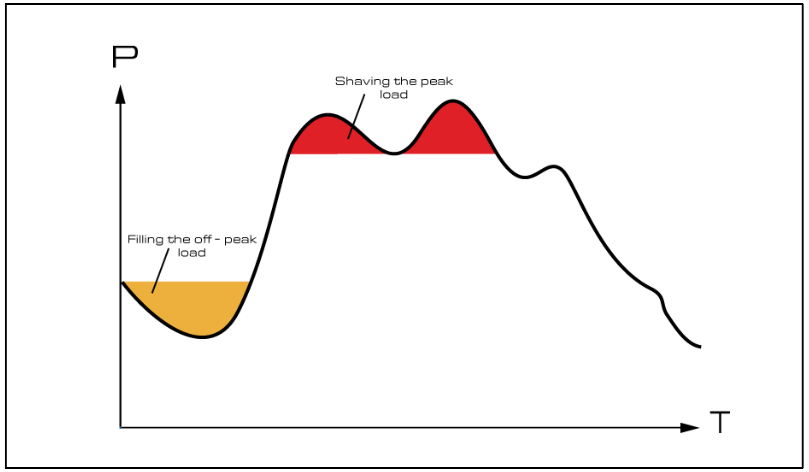



Source: Draheim et al. (2020)

## Peak Shaving

= Avoiding peak load charges (e.g. industry consumers)

- Profitability highly dependent on load profile
- General statements are difficult




Source: ae-solar.com

<u>→ In the future, higher cycle stability and lower battery costs might offer new opportunities</u>

# Why focus on hybrid BESS?

1. There is a high cost-saving potential of hybrid solutions

- → However, sector coupling is currently avoided due to PtX taxes

2. FCR as a single application for large BESS is not economically profitable

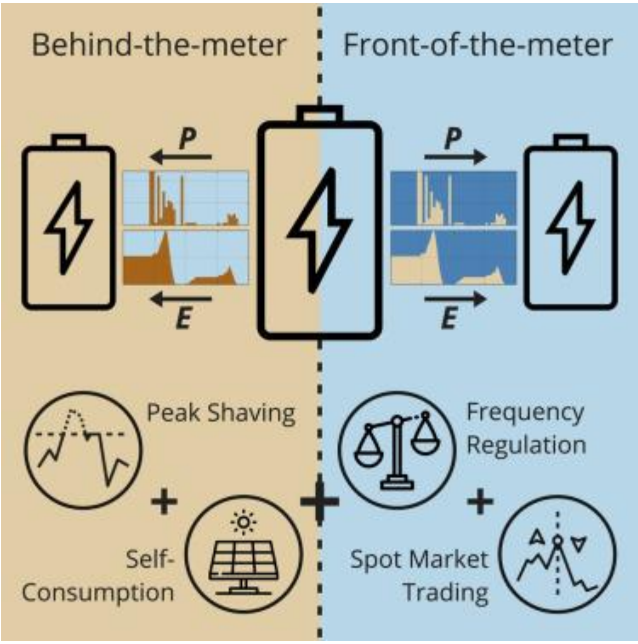
- → Price are low and hard to predict, market requirements are changing
- → New business models are possible, especially for hybrid concepts

3. Battery cell cost are going to decrease

- → Influence on the economics of (hybrid) BESS and its applications

# Potential PhD Topic 1
# Business Cases for BESS and sector coupling

Source: Englberger et al. (2020)




**Possible Results**

- Identification of attractive (new) applications or combinations
- lucrative BESS sizes depending on served applications could be identified
- Specific political measures are necessary to promote sector coupling (tax reliefs) and cost-efficient ancillary service provision

**Challenges**

- Many institutes research in business cases for BESS, there are many contributions with regards to standalone BESS already.
- Currently, there are many “ifs” regarding possible future applications or markets (black start, momentary reserve)
- Hybrid concept does not make economic sense

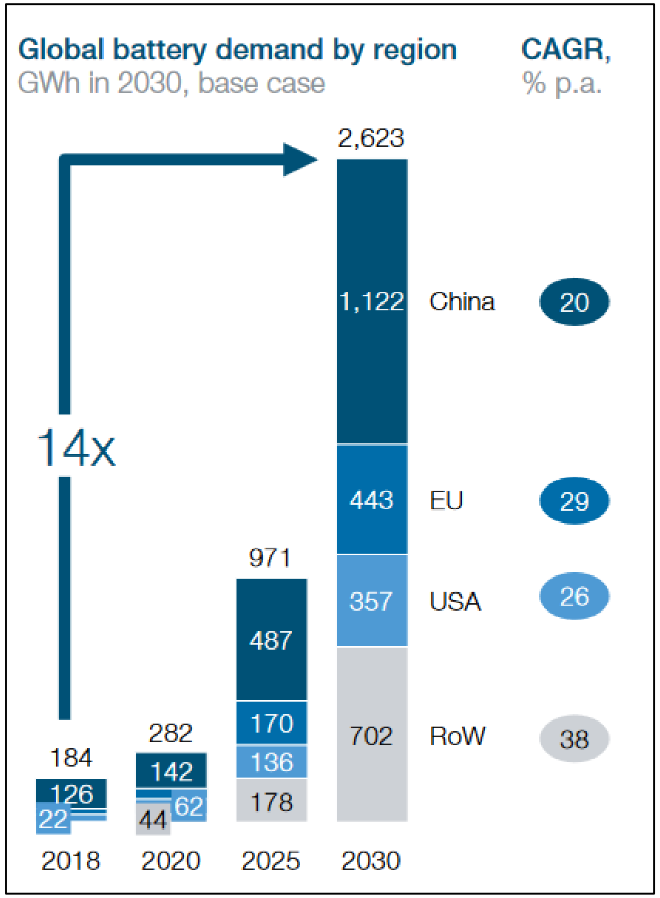
→ Maybe regulatory framework for sector coupling needs to be set first

# Potential PhD Topic 2
# Circular Economy for BESS

## Starting Point

- Global battery demand is expected to increase 14-fold by 2030 (WEF 2019)
- Use of second-life batteries has a high environmental and economic potential (Haram et al. 2021)
- Investment profitability is a main sucess factor of (sustainable) innovations (de Medeiros et al. 2013)
- Data availability is very scarce

Source: WEF (2019)



# Potential PhD Topic 2
# Circular Economy for BESS

## Possible Research Questions

Business Models for Second life Applications

- Which business models for second-life BESS are possible? Which first-life application could fit which second life application?
- Which regulatory adaptions are necessary to ease second-life applications of BESS? (e.g. safety)

Recycling economics

- How can the recycling of large amounts of BESS be organized? (infrastructure, cell design)
- What is the energy demand of energy-intensive recycling processes?
- Is their justified from an environmental and economic perspective (also regarding the general increase in electricity demand)?

## Challenges

- Regulatory and technical questions might have to be answered first, before economic questions can be addressed

Thank you!

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