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TECHNO-ECONOMIC ASSESSMENT OF LATENT THERMAL ENERGY STORAGE INTEGRATION WITH LOW-TEMPERATURE DISTRICT HEATING

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4DH
4th Generation District Heating
Technologies and Systems

Background / Introduction

- Heading for a Smart Energy System:
  - Benefits: energy efficiency, economics, environment
  - Requirements: **flexibility**, demand/supply matching, …
- Opportunity for **Thermal Energy Storage** (TES)
  - Enhance benefits when integrated to **4DH**
  - Sensible heat storage dominant (water)
  - Typical use: load shifting, lower heat production costs
- TES operating at lower temperatures
  - T_{low} 25°C , T_{high} 50-65°C
  - Advantages / drawbacks (?)

Objectives and Scope

- Focus on **Latent Heat TES** (PCM)
  - Comparison to Sensible TES (Water) as baseline
  - Short-term storage
- Comparative assessment (techno-economic)
  - TES System (rather than the material)
- Identify suitable LH-TES for LTDH
  - Types with most favourable conditions
  - Explore TES integration at the substation/subnet level

Methodology

TES + LTDH Compatibility

- Latent Heat Storage: **PCMs**
- Sensible Heat Storage **(Benchmark)**

Qualitative Assessment

- Availability of Materials (PCMs)
- Short-term / Long-term suitability
- Ease of handling, toxicity …

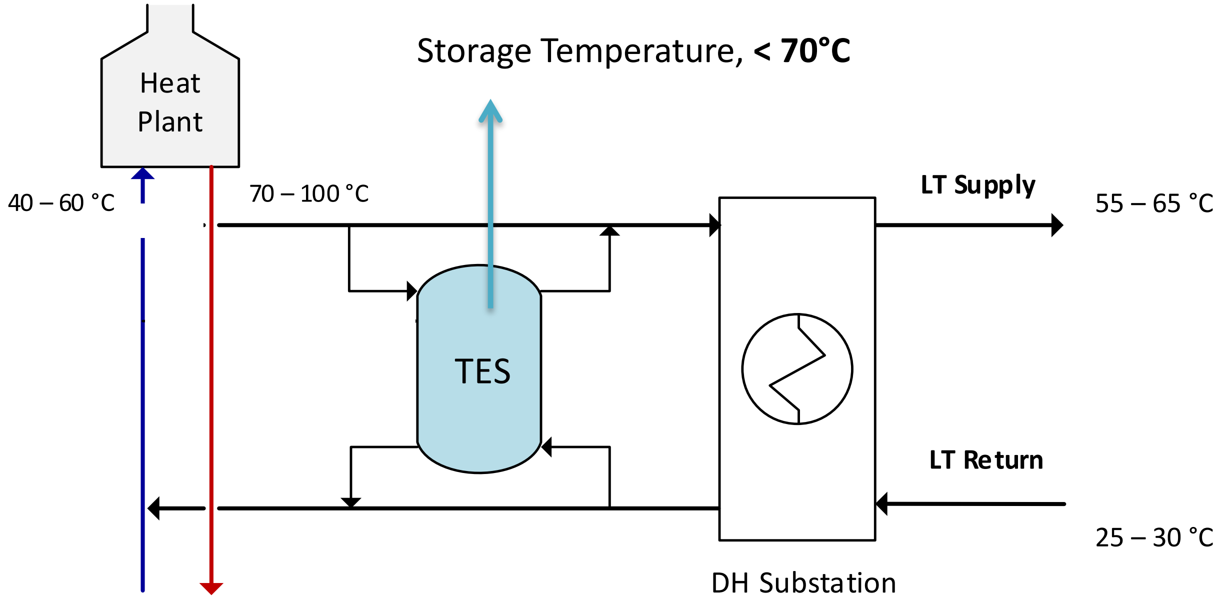
Technical Assessment

- Operating Temperatures
- Phase Change Temperature (PCM)
- Volumetric Energy Density **(kWh/m^3)**

Cost Comparison

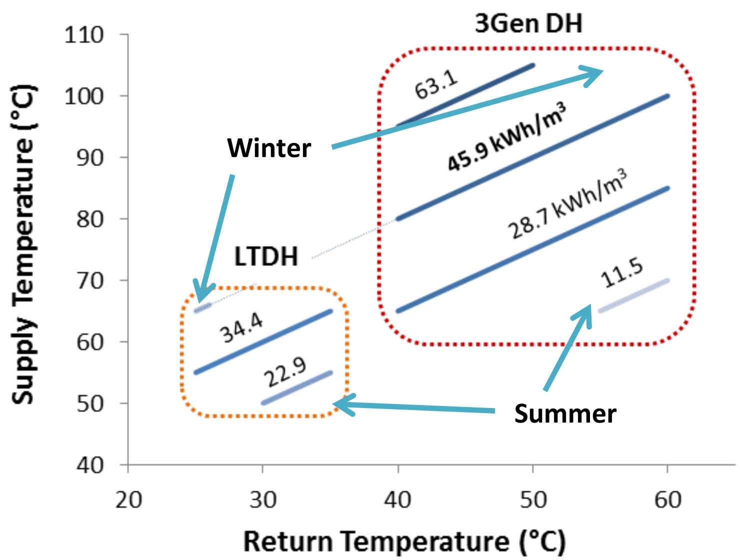
- Storage **System** (~~material~~)
- Costs Breakdown
- **€/kWh**

System: LTDH + TES



Technical Evaluation

Sensible Heat (water)



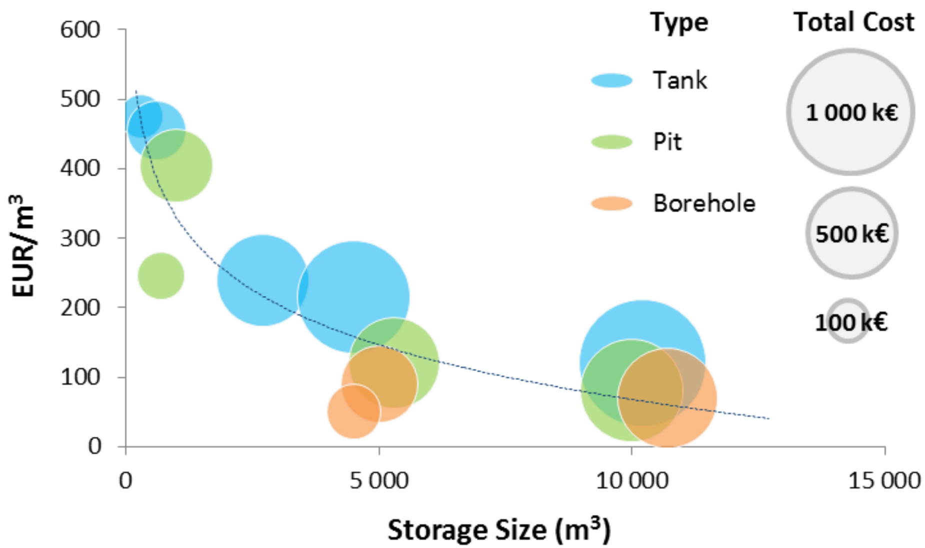
- **Volumetric capacity depends on the operating temperature ranges (Delta T)**

Volumetric capacity:

- Sensible heat TES systems, lower volumetric capacity when LTDH operation is in place
- Latent TES systems present an advantage: less sensible to Delta T
- Example: a paraffin PCM operating with LTDH, Volumetric capacity range
  - min: 52 kWh/m^3
  - max: 64 kWh/m^3

Minimum charging temperature 50-55°C (supply, above PC temperature)

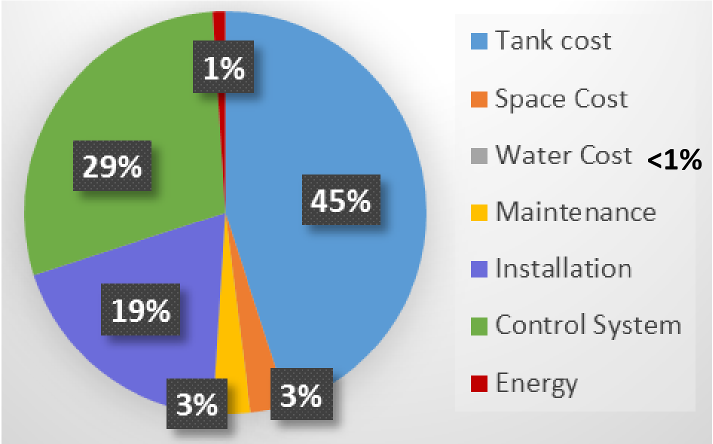
Costs SH-TES



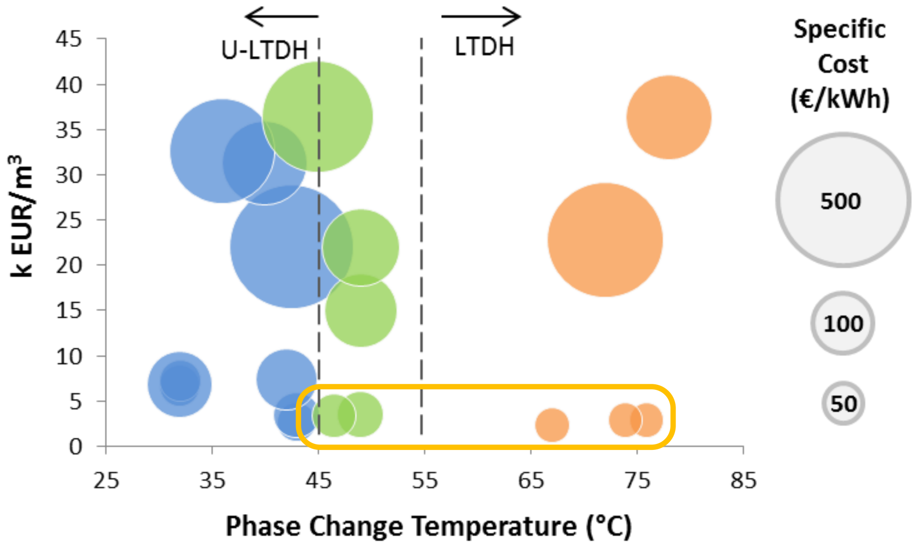
Sensible Heat (Water) Systems

Specific cost range: **0.5 - 8 EUR/kWh**

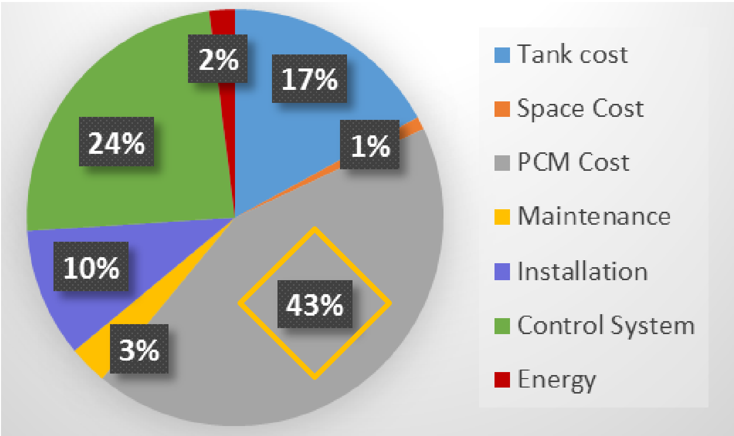
Waster Tank System (average)



Costs LH-TES



PCM System (average)



PCM Systems

Materials:

Paraffins, Fatty Acids, Salt Hydrates, Metallics

Specific cost: **>30 EUR/kWh**

Ongoing Work

- Impact of TES for suppliers and LTDH customers
  - Supply of heat with lower marginal costs, same network
  - Load shifting (short term)

- Impact of TES + LTDH in the main network
  - Differences in pumping power on the primary side
  - Reduction (?) of T_{return} due to charge/discharge process

Conclusions

- Sensible TES (water) is more economical than Latent TES
  - The storage material itself is the main difference
  - Costs of LH-TES systems are expected to drop in the future
- Latent TES for **small scale (short term) applications** with LTDH will become competitively closer to water tanks
  - Lower DeltaT (for LTDH) and space restrictions are the main drivers
  - For large scale and seasonal storage applications water is superior
- Current best case for Latent Heat TES systems:
  - cost per kWh stored is still at least 2 times higher than for a water tank
  - requires half of the volume in average

Thank you!

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Supporting Slides

Qualitative Assessment PCMs

4DH
4th Generation District Heating Technologies and Systems

Latent Heat Storage	**Paraffins**	Organic compounds Use of technical grade paraffin for cost reasons Chemically stable, non-corrosive and no subcooling phenomenon Wide phase change temperature (PCT) range Low volume variation when changing phase (10%) Low thermal conductivity and low volumetric storage density (compared to inorganic compounds)
	Fatty Acids	Organic compounds Wide phase change temperature range Low thermal conductivity and low volumetric storage density (compared to inorganic compounds) Mild corrosive Behavior similar to other organic compounds for the remaining properties
	Salt Hydrates	Inorganic compounds Wide PCT, low volume change High latent heat of fusion and higher thermal conductivity (double of paraffins) Slightly toxic, corrosive, non-flammable Face problems of incongruent melting and super-cooling
	Metallics	Inorganic compounds Used in high working temperature application (such aerospace) Very high heat of fusion per unit volume Weight penalties

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Methods: Costs Breakdown

Main cost items:

- Storage medium (material)
- System purchase cost (e.g. tank)
- Other fixed costs (insulation, piping)
- Control system
- Installation (incl. labour)
- Operation and Maintenance (O&M)
- Replacement

*Special attention to influence of system size (scale)