Technical opportunities and barriers for utility scale energy storage

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Berlin, 23 October 2014
Overview

✓ Potential role of energy storage
✓ RD&D questions
✓ Storage value
✓ Conclusion
Role of storage

Storage considerations along the electricity value chain

Electricity value chain

- Generation
- Trade
- Transmission
- Distribution
- Retail
- End User

- Portfolio Optimisation
- Power Arbitrage
- Capacity Firming
- Reserve Power
- Congestion relief
- Investment deferral
- Voltage control
- Demand aggregation
- Self-consumption

Capacity markets? Imbalance penalties? Nodal pricing?

Interaction – stability of regulation? Regulatory challenges

Uninterrupted power sup.
## Role of storage

Storage is "competing" with other options for providing flexibility

<table>
<thead>
<tr>
<th>Supply over 365 days of year</th>
<th>Daily plant optimisation</th>
<th>Adjust production within an hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Flexible) power plants</td>
<td>Hydro reservoir, OCGT, CCGT, Coal, (Nuclear)</td>
<td>Nuclear, Coal, Gas (frequency control)</td>
</tr>
<tr>
<td>Market interconnection</td>
<td>Seasonal power trade (e.g. FR &lt;-&gt; DE)</td>
<td>Market coupling and arbitrage</td>
</tr>
<tr>
<td>Demand response</td>
<td>-</td>
<td>Heavy industry (e.g. Al smelter)</td>
</tr>
<tr>
<td>Flexible RES-E</td>
<td>Biomass</td>
<td>Curtailment?</td>
</tr>
<tr>
<td>Energy storage</td>
<td>Hydro reservoir, H2?, thermal storage?</td>
<td>PHS, CAES, Batteries?</td>
</tr>
</tbody>
</table>

1) Additional system needs (e.g. voltage control, black start capability, congestion management not shown here ...)
Selected inputs by the stakeholders
SET-Plan Integrated Roadmap (work in progress)

- **Advanced R&D**
  - **Enhanced materials**
    - High temp steel
    - Electrolytes
    - Nanostructures
  - **New technologies**
    - LiS, Zn/Air
  - **Improved technologies**
    - Variable speed PHS
    - Adiabatic CAES
    - Very low head turbines
  - **Interfaces**
    - SCADA\(^1\)
    - ICT

- **Industrial research and demo**
  - **System simulation**
    - Embedding storage
    - EU standard models
  - **New technology field tests and demos**
    - Central
    - Decentralised
  - **System integration field tests and demos**
    - SCADA
    - ICT
  - **Manufacturing process**
    - Allow scalability
    - Recycling of materials

- **Innovation and market uptake**
  - **Standardisation**
    - Interfaces
    - Assessment schemes
  - **Global business case demo and evaluation**
  - **New environments**
    - Behind the fence
    - Contractor models
  - **Health Safety and Environment solutions**
    - PHS landscape impact
    - CAES brine deposition
    - Battery fire hazards

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1) Supervisory Control and Data Acquisition
Will Adiabatic Compressed Air Energy Storage (A-CAES) be ready in time?

**Drivers**
- The main large scale alternative to pumped hydro for 'flat' regions
- No dependence on natural gas as heat stored
- Based on well-established turbo-machinery and heat storage

**Barriers**
- Very small existing base for CAES (only 2 plants worldwide)
- Currently little financial incentives to deploy the technology
- Geology, competition for reservoirs?

**RD&D needs**
- Successful demo to establish confidence (latest projects delayed)
- Road mapping and R&D monitoring to understand technology innovation needs
- Continued Techno-economic evaluation and power system studies to evaluate the likely market environment
Can thermal storage, DSR\textsuperscript{1}, E-vehicles push aside electricity storage?

**Drivers**
- Large, yet little developed potential for heat storage (el. heating, CHP, cold)
- Largely untapped potential for residential DSR
- Cost advantage w.r.t. electricity storage
- First deployment cases (DK, DE, FR)

**Barriers**
- No transformation of energy back into electricity
- Might require behavioral change and regulatory challenges
- Infrastructure needs

**RD&D needs**
- Assess potential (TS, DSR, EV)
- Interactions of different sectors (power, heat, transport) with energy system models (e.g. JRC TIMES)
- Interaction with power system (Techno-economic case studies)

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1) Demand Side Response
Would there be enough potential sites for pumped hydro storage in Europe?

GIS based assessment of 21 Member States + 5 other European countries

<table>
<thead>
<tr>
<th>Constraint</th>
<th>Theoretical</th>
<th>Realisable</th>
<th>Existing (incl. mixed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max distance between reservoirs</td>
<td>1, 2, 3, 5, 10, 20 km</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum head</td>
<td>150 m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min new reservoir capacity</td>
<td>100 000 m³</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mini distance to inhabited sites</td>
<td>500 m</td>
<td></td>
<td></td>
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<tr>
<td>Min distance to trans. Infra.</td>
<td>200 m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min distance to UNESCO site</td>
<td>500 m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max distance to transmission grid</td>
<td>20 km</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min distance Natura 2000 co area</td>
<td>not within</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1) Gutiérrez et Lacal e2013 - Assessment of the European potential for pumped hydropower energy storage, JRC report EUR 25940 EN
Will storage technology be driven by a consumer pull or industry push?

**Drivers (for pull)**
- Success story of Li-ion batteries originally developed for consumer goods
- E-vehicles provide potential for further consumer driven technology deployment

**Barriers (and counterfactuals)**
- Potentially unstable regulation of local storage
- Development of NaS in coordinated effort by Japanese stakeholders and current large scale redox flow batteries suggest attractiveness of push approach

**RD&D needs**
- Understand innovation processes for historical and current storage technologies
- Mapping of ongoing R&D activities
Will PV self-consumption plus storage make electricity grids "redundant"?

Drivers

- Increasing PV share requires solution for distribution grids (e.g. over voltages)
- First commercialisation of products (DE) after driven by incentives (e.g. DE)
- Consumer costs of capital below utilities

Barriers

- Counterproductive from DSO point of view (less utilisation, same costs)
- Decentralised storage can also increase grid needs if dispatched according to market signals
- To a degree driven by high fees and taxes on power \(\rightarrow\) unstable?

RD&D needs

- Improve battery CAPEX
- Understand business model under different regulatory schemes
- Implications of distributed storage on distribution grid sizing and operation (distribution grid models)
### Storage value can be assessed in two fundamental ways

<table>
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<th>Mathematical formulation</th>
<th>Typical application</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maximise profit</strong> resulting from (different) storage revenue streams</td>
<td>Assess the <em>profitability</em> of power storage from the <em>investor's</em> point of view. Applied to current system, often arbitrage + reserve.</td>
</tr>
<tr>
<td><strong>Minimise total costs</strong> of operating the power system</td>
<td>Assess <em>benefit</em> of adding storage to the generation <em>system</em>. Applied to future systems, x-value chain assessment.</td>
</tr>
</tbody>
</table>
Storage could generate 6% IRR in IT if battery CAPEX at 100–150 €/kWh

Storage Energy (left) and power (right) CAPEX for obtaining an IRR of 6%\(^1\)

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1) Zucker et Hinchliffe 2014
Different conclusions regarding the value of hydrogen and "power 2 gas"

**Agora Energiewende**

- Study on short (PHS, CAES) and long-term (H2) storage
- Value of different storage options for future German low carbon energy system with very high RES-share

- Low need for storage investments before 2030 (existing system can cope)
- P2Gas could for chemical industry and transport could break even with oil in mid 2020s...
- ... under slightly optimistic assumptions (30-50 €/MWh, 4000-5000 h/a utilisation)

**France Strategie**

- Work note on the economics of hydrogen and power to gas
- Costs of hydrogen production (now and in future) compared to current costs of gas

- Hydrogen from P2Gas cannot compete with hydrogen from steam reforming for foreseeable future
- Costs of hydrogen car at 13 €/100km vs 3.5 €/100 km for diesel car
- CO2 price of 993 €/t to break even
- 70 €/MWh price, 2000 h/a utilisation

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1) Fürstenwerth et al. 2014, Stromspeicher in der Energiewende
2) Beeker 2014, Y a-t-il une place pour l’hydrogène dans la transition énergétique
A number of regulatory hurdles could be addressed

- Application of final consumption fees (grid and RES-E) to storage, even if storage does not constitute final use of the energy
- Payments for curtailment to RES producers, without an incentive to encourage productive use of the curtailed electricity
- Lack of clarity on rules under which storage can access markets (e.g. TSOs and DSOs generally not allowed to own and operate storage)
- Missing rules on access of storage to the ancillary services market
Conclusion

• Storage is not a simple asset class → rather it can have many different functions

• RD&D needed for a number of storage technologies

• Assessing the value of storage does not always yield simple answers and many assumptions might be inadequate
Please visit http://setis.ec.europa.eu

Thank you!