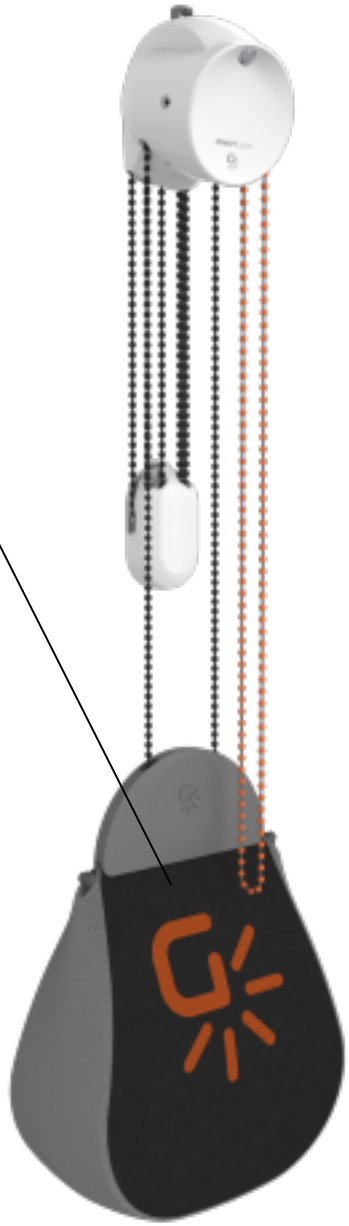
Energy
NYU / ITP / Feddersen

Energy can be stored in many forms

Suspended mass



Chemical bonds (in food, firewood, fuel)

Elastic deformation

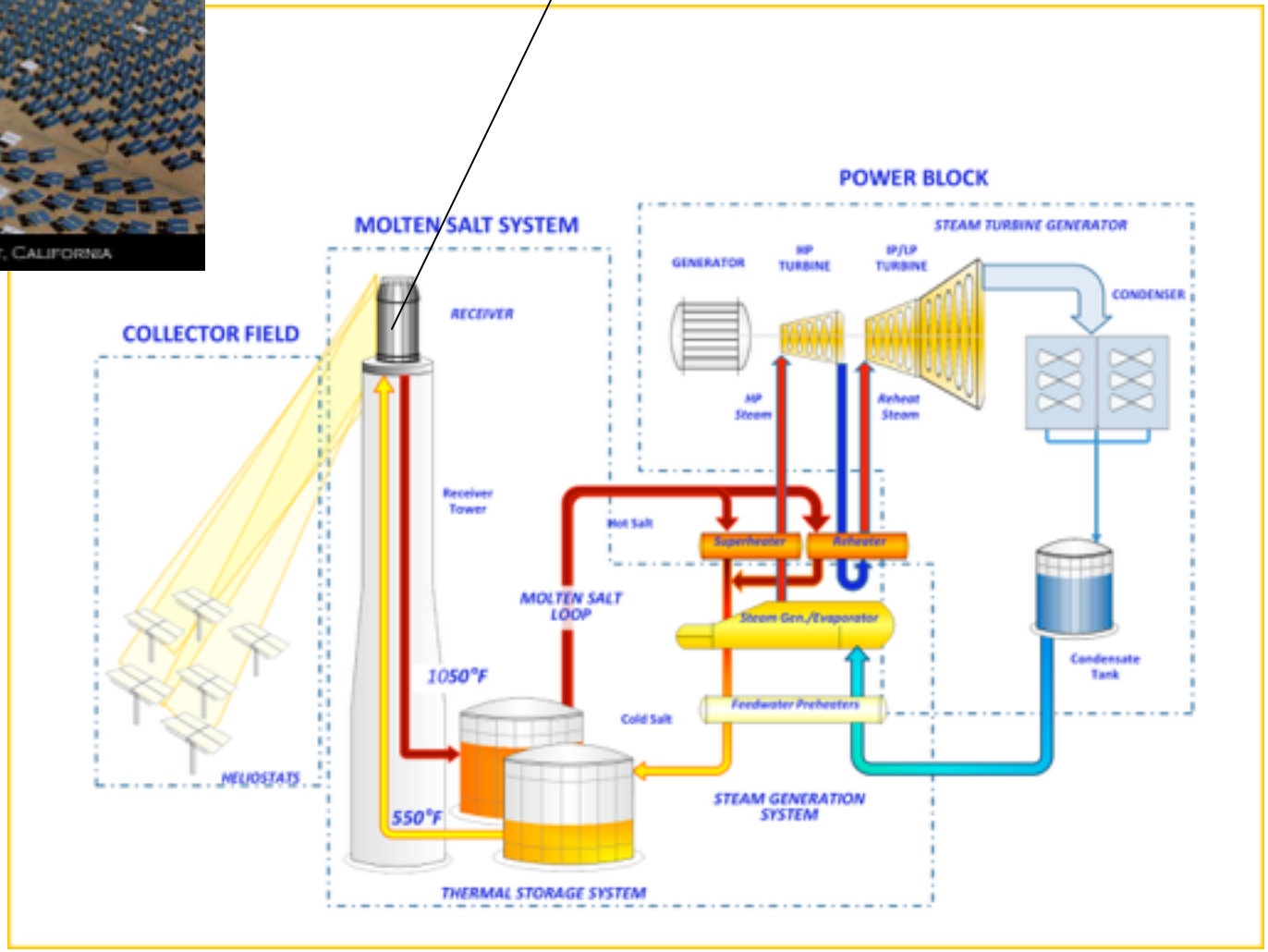
Compressed fluid

Rotating mass (flywheel)

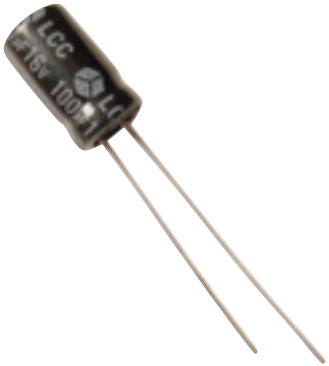

Solar Two - Mojave Desert, California

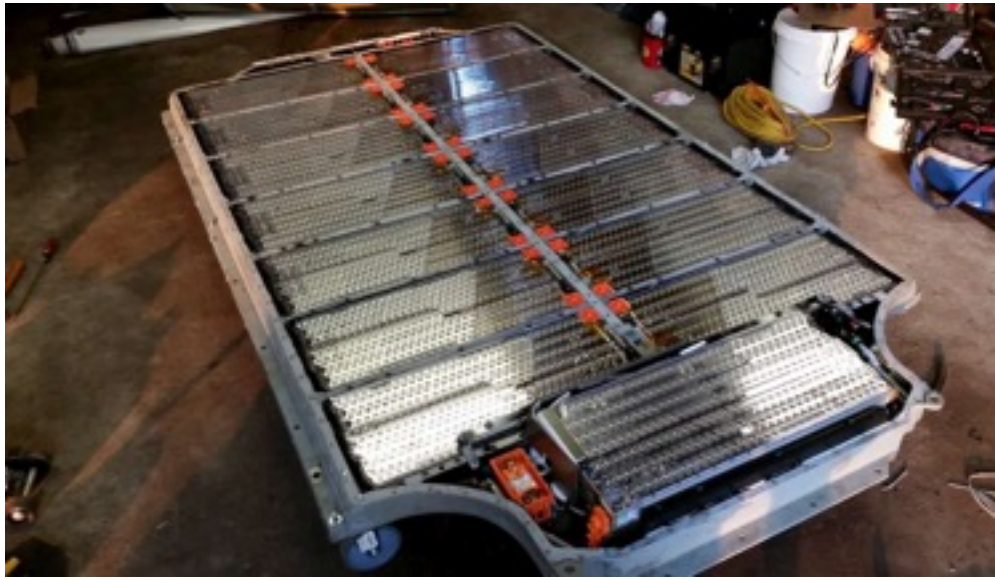
Heat


ZOJIRUSHI


POWER BLOCK
MOLTEN SALT SYSTEM
STEAM TURBINE GENERATOR
GENERATOR
HP TURBINE
IP/LP TURBINE
CONDENSER
COLLECTOR FIELD
RECEIVER
HP Steam
Reheat Steam
Receiver Tower
Hot Salt
Superheater
Reheater
MOLTEN SALT LOOP
Steam Gen./Evaporator
Condensate Tank
1050°F
Feedwater Preheaters
Cold Salt
HELIOSTATS
550°F
STEAM GENERATION SYSTEM
THERMAL STORAGE SYSTEM

Electrical potential





Basic concepts for any energy storage:

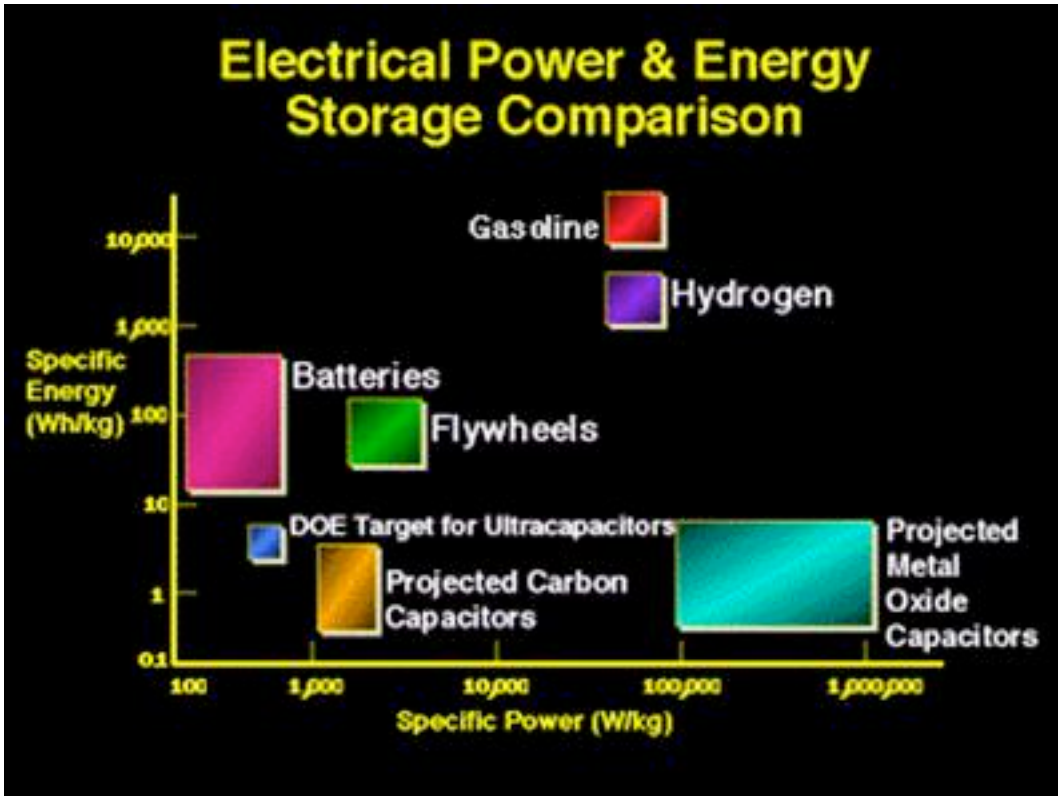
Specific Energy : energy / mass

Energy Density : energy / volume

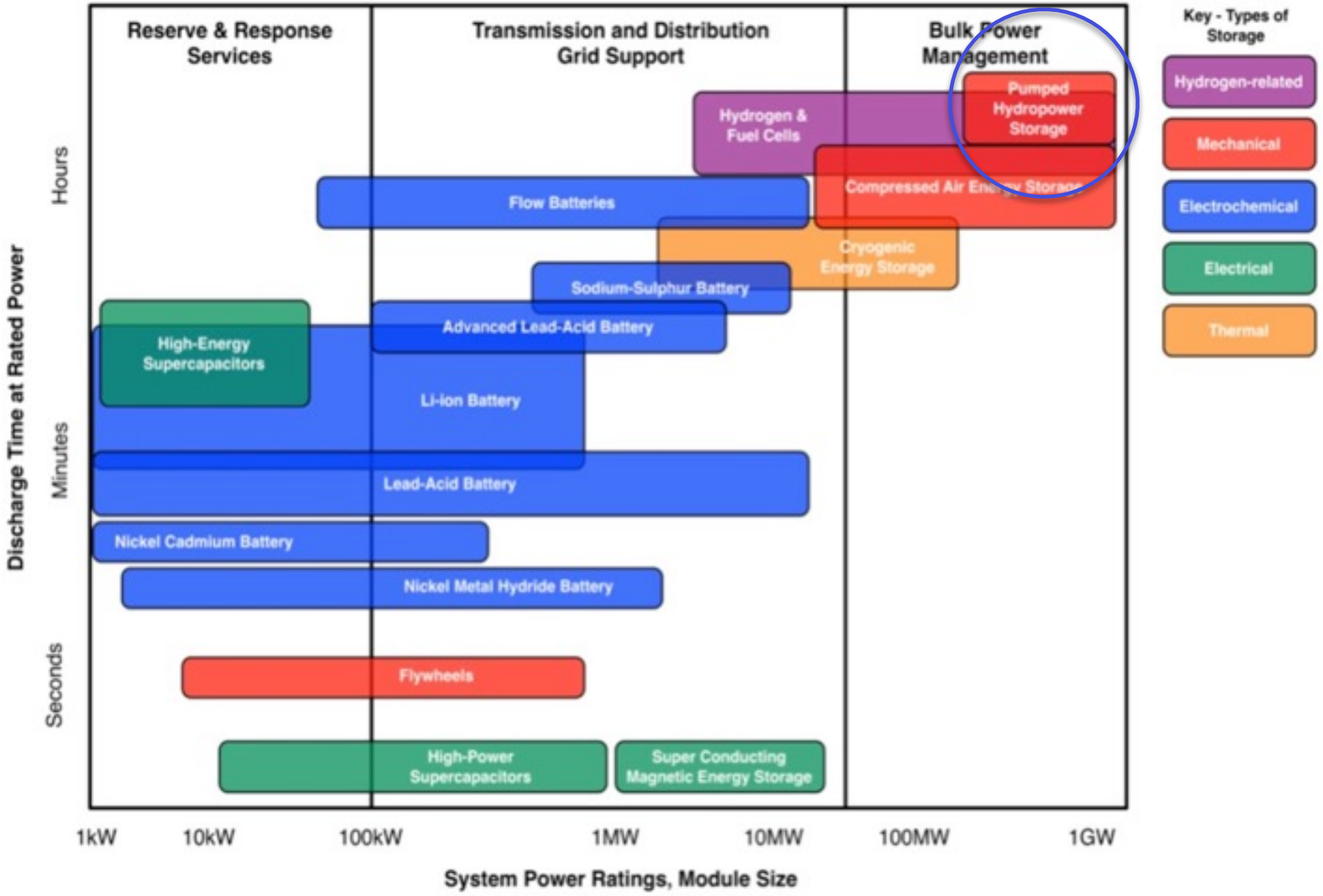
Specific Power : power (input or output) / mass

Power Density : power (input or output) / volume

Efficiency: energy in / energy out

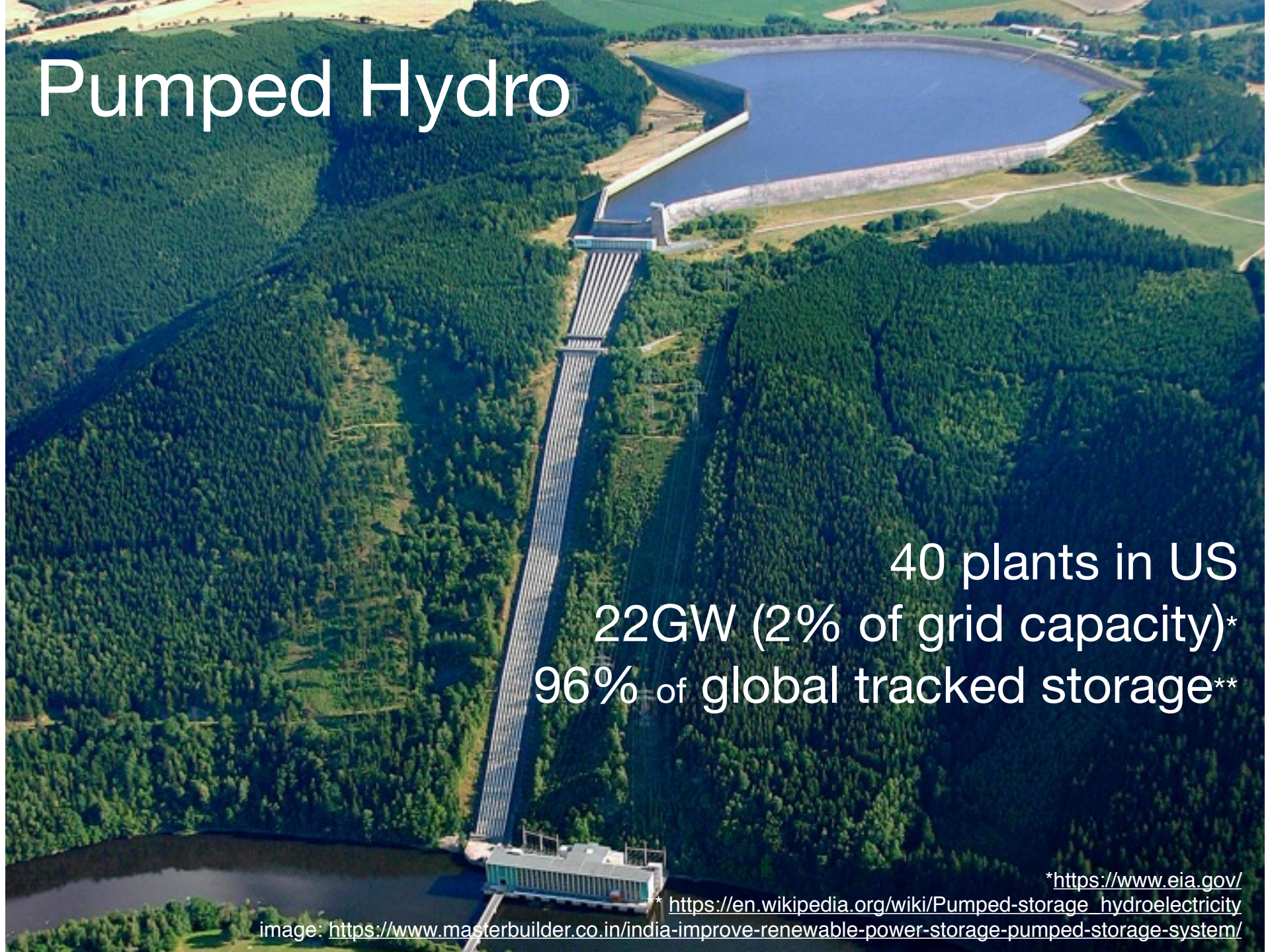

Electrical Power & Energy Storage Comparison
Gasoline
Hydrogen
Batteries
Flywheels
DOE Target for Ultracapacitors
Projected Carbon Capacitors
Projected Metal Oxide Capacitors
Specific Energy (Wh/kg)
10,000
1,000
100
10
1
0.1
100
1,000
10,000
100,000
1,000,000
Specific Power (W/kg)

NREL



http://energystoragesense.com/energy-storage-technologies/

Pumped Hydro



40 plants in US

22GW (2% of grid capacity)*

96% of global tracked storage**

*https://www.eia.gov/

** https://en.wikipedia.org/wiki/Pumped-storage_hydroelectricity

image: https://www.masterbuilder.co.in/india-improve-renewable-power-storage-pumped-storage-system/

Grid-tied batteries starting to make a dent

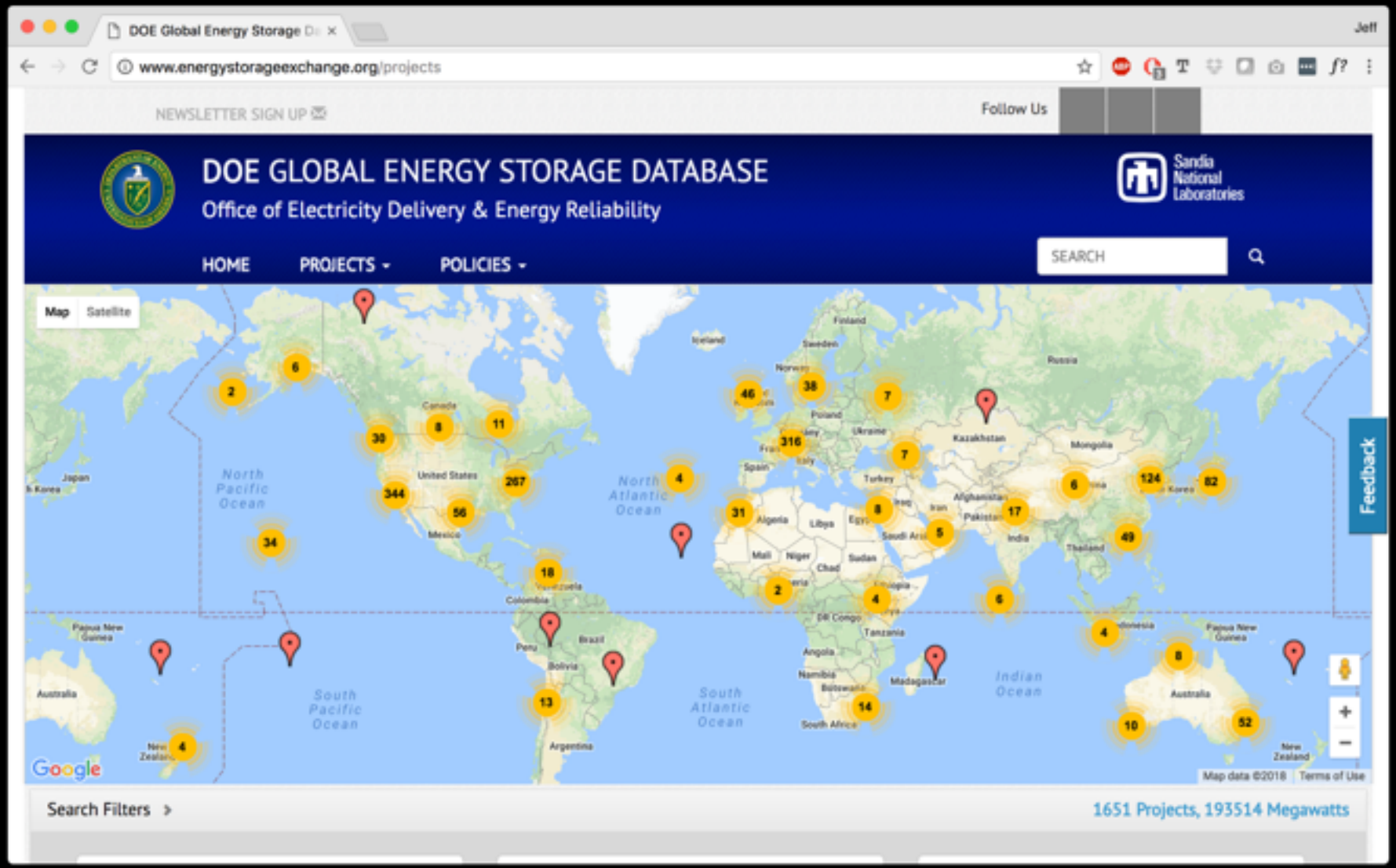
GTM forecast: 1.6GW in US by 2020

This was built in 2017 in West Caldwell, NJ

More data: http://css.umich.edu/sites/default/files/U.S._Grid_Energy_Storage_Factsheet_CSS15-17_e2017.pdf


Coal storage
This was shuttered in 2017 in Jersey City
660MW

DOE Storage Database



A sustainable system by definition uses energy at or below the rate it is generally available from the environment.

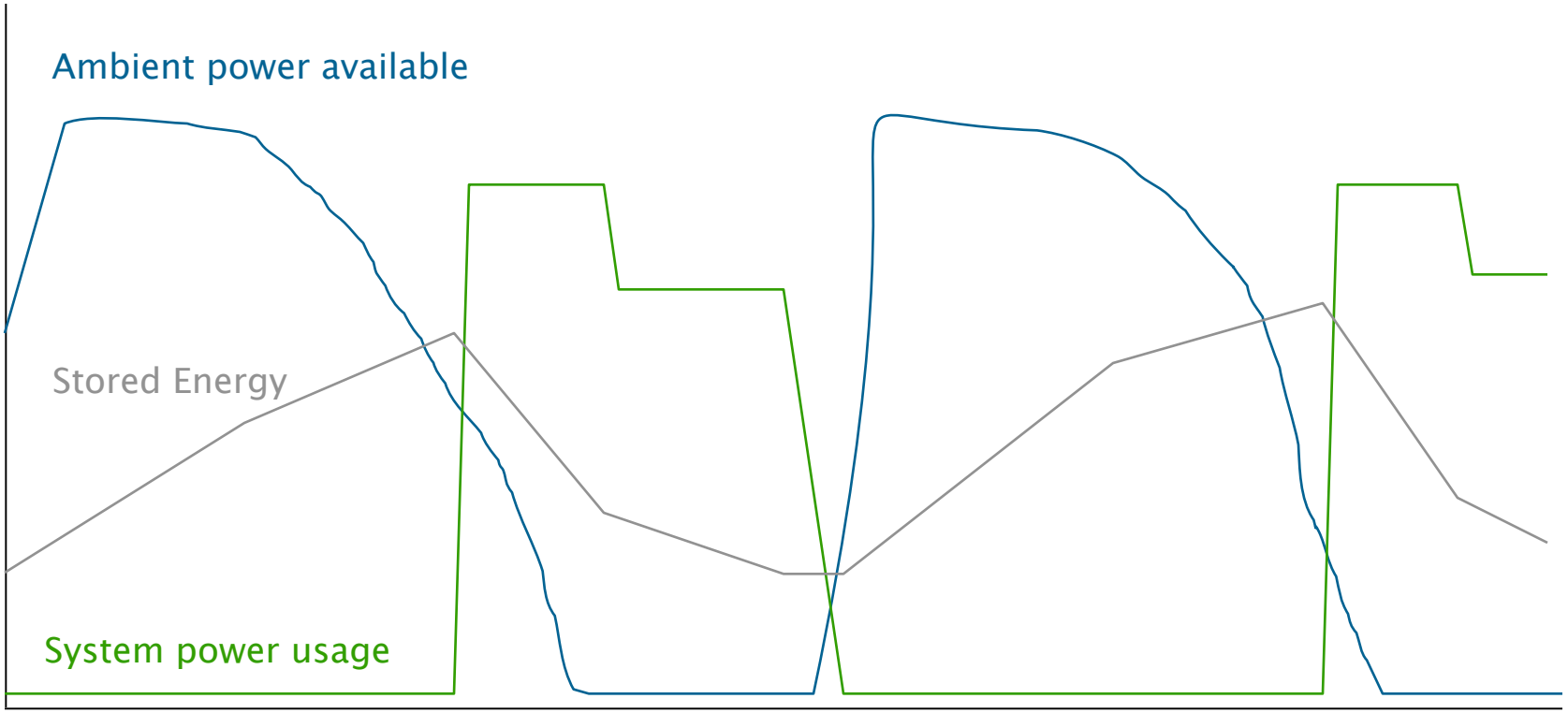
However, it may be necessary for a system to:

- **time shift** energy usage independent of fluctuating ambient availability
- **momentarily exceed** the ambient power available
- and/or handle momentary **power interruptions**

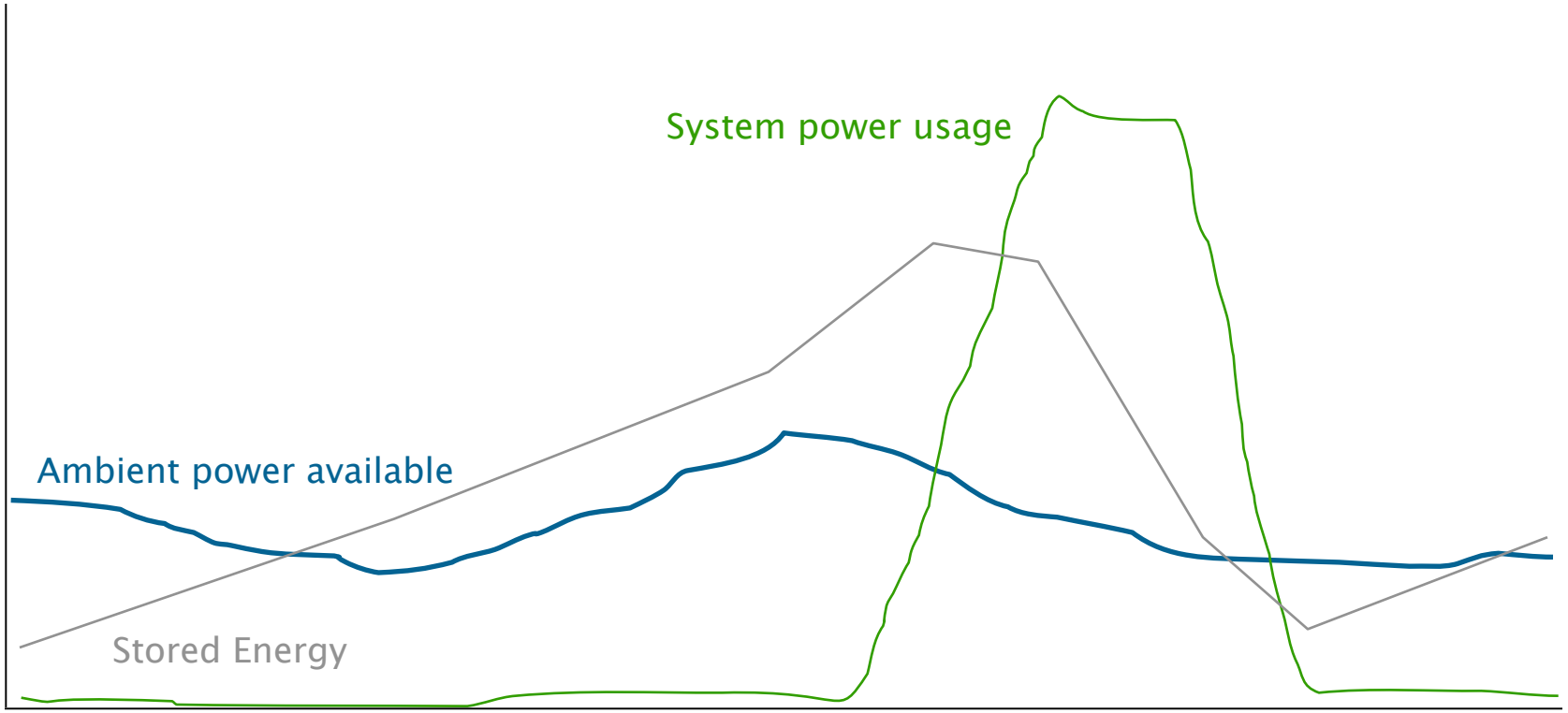
In these cases, **energy storage** will be necessary.

Time shift

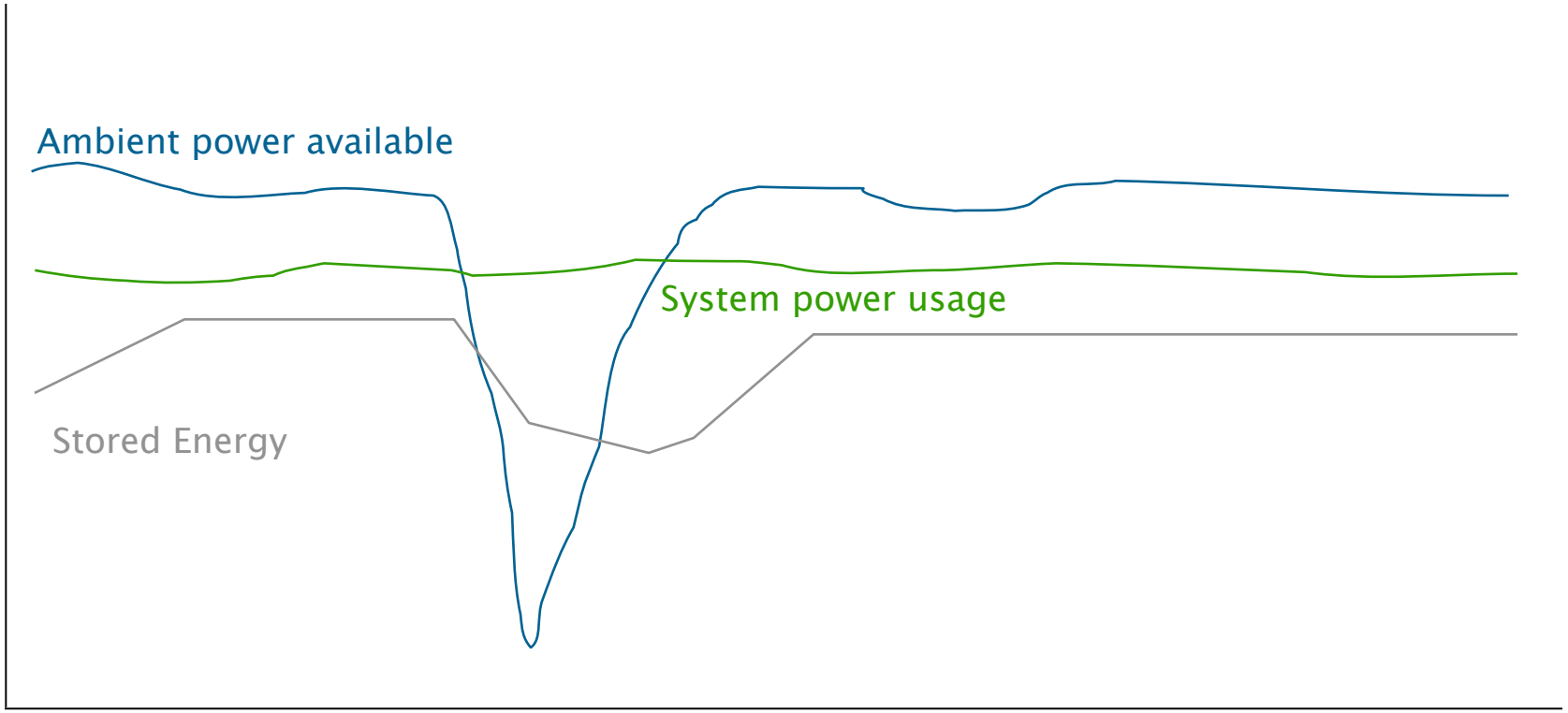
Energy usage is out of phase with ambient availability:



System requires higher momentary power than is available from the environment:



System must handle power fluctuations:



*

Smoothing

.5 * (100 microfarads) * ((5 volts)^2) = 0.00125 joules
More about calculator.

.5 * (3300 microfarads) * ((5 volts)^2) = 0.04125 joules
More about calculator.

.5 * (1 farad) * ((5 volts)^2) = 12.5 joules
More about calculator.

Storage

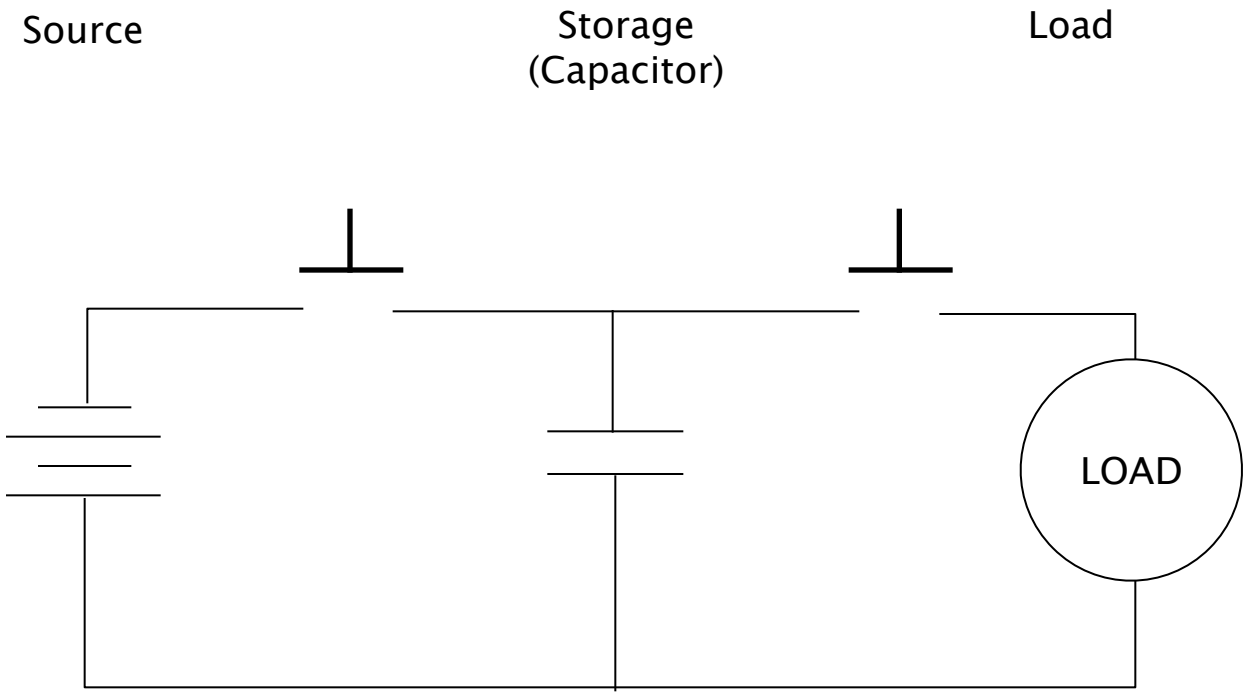
.5 * (60 farad) * ((5 volts)^2) = 750 joules
More about calculator.

Energy in a capacitor is:

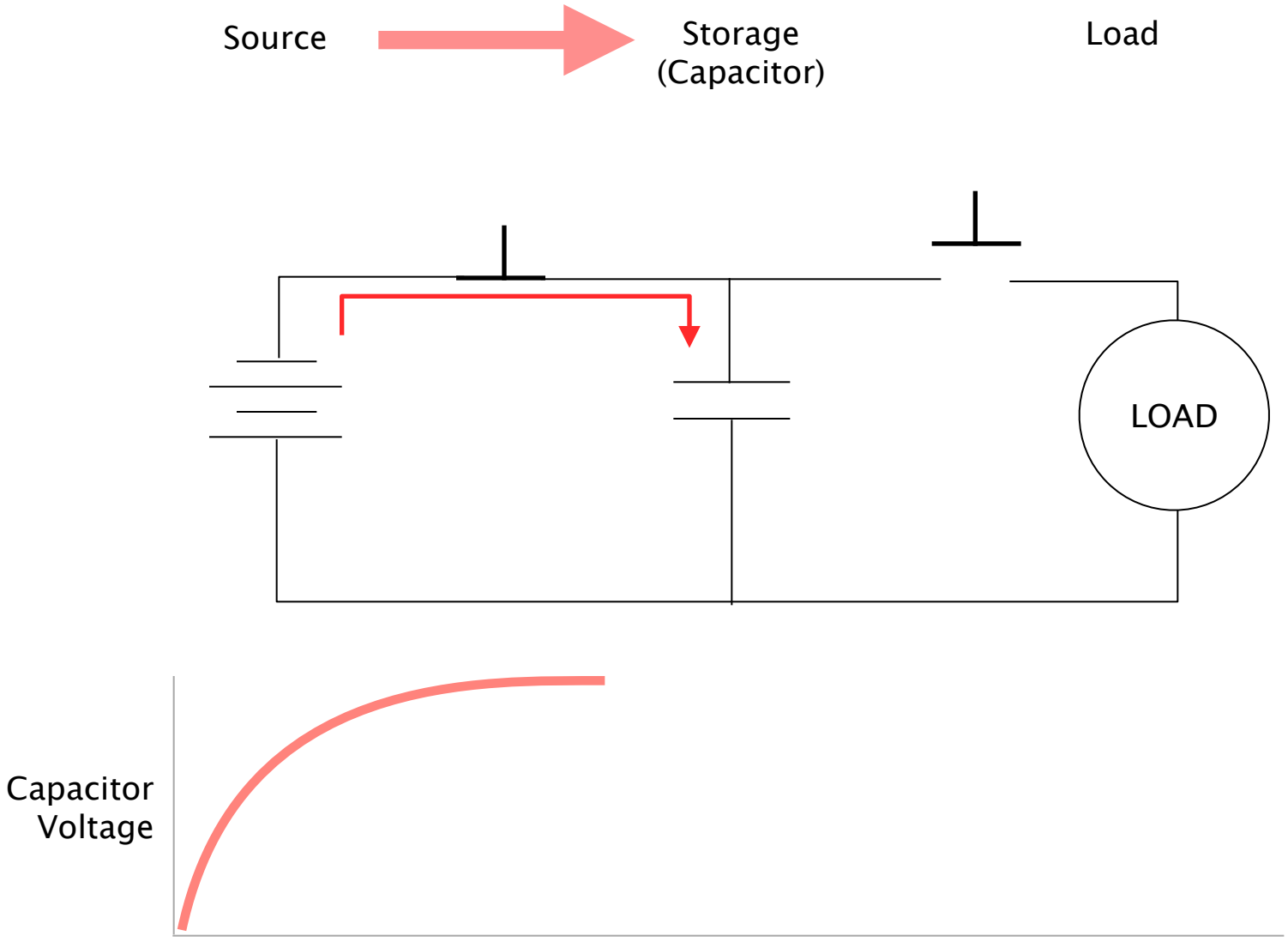
$1/2\ C * V^2$

* Would need 2 2.5V caps in series to get 5V.

Lots of joules


Source
Storage
(Capacitor)
Load
LOAD

Charging

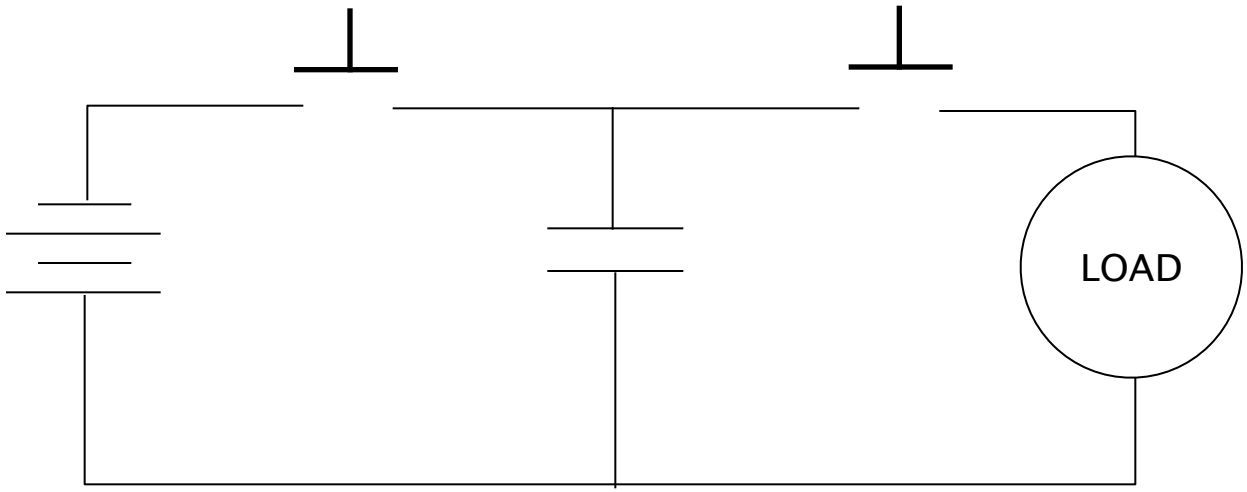


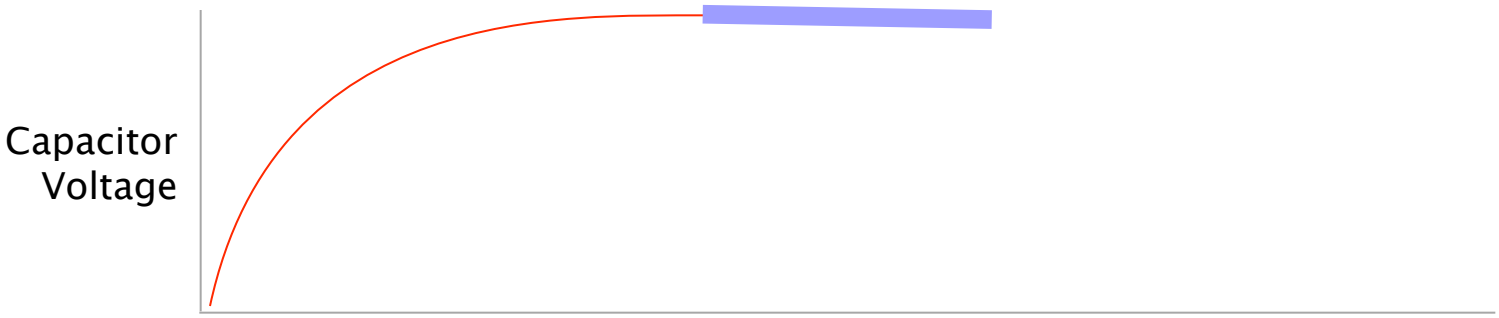
Stasis

Source

Storage
(Capacitor)

Load





Discharge

Source

Storage
(Capacitor)

Load