

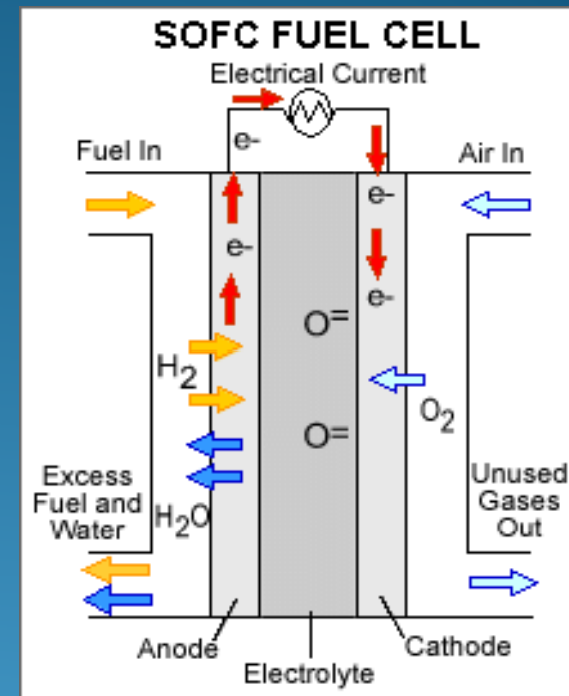
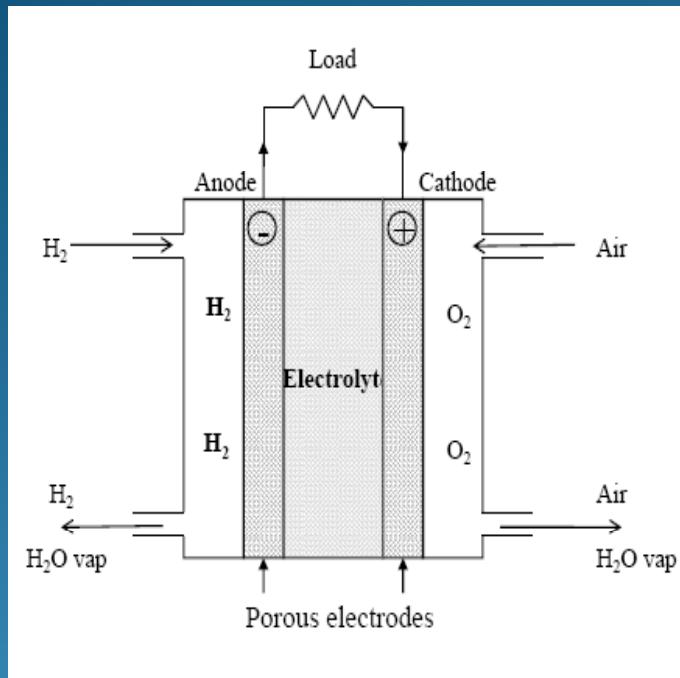
# Electrochemical Energy Storage International State of Play

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# Hydrogen Fuel Cells    Solid Oxide Fuel Cells



- Must supply a fuel (hydrogen) and oxidant (air) to generate power
- Types include PEM, Phosphoric acid, Alkaline
- Require expensive noble metal catalysts – high cost
- Hydrogen produced from hydrocarbon / alcohol reforming or water electrolysis
- Catalysts poisoned by CO
- Overall energy efficiency less than 40%

- 50-60% efficient.
- If utilize system's waste heat (co-generation), overall fuel use efficiencies could exceed 80-85%.
- Operate at around 1,000° C.
- High temperature operation removes need for precious-metal catalyst, reducing cost. Also allows internal fuel reforming, reducing cost of reformer.
- Not poisoned by CO.
- Not energy storage technology, but being developed as alternative power generation

# Lead-Acid Battery



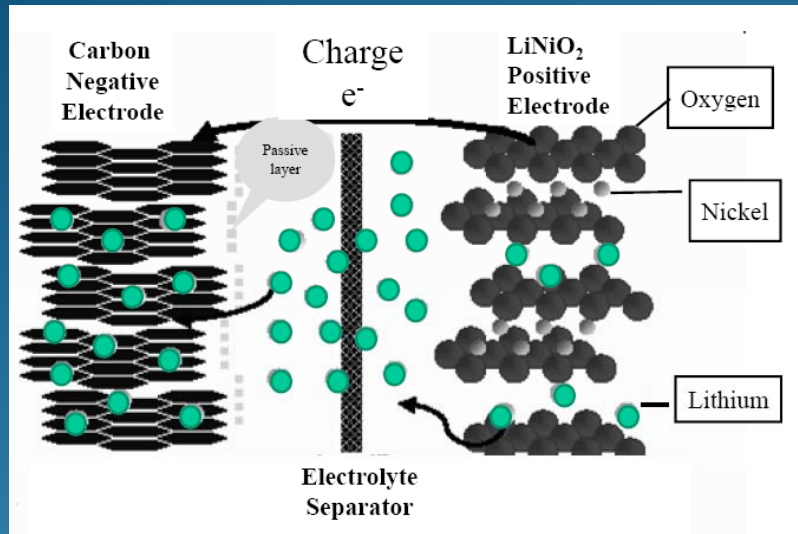
5-MVA, 3.5-MWh valve-regulated lead-acid battery system installed at lead recycling plant in Los Angeles area - provides power-quality protection for plant's pollution-control equipment (Ref: *U.S. Climate Change Technology Program – Technology Options for the Near and Long Term* August 2005)

UltraBattery - hybrid energy storage device recently developed by CSIRO  
 Integrates supercapacitor with a lead acid battery in one unit cell.  
 Incorporates carbon plates at the negative electrode to act as supercapacitor hybrid electrodes, allowing fast charge acceptance compared with conventional technology.

Plant Name & Location	Year of Installation	Rated Energy/MWh	Rated Power/MW	\$/kWh (1995\$)	\$/kW
CHINO					
California	1988	40	10	805	201
HELCO					
Hawaii	1993	15	10	456	304
PREPA					
Puerto Rico	1994	14	20	239	341
BEWAG					
Berlin	1986	8.5	8.5	707	70

\* Source of Table Data: Sandia Report No. SAND97-0443 . UC-1350

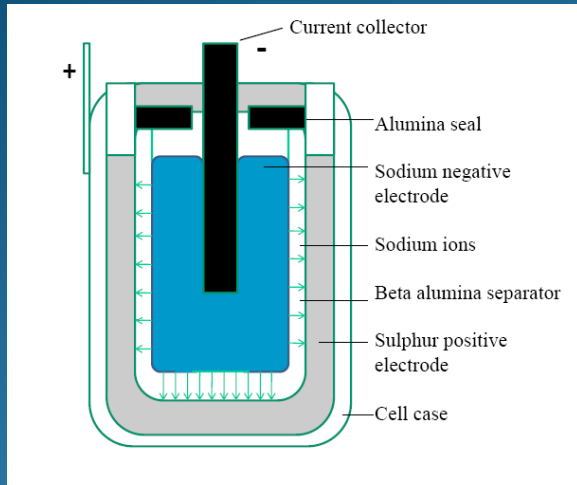
# Lithium Ion Batteries



1 MW/250 kWh Altairnano Li battery in trailer  
([http://www.b2i.cc/Document/546/Power\\_Magazine\\_Article\\_Reprint.pdf](http://www.b2i.cc/Document/546/Power_Magazine_Article_Reprint.pdf), accessed 8-11-09)

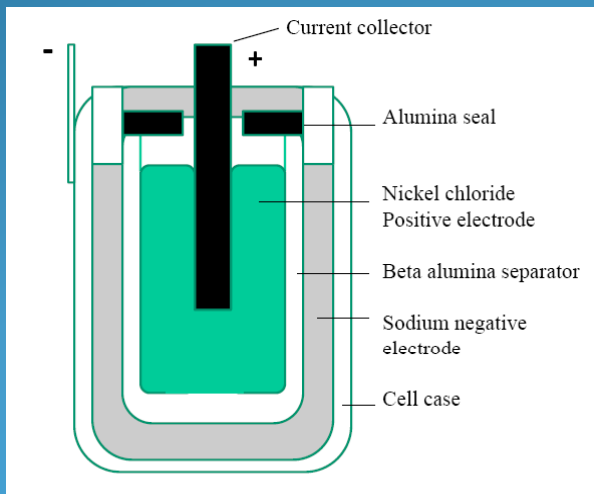
- Li-ion batteries work well in small portable appliances, but challenges for large-scale applications are:
  - High cost (above \$600/kWh)
  - Safety due to possible lithium metal deposition leading to shorting and fires/explosions
  - Require special packaging and internal overcharge protection circuits to prevent accidental overcharge
  - Safety concerns have delayed deployment of Li-ion batteries in plug-in hybrid and all-electric vehicles.
- Several companies working to reduce the manufacturing cost to capture large energy markets.
- MW size demonstration based on Altairnano Lithium-Titanate material battery cells installed and operated at substation owned by Indianapolis Power & Light (IPL) in 2008.
- MW scale Li-phosphate being commercialised by A123 - considered safer but lower energy density

# Sodium Sulphur



- NaS battery operates above 400°C.
- Uses molten sodium and sulphur separated by beta alumina
- First developed in Ford Research Laboratories in 1960s as part of early effort to develop a high energy density electrochemical power source for electric vehicles.
- Only companies currently commercializing NaS battery technology are Tokyo Electric Company (TEPCO) and NGK Insulators Ltd
- NaS battery technology now demonstrated at over 190 sites in Japan totaling more than 270 MW with stored energy suitable for 6 hours daily peak shaving.
- In USA, American Electric Power's goal is to install 25 MW of NaS by 2010, and up to 1,000 MW by 2020 to support its electricity grid operations

# BETA Battery



- BETA battery operates at  $\approx 350^{\circ}\text{C}$  and due to elimination of molten S, considered safer than NaS
- Currently being developed for electric locomotives by GE.

# Examples of NaS Demonstrations for Diurnal Storage for Wind



Xcell's 1MW / 6hr  
Sodium-Sulfur Facility  
Luverne, Minn.  
Complementing 11 MW Wind



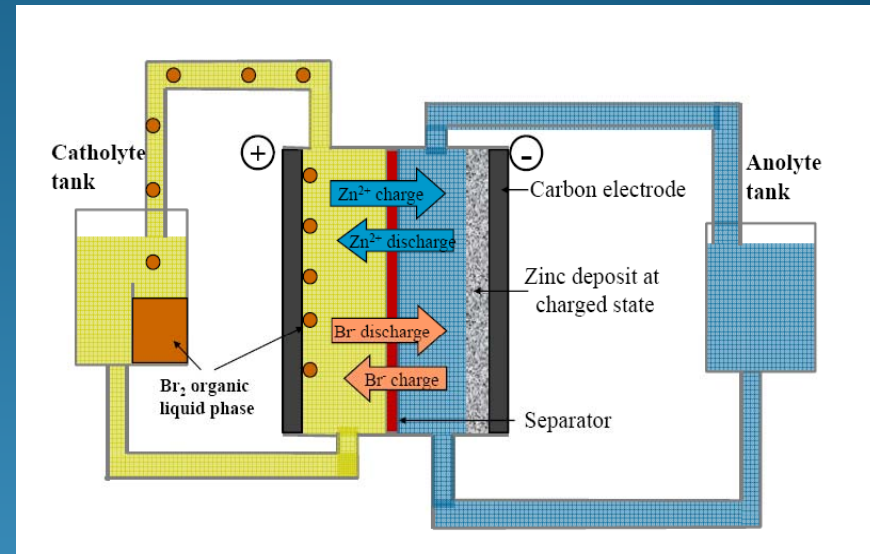
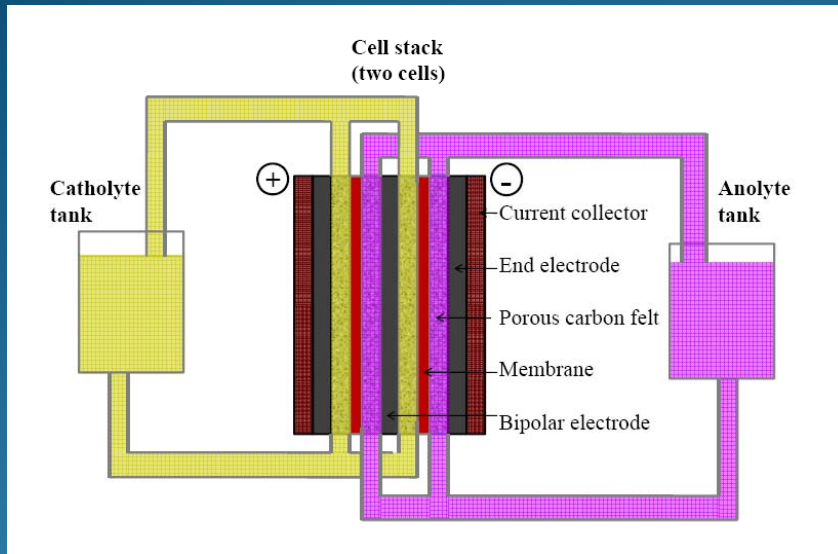
Rokyasho, Japan:  
34 MW / 7 hr NaS Storage  
Complementing 51 MW Wind



25 kW / 2 hrs  
15 year life time  
Utility dispatchable

Ref: Imre Gyuk: MS&T'09

# Flow Batteries



## Vanadium Redox Flow Battery:

- Invented at UNSW in 1985
- More than 20 medium to large-scale demos by SEI in Japan, USA and Italy
- Currently being commercialised by Cellstrom (Austria), Cellennium (Thailand), Prudent Energy (China) and V-Fuel (Australia)
- Expected to be lowest cost system for > 4 hour storage
- More than 200,000 cycles demonstrated in 6 MWh wind storage system in Japan

## Zinc-Bromine Battery:

- Hybrid flow system involving plating of zinc metal at negative electrode during charging
- High energy density but requires regular full discharge to prevent zinc dendrites and shorting
- Currently being commercialised by ZBB and Premium Power, USA, and Redflow, Australia
- Mainly for small to medium-scale applications

# Examples of G<sub>1</sub> VRB Energy Storage Demonstrations



Tomomae wind farm on Hokkaido:  
- 30.6 MW rated output

VRB demonstration system:  
- Sumitomo / J-Power  
- 4 MW / 6 MWh

After 3 year operation more than  
200,000 cycles completed



- 200 kW/800 kWh VRB at Kashima-Kita Power Station
  - Used for load-leveling
  - 80% round trip energy efficiency