RWE`s former, current and possible future energy storage applications

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Agenda

- Introduction
- Pumped Hydro
- Power-to-Hydrogen
- Power-to-Heat
- Compressed air energy storage
- Battery storage
- Future applications
RWE with clear focus on storage perspectives in core markets Germany, Netherlands and UK

Share of renewables expected to grow significantly in the next decade

- Political target is 65% share of renewables by 2030
- Regulatory environment not storage-friendly
- Political target is 49% emission reduction in 2030 (compared with 1990)
- Flexibility options including storage on the agenda of Energie-akkoord; process just started
- Political target is 40% reduction in emissions vs. 1990 but by 2030
- The regulatory framework for storage is on the agenda, but no concrete details yet
2,500 hours with electricity surplus over the year on national level at 75% renewables

Introduction

Duration curve of residual load$^1$ for German electricity market at a 75% share of PV and Wind in GW

Generation of electricity in a balanced scenario (generic)

Onshore Wind: 25%
Offshore Wind: 25%
PV: 25%
conventional, hydro, biomass: 25%

600 TWh

Source: Simulation of hourly residual load without export. RWE AG

1) Electricity demand minus infeeds from PV and Wind
High share of renewables requires storage cycles of weeks and months

Exemplary calculation for a month of supply and demand with 75%-share of renewables
What market potential exists currently for energy storage?
Pumped Hydro Principals

Source: RWE Power

RWE’s former, current and possible future energy storage applications
Pumped Hydro Sites

Schluchsee-Werk
836 MW

Herdecke
153 MW

Source: RWE Power

RWE's former, current and possible future energy storage applications
Power-to-Hydrogen replaces conventional $H_2$ in chemical industry - existing $H_2$ infrastructure is used

Hydrogen sector coupling with the chemical industry

Use of hydrogen in Germany

> Hydrogen serves as an important raw material in the **chemical industry**, e.g. production of fuel

Potential for sector coupling

> Natural gas can be stored and later used to generate electricity

> In the long term, around 10-20 TWh can be substituted without hydrogen intermediate storage

Hydrogen production DE by primary energy carrier in TWh

- 50% By-product in refineries
- 33% Steam reforming from natural gas
- 12% Extraction from naphtha (petroleum)
- 5% Electrolysis

Source: Umweltbundesamt, RWE AG
RWE’s demonstration project has one of the highest total efficiencies for Power-to-Hydrogen plants worldwide

Key facts

> **Technology:** PEM-Electrolyser
> **Rated:** 150 kW_{el}
> **H₂-Production:** 30 m³/h
> **Operation:** since 2015
> **Total Efficiency:** 86% (usage of waste heat)

Source: Westnetz
Power to Heat (PtH) provides the most efficient storage potential with development costs of less than 150 €/kW.

Advantages and applications of PtH

> **Low investment costs** for electric boiler: 100-150 €/kW

> Use of hybrid systems, e.g. PtH + gas, allows **flexible use** of PtH systems in the event of excess electricity

> **Heat can be stored well**, but requires very **high volumes**: at 30-40 kWh/m³

Efficiencies Power-to-Heat vs. total process "PtH & Saved Gas-to-Power"

- **High efficiency**: 100%
- **Process efficiency**: 66%

Source: RWE AG
Case study for an E-boiler at one of the RWE sites

**Specification for an E-boiler**

- Case study for an E-boiler rated 20 MW_{el}
- Efficiency: ~99 %
- From 0 to full load in less than 30s
- OPEX < 1% CAPEX/a
- Implementation time less than 1 year after FID
- CAPEX is guestimated at 3 million € for a 20 MW boiler including electrical connection

**Flow heater and E-boiler**

Source: RWE Technology International
Adiabatic compressed air energy storage (ADELE - Adiabater Druckluftspeicher für die Elektrizitätsversorgung)

Key facts

> Developing components for an adiabatic compressed-air energy storage facility

> Selecting a concept

> Clarifying all technical, economic and approval-law questions in connection with a demonstration project at Staßfurt

> ADELE (until 06/2013): €12m, including €4.9m by RWE Power; BMWi funding

> Construction of a demonstration plant not implemented due to lack of economic viability

> RWE parties involved, General Electric, DLR, etc.

Storage costs, depending on charge and discharge cycles p.a., in €/MWh¹

Source: RWE Power
Large scale battery storage pilot in Herdecke to explore new technologies in existing markets

Specifications

- Technology: Lithium-Ion
- Capacity: 3 x 2.538 kWh
- 552 batteries
- Revenue: mainly PRL
- Investment: approx. 6 million €
- Operation: since Jan. 2018
Electric vehicle charging stations at the new RWE Campus

**Charging stations for electric vehicles**

- Electric vehicle charging stations: 22 kW
- Capacity: depending on car battery
- Operation: Q3 2020

**Electric Vehicles @ RWE Campus**

Source: RWE AG
Thank you very much for your attention