Energy Storage Systems for Solar, Wind, and Hybrid

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Outline

- Overview of energy storage systems
  - Notes from ADB workshop
  - IRENA documents
- Supercapacitors from waste biomass

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ADB is organizing the workshop on **Energy Storage Technologies and Applications** as a forum for industry, academia, government agencies, and development partners to discuss the state of the art and current challenges in battery storage technologies, to enhance the partnership among participating institutions, and to identify future collaboration opportunities for further development and dissemination. Defining these activities and their objectives will be a key output from this workshop.

ADB Workshop Notes
http://www.adb.org/sites/default/files/esta-workshop-2013-flyer.pdf

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RE offers access to affordable, clean, and reliable energy services for sustainable development.

- In remote communities, including mountains and islands, where grid extension is difficult and the conventional fuel supply chain is easily broken
- the intermittent nature of most RE-based electricity (e.g. wind, solar) must be managed appropriately to ensure continuous availability and stability of the power network
- Management strategies for RE:
  - a balanced generation portfolio
  - geographical dispersion of supply
  - better forecasting tools
  - demand side management, and
  - appropriate storage solutions

ADB Workshop Notes
http://www.adb.org/sites/default/files/esta-workshop-2013-flyer.pdf

Storage and smart grid systems with increasing share of intermittent RE going beyond10-20%

- Soon become a critical issue for most countries which intend to increase energy access for the poor and more so for those targeting to use greater shares of RE
- Globally, most grid-connected electricity storage systems are ***pumped hydropower*** installations with typical capacities of several hundred megawatts (MW)

ADB Workshop Notes
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New storage solutions are emerging.

- long-lasting ***batteries*** and related technologies which are scalable to the household and community level
- may eventually be feasible for large-scale applications
- This technology field is developing rapidly, with production costs decreasing and energy densities increasing

ADB Workshop Notes
http://www.adb.org/sites/default/files/esta-workshop-2013-flyer.pdf

IRENA
International Renewable Energy Agency

Electricity Storage and Renewables for **Island Power**

A Guide for Decision Makers

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Energy storage plays a major role in smart grid systems.

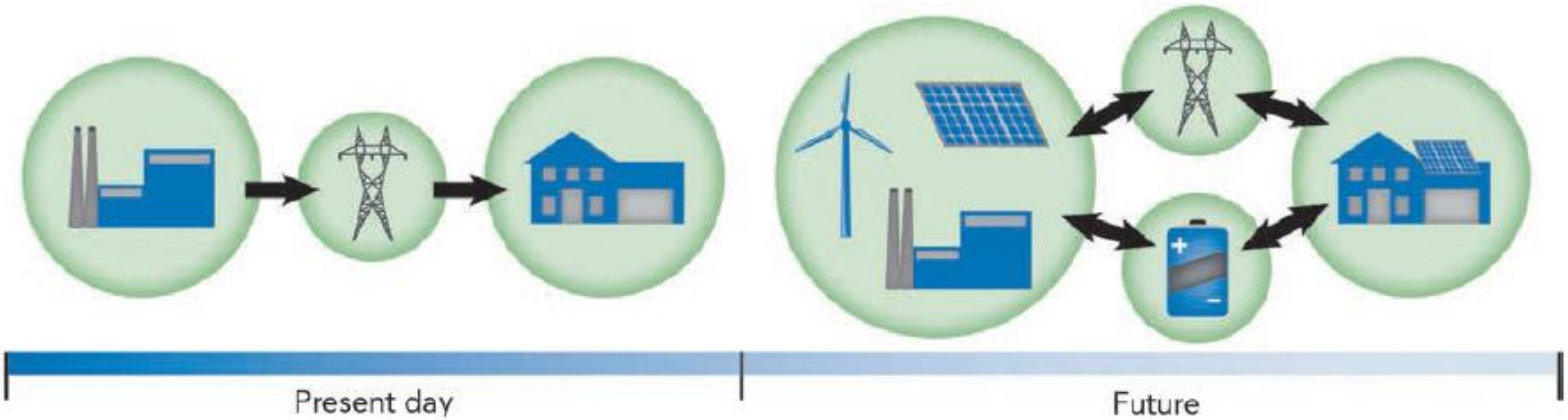

Figure 2A: Visions of the electricity system. Present and future flows.

IRENA document:
SMART GRIDS AND RENEWABLES: A Guide for Effective Deployment

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Energy storage systems

- pumped hydro (70-80%)
- Compressed air energy storage (CAES)
- Flywheels
- Electrical batteries (Li-ion) and vanadium redox flow cells
- Supercapacitors
- Superconducting magnetic storage
- Thermal energy storage

IRENA document:
Energy Storage: Technology Brief

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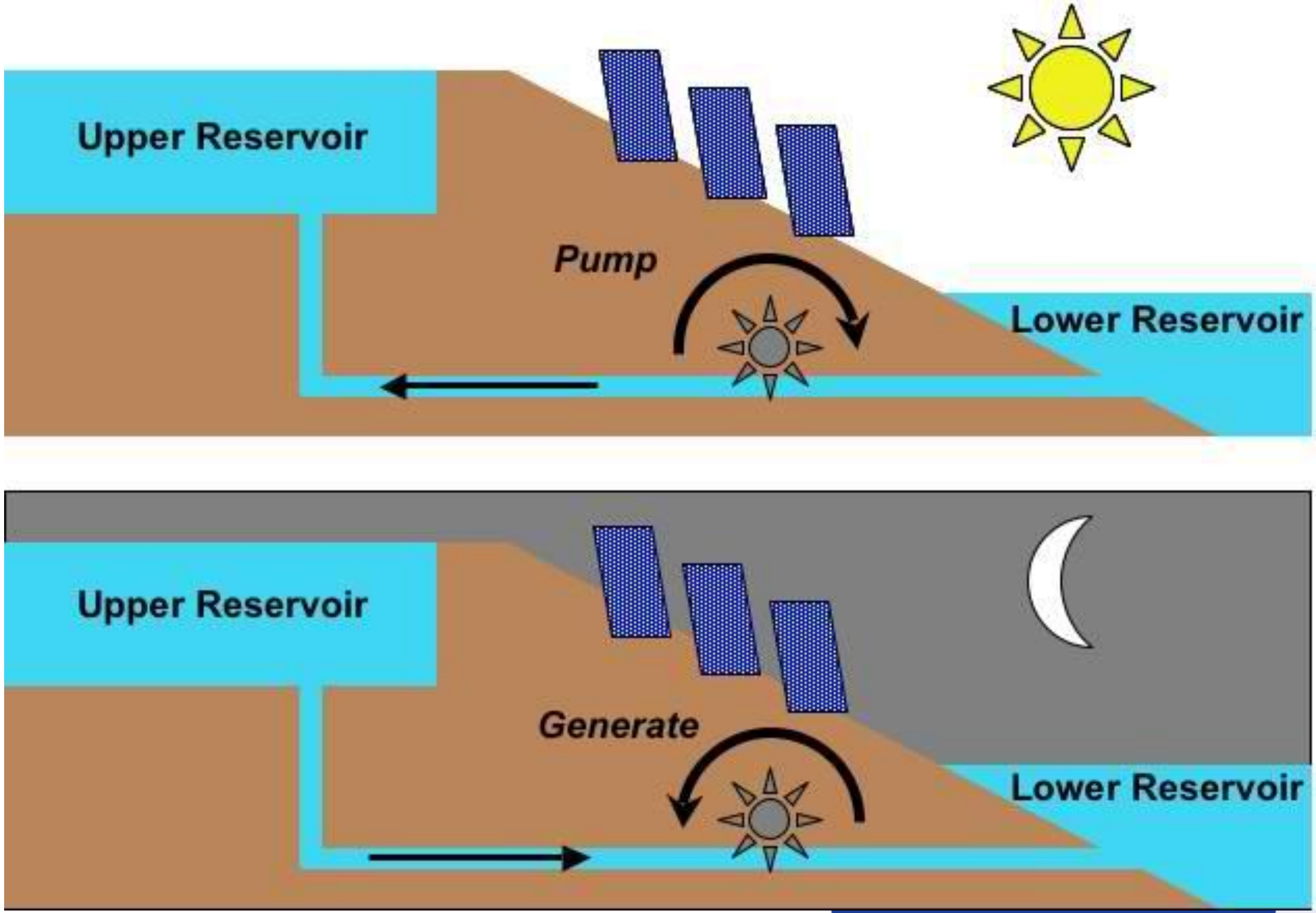
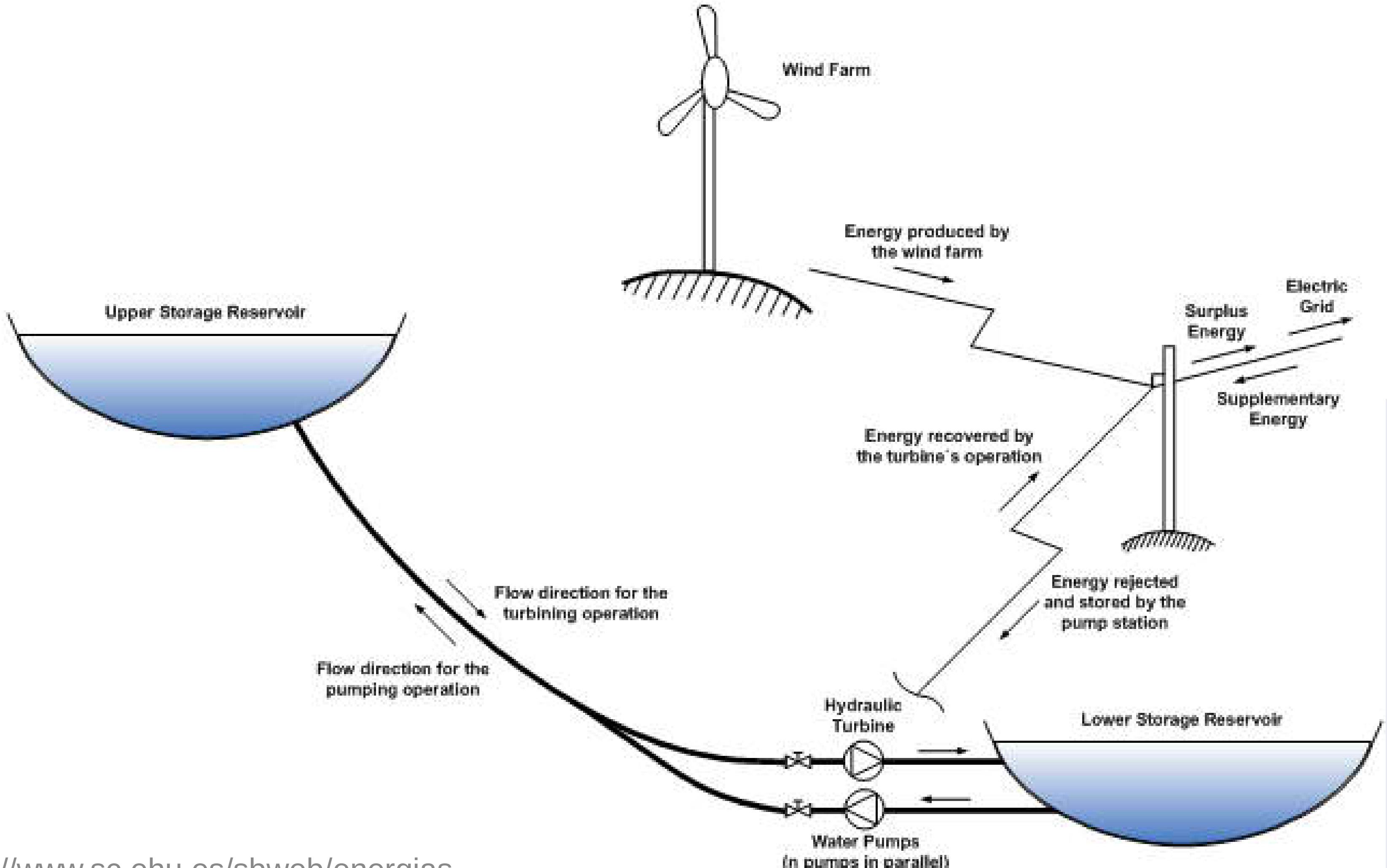
Pumped hydro plants are large-scale storage systems with 70-80% efficiency.



Pumped hydro and wind



http://www.sc.ehu.es/sbweb/energias-renovables/temas/almacenamiento_1/figura_5.jpg

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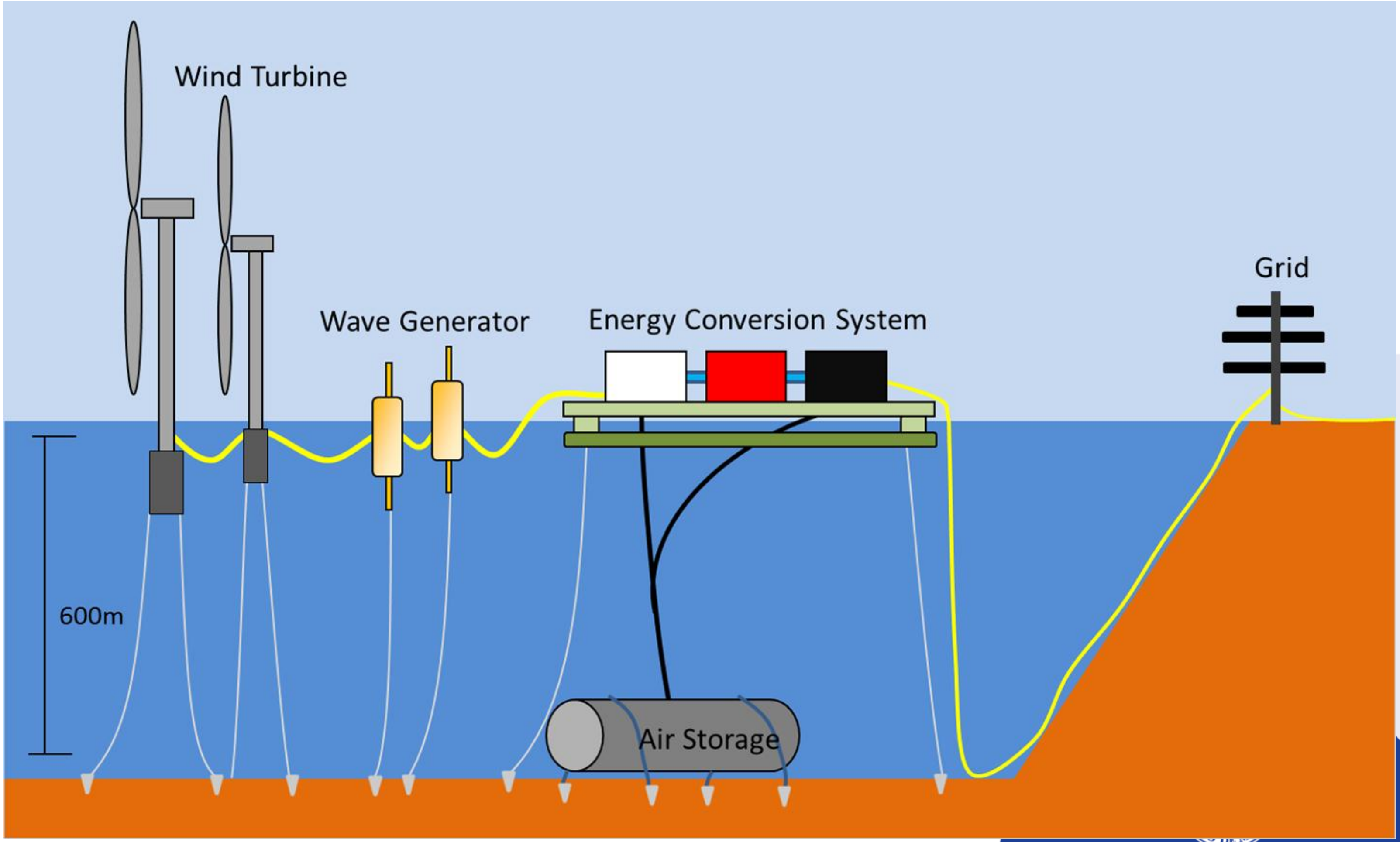
Compressed air energy storage (CAES)



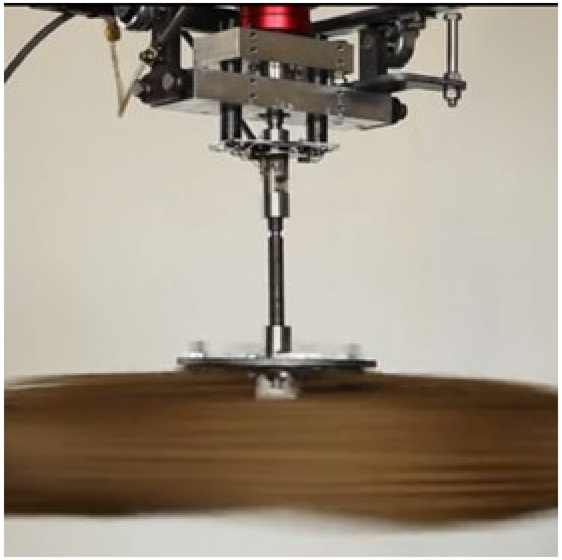
http://www.mae.ncsu.edu/mazzoleni/emssl

Flywheel—stored as mechanical energy.

Turn Up the Juice: New Flywheel Raises Hopes for Energy Storage Breakthrough

Storing electricity in spinning wheels isn't new, but a new design may make it cheap enough to compete with other technologies

Apr 10, 2013 | By Chris Nelder



Renewables could be the world's primary source of energy if only someone could solve the storage problem—how to store lots of electricity cheaply on a wide scale? Batteries are too expensive and don't last long enough. Pumped hydro is cheap but not feasible for most locations. Thermal storage is promising but still too expensive or hard to scale. Compressed air is cheap and scalable but not yet efficient enough (although LightSail, a new company backed

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Superconducting magnetic storage

- Superconducting technology
- Needs further R&D

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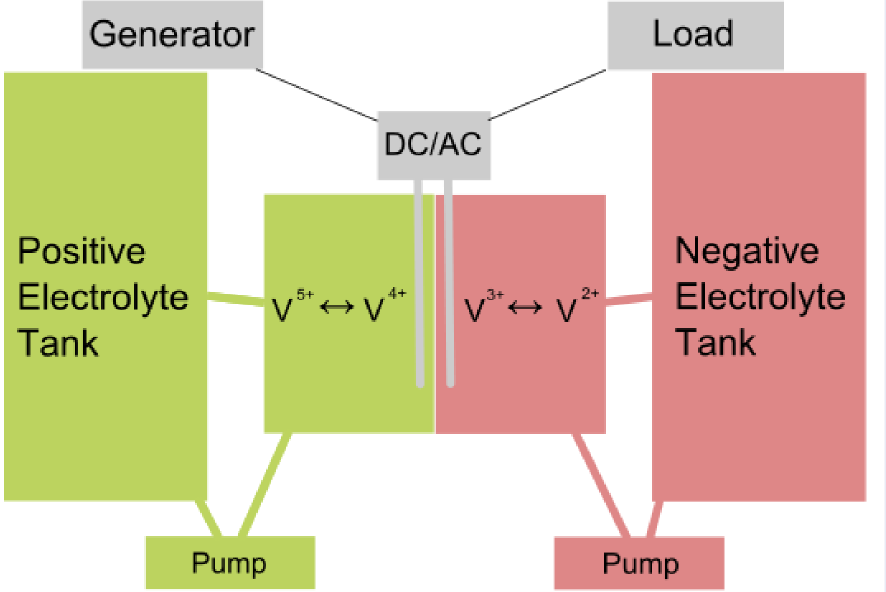
Thermal energy storage

- Used mainlyl with solar concentrating power (CSP) plants
- Superheated steam storage or molten salt

Batteries—chemical energy

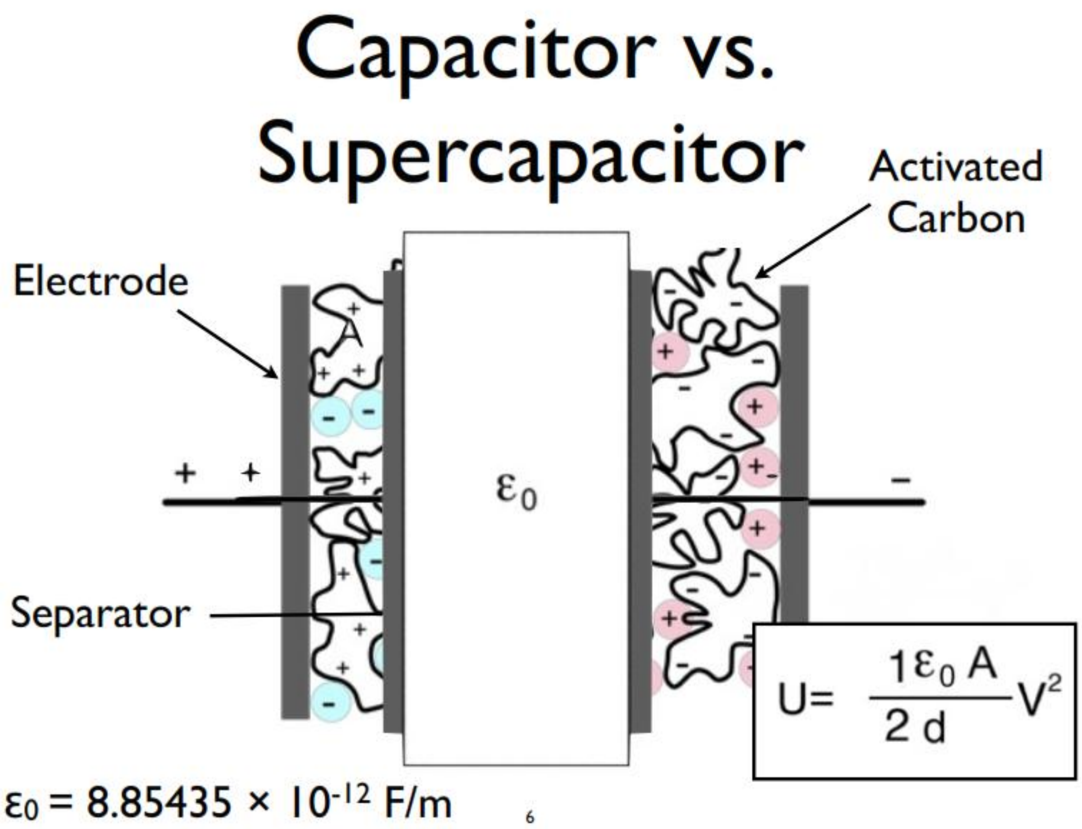
- Lead-acid is still popular
- Li-ion is the projected main storage solution
- Others: Na-S, fuel cell
- Vanadium flow cell



Images: Wikipedia

Supercapacitors = electrochemical double layer capacitor (EDLC)

- Stores energy through electrostatic energy



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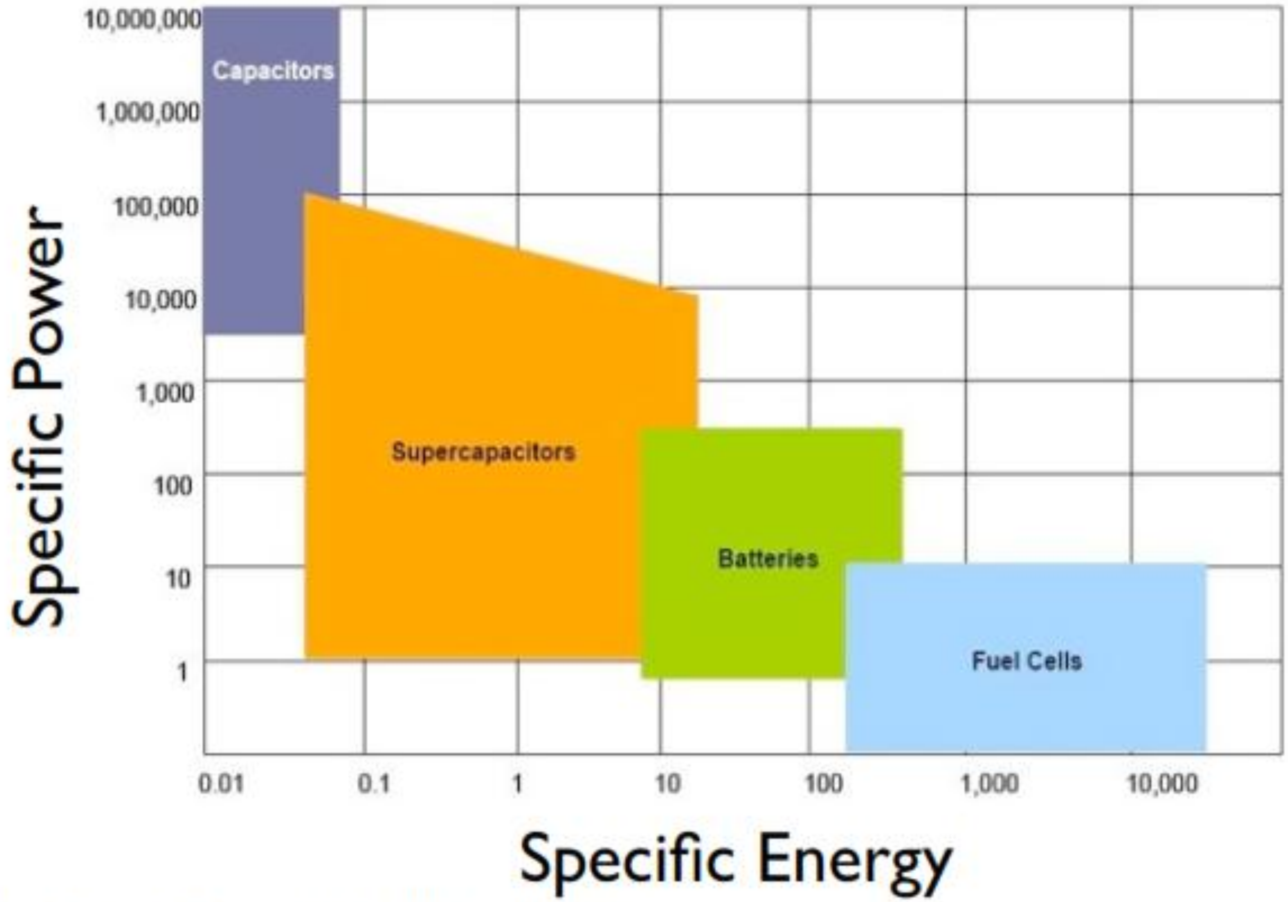
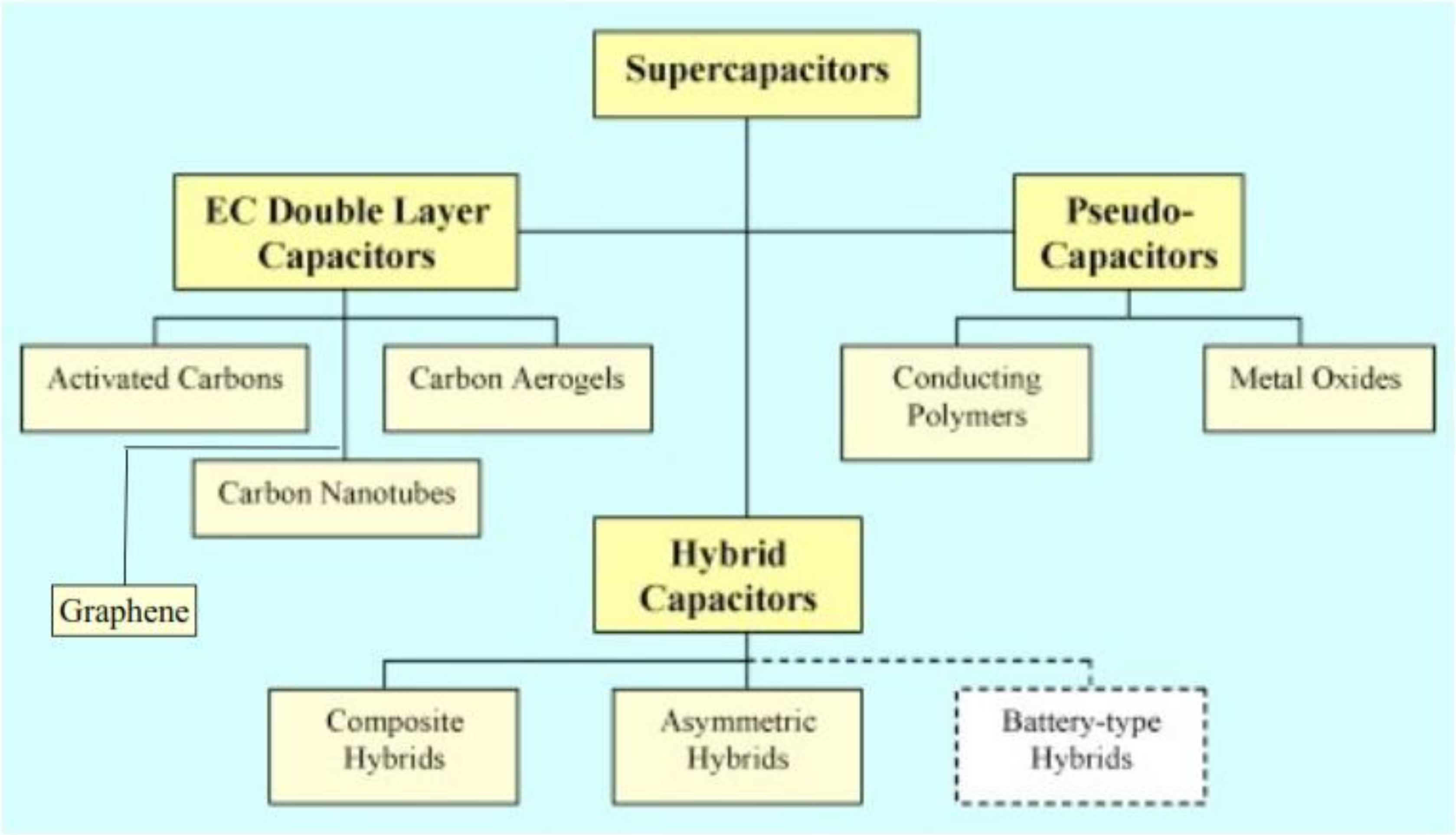
Supercapacitors have properties in between traditional capacitors and batteries.



http://www.observatorynano.eu/project/filesystem/images/2en.p07.jpg

Carbon, metal oxides and conducting polymers are used to make supercapacitors.



1. Hadjipaschalis, I.; Poullikkas, A.; Efthimiou, V., Overview of current and future energy storage technologies for electric power applications. *Renewable and Sustainable Energy Reviews* *13* (6-7), 1513-1522.

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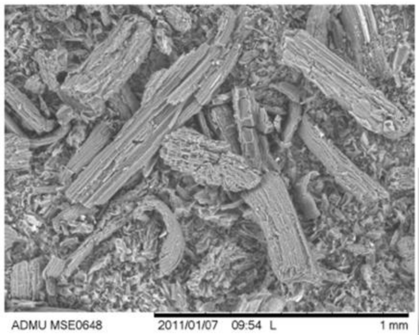
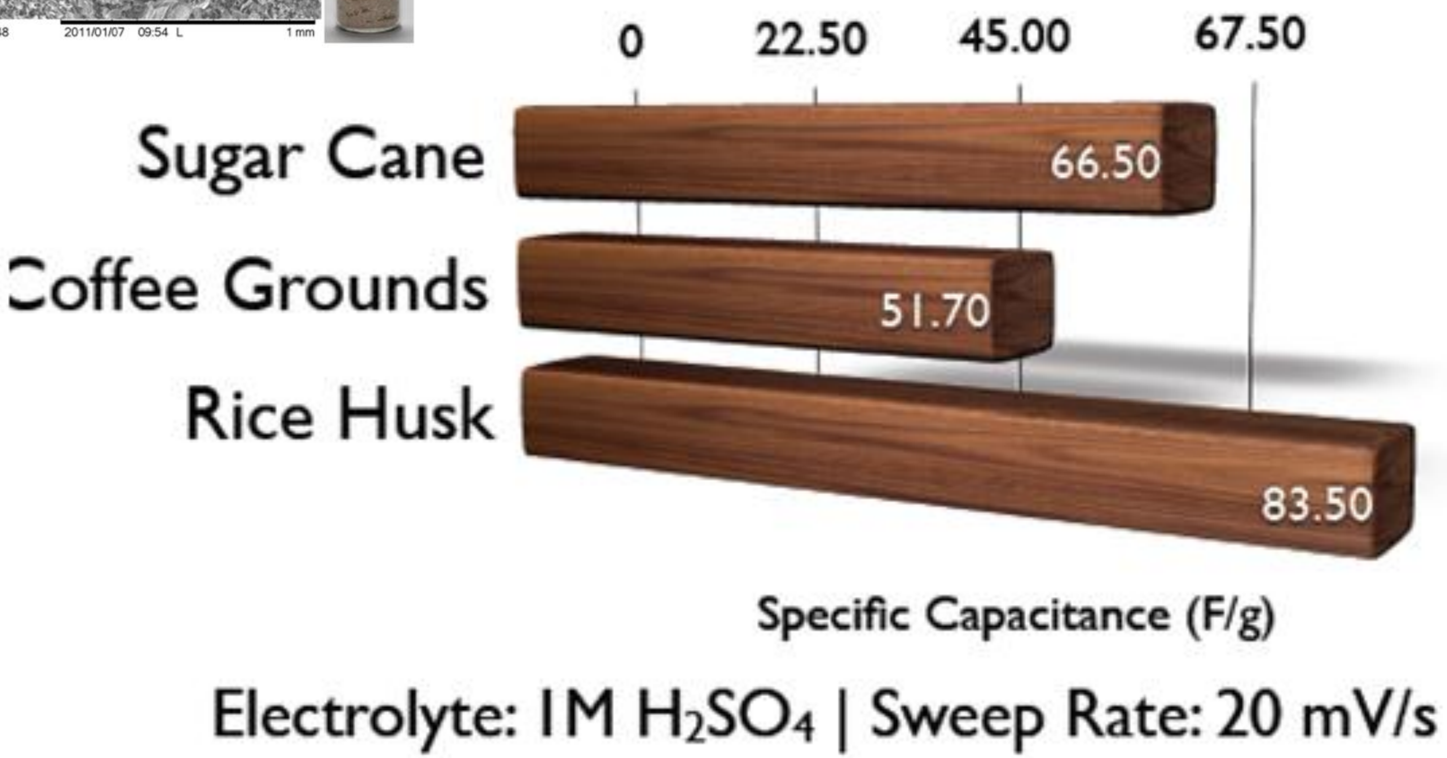
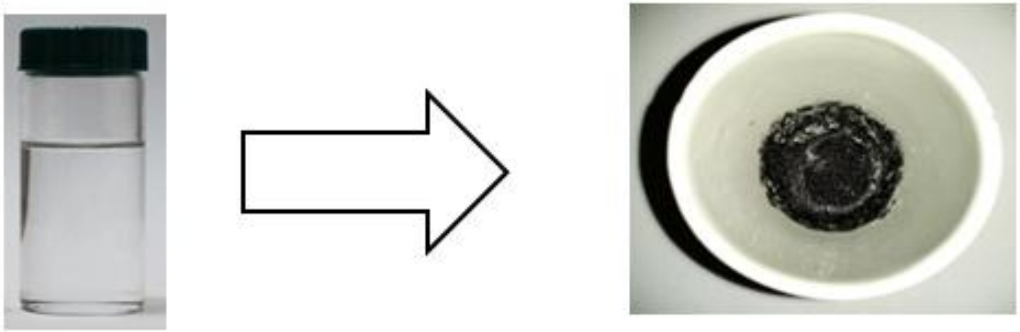
Supercapacitor electrodes from waste biomass





Carbon from glycerol for supercapacitor electrode.

Glycerol to carbon



$C_3H_8O_3$ → C

- Glycerol is a liquid: boiling point /decomposition ~ 185 ºC.
- There has been no report of direct carbonization of glycerol.
- We developed a simple process to carbonize glycerol in high yields.
- Advantages: lower energy and utilizes low-cost starting material

Enriquez, E. P., Imbao, J., and Tan, G. Patent pending IPOPHL

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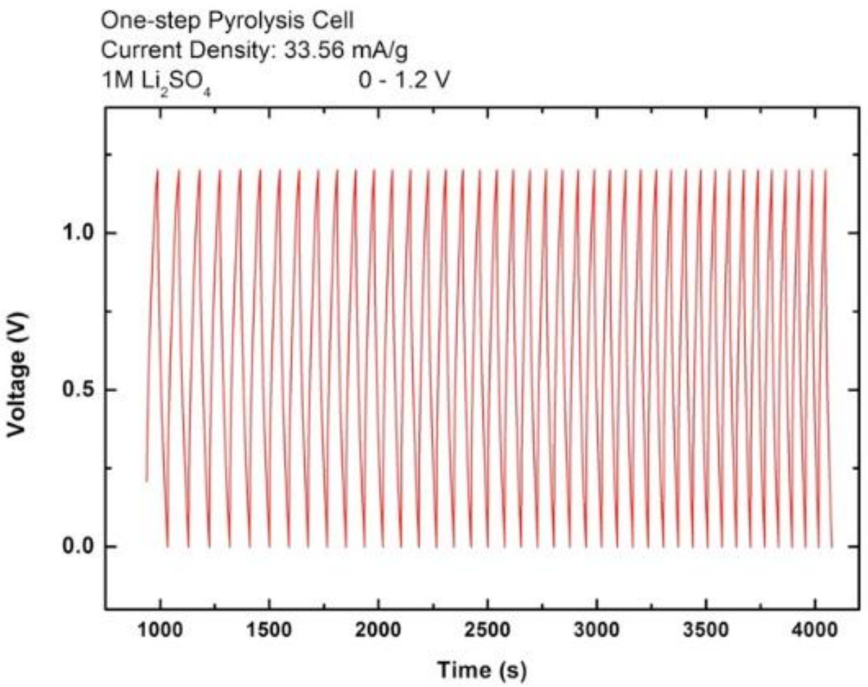
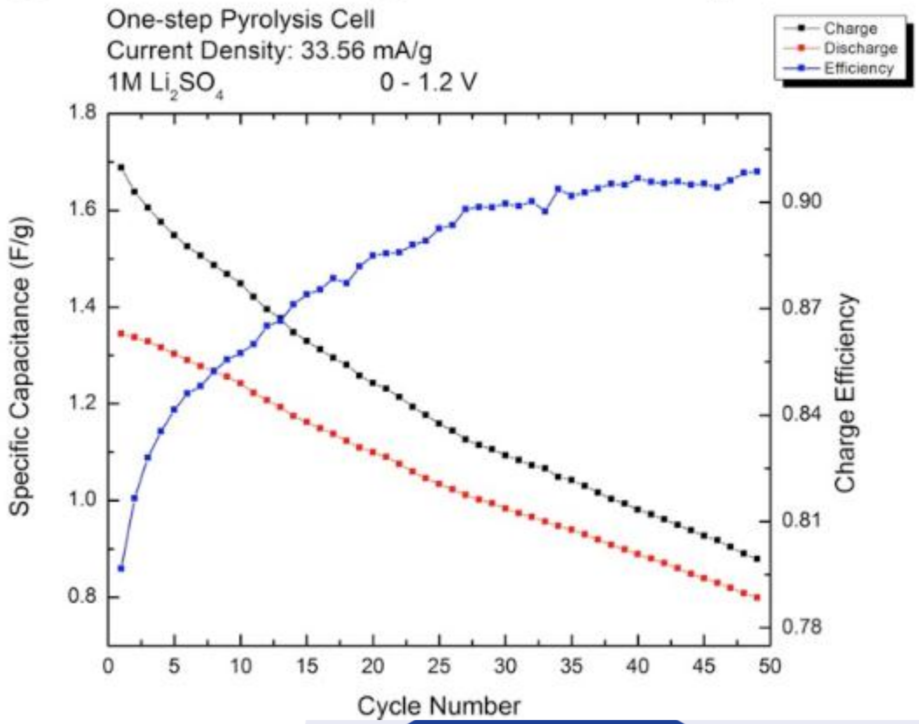
Non-activated C from glycerol display ~1F/g specific capacitance





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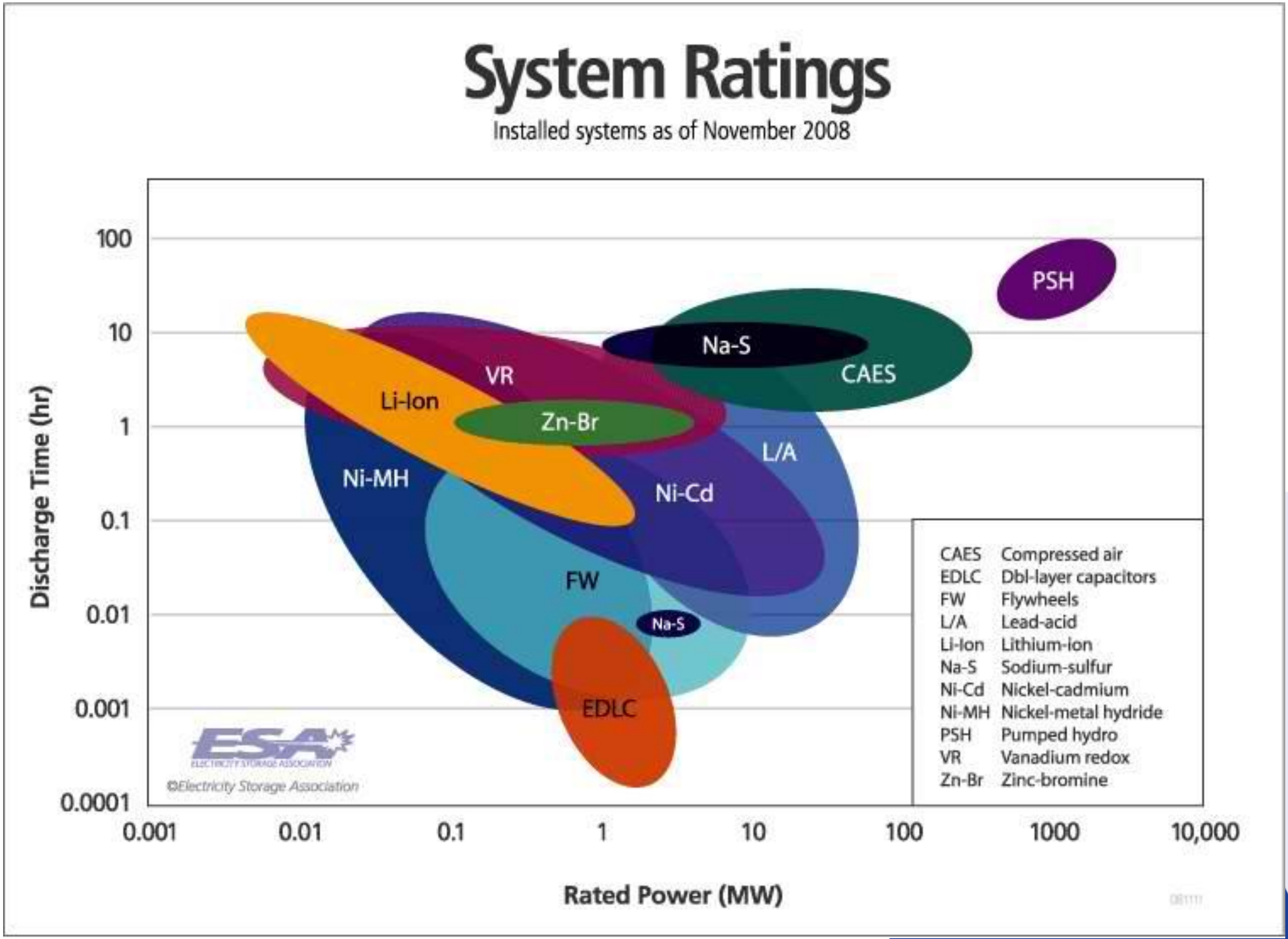

http://www.agrion.org/

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Concluding remarks

- Business forecast for energy storage from the ADB meeting
  - Best technology may not be what will be commercialized
  - Li-ion has lead because of maturing manufacturing technology and adoption
  - Lead-acid still popular in developing countries

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Thank you for your attention

Acknowledgments:

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DOST-PCIEERD

Ateneo URC