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Temperature utilization in TES and its impact on 4GDH

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Short introduction about me, Johan Dalgren

- I completed my MSc in Mechanical engineering/Energy Technology in 2006 at KTH (Royal Institute of Technology in Stockholm, Sweden).
- Started as a technician in 2007 at one of Fortum's production sites in Stockholm (Värtaverket); and later became the operator of its 250MW heat pumps and district cooling production.
- Since 2009 I have worked with System Optimization and mainly focused on the steering and design of our distribution network.
- Started my PhD in February 2017 within the same field at KTH with focus on developing a supply temperature strategy for complex DH systems.
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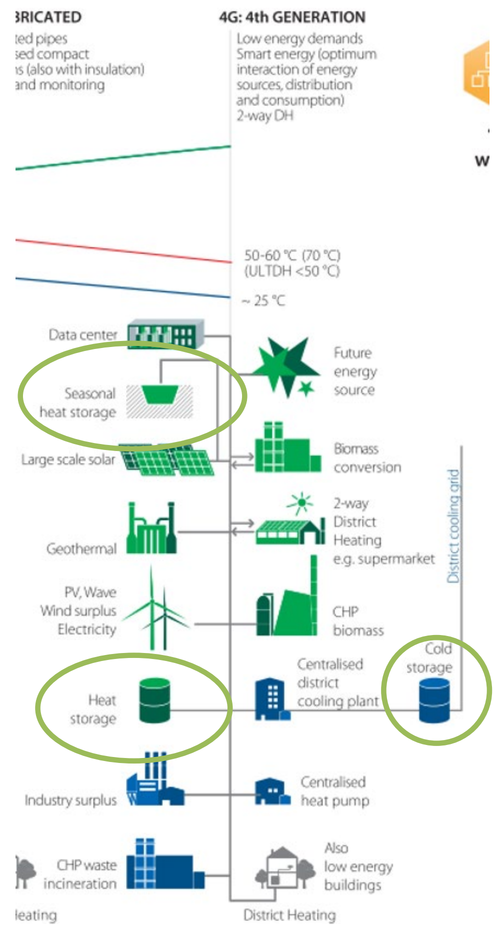
Why do we need TES in 4GDH?

- Key assumptions in 4GDH are that there will be a ban of fossil fuels and high demand (prices) for bio-fuels.
- Instead of combustion based high temperature heat sources (HTS), more surplus heat shall be recovered from multiple low temperature sources (LTS). E.g. industry surplus, solar collectors, sea water, ground heat, waste heat from cooling, etc.
- To enable LTS directly or with the help of heat pumps, and increase their efficiency, the temperature levels in the DH system should be as low as possible. Which also reduces heat losses from the network.
- To replace the traditional peak boilers TES will **balance the heat demand and production**. To cover daily to seasonal variations.
- Research in the field of 4GDH has also shown a large economic and environmental potential of balancing the electricity market. Especially surplus of wind power can give very low electricity prices.
  - This surplus power can then be used to increase the heat production, with heat pumps and by by-passing the turbine in CHP plants, which can be stored in TES.
  - When the wind eventually stops blowing there will be a scarcity of wind power.
  - To balance this power scarcity, the heat pumps can be taken out of operation and the CHP operate with full back pressure.
  - To still fulfil the heat demand the TES can be discharged, and thus being used for **power-to-heat storage** to balance the volatility in the wind power production. Hourly to seasonal.
- TES is also still needed for **security of supply**.



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Why do we need high temperature TES?

- Maximize capacity
  - It's the difference between the discharge temperature and the system return temperature that creates value.
- Seasonal variations
  - During a cold period with high heating demands, the customers and network demand the highest temperature.
  - The heating demand has a strong correlation with electricity demand, so boosting the discharge temperature with HP should be minimized.
- Daily variations
  - For power to heat storage
    - With high electricity price the HP are running on minimum and CHP are producing maximum electricity. Discharge from TES with high temp enables lower temp from sources and thereby higher alpha/COP.
    - When electricity price is low, HP and direct heat from CHP is used to charge the TES. Direct heat enables high temp.
  - For daily load variations
    - At peak demands a higher discharge temperature from TES reduces the flow increase to the network.

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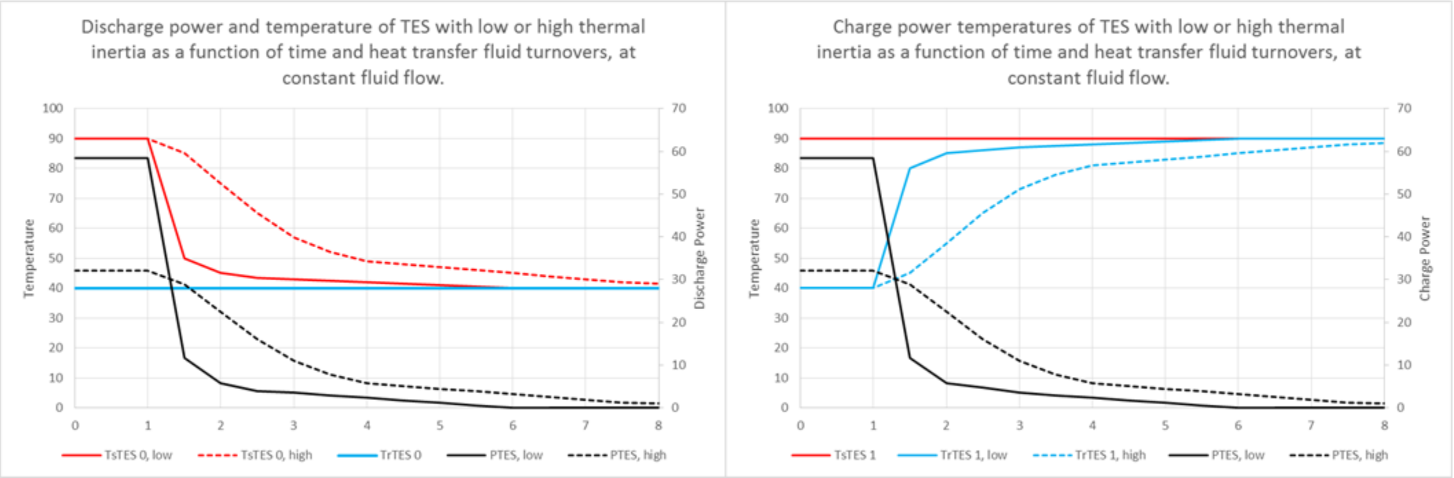
Temperature loss in TES

- To preserve the high temperature in the TES, it is of course important to minimize the heat losses.
- If the heat is stored in another media than the DH water, a heat exchange with that media occurs, with a certain temperature efficiency. E.g. aquifer, rock cavern, etc.
- The more thermal inertia or latent heat there is in such a storage the greater the effect on the supply temperature when discharged and the return temperature when charged.
- A higher flow will also increase the temperature drop.
- When the discharge temperature becomes lower than what's needed for the network, the remaining energy content is of less value. Instead of enabling more LTS it then needs something to boost its own temperature.



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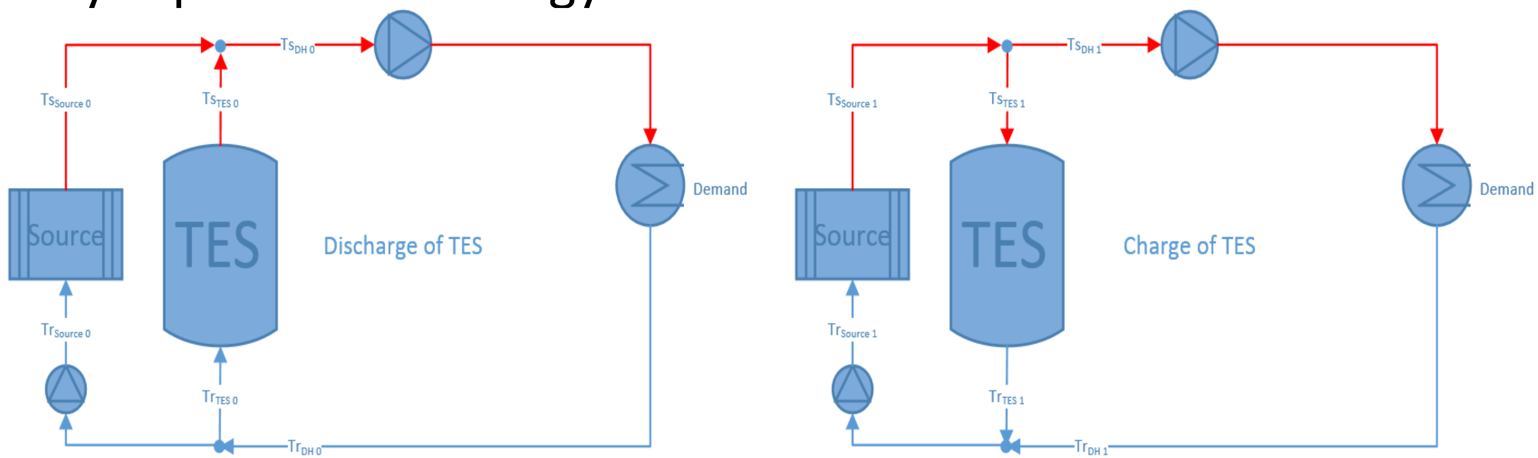
Useful energy content in TES

- Even if we would have a loss free accumulator with perfect stratification, the temperature variations in a DHS affects the useful energy content.
- When discharging we have a high return temperature and the network need a high supply temperature. But when charging we have excess of LTS and high return temperature from the TES.
- The TES can therefore not directly be charged with LTS, instead a mayor part of the energy content must come from HTS.



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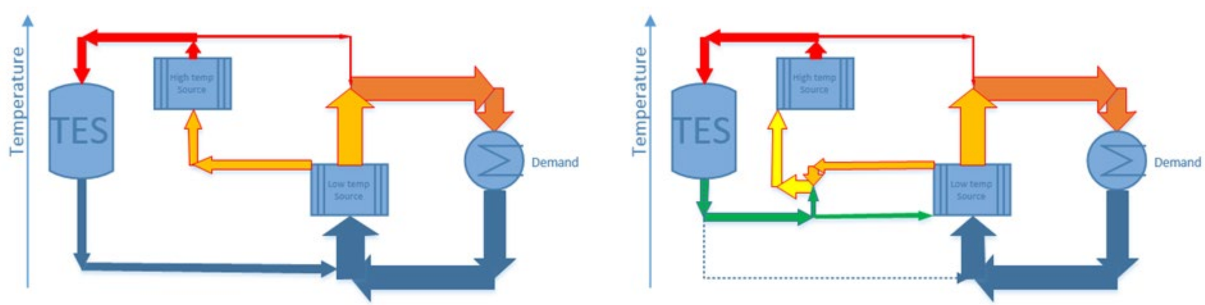
Connection of TES in 4GDH to maximise temperature utilization

- 4G customers might however at low heat demands be supplied directly from LTS, or at least significantly reduce the share needed of HTS.
- By connecting a High Temperature Source (HTS) like a CHP waste incineration plant directly to the storage, it can be used as an enabler to store LTS with high temperature in a seasonal TES.
- This also allows to have a higher fraction of LTS distributed in the system, to create more efficient low temperature areas in the DHS.
- A high thermal inertia in the storage would however still decrease the useful energy content of the storage due to the temperature efficiency.



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Relation to other literature on the topic

- Most literature focus on the energy content and efficiency of the storage, with a possible mismatch of temperatures when charging/discharging.
- Studies that do consider temperatures, have focused on calculations with average system temperatures, not the daily and seasonal variations in the DHS (what may appear as an energy loss, might in fact be a temperature loss).
- The energy loss in TES has further not been translated to a temperature drop, and its consequences to the reduced share of LTS available in the system.

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Conclusions

- TES can not directly be used to balance heat demand variations with LTS.
- When discharging TES it’s likely that electricity is scarce, so HP should be minimized to boost the temperature
- The charge and discharge temperature of a TES should be as high as possible.
- The return temperature to or from the TES should be as low as possible when charging and discharging, respectively.
- The TES should therefore be well insulated, have a small thermal mass of inactive material and be connected directly to a high temperature source.

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