# Micro Particle Energy Storage System

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Presently available Energy Storage Systems are the major limitation in making solar and wind energy systems a viable part of the US electrical energy supply

- Battery systems
  - good energy density
  - expensive
  - efficient
- Superconducting Magnetic Energy Storage Systems
  - good energy density
  - even more expensive
  - must be large to be economical
- Pumped Water and Air Energy Storage systems
  - requires large areas
  - expensive
  - simple

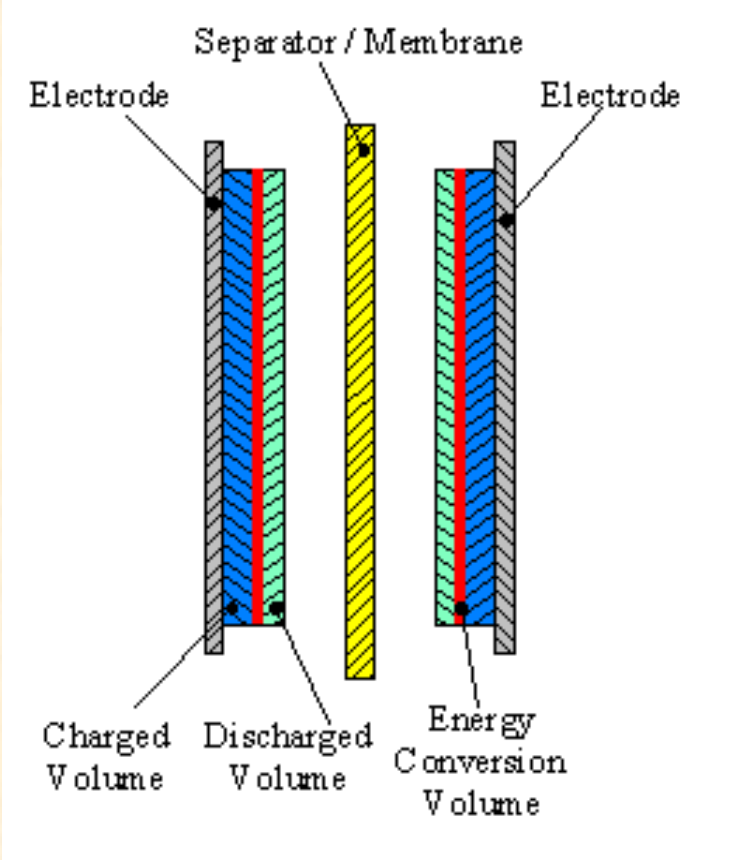
All of these systems are too expensive for solar and wind because sources are distributed and small – Batteries best, but not economical

Batteries, even Lithium Ion, have limitations in energy storage applications

- Lifetime limitation => Recycling damages material structure => replacement => increased cost
- Charge rate (current density) limitation => increased area => increased cost
- Series Resistance => thin layers on electrode
- Thermal limitations => increased size => increased cost
- Energy Density Limitation => increase in volume
- Manufacturing size limitation => Unit size small => more units => increased cost

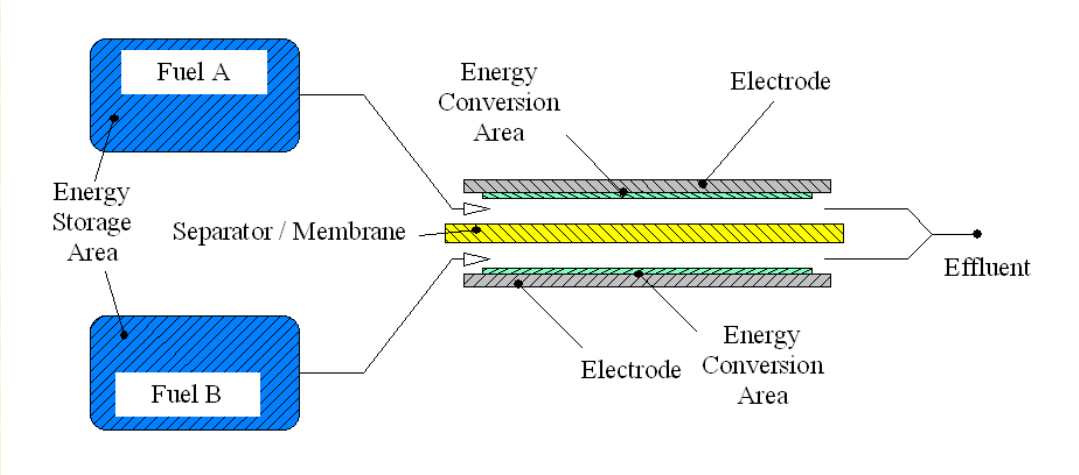
# Batteries incorporate energy storage function and energy conversion function in the same volume

- Energy Storage volume is converted to another material during charge and discharge activity
- Energy Conversion volume moves through Energy Storage Volume during charging and discharging
- Thermal Energy is generated during charging and discharging that is transferred through energy storage volume
- Current density capability is proportional to face area
- Energy Storage density is proportional to the volume of material




These realities lead to thin layers and massive areas of electrodes

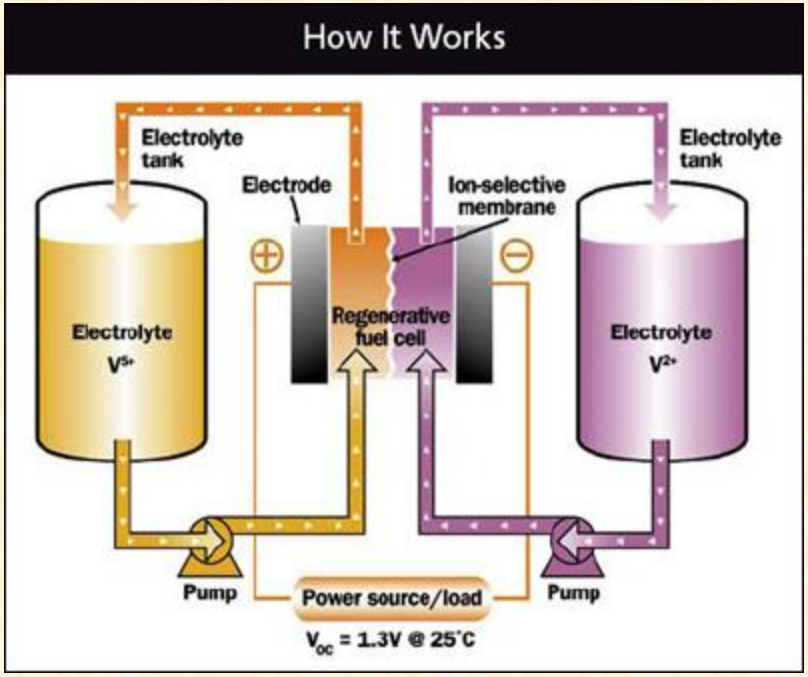
# A Fuel Cell separates the functions of energy storage and energy conversion



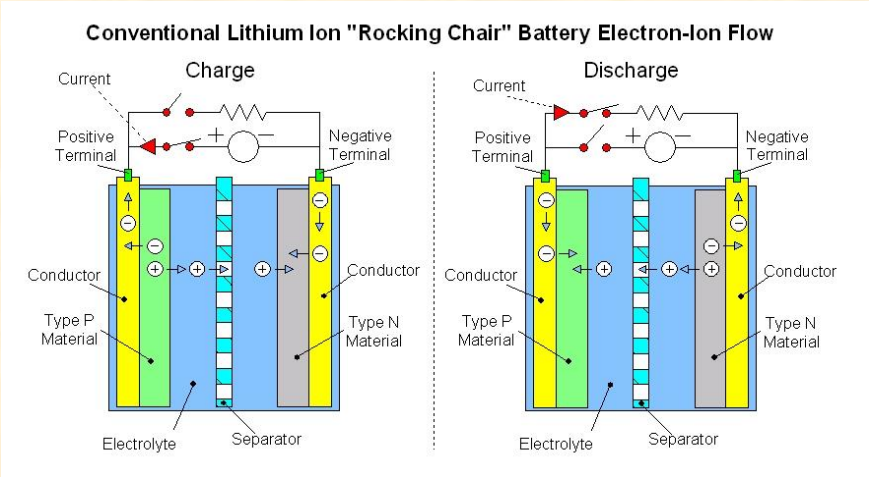

- Requires Catalyst or temperature make chemical reaction efficient
  - expensive and/or cumbersome
- Current density proportional to electrode area
  - Large areas required for current
- Chemical Fuel Cells “burn” fuel
  - Oxygen can be used as one fuel
- Effluent sometimes can be reclaimed or used as storage
  - Inefficient recovery processes (electrolysis for H2 O2 Fuel Cell)

Flow Batteries in which Oxidation state of Vanadium is changed during flow through a converter cell is an example of using the same material for storage: However, the energy density is about 10% of that for the micro particle system

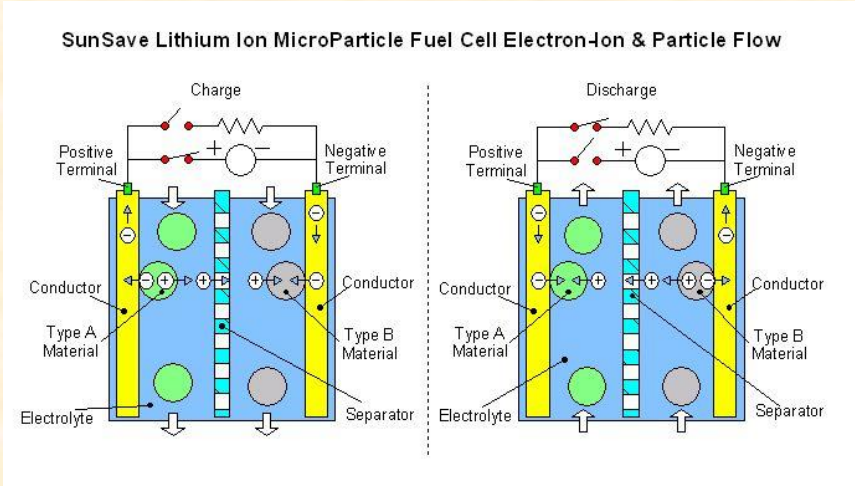
- Electrolyte consists of emulsified vanadium particles in sulfuric acid
- The electrolyte is pumped from separate storage tanks into flow cells across a proton exchange membrane (PEM)
- One form of electrolyte is electrochemically oxidized
- The other is electrochemically reduced



# The SunLase Micro Particle Fuel Cell (MPFC) System is a reversible Fuel Cell , based on micro-particles, that addresses the limitations of batteries and conventional fuel cells



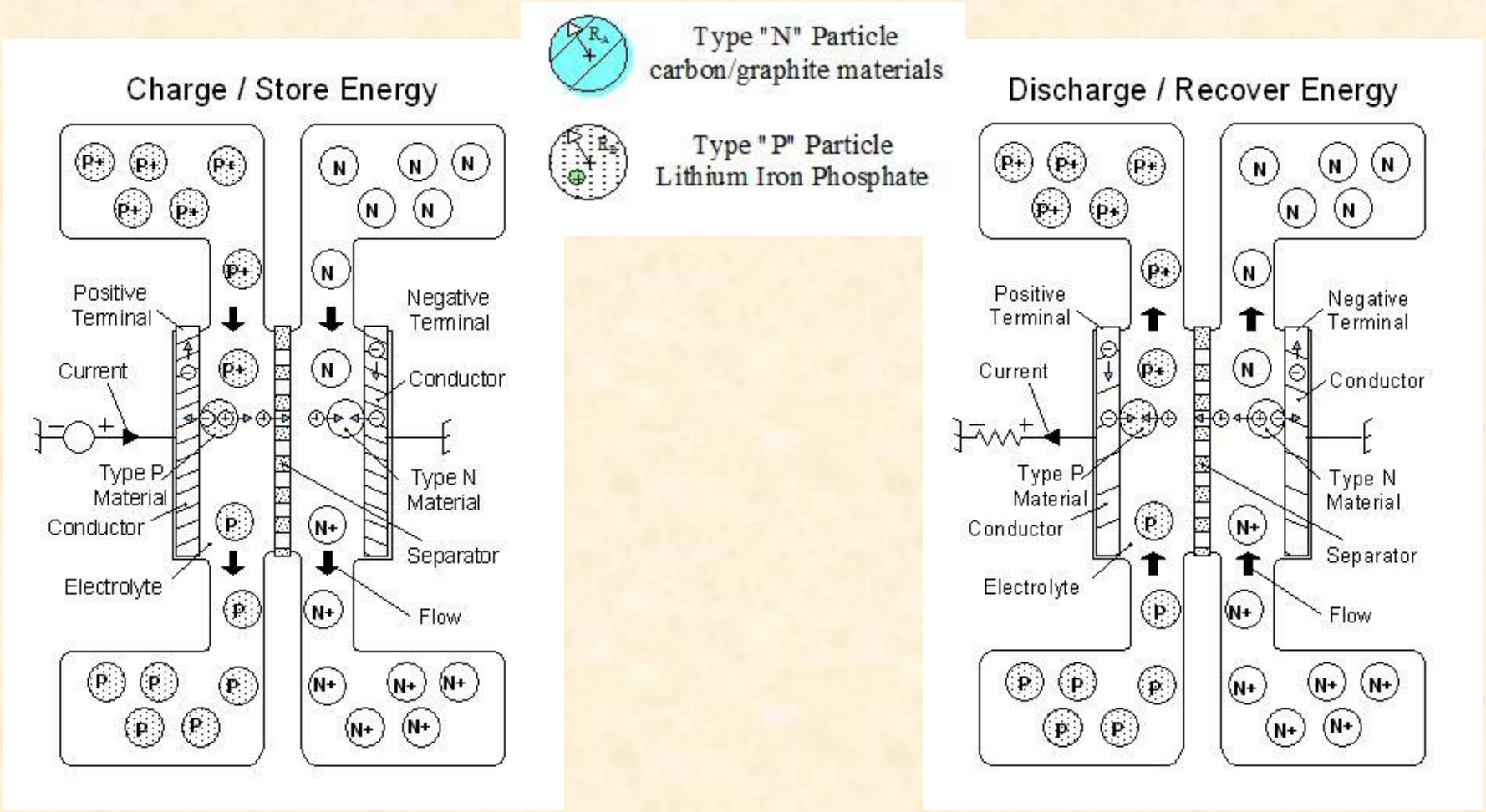

Conventional Li-Ion Battery




SunSave Li-Ion MPFC

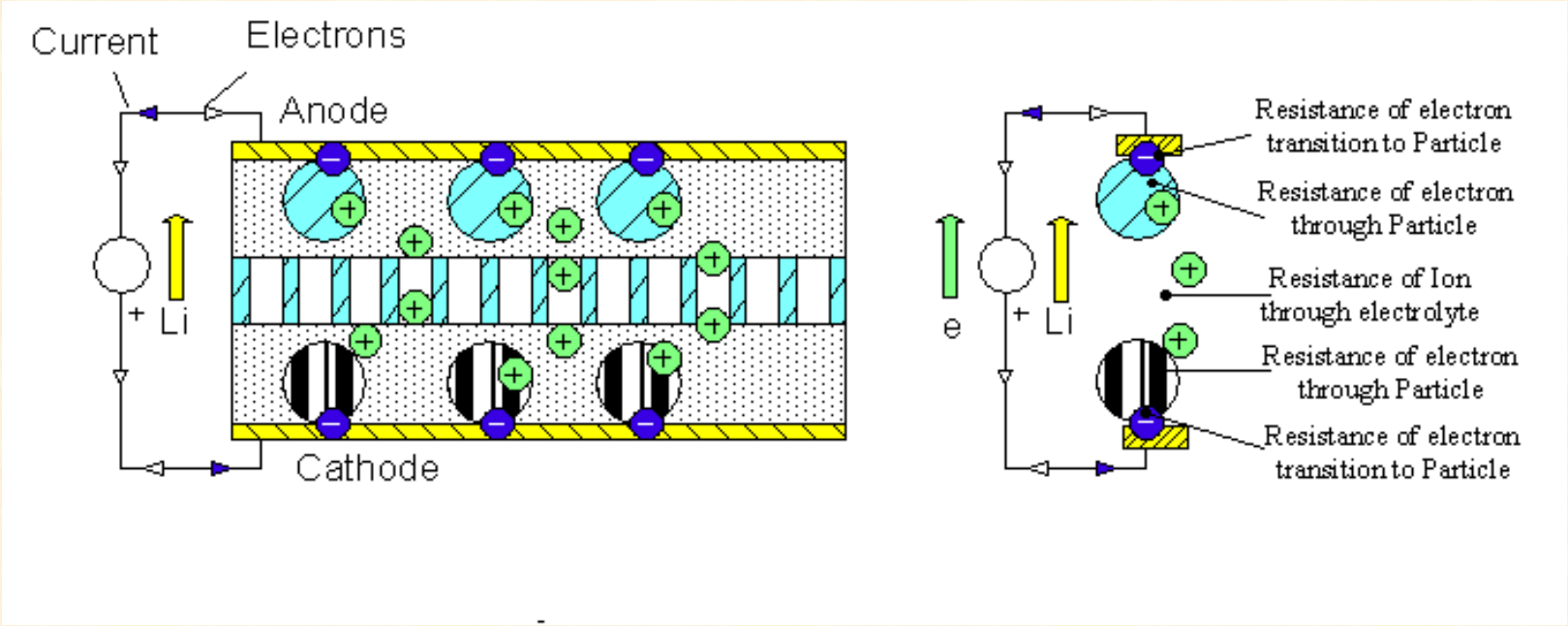
- Energy storage material size change => minimize problem
- Thermal energy removal inherent during flow
- Current Density increase due to surface area of particles
- Particle condition refurbished in real time
- Cost of energy converter and energy storage sized to application
- Energy storage defined by volume of tanks.

SunSave MPFC stores energy by transferring Lithium ions from Ptype particles to Ntype particles as they traverse the converter cell.




"+" denotes Lithium Ion

# The contact of micro particles to the electrodes is a critical part of the system operation.




- Resistances have been characterized, except particle contact
- Particle contact methods remain to be optimized
- Potential between electrode and unconnected particle is attractive
- Membrane ion permeability is also a resistance factor
- Boundary Layer effects being investigated

# Immediate Applications of this technology are dependent upon cost of implementation

| 1 | Solar Power Systems | Tank volume sized to energy available |
|---|---|---|
| 2 | Wind Power Systems | Converter sized to power available |
| 3 | Farm Power Systems | Wind power generation of energy to power farm equipment |
| 4 | Truck Power Systems | Dependent upon power available for rapid recharge |
| 5 | Home Power Systems | Homes can be independent of grid with wind or solar power and sufficient storage |
| 6 | Electrical Power Systems | Energy storage dependent upon the volume of tanks available for storage |
| | | |

# Replacing Battery Energy for any Auto battery system is dependent on the time allocated for recharge

The amount of energy used by a conventional auto over a 4 hour period is large

A Fuel Station recharge in 10 minutes requires 440 Volts and over 1600 Amps

A home garage recharge in 5 hours is possible with a modest voltage and current

The energy storage volume required is about ¼ of a cubic meter.

A converter / recharger can be sized for either mode of recharge.

Electric Vehicle Recharge Requirements

| Parameter | | Value | Unit |
|---|---|---|---|
| | | | |
| Avg Cruise Power | | 3.00E+04 | W |
| Avg Duration | | 4 | hr |
| Energy | | 1.20E+05 | W-hr |
| | | 4.32E+08 | J |
| Fuel Station Charge | | | |
| Recharge Time | | 10 | min |
| | | 0.166667 | hr |
| Recharge Power | | 7.20E+05 | W |
| Voltage | | 440 | V |
| Current | | 1636.36 | A |
| | | | |
| Home Garage Charge | | | |
| Recharge Time | | 300 | min |
| | | 5 | hr |
| Recharge Power | | 3.27E+02 | W |
| Voltage | | 100 | V |
| Current | | 3.27 | A |
| | | | |
| Energy Density | | 7.20E+05 | J/kG |
| Mass Required | | 6.00E+02 | kG |
| Battery Material Density | | 2.50E+03 | kG/m3 |
| Volume of Energy Storage | | 2.40E-01 | m3 |
| | | | |

Summary

- ❑ Lithium Ion Micro particle energy storage system
  - ❑Energy Storage density >/ = Li-Ion Battery
  - ❑ Energy Storage Scalable to any size with tankage
  - ❑Conversion hardware dependent upon rate of storage and recovery
  - ❑Majority of technology demonstrated
  - ❑ Key demo required: Efficient Particle contact with electrodes
- ❑Competition - Vanadium Flow Redox Battery (VFB)
- ❑ Comparison

| Parameter | Vanadium FB | Lithium Ion MP | Unit |
|---|---|---|---|
| Energy Density | 72 | 720 | J/kG |
| Cell Voltage | ~ 1 | ~ 3 | V |
| | | | |