Electrochemical Energy Storage

Making Hay When the Sun Shines

TISED Symposium on

Storage in Sustainable Electric Energy Systems,

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Porous Materials
Engineering
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PMEAL

Real World Example Green Gas

Problem 1: Surplus power during windy periods

- Windy periods and consumer demand don't always coincide
- Excess power is given away to neighboring countries

Solution:

- **Store the energy for later use…**

Problem 2: Energy storage options are limited

- Geological energy storage is not available (pumped hydro)
- No other storage options are ready

Solution:

- **Water splitting to make hydrogen is old technology**

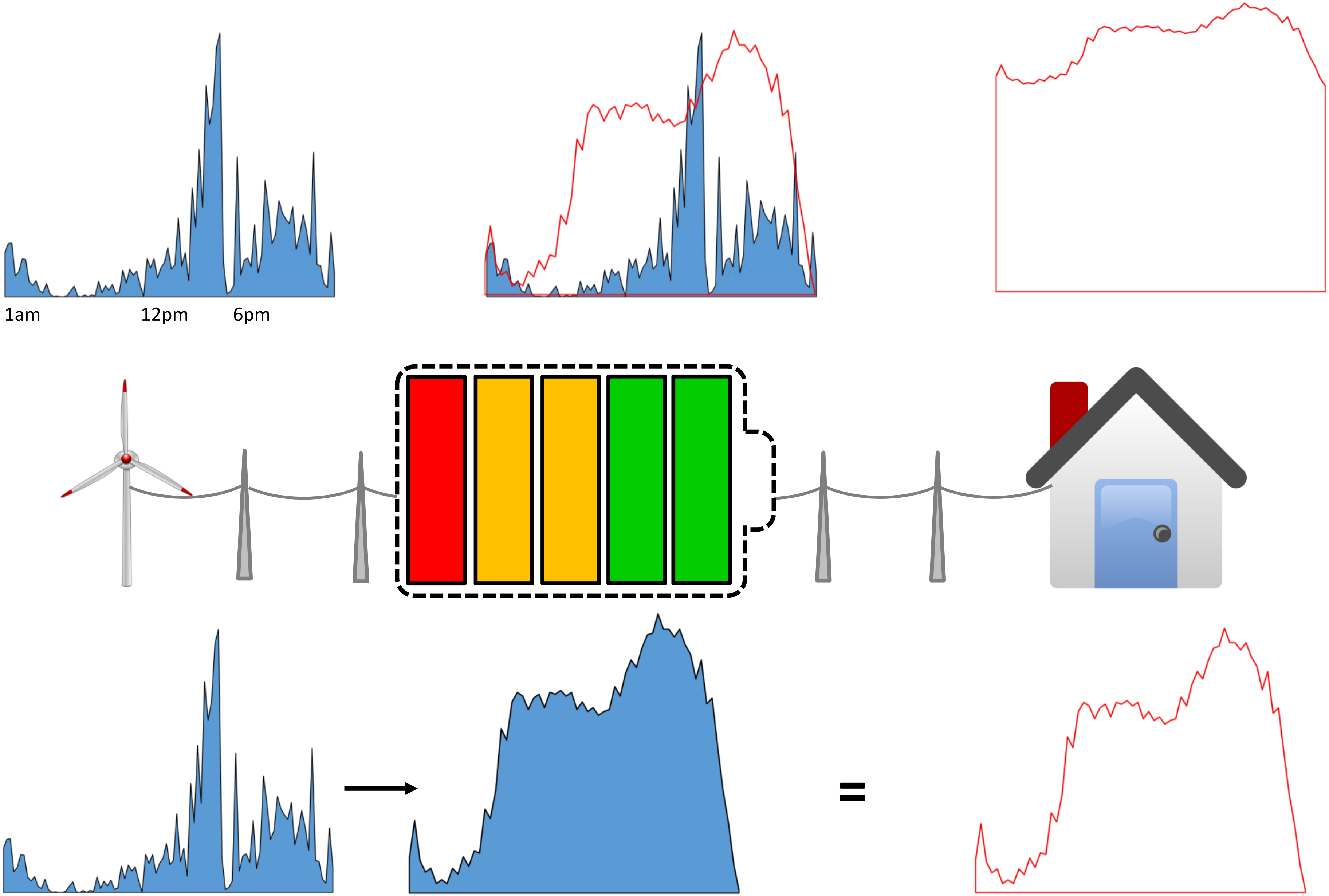
Problem 3: Where to put the hydrogen

- Hydrogen storage tanks are expensive
- Hydrogen pipelines and infrastructure are nonexistent

Solution:

- **Inject hydrogen into natural gas pipeline – "Green Gas"**

Energy Storage A Battery-Shaped Hole



Energy Storage Rules for Joules

Rule #1 Location dictates options

Rule #2 Decouple storage and generation

Rule #3 Process must be reversible

Rule #4 Size doesn't matter

Rule #5 Cost does matter

Rule #6 Use only plentiful resources

Rule #7 Provide a real offset of CO_2

Rule #8+ To Be Determined*

* Complete set of 'Rules' will be discussed at tomorrow's workshop

Rule #1 Location, Location, Location

Geographic Viability

- Pumped Hydro is the perfect solution…
- …but violates Rule #1
- It is not possible in MOST places

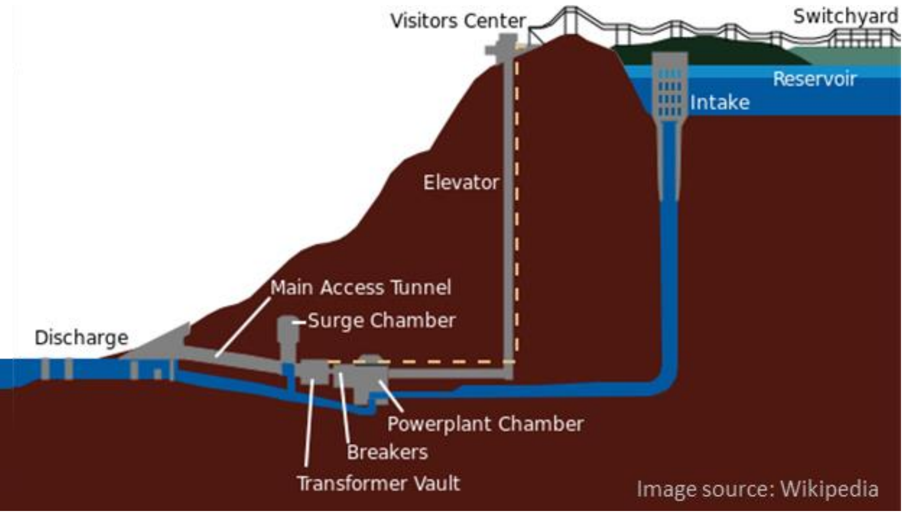
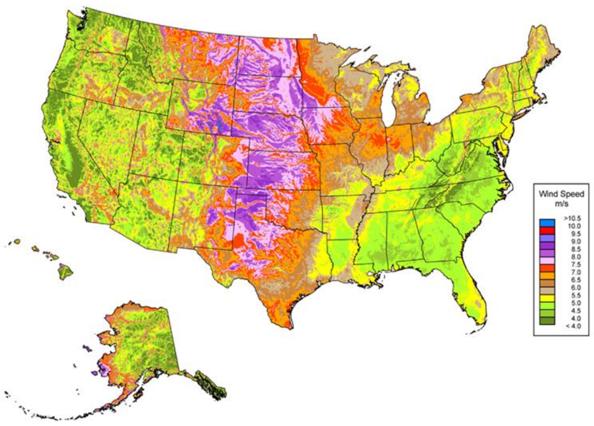


Image source: Wikipedia

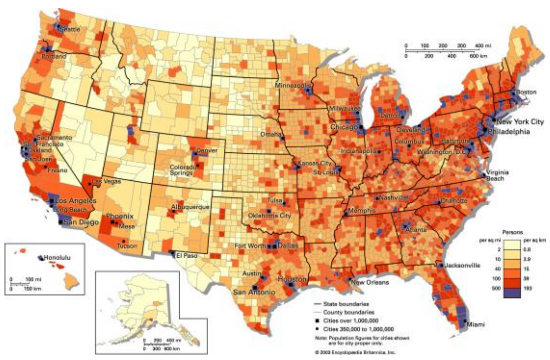
Remote Locations

- Power must be moved from where its generated to where its needed
- Transmission lines have limited capacity
- Deferred transmission requires storage at the generation site
- Sending to a remote hydro reservoir is not feasible

Wind



People



Map images courtesy of NREL

Electrochemical Energy Storage is Location-Neutral

Rule #2 Decouple Storage and Generation

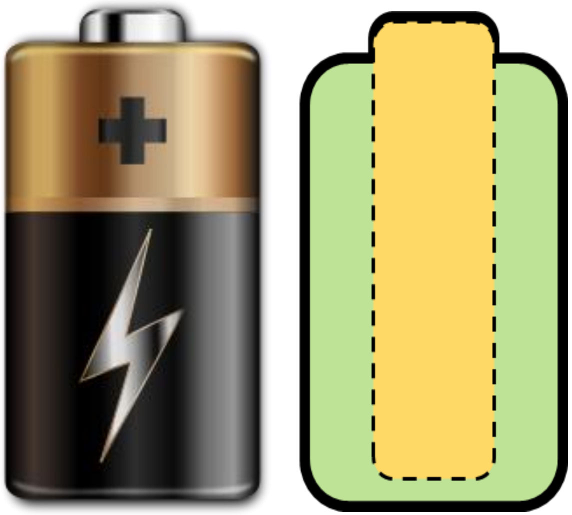
"Would you rather":

Heat your house with a stove made of wood…

…or a wood stove?

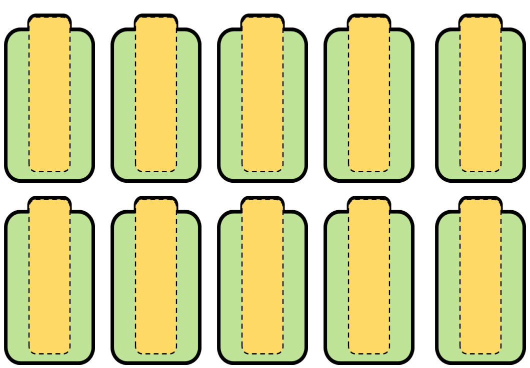
Rule #2 Decouple Storage and Generation

A flow of batteries…



More Storage?

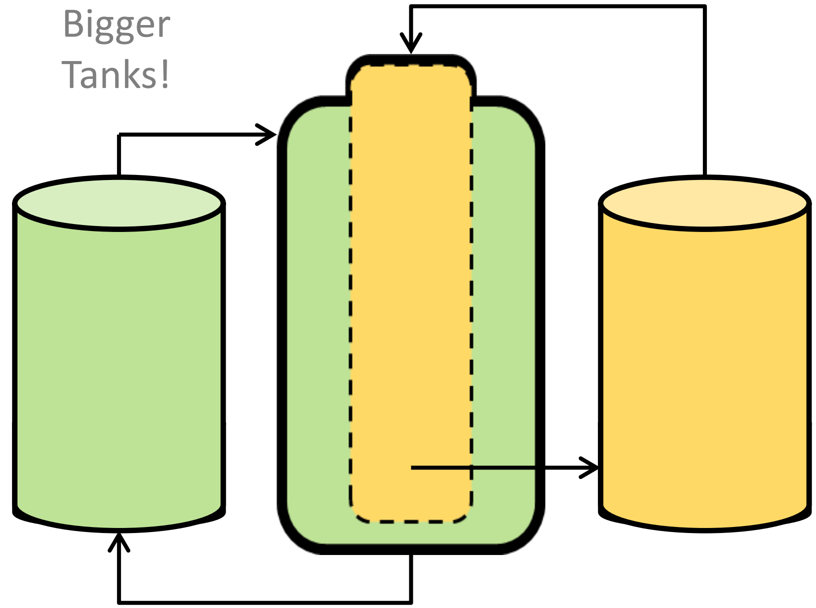
More Batteries!



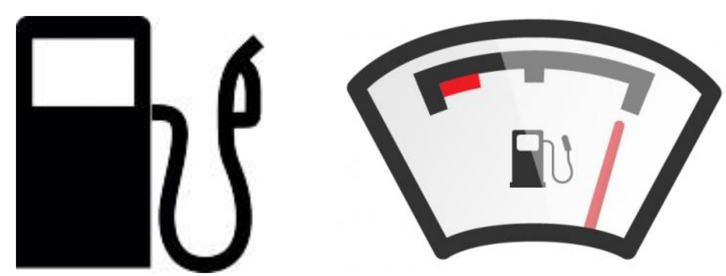
More Storage?

Bigger Tanks!

…or a flow battery

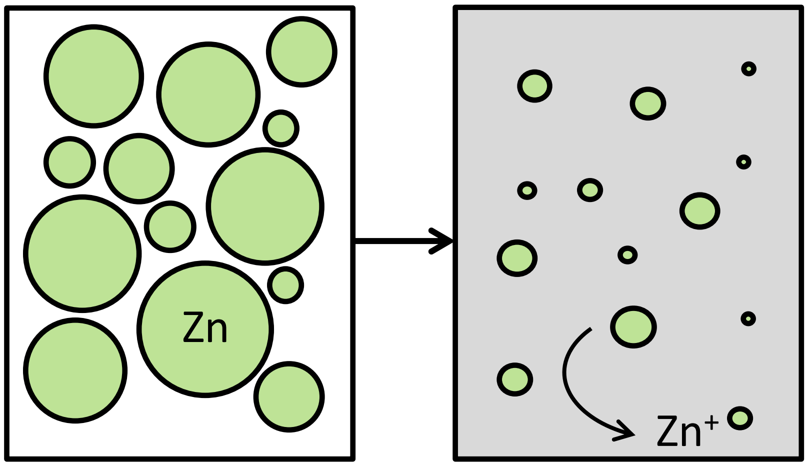


A familiar concept:



Rule #3 Process Must be Reversible

Disposable Batteries



Disposable Batteries

- Active species IS the structure
- It dissolves when used, and can't be recovered

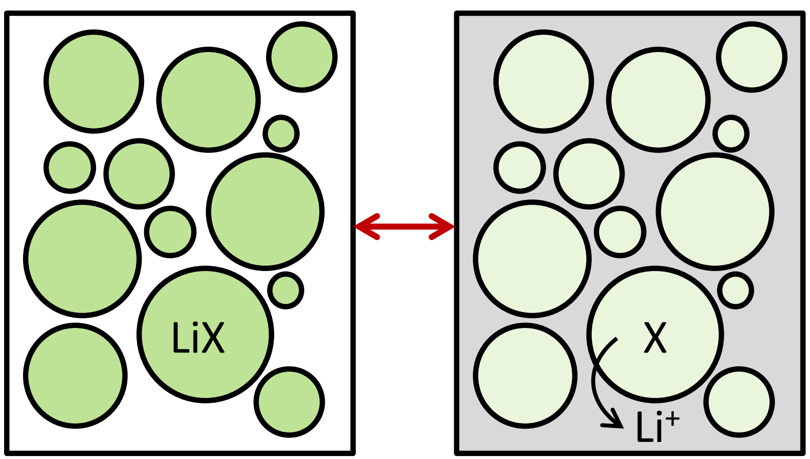
Rechargeable Batteries

- Active species resides IN structure
- It moves IN and OUT reversibly (almost)

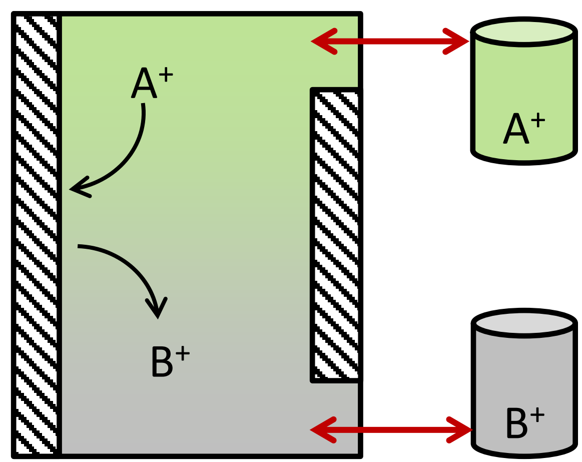
Flow Batteries

- Active species and structre are independent
- Reaction is a simple chemical alteration of a species in a fluid

Rechargeable Batteries



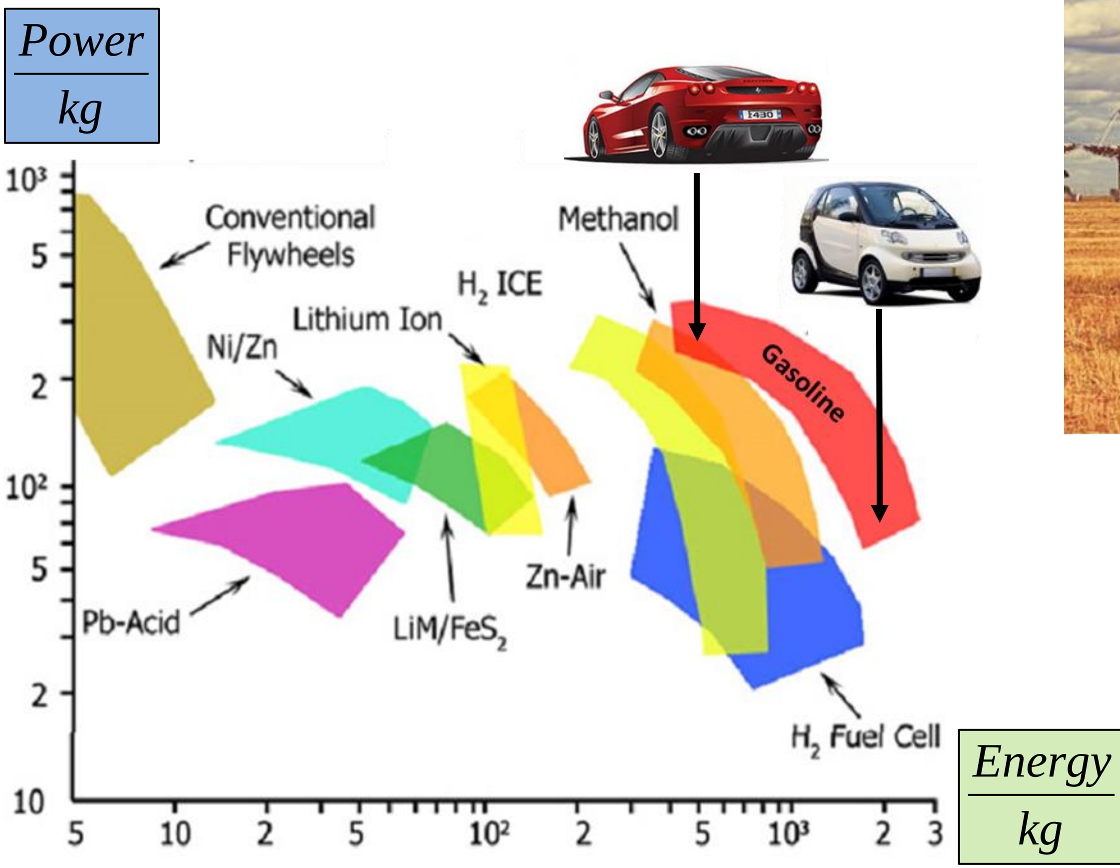
Flow Batteries



Rule #4 Size Does NOT Matter

Automotive Applications Require HIGH density

- Space on a vehicle is limited
- Performance and mileage is weight limited



Stationary Applications Have No Size Limits

- Mass is completely irrelevant
- Volume or footprint is not important (within reason)

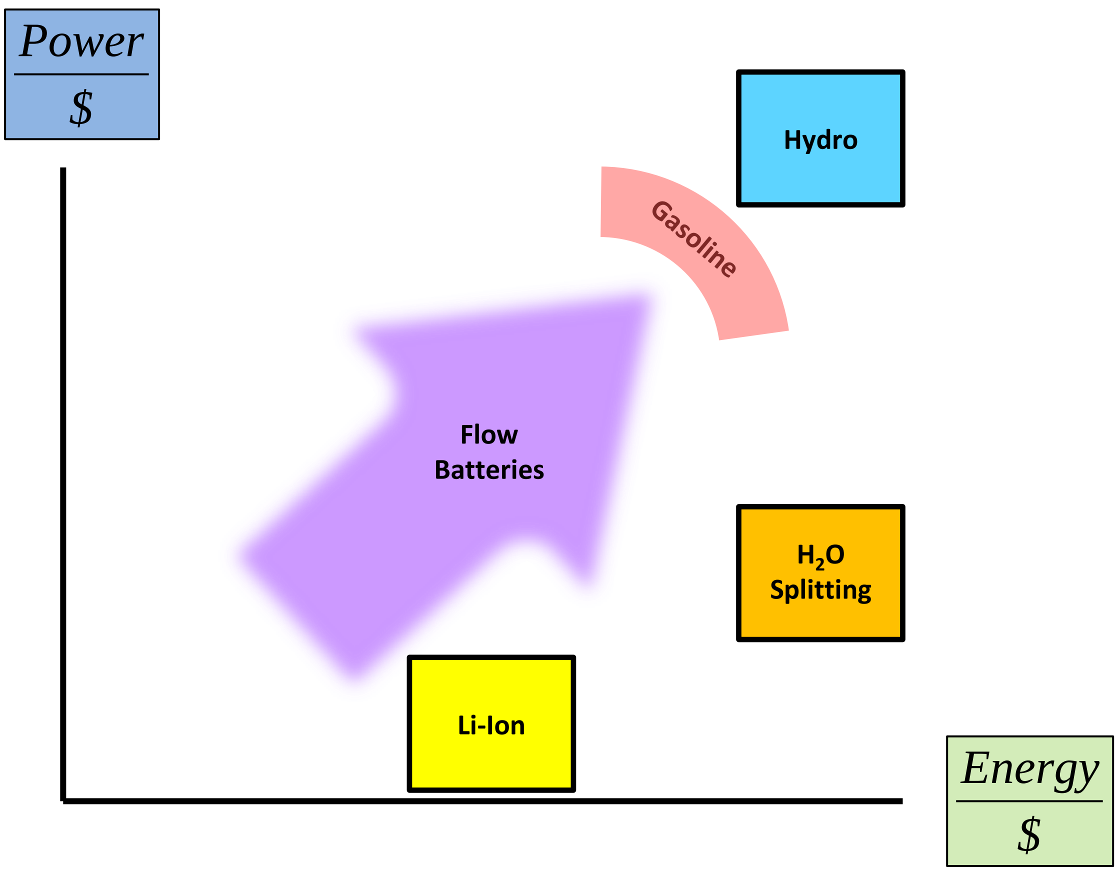
Power Density = Horsepower
- The amount of power produced by the engine
- Larger engines are more powerful

Energy Density = Range
- The amount of energy in a gallon fuel
- Dictates the size of the fuel tank
- Limits the range of the vehicle

Rule #5 Cost Does Matter

Stationary Applications Have No Size Limits

- Mass is completely irrelevant
- Volume or footprint is not important (within reason)
- Only cost and durability matter
- The longevity of a device helps cost too



Pumped Hydro
- Very cheap raw materials (water)
- Huge construction, but lasts ages

Electrolyzer
- Very cheap raw materials (water)
- Requires Platinum

Li-Ion Battery
- Fairly cheap raw materials
- Expensive structure, need many!

Flow Battery
- Potentially very cheap chemicals
- Potentially very cheap system

Energy Cost = Chemicals
- The cost of the chemicals used in device
- The amount of the chemicals needed

Power Cost = Equipment
- The cost of building the device
- The size and number of devices needed

Global Energy Production Simply Terra-fying

Power Consumption per Person	Canada	China	India	World
2015	9.51 kW	2.38 kW	0.73 kW	2.30 kW
2050	2.30 kW	2.30 kW	2.30 kW	2.30 kW

Population	Canada	China	India	World
2015	35m	1.2b	1.5b	7.13b
2050	---	---	---	10b

Total Power Consumption	World		
2015	16.8 TW	+6.2 TW	6.2 TW = 6200 GW
2050	23.0 TW		3100 Nuclear Power Plants

- Since there are ONLY 1820 weeks between now and 2050…
- Humanity needs to build *1.7* nuclear power plants *PER WEEK* for the next 35 years
- And that assumes our present supply of 16.8 TW continues uninterrupted

Acknowledgements

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