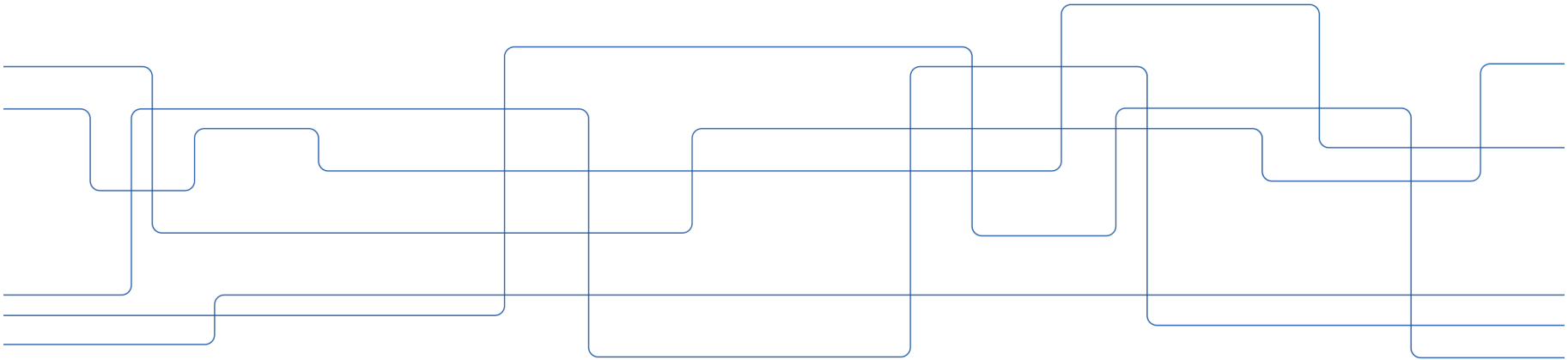
KTH ROYAL INSTITUTE OF TECHNOLOGY

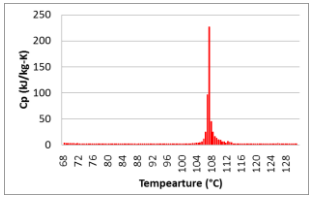
Innovation in District Heating and Energy Storage

Viktoria Martin, Ph.D.



Who's talking?

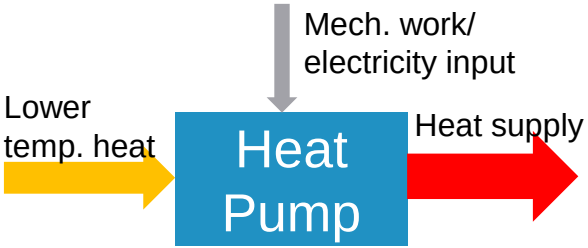
- Viktoria Martin, Professor in Energy Technology,
- Head of Division of Energy Systems at KTH-Royal Institute of Technology, Sweden
- Area of research is:
  - related to technologies, thermal energy storage and heat driven heat pumping technology
  - related to systems, district energy systems, industrial energy systems, and decentralised applications related also to developing regions of the world.
- PhD Mech Eng., U of Florida (1998)
- MSc Chemical Eng, KTH (1993)
- You can reach me at vmartin@kth.se



Erythritol	
Enthalpy change (87°C to 127°C) [kJ/kg]*	330
Peak melting point [°C]*	107
Density [kg/m3]	1480 (at solid state)
	1300 (at liquid state)
Viscosity [Pa s]	2.90 × 10 − 2 (at 120C)
	1.60 × 10 − 2 (at 140C)
Thermal Conductivity [W/m-K]	0.326

Some introductory inspiration…

- Herleen District Heating network, Netherlands
  - Circular District Heating, using ground water filled mines for heating/cooling of buildings
  - Heated by geothermal energy
  - When a building is cooled, it releases heat to be stored in the mining wells. When the building is heated, cold is charged into the store. A heat pump ensures the correct temperature.
  - Enables storing excess energy (electricity) from wind and PV as heat, via the heat pump.
  - Only work with established technologies, linking them together in a smart way.
- Kalundborg Industrial Symbiosis
  - Create loops of water, energy and material flows between industrial partners to demonstrate circular economy.
  - Minimize ”outflows” from symbiosis, that is effluents…
- Hamburg: ”…*“re-municipalise” the local electricity and district heating networks, as proposed by grassroots initiative “Our Hamburg Our Grid”.* ”
  - By 2030, get coal power out of DH
  - Biomass, waste incineration, solar
  - Air rade bunker transformed into a heat reservoir
  - Pumping hot salt far into the ground



District heating? Let’s boil some water!

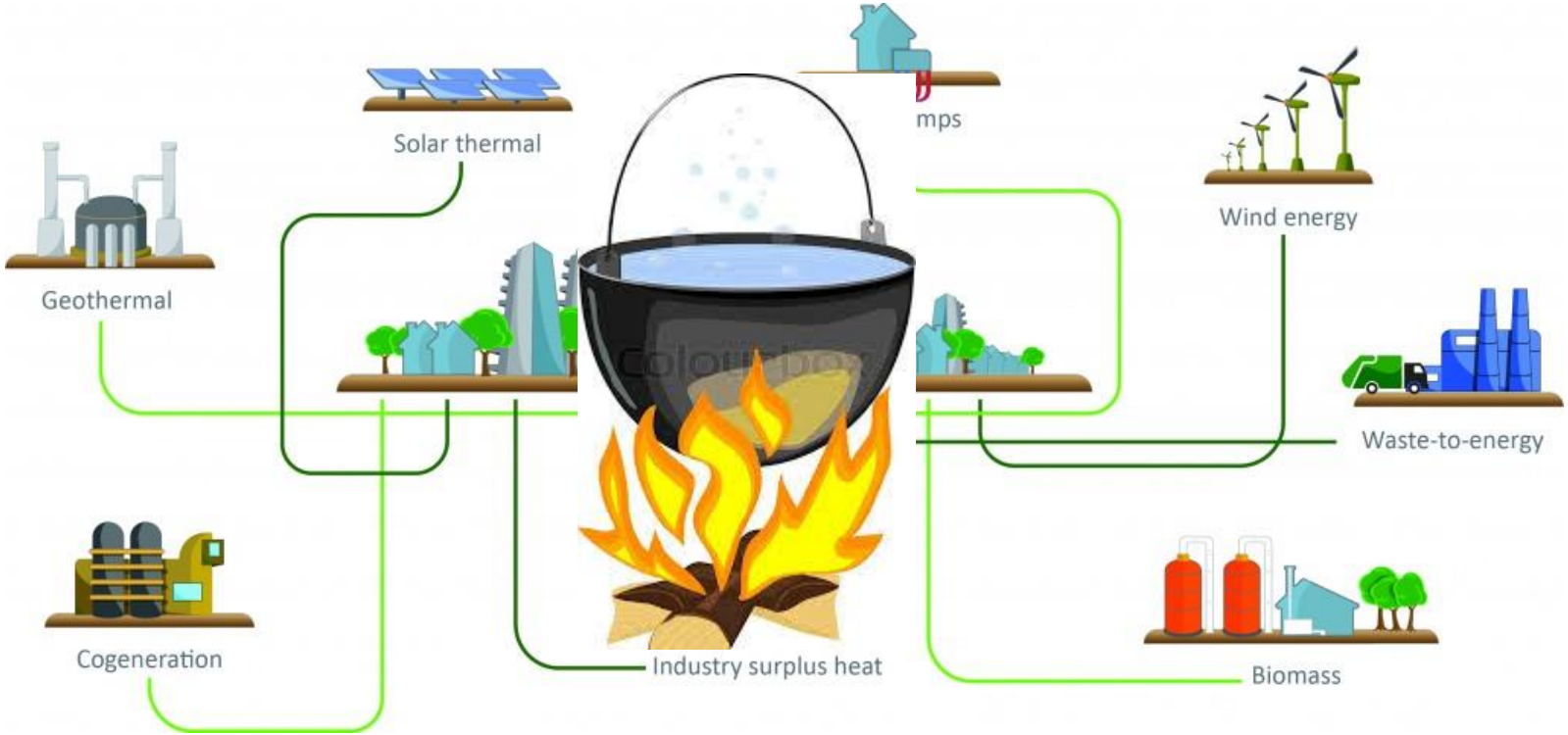
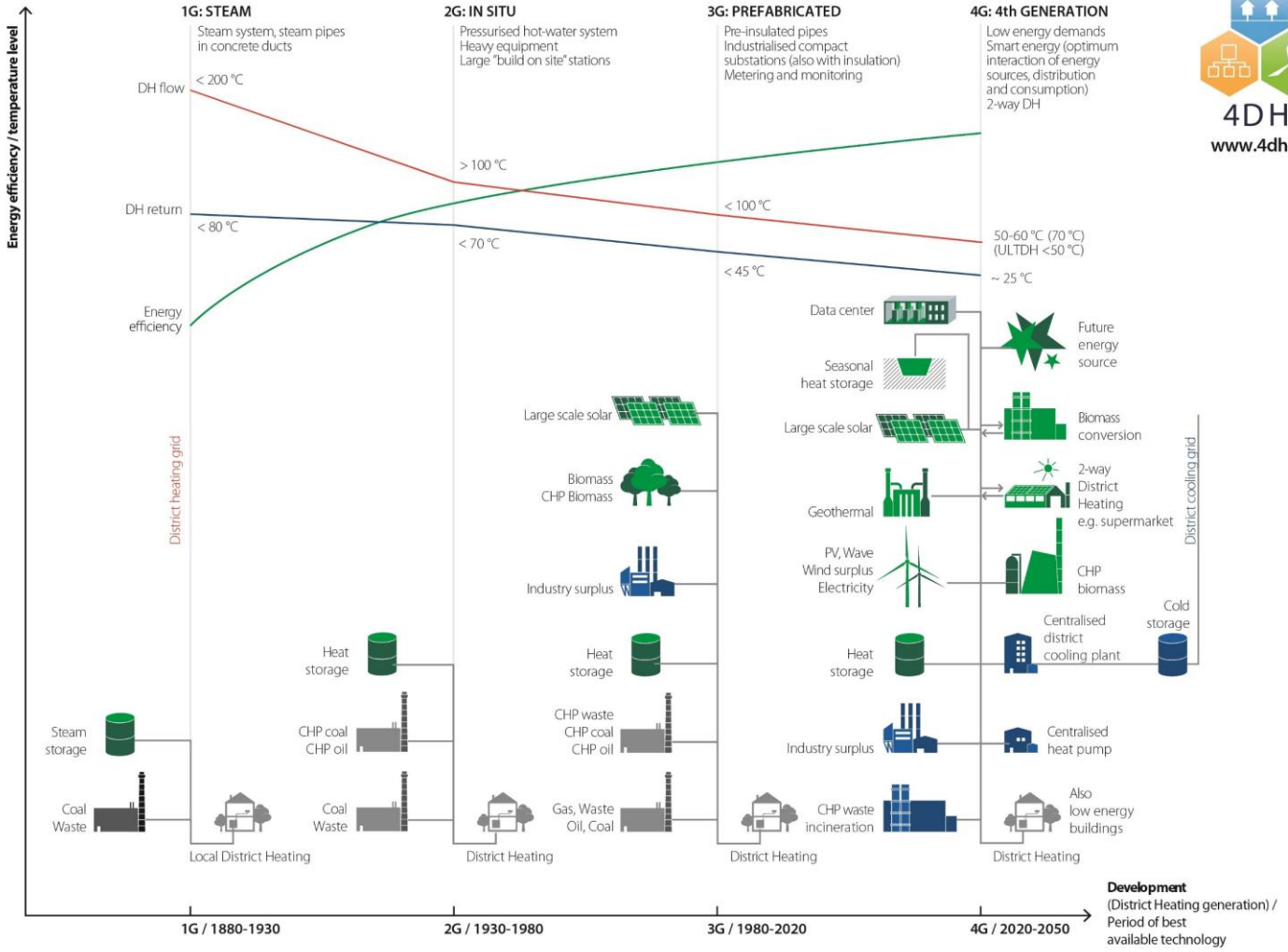


Image: www.euroheat.org

The evolvement of district heating over time …



5th generation district heating?

- Smart Thermal Energy Network
- Early stage of development … the same pipes provide heating AND cooling!
- Free-floating temperatures in the system, and close to the ground temperature for minimizing losses.
- Check out for example:

A starting point – renewable District Heating based on biomass.

The Building Sector

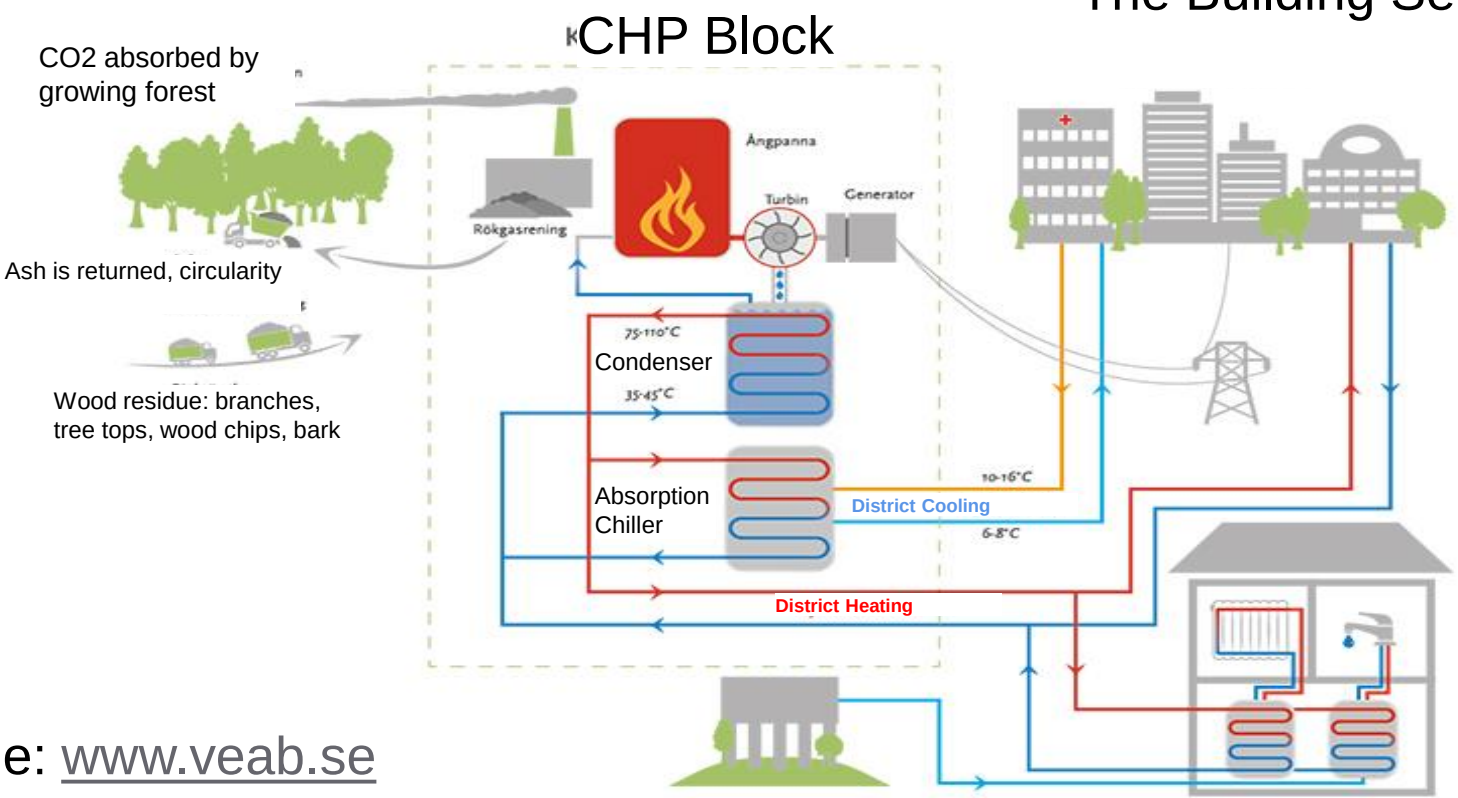


Image: www.veab.se

Flue gas condensation

- Using the ”return” flow on the district heating line, flue gas is cooled below the dew point.
- As water condenses (heat of condensation approximately 2500 kJ/kg) heat is released, and recovered back to the district heating net (pre-heating of return line).
- For ”wet” fuel (biomass and waste) this may result in thermal efficiencies ”above” 100%, based on the fuel’s lower heating value (MJ/kg, calculated assuming combustion product water in gas form) ☺.
- Flue gas condensation ALSO purifies the flue gas…

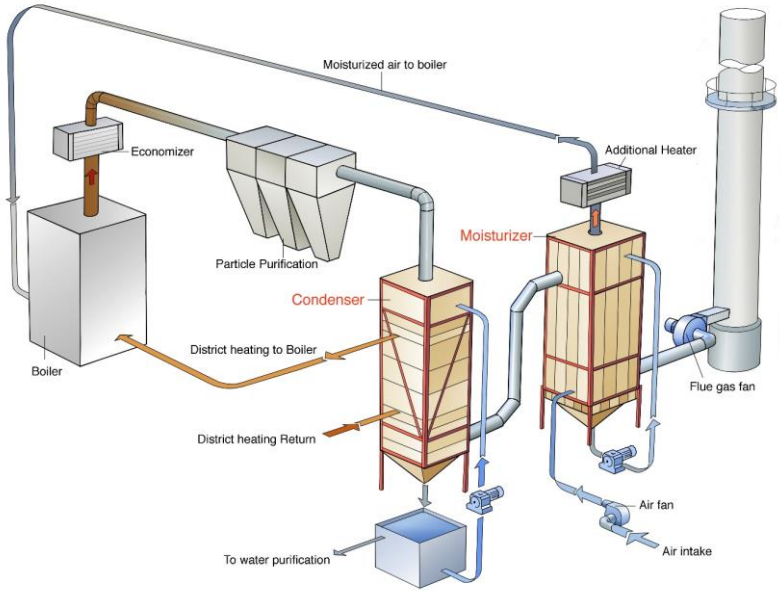
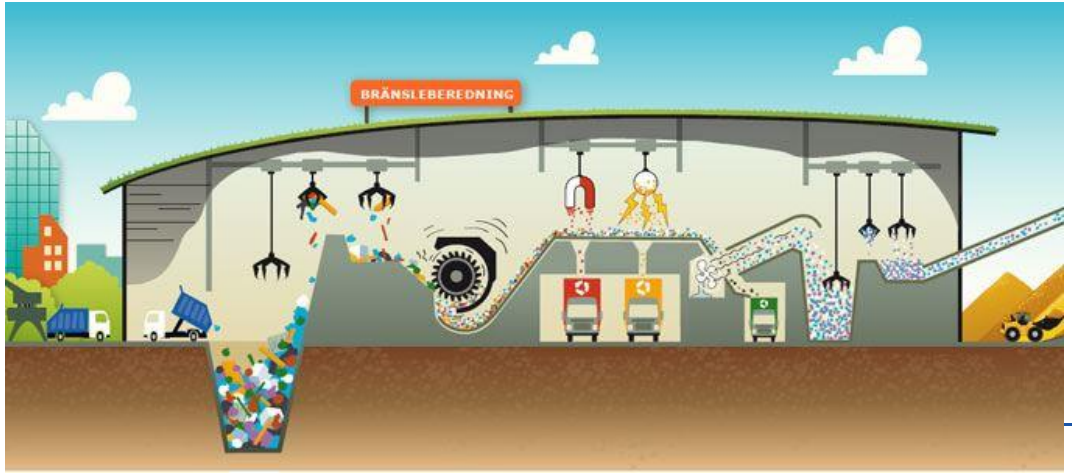


Image: www.envibat.se

One Swedish Example ”Mälarenergi”

- Circulating Fluidized Bed Boiler allows for a mix in fuel: biomass and municipal waste …
- Commissioned 2014
- 167 MW_{fuel}
- 50 MW_{el}
- Up to 30 MW heat recovered in Flue Gas Condensation

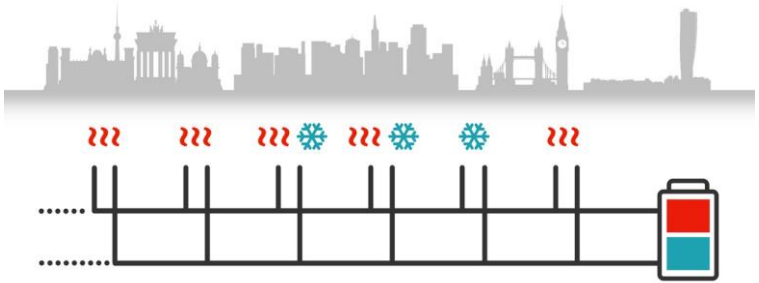


ectogrid™ – similar to the Herleen case…

- Nothing ”new under the sun” – still, a recently trademarked concept:

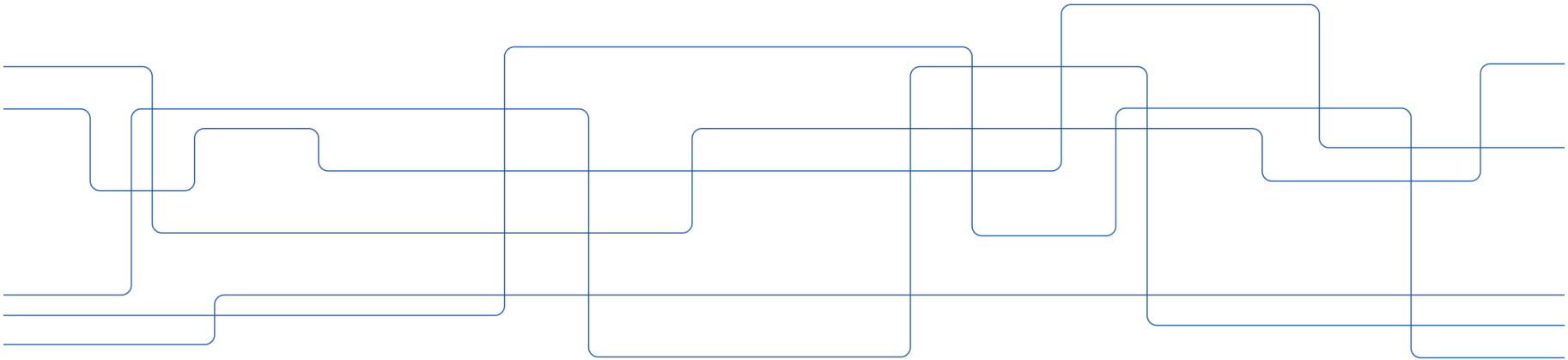
Time to start ”sharing” for a sustainable city!

- Distributing energy flows between neighbors, using the same network for heat and cold.
- Heat Pumps between each building and the grid.
- The buildings make ”withdrawals and deposits of heat”
- The accumulative demand of all buildings are balanced. Energy is only ”added” to the grid when needed
- Beyond technologies – innovation in business models, ICT etc.



(Critically) review the concept at: http://ectogrid.com/use-cases/medicon-village/

A closer look at energy storage



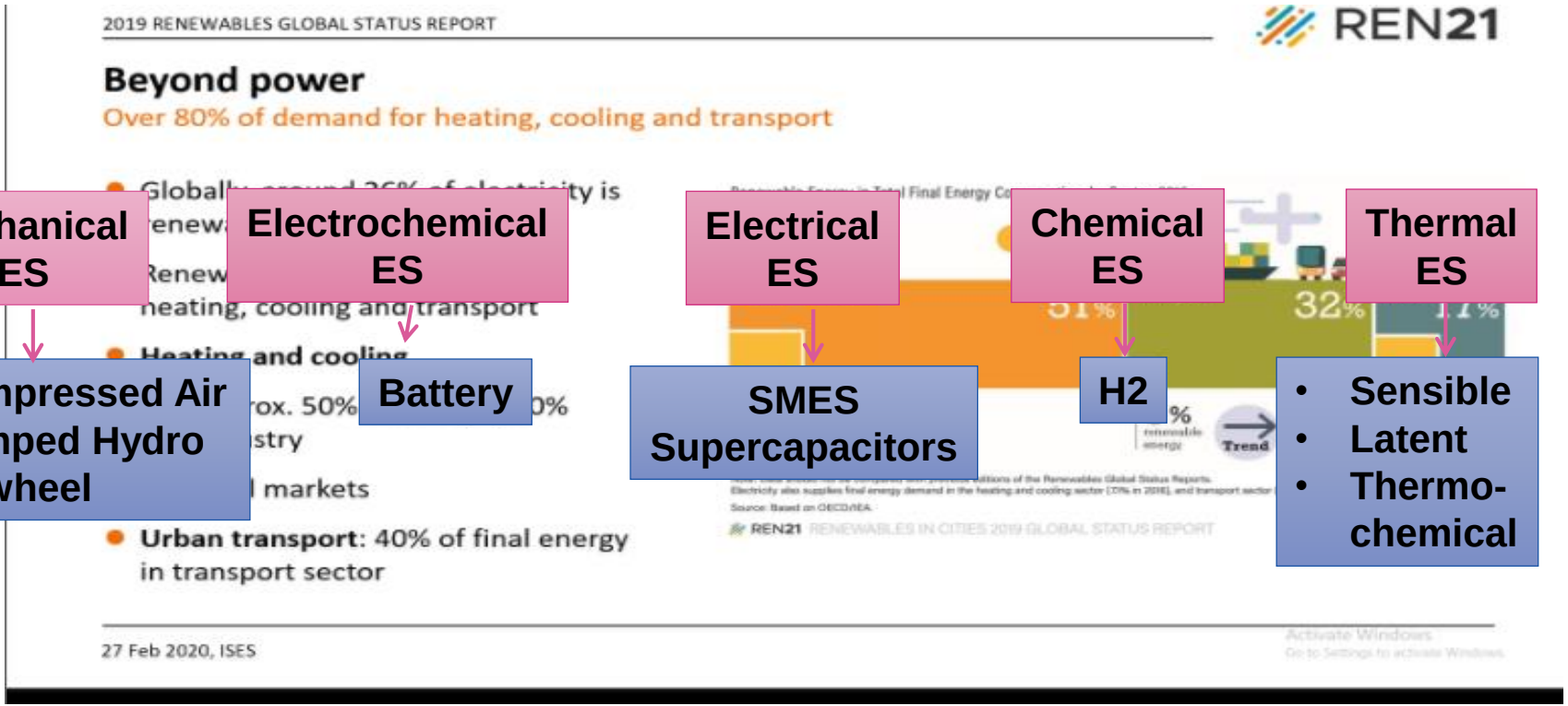
Why Energy Storage?

- Global Annual Energy Demand: 586 EJ/year *(IEA, 2019)*
  - Approx. 162800 TWh/year
  - Of which Sweden demands 573 TWh year or 0.4%; and
  - PR of China demands 7150 TWh/year or 4%
- Annual Solar Energy Potential *(World Energy Assessment 2000)* between 1500 EJ/year to 49000 EJ/Year

Energy is not a problem – solar energy intercepted by earth is more than 3 orders of magnitude higher than annual global energy demand!

There is a mis-match in time, place, and temperature!

What type of storage?



From ISES webinar Feb 27, 2020

Storage of Thermal Energy in District Heating

- Hot water accumulators – state-of-the-art.

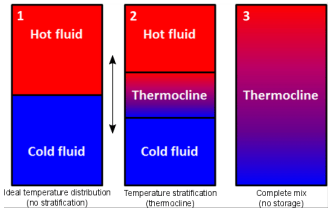


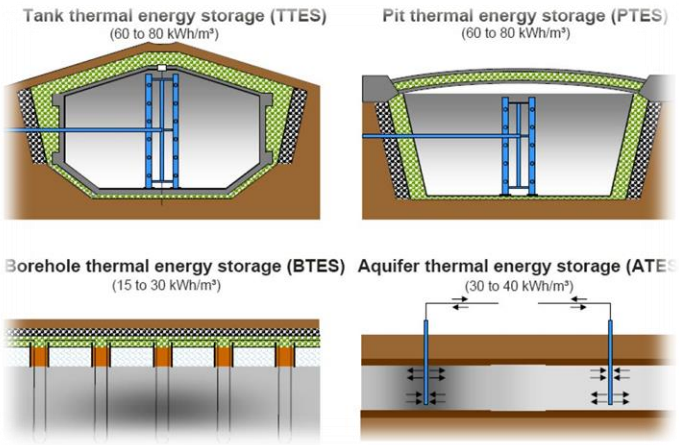
Image:

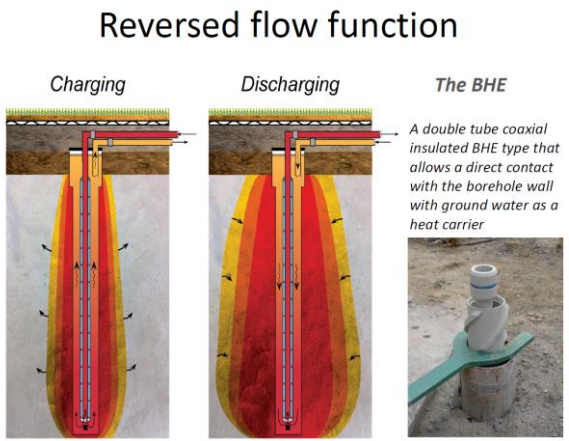
Baeuerle, Yvonne. (2017). Life Cycle Assessment TES Systems Using Recycled Steel Industry Waste for Concentrated Solar Power Plants. https://doi.org/10.13140/RG.2.2.26903.27043

and

www.veab.se

- Using the ground, for ”seasonal” (or monthly) storage



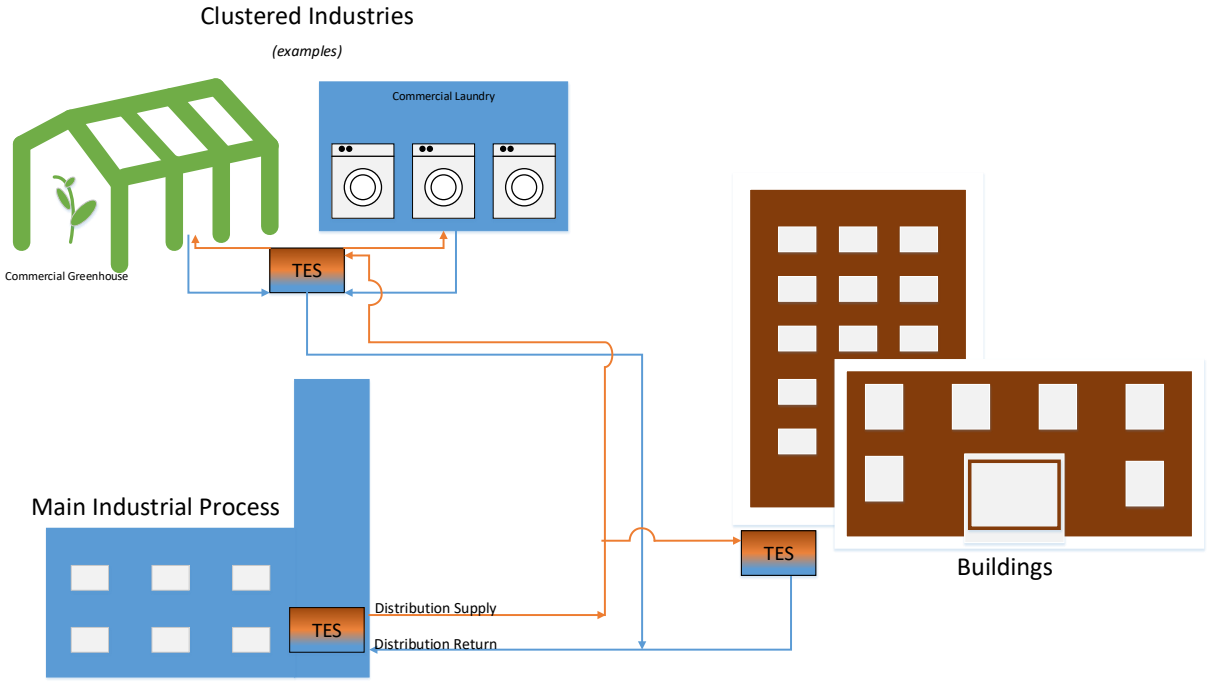


140 boreholes
150 m depth

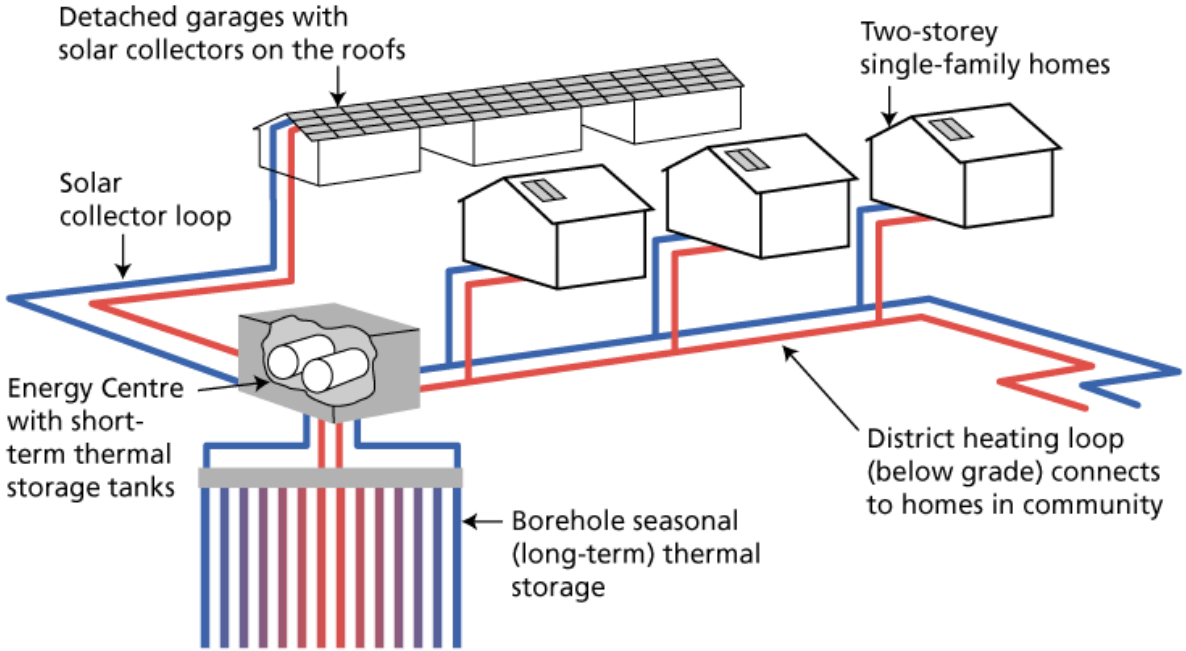
Emmaboda Foundry
Storing Industrial Surplus Heat at high temperature (60 C) during Summer

Image: www.flexynet.eu ; www.energiforsk.se

TES enabling Industrial Surplus Heat for Societal Use, and absorbing surplus from wind/PV



Seasonal Storage of Solar Heat



Drake Landing Solar Community – schematic Layout

Thermal Energy Storage – Merging Concepts

- Using Phase Change Materials, below for Seasonal Storage:

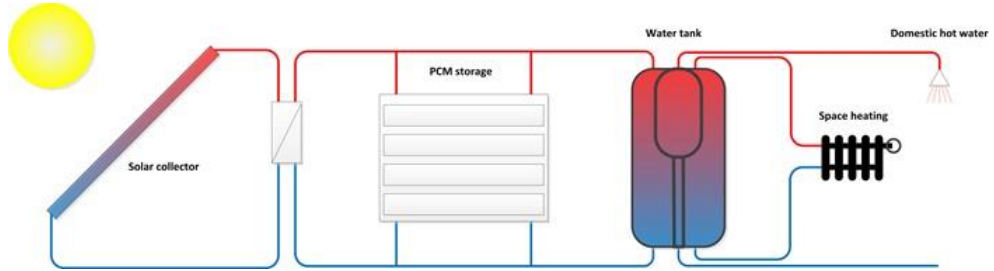
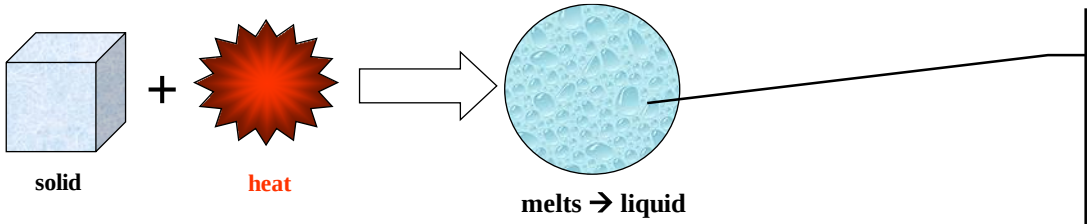


Image from DTU:
https://www.byg.dtu.dk/english/news/Nyhed?id={B7308E23-2A68-4356-B67D-E285E2158830}

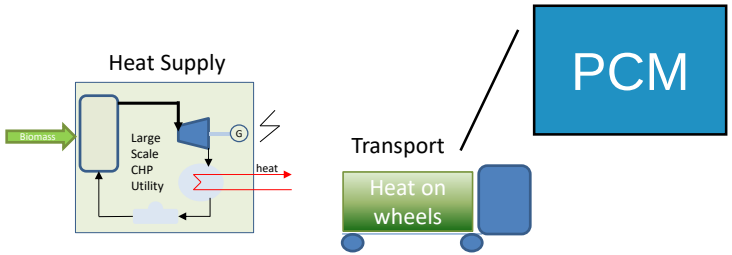


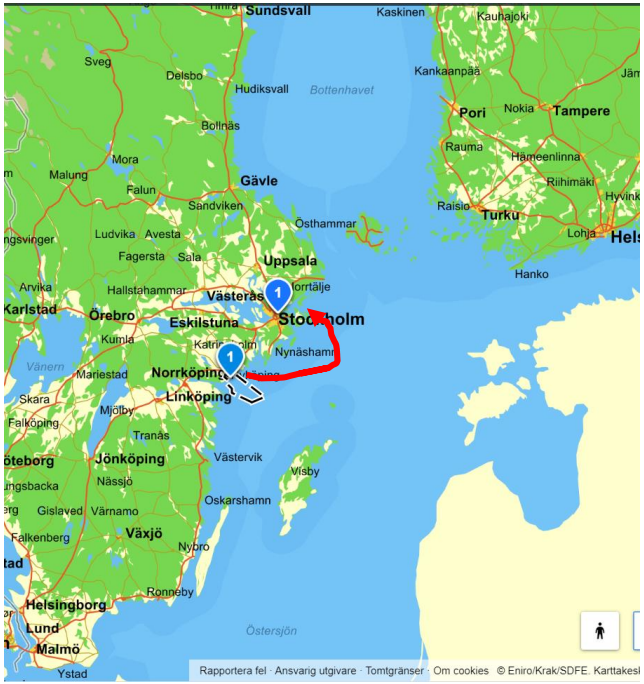
Contemplate the cost of heat! Investment only used one cycle per year … The ”salt” (PCM) is cheap, but the ground is cheaper still!

Storage Capacity: 70-100 kWh/m³

PCM Thermal Energy Storage has potential where water or ground is NOT an option…

- Heat on ”wheels” (or boat) instead of pipe-transferred heat – for longer distances





Concluding Remarks

- Many commercial, and pilot plants showing 4GDH concepts, as well as 5th Generation concepts.
- In 5th Generation, treat district heating AND cooling together, match temperature levels to actual demands, enable multiple sources and minimize losses.
- Storage of heat and cold, that is Thermal Energy Storage, is important for resource and cost efficient solutions, and for integrating the heating/cooling sector with fluctuating wind and PV technologies.
- Local conditions, including business landscape and policy, are crucial to consider for successful projects.

Some reading

- https://www.4dh.eu/about-4dh/4gdh-definition
- Buffa et al, 2019, ” 5th generation district heating and cooling systems: A review of existing cases in Europe”, Renewable and Sustainable Energy Reviews 104 (2019) pages 504–522 https://doi.org/10.1016/j.rser.2018.12.059
- http://www.flexynets.eu/en/Home
- Euroheat & Power: https://www.euroheat.org/

Thank you for your attention!