Lecture 13: Energy Storage

Energy Law and Policy

Fall 2013

Energy Storage Applications

- Distributed Power Generation Support
  - Wind Power Grid Integration
  - Solar Power Variability
- Peak Load Reduction
- Regulation Services
- Spinning Reserve Management
- Smart Grid Energy Management
- Transmission System Support
- Transportation Emphasis on Storage

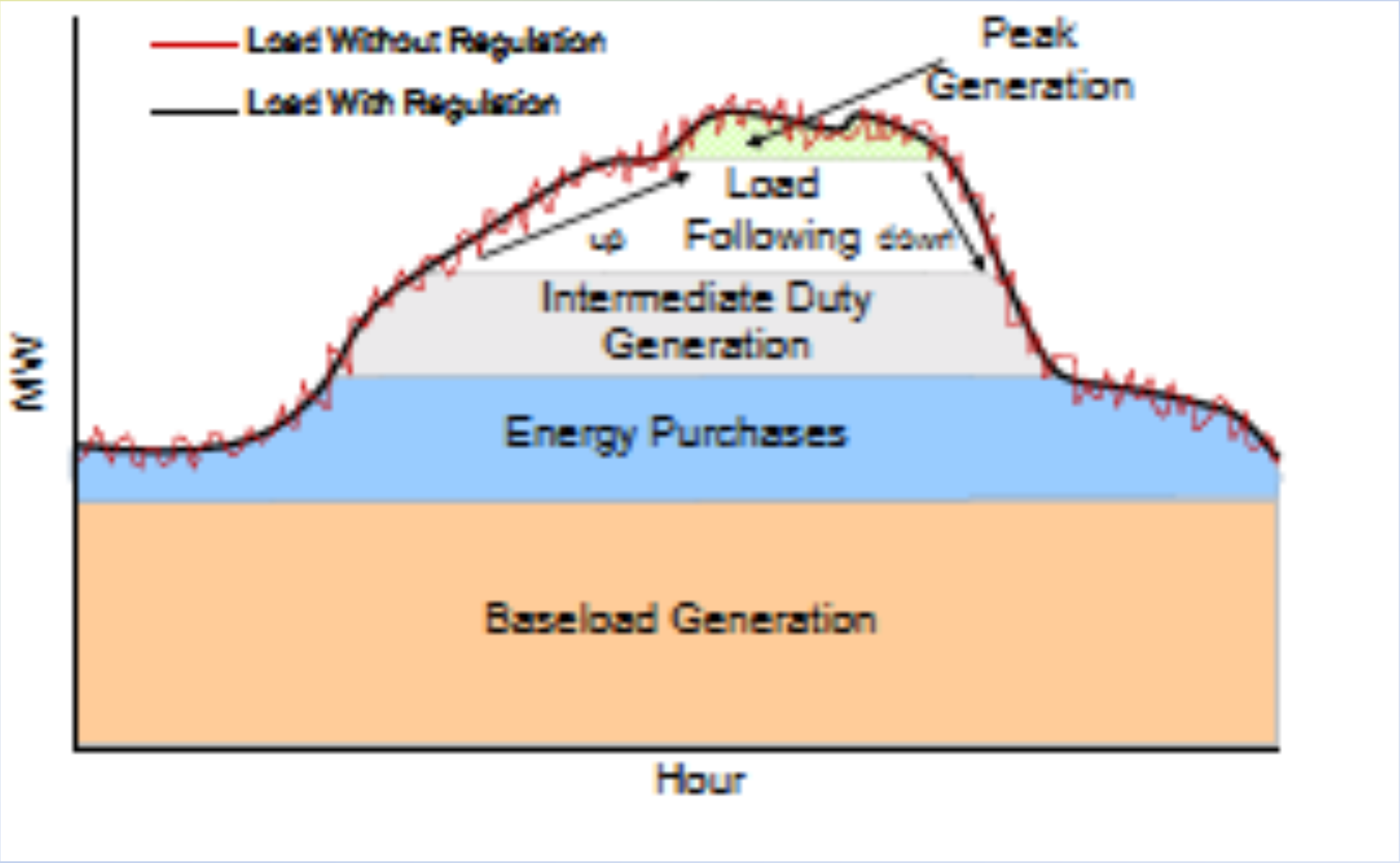
Energy Storage – Policy Issues

- Role with renewables.
  - Wind – production of power when not needed
  - Solar – less of a problem
- Problem for batteries
  - Mature technology – no major breakthroughs
  - High Cost
  - Short lifespan – recharging time
  - Environmental – unclear life cycle costs

Fundamental Policy Issues for Energy Storage

- Subsidies for research and implementation.
  - Which technologies?
  - How much?
  - What sorts of subsidies?
- What role does utility play in the plug in hybrid model?
- What incentives can be brought to bear?
  - Gasoline taxes, CAFE standards, carbon tax
  - Net metering, smart grid

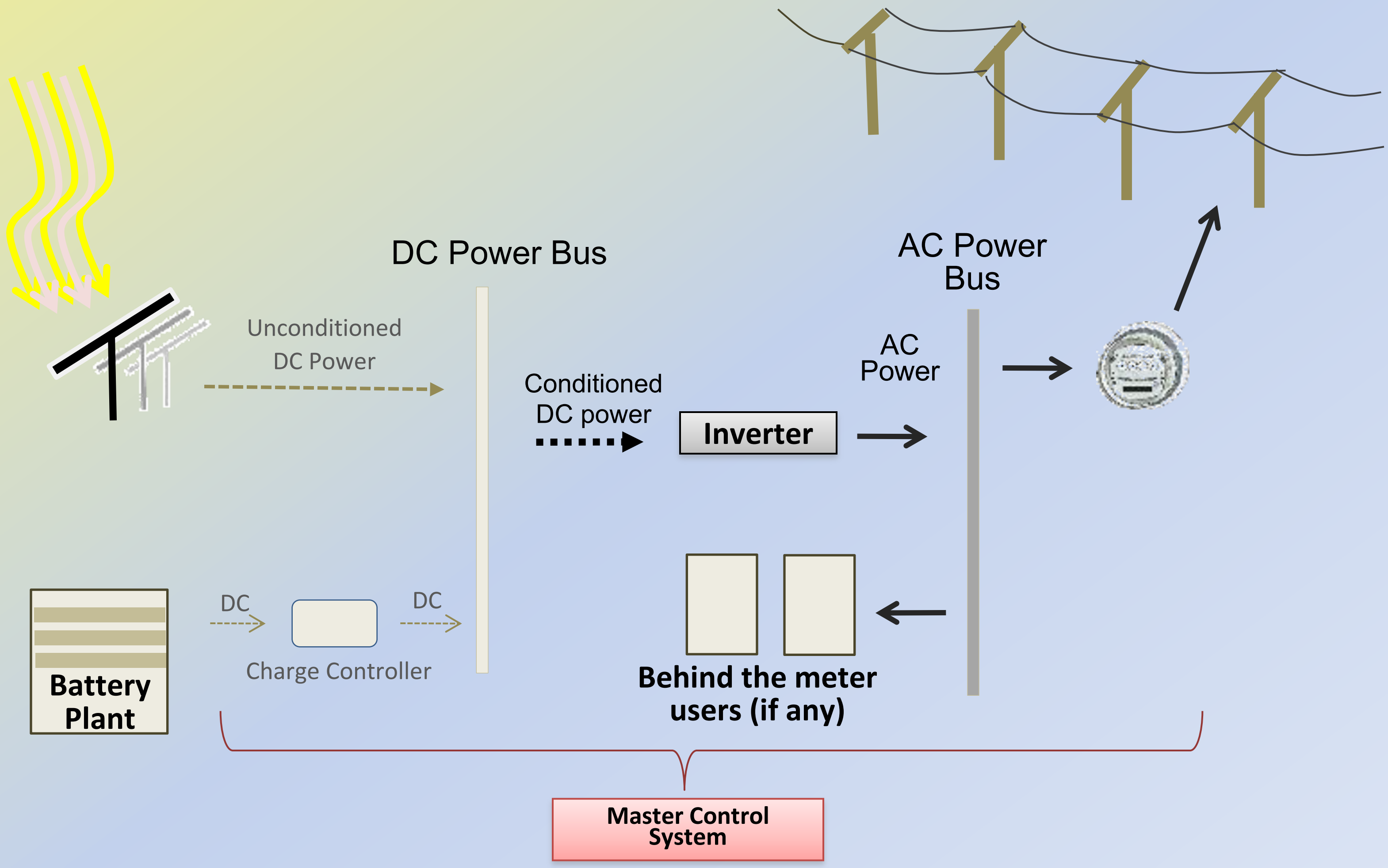
Distribution System Overview



The Market

- Almost Too Big To Measure
  - Wind Power – 80,000 MW by 2030 – if 20% uses storage $200 B
  - Utilities
    - Municipals, Rural, Investor Owned - $1.5 B growing at a rate of 2.5% per year
  - Solar – 2,000 MW growing 37% per year
- Storage is currently very high on governments priority list.

The Concept

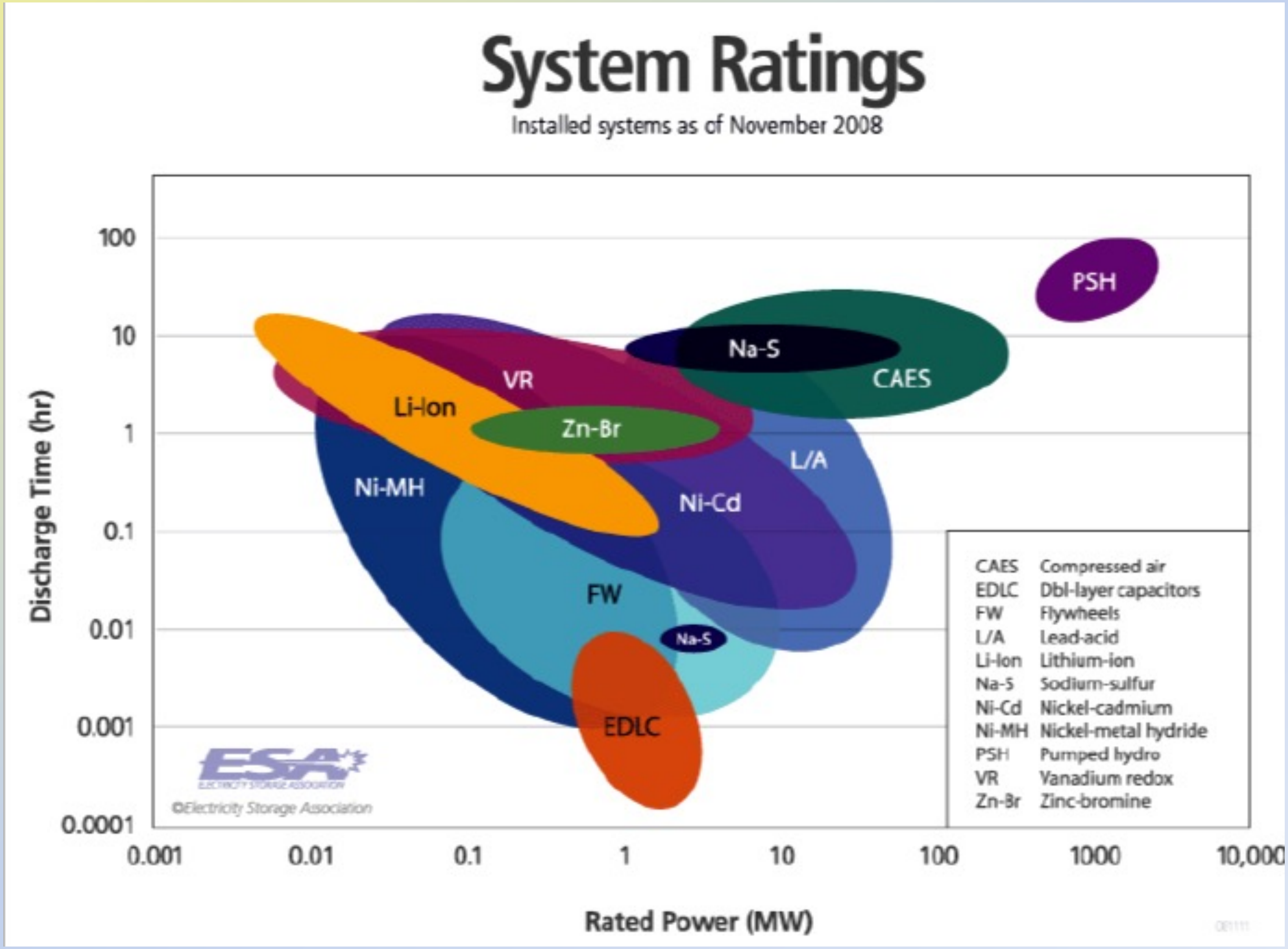


DC Power Bus
AC Power Bus
Unconditioned DC Power
Conditioned DC power
Inverter
AC Power
DC
DC
Charge Controller
Battery Plant
Behind the meter users (if any)
Master Control System

Storage Parameters of Importance

- Electrical Power Capacity (MW)
- Duration of Power Capacity
  - Ex. 2 MW Battery for 4 Hours = 8 MWh
- Charge/Discharge Cycles
- Lifetime
- On Line Time Requirement

Storage Technologies



Stored Hydro

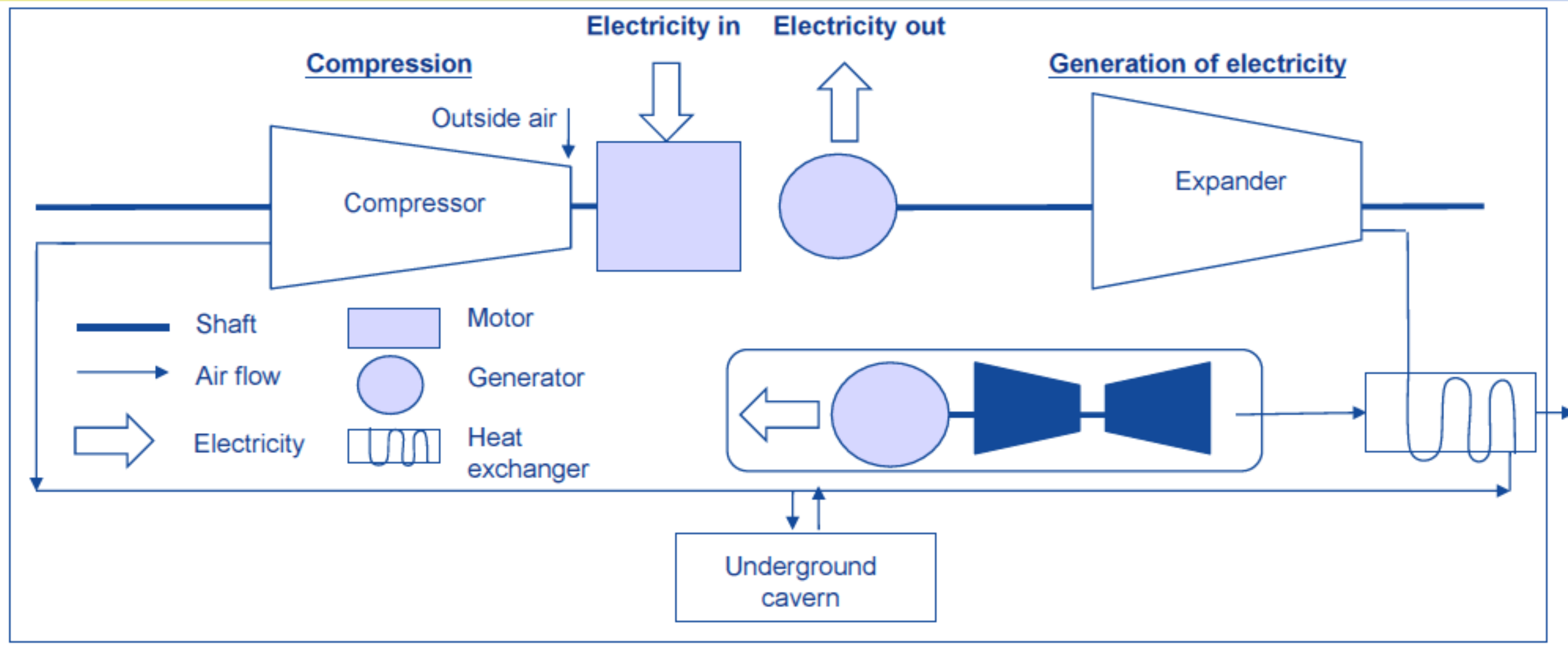
100,000 MW
Installed Worldwide

Mature Technology

80% Round Trip
Efficiency

Limited By Geography

Compressed Air Energy Storage

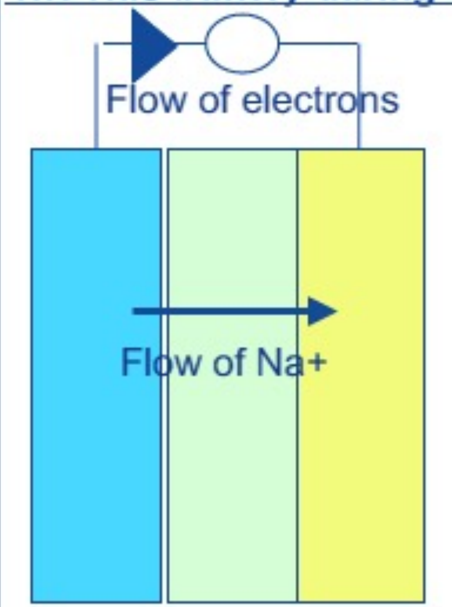


500 MW Operating World Wide   With Co-Generation 50% Efficient

Sodium Sulfur Solid State Batteries

The NaS battery	NGK is the sole manufacturer of NaS batteries

The NaS battery during discharge



Anode (Sodium) Cathode (Sulfur)

$$2Na + xS \rightleftarrows 2Na_2S_x$$

$\longrightarrow$ discharge

- The NaS battery works at high temperature (>300°C)
- The cells are hermetically sealed as Sodium and water react violently

NGK is the sole manufacturer of NaS batteries

- 196 systems installed globally, totaling 270 MW
- NaS is today the 3rd installed grid storage technology in terms of capacity after PHS and CAES
- NGK increased its production capacity from 80MW in 2008 to 150 MW in 2010 to face demand

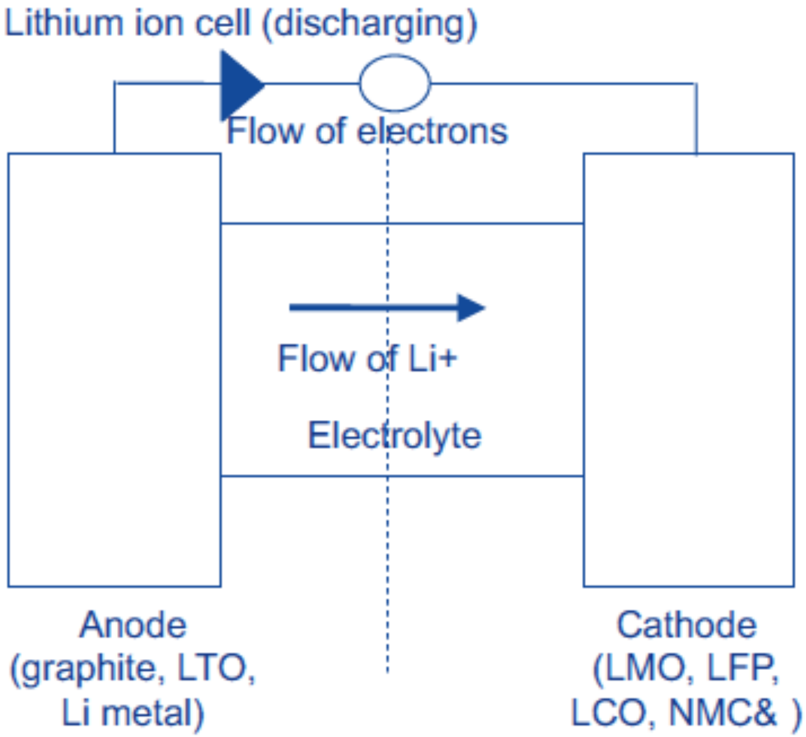
Typical systems are 1 MW/ 7 hours

World's largest battery system: 34MW at Rokkasho, 51MW wind farm (Japan)

Lithium Ion Batteries

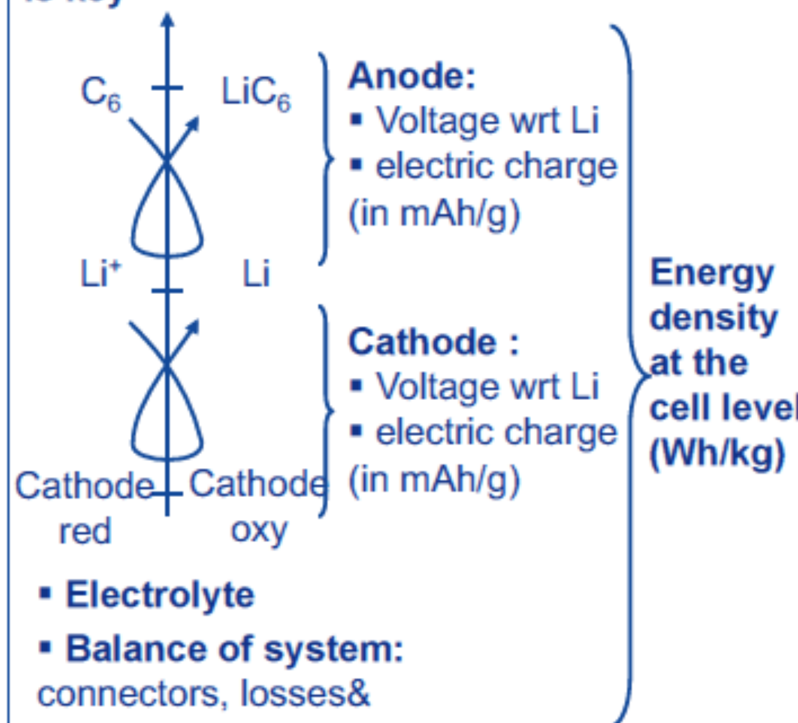
Principle

Lithium battery : an ion of Lithium (the lightest metal) is exchanged between two electrodes



Key characteristics: cycle life, and energy density

Li-Ion battery are actively considered for automotive application where **energy density is key**

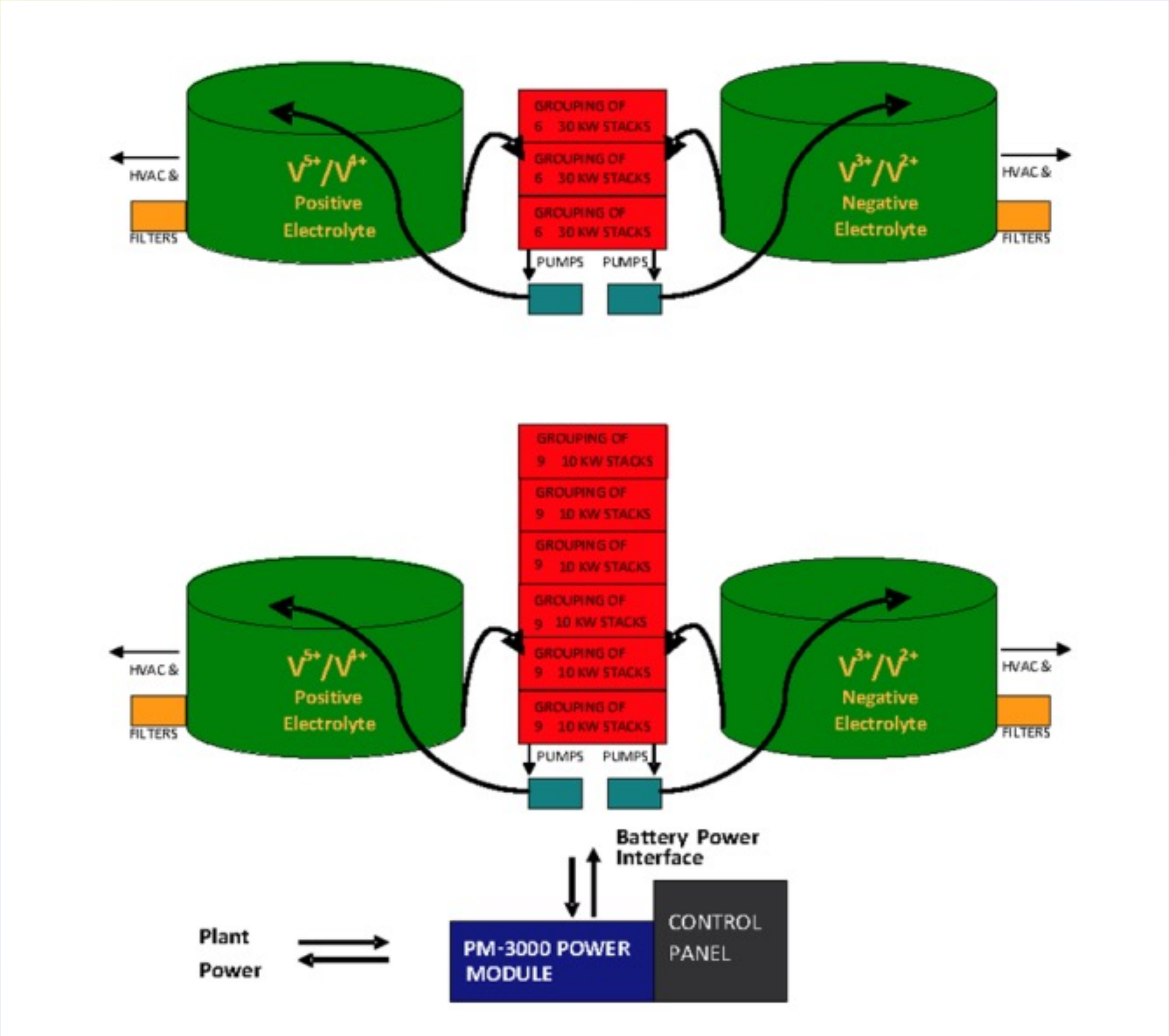


Lithium Ion Full Scale Demo

Flow Batteries

- Electrolyte Stored Externally to Battery and Circulated to Charge/Discharge
- Large Capacity Achievable (MWh)
- Quick Response Available
- Long Life Time (Cycles)
- Stable Output
- Heat Generation

Vanadium Redox Flow Batteries



Vanadium Redox Battery Advantages

- Modular Power and Duration
- Vanadium On Anode/Cathode No Cross Contamination
- Environmentally Friendly
- Completely Recyclable
- Battery Construction Well Understood
- Long Lifetimes
- Low Temperature Low Pressure Operations

Vanadium Disadvantages

- Vanadium Cost
- Vanadium Availability

Summary

Drivers	Barriers
▪ Massive deployment of renewables: ▪ Compensate generation intermittency ▪ Avoid wind curtailment ▪ Weakness in the electric grid ▪ Capacity limit: at peak demand, all needed power can not transit ▪ Frequency and tension drops/ spikes ▪ Optimization of power generating assets	▪ Economics still unclear ▪ Regulation not yet ready, although situation is evolving in the US How to cumulate revenue streams from regulated and non regulated sources? ▪ Technology still evolving ▪ Grid interconnection and cheap coal power

Promises of Plug in Hybrid Technology

- Use grid at night to recharge batteries
- Use batteries during day for peak load
- Reduce dependence on oil
  - Reduced carbon emissions
  - National security issues
  - Repatriate dollars in the US
- Create jobs in Midwest
- Profit center for utilities – could use to subsidize costs

Problems of Plug in Hybrids

- Expensive, short life span of batteries, uncertain performance record
- Time for recharging
- Recharging infrastructure does not exist yet
- Requires more and smarter grid
- Cost of plug in hybrid cars are not yet competitive

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Thank you!