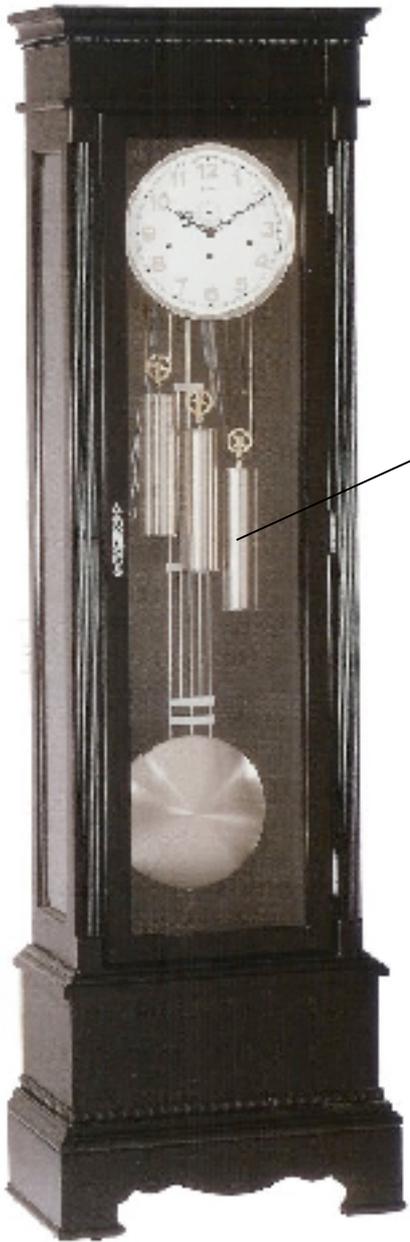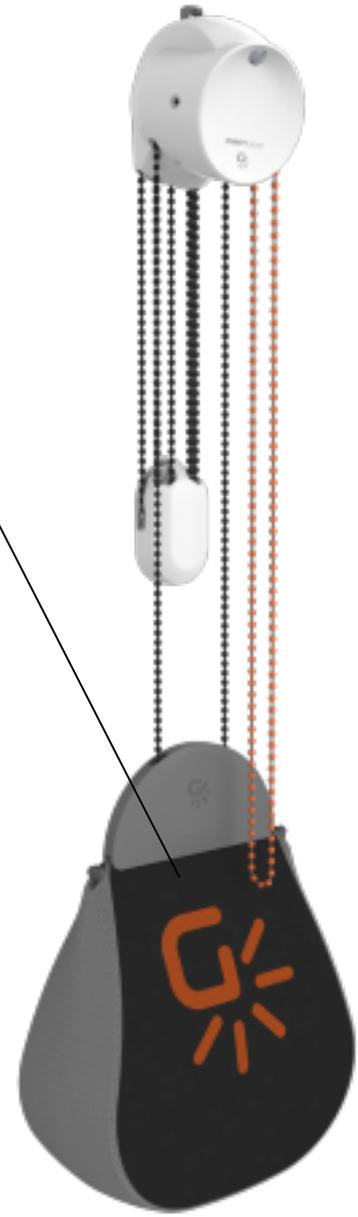energy storage

Energy
NYU / ITP / Feddersen

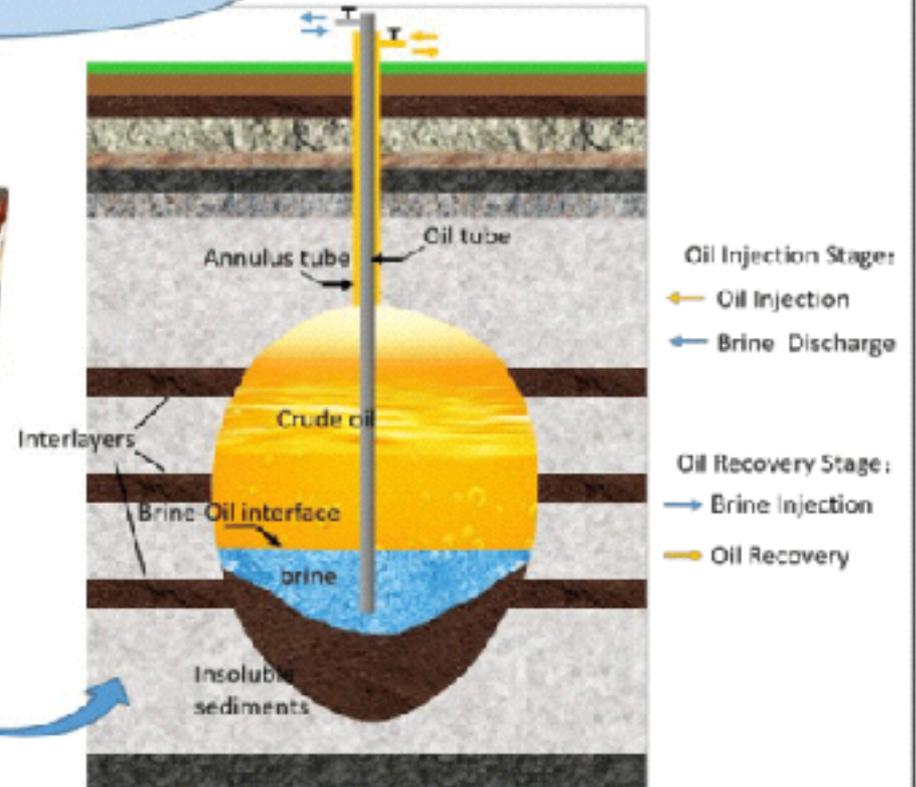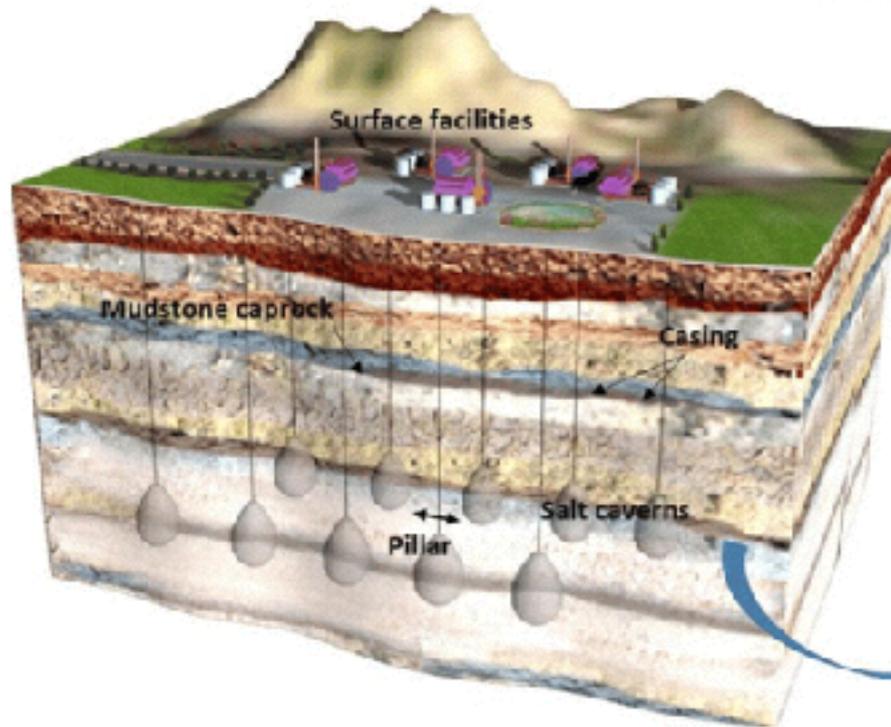Energy can be stored in many forms

Suspended mass
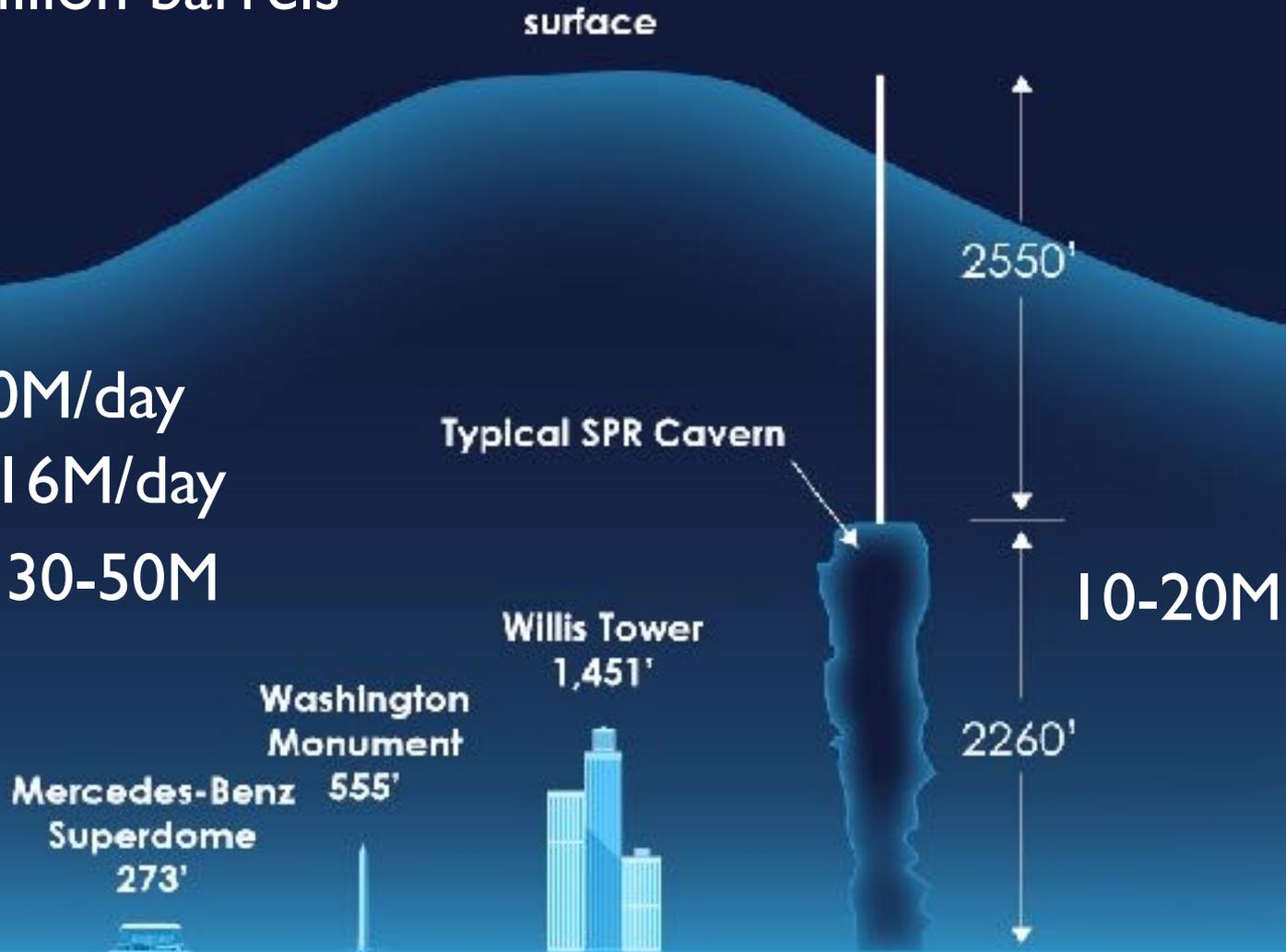
Chemical bonds (in food, firewood, fuel)

Underground Energy Storage

The SPR comprises 60 salt caverns. Each cavern is roughly cylindrical in shape with an average diameter of about 200 feet and a height of 2,550 feet, which is large enough for Chicago's Willis Tower to fit inside with room to spare.

714 million barrels

surface

2550'

US: 20M/day
China: 16M/day
US/Vz: 30-50M

Typical SPR Cavern

10-20M

Willis Tower
1,451'

2260'

Washington
Monument 555'

Mercedes-Benz
Superdome
273'

https://www.curzioresearch.com/wp-content/uploads/2023/04/salt-caverns-of-the-spr.png

Coal storage

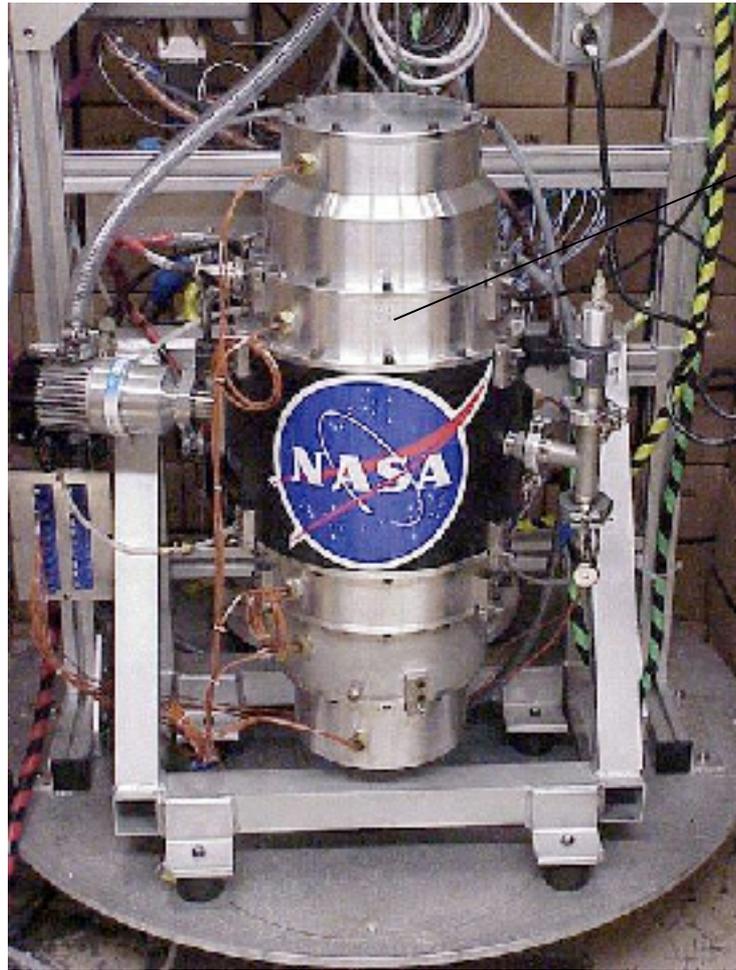This was shuttered in 2017 in Jersey City

660MW

LNG storage

LNG storage

Elastic deformation

Compressed fluid

Rotating mass (flywheel)
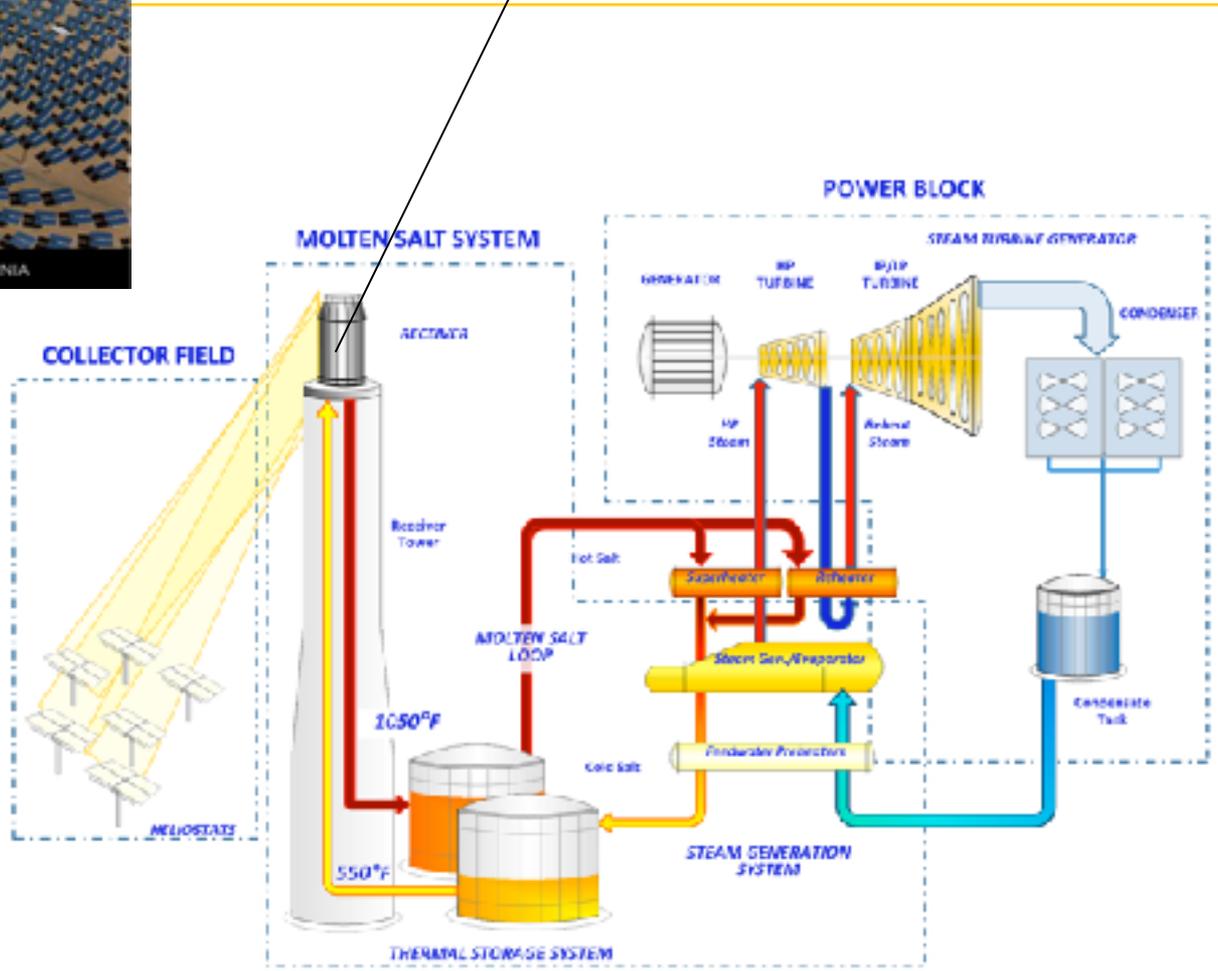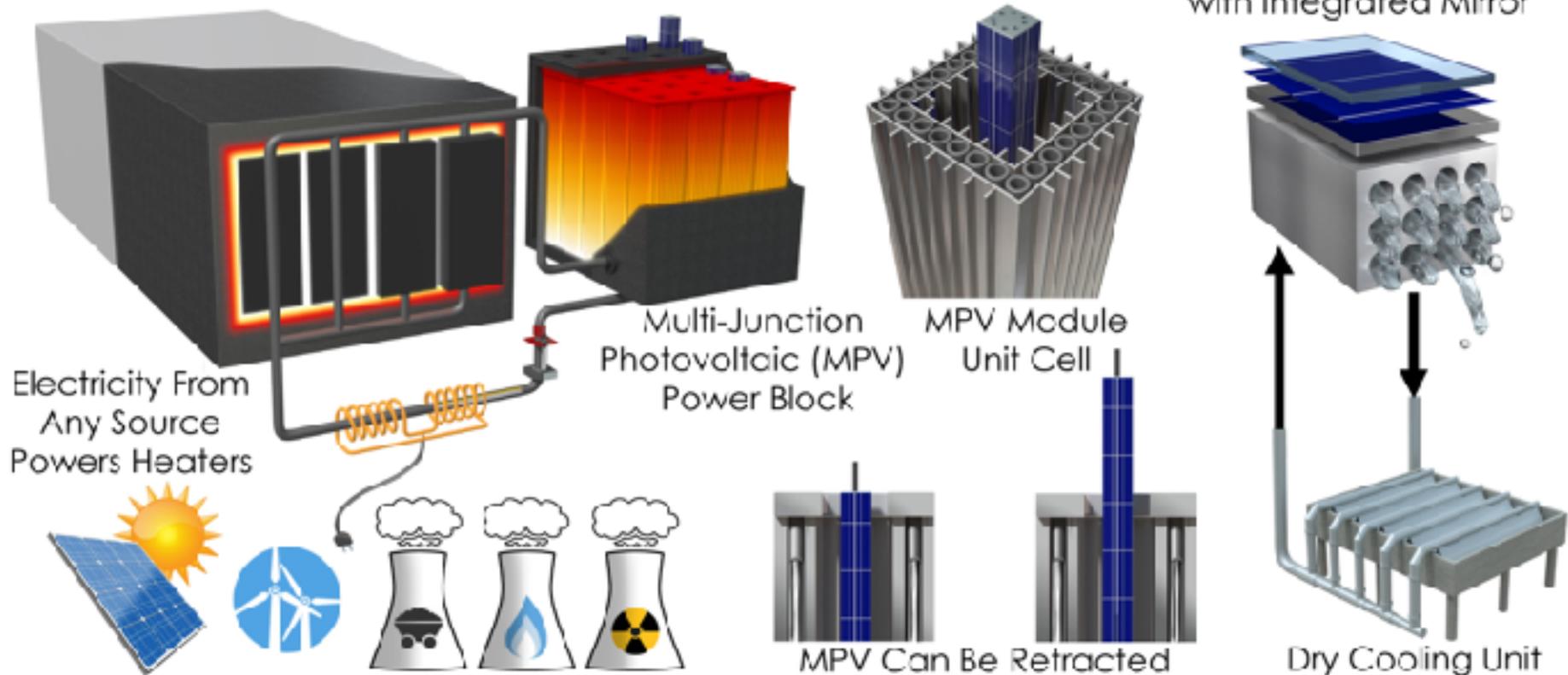
SOLAR TWO - MOJAVE DESERT, CALIFORNIA

Heat

POWER BLOCK

MOLTEN SALT SYSTEM

STEAM TURBINE GENERATOR

GENERATOR

HP TURBINE

IP/LP TURBINE

CONDENSER

COLLECTOR FIELD

RECEIVER

Receiver Tower

HP Steam

Reheat Steam

Hot Salt

Superheater

Reheater

MOLTEN SALT LOOP

Steam Gen./Evaporator

Condensate Tank

1050°F

Cold Salt

Feedwater Preheater

HELIOSTATS

550°F

STEAM GENERATION SYSTEM

THERMAL STORAGE SYSTEM

More Heat

Electricity → Heat → Electricity

Electricity From Any Source Powers Heaters

Multi-Junction Photovoltaic (MPV) Power Block

MPV Module Unit Cell

MPV Can Be Retracted

Water Cooled MPV with Integrated Mirror

Dry Cooling Unit

Electrical potential
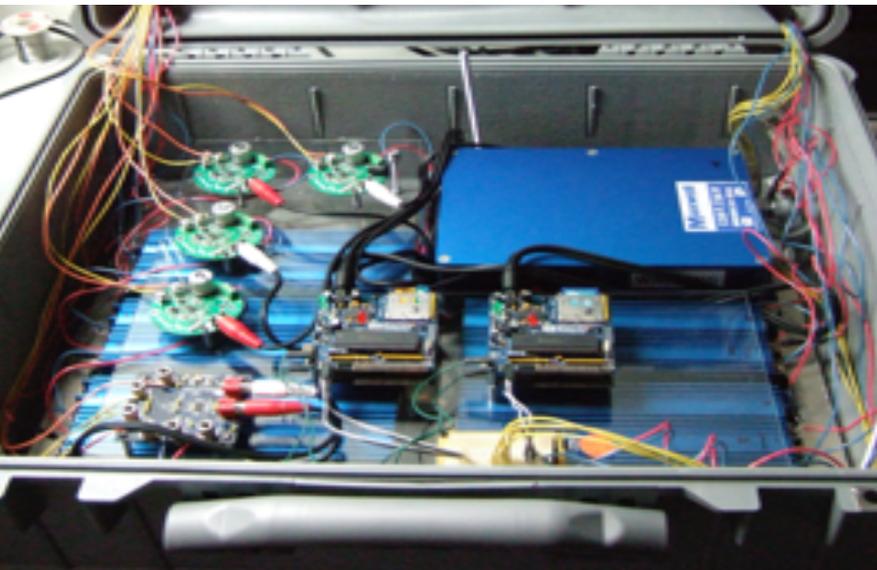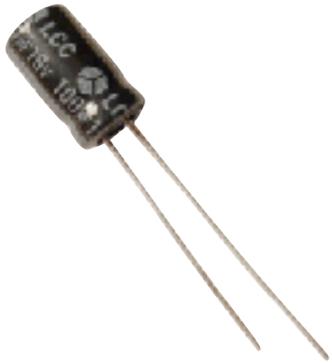
Basic concepts for any energy storage:

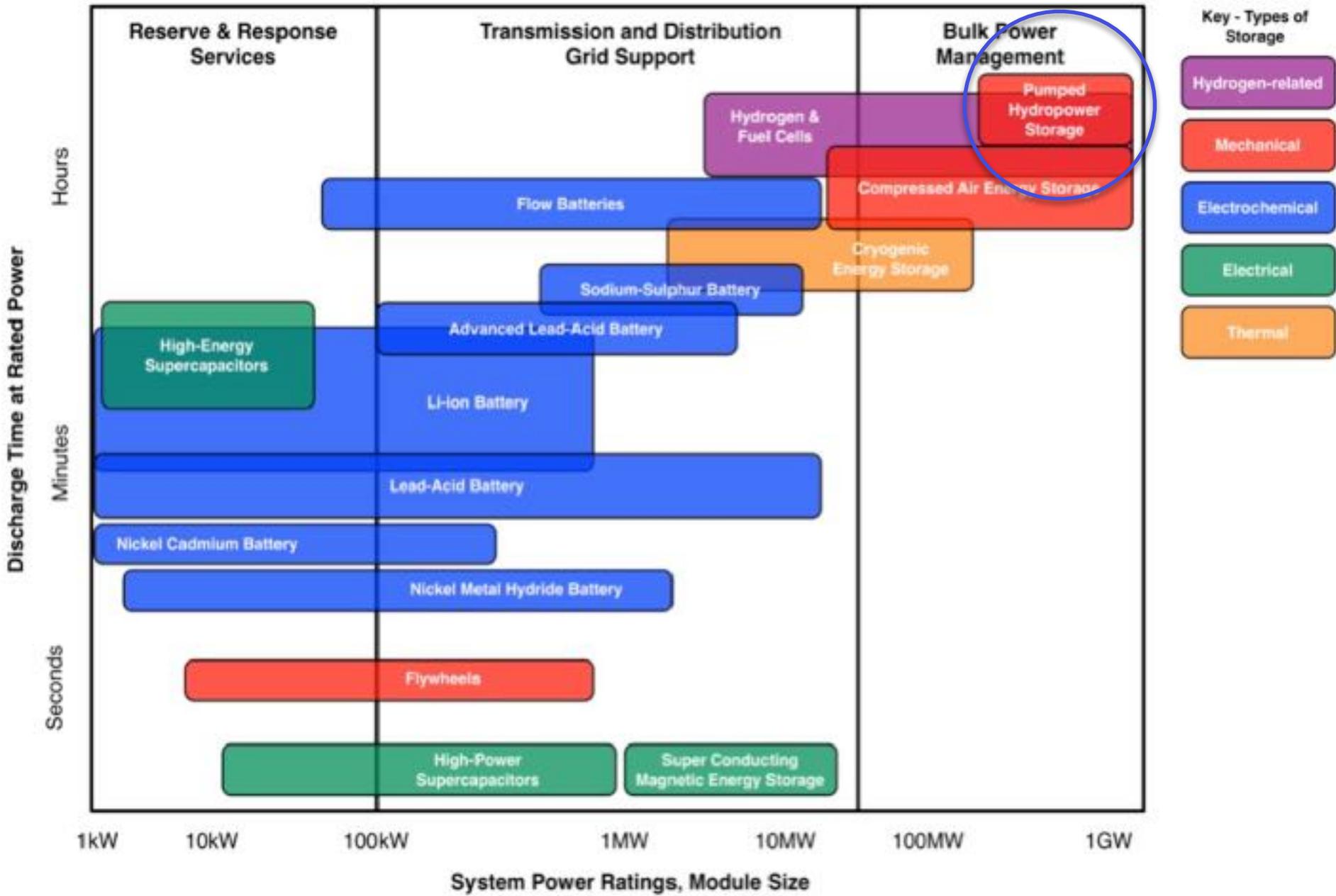**Specific Energy** : energy / mass

Energy Density : energy / volume

Specific Power : power $^{\text{(input or output)}}$ / mass

Power Density : power $^{\text{(input or output)}}$ / volume

Efficiency: energy in / energy out
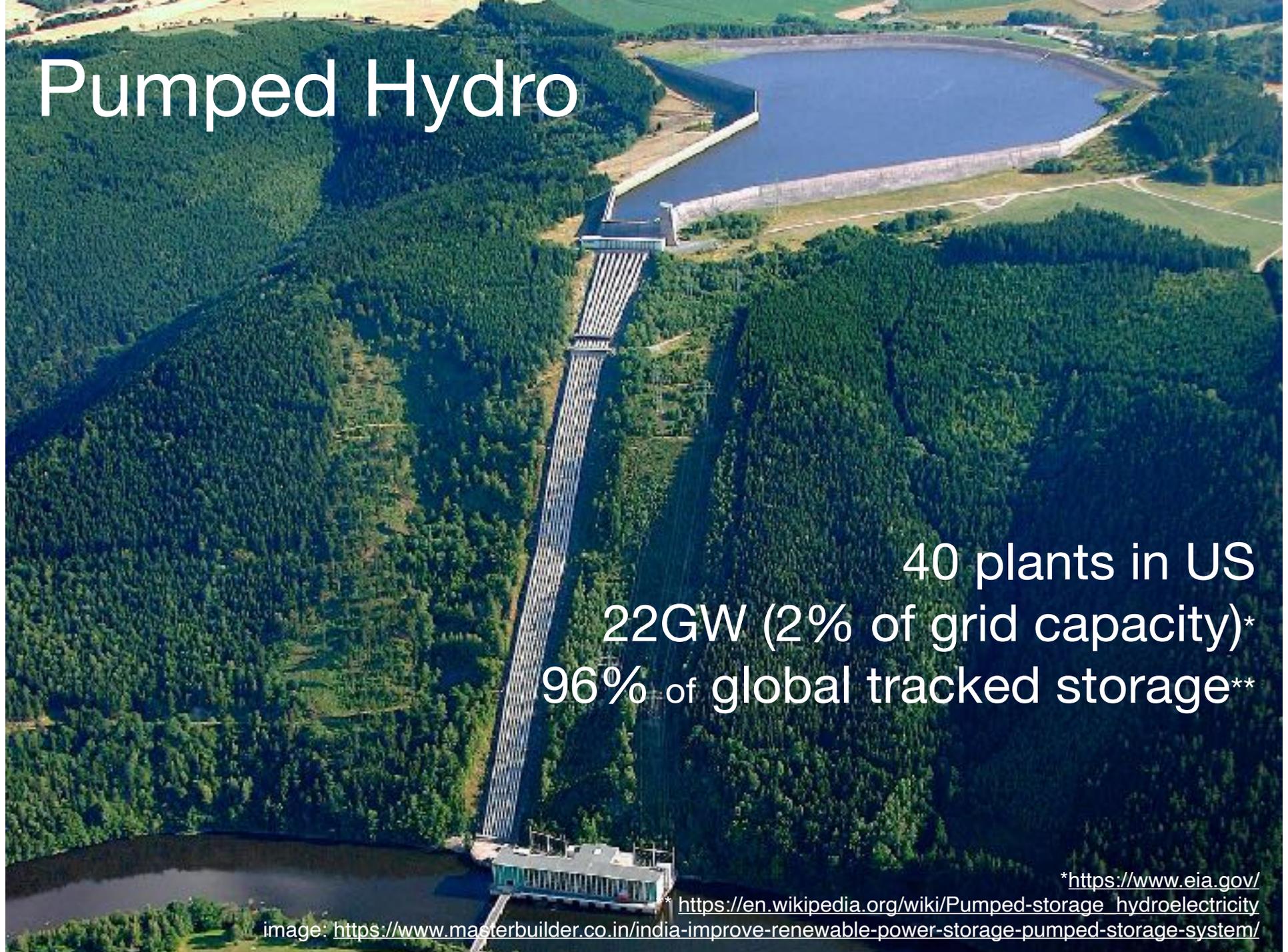
NREL

Chart: Energy Storage Technologies — Discharge Time at Rated Power vs. System Power Ratings, Module Size

Columns (top): Reserve & Response Services | Transmission and Distribution Grid Support | Bulk Power Management

Key - Types of Storage:
- Hydrogen-related
- Mechanical
- Electrochemical
- Electrical
- Thermal

Technologies shown:
- Pumped Hydropower Storage
- Hydrogen & Fuel Cells
- Compressed Air Energy Storage
- Cryogenic Energy Storage
- Flow Batteries
- Sodium-Sulphur Battery
- Advanced Lead-Acid Battery
- High-Energy Supercapacitors
- Li-ion Battery
- Lead-Acid Battery
- Nickel Cadmium Battery
- Nickel Metal Hydride Battery
- Flywheels
- High-Power Supercapacitors
- Super Conducting Magnetic Energy Storage

Y-axis: Discharge Time at Rated Power (Hours, Minutes, Seconds)
X-axis: System Power Ratings, Module Size (1kW, 10kW, 100kW, 1MW, 10MW, 100MW, 1GW)

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

Pumped Hydro

40 plants in US
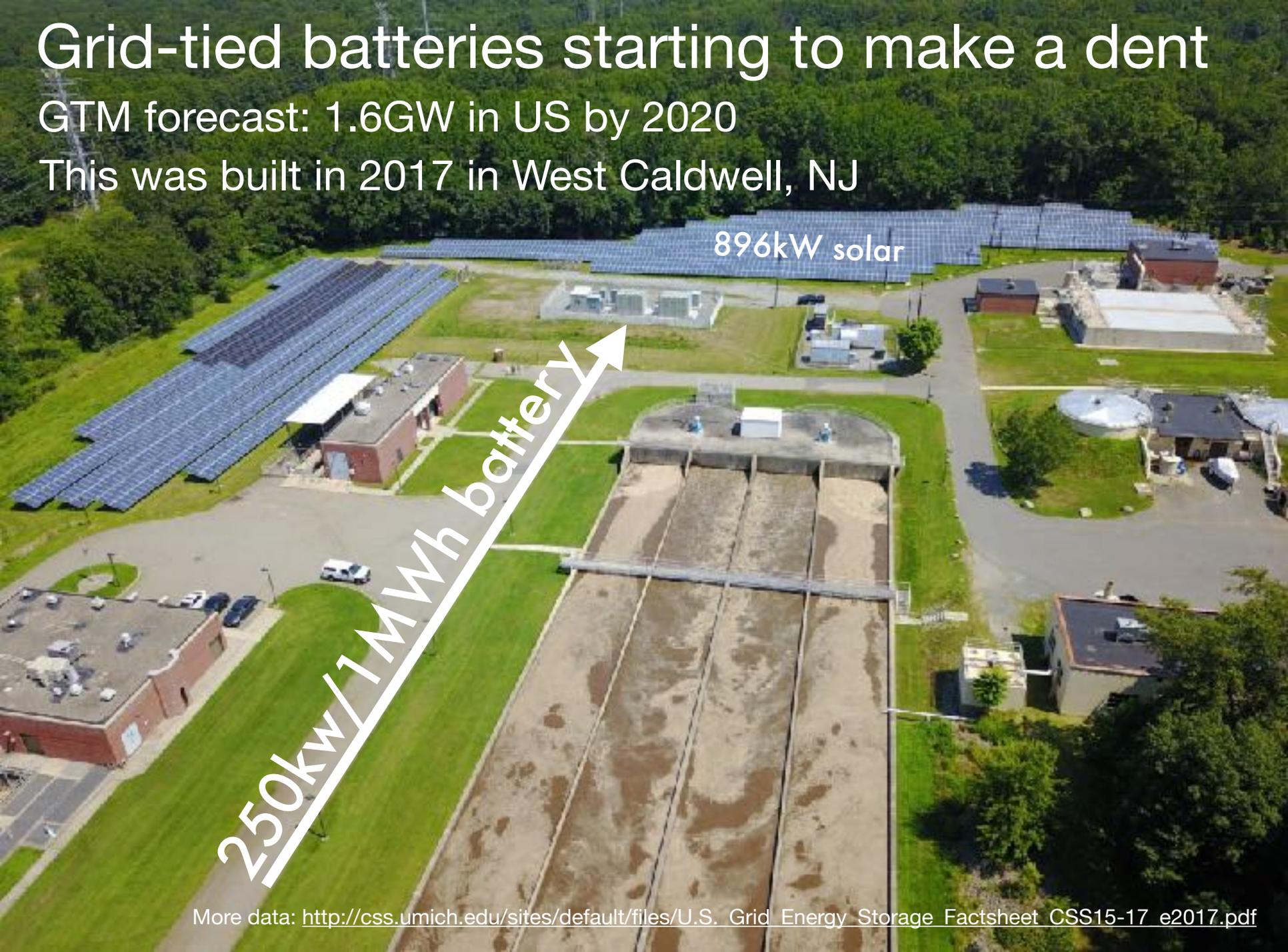22GW (2% of grid capacity)*
96% of global tracked storage**

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

896kW solar

250kw/1MWh battery

DOE Storage Database
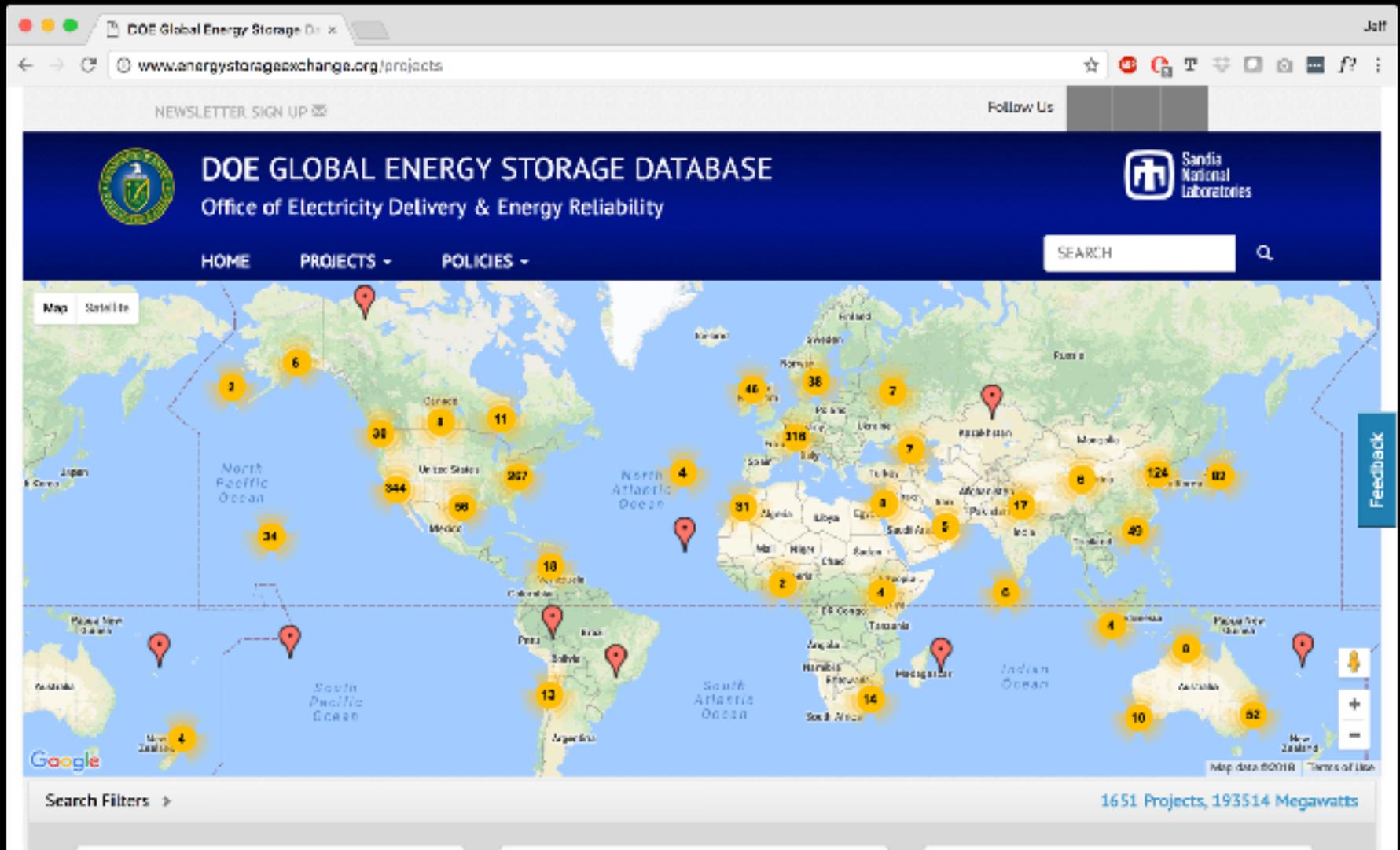
https://www.energystorageexchange.org/projects/data_visualization/

A sustainable system by definition uses energy at or below the rate it is generally available from the environment.
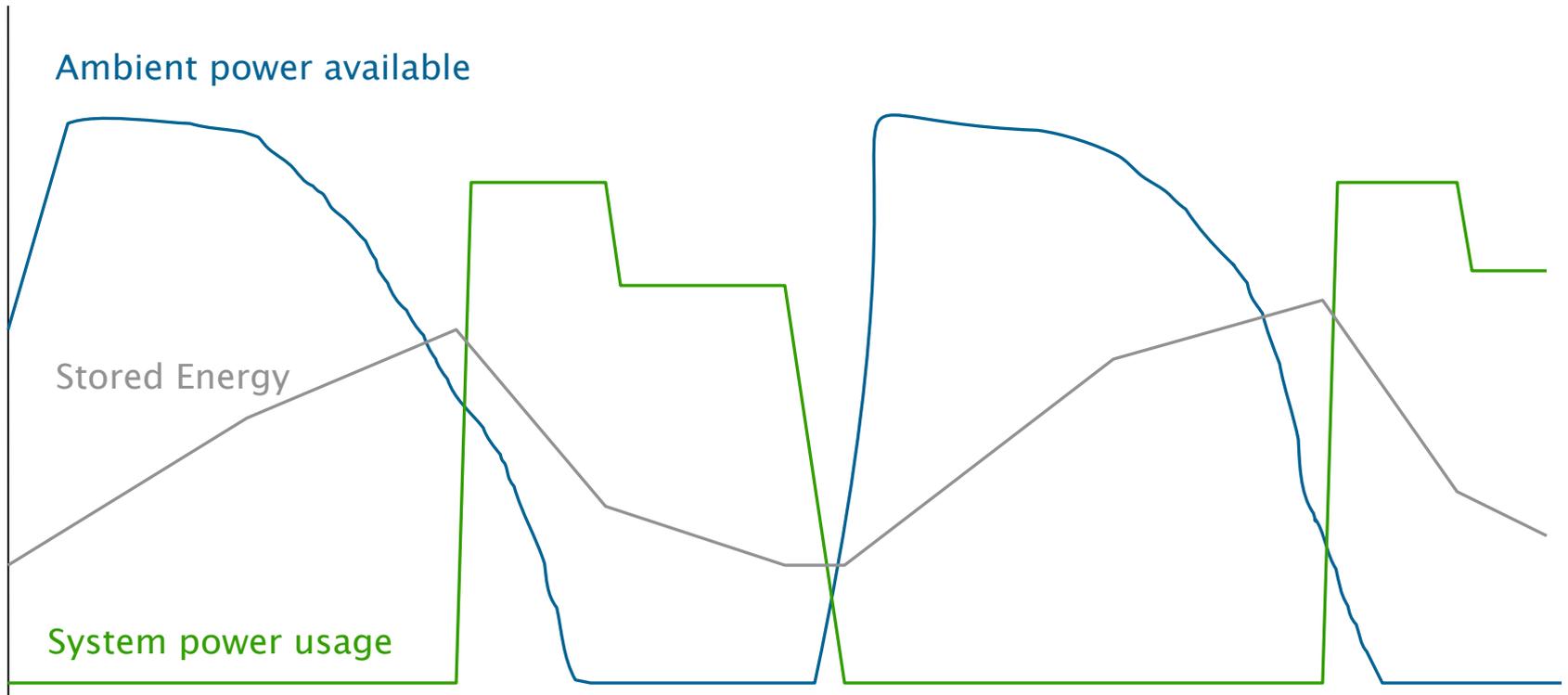
However, it may be necessary for a system to:

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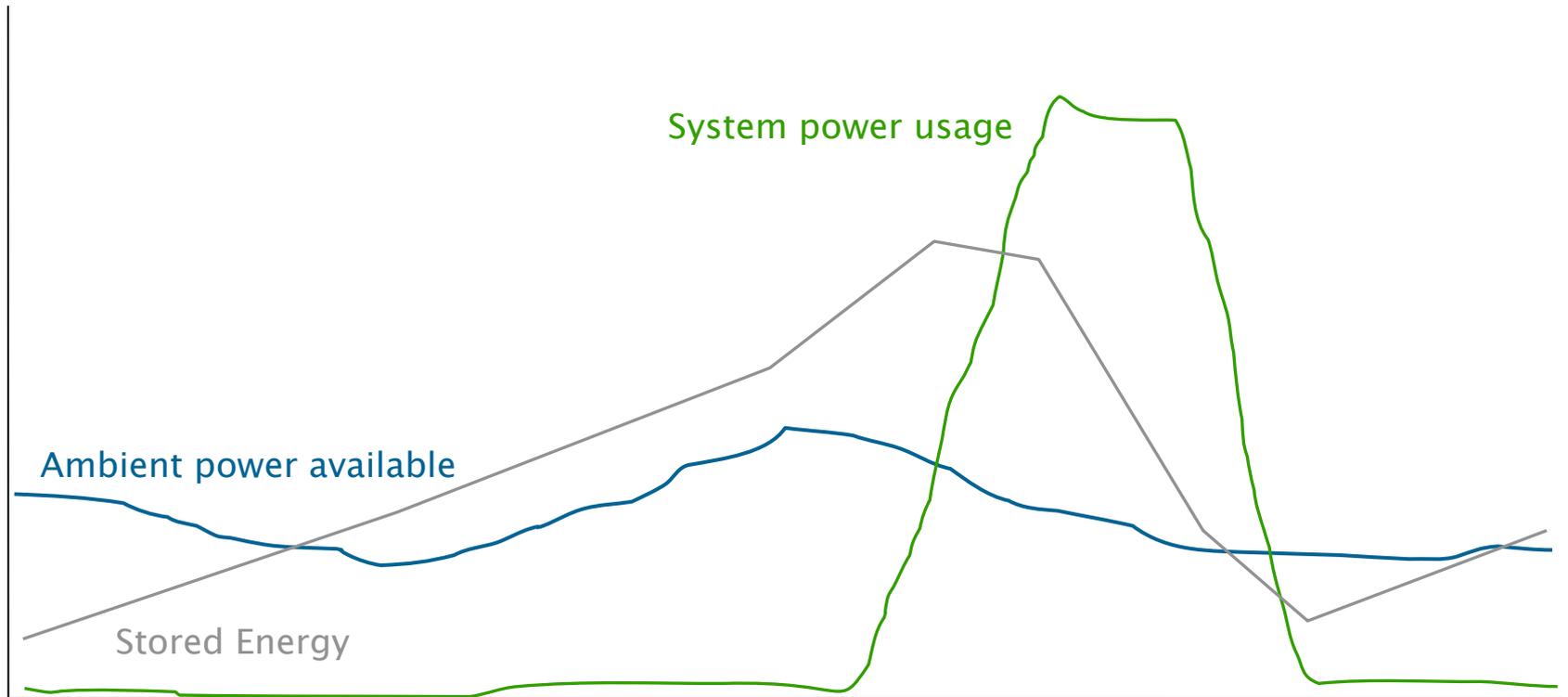- and/or handle momentary **power interruptions**

In these cases, **energy storage** will be necessary.
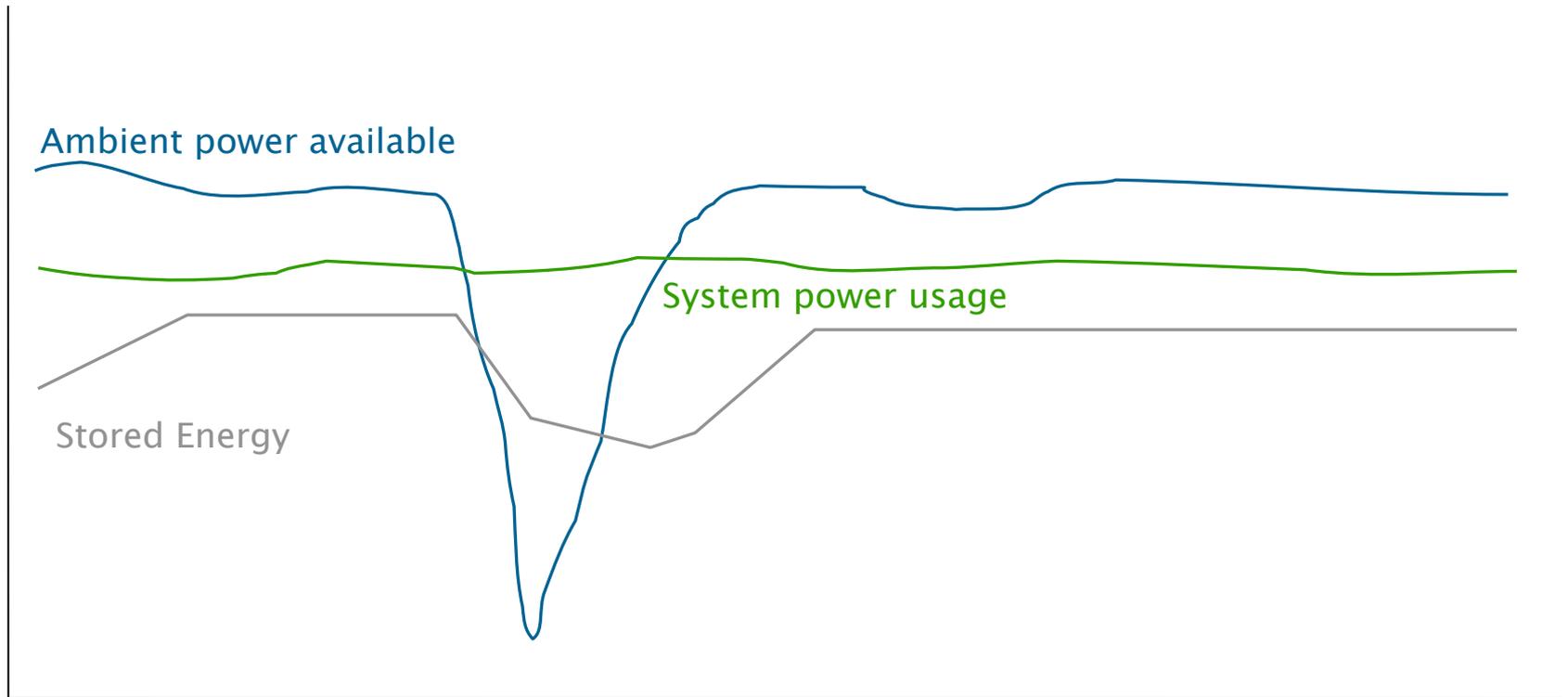
Time shift
Energy usage is out of phase with ambient availability:

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

System power usage

Ambient power available

Stored Energy

System must handle power fluctuations:

Smoothing

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

Energy in a capacitor is:

$$\frac{1}{2} C * V^2$$

.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.

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

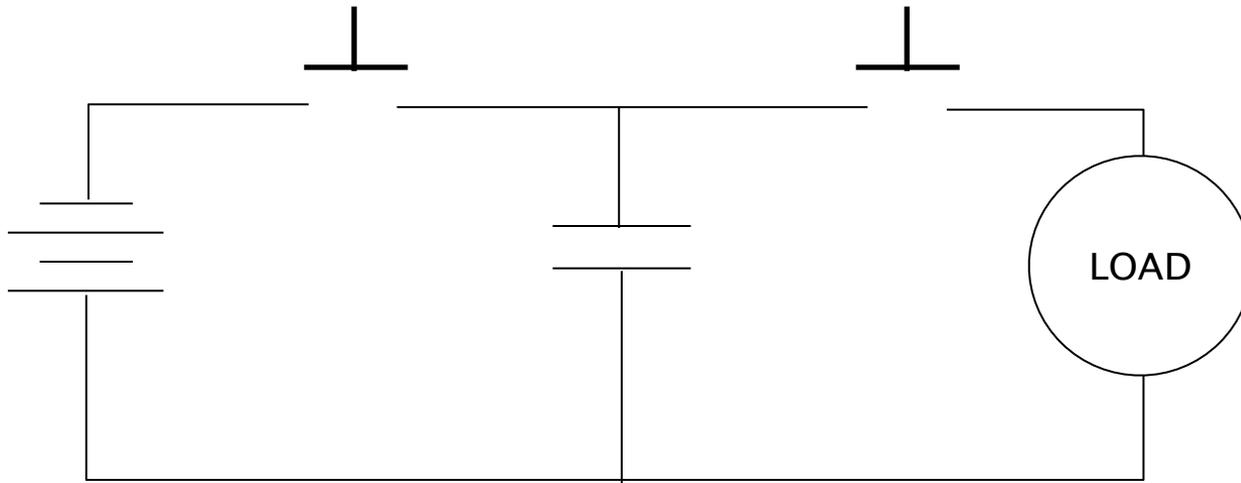Lots of joules

Source

Storage
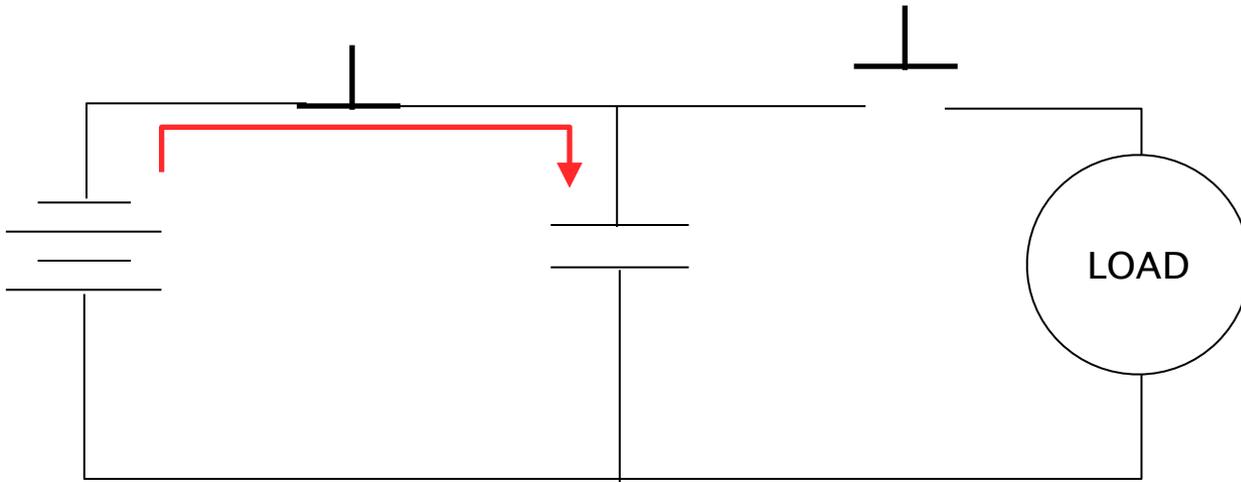(Capacitor)

Load

LOAD

Charging

Source → Storage
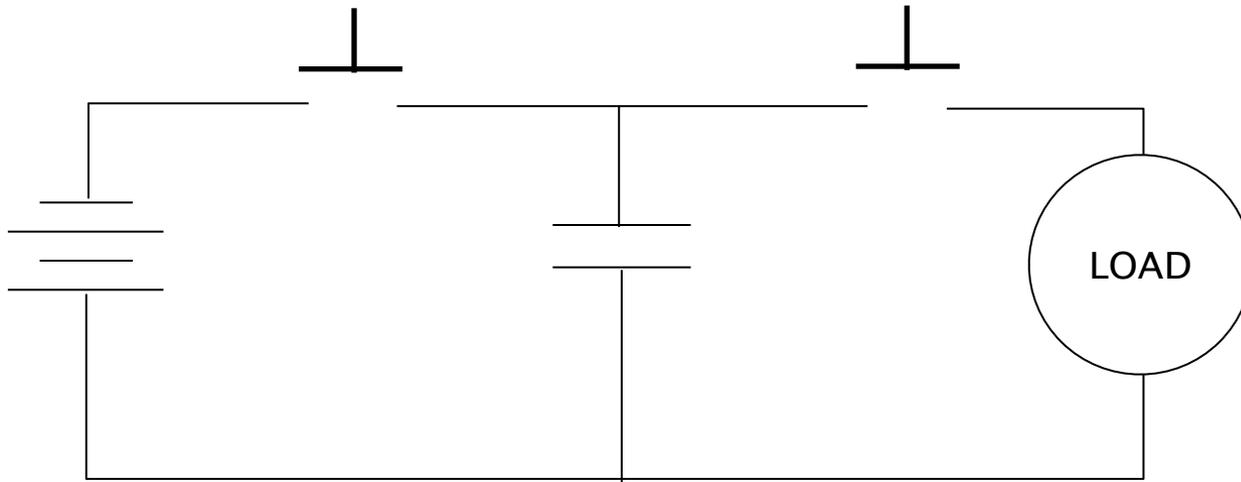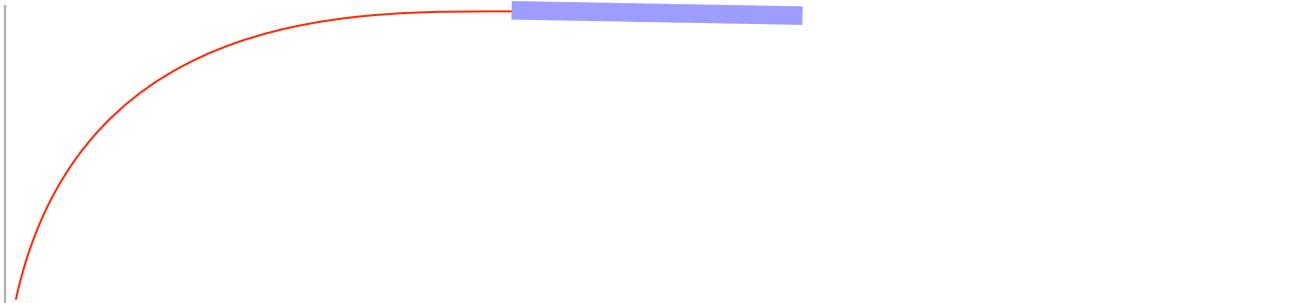(Capacitor)

Load

LOAD

Capacitor
Voltage

Stasis

Source

Storage
(Capacitor)

Load

LOAD

Capacitor
Voltage

Discharge

Source

Storage
(Capacitor)

Load

LOAD

Capacitor
Voltage