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A CHANGING LANDSCAPE IN 2020
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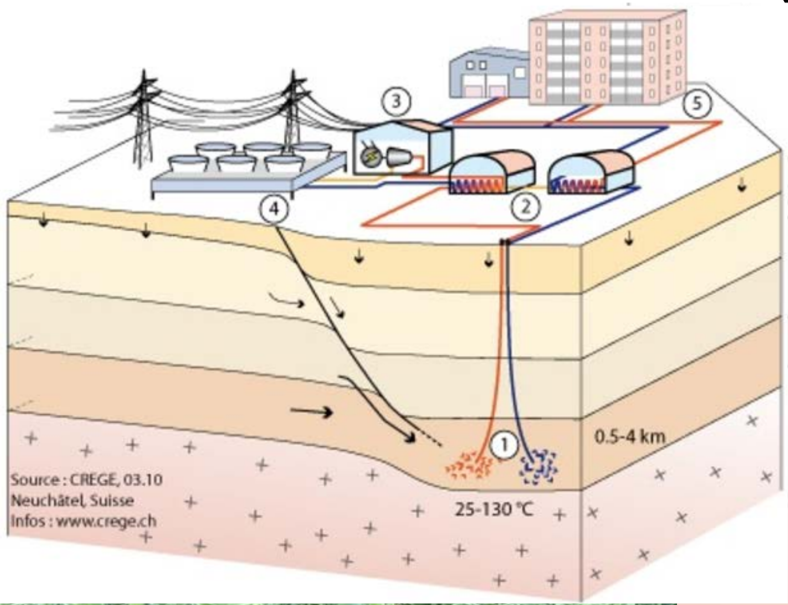
Energy storage for a more sustainable energy future

Content

- Keys to energy sustainability: renewables and efficiency
- Dominant fields of consumption and opportunities
- Classification of energy storage schemes versus time
- Efficiency and specific cost of energy storage technologies
- Synergies and example of advanced approaches for urban energy networks
- Conclusions

Renewable energies



Allows seasonal heat & cold storage

Allows seasonal fuel storage

Efficiency: large potential but confusing indicators

Example:

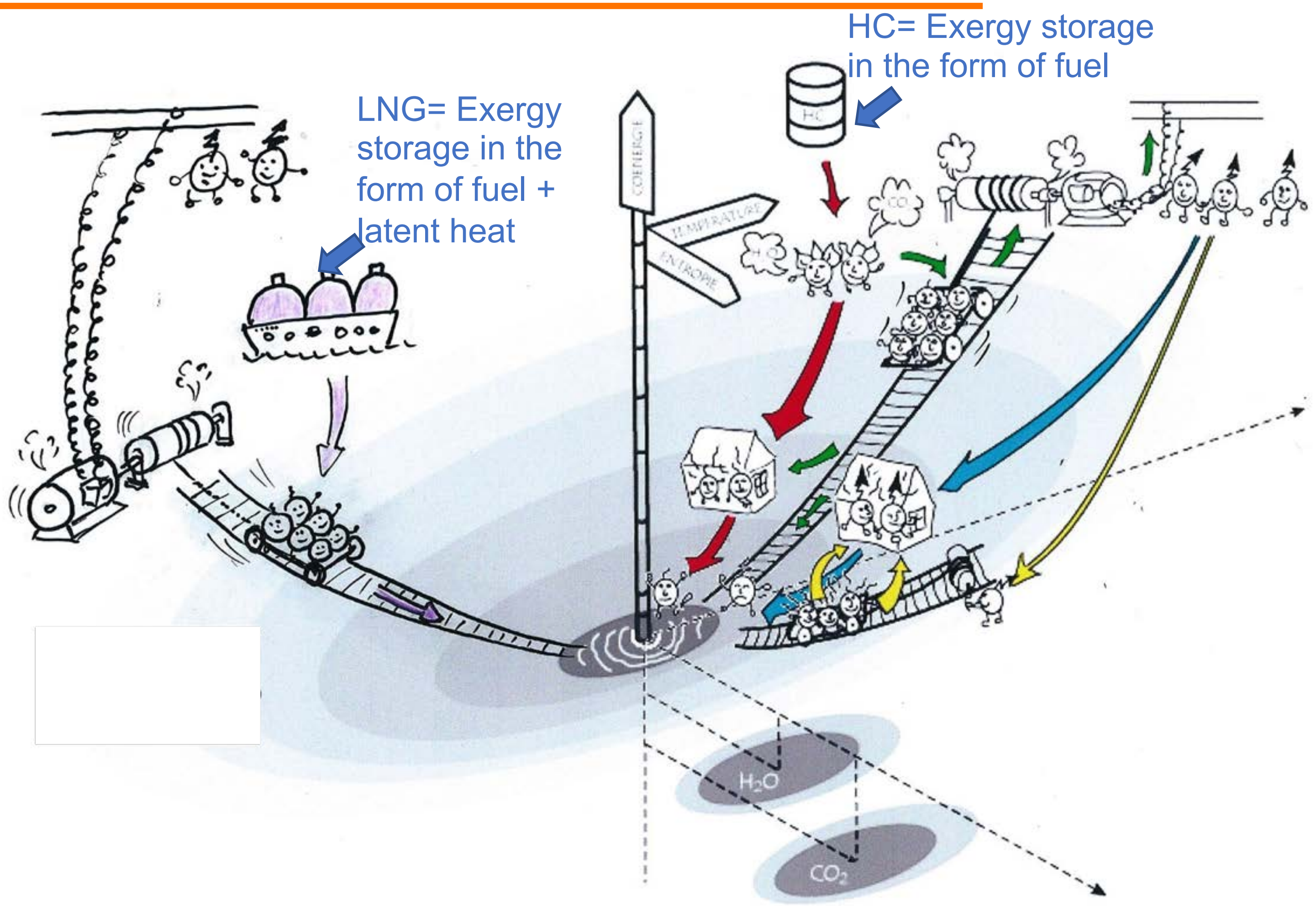
- First Law efficiency of domestic fuel boilers close to 100 % (or even more in commercial literature with condensing boilers)
- but Second Law efficiency (exergy efficiency of the order of **7%**)

For the same heating duty:
Exergy efficiency of heating based on cogeneration and heat pumps >**14%** and growing with technology improvements

- Wrong indicators for wrong strategic decisions
- Strong need to switch to exergy efficiency as an indicator of the real potential of resources and therefore of improved sustainability

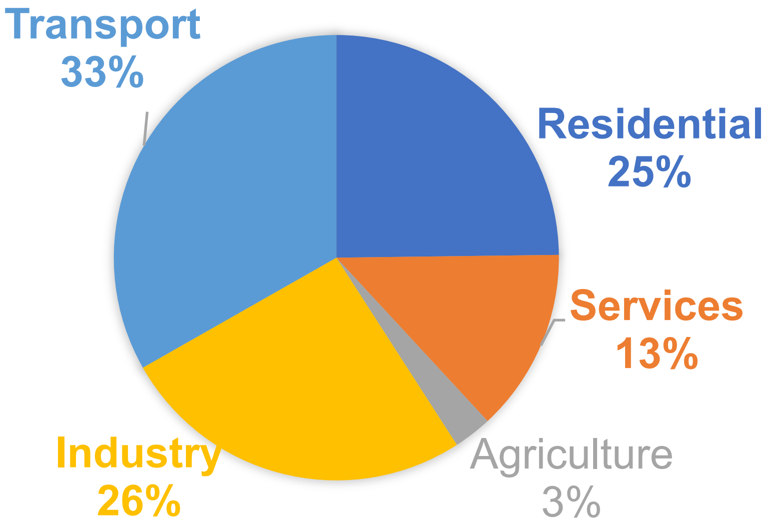
See: Favrat et al. The challenge of introducing an exergy indicator in a local law on energy. Energy 33 (2008) 130-136
Haldi, Favrat. Methodological aspects of the definition of a 2 kW society. Energy 31 (2006) 3159-3170

3D cartoon exergy representations of common energy systems



Favrat et al. Exergy graphical representations in thermodynamics. Conference HEFAT 2015, South Africa
Iglesias, Favrat Comparative exergy analysis of compressed, liquid nitrogen and classical power cycle for urban vehicles, ECOS 2013, China

EU-28 Final energy use by sector



2014

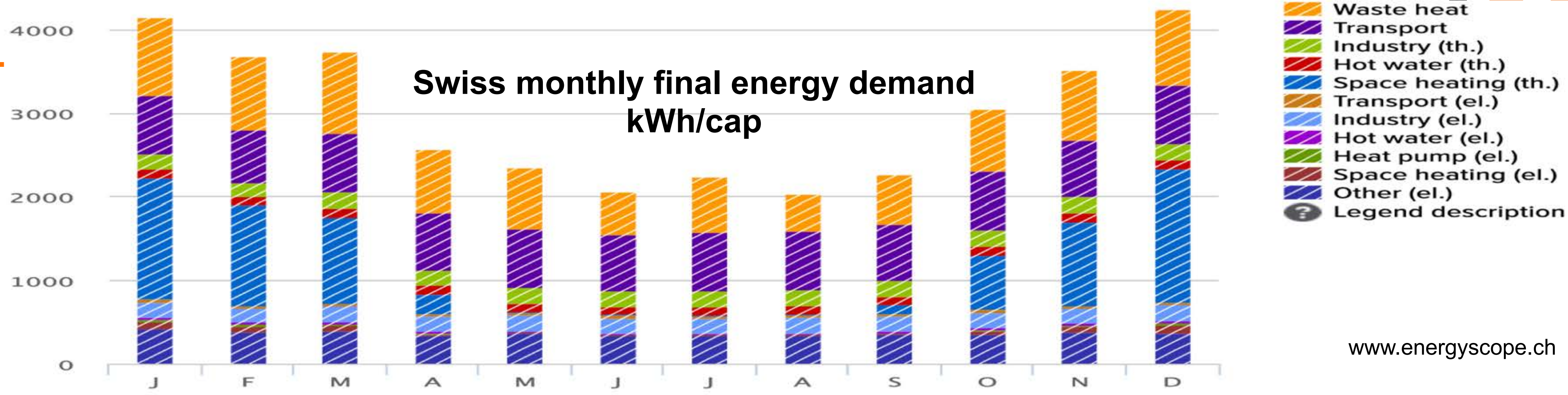
- 38% for residential and services (mainly for building HVAC)
- 33% for transportation (of which only <1% using electricity)

Major efficiency gains to be expected through:

- heat pumps, co- or trigeneration, District heating and cooling (DHC)
- Electric vehicles

Energy storage essential for both

Examples of seasonal variations



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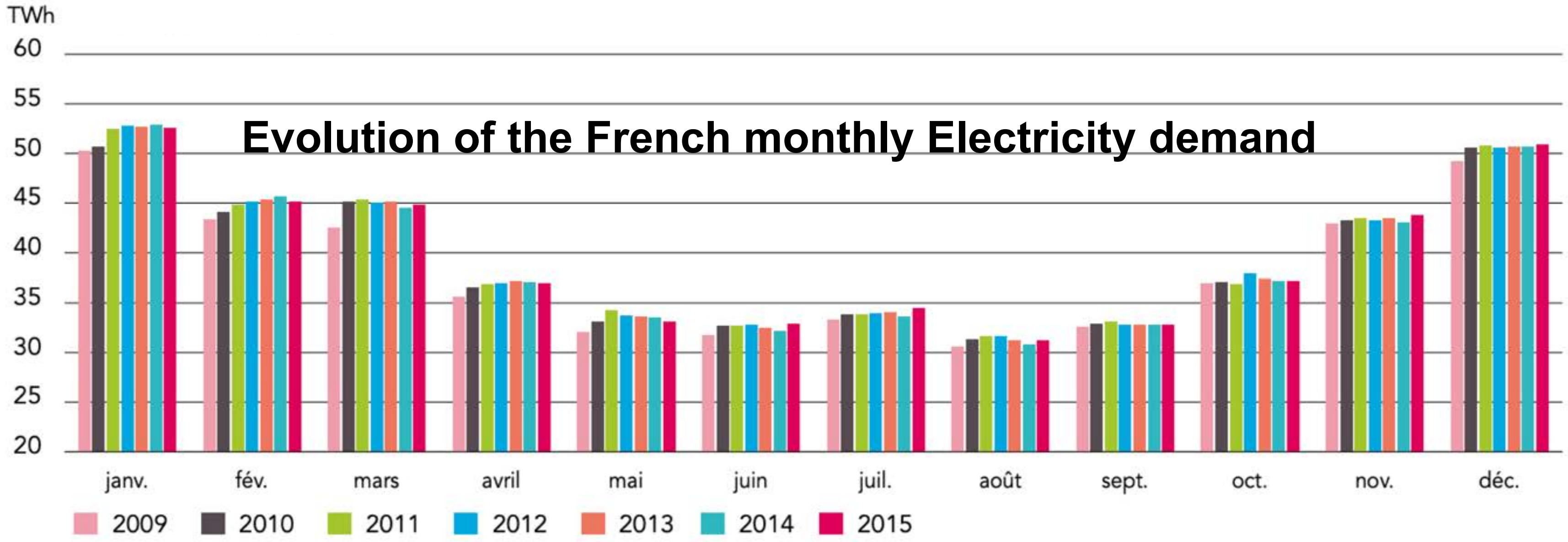


Storage types (time scale)

Seasonal

- Elevation of hydraulic accumulation dams
- Biomass and/or synthetic fuels
- Heat and cold ground storage

Hourly/ Daily / weekly

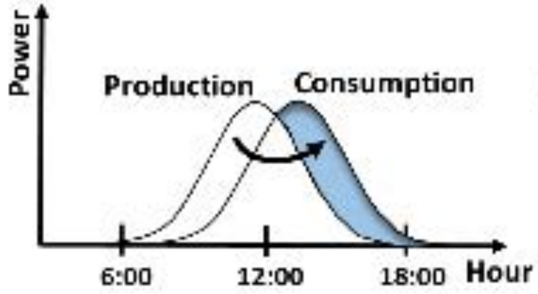
- Hydro pump-turbine plants
- Compressed air
- Electric batteries (including of vehicles)
- Hydrolyser+ H_2 storage + engine/fuel cells
- Thermal storage (hot water, ice, ground, molten salts)

Rapid

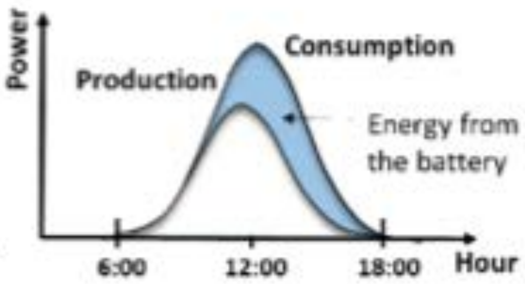
- Supercap, flywheel, magnetic

Examples of use of electricity storage

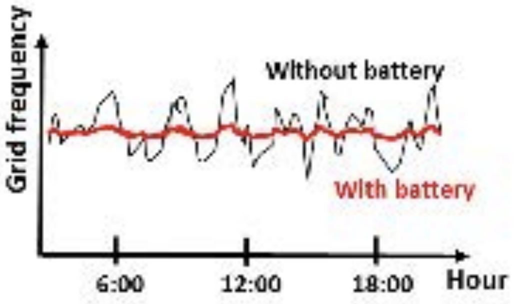
Load balancing



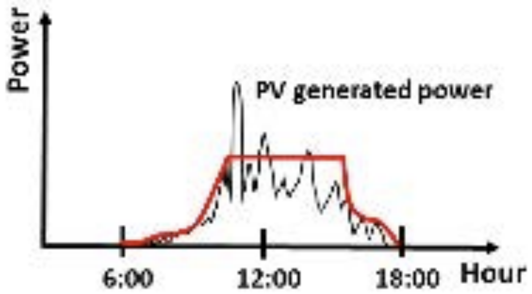
Peak shaving



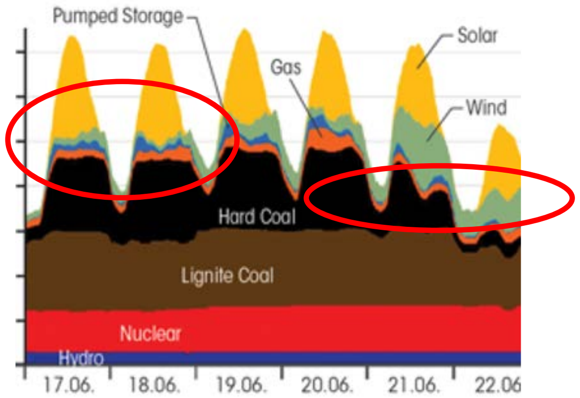
Frequency control



Smoothing supply



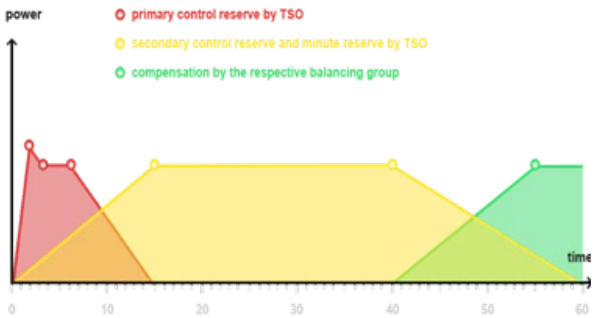
Avoiding inefficient partial loads



Reducing rotating reserves

Emergency supply & "black start"

Power control & capacity market



Seasonal storage

Ex: alpine cheese

Height increase of dams

- Storage of more water
- Better protection against floods

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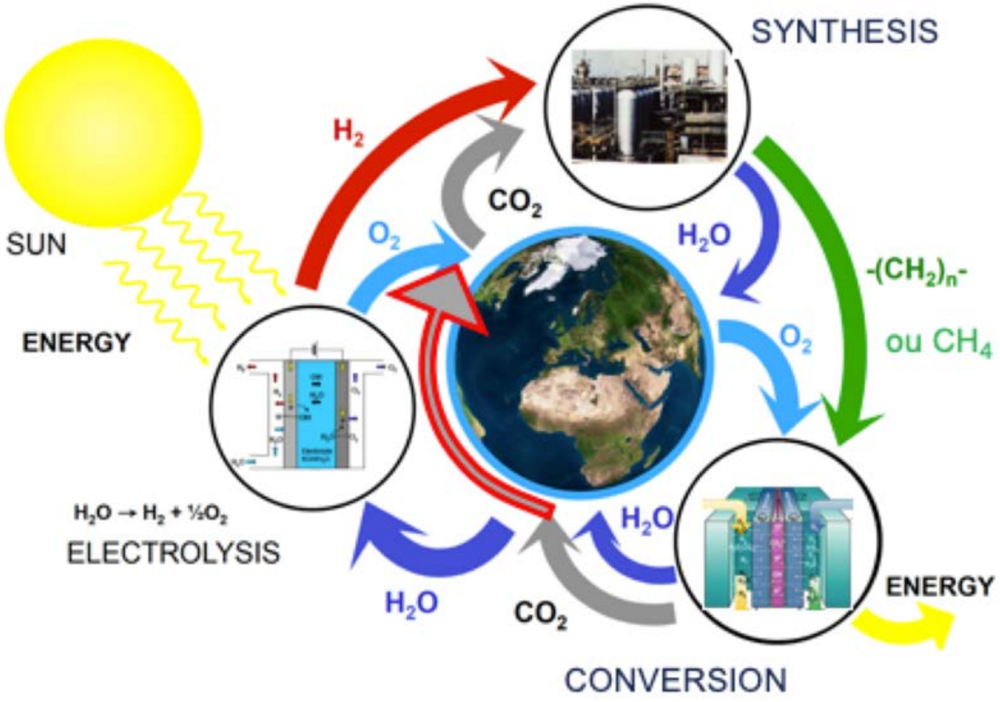
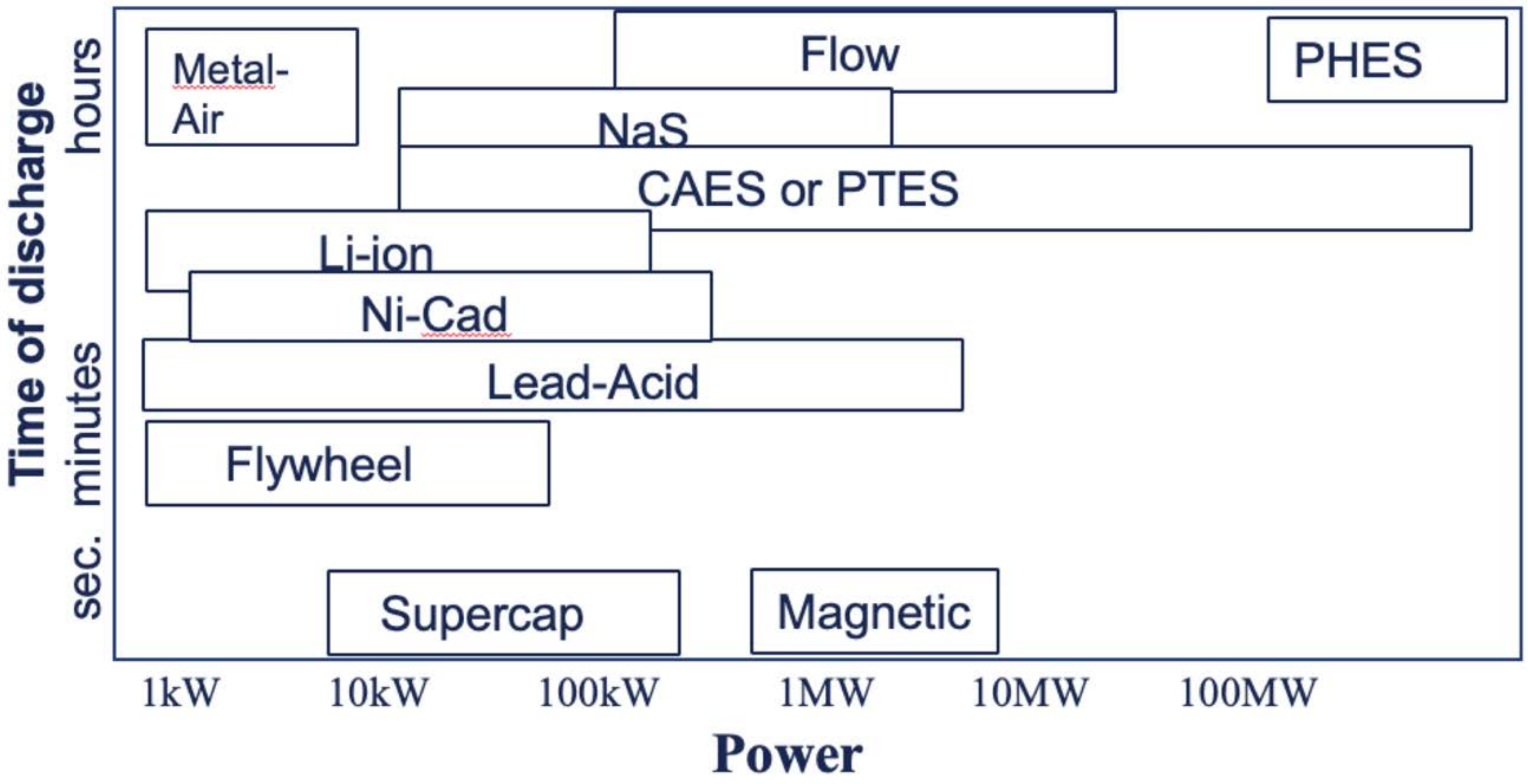
Synthetic fuels

(gas or liquid)



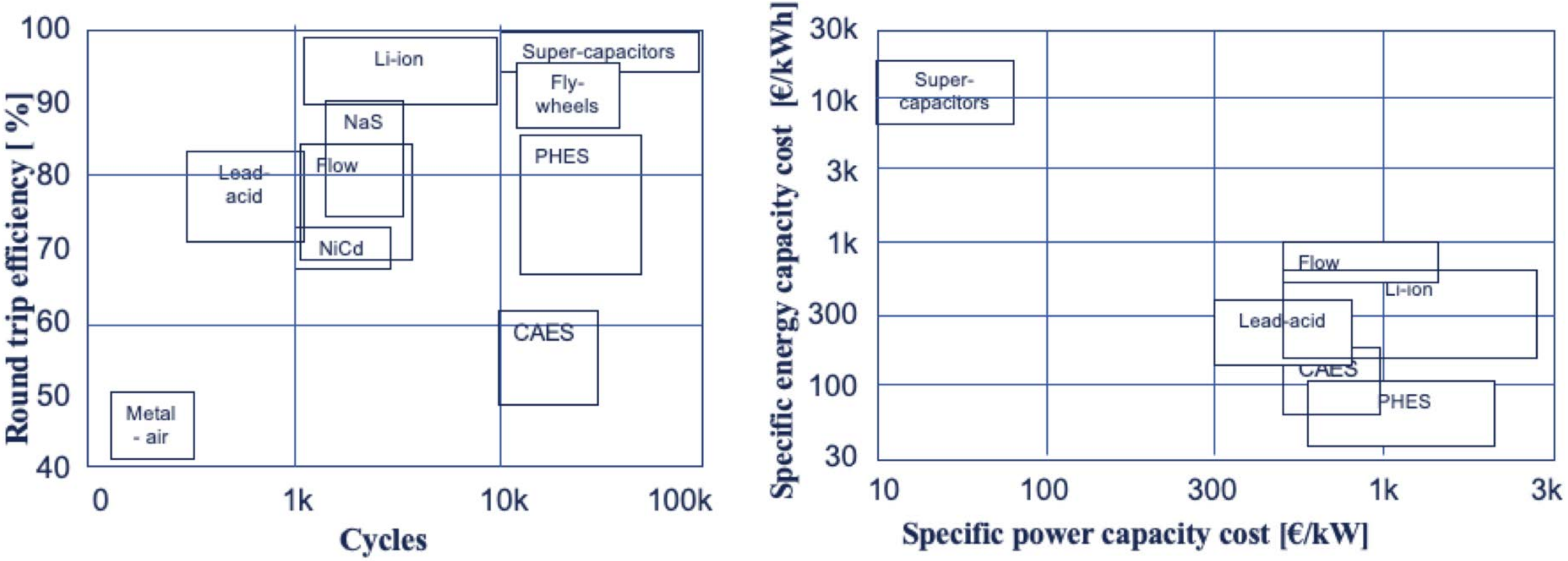
Adapted from Zuttel et al. sus. Energy &fuels 2017;1,1748

Time of discharge and power range



PHES= Pumped Hydro Energy Storage
PTES=Pumped Thermal Electricity Storage
CAES= Compressed Air Electricity Storage
NaS= Sodium Sulfur battery

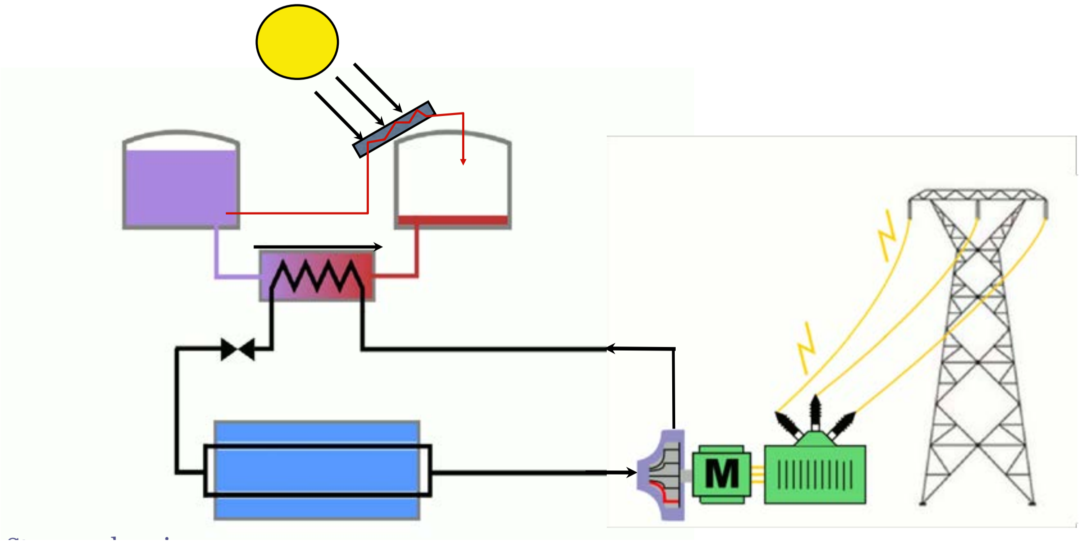
Daily or hourly storage: round trip efficiency and cost



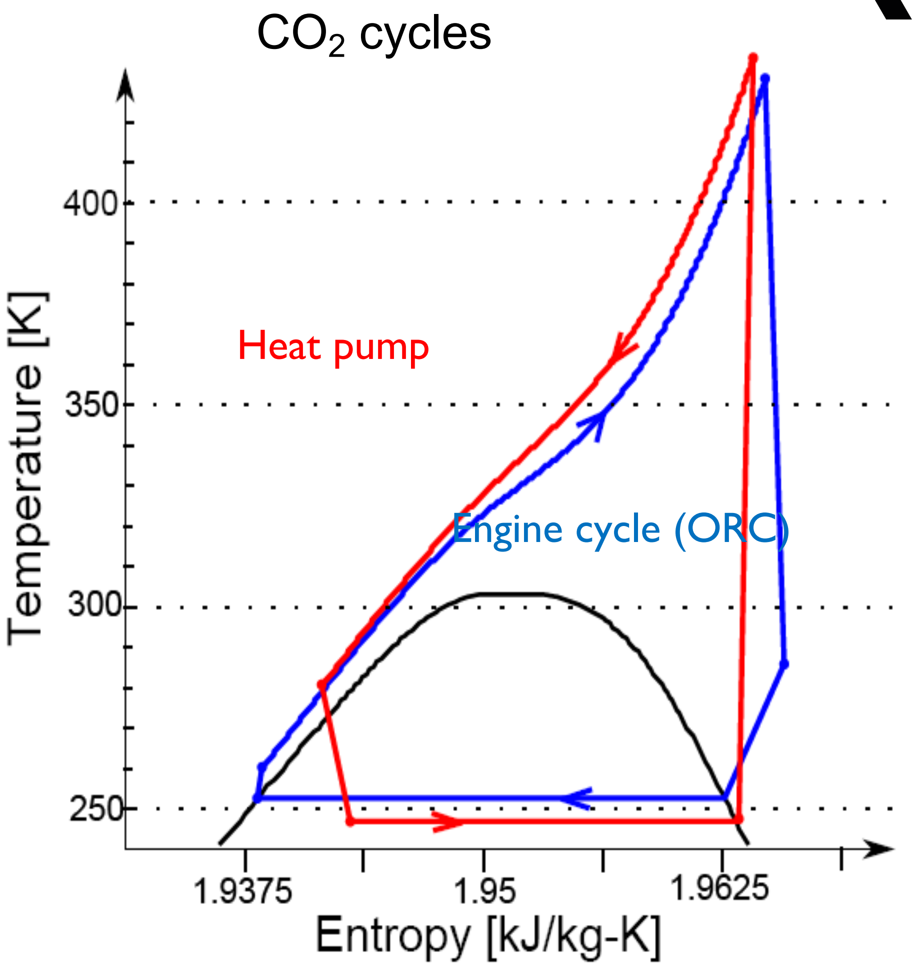
PHES= Pumped Hydro Energy Storage
CAES= Compressed Air Electricity Storage

Adapted from: Rufer A, Energy storage, CRC Press 2018

Alternative to batteries for daily storage: PTES: Pumped thermal electricity storage



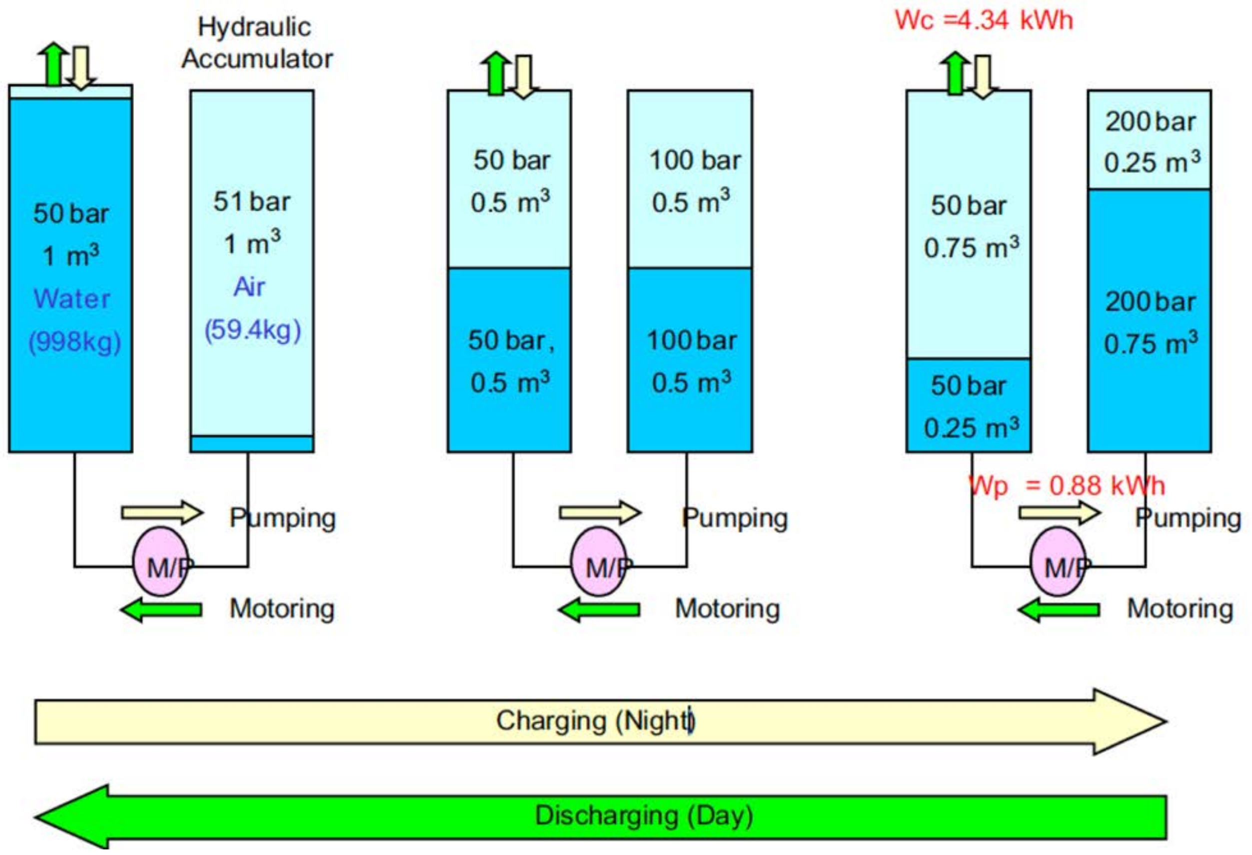
Charge: heating storage water using heat pumps
Discharge: electricity production by engine cycles like ORC



Morandin et al. Thermoeconomic design optimization of a thermo-electric energy storage system based on transcritical CO2 cycles. Energy 58(2013)571-587

Compressed air-storage

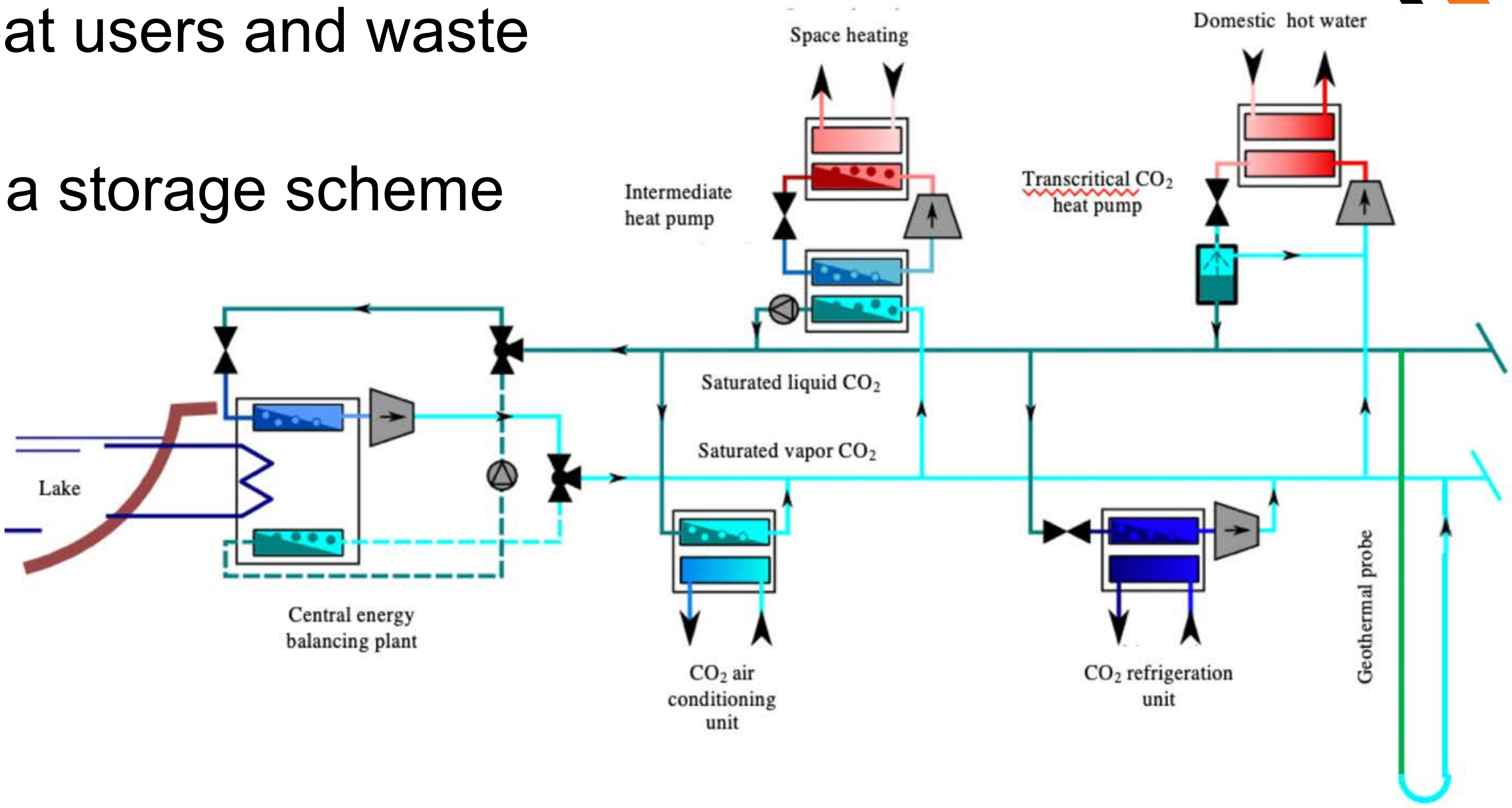
Schematic representation with so-called liquid piston for micro-CAES systems



Kim Y.M., Favrat D. Energy and exergy analysis of a micro-compressed air energy storage and air cycle heating and cooling. Energy 35 (2010) 213-220

Advanced CO_2 District Heating and cooling network

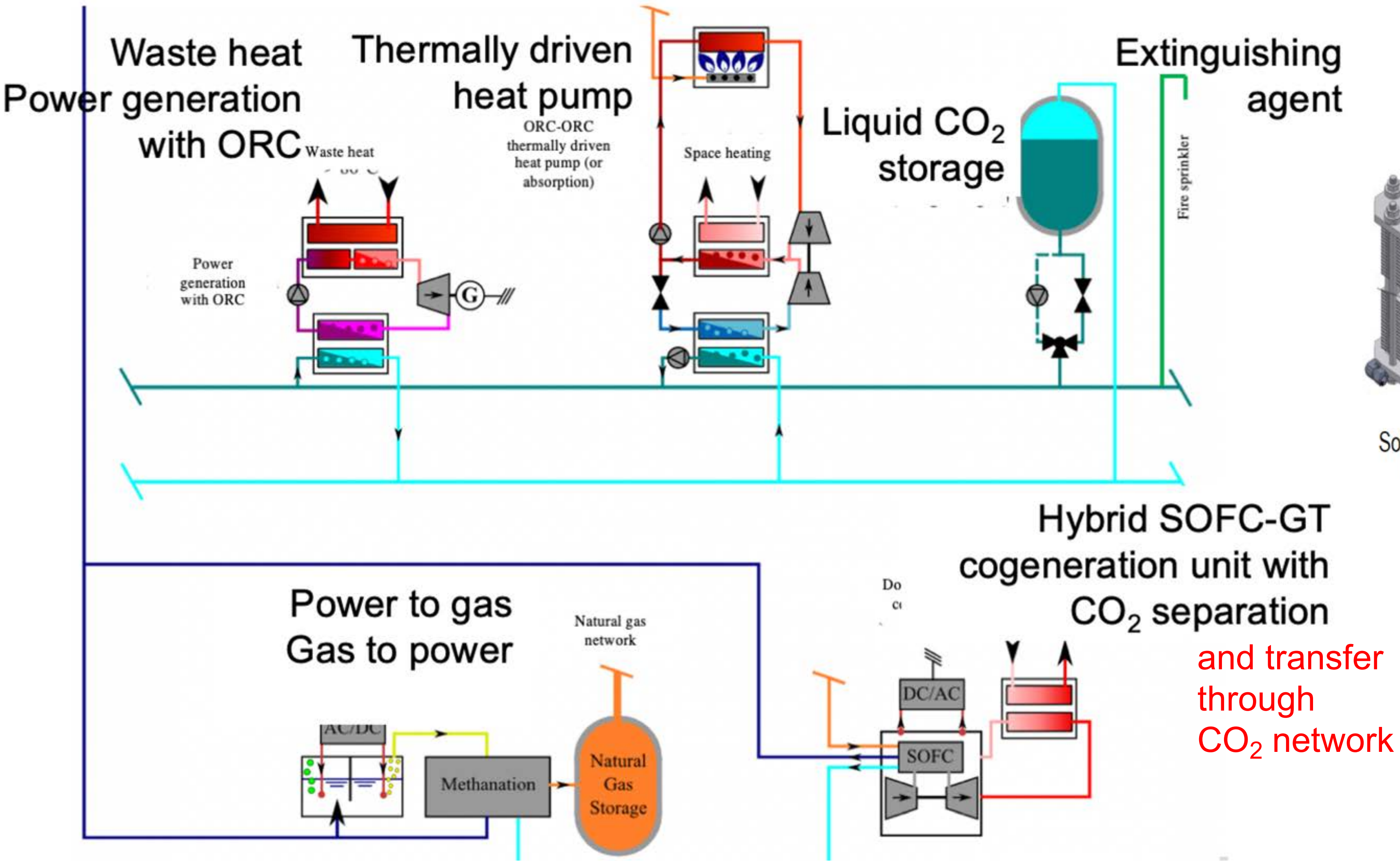
- Distributes energy between environmental heat users and waste heat providers
- Indirectly acts as a storage scheme

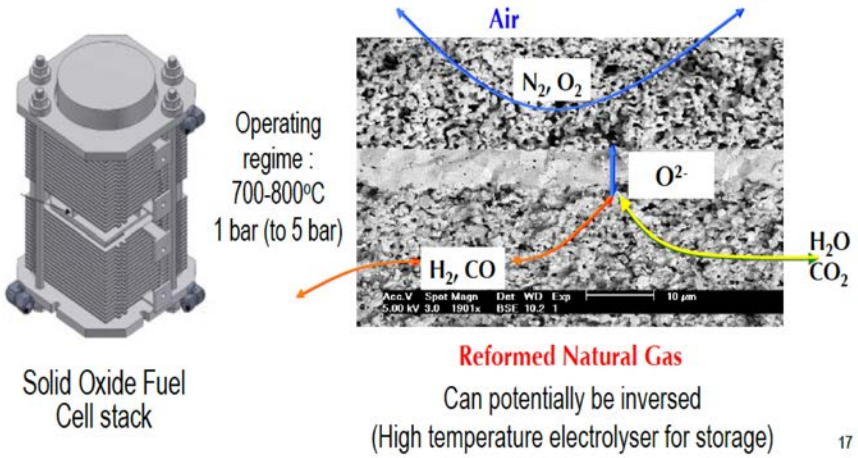


Concept ExerGo.ch

Henchoz et al. Key energy and technological aspects of three innovative concepts of district energy networks. Energy 117 (2016) 465-477

Extensions of CO_2 urban network concept





Conclusion

- Major progress to be made in using more coherent efficiency definitions (exergy)
- Storage schemes should be differentiated according to time and cycle numbers
- Storage technology are essential and significant progress is expected
- Seasonal storage is energetically and economically difficult and will require an extensive use of synthetic renewable fuels (green fuels)
- Storage is an important part of future city networks

References. (Daniel.favrat@epfl.ch)

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