Energy Storage Seminar

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# Electrochemical storage

## Grid scale energy storage in batteries

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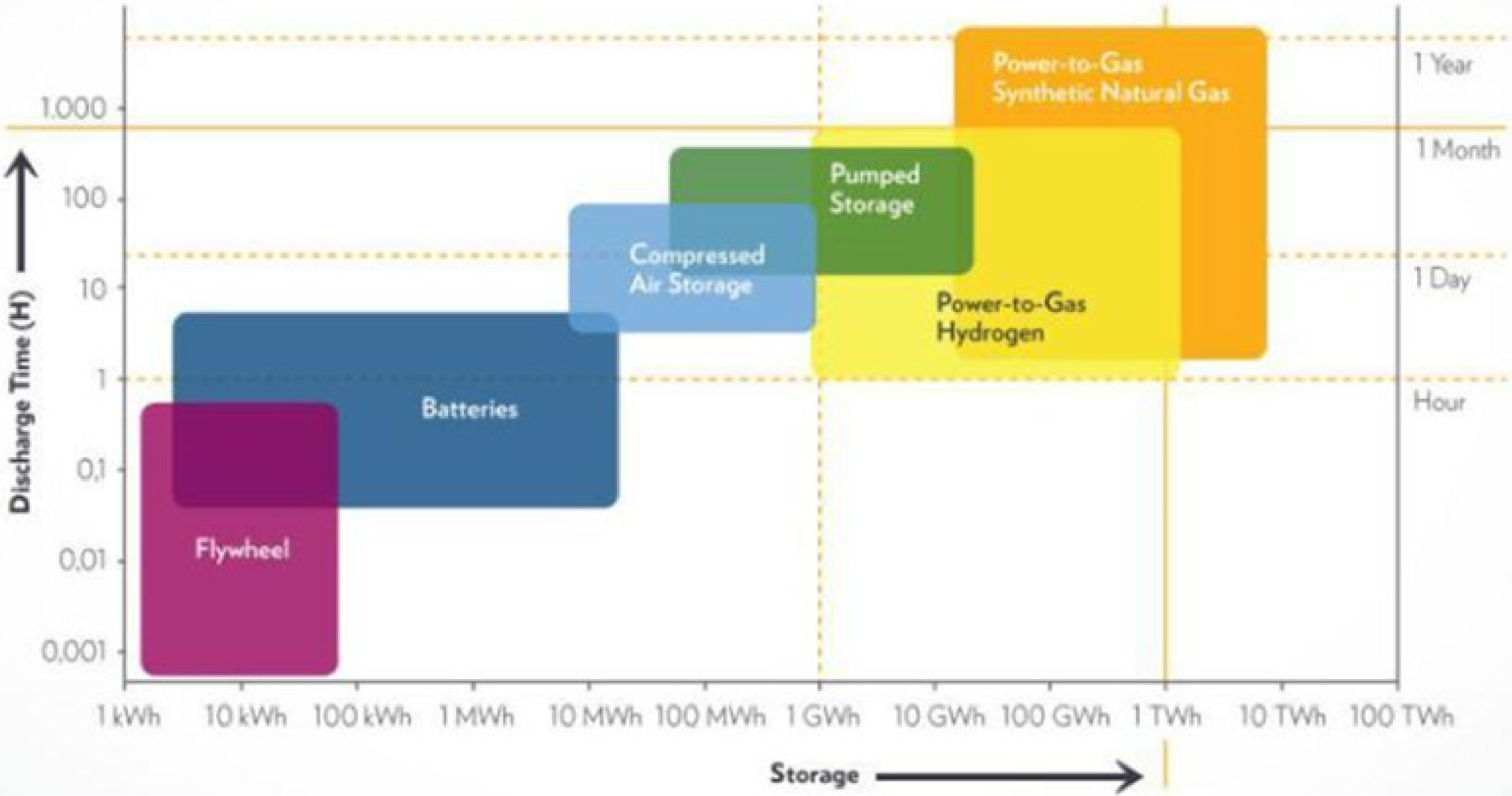
# Overview

| Deployed | Demonstration | Early stage technologies |
| --- | --- | --- |
| Pumped hydro & CAES | Flow Batteries | Hydrogen |
| NaS batteries | Electrochemical Capacitors | Synthetic NG |
| Li-ion Batteries | Superconducting Magnetic energy storage | Liquid metal batteries |
| Pb-Acid batteries | | Metal – Air batteries |
| Flywheels | | |

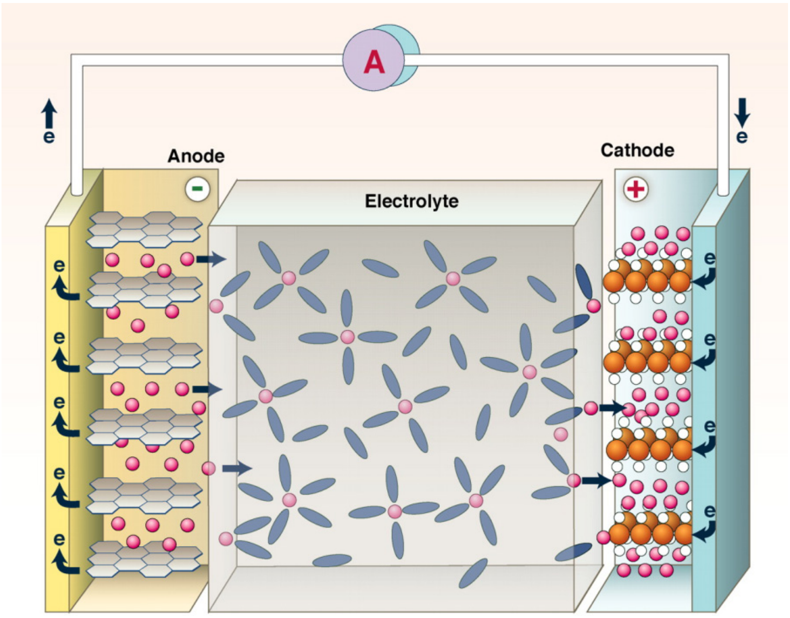
# ENERGY STORAGE TECHNOLOGIES



# Lithium ion batteries

- High energy density
- Good cycle life
- High efficiency
- Benefits from use in electronics and transport

- Very sensitive to high temperature
- High cost

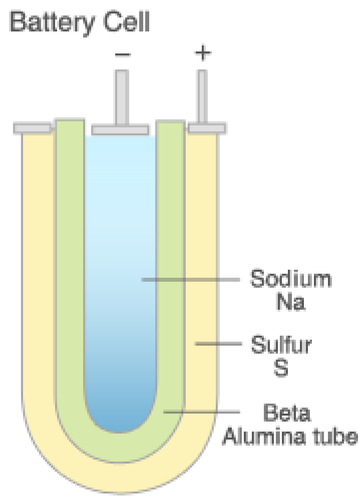
# Lithium ion batteries

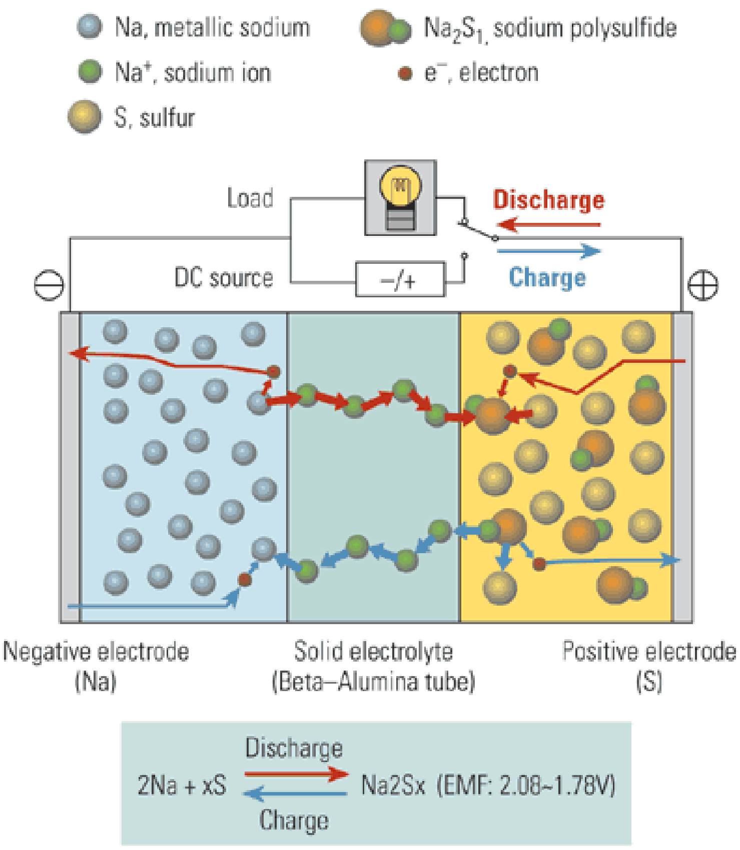
- AES Laurel Mountain, USA
- Coupled to a 98 MW wind power plant for flexible power generation/frequency regulation
- 32 MW
- 8 MWh

# NaS batteries

- High energy density
- Long discharge cycles
- Fast response
- Long lifetime

- High operation temperature (250-300 °C)
- Containment issues (Liquid electrodes, glass seals)



# NaS batteries

Rokkasho Village Wind Farm, Japan

"Smart Grid" wind farm. Batteries are used for energy time shift (night/day)

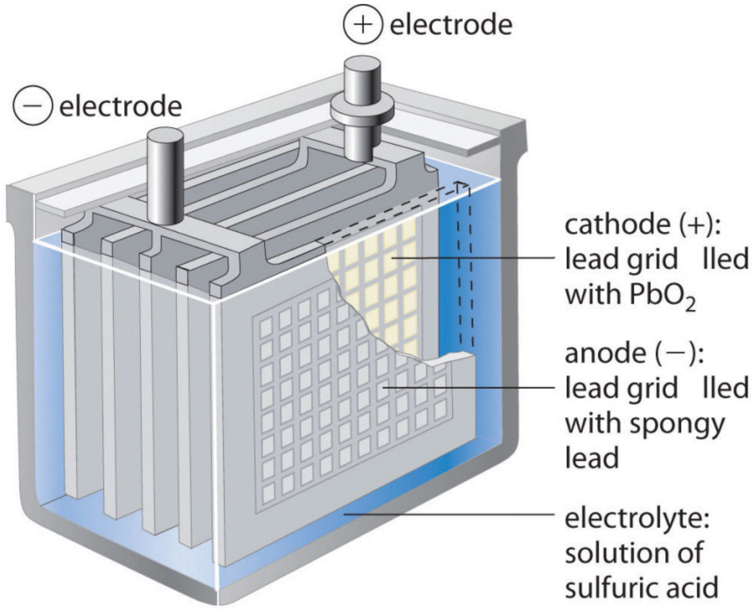
34 MW / MWh

238 MWh

# Pb acid batteries

- Mature battery technology
- Low cost
- Good battery life

- Limited depth of discharge
- Low energy density
- High maintenance




cell reaction:

$$Pb(s) + PbO_2(s) + 2HSO_4^-(aq) + 2H^+(aq) \rightarrow 2PbSO_4(s) + 2H_2O(l)$$

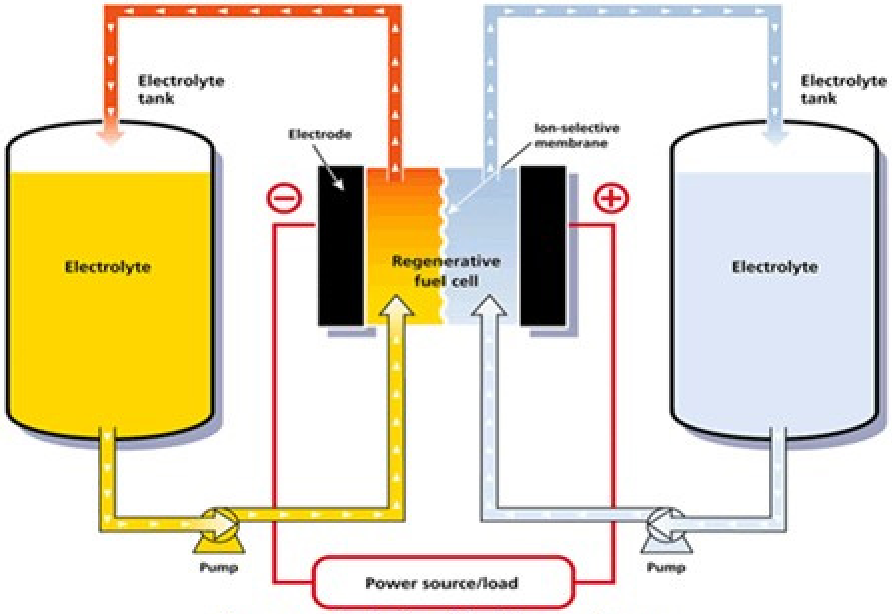
# Pb acid batteries

- Duke Energy Notrees Wind Storage Demonstration Project, USA
- Installed at a 153 MW Wind farm for peak shaving, frequency regulation
- 36 MW
- 20 MWh

# Flow Batteries

- Vanadium , Zinc-Bromine, Iron-Chromium
- Large number of cycles
- Very long lifetime
- Higher design freedom
  (capacity and power decoupled)

- Lower efficiency
- Complicated design
  (pumps, valves)
- Developing technology




*Concept of a Redox Flow Battery System*

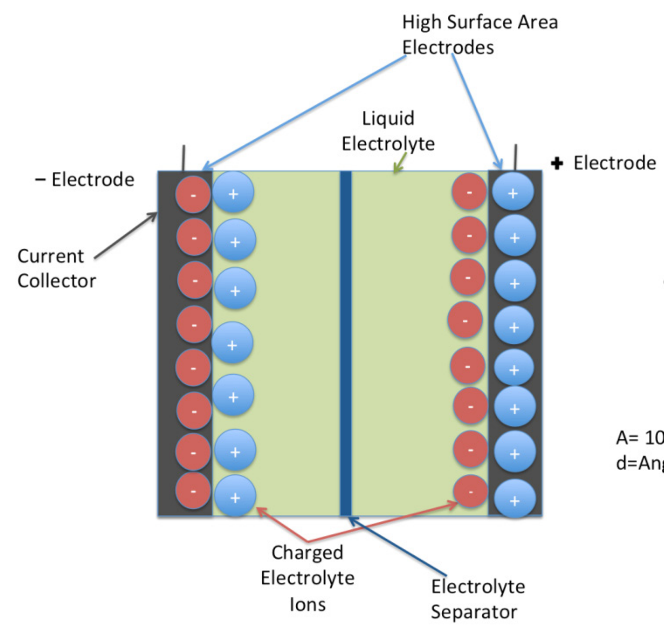
# Flow Batteries

- Vanadium redox flow battery
- Gills Onions, located in Oxnard, California (Onion processing plant)
- Peak shaving, load shifting of electricity use
- 600 kW
- 3.6 MWh

# Supercapacitors

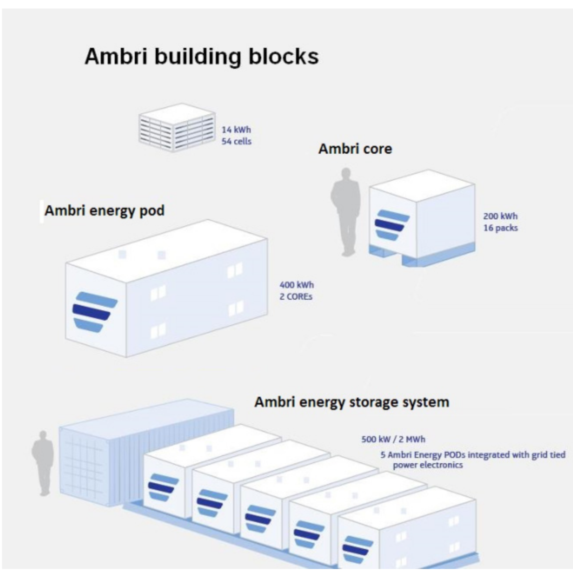
- Very long life (cycles)
- High efficiency (>95%)
- Very fast charge/discharge

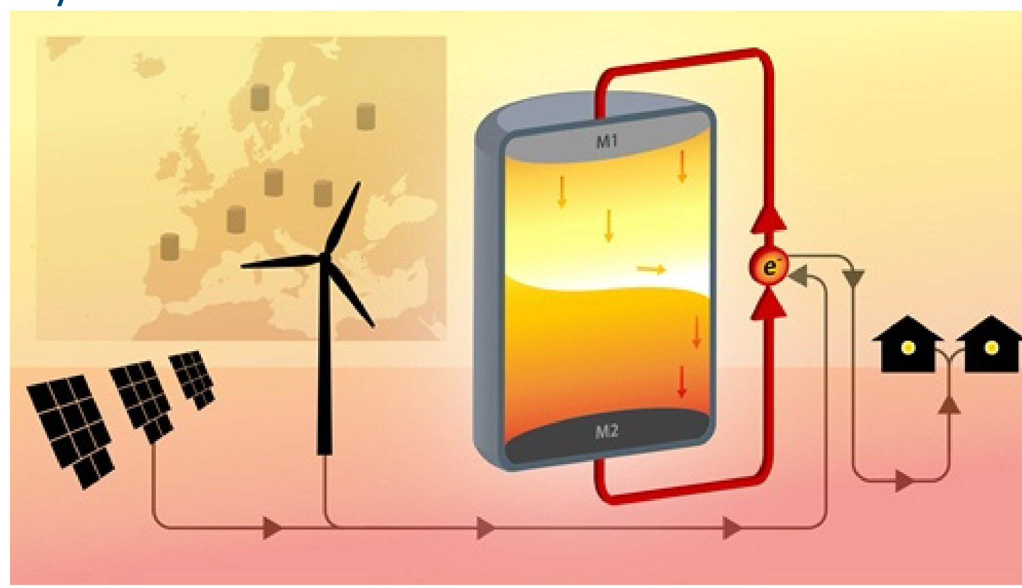
- Low energy density
- Variable voltage input/output
- High cost for energy storage




# Liquid metal batteries

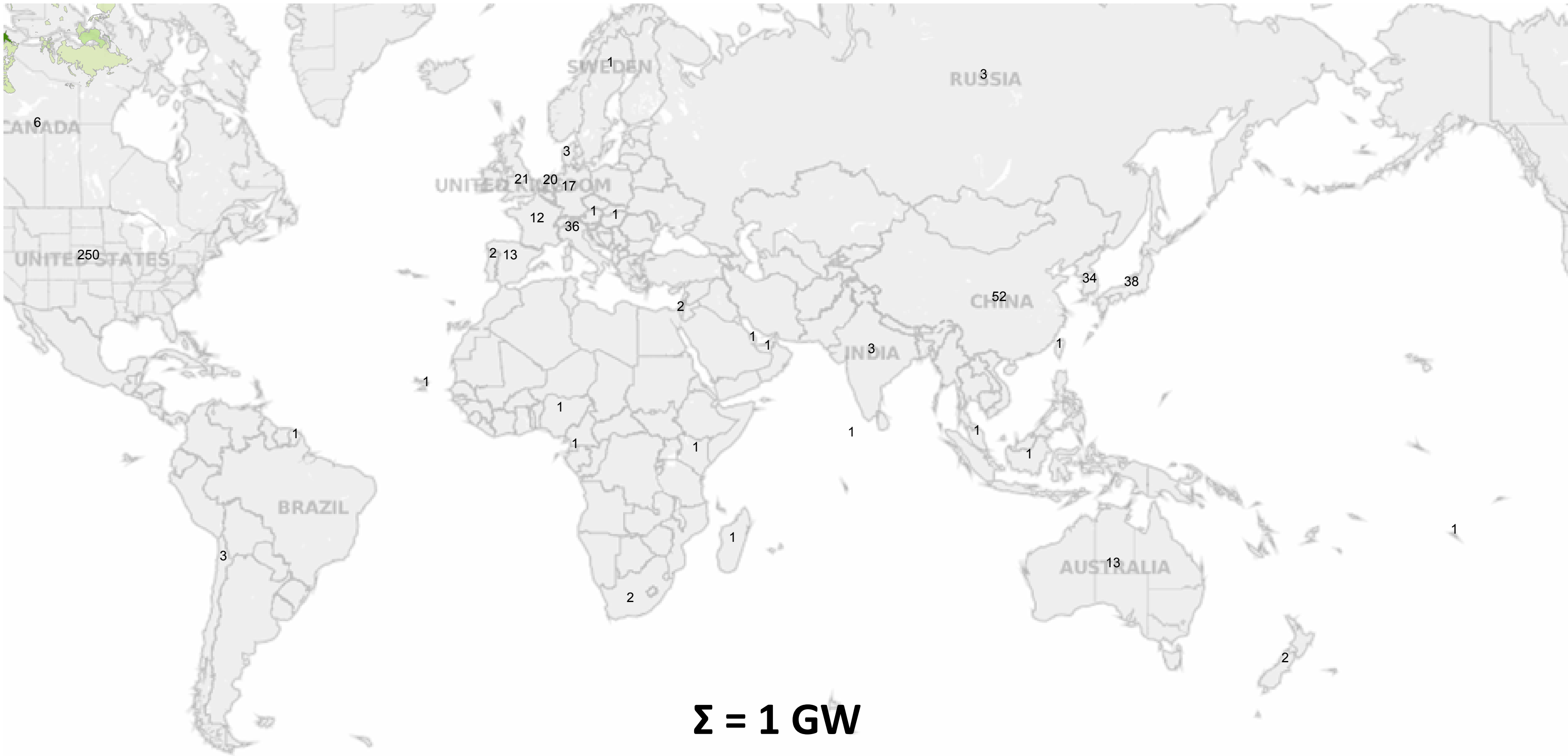
- All liquid system, separated due to differences in density
- Original system developed at MIT used Mg and Sb with 700 C operating temperature
- New system using Li and Pb/Sb have reduced temperatures to 450 to 500 C.
- Potentially low cost and high efficiency.



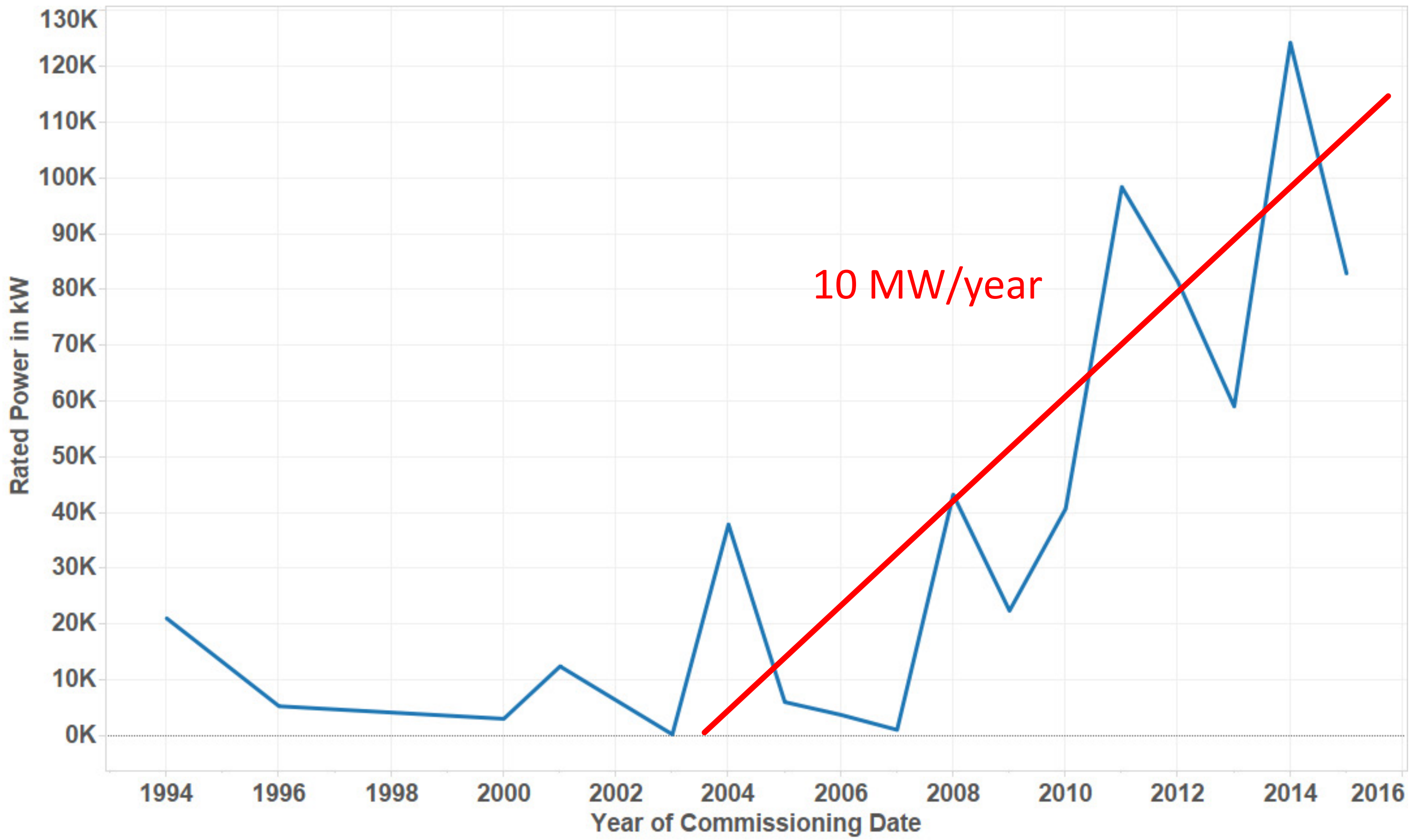
# Electrochemical energy storage in the world

## -some numbers from DOE energy storage database

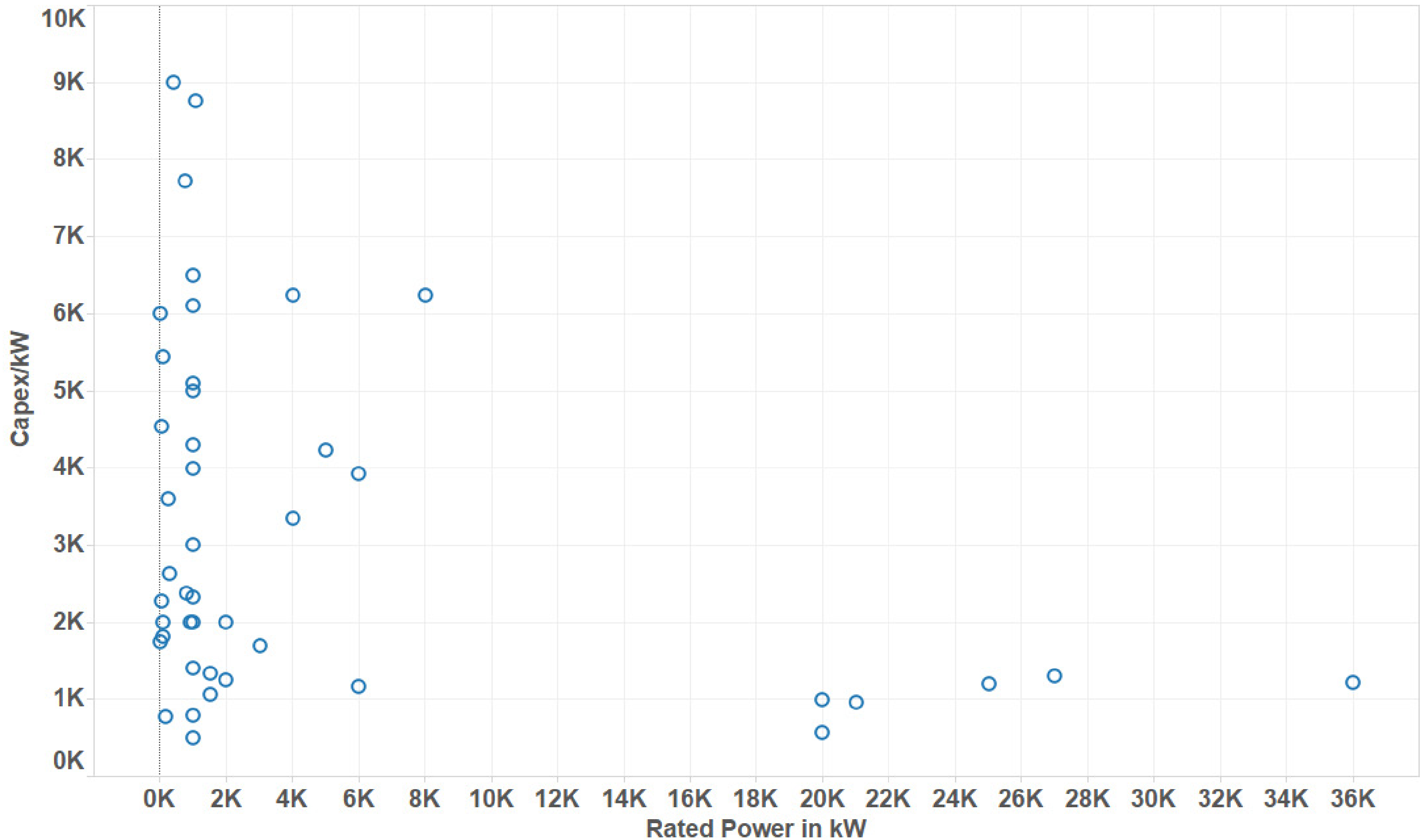



**Σ = 1 GW**

# Annual installed capacity

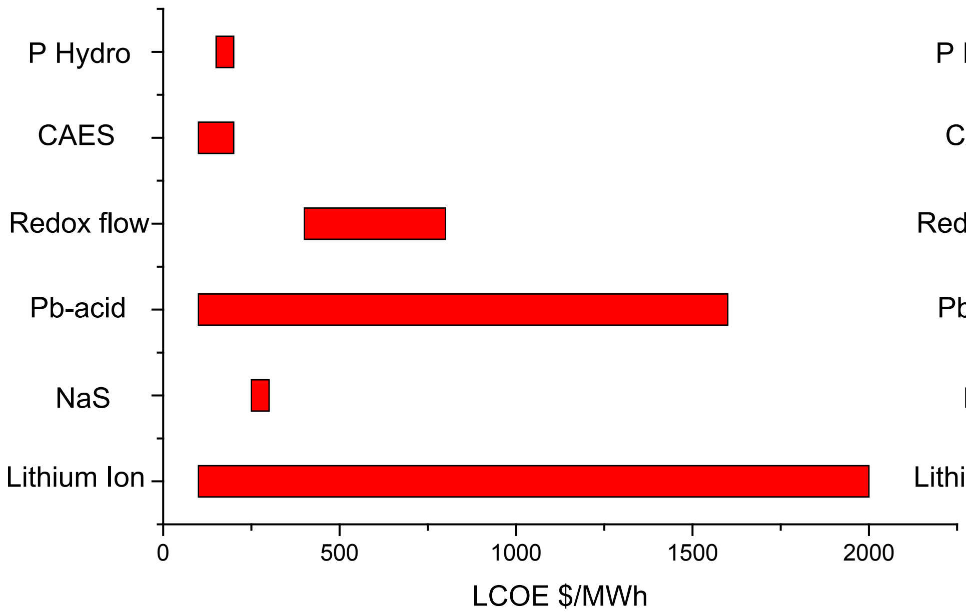


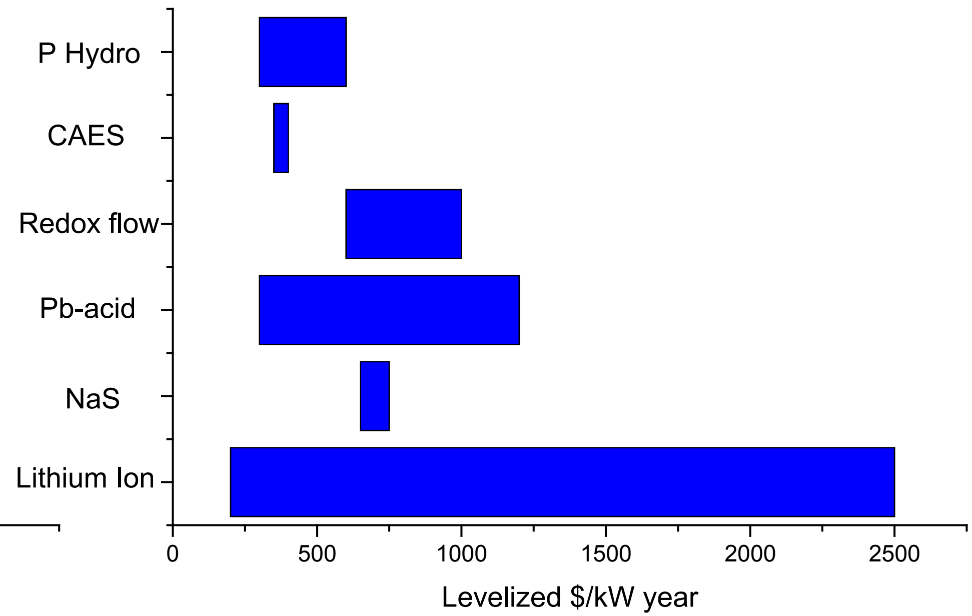
# CAPEX $/kW



10K
9K
8K
7K
6K
5K
4K
3K
2K
1K
0K
Capex/kW
0K 2K 4K 6K 8K 10K 12K 14K 16K 18K 20K 22K 24K 26K 28K 30K 32K 34K 36K
Rated Power in kW

# Typical life cycle costs




*DOE/EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA Sandia National labs July 2013*

# Conclusions – Electrochemical energy storage

- Several electrochemical storage solutions exists
  - High flexibility, high efficiency, high cost
- Total lifecycle costs vary significantly depending on use
- The volume of annual installed capacity is increasing
  10 MW/year increase last 10 years
- Significant technological development can be expected
  - Cost reduction of existing technology
  - Emerging technologies with improved attributes

# Thank you for your attention

# Typical life cycle costs

| | | |
|---|---|---|
| Lithium ion : | LCOE - $/MWh: | 100 – 2000 |
| | Levelized – $/kW yr: | 200 – 2500 |
| NaS: | LCOE - $/MWh: | 250 – 300 |
| | Levelized – $/kW yr: | 650 – 750 |
| Pb-acid | LCOE - $/MWh: | 100 – 1600 |
| | Levelized – $/kW yr: | 300 – 1200 |
| Redox flow: | LCOE - $/MWh: | 400 – 800 |
| | Levelized – $/kW yr: | 600 – 1000 |
| CAES | LCOE - $/MWh: | 100 – 200 |
| | Levelized – $/kW yr: | 350 – 400 |
| Pumped Hydro | LCOE - $/MWh: | 150 – 200 |
| | Levelized – $/kW yr: | 300 – 600 |

*DOE/EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA*
*Sandia National labs July 2013*