Aalto-yliopisto

Workshop I Renewable Energy Systems

Annukka Santasalo-Aarnio

Who are we?

Student at CHEM (master’s or PhD)

Student at Energy Master’s (Energy conversion major)

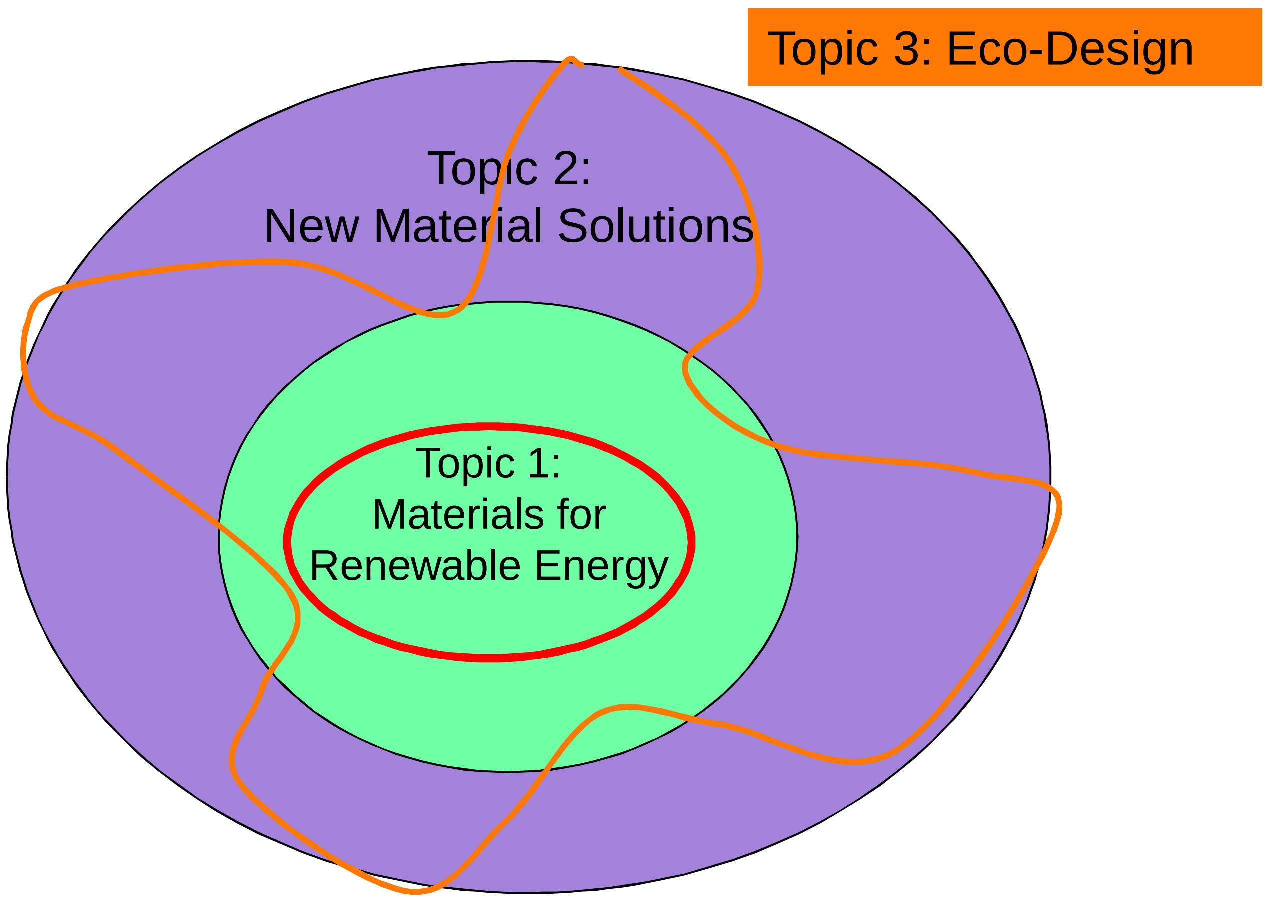
Other Student

Getting to know each other

- Name

- What you study (major/level)

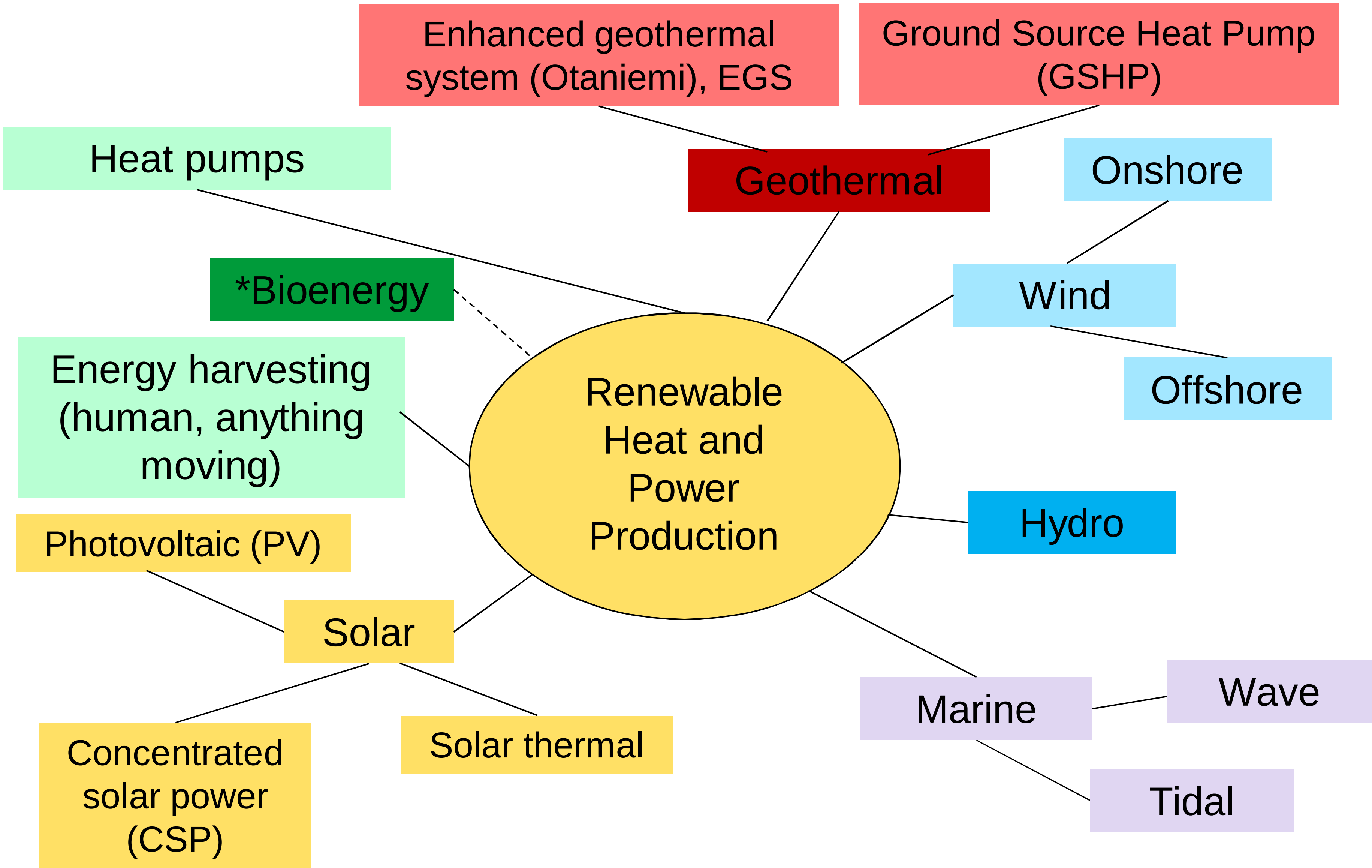
- Special interests on Renewable Energy systems


Topic 3: Eco-Design
Topic 2:
New Material Solutions
Topic 1:
Materials for
Renewable Energy

Which are the renewable energy systems that you know?

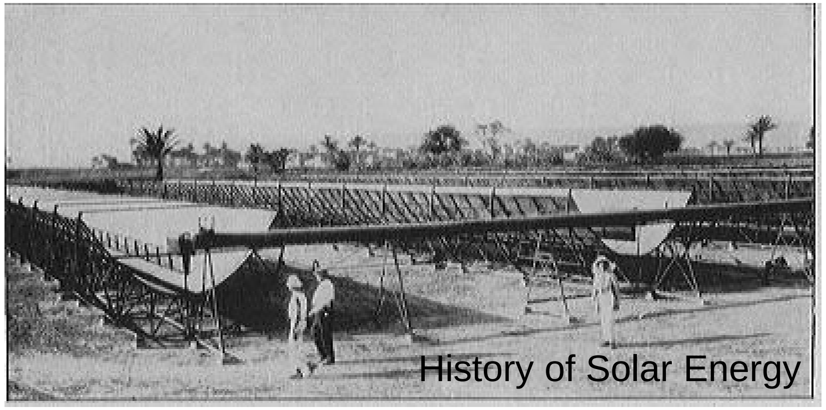
Renewable Heat and Power Production

Prepare a mindmap

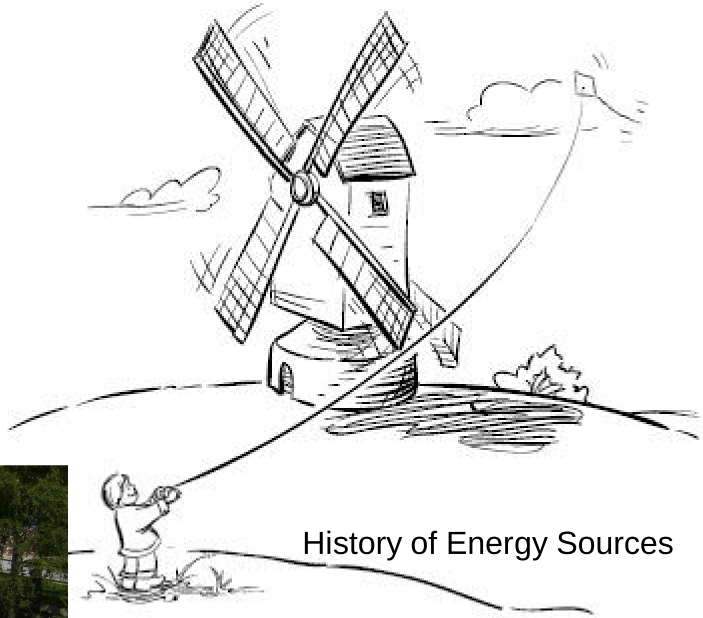


* Bioenergy is not focus on this course.

Renewable Energy – A new thing?



History of Solar Energy



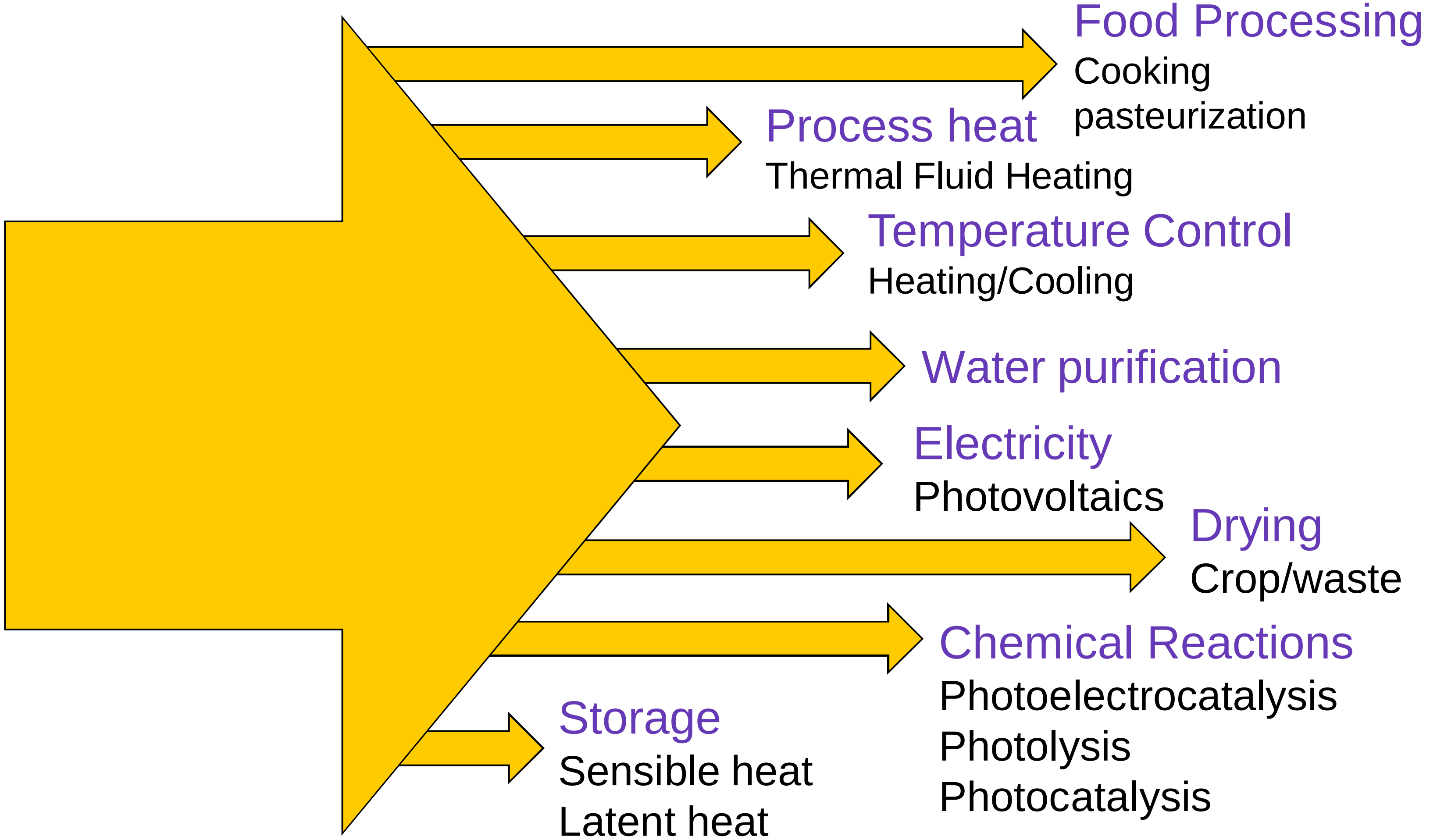
History of Energy Sources

Jämsänkoski, Wikimedia Commons

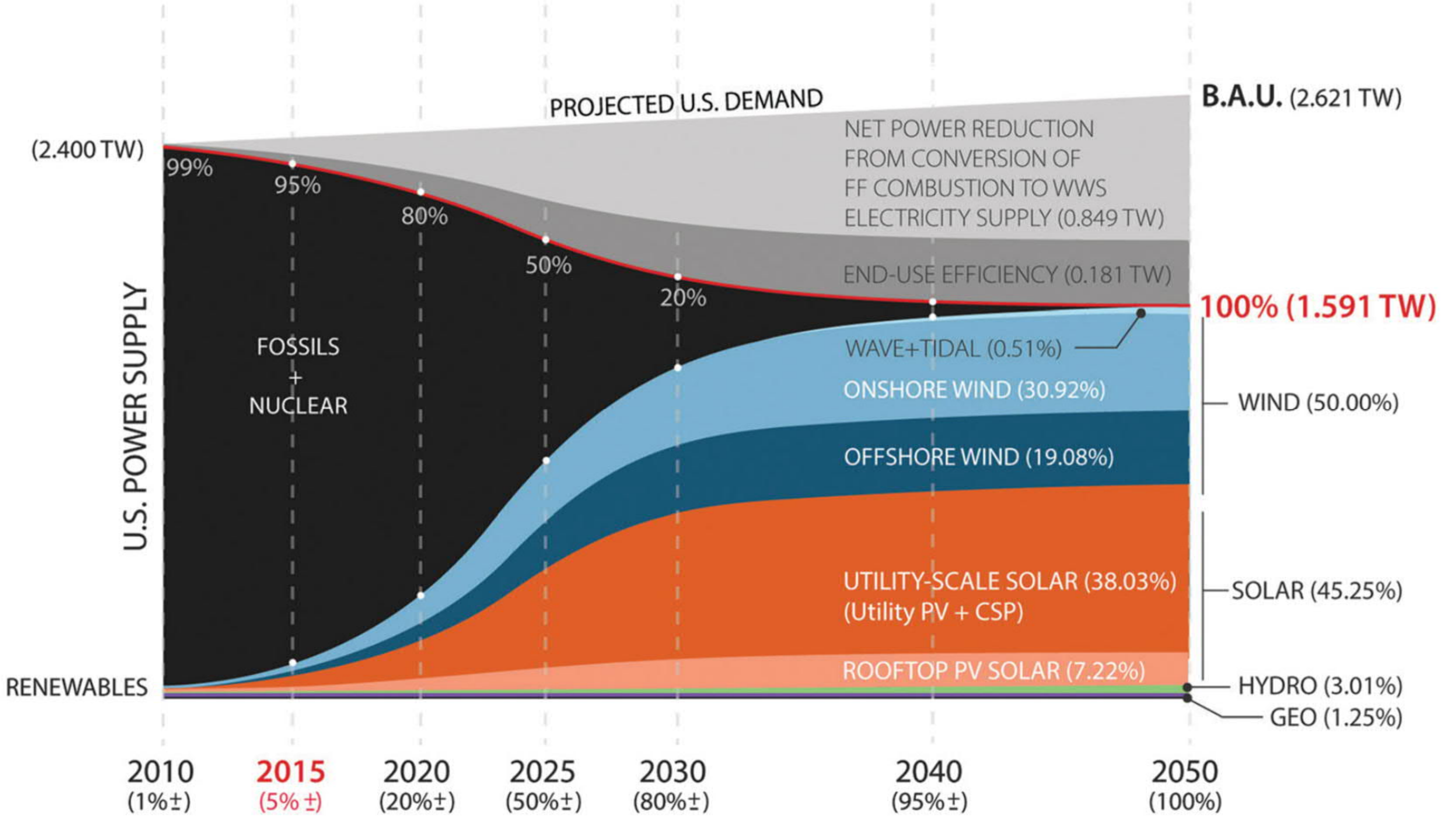
Can it be used in industrial scale?

Solar Energy utilization

where can it be used?



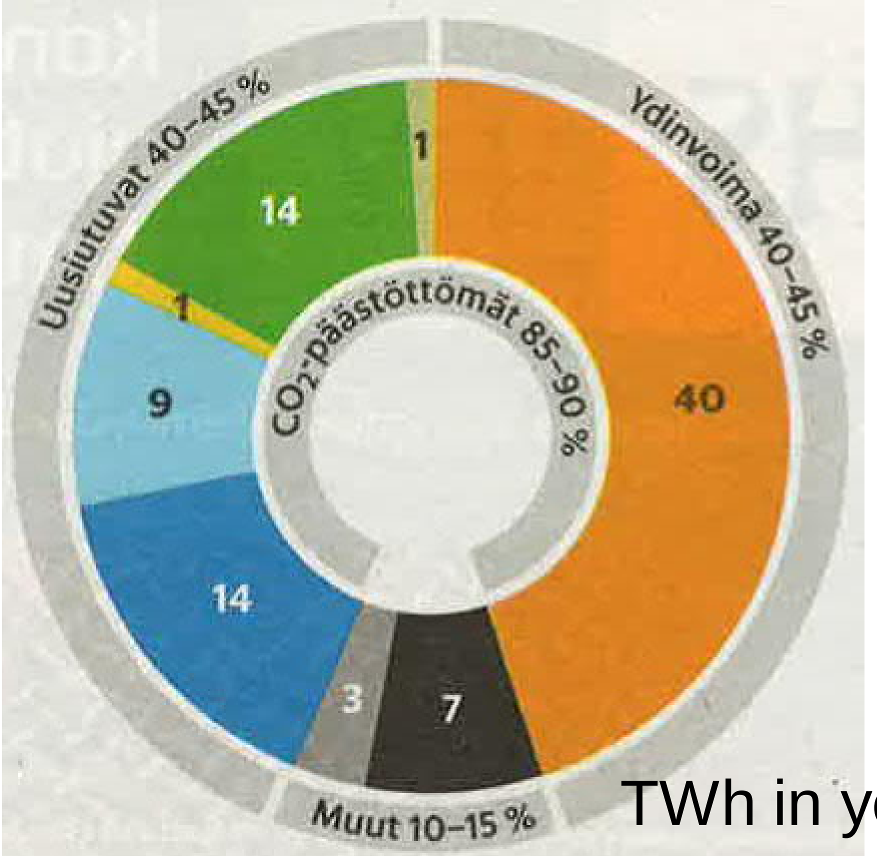
Trend of change



Energy Environ. Sci., 2015, 8, 2093--2117

What could the situation look 2030 Finland

Renewables
40-45 %
Waste
Bioenergy
Solar
Wind
Hydro



Nuclear power
40-45 %

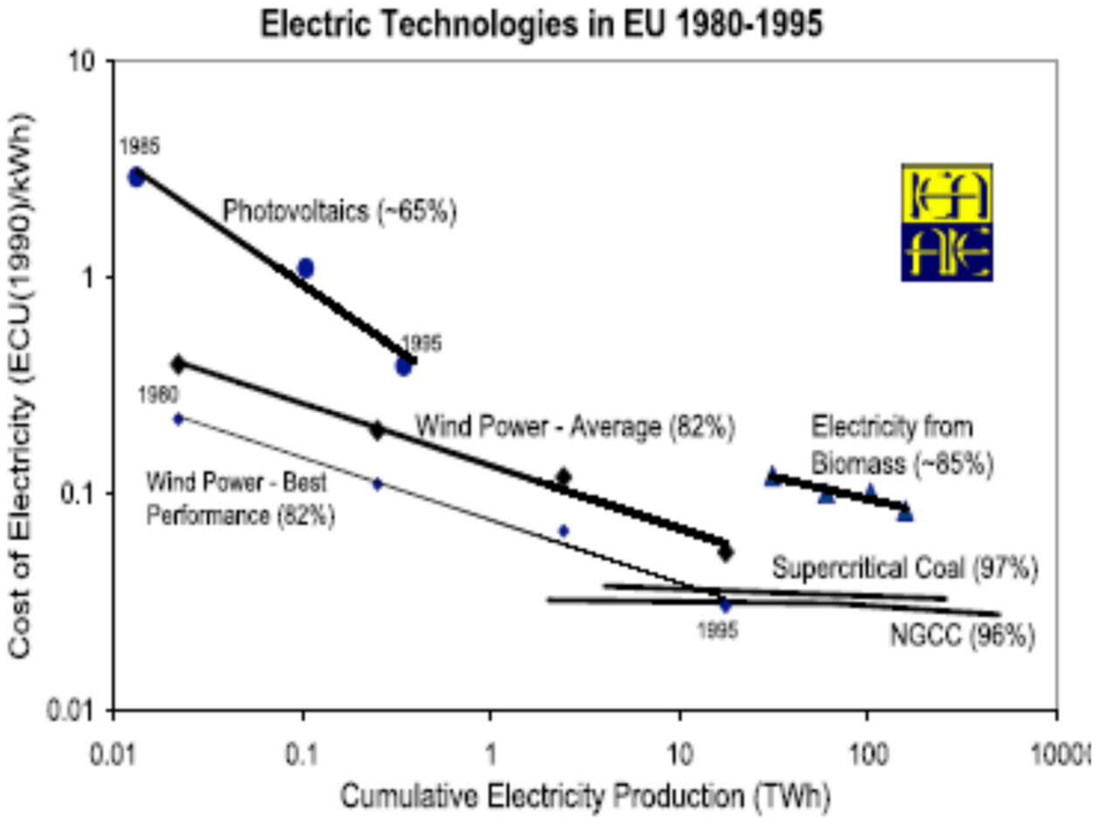
TWh in year

Others
10-15 %
Fossil
Peat

Aalto University

Source: Helsingin sanomat 2016, Heikki Arola, Data: Energiateollisuus

Cost development



Topic 1 – Renewable Energy Systems

Intorduction
to
Technologies

Solar Energy - differences

Solar Photovoltaic

- Low efficiency 10-30%
- Wide use
- Expensive materials

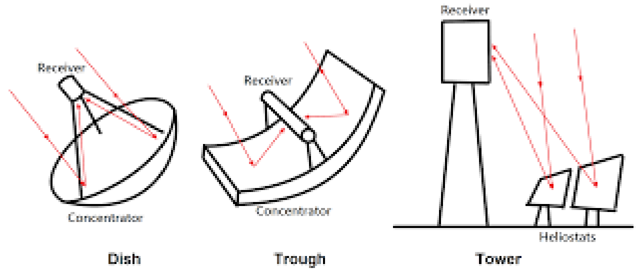
www.365solar.co.uk

Solar Heat

www.zenenergy.com.au

- Higher efficiency (40-70 %)
- Limited use
- Cheap materials

efergy.com

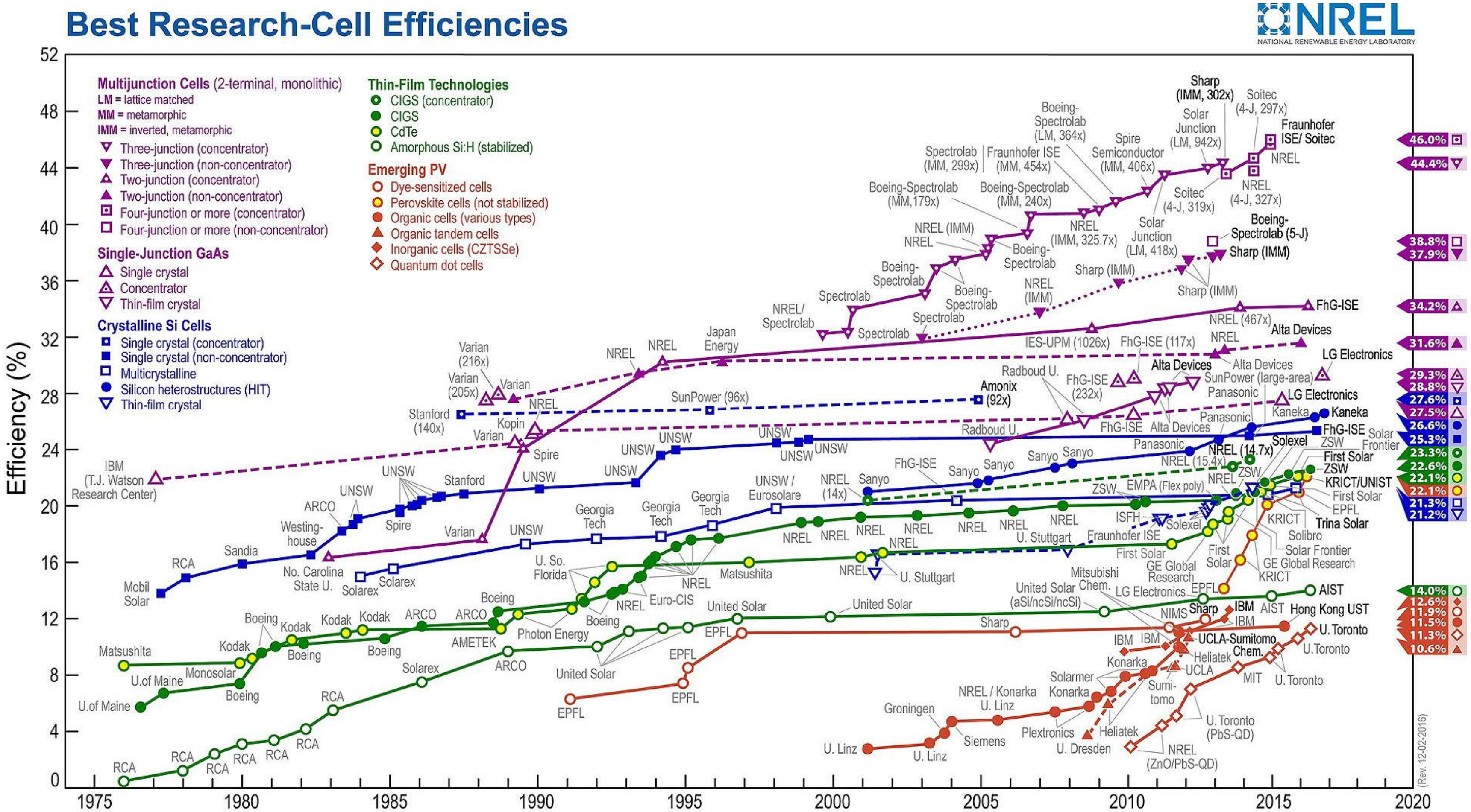


commons.wikimedia.org

Concentrated Solar Power (CSP)

- Higher efficiency (25-60 %)
- Targeted use [high temp.]
- Cheap materials

Solar PV efficiencies

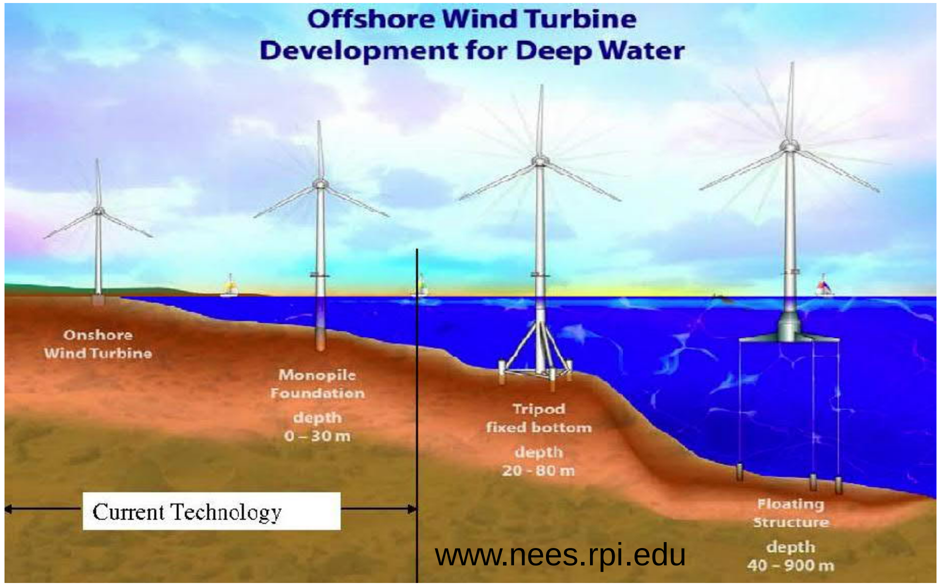


National Renewable Energy Laboratory, 2016

Wind Energy - differences

Onshore

Offshore

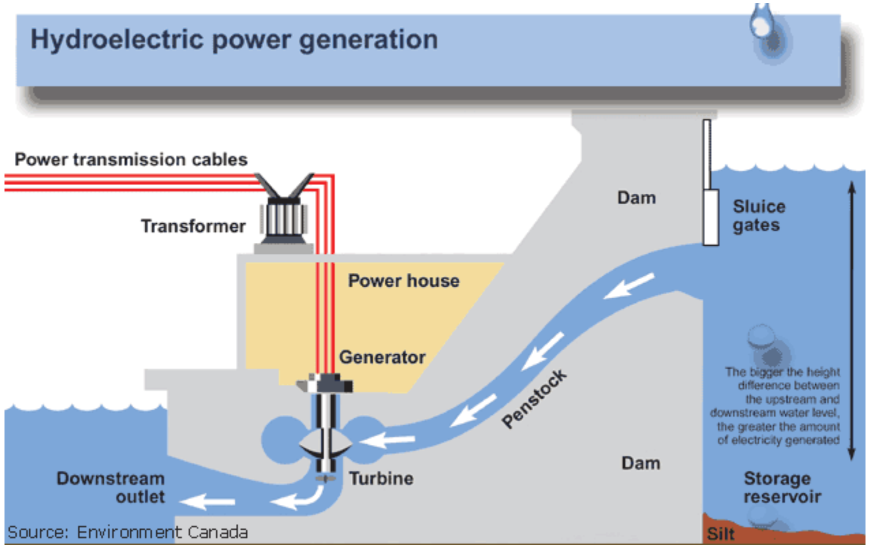


Why?

Differences in material selection…

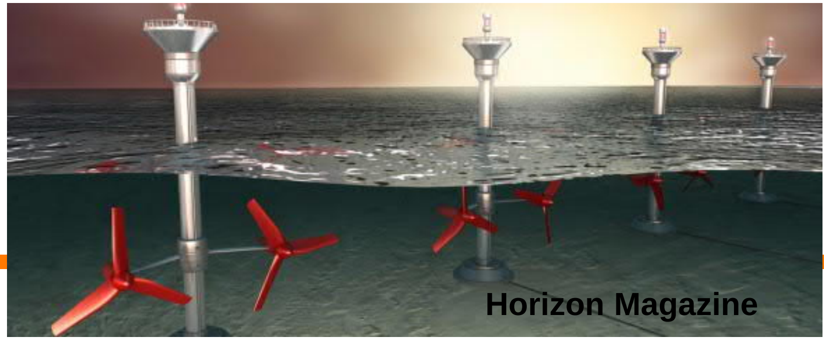
Hydro and Marine Energy

Hydro



Wave Energy

Tidal Energy



Energy Production – Sum up

"It is clear that no single energy source is going to take over from the polluting fossil fuels in the new century"

By: I.B Fridleifsson

How can renewable energy systems be combined?

Renewable Energy - Fluctuations

Energy production

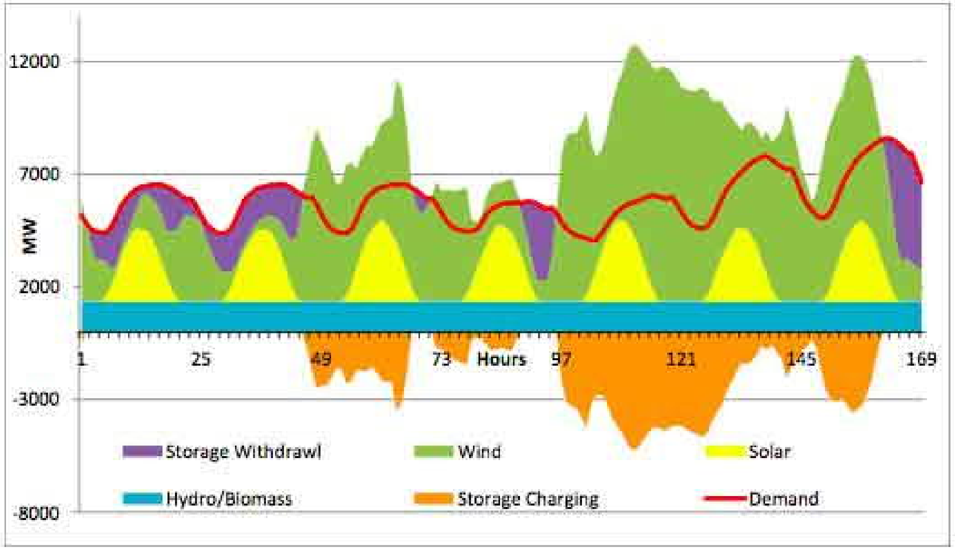
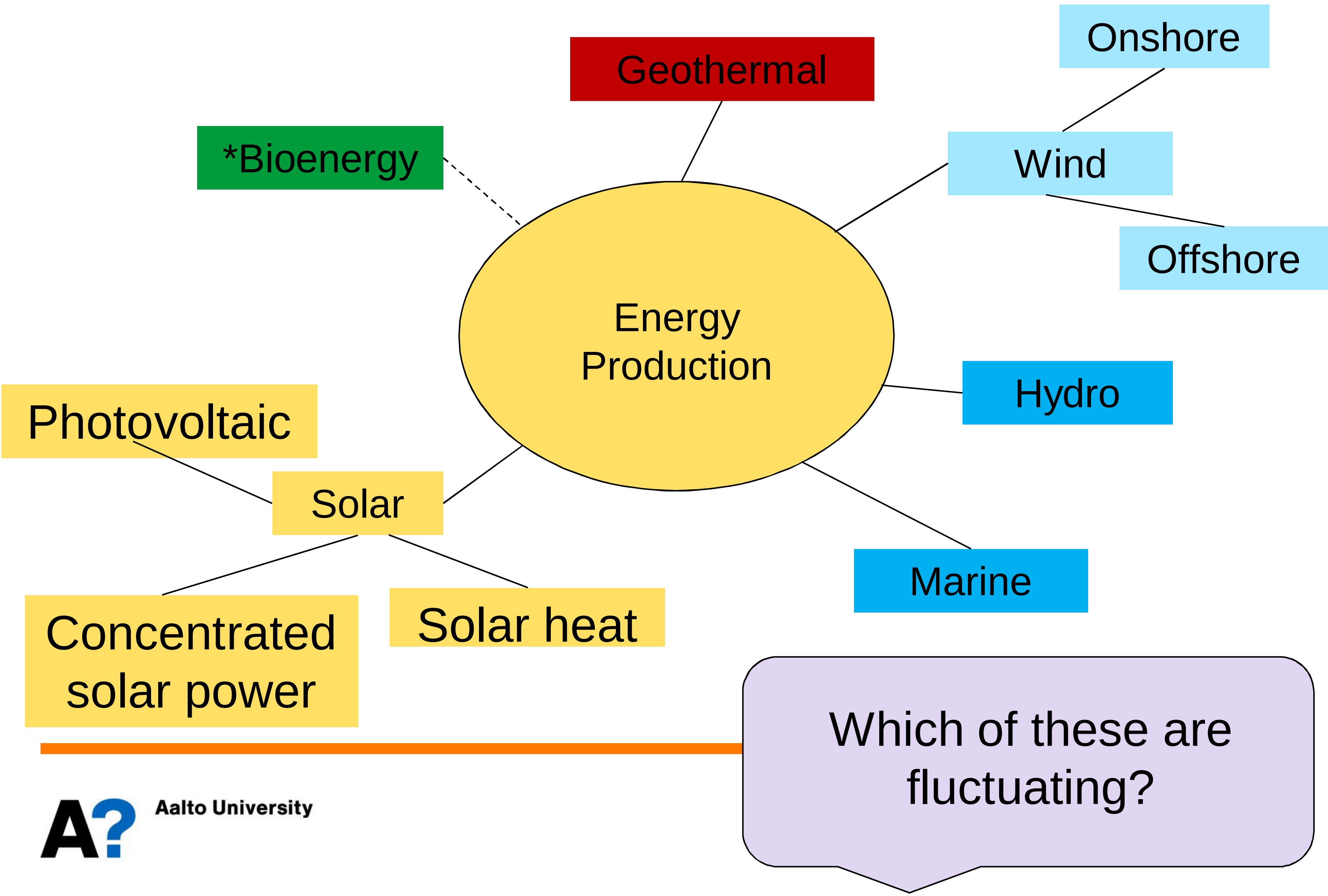
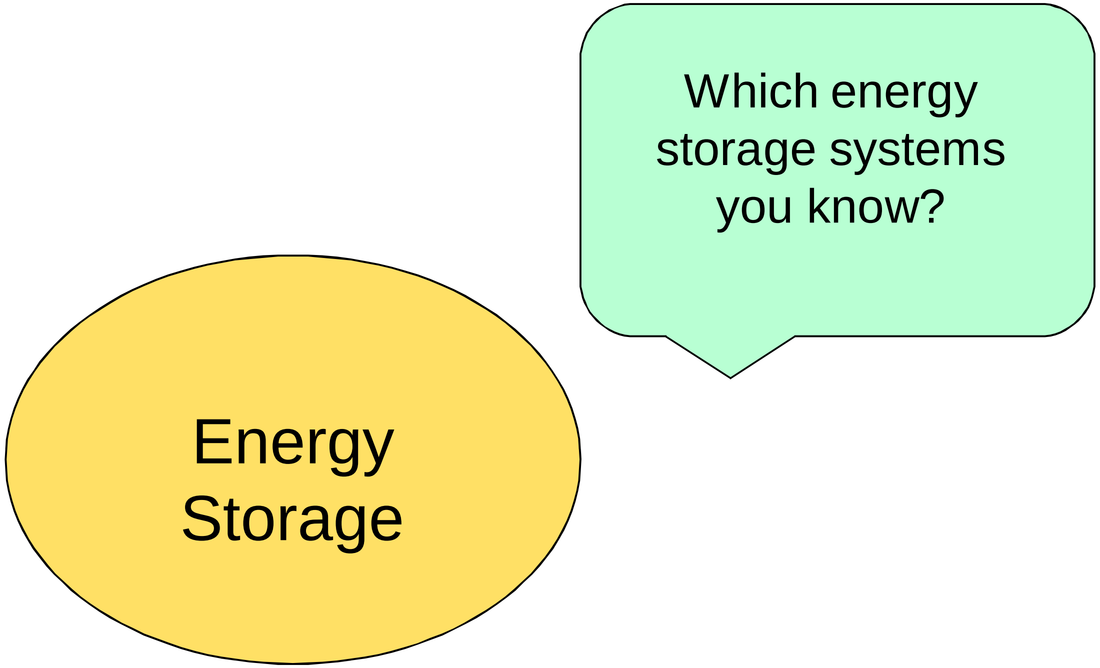


Figure III-7: Hourly supply and demand, with storage. July 11-17, 2007. *Source: IEER.*

Renewable energy

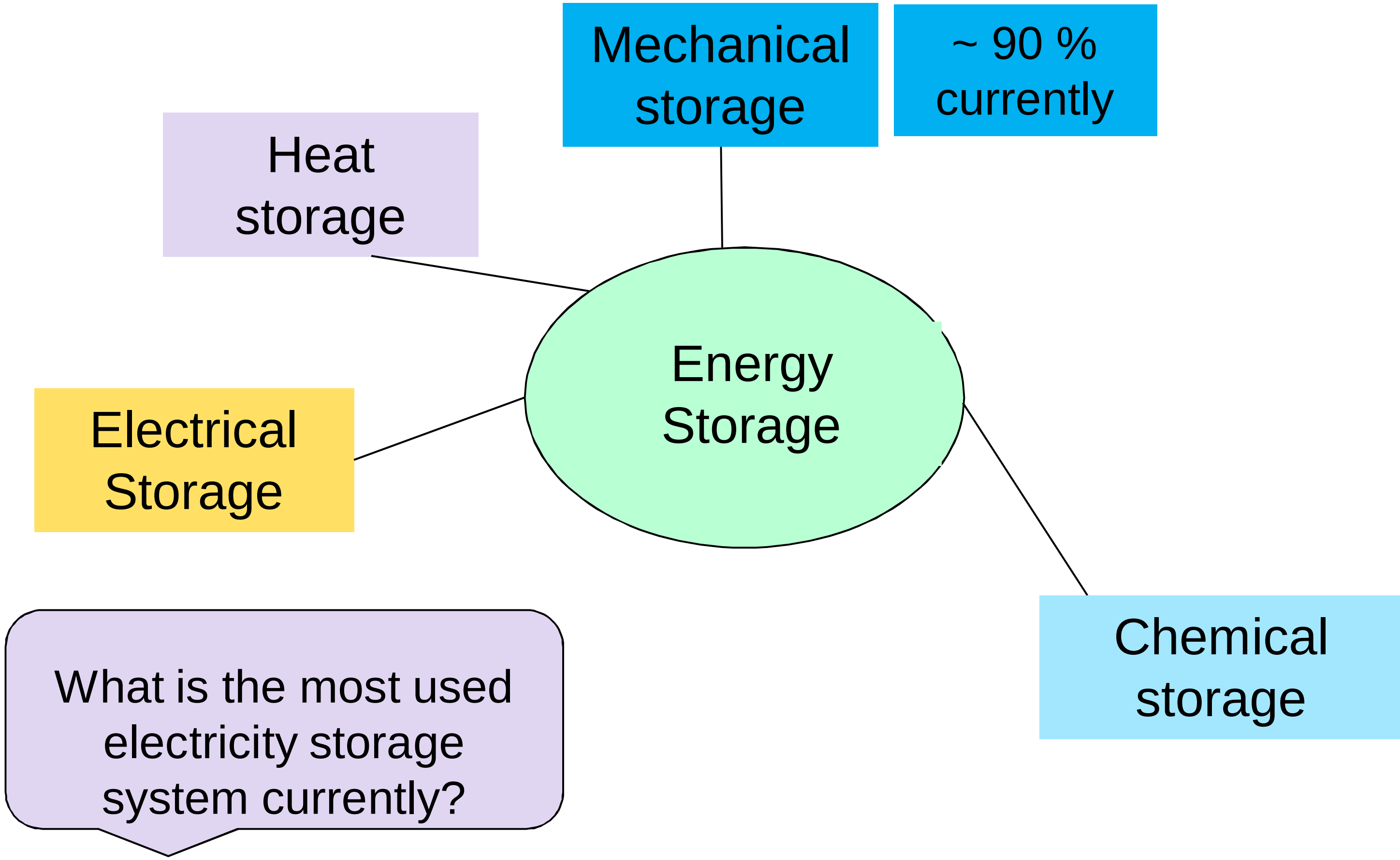


Energy Storage

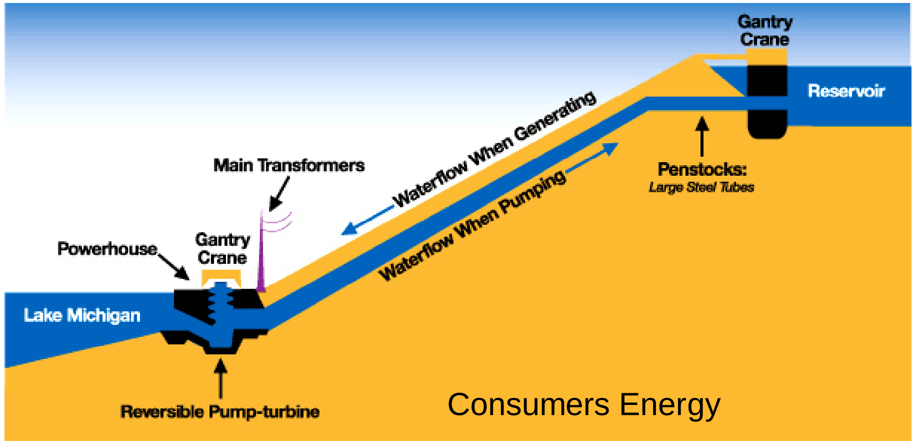


Prepare a mindmap

Energy storage systems



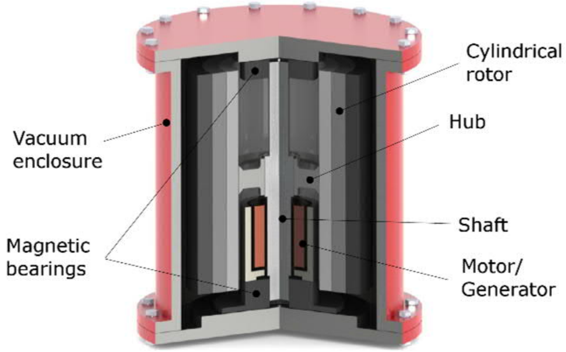
Mechanical Storage (90 %)



Pumped water energy
- Low cost
- Demands proper location, reservoir

Compressed air in a tunnel/old mine
- Low cost
- Demands proper location

Flow wheel
- Higher cost
- Flexible to install
- Low capacity (now)



au.pinterest.com

No interesting material questions

Transport

Electric Vehicle

Fuel Cell Vehicle

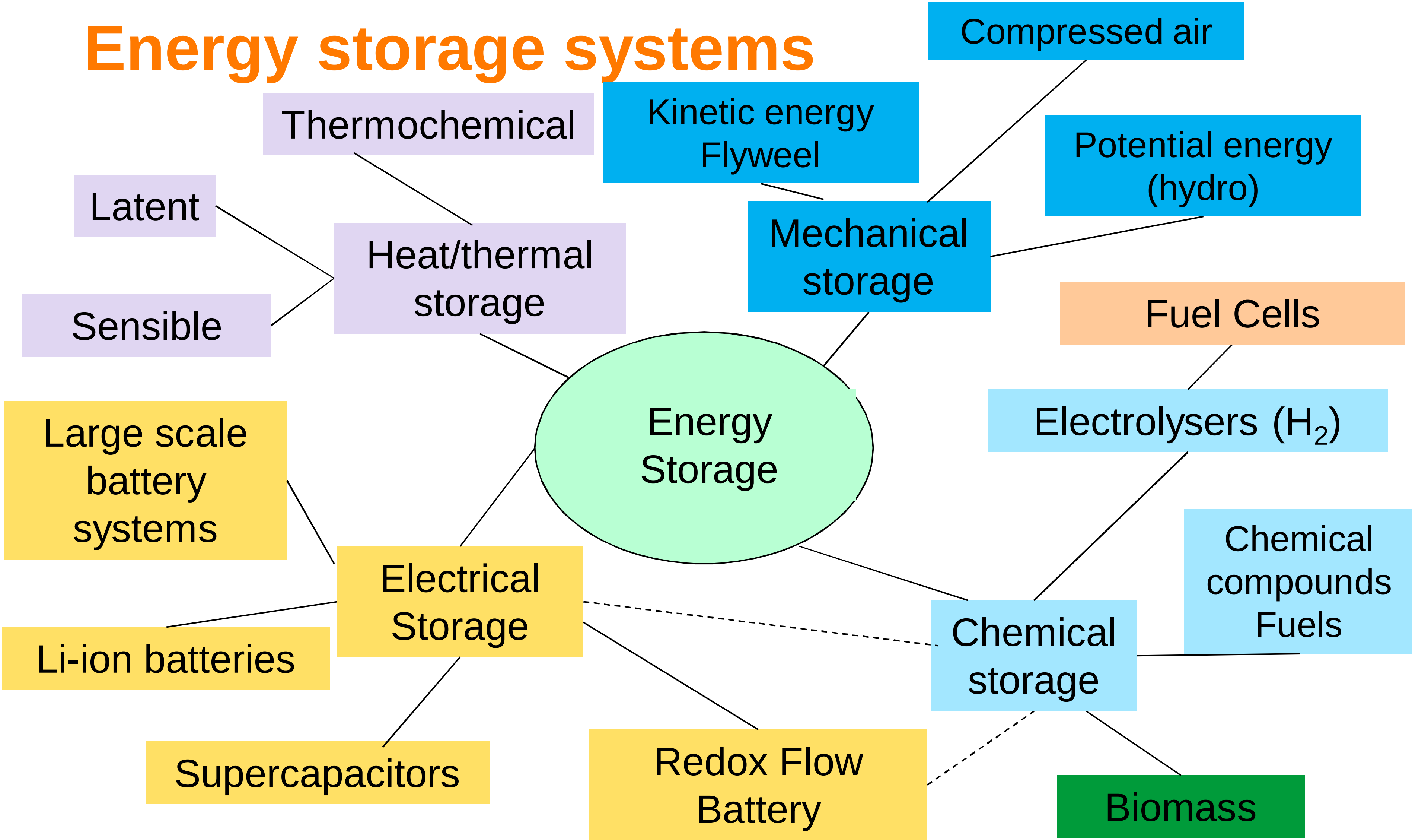
Storage is needed also for Transport

Electrical Storage

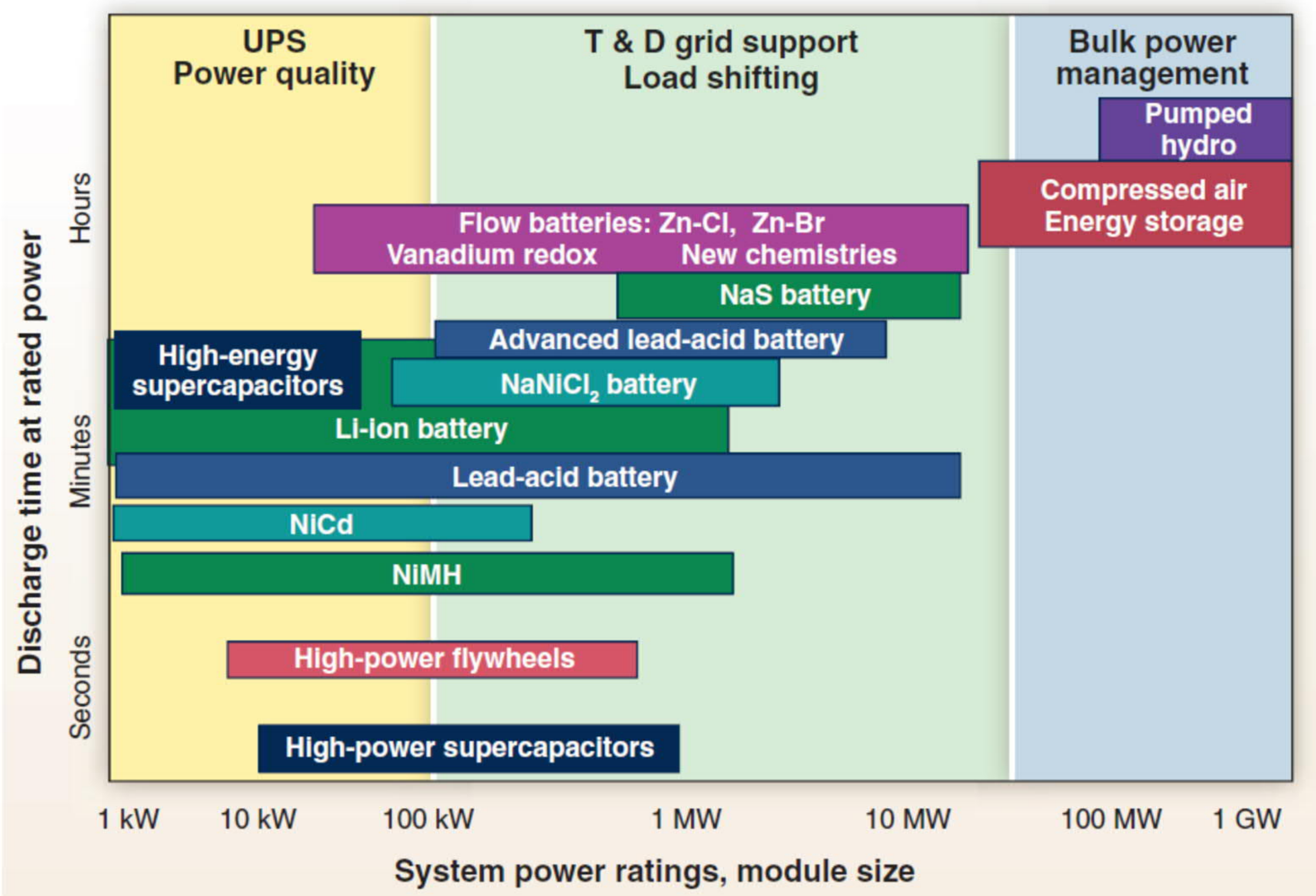
Chemical storage

From reading at home:
30 % of all emissions are from transport

Energy storage systems



Energy storage – Technical issues

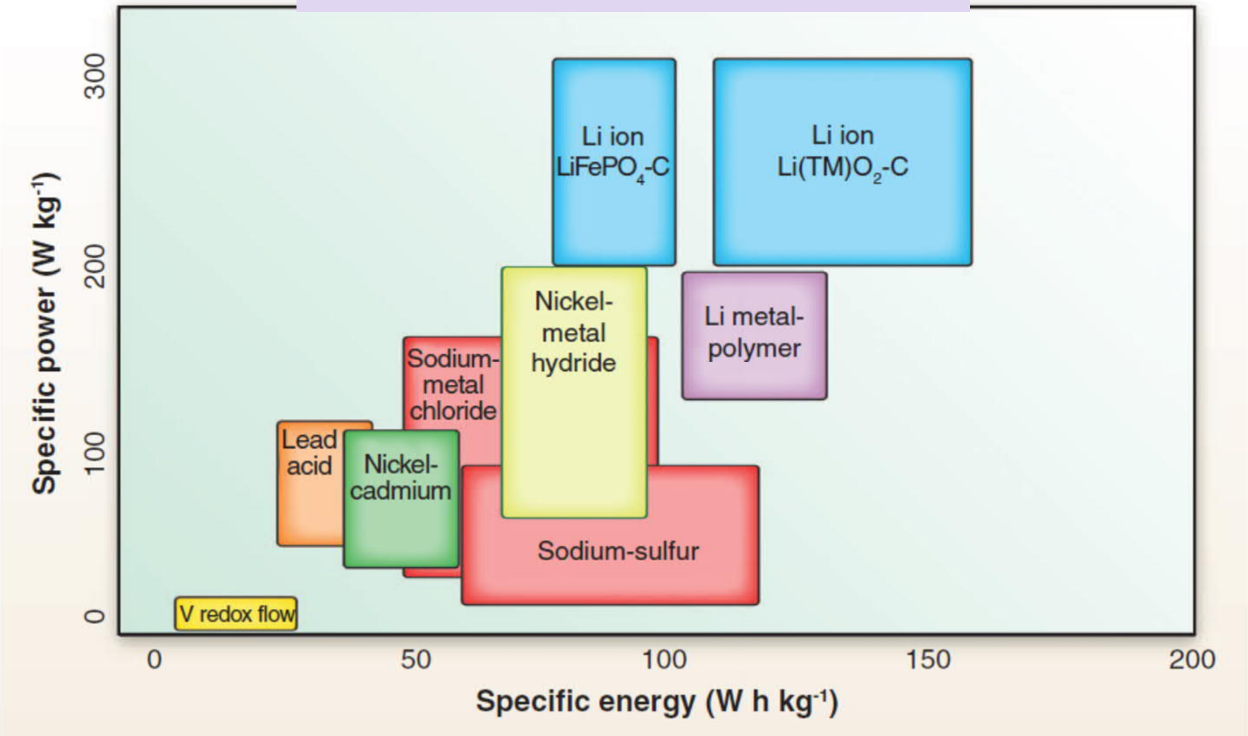


Aalto University

B. Dunn et al. “Electrical Energy Storage for the Grid: A Battery of Choices, Science 334 (2011) 928-935

Batteries

For which type of application!



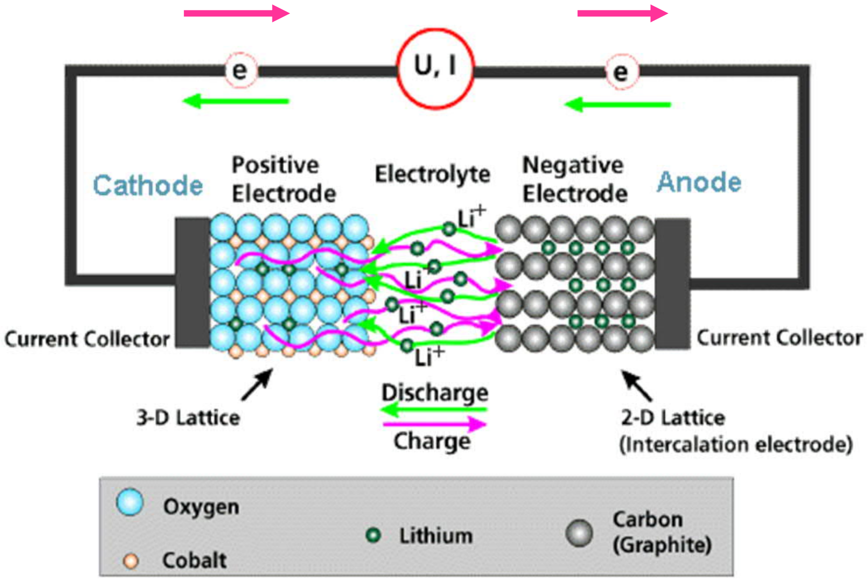
Primary batteries = Discharged only ones

Secondary batteries = Can be charged and discharged various times

B. Dunn et al. “Electrical Energy Storage for the Grid: A Battery of Choices, Science 334 (2011) 928-935

Li-ion Batteries

Li-ion batteries

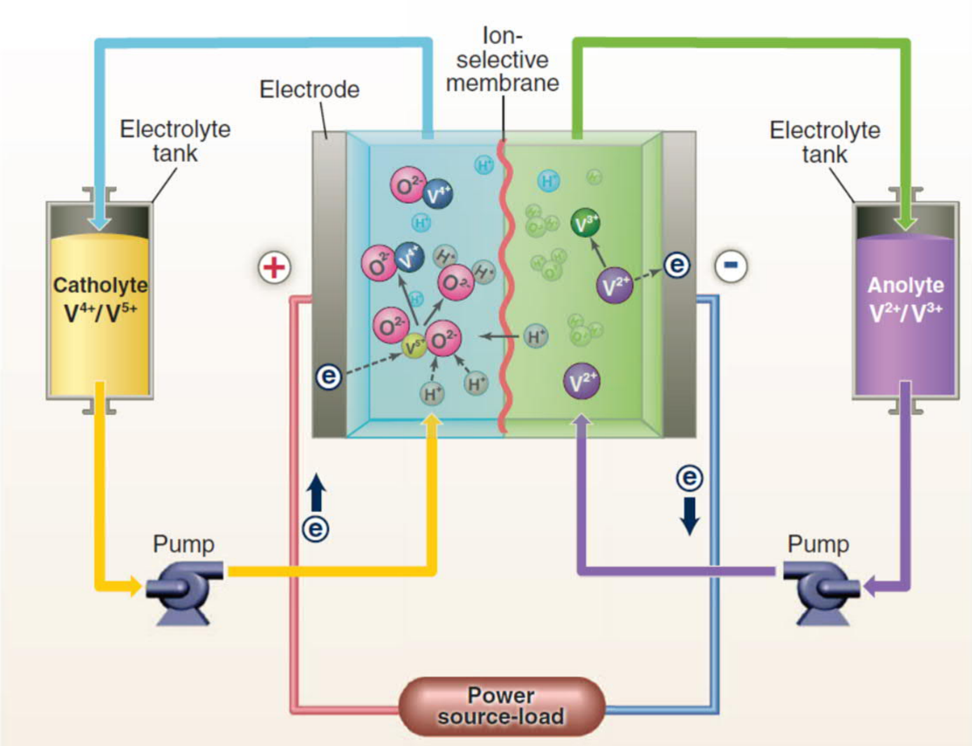


www.tf.uni-kiel.de

Large battery pack for EV

3.7V 600mAh Lithium Polymer Battery
for Bluetooth Headset

Vanadium Flow Battery



Reactions

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

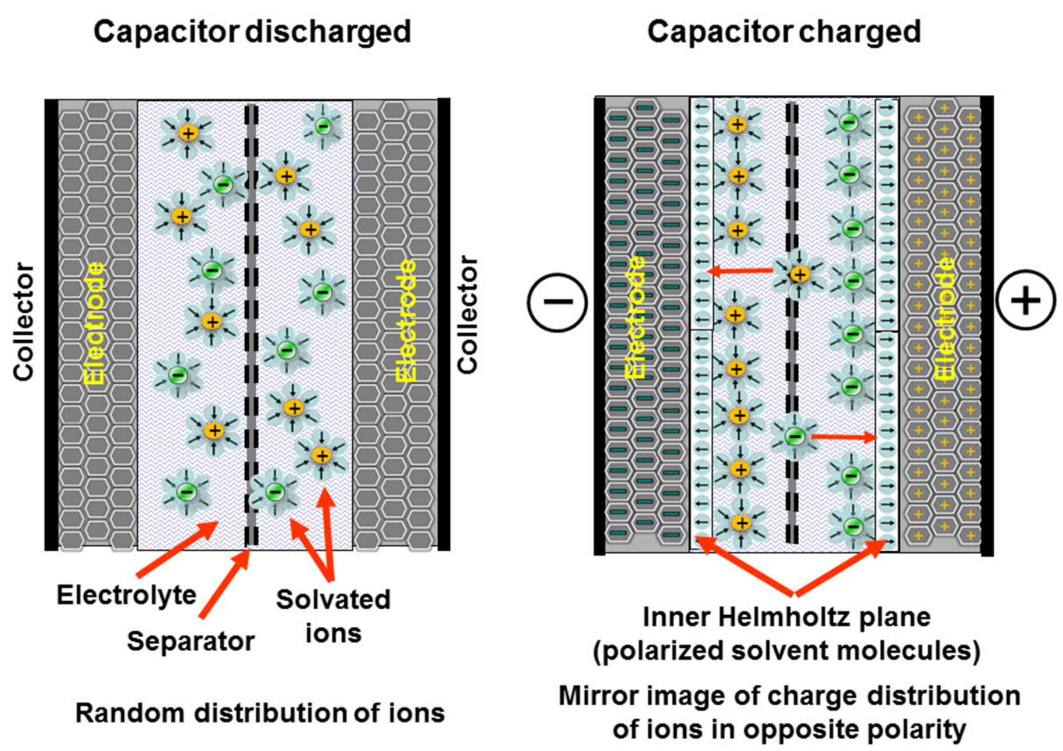
Negative electrode:
$V^{3+} + e^{-} \rightleftharpoons V^{2+}$

Requirements

Large space for the compartments
Material issues…

B. Dunn et al. “Electrical Energy Storage for the Grid: A Battery of Choices, Science 334 (2011) 928-935

Supercapacitors

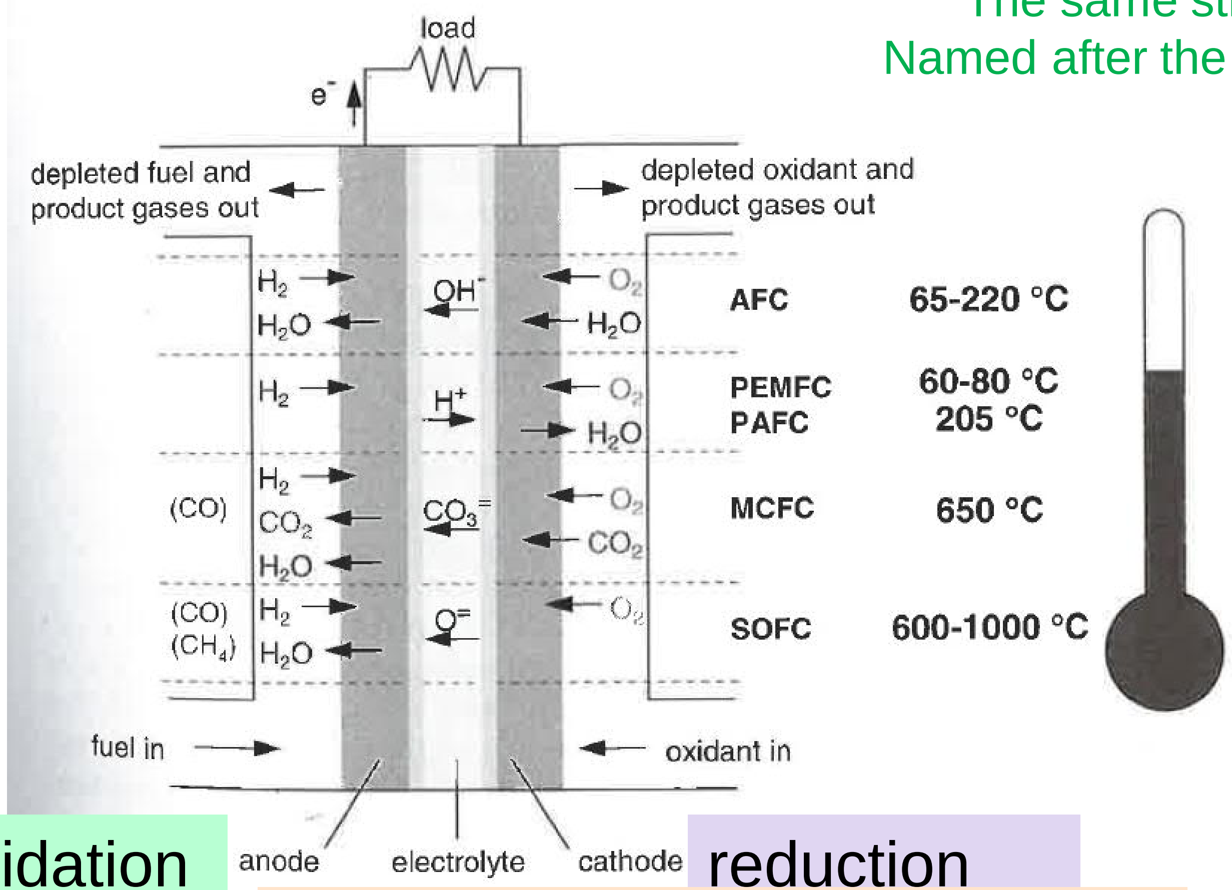


wikipedia.org

- Can accept and deliver charge much faster than batteries
- Combined with batteries
- Excellent for EV + FCV

Fuel Cells

The same structure
Named after the electrolyte



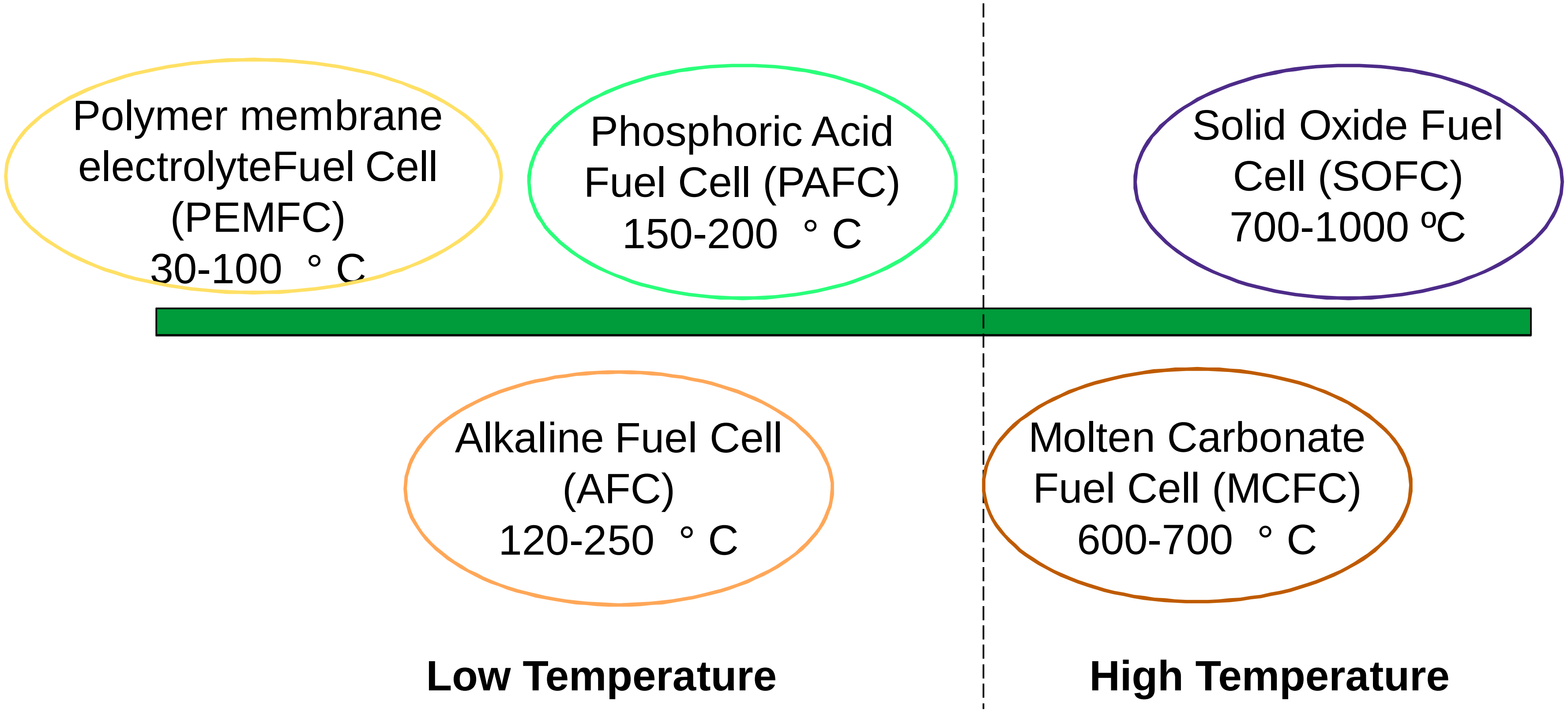
oxidation

reduction

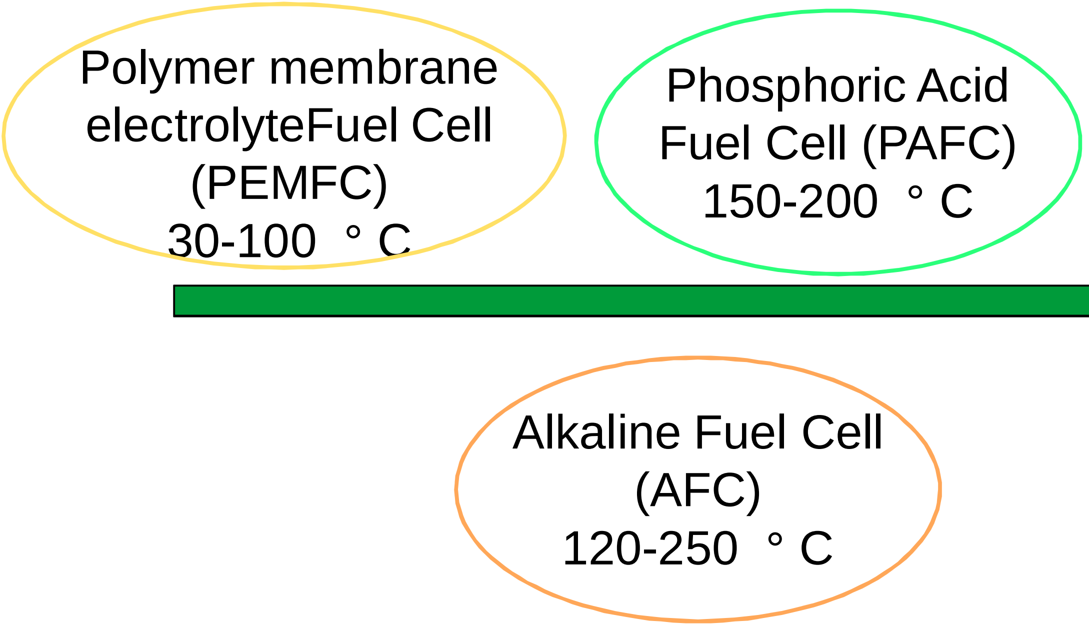
Movement of ions, no electron permiation

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

Fuel Cells



Low Temperature

PEMFC have a solid polymer membrane as the electrolyte material. Therefore they operate under 100 ° C where water is still in liquid form.

They are used in small scale applications such as laptops as well as in fuel cell cars.

Fuel Cells

Low Temperature

Polymer membrane electrolyteFuel Cell (PEMFC) 30-100 ° C

Phosphoric Acid Fuel Cell (PAFC) 150-200 ° C

Alkaline Fuel Cell (AFC) 120-250 ° C

AFC were the first commercial fuel cells in the 1960s. They have liquid KOH as an electrolyte and use chaper Ni, Ag or metal oxides for catalyst.

They are still in use for space applications, however, AFCs are intolerant for CO_2 poisoning and therefore have limited use in earth.

Fuel Cells

Low Temperature

Polymer membrane electrolyteFuel Cell (PEMFC)
30-100 ° C

Phosphoric Acid Fuel Cell (PAFC)
150-200 ° C

Alkaline Fuel Cell (AFC)
120-250 ° C

PAFC use concentrated phosphoric acid as the electrolyte material and mainly use Pt for catalyst.

They have been installed for container packages for stationary electricity generation.

Fuel Cells

High Temperature

MCFC use a mixture of alkali (Li, Na, K) carbonates as the electrolyte material that forms highly conductive molten salt at 600-700 ° C. No need for noble catalysts.

Solid Oxide Fuel Cell (SOFC)
700-1000 ºC

These cells are precommercial/demonstartion stage for stationary power generation.

Molten Carbonate Fuel Cell (MCFC)
600-700 ° C

Fuel Cells

High Temperature

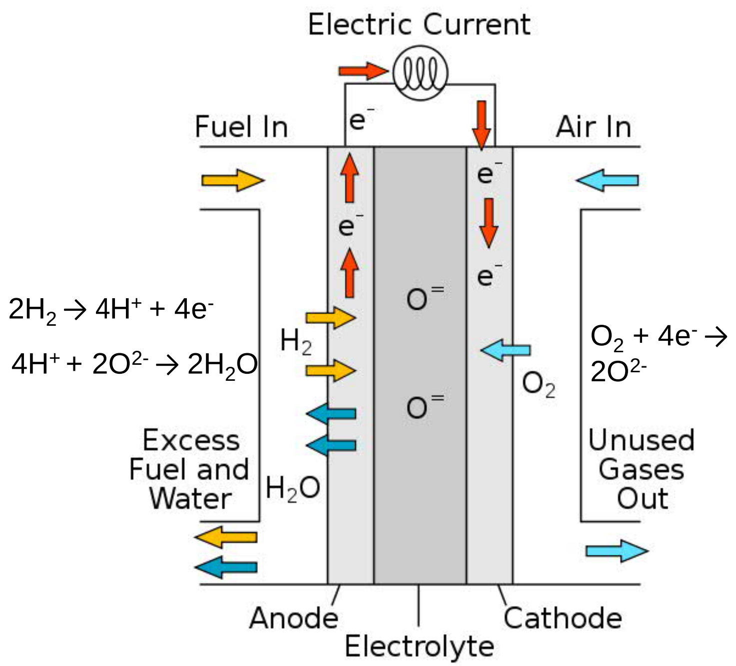
SOFC use a solid oxide (most often Ytria-stabilized Zirconia (YSZ) as the electrolyte material. The charge carrier is an O^{2-} ion.

Solid Oxide Fuel Cell (SOFC)
700-1000 ºC

These cells are precommercial/ demonstartion stage for stationary power generation.

Molten Carbonate Fuel Cell (MCFC)
600-700 ° C

SOFC
Solid Oxide Fuel Cell



- **O^{2-}** ion as the charge carrier
- Operation temperature **700**±100°**C**
- Can use various **hydrocarbon fuels**:
  - natural gas
  - biogas
  - even gasoline or diesel
- The fuel is **reformed** externally in a reformer and internally within the anode **to a H_2-rich gas**.
  e.g. steam reforming

$$CH_4 + H_2O \rightarrow CO + 3H_2$$

- Several single cells are connected together to form a **stack**

Hydrogen is needed… WEHC

World Energy Hydrogen Conference 2016

Electrolysers

Hydrogenics

PEM electrolyser

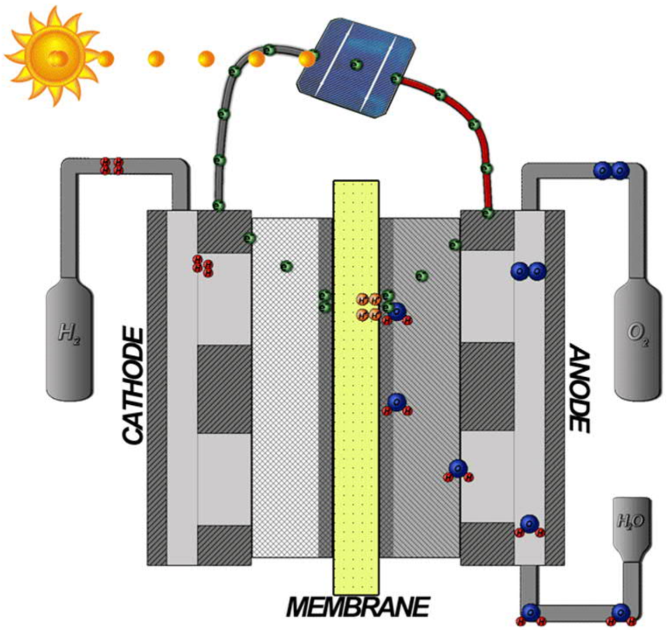
Hydrogen and Fuel Cell Archives

Alkaline electrolyser

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

Solid Oxide Electrolyser

Electrolysers
PEM electrolyser



En.Wikipedia.org

Anode

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

Cathode

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

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

Electrolyser
Alkaline

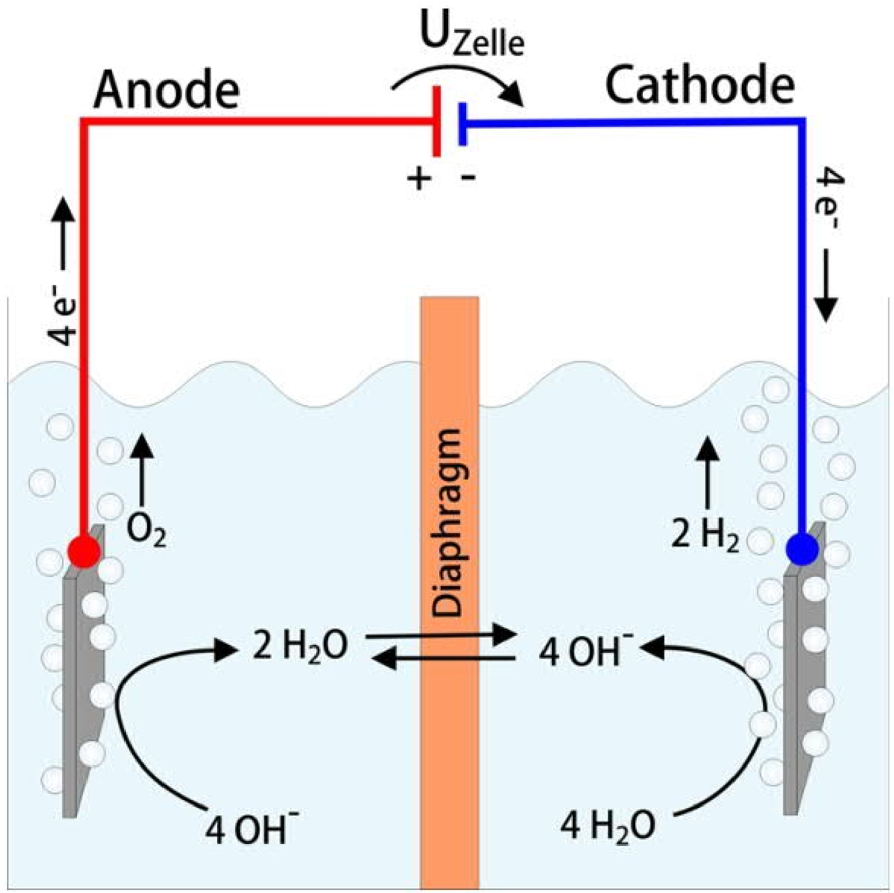
Cathode

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

Anode

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

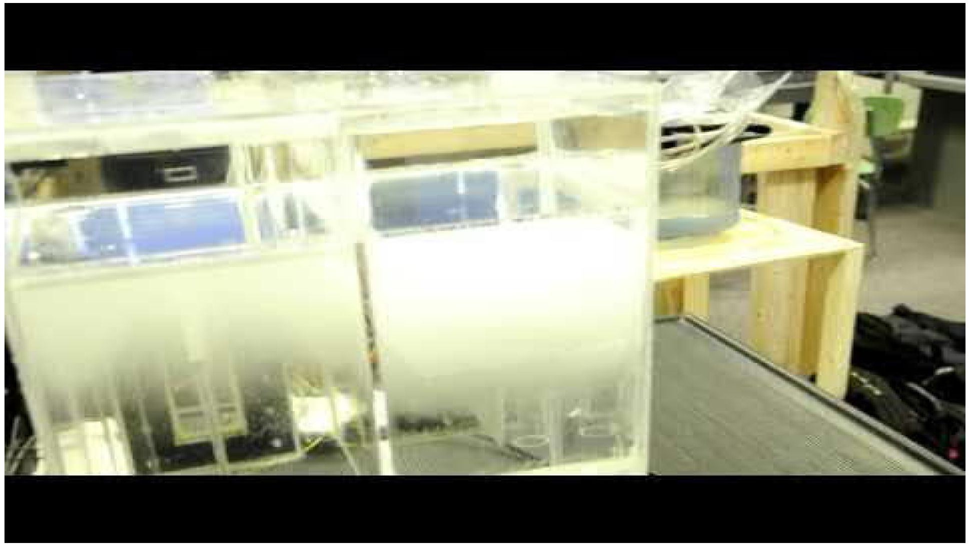
$2\,H_2O \rightarrow 2\,H_2 + O_2$



Fraunhofer IFAM - Fraunhofer-Gesellschaft

Electrolyser
Alkaline

Where is the largest alkaline electrolyser in Europe?



Youtube: alkaline electrolyzer 2, 3.1.2017
https://www.youtube.com/watch?v=tueEBIqKDK8

Electrolyser
Alkaline

- Woikoski, Kokkola, Finland

Woikoski

Electrolyser
Alkaline

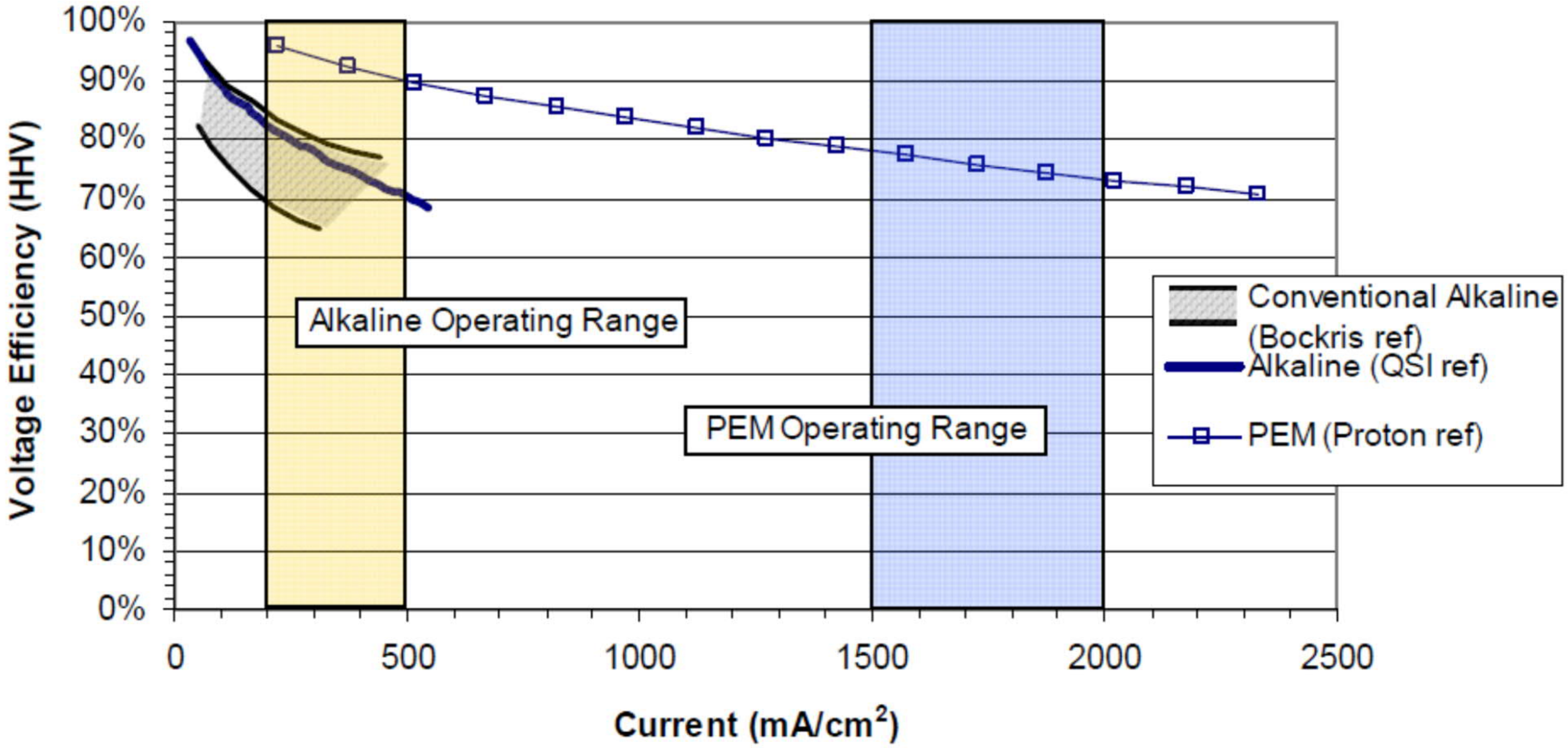
- A mature technology
- Reliable and safe, lifetimes 20-30 years
- High production capacities:
  500–760-Nm^3/h

Hydrogen and Fuel Cell Archives

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

Electrolyser
PEM vs. Alkaline

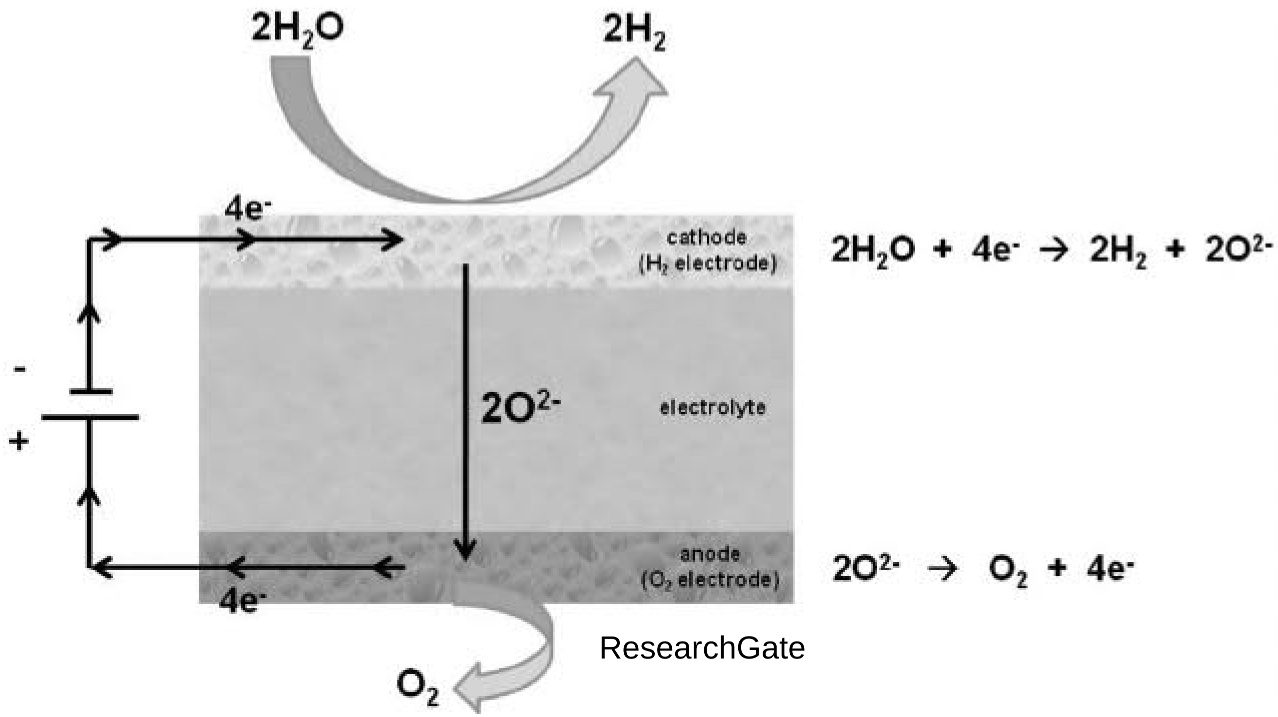
Why do we need PEM?



Aalto University

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

Solid Oxide Electrolyser Cell (SOEC)



ResearchGate

Group formation

Topics and groups for Task 1 and 2

Groups and Topics: Task 1 + 2

Group A
Off-Shore Wind
- Tuulia
- Katriina
- Veera
- Sai
- Konsta

Group B
Thermal Storage
- Moriam
- Reima
- Riina
- Lucas
- Henna-Liisa

Group C
Flow Battery
- Henri
- Neea
- Veera
- Ella
- Marina

Group D
Solid Oxide Fuel Cell
- Nikhil
- Jarkko
- Aino
- Judit
- Julia

Group E
Concentrated Solar Power
- Verna
- Hamidreza
- Anna
- Lillian
- Efran

Group F
Marine
- Alexandra
- Karri
- Jacopo
- Jyrki

Continues…

Groups and Topics: Task 1 + 2

Group G
Solar PV
- Tomi
- Karim
- Irina
- Frej

Group I
Pem Electrolyser
- Marko
- Sandesh
- Ahmad

Flip report I

- Now you have your topic
- You will work alone (at home), in group at the Workshop
  - No need to see before the WS
  - If you want you can coordinate that you are going to read different papers (in the future – provide you more depth)

- You will work in this group at the first part of the course, the groups will change for the third part (you will get to pick your own topic)

Flip I – Reading for the next week

1) Common reference for ALL STUDENTS

- Course book: Chapter 1, pages 1 – 15

2) Newspaper article on your topic

(from your own country – no need to be at language others understand – you will make a summery)

Preferable not older than 2 years

Some older clips at Finland - MyCourses – Under each topic

Flip I – Materials for these applications

3) Provided reference on your topic

or find yourself a review paper:

- Si solar cells, course book Chapter 11.4 (p. 470-479)
- CSP: “*Concentrated photovoltaics*” MyCourses
- Wind: “*Wind turbine technologies*” MyCourses
- Supercapacitors, course book Chapter 8 (p. 317-357)
- Large batteries “*Batteries for Grid applications*“ MyCourses
- Solid Oxide Fuel Cell, course book Chapter 14 (p. 671-694)
- PEM Electrolysers, course book Chapter 9 (p. 383-422)

Workshop II - Poster

The poster at WS 2 should include:

What is the application

How does this application function?

What are the advantages/disadvantages of this application?

What are the materials used in this application?

Task 1

- How long do you need to operate a device to obtain the energy that was needed to produce the raw materials in the device?

The DL for this submission is 24.1 at 8.30 am
Submitted to MyCourses

Task 1 gives you both max. 10 p. and both team members will get same amount of points!

2 Groups will work with a same topic, but should work independently (and not to come a same conclusion)

Task 1

- Prepare a power point presentation
  - Template available at MyCourses – Assignments
  - All the **Assumption** that were made for the calculations
  - List of State-of-the-art materials and how much you need them
  - Step by step write down the calculations
  - All the values are marked with a reference number, (you can put all the references at the last slide)
  - Submit to MyCourses (each team member own submission, same file), everyone responsible on their own submission

Reflection


www.123rf.com

1. The most interesting today
2. I would have wanted to hear more on?