Drivers for storage needs, current and future technologies and potentials

International seminar on large scale balancing from Norwegian hydropower
Sand, Norway - September 12/13\textsuperscript{th}, 2012
EnBW AG, Holding, Head of Conv. Generation & Hydro Power, Dr. Bernd Calaminus
Brief Portrait
EnBW Energie Baden-Württemberg AG

- Third-largest energy company in Germany
- Business segments: electricity generation and trading, electricity grid and sales, gas, energy and environmental services
- Annual revenue 2011: ~ € 18.8 billion
- Costumers: ~ 6 million
- Employees: ~ 20,000
- Headquarter in Karlsruhe

<table>
<thead>
<tr>
<th>EnBW group</th>
<th>31/12/2011</th>
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</thead>
<tbody>
<tr>
<td>Nuclear</td>
<td>MW 3,333</td>
</tr>
<tr>
<td>Conventional power stations</td>
<td>MW 6,986</td>
</tr>
<tr>
<td>Storage plants / PSP with nat. inflow</td>
<td>MW 1,299</td>
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<tr>
<td>PSP without nat. inflow</td>
<td>MW 545</td>
</tr>
<tr>
<td>Run of River Plants</td>
<td>MW 926</td>
</tr>
<tr>
<td>Other renewable energies</td>
<td>MW 313</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>MW 13,402</strong></td>
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To Start with a Fundamental, Robust Question:
Prerequisite (not only) for a Strongly Industrialised Economy

(NO In Situ Experiment!)

Where do I reliably get the needed electric power from at any moment at competitive conditions?

- Transport / distribution
- Domestic or import

- Resource dependency
- Mix of supplies
- Grid stability

- Efficient demand, but still at high level
- Squeeze-out of electricity-intensive industries does not help

- Weather-driven?
- Limited elasticity of demand (DMS)

- Regional
- EU
- World markets

- Reliable Power \(\textit{(quantity and quality)}\) is needed, not only random yearly production (..TWh)
**Some German Electricity System Flashlights**

**Still a Strongly Industrialised Country, *Little Virtual Bear Sale***

- Reliable, secure and competitive supply (16’ average downtime/a)
- Net exporter
- Nuke phase out (last in 2034)

- Nuke phase out (last in 2022); 7+1 units shut down (mainly South)
- Reliable, secure and competitive supply as a SINE QUANON!
- Net importer? Secured power ext.?
- RES boost: share of generation
  - 35% in 2020
  - 50% in 2030
  - 80% in 2050 (minimum)
- New „centralisation“? Wind in North, Solar in South...; grid is behind schedule!
- More regulation, less market?
- Future business models? „Capacity“
- Real cost, NIMBY („S21“)...

max. vertical load TNG (2010) ca. 11,000 MW

min. vertical load TNG (2010) ca. 3,500 MW

Real data till 2010; Prognosis from 2011

Source: EnBW TransNetBW
“Energiewende” in Germany with Ambitious Objectives

- German demand: app. 590 TWh\(_{el}\)
- In 2011 app. 122 TWh\(_{el}\) from RES
  - \(\Rightarrow\) 65 TWh\(_{el}\) volatile feed in (wind & solar) – app. 50%!
- Objective: 300 TWh\(_{el}\) from RES in 2030
“Installed Capacity” is one Aspect ⇒ Contribution to Secured Power Supply at Any Moment is the Other

- PSP
- PV
- Wind
- CCGT
- Nuclear
- Brown Coal
- Hard Coal

- secured power
- availability
PV in Germany
As of 08/2012: about 28 GW (+7,5 GW in 2011!) / ca. 1,000 Full-load hours / Invest based on „EEG“ feed-in tariffs / hardly dispatchable / high share in regions with comparatively weak grids

50 to 70 GW by 2020?!
Peak/Off-Peak Spread Damped by PV
Peak Cut-off, Affecting Margins of Short-term Storage
Price-Spreads as the Relevant Parameter for Storage Futures Markets: Volatile and Decreasing Spreads

Control power, in addition, is more an economic optionality, (a chance) for storage rather than a significant long-term benefit enabling construction decisions!

Source: EEX; Graph: Öko-Inst.
Attempts to Quantify Time Patterns for Needs of Balancing Power

notable excess of electricity starting from 50% RES feed-in is expected

source: Nitsch et al. 2010, Prof. Dr. M. Sterner
http://www.efzn.de/uploads/media/008_Prof._Michael_Sterner.pdf
Dynamic, Residual, Dispatchable Power & Energy Needed with Increasing RES

Source: ISI Fraunhofer
Multiple Day Storage: To Fill Calm-Periods by “Stored” RES, Need Exceeds Capacity by Orders of Magnitude

Rough estimate (order of magnitude):

600 [TWh/a] : 365 [d/a] = 1.64 [TWh/d]
1.64 [TWh/d] x 14 [d] = 23 [TWh]
23 [TWh] : 0.04 [TWh] = 575 = factor vs today, in D:

Order of magnitude: TWh
Infrequent operation

Generation of 8 GW cont. by operation of all pumped hydro plant (ca. 40 GWh): max. 8h
(necessary storage cap. for whole week: ca. 1,050 GWh)

Generation of 5 GW cont.: max. 14h
(necessary storage cap. for whole week: ca. 540 GWh)
Dynamic Mismatch of RES Surplus and Demand
Sorted Hours over the Year

The total surplus of electricity in Germany will rise from 4 TWh in 2020 to 38 TWh in 2050.

"RES integration"... not sufficient (η < 1)

surplus of fluctuating renewables
2050: 38 TWh

necessary electricity generation of controllable power plants

Need for backbone power remains high

Source of graph: PROGNOS 08-2012, 3. Workshop Berlin
As Long as Backbone Exists and RES May be Redispached, the Hard Need for Storage is Limited ("System Boundary")

Dynamic, volatile RES supply

Balance out mismatch at any second: FLEXIBILITY

Storage

Dispatchable backbone mix

Smart DMS P. to Heat

Import / Export

“redispach” of RES ("last kWh")

(cover residual load, take-up excess power, control gradients, optimise economically within the system)

Variable load (daily, seasonal...)

“Breathing System” can cope with RES still for a while: drivers for storage?
Potential PHP-Projects in Germany

- 1 project under construction ⇒ 0.2 GW
- tot. 11 projects planned ⇒ 4.8 GW
  Σ 5.0 GW

Planned, different maturity

PHP at EnBW
Obervermuntwerk II – Project Overview (Lead by VIW)

- pressure conduit (1943) has to be renewed
- opportunity for a new pump storage plant
- construction time app. 5 years
- start of construction planned in 2014 (decision taken)
- start of operation planned in 2018

- capacity 360 MW; 2 ternary units
- head 280 m
- storage volume Vermuntsee ca. 5 Mio. m³
- rated discharge ca. 144 m³/s
- length of pressure tunnel ca. 4.5 km
PHP at EnBW
Atdorf – Project Overview (together with RWE, Schluchseewerke)

Project data:
> 6 Units à 234 MW, in total 1,400 MW
> 9h/12h turbine-/pump-hours
> head 600 m
> rated discharge app. 280 m³/s
> expected permit in 2014, start of constr. planned in 2016 (open)
PHP at EnBW
Forbach – Project Repowering/Extension (1926)

- Power of 2 stages: 70 MW + 200 MW
- Start of construction foreseen in 2014, COD in 2019
- Upper stage shaft power house
PHP Renaissance in Europe?
Mind the Gaps between Potentials – Announcements – Reals Projects!

› Additionally around 21 GW in D, E, F, I, A, P, CH till 2020
› Some 10 GW announced in other Europ. Countries (e.g. Ukraine: +1,4 GW)
New Concepts: “Naturstromspeicher” (by VOITH et al.)
Upper Storage Basin in Lower Windtower-Section

Pilot concept for Gaildorf
- Wind: 4 x 4.5 MW
- PSP: upper basin in 4 towers, each 40,000 m³
- PSP: lower basin at Kocher river
- PSP: 12 MW
- Head: max. 230 m
- Capacity: 70 MWh
"Granite Piston" – Concept for Large Hydro Storage
[r = 500 m: \(\approx 400.000.000 \text{ m}^3\) Water; Granite: \(\times 2\) \(\Rightarrow\) ca. 2,2 Bill. t; \(\approx 1,6\) TWh]

[by E. Heindl, Rome 7-2012]
Power-to-Gas – Chain (1/3)

Differentiate: Exergy Efficiency / Power & Heat / Apps. for Mobility, Industrial Resource etc.

η = 25 – 30% over complete cycle „elect. to elect.“

H₂-Production: 33,000 Nm³/h

Assuan (EGY); 156MWel

H₂ - Production: 33,000 Nm³/h
Gas System in Germany with High Performance (2/3)

However: Cold Period in Europe in 02/2012 Revealed Transport Bottle-necks

- Length of pipeline grid: 436,000 km (2009)
- Number of major gas storage plants: 47
- Storage volume: ca. 21 Bill. Nm³ working gas, equivalent of about 220 TWh
- Gas needs: 976 TWh (2010)

⇒ Infrastructure is available in D
⇒ ...and asks for further use

Caverns and pore storage as well as pipeline grid in 2010 (source: DBI GUT GmbH; additional feed-in points)
Gas Demand (and Flow) is Seasonal  (3/3)
Injection Potential for H₂ Varies over Time

- Hydrogen injection depends on gas flow (respectively gas demand; time & location)
- Potential is actually limited at 2 Vol% due to gas vehicle reservoirs (tightness of tanks)
Adiabatic Compressed Air Energy Storage
AA-CAES with Considerable Potential, but also Need for Development Progress

- Salt dome formations are available in „windy“ areas in northern Germany
- If roughly 10% of potential gas caverns were used for AA-CAES, this would represent about 21 GWh of capacity (1,200 GWh as hydrogen)
- CAES comparable to today’s PHP capacity in D
Distributed Accumulators for Various Purposes
EnBW Examplary Pilot Projects / „Volksspeicher“ Are under Discussion

› „Netlab 2“ - Zwiealten/Sonderbuch:
  › 1.2MW local town grid
  › high PV feed-in
  › ⇒ find intelligent methods to prevent overload through active control of
    › producers
    › consumers
    › controlable local transformer
    › storage (Evonik, 16 kWh, 33 kW)

› Varta Microbattery & EnBW ODR in Neuler-Schwenningen:
  › Lithium-Ion-battery system (63kWh/27kW)
  › ⇒ Integration of PV in the distribution grid of ODR
  › ⇒ Grid stability (prevent from grid extension)
  › ⇒ Smart Grid control
Study on PHP-Potential in Baden-Württemberg
Procedure Applied by EnBW with HPI

- Criteria for the selection process
- Determination of potential-surfaces ⇒ sites
- Determination of power [GW]
- Determination of working capacity [GWh; „Tank-size“]
- Ranking of sites following techno-economical criteria
- Validation of invest estimates for samples

GIS-based process, data:
- „DGM 50“ (DGM 5)
- Topographical maps (TK 25, TK 100)
- Digital landscape-model „DLM 50“
- Grid (high and highest tension)
- „FFH“-areas and „Natura 2000“
- Nature preservation areas
- Water protection areas (zone 2 and 3)
- Geological survey maps
- Administrative areas (Regional planning, communities...)

Surface of the „Land“ 35,794 km²
Topographically Suitable Areas for PHP in Baden-W. Criteria and Graphical Results

Topography minus main infrastructure:
Potential upper basin areas (yellow), lower basin areas (blue), respectively both (red)

Main criteria:
› min. 40.000 “MWm” (200m / 200MW)
› capacity (energy) 8 pump-hours
› max. 5 km distance UB to LB

Flatness criteria for analysis of relief:
› summit
› slope
› valley

3 Cost-categories A, B, C:
› < 1.200 €/kW
› 1.200 – 1.600 €/kW
› > 1.600 €/kW
Example for Surface Exclusion:
„Inhabited Areas“
Example for Surface Exclusion:
„Main Infrastructure“ (Highways, Railways...)
Results of GIS-Based Research for Locations after Plausible Filtration
Technically Reasonable Sites (845), 201 of which Show Low Conflict Level

- **845 Sites** between 71 MW and 15.234 MW (medium 678 MW) / power $\sum 573$ GW / working capacity $\sum 4.584$ GWh

- **201 low conflict sites** between 84 MW and 10.828 MW (medium 580 MW) / power $\sum 116$ GW / working capacity $\sum 928$ GWh
“Green Batteries in the Heart of Europe”? Switzerland and Austria Express their PHP ambitions
CH: hydro tot. 13.3 GW (incl. 1.7 GW PHP); 2020: + 6 GW Turb. + 4 GW Pump
Very recent report (12/2011) issued by CEDREN/SINTEF

- Hydro potentials for EU markets to balance out fluctuating wind power
- **Main scenario**: #12 new hydro power plants using existing reservoirs *(within working level permits)*
- **11.2 GW** in parallel to existing plants
- #5 of which as **PHP with 5.2 GW**, remaining 6 GW as dams (turbining only)

**NOR_LINK & NOR_GER confirmed?**
Some Conclusions and Messages

Need for system „flexibility“ increases with share of RES

- „Flexibility“ means: +/- balancing, short and frequent start-up, fast ramping, broad amplitude range, black-start capability (POWER-storage; volatility of prices)
- Storage of „electricity“ is – if already in place – the „friend“ of RES (PHP = 1st choice: efficient, large, fast, affordable)
- Intraday storage (conv. PHP) fits well with PV-patterns – but peak damping leads to spread decrease, hampering arbitrage

Market and other framework conditions

- Actual conditions do not favour longterm investments in storage plants (regulatory drivers, e.g. for balancing power, adapted to actual situation?)
- To have the chance of getting realised, specific invest of efficient storage should not exceed around 1,000€/kW
- System-perspective is key for longterm decisions! (Grid extension is prerequisite ⇒ spatial balancing!)
- Residual “backbone” of dispatchable, secured power will remain essential for long period (but: redispatch by TSO, strategic reserve, part-load, little full-load op. hours per year ⇒ “Drivers” to continue operation?)
- National (or even sub-national) autarkie ambitions lead to sub-optimal solutions (win-win for all partners is needed); EU-market-coupling and market-integration of RES would be helpful
- Euphoria around storage does not automatically translate through acceptance „IMBY“
- No „silver bullet“, but the need for intelligent MIX of measures / technology contributions