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Energy Storage Technologies

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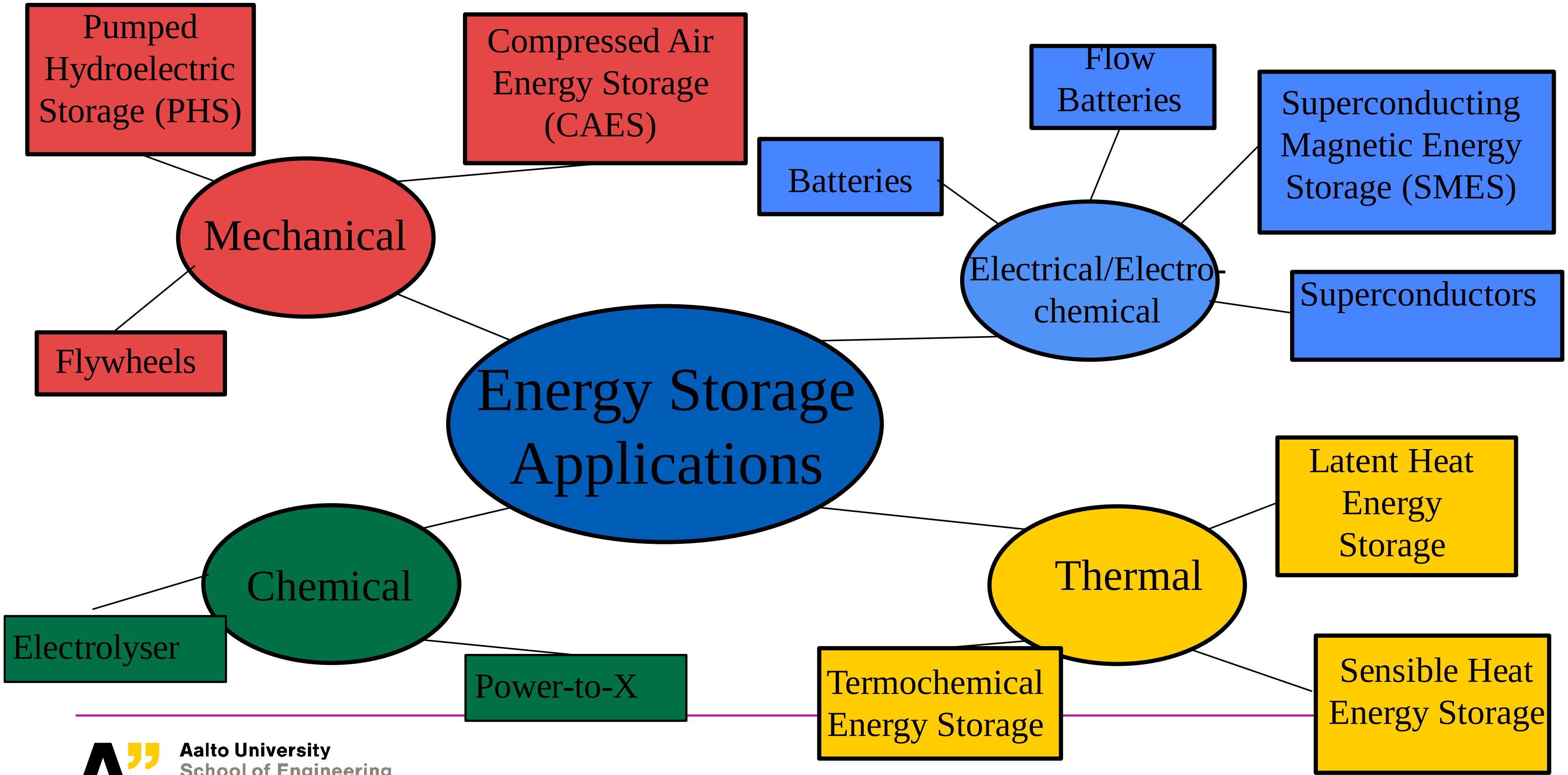
Learning outcomes

- What are the most commonly used Energy Storage systems
- Introduction to operating principles for ES systems
- Few highlights of the energy system definition

Learning by Discovery

Prepare a mind map for
Energy Storage
Technologies

Example mind map



Mechanical Storage

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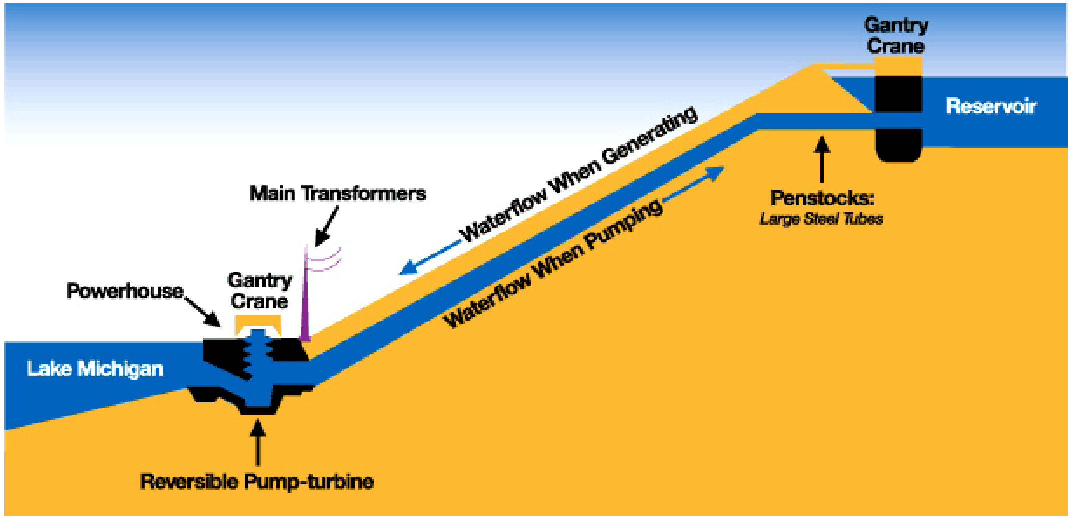
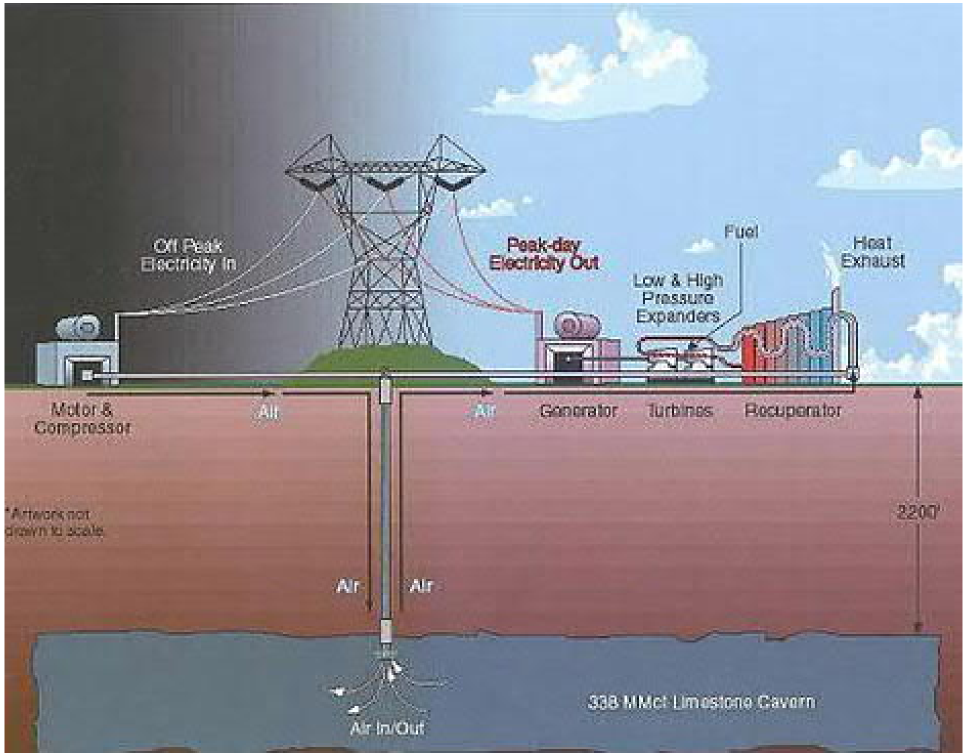
Pumped Hydro power



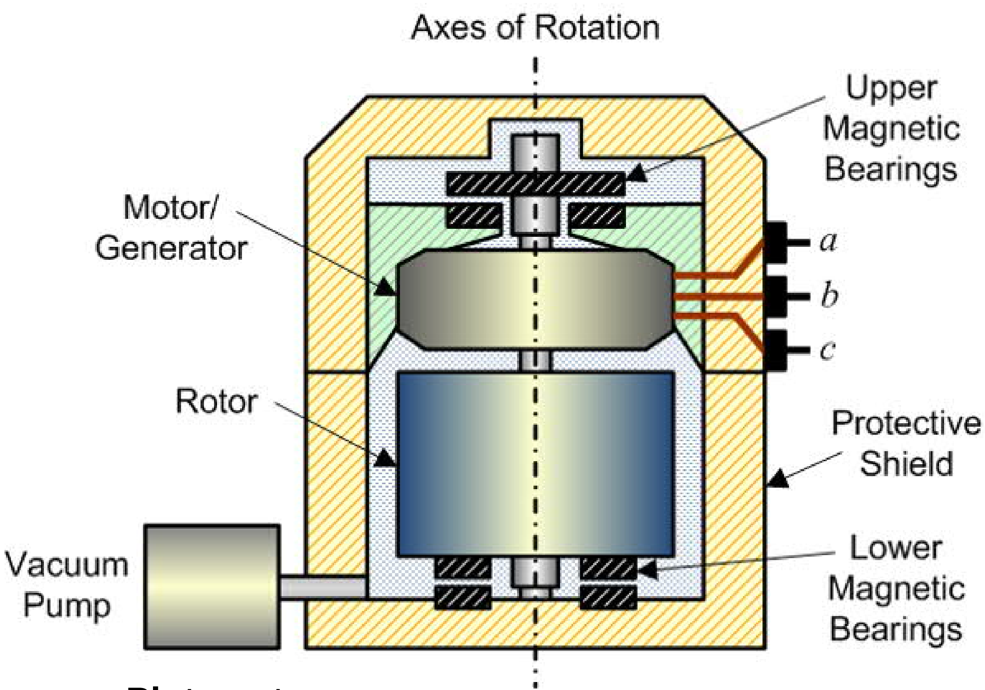
- Efficiency 70-87 %
- Quite low cost (case by case)
- Demands a proper location (hight or reservour)

Compressed Air Energy Storage (CAES)



- Efficiency 75-80 %
- Low cost (2-3 times lower than pumped hydro)
- Requires a cavern (or old mine..)
- Utilized still a fuel (currently fossil) to heat up the compressed air before turbine

Flywheel Energy Storage



Pinterest.com

- Electrical energy into kinetic energy
- Efficiency up to 90 %
- Charging -> motor provides more speed
- Discharge -> energy from flywheel drives the generator

Electrical/ Electrochemical Storage

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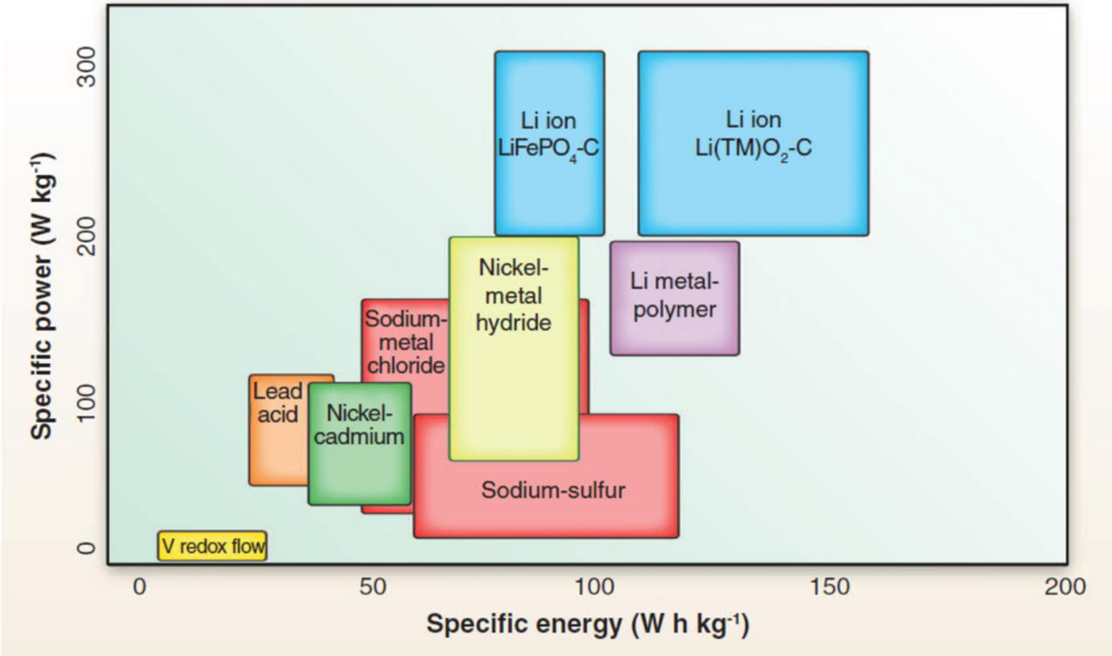
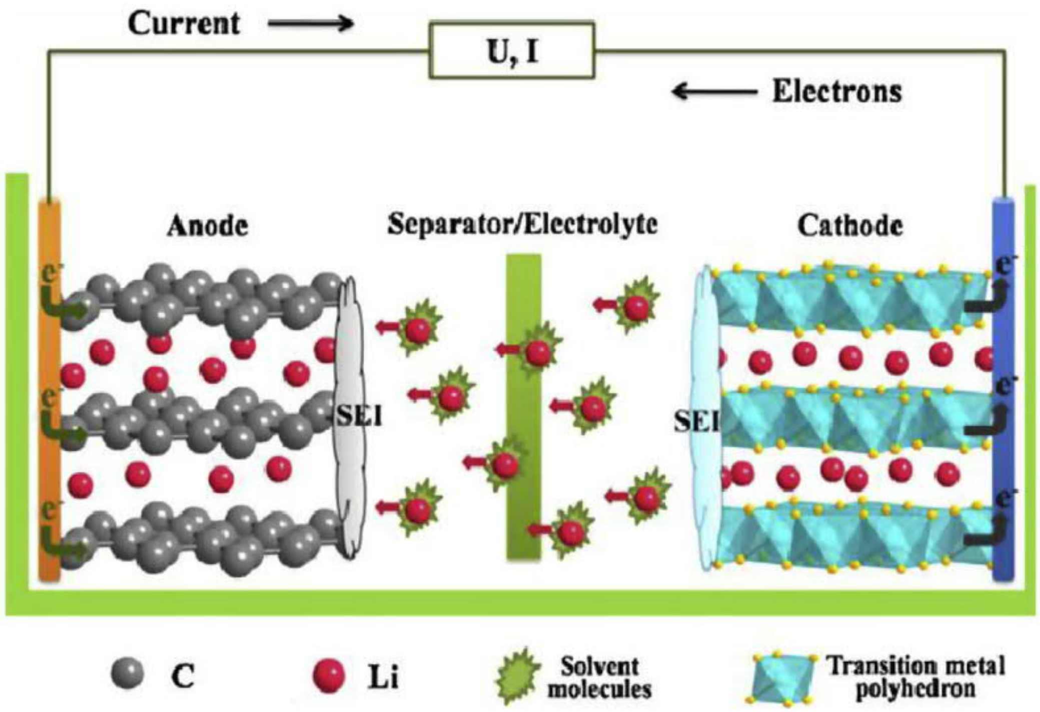
Different type of batteries – why?



Primary batteries = Discharged only ones

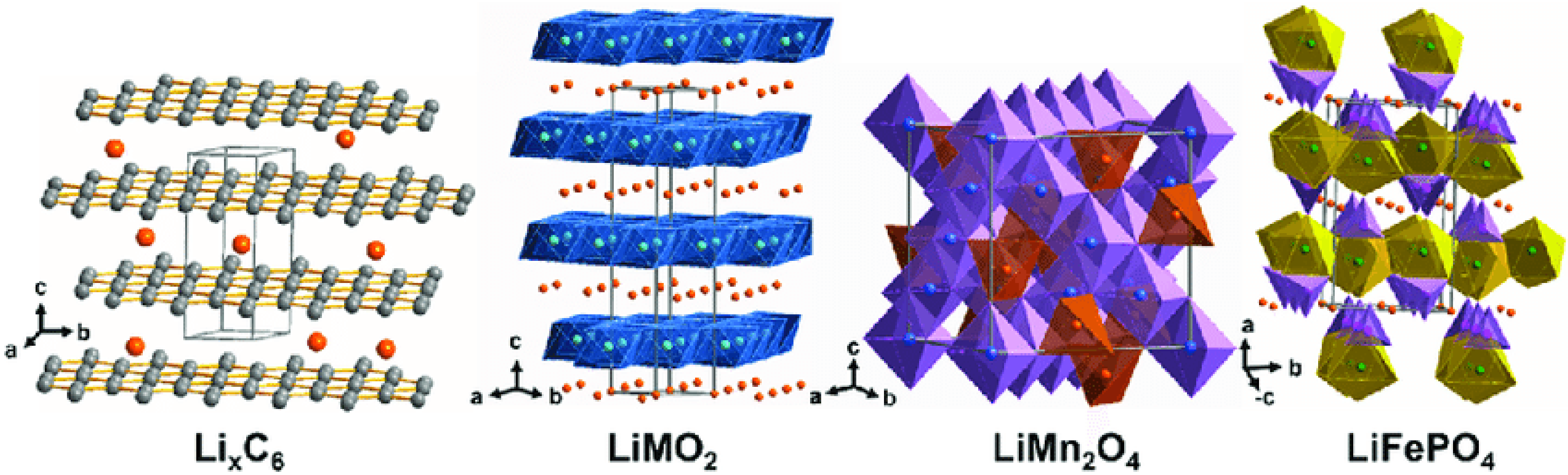
Secondary batteries = Can be charged and discharged various times

Lithium-ion battery (LIB) - operation



M.K. Shobana / Journal of Alloys and Compounds 802 (2019) 477

The main LIB chemistries - Structures



Layered structures with movable Li ions…

A. Manthiram, An Outlook on Lithium Ion Battery Technology – ASC Central Science DOI: 10.1021/acscentsci.7b00288

Different voltages and chemistries
Lithium ion battery (LIB)

Positive electrode

Discharge ->

$CoO_2 + Li^+ + e^- \leftrightarrow LiCoO_2$ $E^0 \sim 3.8$ V

<- Charge

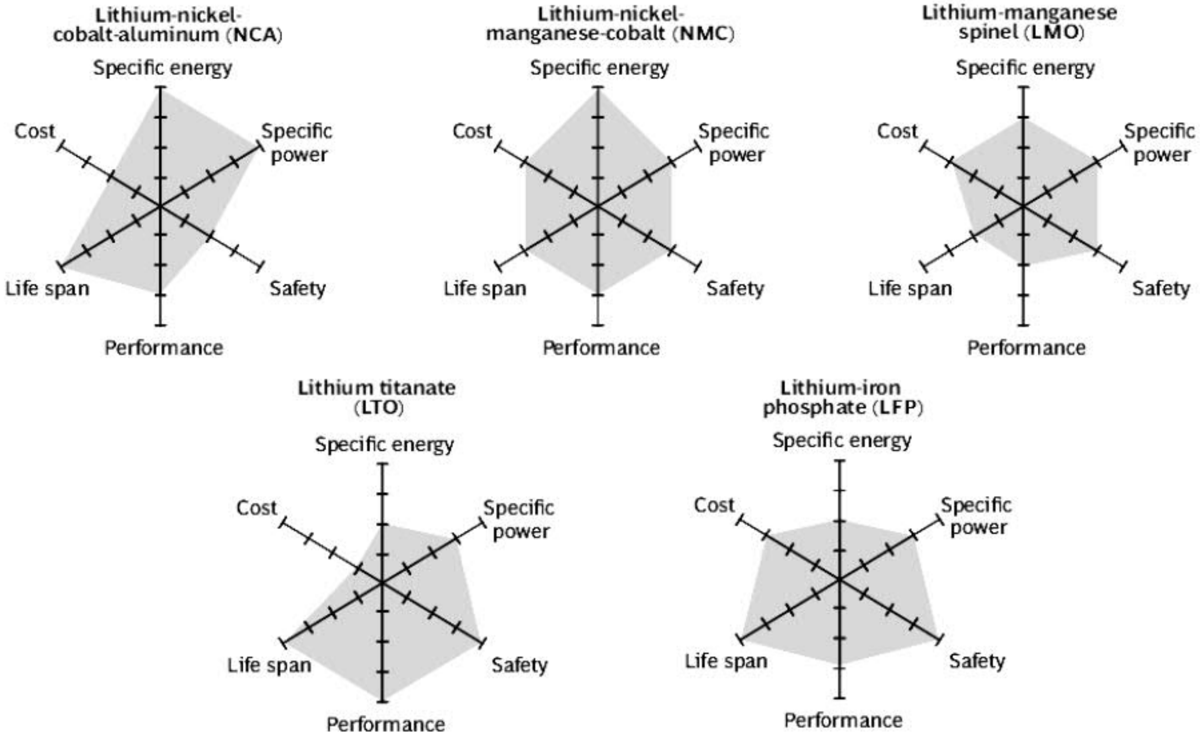
Negative electrode

$LiC_6 + \leftrightarrow C_6 + Li^+ + e^-$ $E^0 \sim 0.1$ V

Full reaction

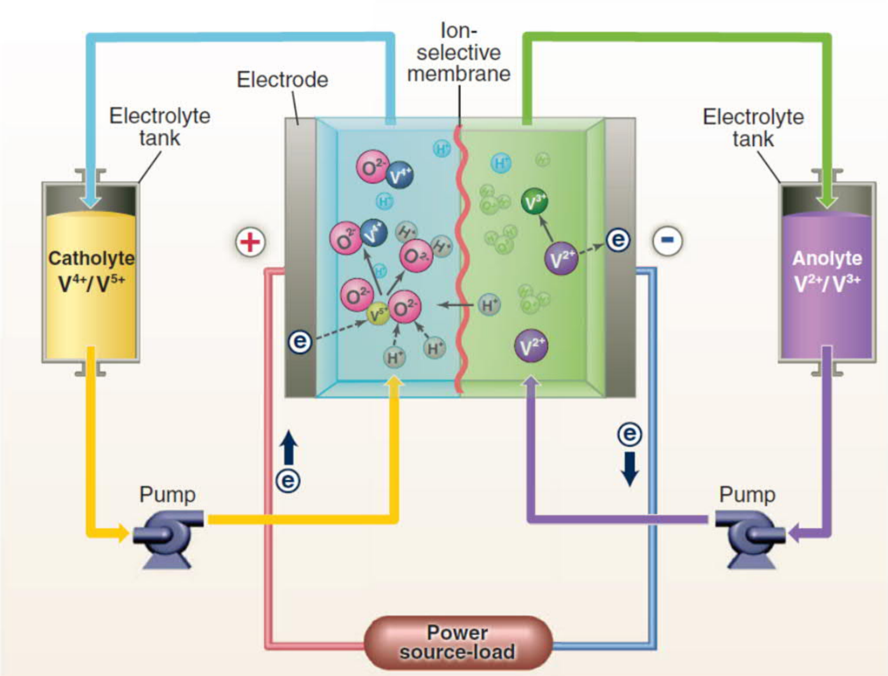
$CoO_2 + LiC_6 \leftrightarrow LiCoO_2 + C_6$ $E^0 \sim 3.7$ V

The main LIB chemistries
- Properties



The Boston Consulting Group. Batteries for Electric Cars. Challenges, Opportunities, and the Outlook to 2010. Available online: http://www.bcg.com/documents/file36615.pdf, 18 pages.

Vanadium flow battery



P. Peljo et al. Green chemistry 18 (2016) 1785

Reactions

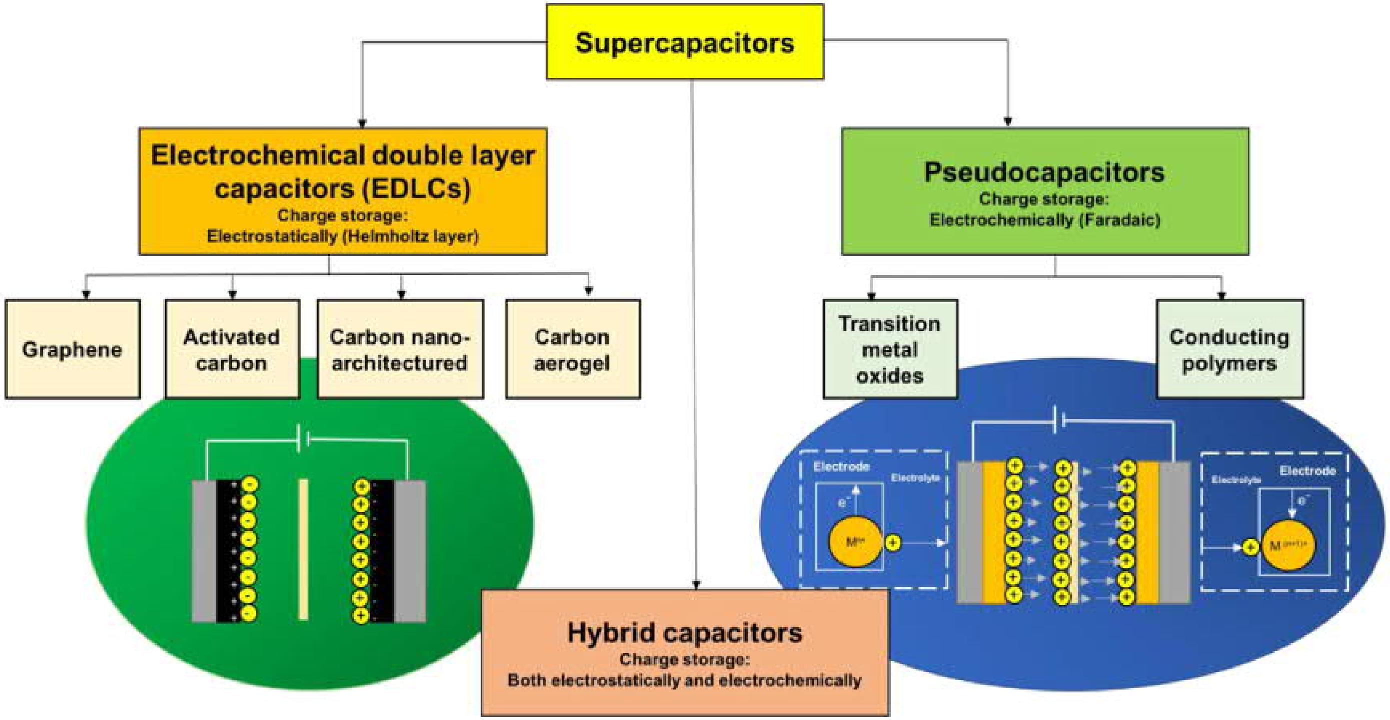
Positive electrode
$VO^{2+} + H_2O \rightleftharpoons VO_2^{+} + 2\ H^{+} + e^{-}$

Negative electrode:
$V^{3+} + e^{-} \rightleftharpoons V^{2+}$

Requirements

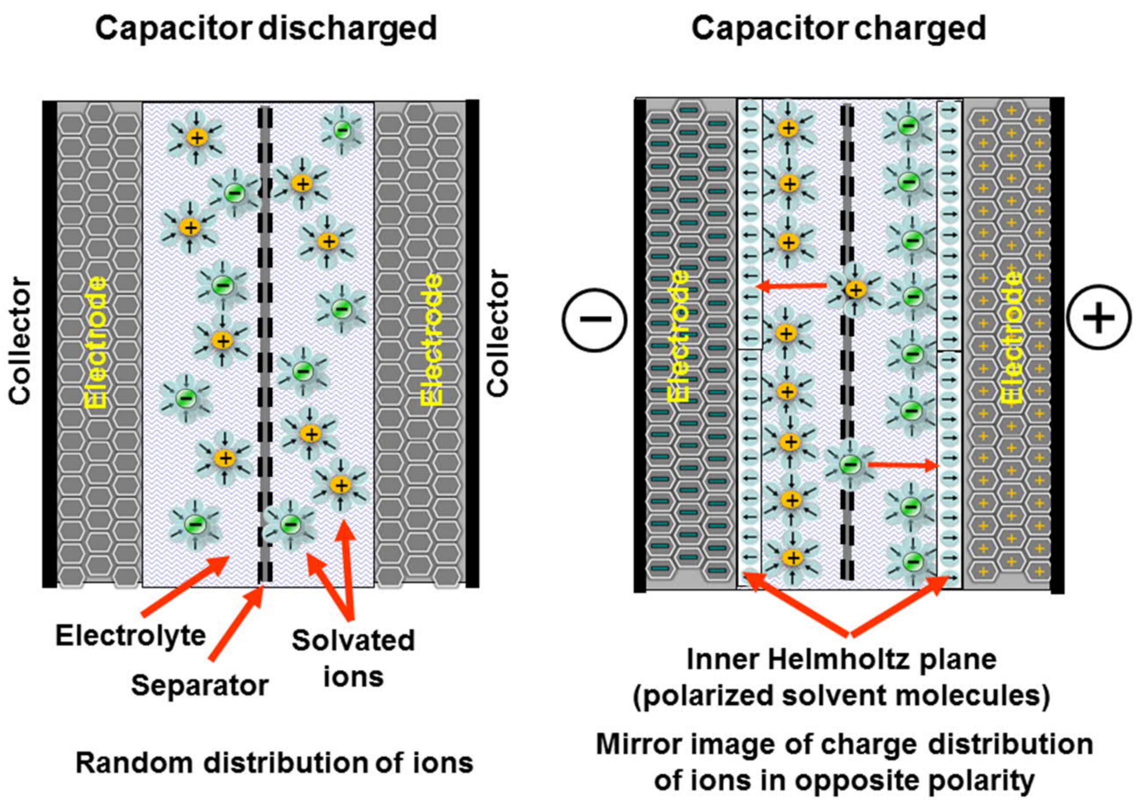
Large space for the compartments
Material issues…

Supercapacitors



M.A.A. Mohd Abdah et al. / Materials and Design 186 (2020) 108199

Supercapacitors - EDLC



- Graphene sheets
- Can accept and deliver charge much faster than batteries
- Often Combined with batteries

Chemical Storage

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Electrolysers – Power to Hydrogen

Hydrogenics

PEM electrolyser

Also Power to X

Larger chemical compounds
(traffic fuels)

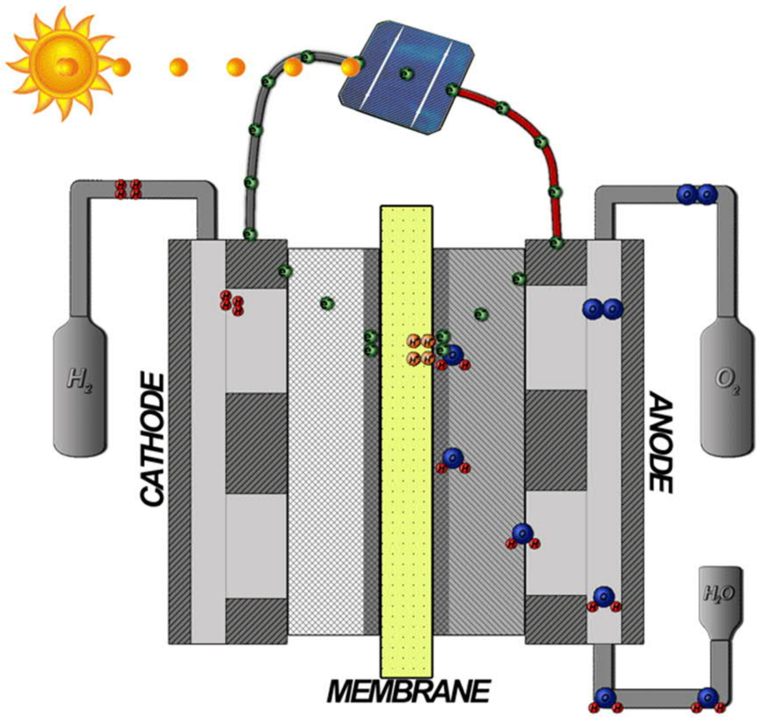
Figure 11. Example of an SOEC stack www.scielo.br

Solid Oxide Electrolyser

Hydrogen and Fuel Cell Archives

Alkaline electrolyser

PEM water electrolyser



Anode

$$2\,H_2O \rightarrow 4\,H^+ + 4\,e^- + O_2$$

Cathode

$$4\,H^+ + 4\,e^- \rightarrow 2\,H_2$$

$$2\,H_2O \rightarrow 2\,H_2 + O_2$$

https://en.wikipedia.org/wiki/Polymer_electrolyte_membrane_electrolysis

Electrolysers – Alkaline

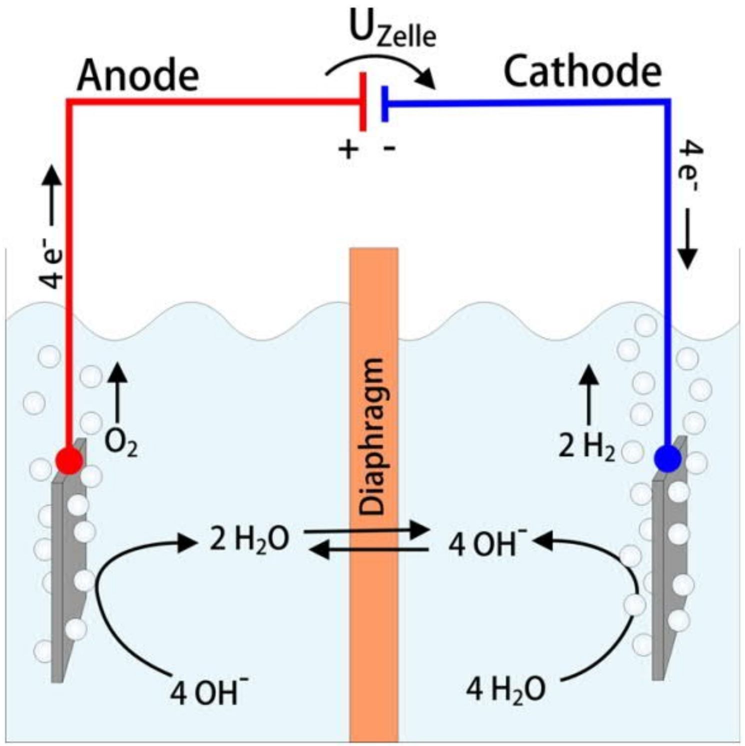
Cathode

$4\,H_2O + 4e^- \rightarrow 2\,H_2 + 4\,OH^-$

Anode

$4\,OH^- \rightarrow 2\,H_2O + O_2 + 4\,e^-$

$2\,H_2O \rightarrow 2\,H_2 + O_2$



Fraunhofer IFAM - Fraunhofer-Gesellschaft

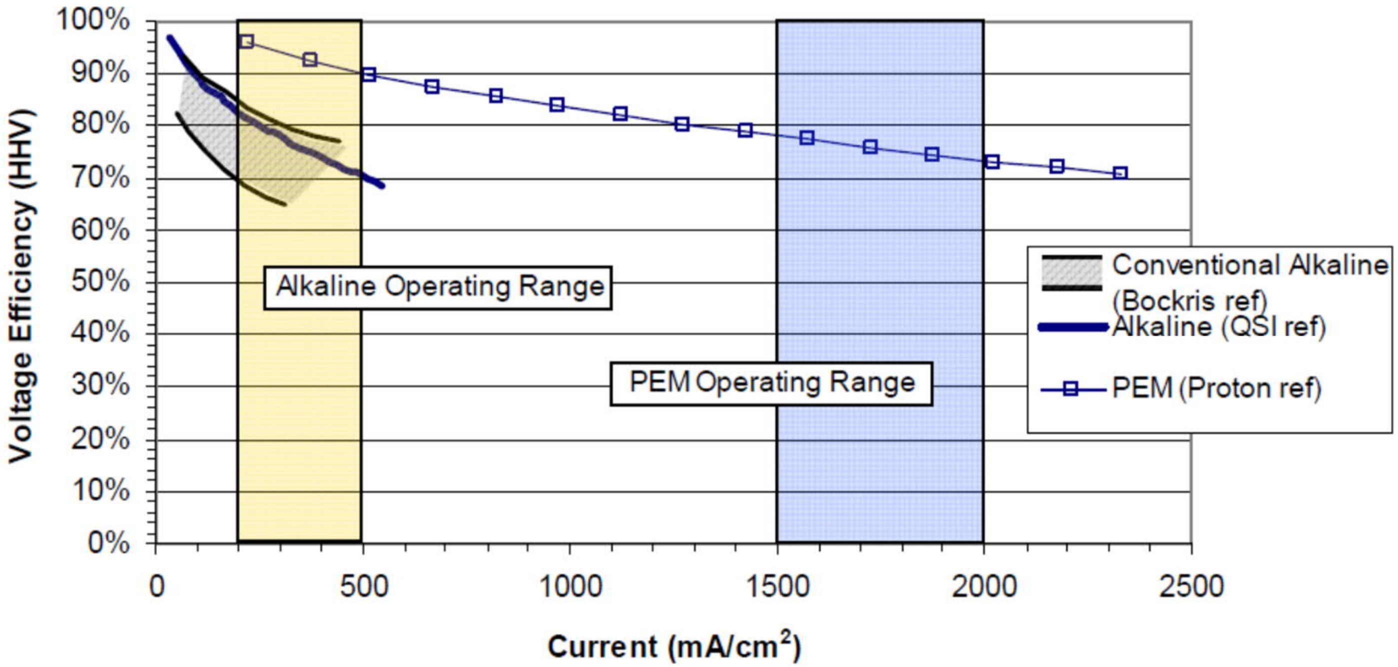
Electrolysers – Alkaline

Woikoski

- A mature technology
- Reliable and safe, lifetimes 20-30 years
- High production capacities: 500–760-Nm^3/h

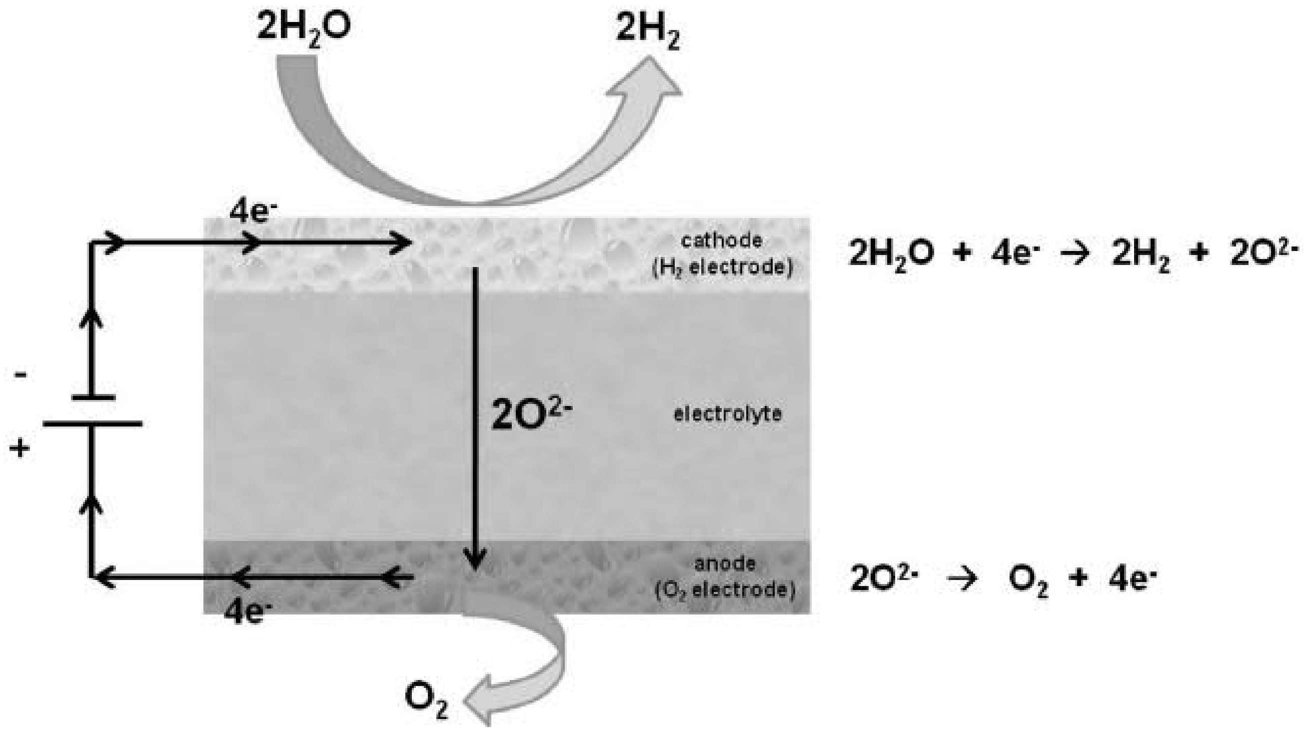
- Recent advances:
- Improved efficiency, reduction in operating costs
- Increased operating current densities, reduction in investment costs

Electrolysers – Alkaline vs. PEM



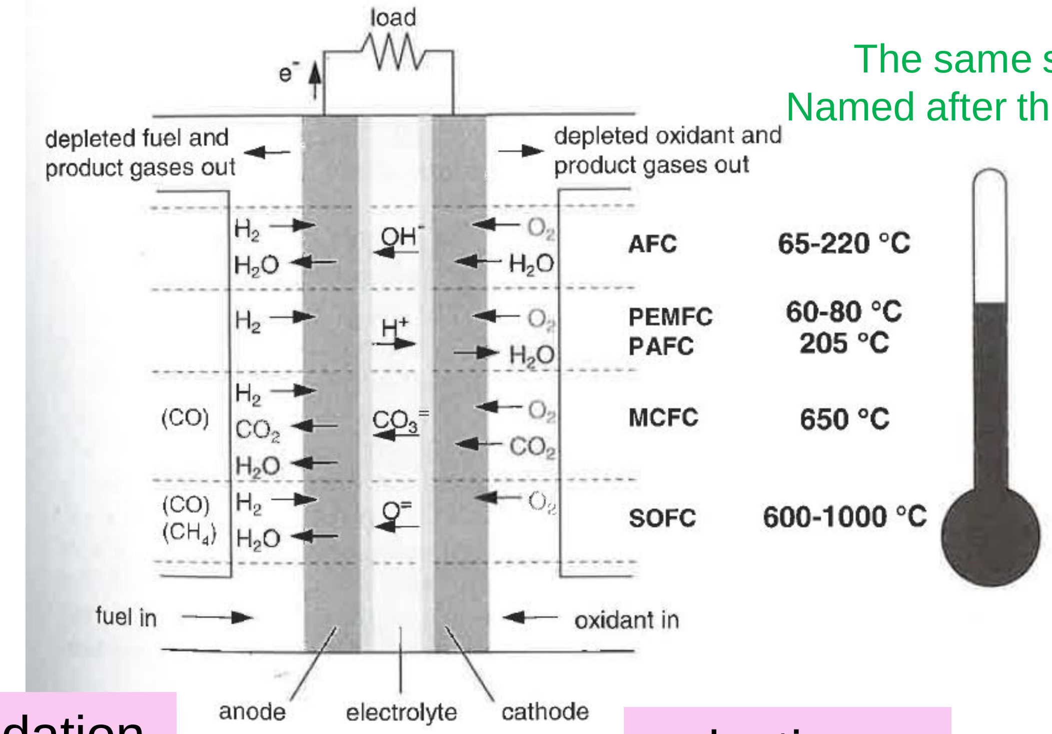
K.E. Ayers, ECS transactions, 33 (2010) 3-15

Electrolysers – Solid Oxide Electrolysis



Fuel Cells

The same structure
Named after the electrolyte



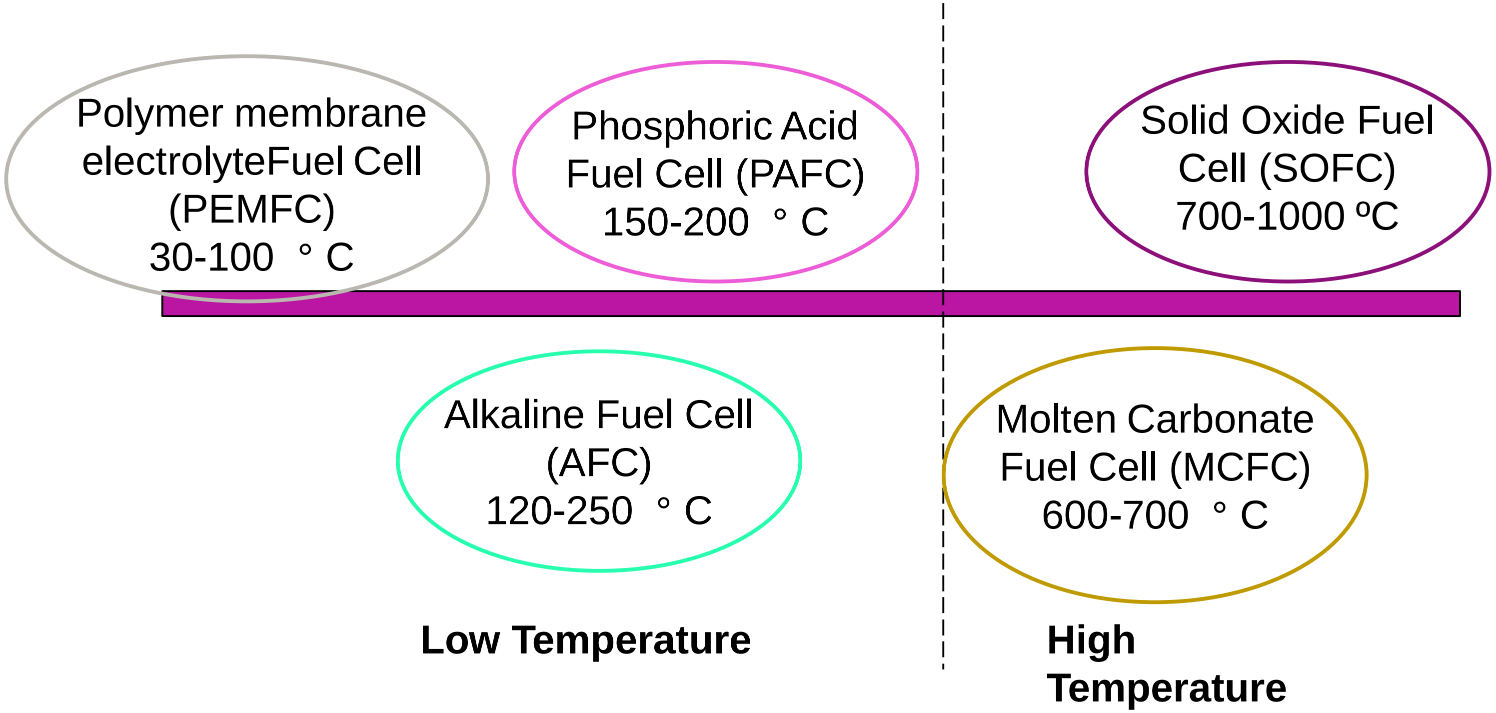
oxidation

reduction

Electrolyte: Movement of ions, non electron permiable

F. Barbir, PEM Fuel Cells – Theory and Practice, Elsevier, 2005.

Fuel Cells


Polymer membrane electrolyteFuel Cell (PEMFC) 30-100 ° C
Phosphoric Acid Fuel Cell (PAFC) 150-200 ° C
Solid Oxide Fuel Cell (SOFC) 700-1000 ºC
Alkaline Fuel Cell (AFC) 120-250 ° C
Molten Carbonate Fuel Cell (MCFC) 600-700 ° C
Low Temperature
High Temperature

KL1

Thermal material storage

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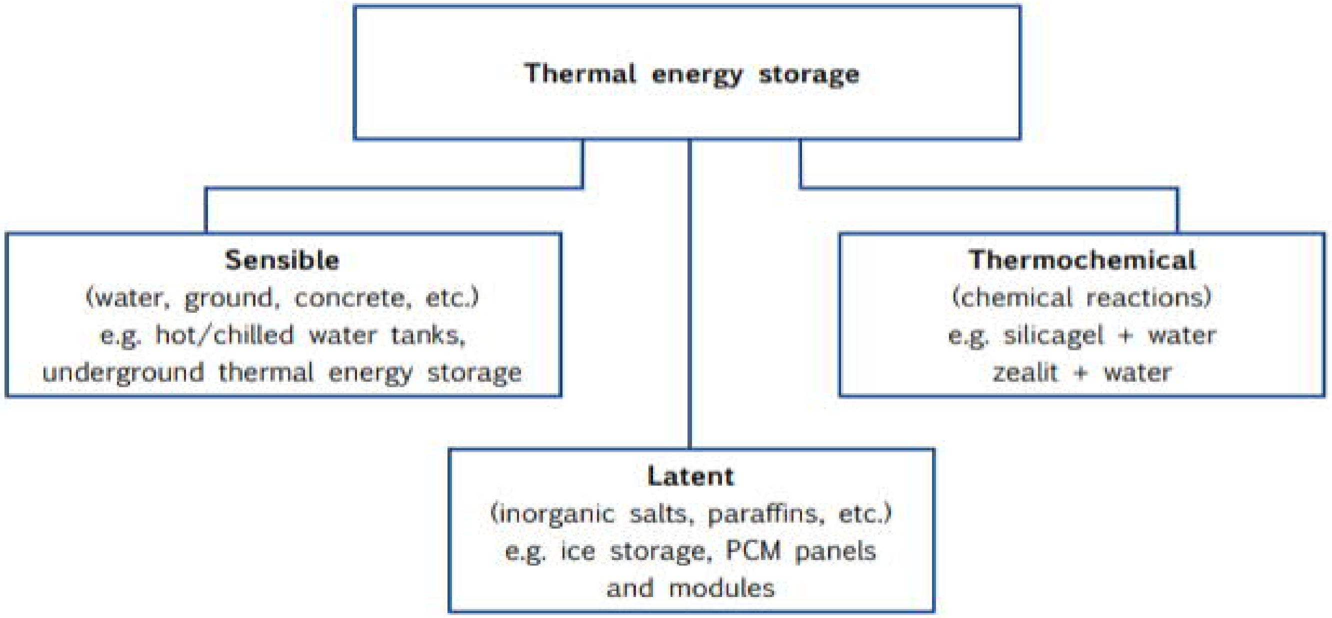
KL1 onko tämä "thermal storage material"?

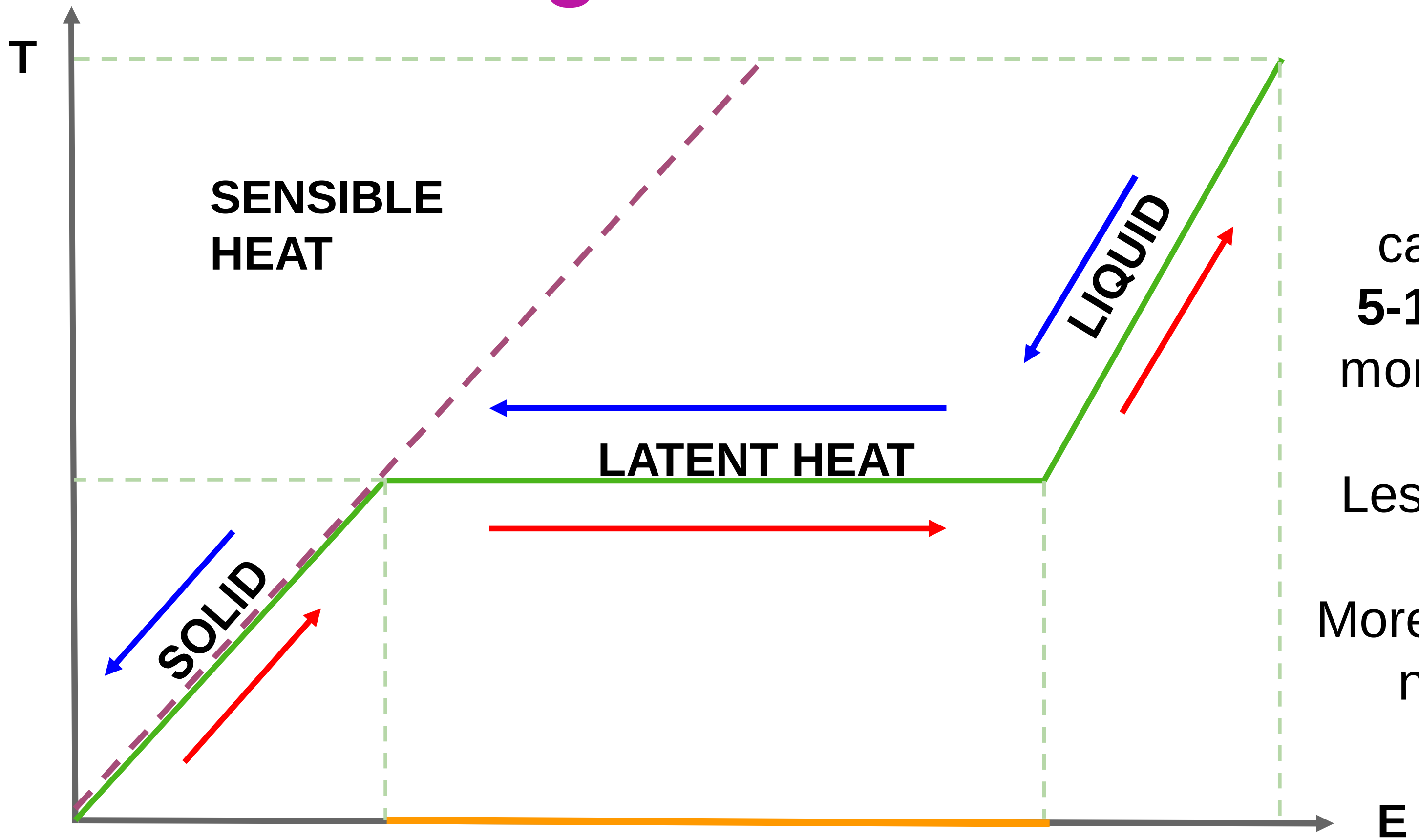
Knuutila Lotta, 24/08/2020

Different TES material systems



Simone Landolina, EUREC Agency, 2012, Strategic Research Priorities for Cross-cutting Technology, European Technology Platform on Renewable Heating and Cooling

Thermal storage materials

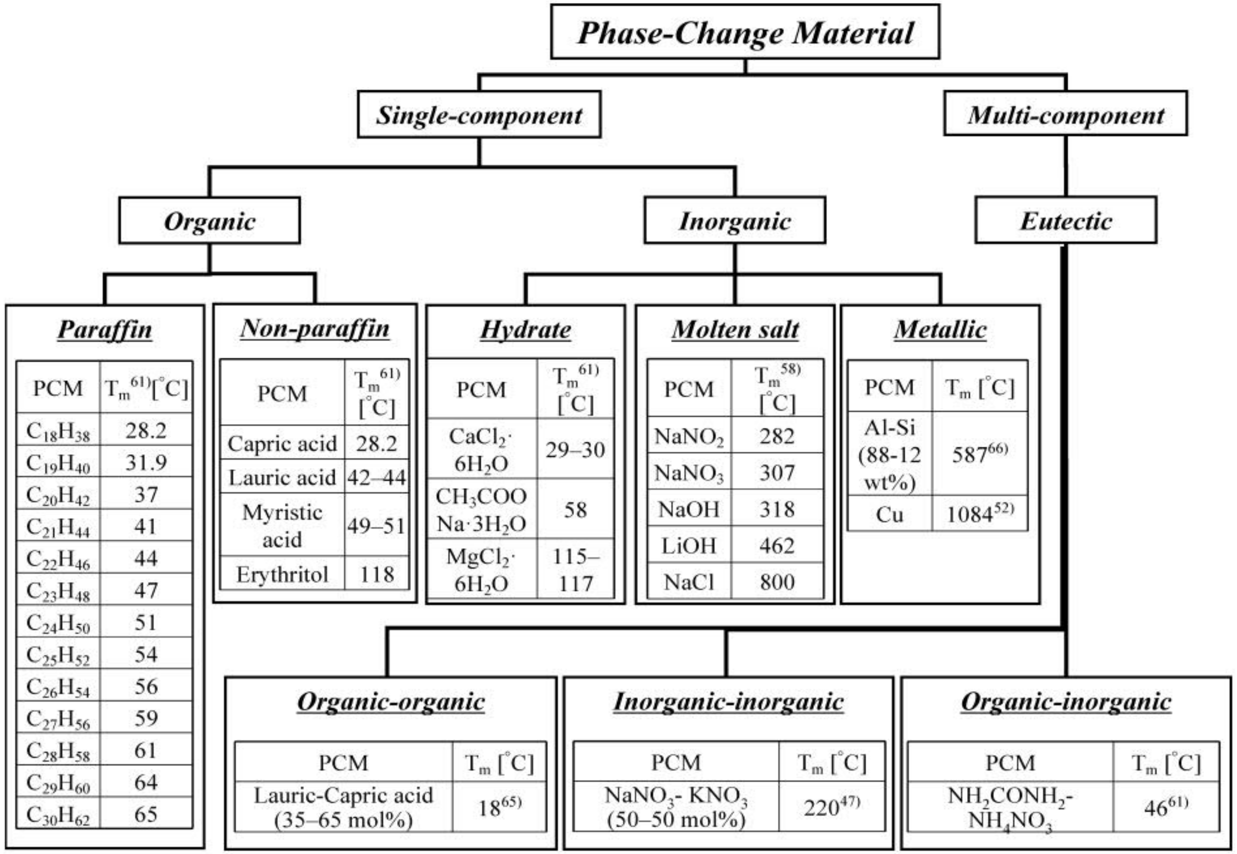


LHSS
can store
5-14 times
more energy

Less mature

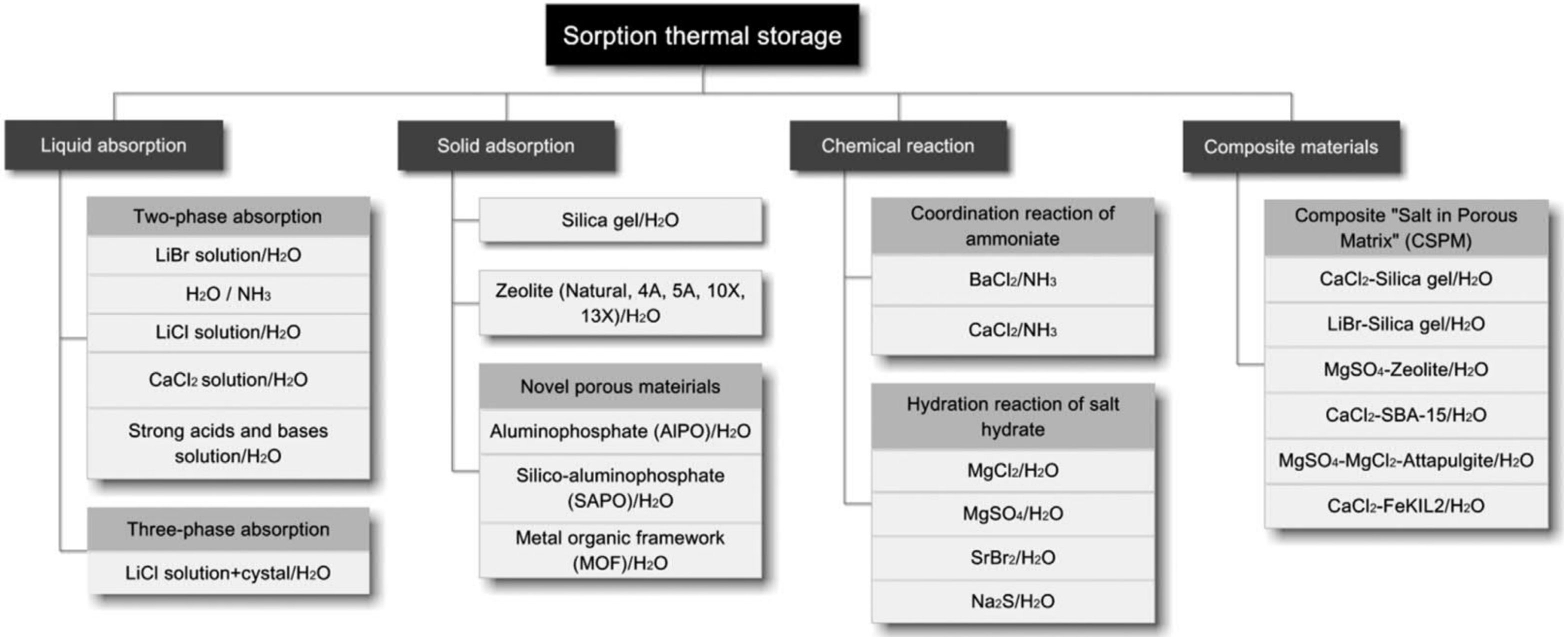
More research
needed

Sini Bäckman, Elias Länsisalo, Nicolas Piron & Joel Raikamo



Takahiro Nomura ,et al. Technology of Latent Heat Storage for High-Temperature Application: A Review, ISIJ International, Vol. 50 (2010), pp. 1229–1239

Thermochemical Energy Storage reactants



Yu, N., et al. Sorption thermal storage for solar energy. *Progress in Energy and Combustion Science.* (2013) DOI: 10.1016/j.pecs.2013.05.004

What did you learn?

Lecture Journal

What did you learn today that was new to you?

Do you want to reflect on your mind map?