Seasonal Thermal Energy Storage in District Heating Systems

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Hypothesis of Project

``Thermal energy storage (TES) technologies and low temperature district heating systems have the potential to play a significant role in the transition towards 100% renewable energy systems through increasing system flexibility and overall efficiency and thus reduce CO_2 emissions and increase domestic energy security."

- Techno-economic and socio-economic feasibility of different types of TES systems to be employed
- Energy systems analysis including TES systems to be employed
- Different regulatory and policy framework

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Motivations for Research

- Increased integration of renewable and industrial waste energy sources in to the energy system
- System flexibility through decoupling of heat and electricity production/consumption
- Energy system stability
- Analysis of seasonal storage`s impact on the energy system
- Compatibility with low-temp district heating

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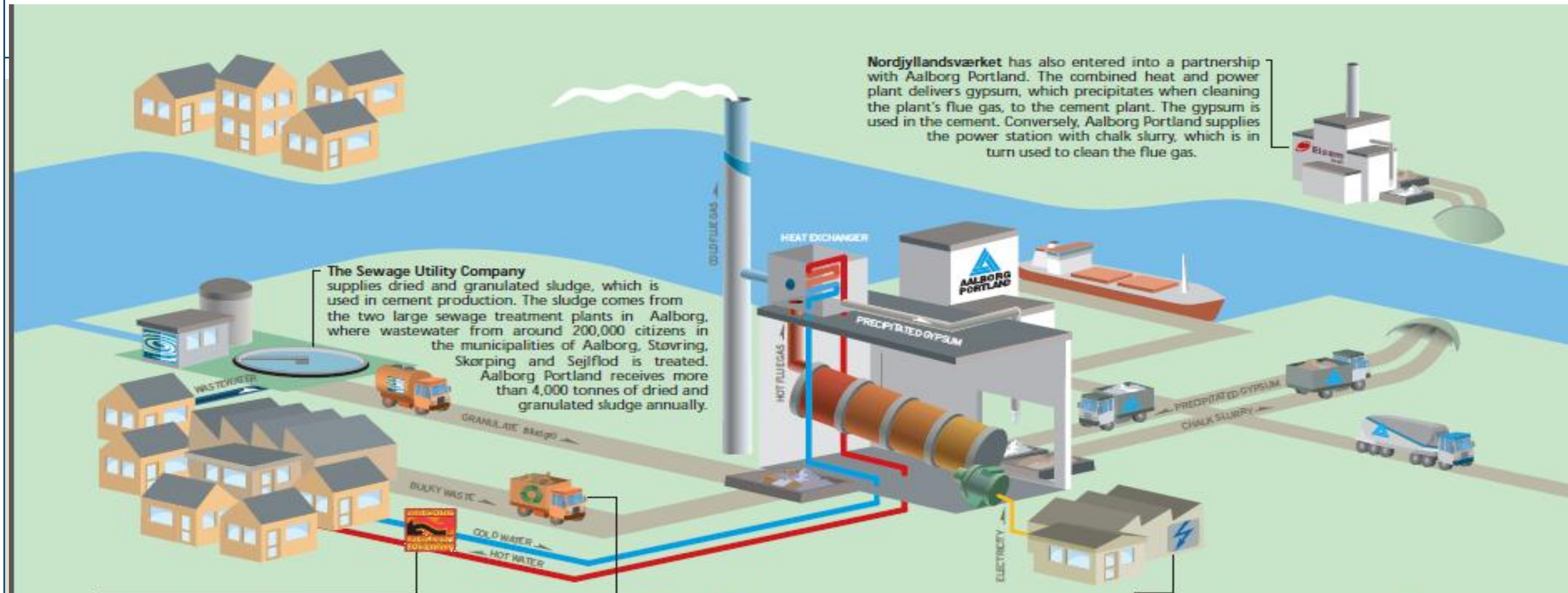
Sources of Waste Heat



The District Heating Utility Company receives more than 20% of Aalborg's district heating from Aalborg Portland. From 2006 this amount will have risen to approximately 30% as a result of an increase in Aalborg Portland's production capacity. This corresponds to the consumption of heat in more than 28,000 single-family dwellings.

The Refuse Collection Utility Company delivers old furniture and other bulky waste to Aalborg Portland. The furniture is ground down and used as fuel in the kilns. The Refuse Collection Utility Company also receives refuse from Aalborg Portland.

The Electric Utility Company supplies Aalborg Portland with electricity. The cement factory is Denmark's largest consumer of electricity, with an annual consumption of 330 million kWh. This figure corresponds to the consumption of more than 80,000 families and makes up more than a third of the Electric Utility Company's energy turnover. Aalborg Portland is connected directly to the Electric Utility Company's high voltage network.

In Aalborg, there is a unique cooperation between the cement manufacturer Aalborg Portland A/S and the Public Utility Companies.

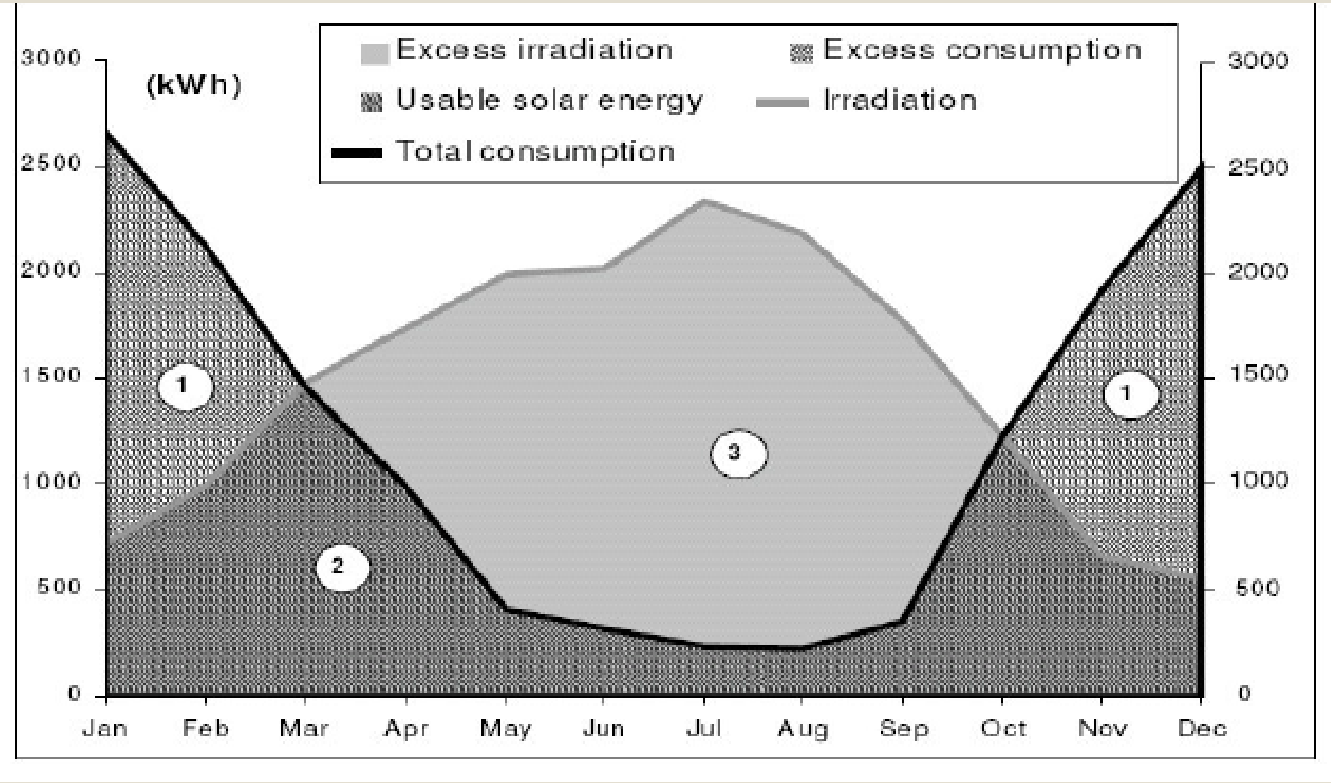
The Public Utility Companies supply electricity to Aalborg Portland, as well as fuel and raw materials in the form of old furniture, bulky waste and sludge for use in the energy-intensive production of cement. In return, Aalborg Portland delivers surplus heat to the District Heating Utility Company and endeavours to dispose of waste in an energy efficient and environmentally friendly manner.

Aalborg Portland also assigns areas for a waste and recycling centre, which the Refuse Collection Utility Company operates in cooperation with a recycling company.

Cement production involves large amounts of wastewater which wherever possible is treated and recycled in situ. Aalborg Portland has permission from the County of North Jutland to carry out the treatment and discharge of wastewater itself.

Collectively, this cooperation benefits the environment in the local society and limits the emission of greenhouse gases into the atmosphere. District heating is produced without the use of extra fuel and is therefore CO_2-neutral. Such cooperation is also of huge economic benefit to both parties – and their customers.

Solar Thermal Potential



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Thermal Energy Storage Systems

Passive vs. Active Systems:

- Passive: Separate energy carrier/transport medium that passes through the storage medium
- Active: Energy carrier/transport medium is the same as the storage medium

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Types of Storage Mediums and Processes

- Sensible Heat Storage
  - Heat stored and released through change in temperature of a medium

- Latent Heat Storage
  - Heat stored and released through phase change

- Thermochemical Heat Storage
  - Heat stored and released through chemical or sorption reactions

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Technical Feasibility Factors

Factors that affect storage medium technical feasibility include:

- Specific Heat/Volumetric Thermal Capacity
- Thermal Conductivity/Resistance
- Stratification

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Thermal Capacities of Common Materials

Material	Density (kg/m^3)	Specific heat (J/kgK)	Volumetric thermal capacity ($10^6 J/m^3K$)
Clay	1458	879	1.28
Brick	1800	837	1.51
Sandstone	2200	712	1.57
Wood	700	2390	1.67
Concrete	2000	880	1.76
Glass	2710	837	2.27
Aluminium	2710	896	2.43
Iron	7900	452	3.57
Steel	7840	465	3.68
Gravelly earth	2050	1840	3.77
Magnetite	5177	752	3.89
Water	988	4182	4.17

(Dincer, 2004)

Sensible Storage Medium Properties

- Available Media for Sensible Seasonal TES Systems

- Rock beds and caverns
- Earth beds
- Large water tanks
- Aquifers
- Pits & Ponds

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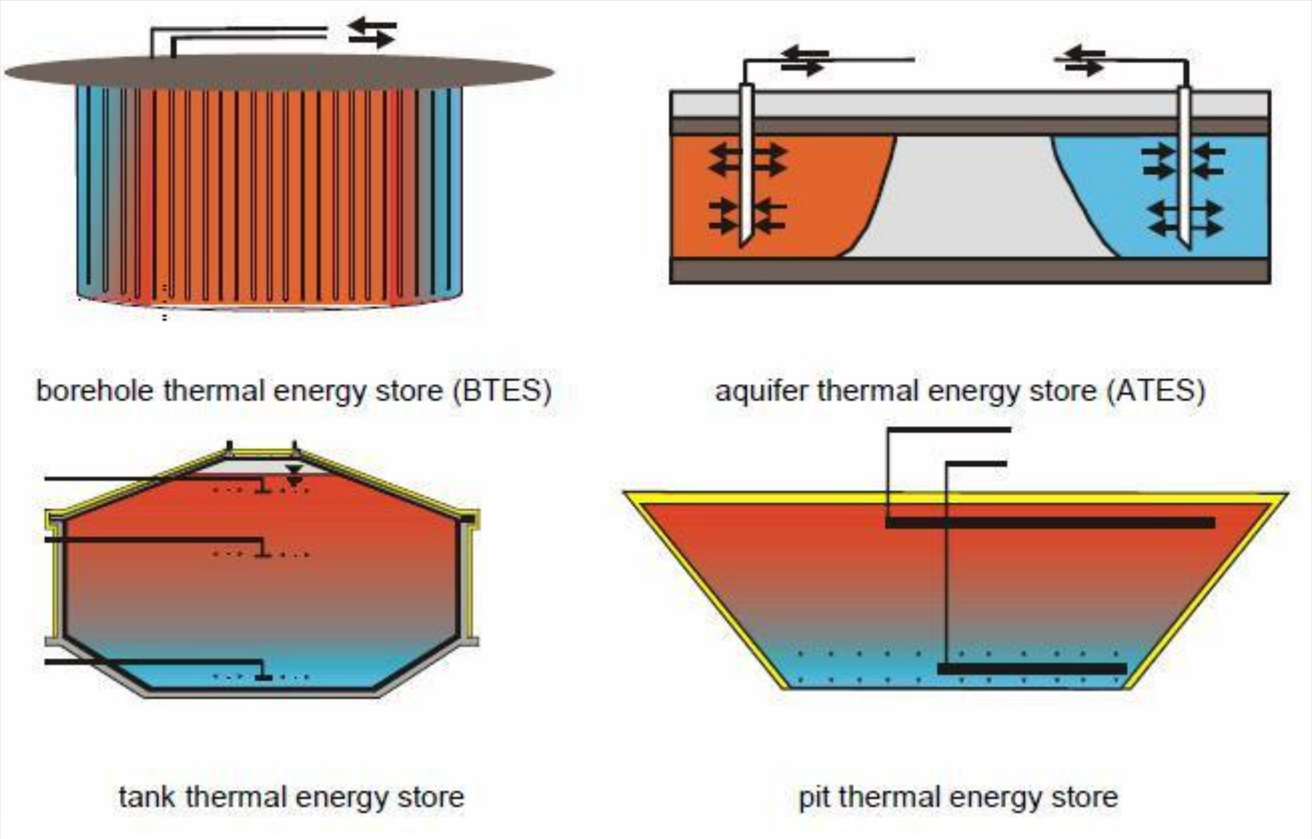
Storage Types to be Evaluated



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(Ochs, 2007)

Economic Feasibility

Factors that affect storage medium economic feasibility include:

- Size requirements
- Thermal losses
- Life time of storage
- Availability of the medium

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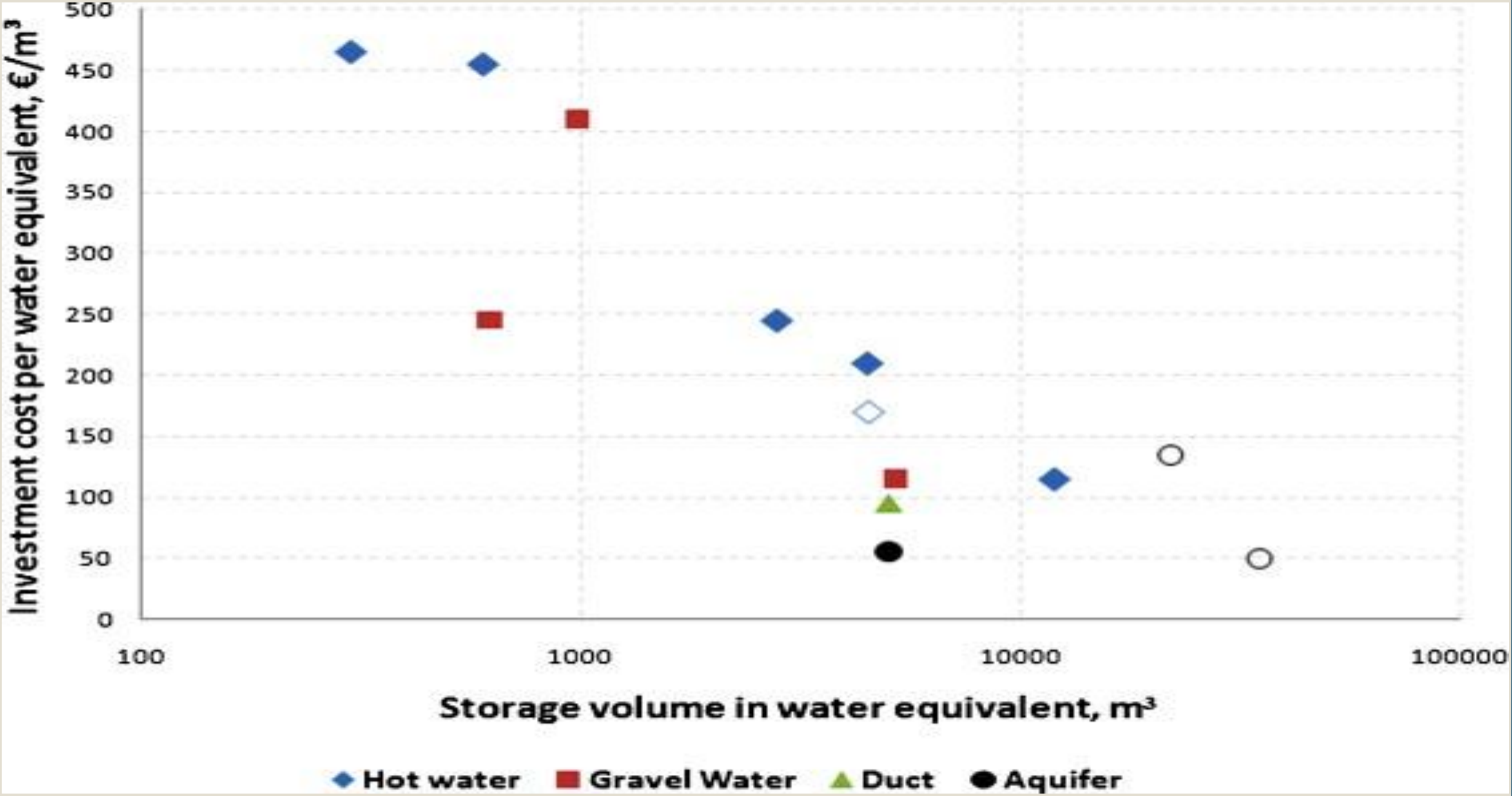
Investment Costs of Various Systems



(Schmidt and Mangold, 2008)

How does the research apply for 4DH

What role will seasonal thermal storage play in future systems where:

- Low temperature district heating is implemented?
- Heat demand is reduced through conservation and energy efficiency measures?
- Systems characterized by lowered losses?

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Research Questions

- Is large scale seasonal thermal storage technically and economically feasible?
- What capacity is optimal? How does it impact system flexibility?
- How will seasonal thermal storage impact the operation strategies of dispatchable conversion units in the energy system?

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Research Questions

- Can system stability be improved through electrification of heat supply coupled with seasonal storage?
- What kind of barriers to implementation exist and what kind of policy can be developed to facilitate said implementation?
- What if a cooling demand is included? Cold Storage?

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Research Challenges

- Quantification of industrial waste heat streams available
- Acquisition of data
- Determination of technical make-up of the system and to develop scenario's for analysis
- Methods for assessing seasonal storage feasibility
- Methods and tools for energy system analysis

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Possibility for Collaboration

- WP 2.3: Distributed CHP plants optimized across more electricity markets
- WP 2.4 Low-temperature energy sources for district heating
- WP 3.3 Geographical representations of heat demand, efficiency and supply

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Industrial Collaboration

- Aalborg Kommune
- GEUS: Geological Survey of Denmark and Greenland
- PlanEnergi
- Marstal Fjernvarme
- Brædstrup Fjernvarme

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Thank you for your attention!

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