Innovation in District Heating and Energy Storage

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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.
- MSc Chemical Eng, KTH (1993)
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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.

CO2 absorbed by growing forest

Ash is returned, circularity

Wood residue: branches, tree tops, wood chips, bark

Image: www.veab.se
• 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)
  - Approximately 162800 TWh/year
  - Of which Sweden demands 573 TWh/year or 0.4%; and
  - PR of China demands 15900 TWh/year or 4%


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?

- Mechanical ES
  - Compressed Air
  - Pumped Hydro
  - Flywheel

- Electrochemical ES
  - Battery

- Electrical ES
  - SMES Supercapacitors

- Chemical ES
  - H2

- Thermal ES
  - Sensible
  - Latent
  - Thermo-chemical

From ISES webinar Feb 27, 2020
Storage of Thermal Energy in District Heating

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

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

Reversed flow function

140 boreholes
150 m depth
Emmaboda Foundry
Storing Industrial Surplus Heat at high temperature (60 C) during Summer
TES enabling Industrial Surplus Heat for Societal Use, and absorbing surplus from wind/PV
Seasonal Storage of Solar Heat

Detached garages with solar collectors on the roofs
Solar collector loop
Energy Centre with short-term thermal storage tanks
Borehole seasonal (long-term) thermal storage

Two-storey single-family homes
District heating loop (below grade) connects to homes in community

Drake Landing Solar Community – schematic Layout
Thermal Energy Storage – Merging Concepts

- Using Phase Change Materials, below for Seasonal Storage:


  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
- Euroheat & Power: https://www.euroheat.org/

Thank you for your attention!