Storage: Why? What? How?

International trends

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THIS PROJECT IS CO-FUNDED BY THE EUROPEAN REGIONAL DEVELOPMENT FUND
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The Challenges

- **Energy demand growing** — projected to grow globally by 36% from 2010 to 2035, including energy efficiency increases[1]
- **Aging generating capacity** — by 2025, most coal-fired plants and by 2030, most nuclear plants, will need to be rebuilt or retired[2]
- **Need for new transmission and distribution** —150B € of planned US transmission projects[3]
- **Infrastructure driven by peak demand** — 25 % of distribution and 10 % of generation and transmission assets (worth multi hundreds B €) used less than 400 hours per year[4]
- **Growing renewable generation** that is intermittent leads to grid instability and—in some cases—curtailment or negative pricing[5]

Sources:
1) IEA, 2010 2) NERC, 2010 3) Quanta, 2010
4) EPRI, 2010 5) CAISO, 2007

The Solution: Energy Storage

Energy Storage Usage Can:

- Improve efficiency and profit of existing generating assets
- Defer costly upgrades to transmission and distribution infrastructure
- Avoid additional peak generating capacity investments
- Increase integration and profitability of renewable energy

Grid/Utility Benefits:

- Electricity peak shifting
- Supply of flexible, distributable capacity
- Ancillary services
  - Load following
  - Frequency regulation
  - Voltage support
- Transmission congestion relief
- Renewable energy integration support via supply firming and time shift

End User Benefits:

- Time of Use Energy management
- Electricity supply reliability improvement
- Electricity supply quality improvement

Source: http://www.infobarrel.com

Electricity Storage Nowadays

Electricity:

- Total Annual Electricity Consumption is about 20,000,000 GWh
- Energy Storage: 1,270 GWh (0.0064 %)

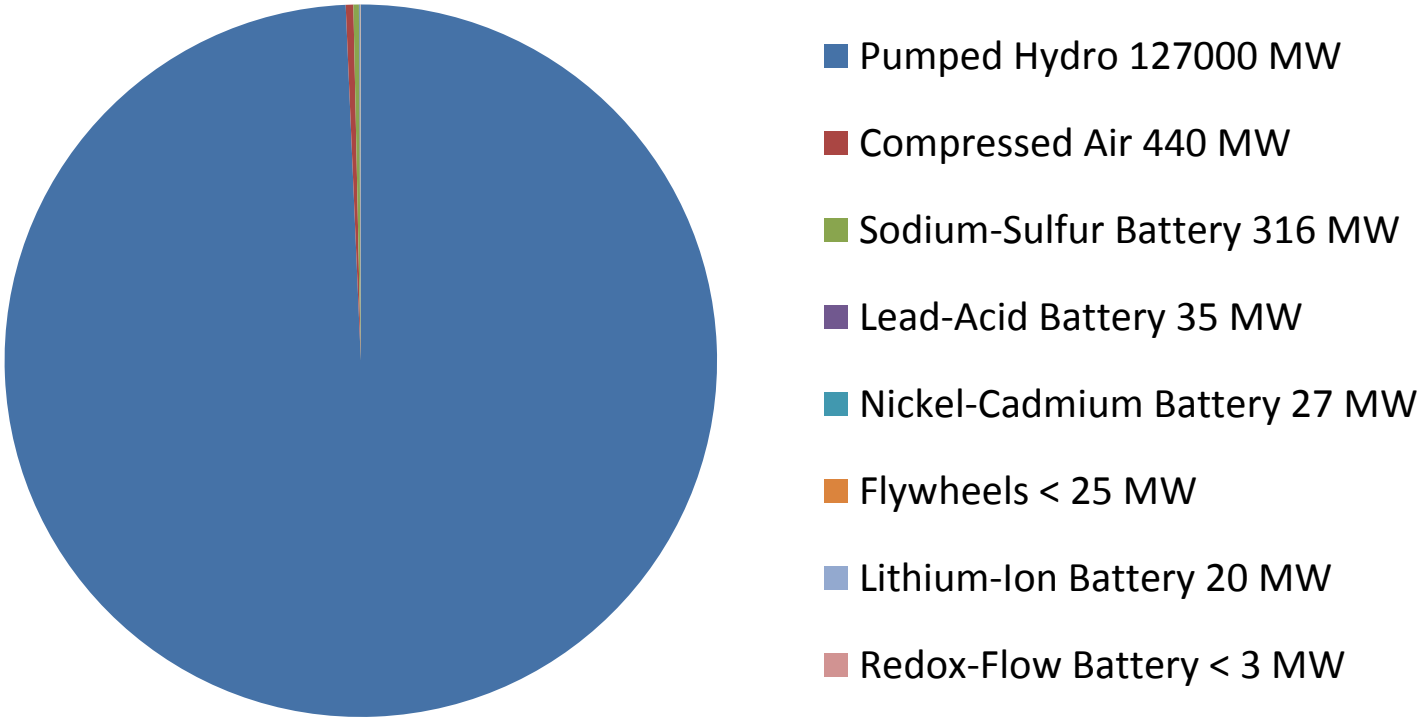
Oil:

- Total Annual Oil Production 4,748,067,825 m^3
- Oil Storage: 600,000,000 m^3 (12.6 %)

Oil Storage = 46 days
Electricity Storage = 33 min

Sources: http://www.eia.gov/forecasts/ieo/electricity.cfm, http://www.investorideas.com/Research/PDFs/Top_10_Global_Oil_and_Chemicals.pdf

Current World Electric Energy Storage Capacity 1/2



- **Today's electricity storage is almost exclusively pumped hydro** – over 99 % of total storage capacity.

Source: EPRI (2010)

Current World Electric Energy Storage Capacity 2/2

*Tab.: Installed electricity storage technologies in **EU**.*

Technology	Installed Capacity MW
PHS	45600
CAES	290
NaS battery	few
Pb-acid battery	20-30
Lithium-ion battery	20
Redox Flow battery	1

*Tab.: Installed electricity storage technologies in **Japan**.*

Technology	Installed Capacity MW
PHS	25500
CAES	-
NaS batteries	270

*Tab.: Installed electricity storage technologies in **US**.*

Technology	Installed Capacity MW
PHS	22000
CAES	115
Flywheels	28
Thermal peak shaving	1000
Lithium-ion batteries	54
Ni-Cd batteries	26
NaS batteries	18
Other (flow, lead-acid batteries)	10

Sources: Prestat (2011), DOE (2012), Electric Storage Association (2010), Electricity Advisory Committee (2011)

Pumped Hydro

Basic principle: to store energy by means of two reservoirs located at different elevations.
Installed Capacity in Europe: ~ 45 GW
Developments in Europe:

- Planned/ ongoing projects by 2020 ~ 7 GW (CH, PT, AT, ES, DE, SI);
- Upgrading old plants + optimizing turbine/ pump system (CH, AT, ES);
- Transformation of standalone reservoirs into PHS
- Norway potential 10-25 GW (driven by large deployment of wind power in the North Sea)

Figure: Seneca Pumped Hydro Station near Warren Pennsylvania.

Sources: *http://www.jrc.ec.europa.eu/, Stathis Peteves:* Power Storage options to integrate renewables, *European Commission, DG Joint Research Centre, Institute for Energy and Transport,* http://www.zero-carbon-energy.com

Compressed Air Energy Storage

Basic principle: to store energy mechanically by compressing the air from the atmosphere, in e.g. underground caverns.
Worldwide capacities: 320 MW (Germany), 110 MW (USA).
Projects: USA, Italy, Japan, South Africa, Israel, Morocco, Korea.
Developments in Europe

- Underground caverns potential: DE, DK, ES, FR, NL, PT, UK
- R&D Adiabatic CAES: ADELE project (DE).

Research fields:

- **Identification of new locations:** in vessels or above ground (SSCAES)
- **Adiabatic CAES (AA-CAES):** demo; lower the cost.
- **Isothermal compression** (thermo-dynamically reversible cycle, theoretical efficiency of 100%): demo; lower the cost.

Sources: *http://www.jrc.ec.europa.eu/, Stathis Peteves:* Power Storage options to integrate renewables, *European Commission, DG Joint Research Centre, Institute for Energy and Transport*

Power to Gas Technology

Methanation

4 H2 + CO2 → CH4 + 2 H2O

Basic principle:

- „Power to Gas“ is the name given to an energy process and storage technology which allows electricity to be held in reserve in the megawatt range.
- Storing electricity which cannot be fed into the grid in the form of sustainable natural gas.

Pros and Cons:

+ Clean sustainable way of storing energy
+ Capable of storing huge amounts of energy
+ Capable of storing energy for several days, even months
— Very low efficiency (up to 50 percent)
— Requires a good constructed natural gas grid

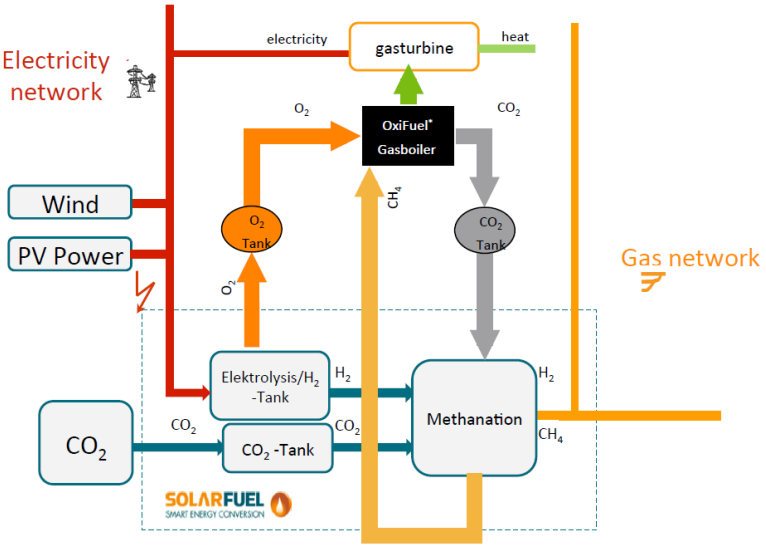


Figure: Linking power + gas grid via methanation.

Sources: *http://www.jrc.ec.europa.eu/, Stathis Peteves:* Power Storage options to integrate renewables, *European Commission, DG Joint Research Centre, Institute for Energy and Transport, SolarFuel.*

Ending Remarks

- Energy storage is a necessary option for future decarbonised systems, complementary to other flexibility and energy security solutions.
- Advanced storage technologies still require long term (research phase) and high risk investment (demonstration).
- The level of innovation in storage technologies is rather low – underdeveloped & underinvested.
- Mechanisms are needed that reward the benefits that storage technologies provide.