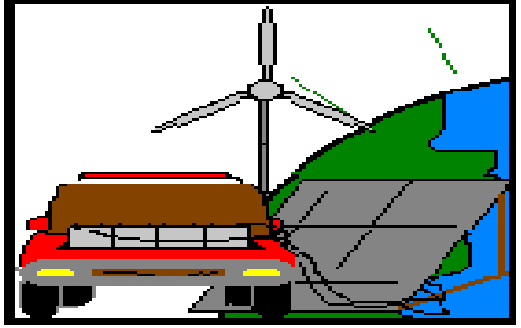


# *Energy storage Technology*


## Dr. Ziyad Salameh/ Director

**CENTER FOR ELECTRIC CARS & RENEWABLE ENERGY**

**DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING**

**UMass_Lowell, USA**

# PRESENTATION

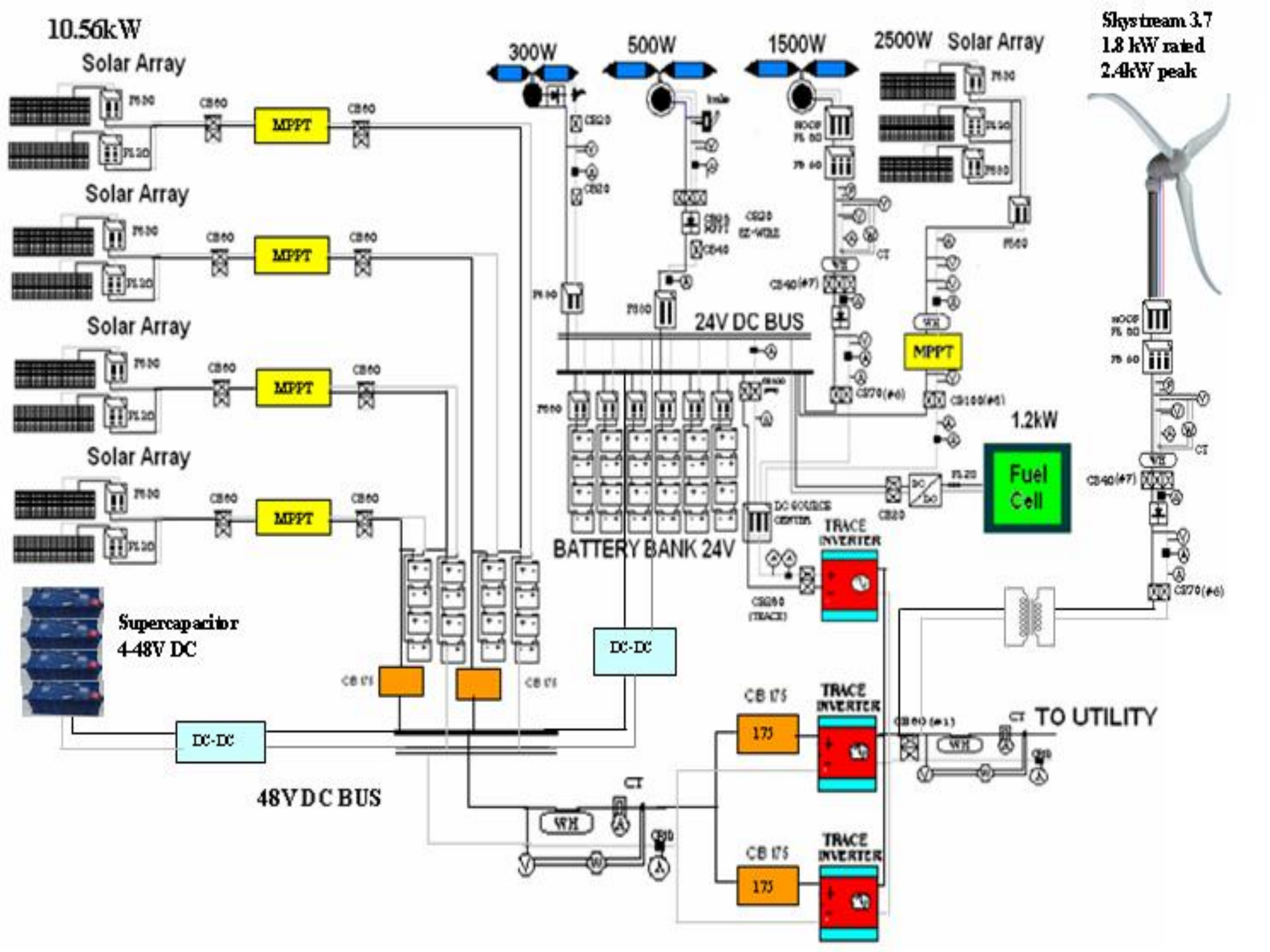
- Brief Research at UML

- Overview of Energy Storage Technology

# 2500W PV System installed 1994

# 10.6KW Installed 2008


DATA ACQUISITION
CONTROL SYSTEM
1500W


10.56kW
Solar Array
Solar Array
Solar Array
Solar Array
MPPT
MPPT
MPPT
MPPT
300W
500W
1500W
2500W
Solar Array
Skystream 3.7
1.8 kW rated
2.4kW peak
24V DC BUS
MPPT
1.2kW
Fuel Cell
BATTERY BANK 24V
TRACE INVERTER
Supercapacitor
4-48V DC
DC-DC
DC-DC
48VDC BUS
CB 175
TRACE INVERTER
CB 175
TRACE INVERTER
TO UTILITY


GEL-TECH
Sealed-Maintenance Free,Rechargeable
Nickel Zinc Battery
Evertroll
EVolyte
EVolyte


CENTER FOR ELECTRIC CAR
& ENERGY CONVERSION
NOTICE
SOLECTRIA
Massachusetts
35 E
ELECTRIC VEHICLE
Center For
ELECTRIC CAR &
ENERGY CONVERSION
36 E
2003 10

# Overview of Energy Storage Technology

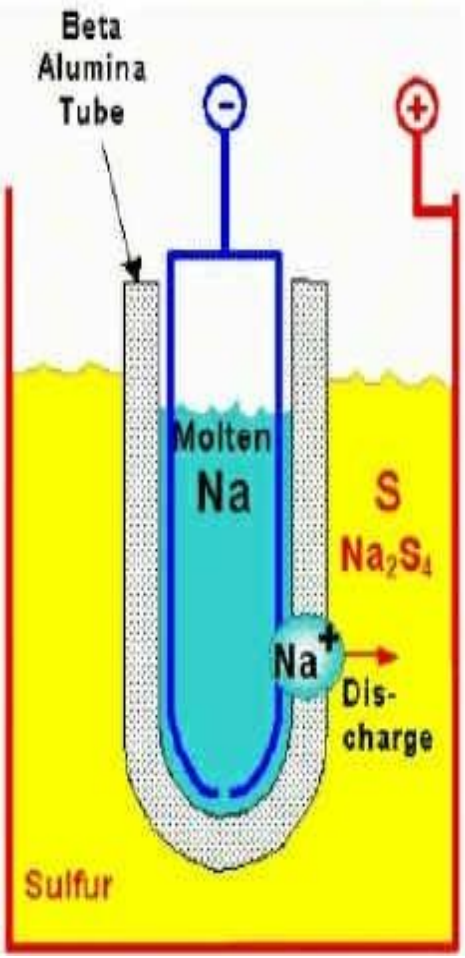
- **Batteries: Lead Acid, NiCd, lithium Ion, Sodium Sulfur, Ni Zn, Zinc Air, Sodium Nickel Chloride, Nickel Hydrogen, Lead Cobalt, Flow batteries(Zinc Bromine, Polysulfide Bromide (PSB) and Vanadium Redox )**
- **Compressed Air Energy Storage ( CAES)**
- **Fly wheel Storage**
- **Hydro Storage**
- **Superconducting Magnetic Energy Storage SMES**
- **Super Capacitor**

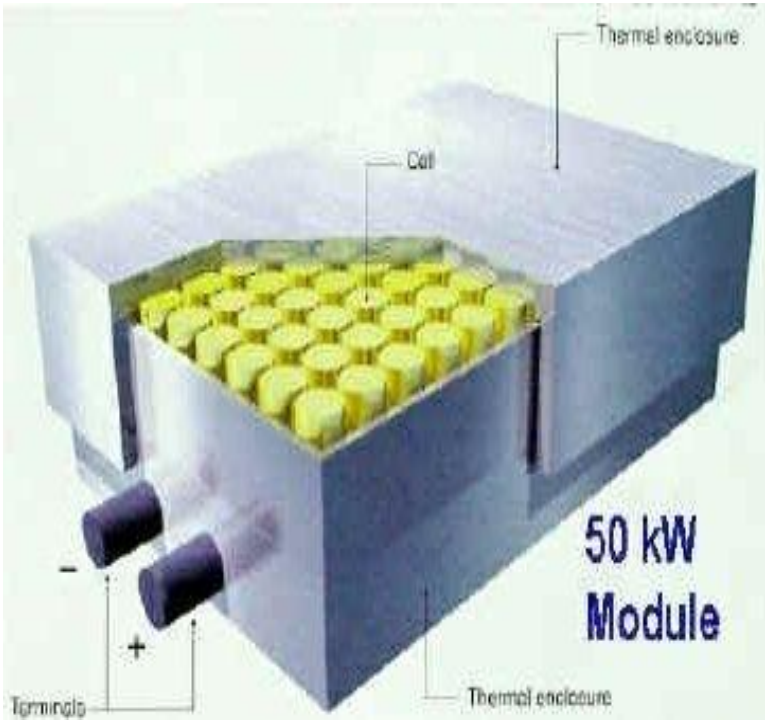
# NiCd VS Lead Acid

| | Item | Lead Acid | NiCd |
|---|---|---|---|
| 1. | Cell voltage | 2V | 1.25V |
| 2. | DOD | 80% | 100% |
| 3. | Cost | Cheap | Expensive |
| 4. | Efficiency | Higher | Lower |
| 5. | Memory | No Memory | has Memory |
| 6. | Life cycle | Short, 500 | long,1500-2000 |
| 7. | Energy Density | Low | Higher |
| 8. | Power Density | Low | Higher |
| 9. | Self discharge | Low 5% | Higher 20% |
| 10. | Internal Resistance | Low | Higher |
| 11. | Accept high C/D rates | No | Yes |
| 12. | Abuse | Cannot be abused | Can( Over C or D) |

# Sodium Sulfur (NaS)

NaS Module and Reaction from NGK Technologies (Japan)



# Sodium Sulfur (NaS)

- **Anode: Liquid (Molten) Sulfur**
- **Cathode: Liquid (Molten) Sodium**
- **Electrolyte: Solid Beta Alumina Ceramic**
  - **Electrolyte allows only positive Sodium ($Na^+$) ions to go through and combine with the Sulfur (S) to form Sodium Polysulfide**

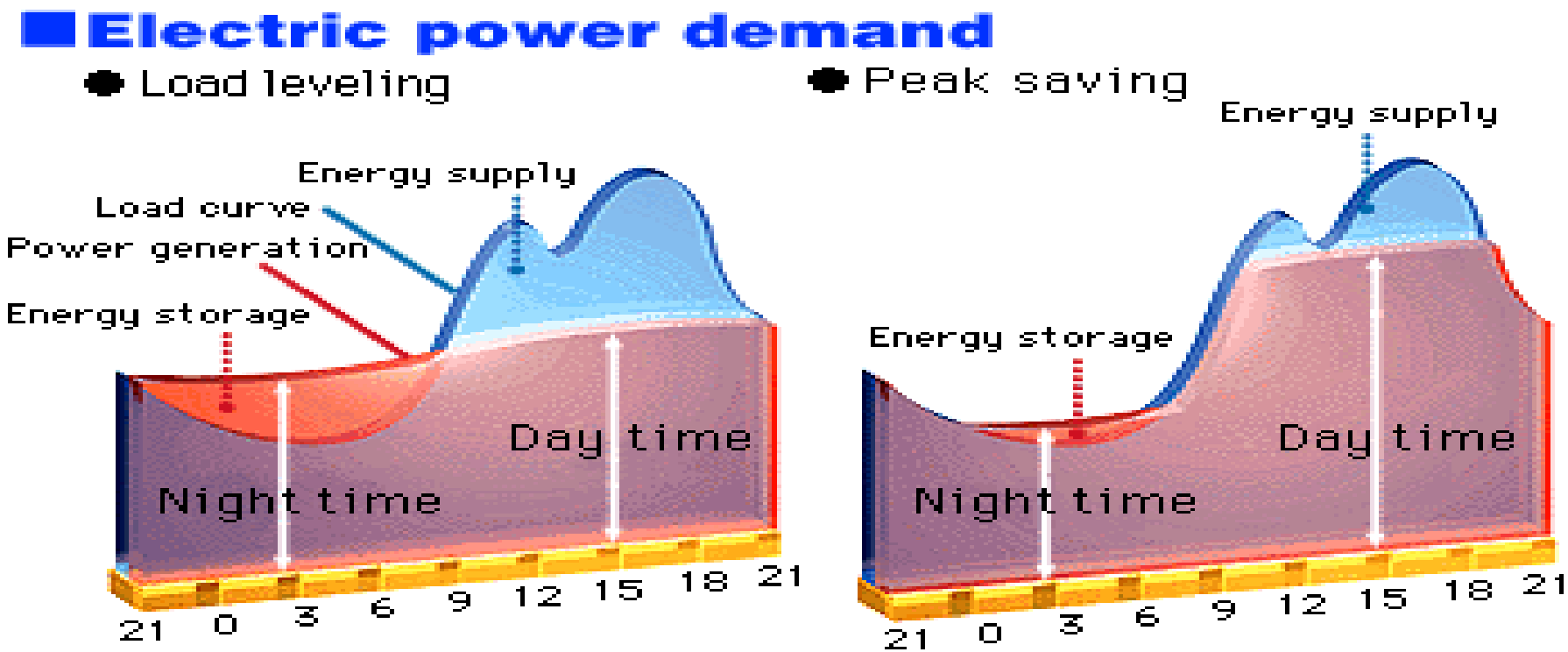
$$2Na \rightarrow 2\,Na^+ + 2e^-$$

$$4S + 2e^- \rightarrow S_4^{-2}$$

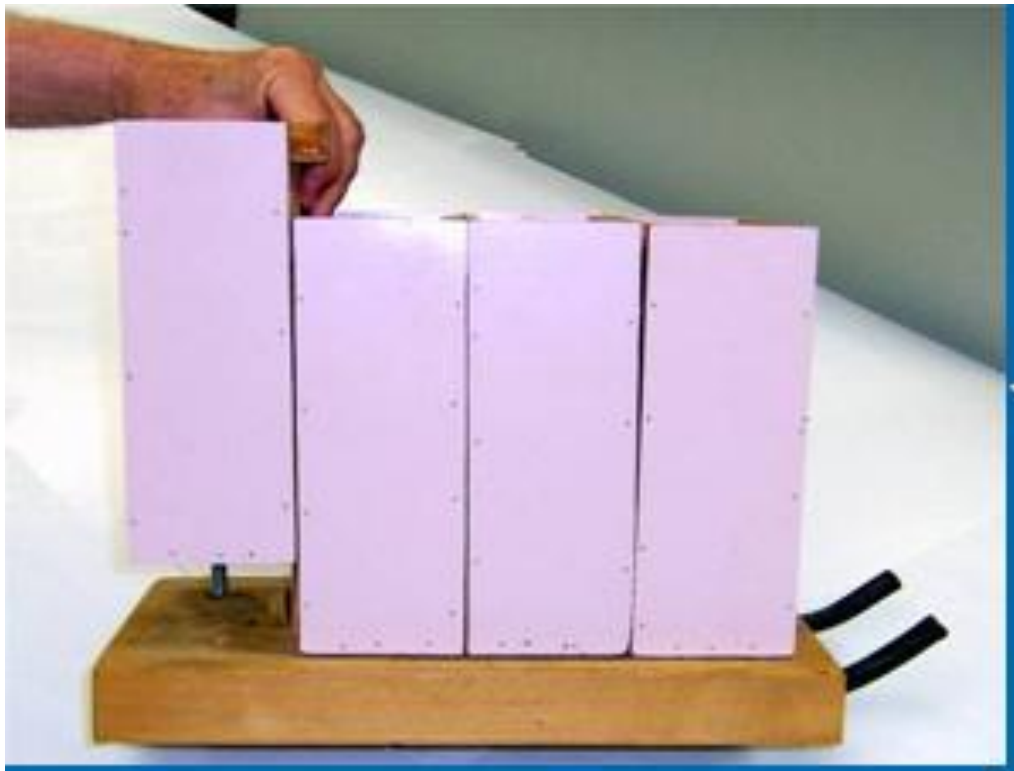
$$2Na^+ + 4S = Na_2S_4$$

# Sodium Sulfur (NaS)

- Kept at about 300°C
- NaS battery cells are efficient (about 89%)
- Pulse power capability over six times their continuous rating (for 30 seconds)
- Used in combined power quality and peak shaving applications and for powering EV



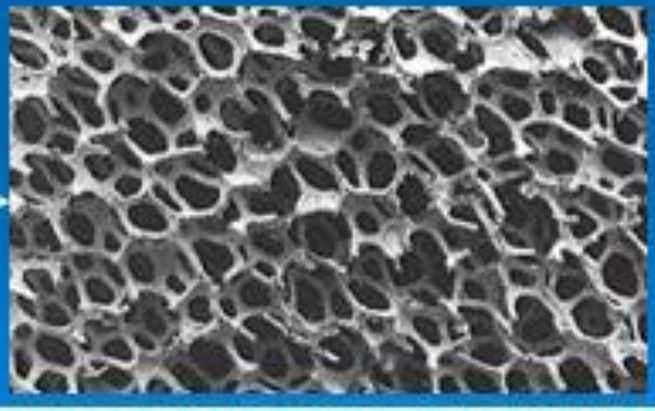
# 30 kwh Lead-Cobalt Battery/Apollo Energy 1900LB, Used in EV



**MULTI-CELLUAR**
**TRI-POLAR BATERY**
**U.S. PATENT 7,037,620 B2**

**LEAD FOAM GRID**

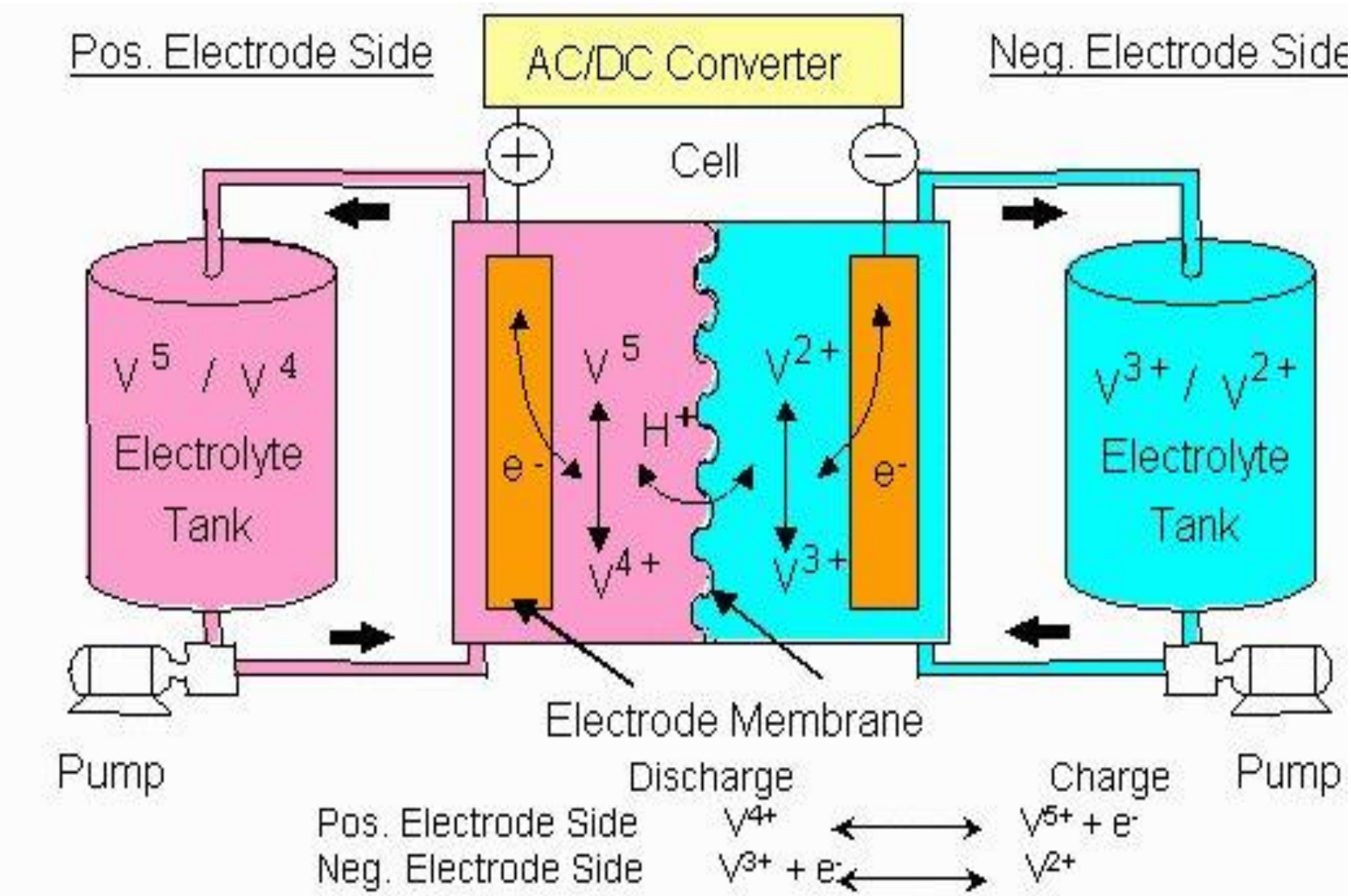
**LEAD FOAM**
***MAGNIFIED***



**WEIGHS 16% OF TRI-POLAR LEAD GRID**

**300% MORE POWER**

# Vanadium Redox

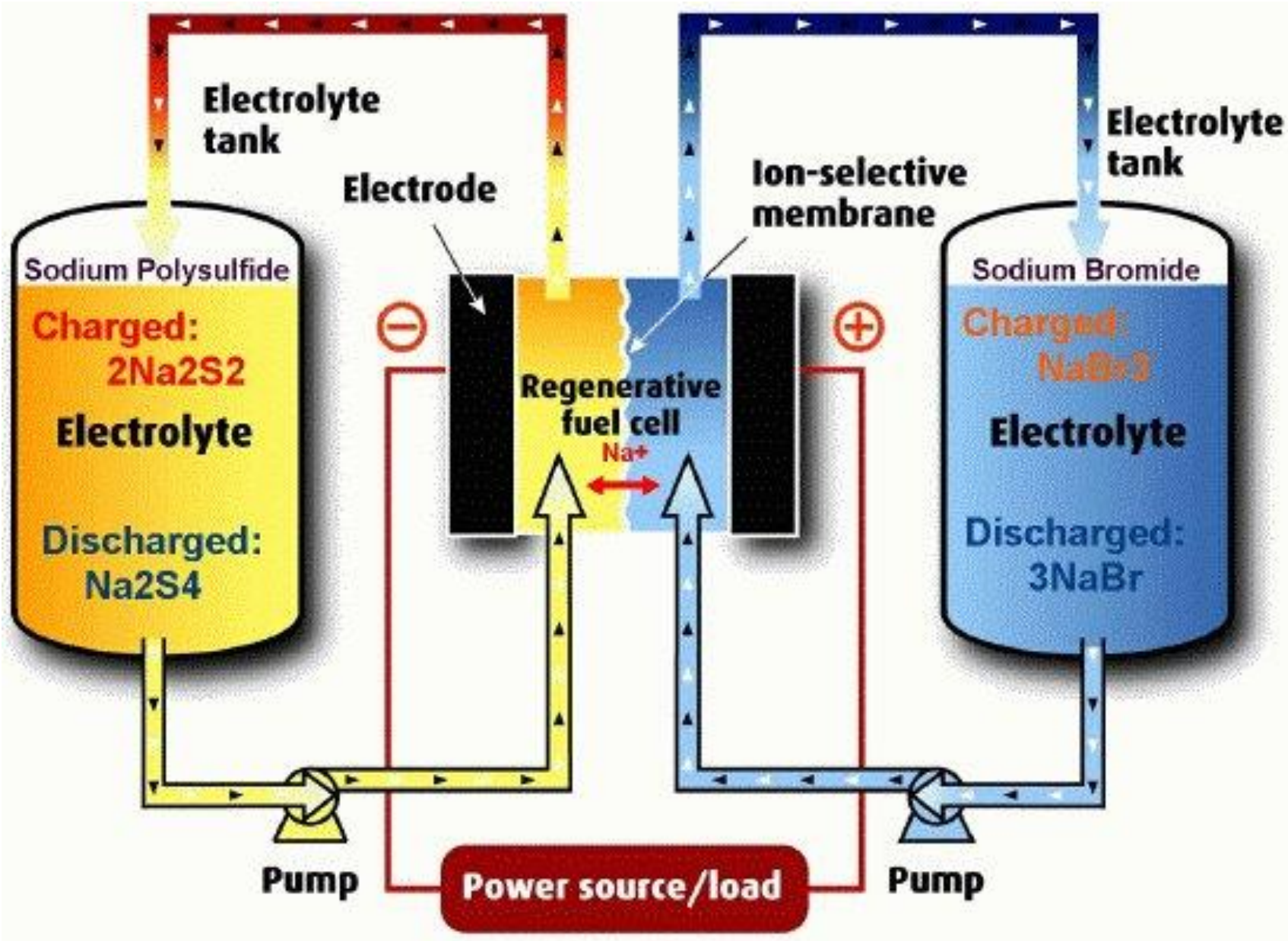


# Vanadium Redox

- VRB storages up to 500 kW, 10 hrs (5 MWh) have been installed in Japan by SEI
- ESKOM, South Africa, by Vanteck (250 kW, 2 hrs)

VRB System from Pinnacle VRB Systems

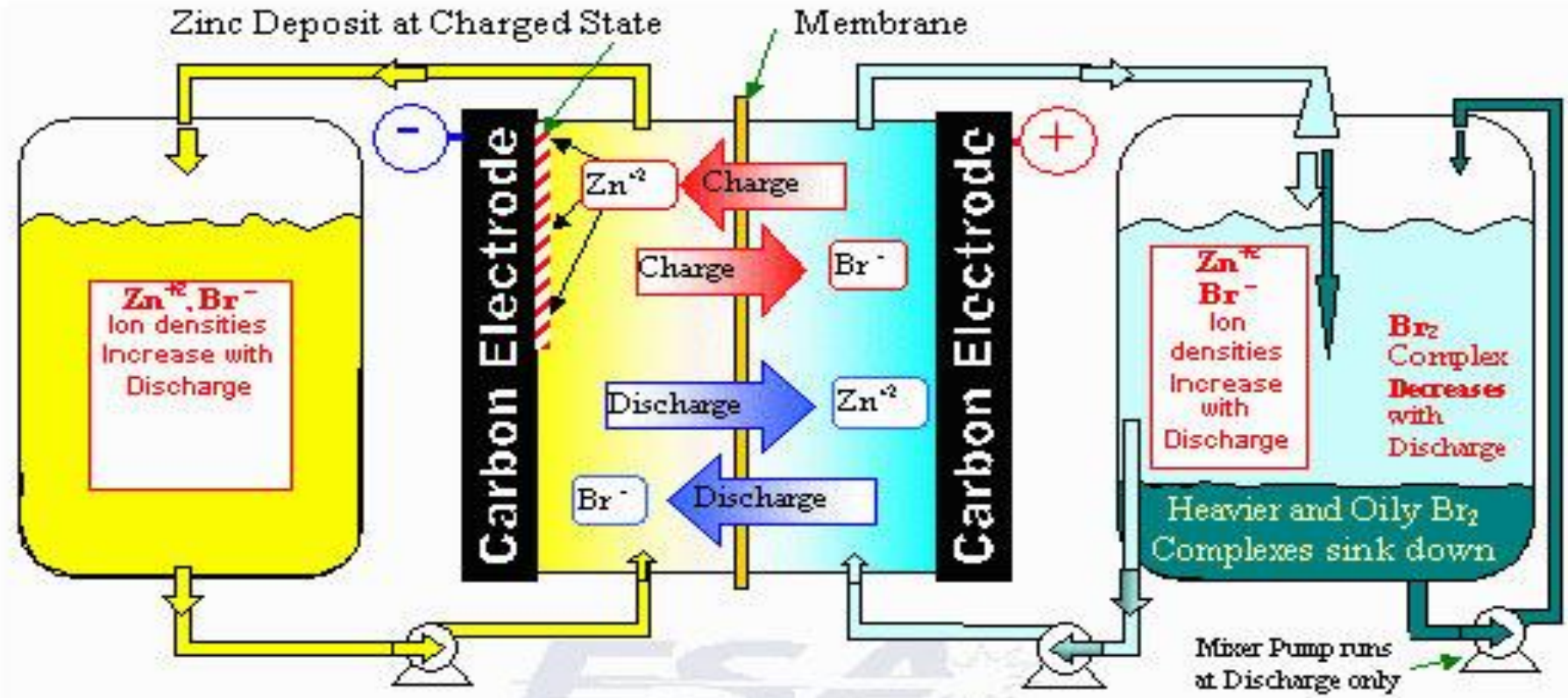
# Polysulfide Bromide



# Polysulfide Bromide

- Regenesys Technologies is building a 120 MWh, 15 MW energy storage plant at Innogy's Little Barford Power Station in the UK.
- Tennessee Valley Authority (TVA) is also planning to build a 12 MW, 120 MWh unit in Mississippi (USA)
- Flow Type Battery
- Cell Voltage :1.5 Volts
- Efficiency is 75%
- Used for Energy Storage

# Charging and discharging of Zinc Bromine batteries.




**At Charge:**

Neg. electrode side: $Zn^{2+} + 2e \Rightarrow Zn^0$ (Zn plated on neg. electrode)

Pos. electrode side: $2Br^- \Rightarrow Br_2\,(aq) + 2e$

(Br, complexed into a thick, oily sludge, is stored in a separate location inside container)

**At Discharge:**

Neg. electrode side: $Zn^0 \Rightarrow Zn^{2+} + 2e$ (Zn ions dissolved in **both** electrolytes)

Pos. electrode side: $Br_2\,(aq) + 2e \Rightarrow 2Br^-$ (Br ions dissolved in **both** electrolytes)

# Specifics of Zinc-Bromine batteries

- Cell Voltage 1.8V
- Efficiency 70-75%
- Used for energy storage and Electric drives
- High energy density
- Stay long time at discharge state/no damage
- No self discharge
- Flow type battery

# 3.Compressed Air Energy Storage CAES

**Store Compressed Air in;**

- **Reservoirs / Metallic spheres**
- **Caverns in salt rocks**
- **Depleted Natural Gas Fields**
- **Aquifers**

**The Compressed air is let out through an air turbine which runs a generator**

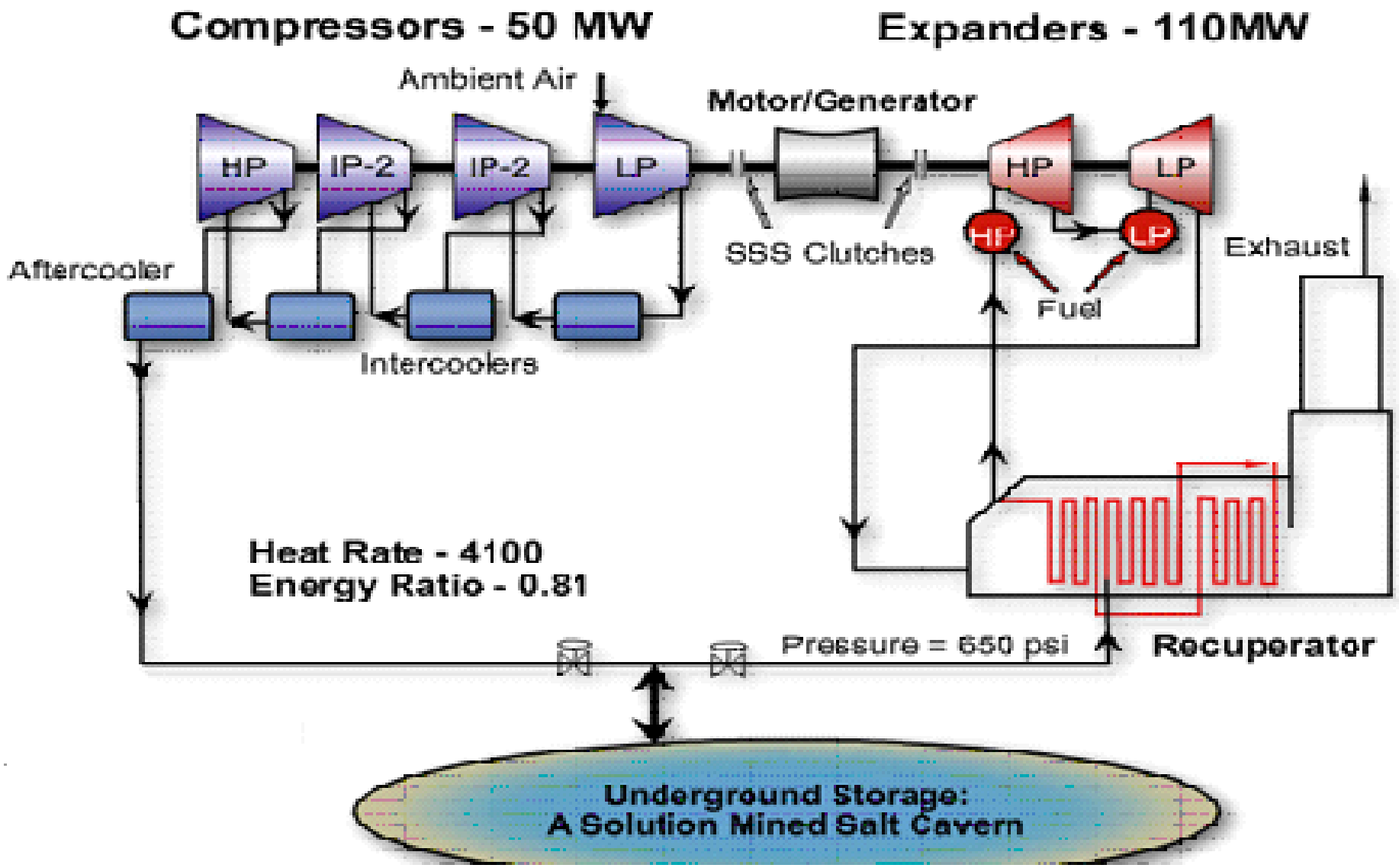
# Components of CAES

- Motor /Generator with Clutches
- Air Compressor pressure 650 PSI
- Recuperator / preheating the air before running the generator mixing with gas and burning it
- Control equipment
- Auxiliary Equipment:

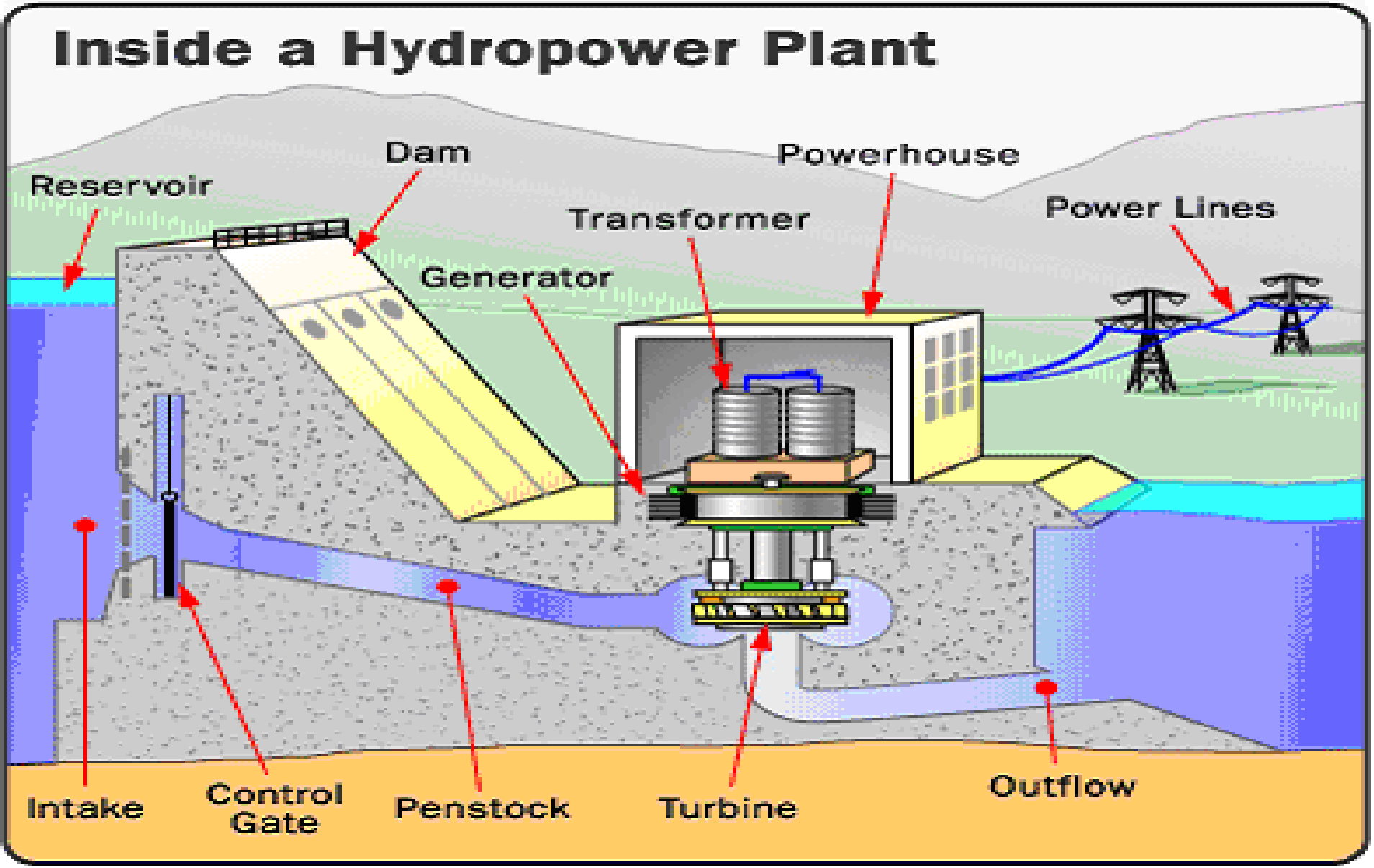
Coolers to accommodate more Air

Fuel storage system

# Block Diagram of a 110MW CAEC Power Plant

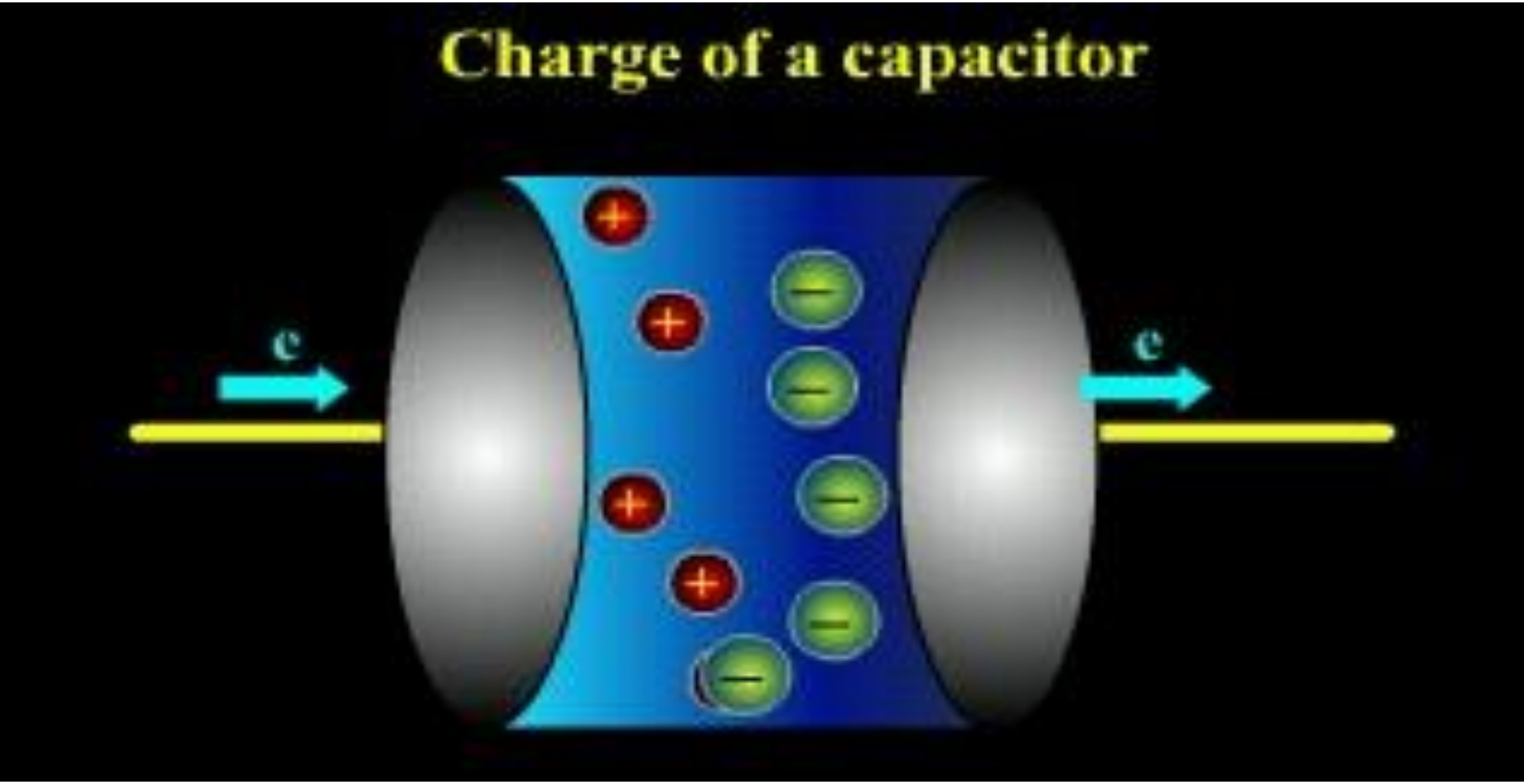


# 6. Hydro Storage / Power Plant



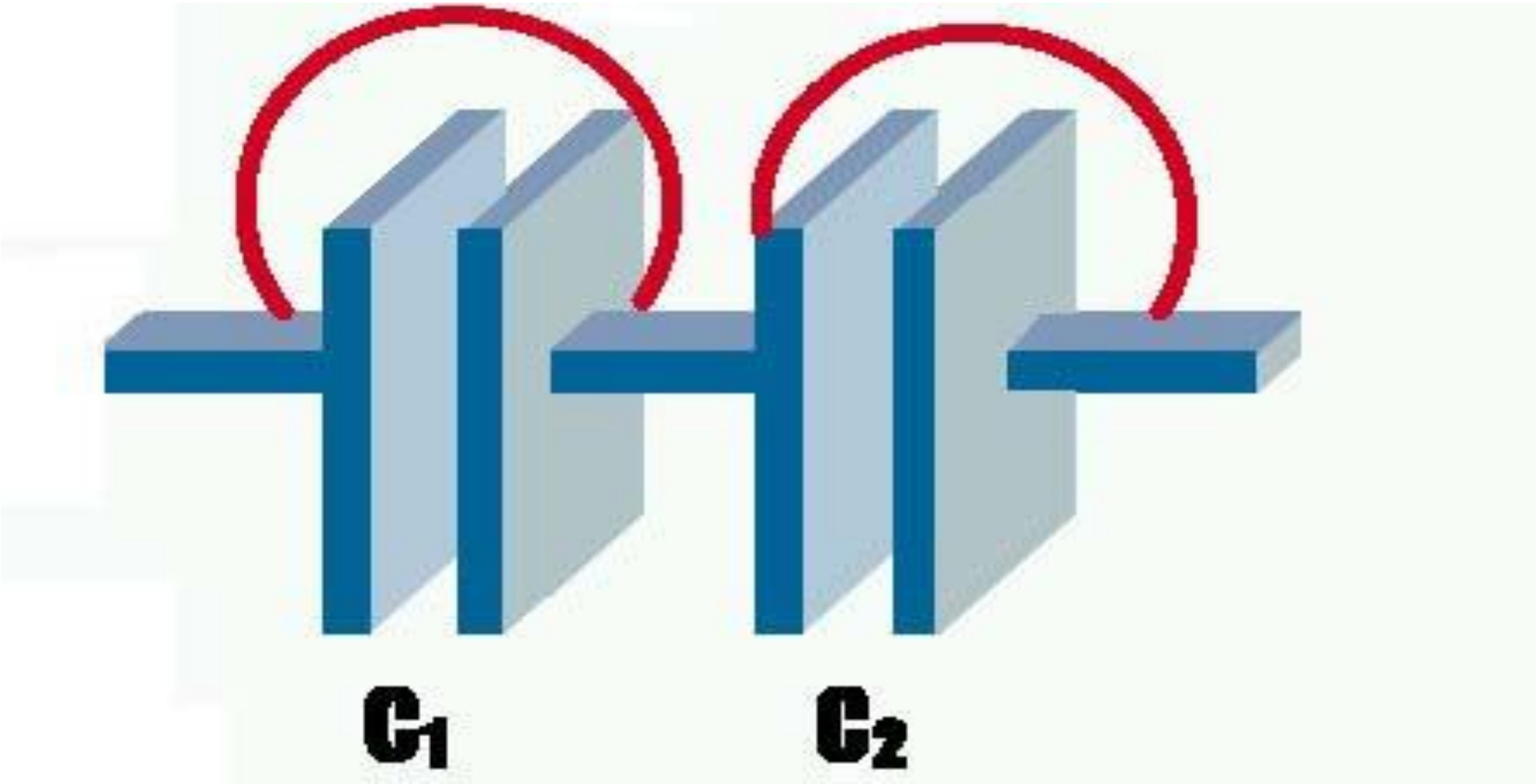
# Hydro Storage In Australia

# 2. Super Capacitor

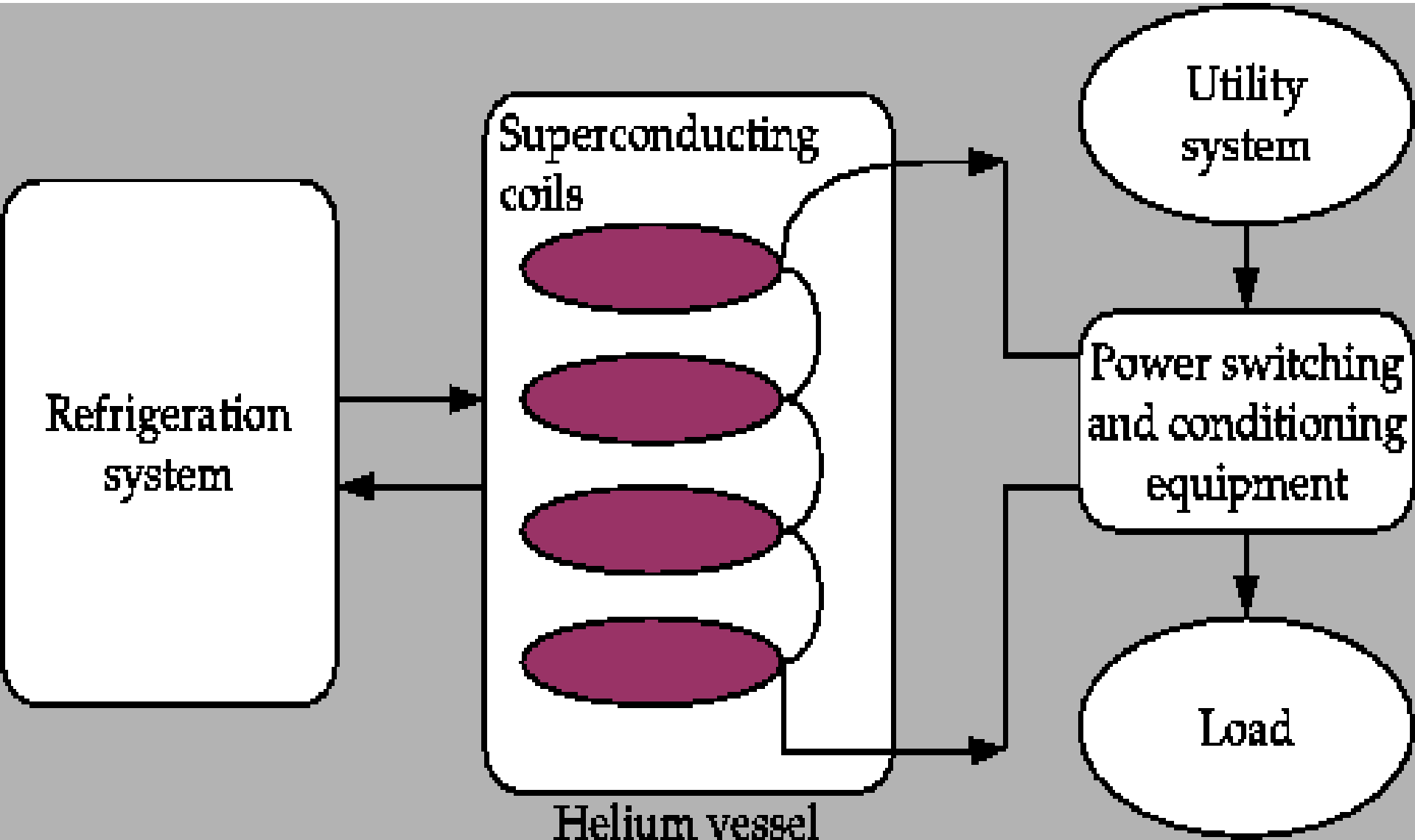


$$C_T = C_1 + C_2$$

$$E = 1/2 * C_T * V^2$$



# Basic Components of a SMES



# Renewable Energy Storage

# Storage Comparison