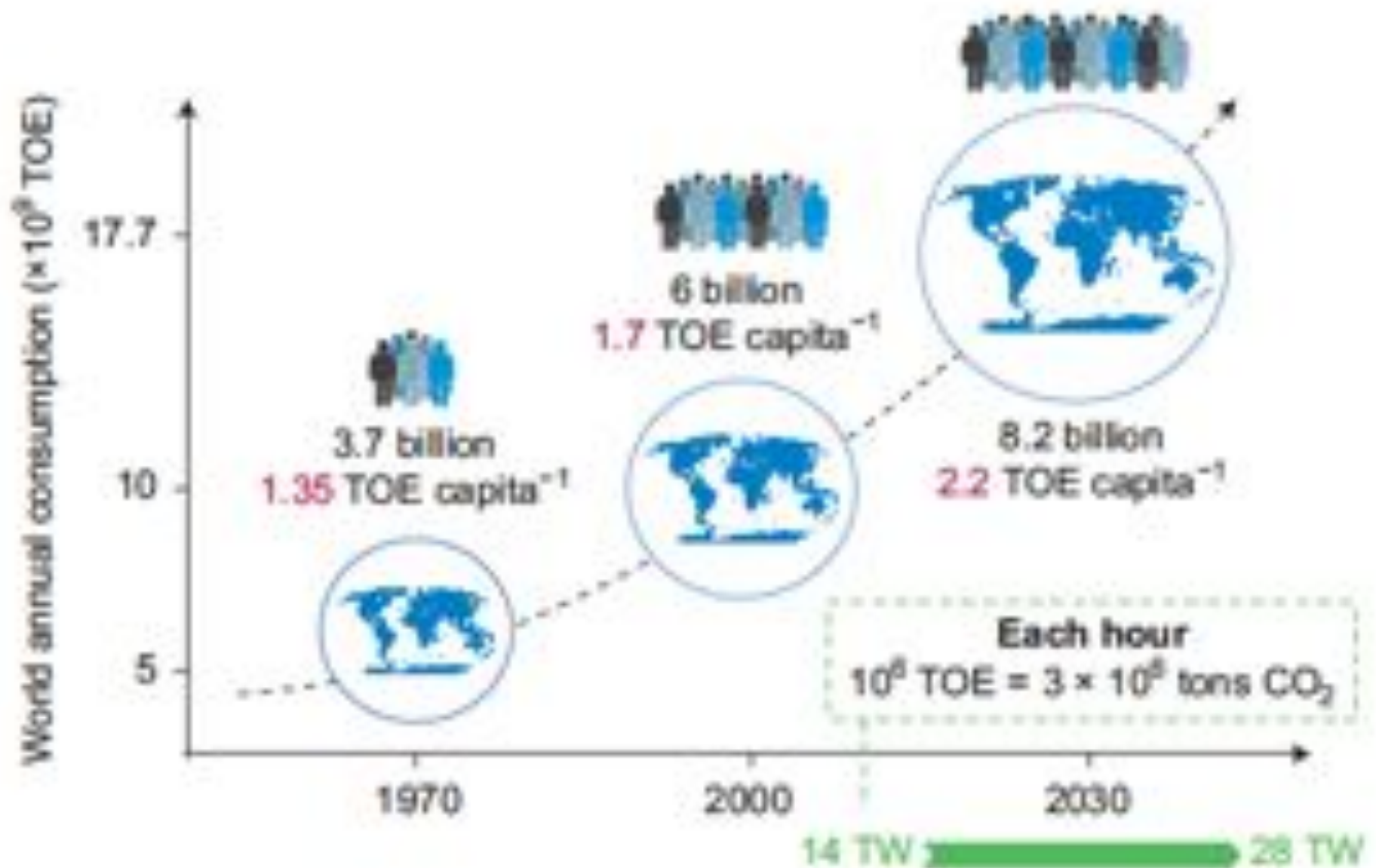


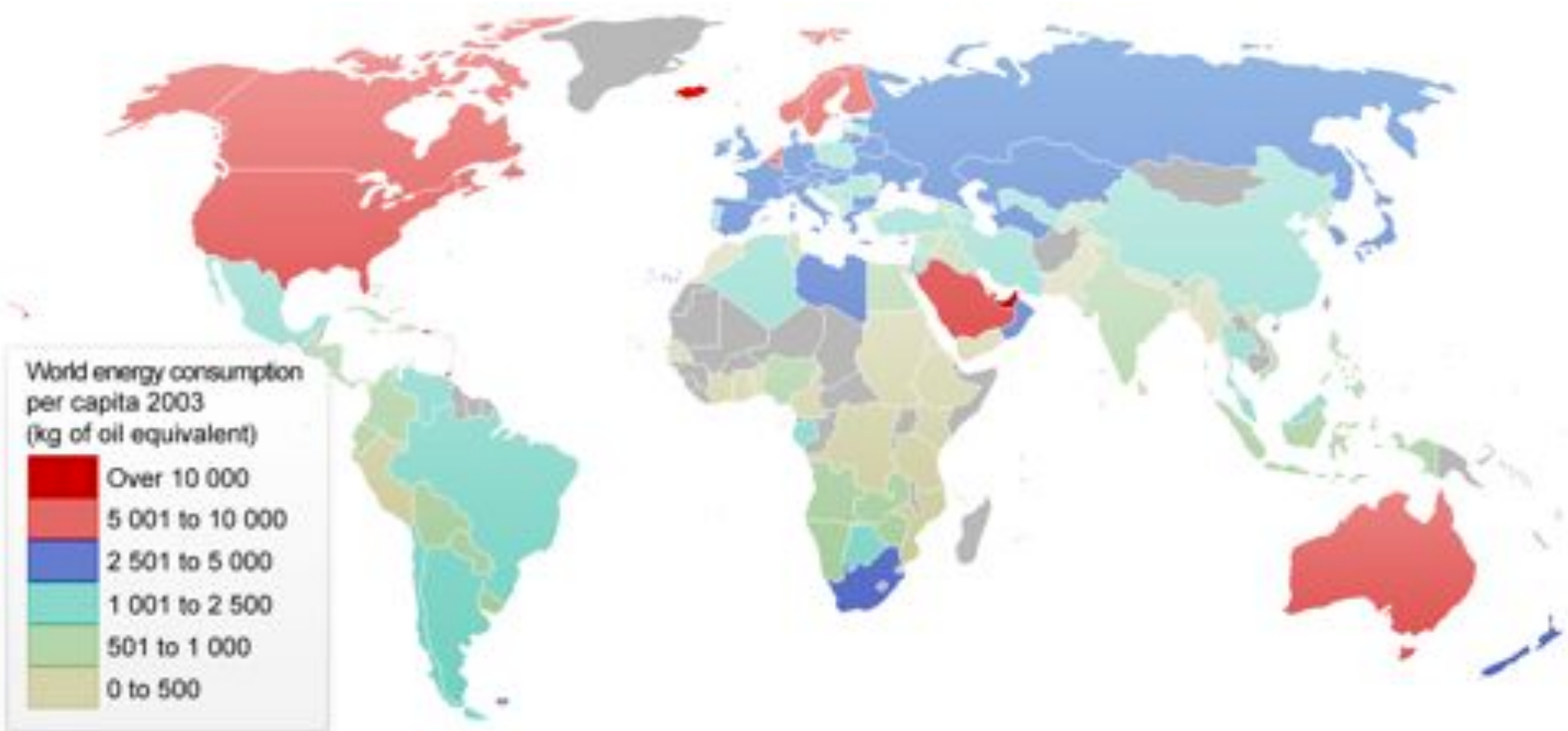
Energy Storage for 21st Century



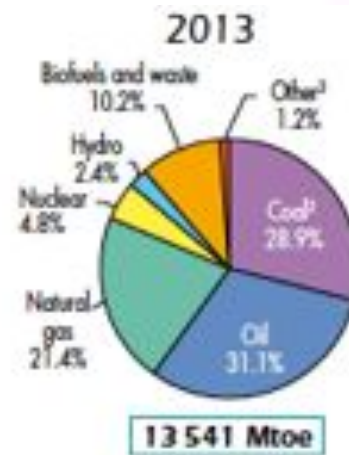
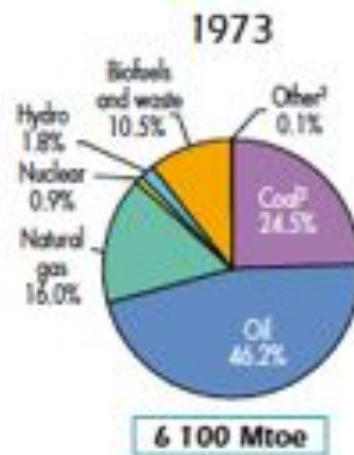
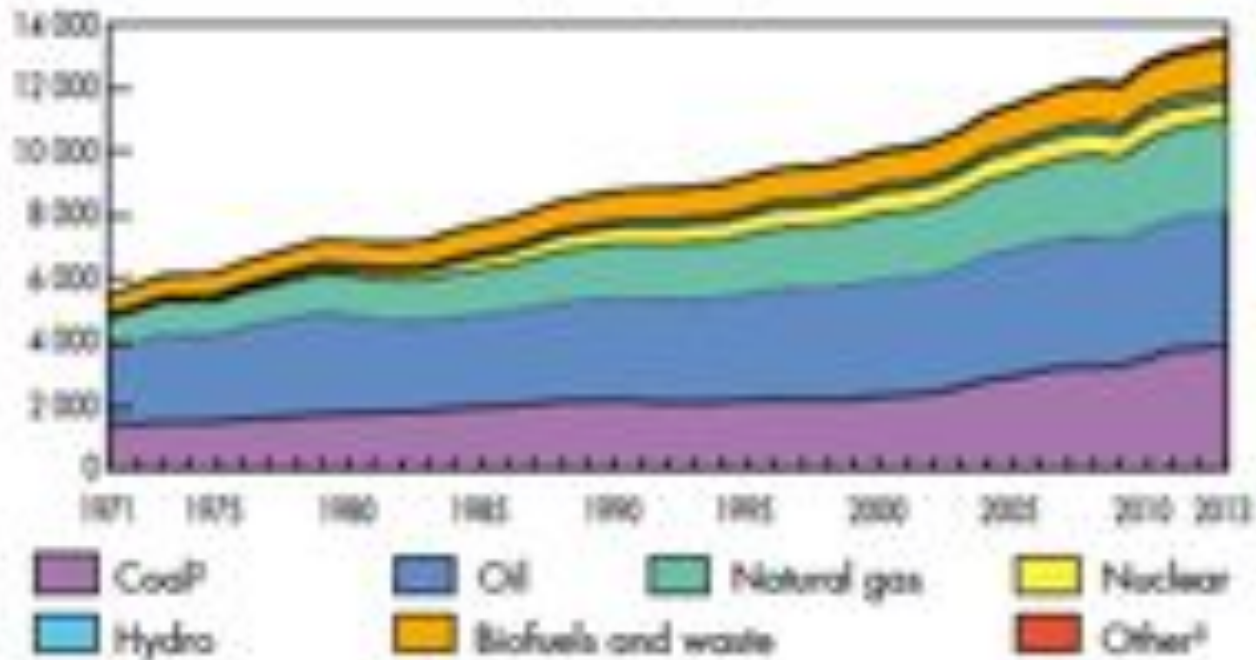
Dr. Xiulei (David) Ji
Assistant Professor of Chemistry
Oregon State University

Energy Use to Be Doubled by 2050





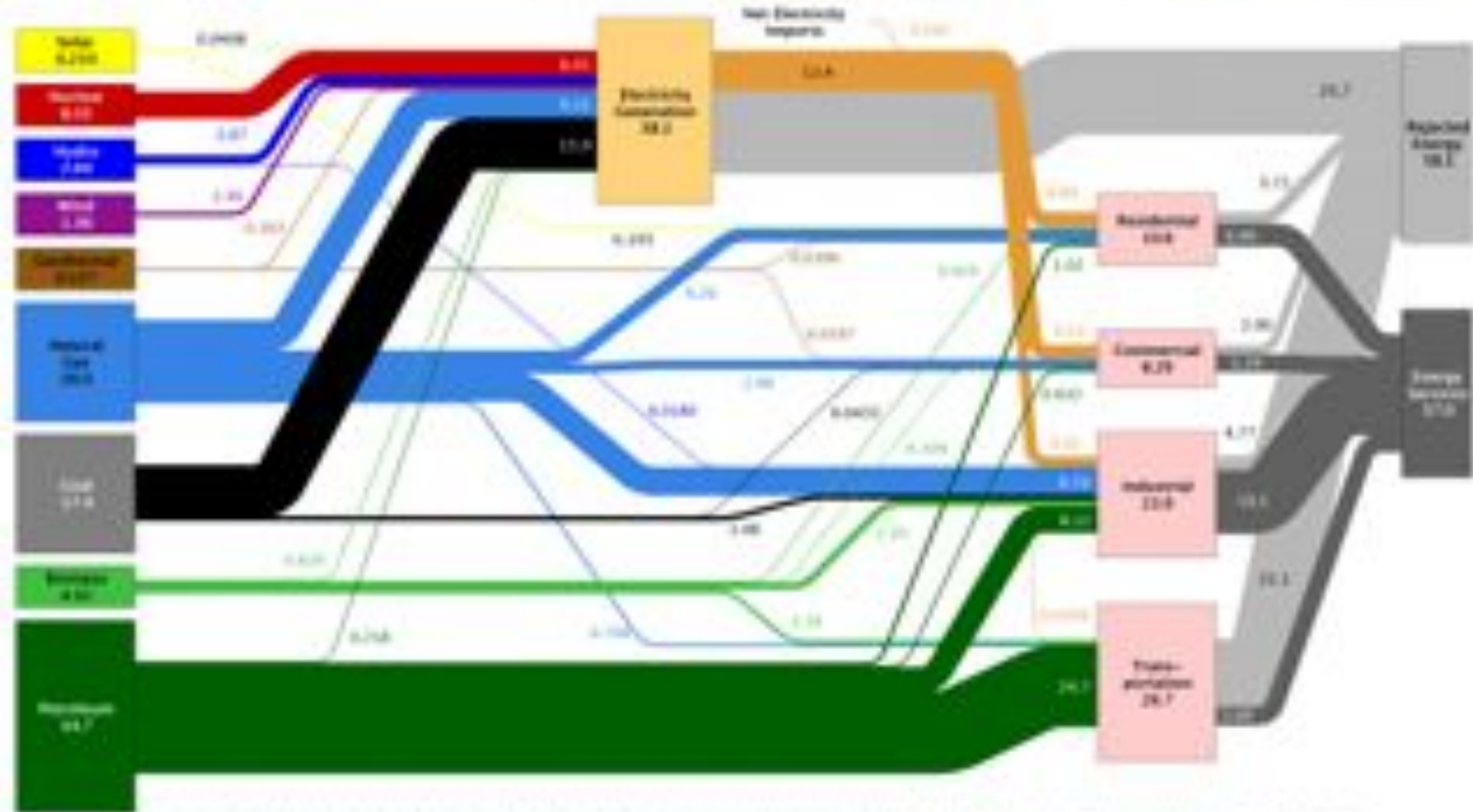
World¹ total primary energy supply (TPES) from 1971 to 2013
by fuel (Mtoe)



61% of Total Energy Wasted

Estimated U.S. Energy Use in 2012: ~95.1 Quads

Lawrence Livermore
National Laboratory

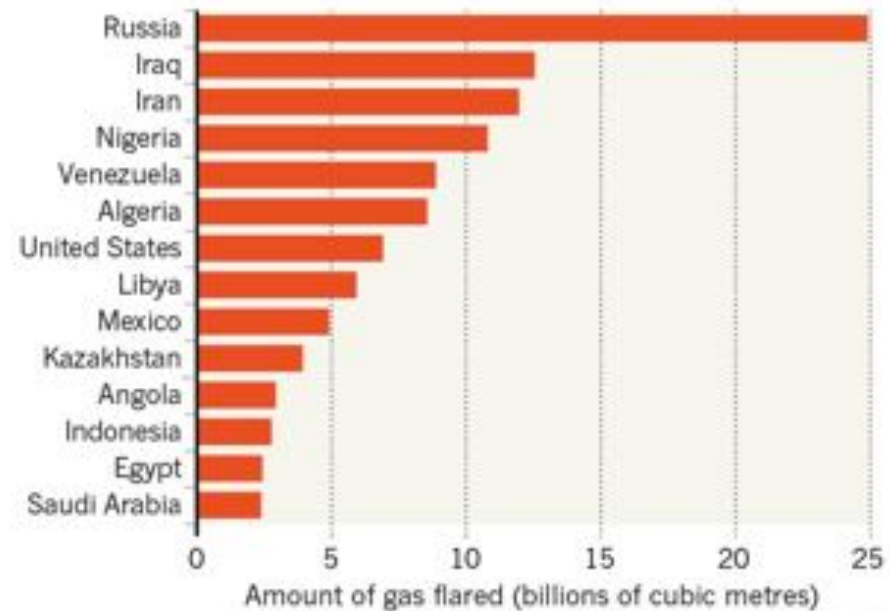


'Flaring' wastes 3.5% of world's natural gas



TOP NATURAL-GAS-FLARING NATIONS

More than 143 billion cubic metres of natural gas was wastefully burned in 2012, around 3.5% of the world's supply.



©nature



Topaz Solar Farm, 9 million solar panels that cover the impressive 9.5 square miles in San Luis Obispo County, California. 500+ MW for 160,000 homes



<http://learnfiberoptic.com/wp-content/uploads/2013/11/wind-energy.jpg>



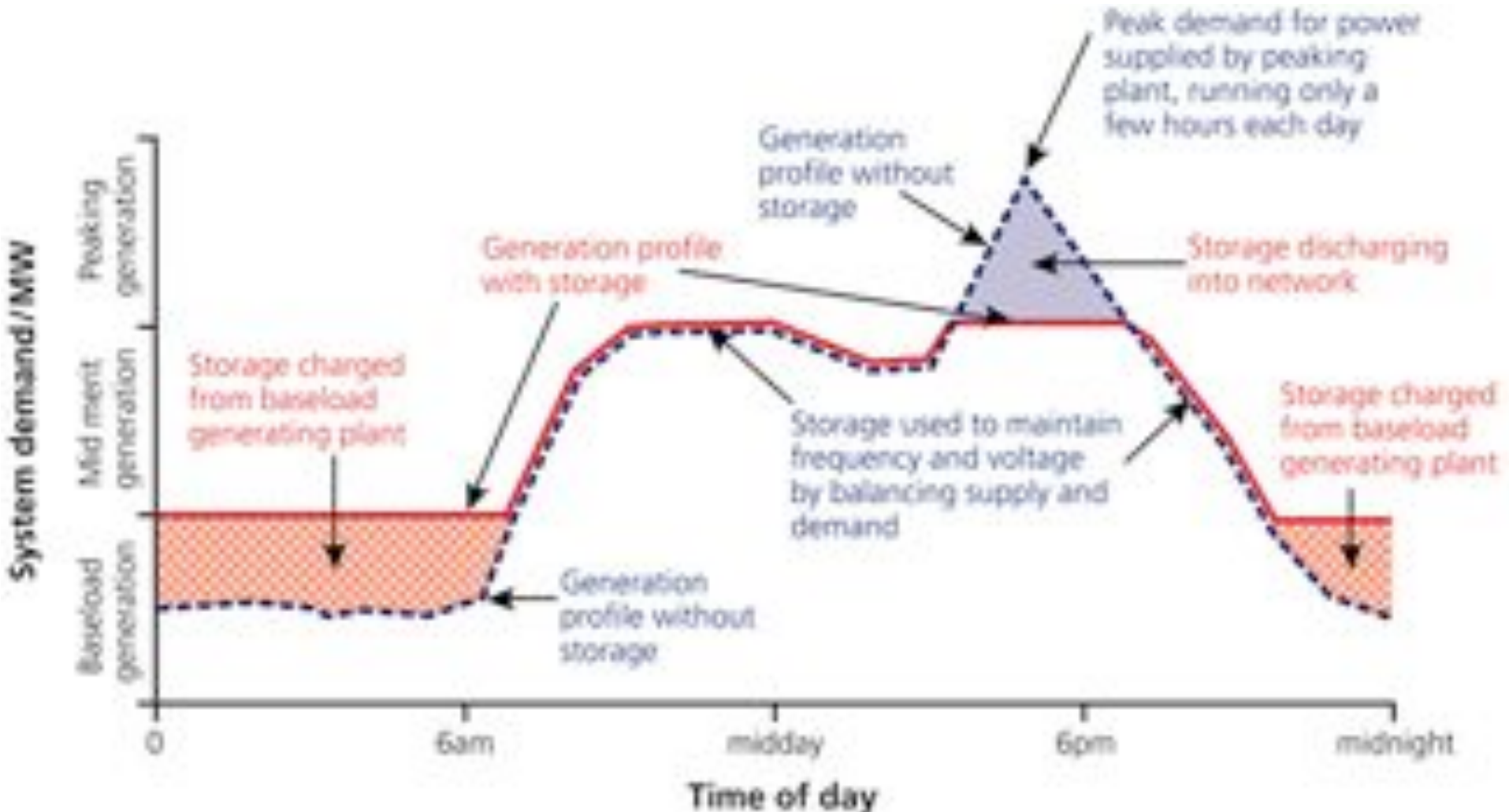
003/45/1844



<http://www.toptenz.net/wp-content/uploads/2014/07/blackout9.png>

ISAT GeoStar 45
23:15 EST 14 Aug. 2003

The Concept of Load Leveling





It is also about strategic security

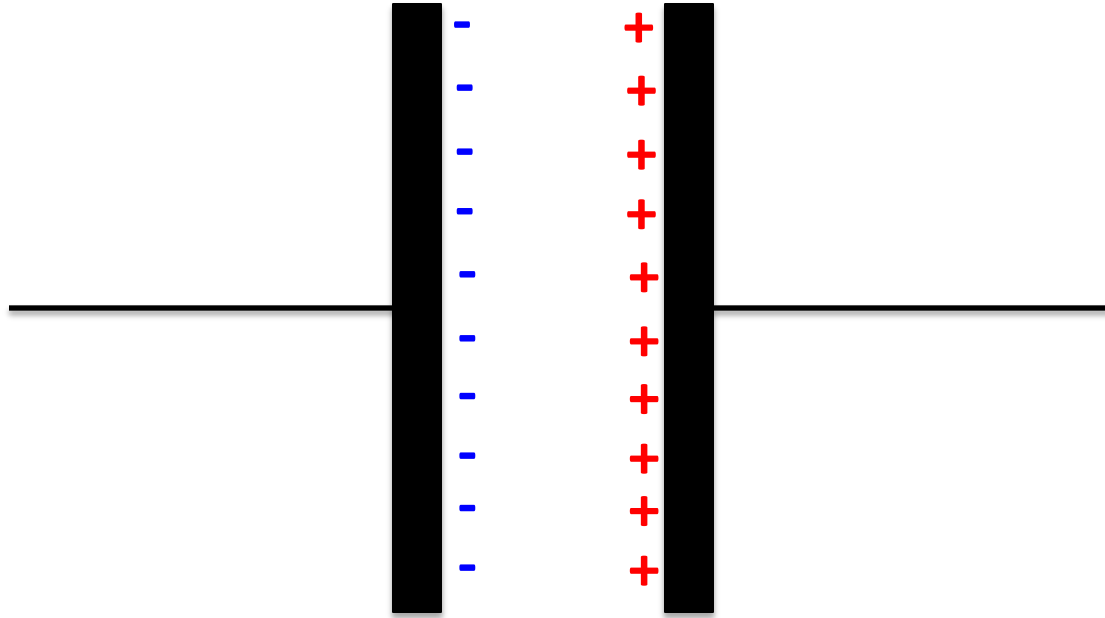
<http://www.solarquotes.com.au/blog/focus-solar-microgrids-fossil-fuel-wavers/>



Rows of battery racks at the
[Salem Smart Power Center](#) in Salem, Oregon

Strategies to Store Energy for Electricity

Direct Storage



$$C \propto A/d$$

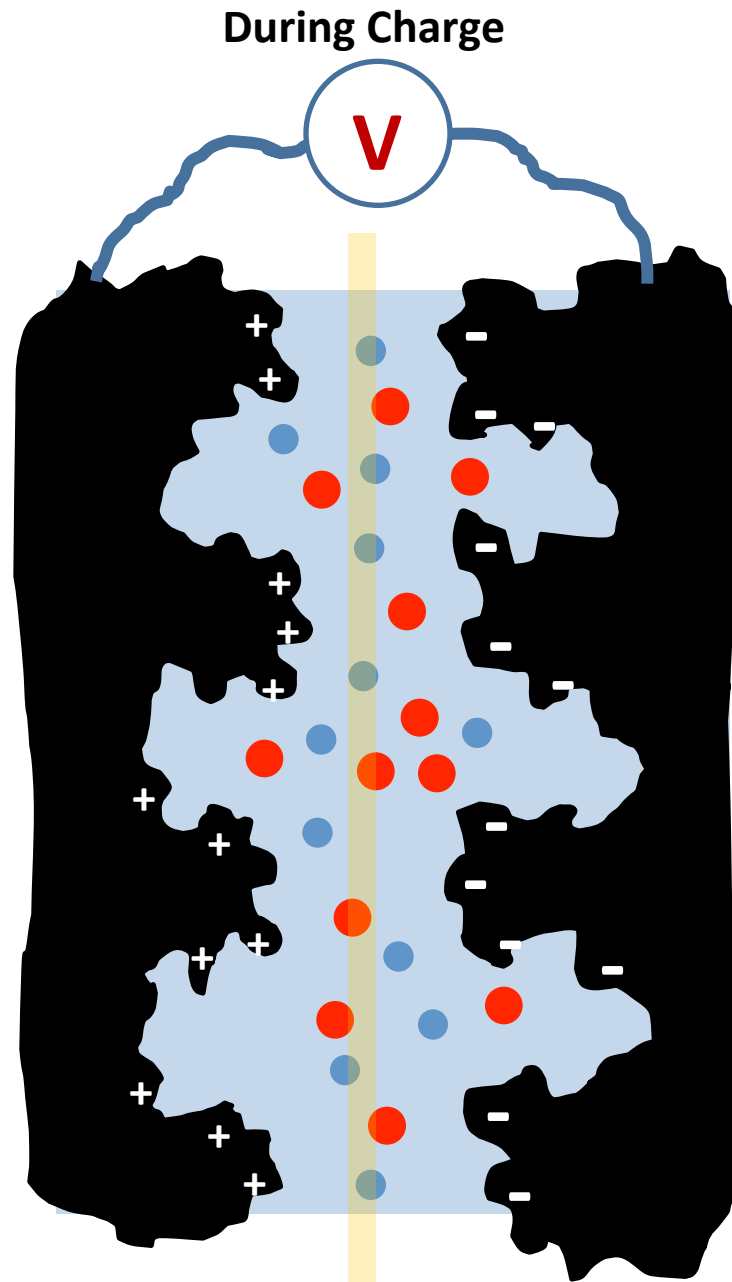


Independently invented by a German
Ewald Georg von Kleist on 11 October
1745 and
by a Dutch scientist Pieter van
Musschenbroek
of Leiden (Leyden) in 1745–1746

A battery of four water-filled Leyden jars,
Museum Boerhaave, Leiden



Electrochemical Capacitors



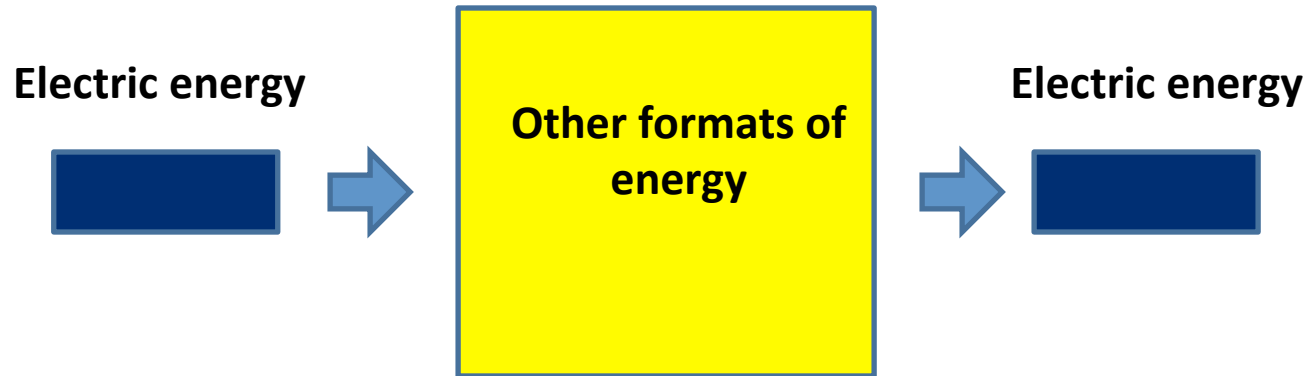
$$C \propto A/d$$

High Power, Low Energy Density



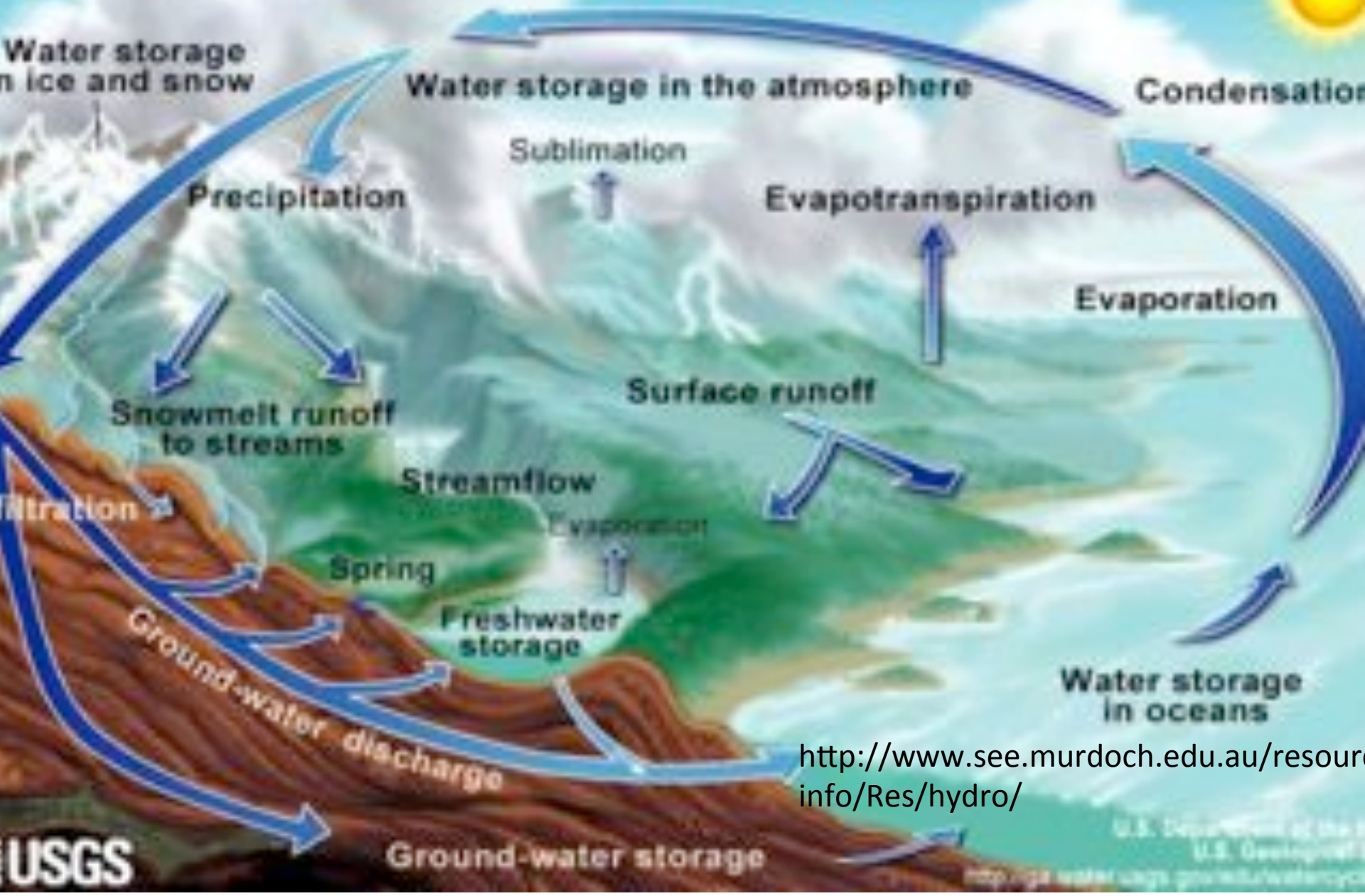
Miller, *Science* **321**, 651 (2008)

Indirect Storage



- Potential energy
- Kinetic energy
- Thermal energy
- Chemical energy

The Water Cycle

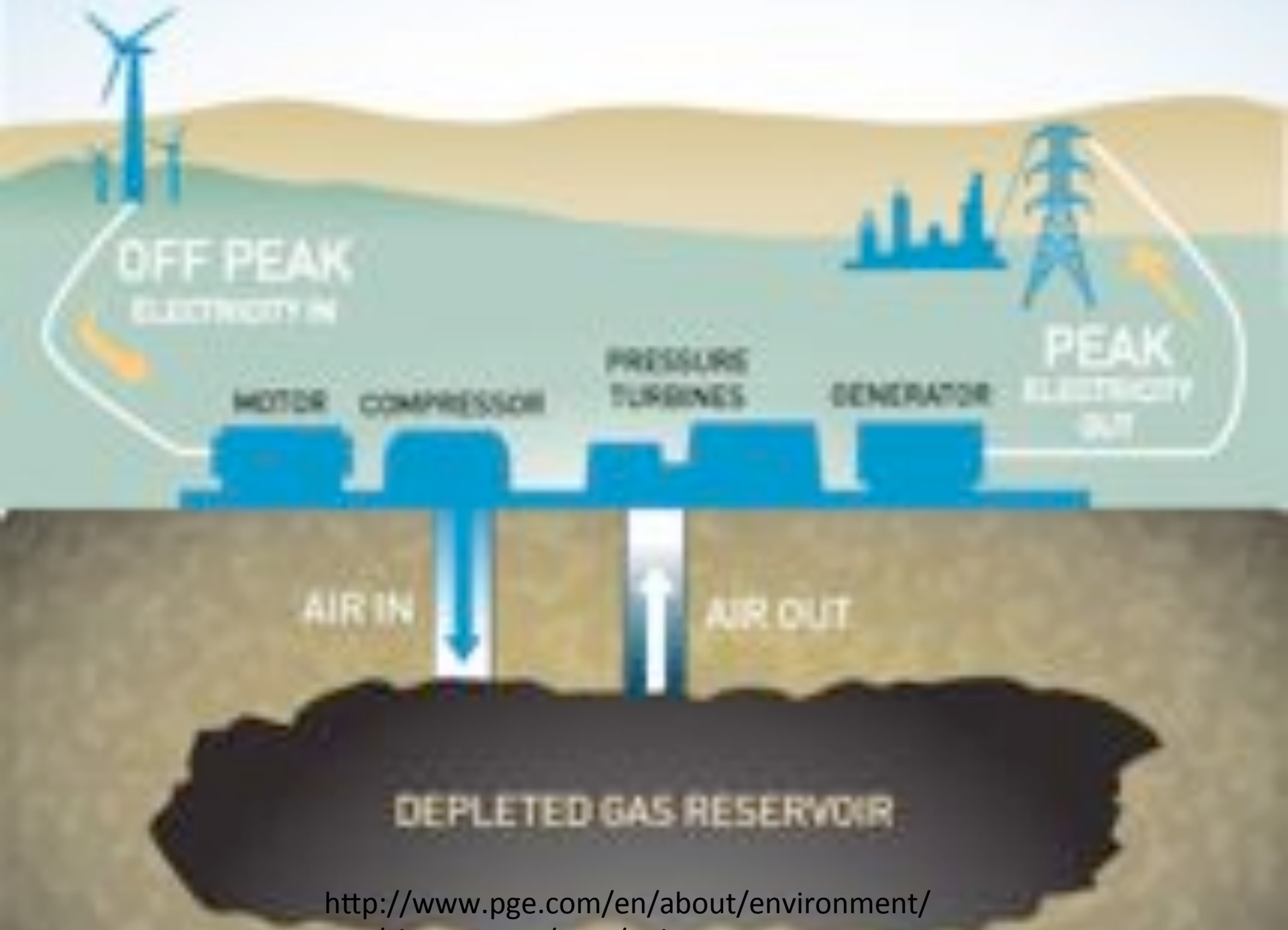




<http://www.ehiyo.com/frozen-niagara-falls-2sh1q>



Seneca Pumped Hydro Generating Station in northwest Pennsylvania





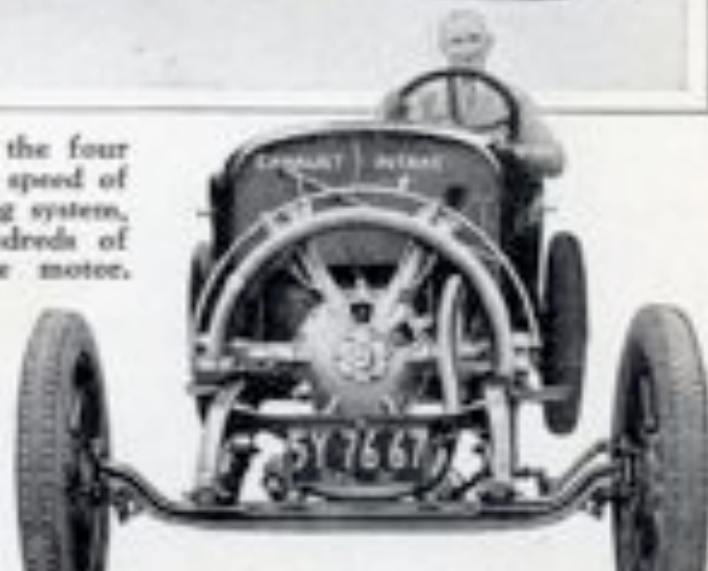
<https://www.youtube.com/watch?v=RcgtWjtk8Dc>

Compressed AIR MOTOR Runs Car



A side view of the compressed air car, showing the four fuel tanks which will drive the car 500 miles at a speed of 35 miles an hour. The engine requires no cooling system, no ignition system, no carburetor, nor the hundreds of moving parts included in a standard gasoline motor.

EITHER the era of "free air" is about to come to an end, or the cost of motor-ing is about to be reduced to practically nothing. In an amazing demonstration conducted recently in Los Angeles a standard automobile chassis, powered with a newly-developed compressed air motor, whizzed



Flywheel Energy Storage



Boeing

http://www.uaf.edu/files/acep/BoeingFlywheelOverview_06_20_2012.pdf

20 MW



Stephentown, New York



**Ivanpah Solar Electric Generating System
(ISEGS) in California's Mojave Desert**

392 MW powering 140,000 homes

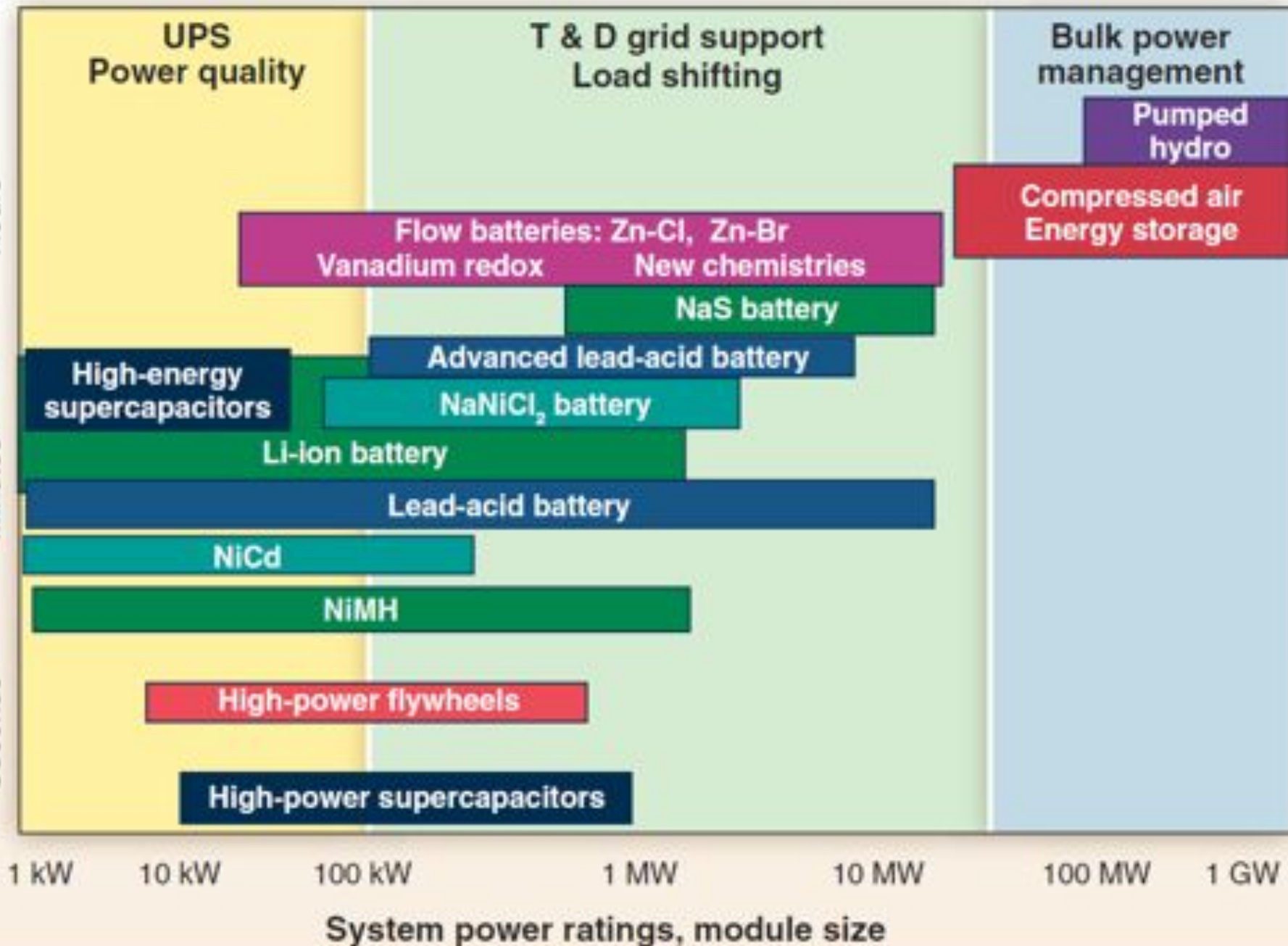
<http://science.kqed.org/quest/video/largest-solar-plant-in-the-world-goes-through-last-test-before-opening/>

Discharge time at rated power

Hours

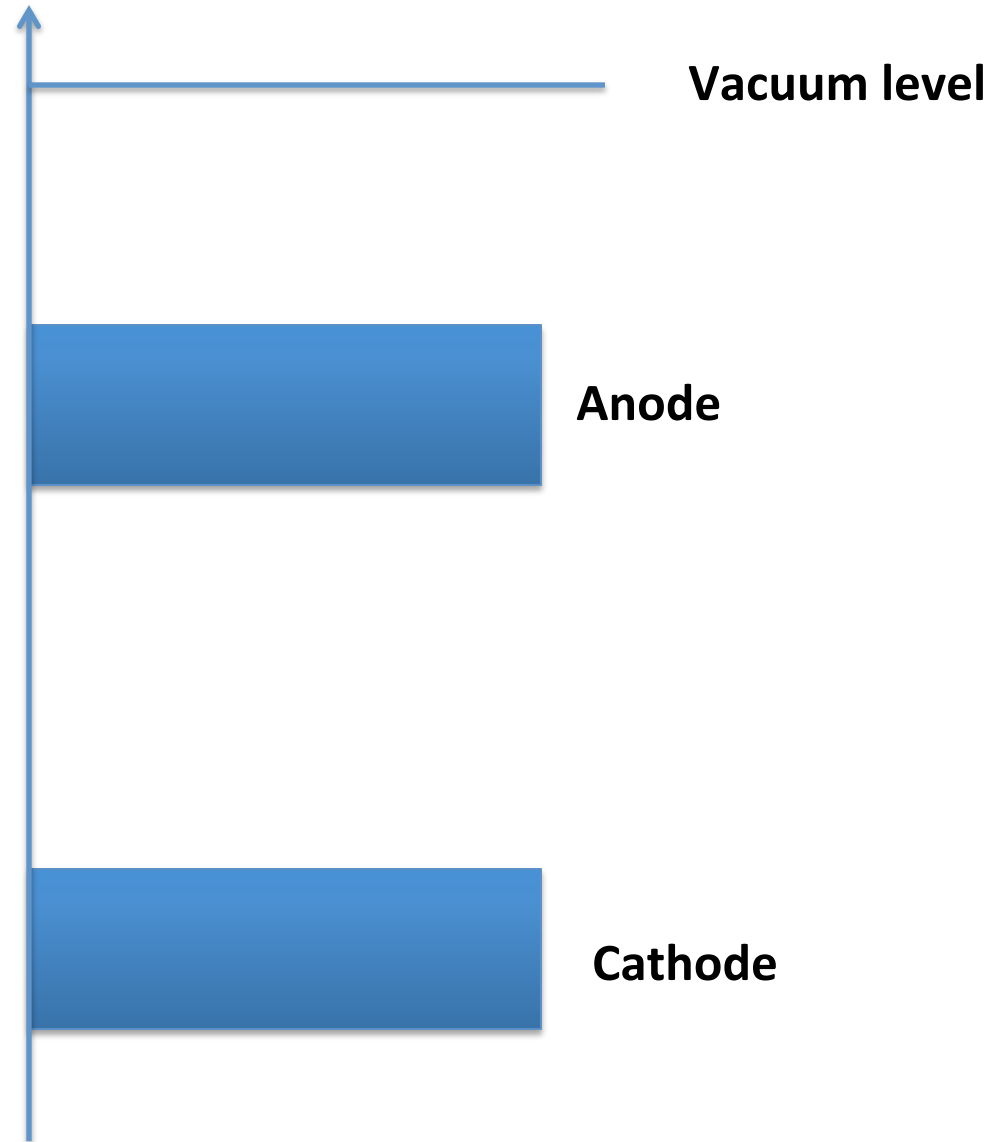
Minutes

Seconds





Potential Energy of Electrons in Atoms





Alessandro Volta
(1745 - 1827)

A voltaic pile on display in the Tempio Voltiano (the Volta Temple) near Volta's home in Como.



This image depicts an 1891 painting by Giuseppe Bertini (1825-1898) of Alessandro Volta demonstrating his battery (called the “Voltaic Pile”) to Napoleon in **1801**. The work is currently maintained at the Volta Temple in Como, Italy.

Lead Acid

Planté, France 1859

Ni-Cd

Jungner, Sweden, 1899

NiMH

1967 K.D. Beccu, Swiss

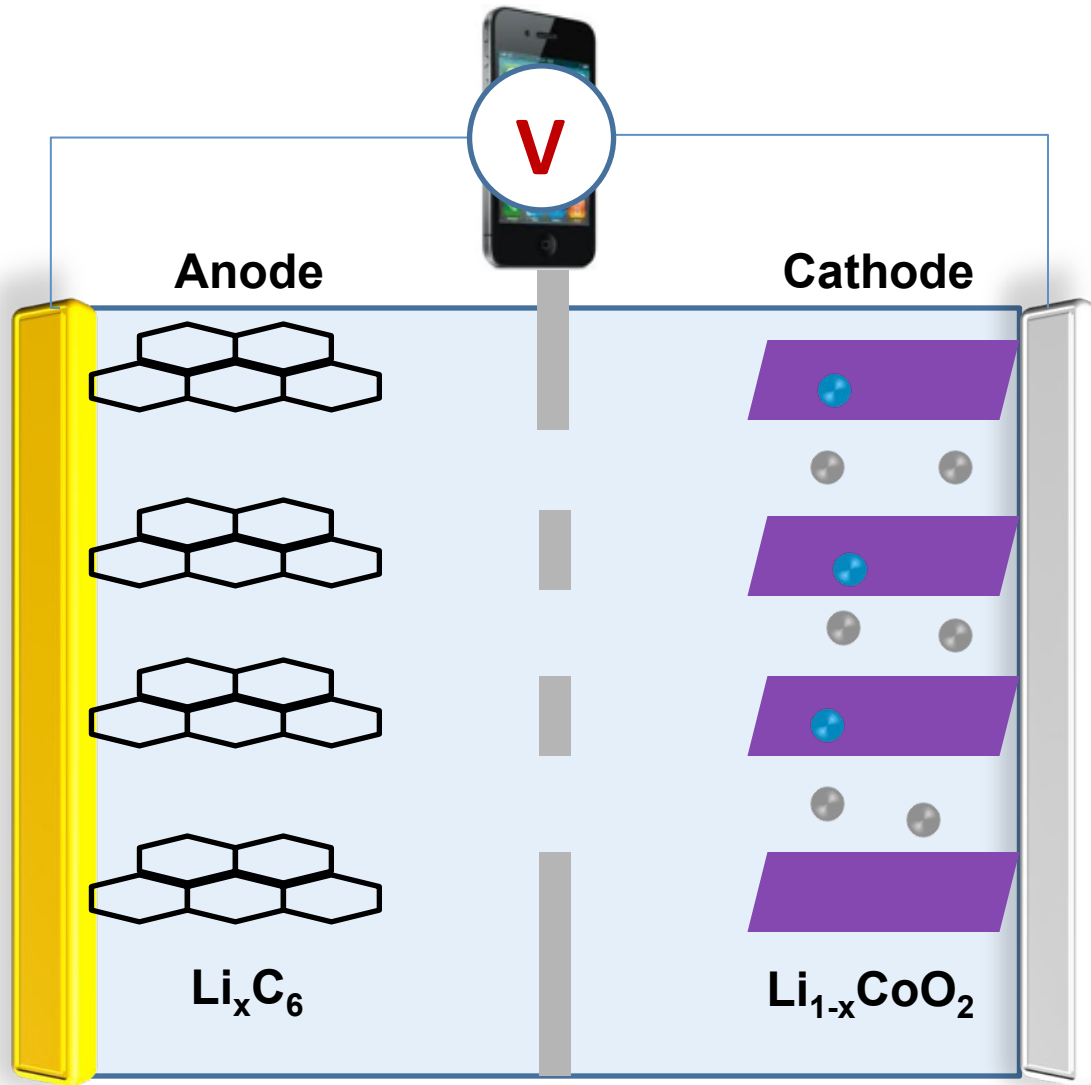
Li-Ion Batteries

Whittingham, Goodenough 1977-1980



2012 at UT Austin
Goodenough's 90 years
old birthday

Charge and Discharge of a Li-Ion Battery



Tesla Gigafactory

Gigafactory Projected Figures

2020 Tesla Vehicle Volume	≈500,000/yr
2020 Gigafactory Cell Output	35 GWh/yr
2020 Gigafactory Pack Output	50 GWh/yr
Space Requirement	Up to 10M ft ² w/ 1-2 levels
Total Land Area (acres)	500-1000
Employees	≈6,500

New Local
Renewables
Solar and Wind



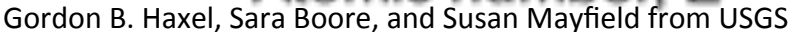
Formula E since Sep. 2014



FIA Formula E 2014/2015 Provisional Calendar







Structure-Property Correlation for Carbon in Na (K)-ion Batteries

Capacity, Cycling life, and Power.

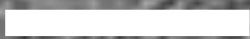
Design Bulk Carbon Structures: Doping, Composites

Carbon Reactivity: Nanostructures, Activation, Surface Modification

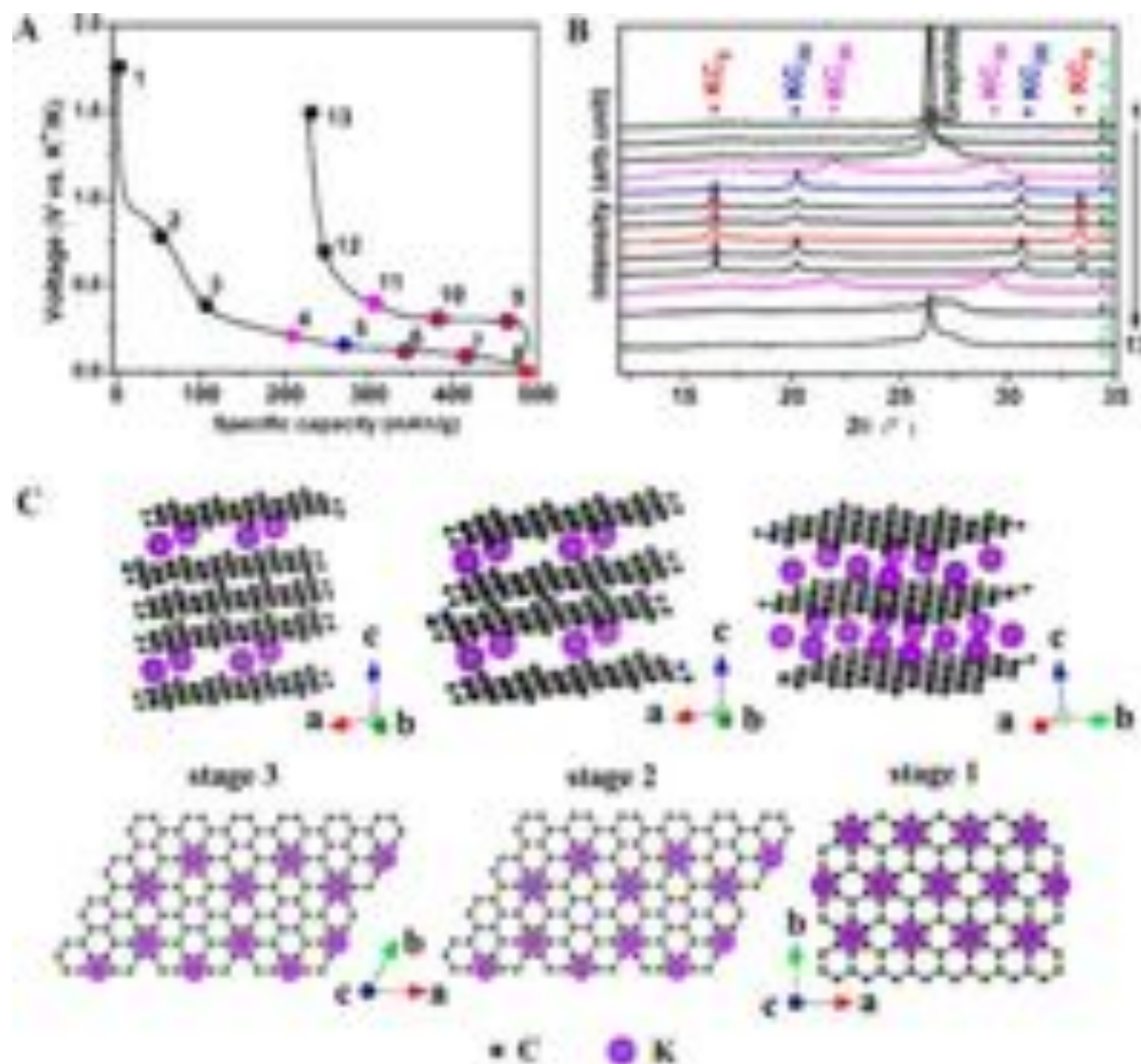
Design Novel Energy Storage Devices based on Carbon

Hydronium, Mg Ion, Anion Storage

5 nm



Identify New Chemistry for Energy Storage



Oregon State Materials Electrochemistry Group



33 publications

4 patent filings

One startup to be founded.

Acknowledgements



OSU Venture Capital Fund

