Heat Storage Webinar Series Pt. 2: HT-Borehole Thermal Energy Storage

System Integration Aspects

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Confidentiality: C1 - Public

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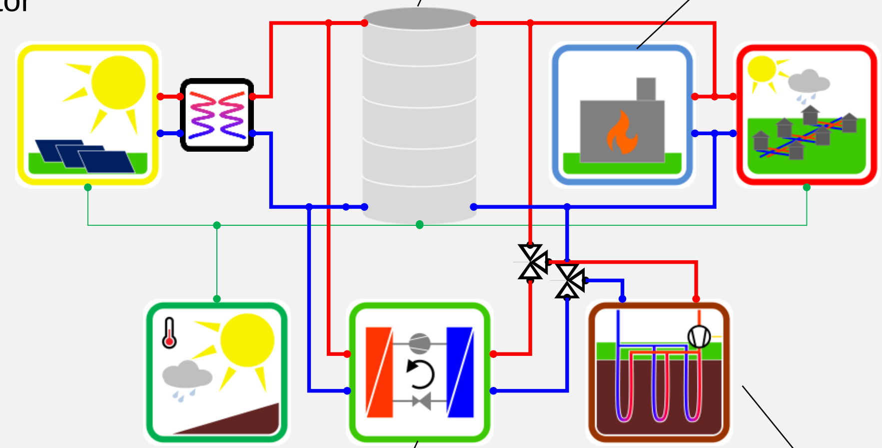
How are HT-BTES typically integrated into DH systems

Non-dispatchable heat source with high temperatures (60-90 °C) and low emission factor

Buffer storages for steady operation of the BTES & HP

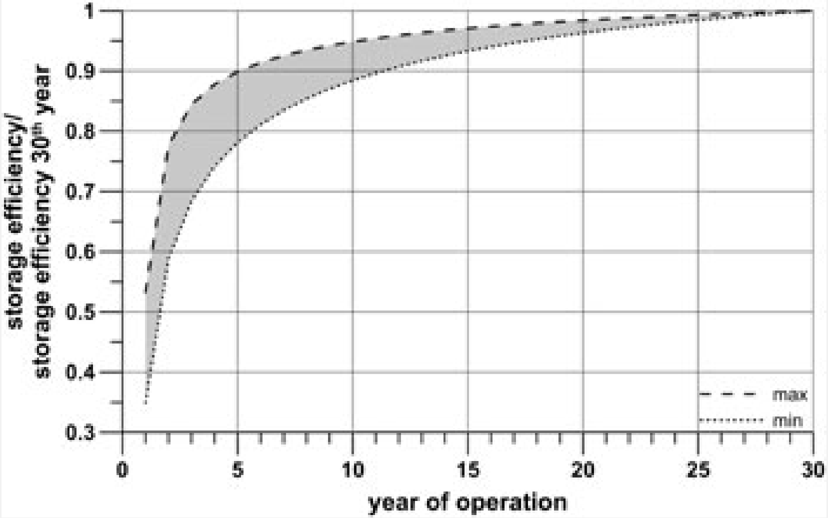
Auxillary heat source to cover peak loads



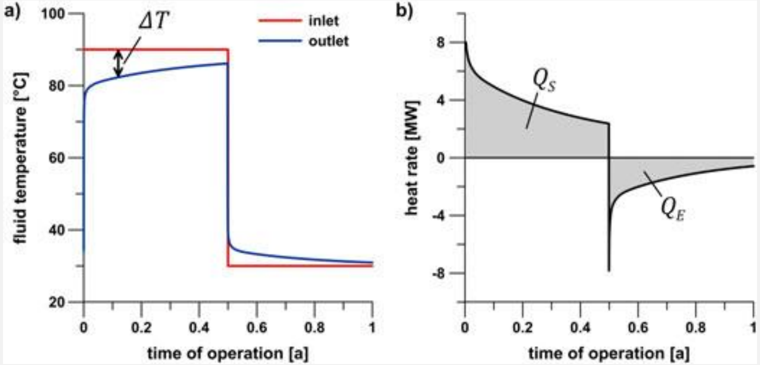
Heat pumps significantly increase heat recovery and usefule storage capacity

BTES for seasonal storage

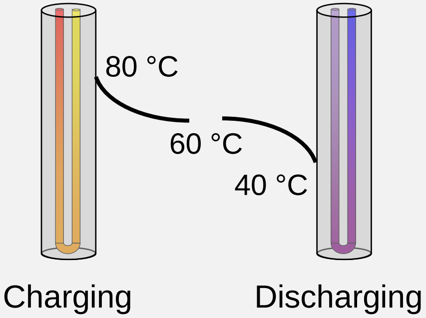
Storage efficiency is not as important as system efficiency



Welsch et al. 2016

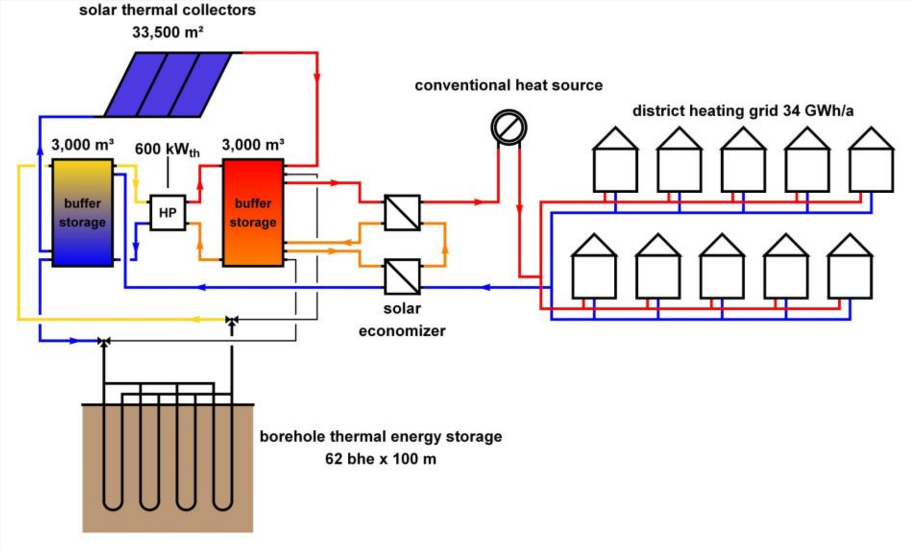


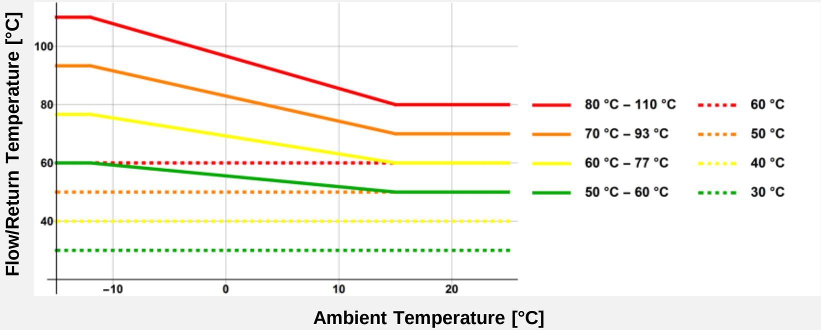
Welsch et al. 2016



Case Study – Grid Temperatures

How do grid temperatures affect storage performance?





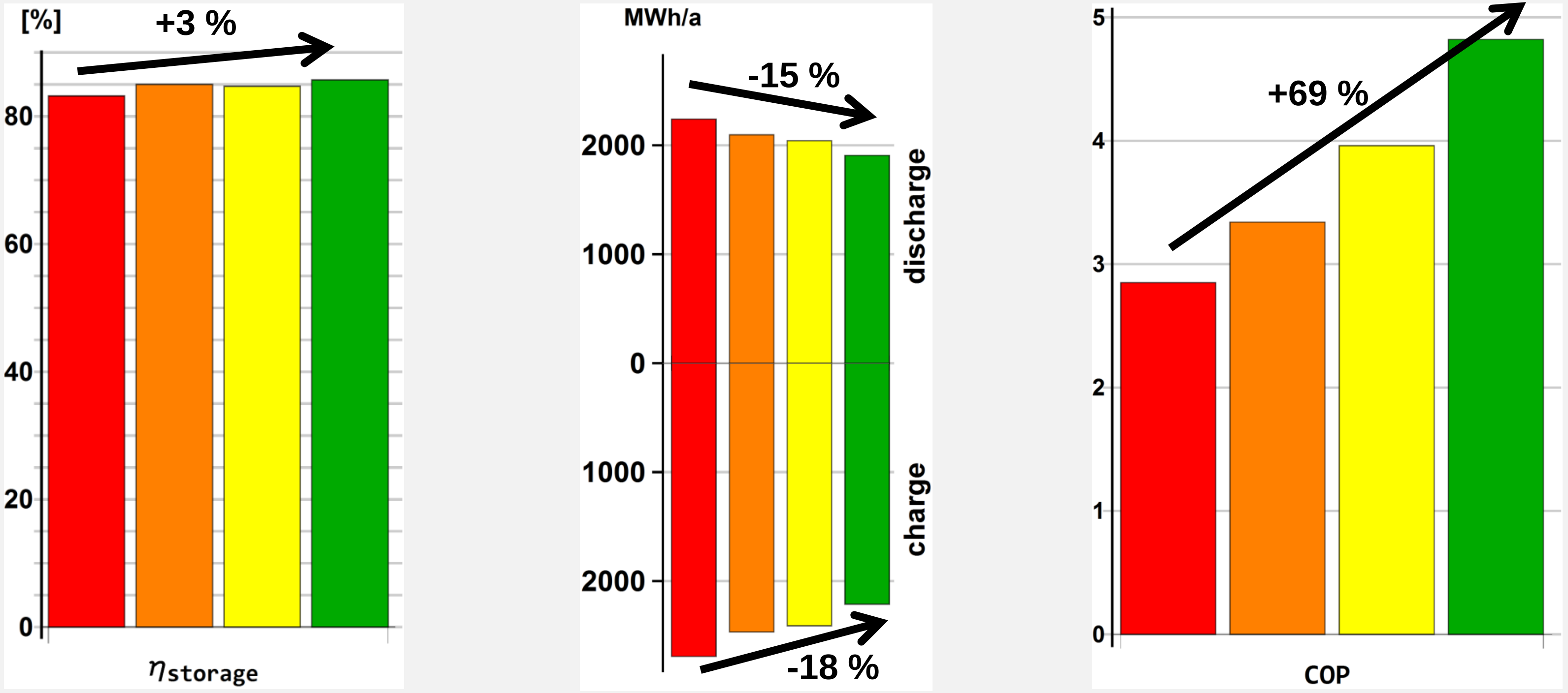
- Fixed sytsem design and control strategy
- Heat pump power adapted to temperature shift
- Simulation over 8 years

(Formhals et al. 2017)

Case Study – Grid Temperatures

Looking at storage efficiency alone does not show the whole story

F: 80 °C – 110 °C; R: 60 °C
F: 70 °C – 93 °C; R: 50 °C
F: 60 °C – 77 °C; R: 40 °C
F: 50 °C – 60 °C; R: 30 °C



(Formhals et al. 2017)

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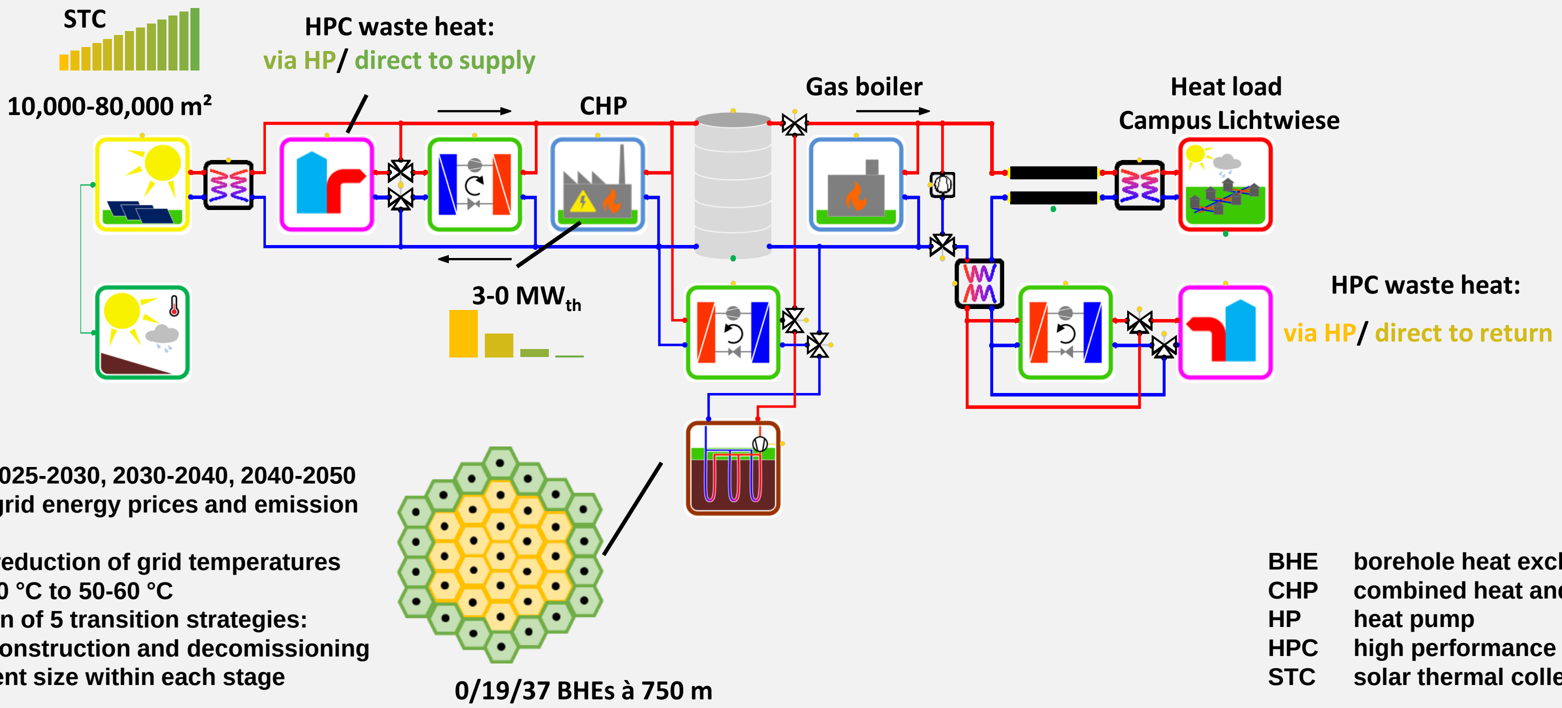
Integration of a medium deep HT-BTES into the TU Darmstadt DH grid

Institute for Sustainable Building Design, TU Darmstadt, 2020.

Project: SKEWS, TU Darmstadt, Geothermal Science & Technology

Case study – transition strategies

Transition to HT-BTES and Solar Thermal – When and how much



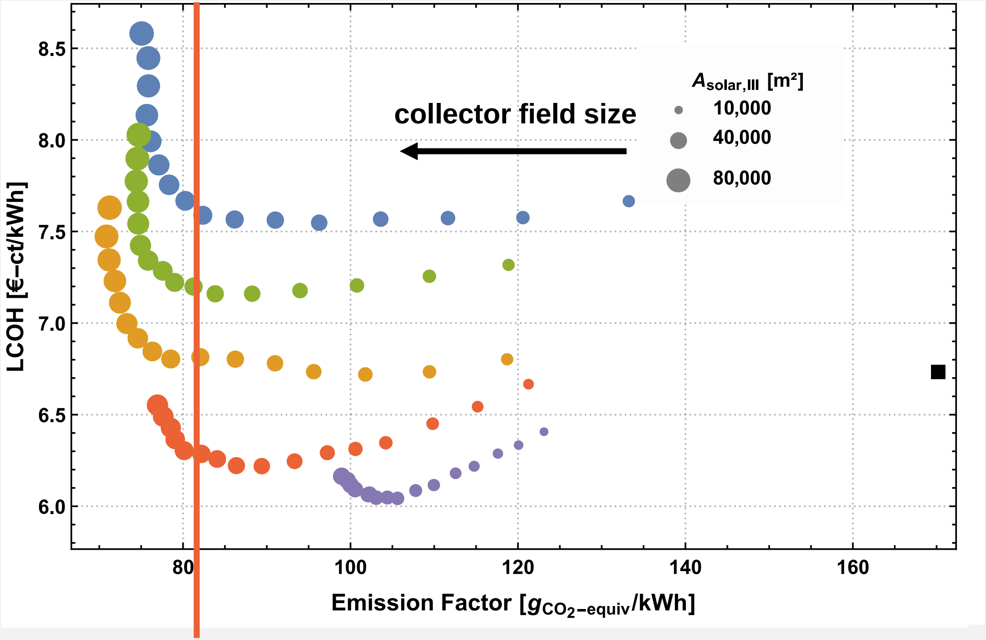
- 3 stages: 2025-2030, 2030-2040, 2040-2050
- Projected grid energy prices and emission factors
- Step wise reduction of grid temperatures from 70-100 °C to 50-60 °C
- Comparison of 5 transition strategies:
  - Time of construction and decomissioning
  - Component size within each stage

BHE	borehole heat exchanger
CHP	combined heat and power
HP	heat pump
HPC	high performance computer
STC	solar thermal collectors

Formhals et al. (2021)

Case study – transition strategies

Time of construction and size should follow efficiency measures of the DH grid



Emission target
øEF 2025-2050

- Reference: status quo system
- Immediate: construction in 2025
- Conservative: low speed and small size
- Step: construction in 2030
- Progressive: maximum system in 2030
- Gradual: gradual construction

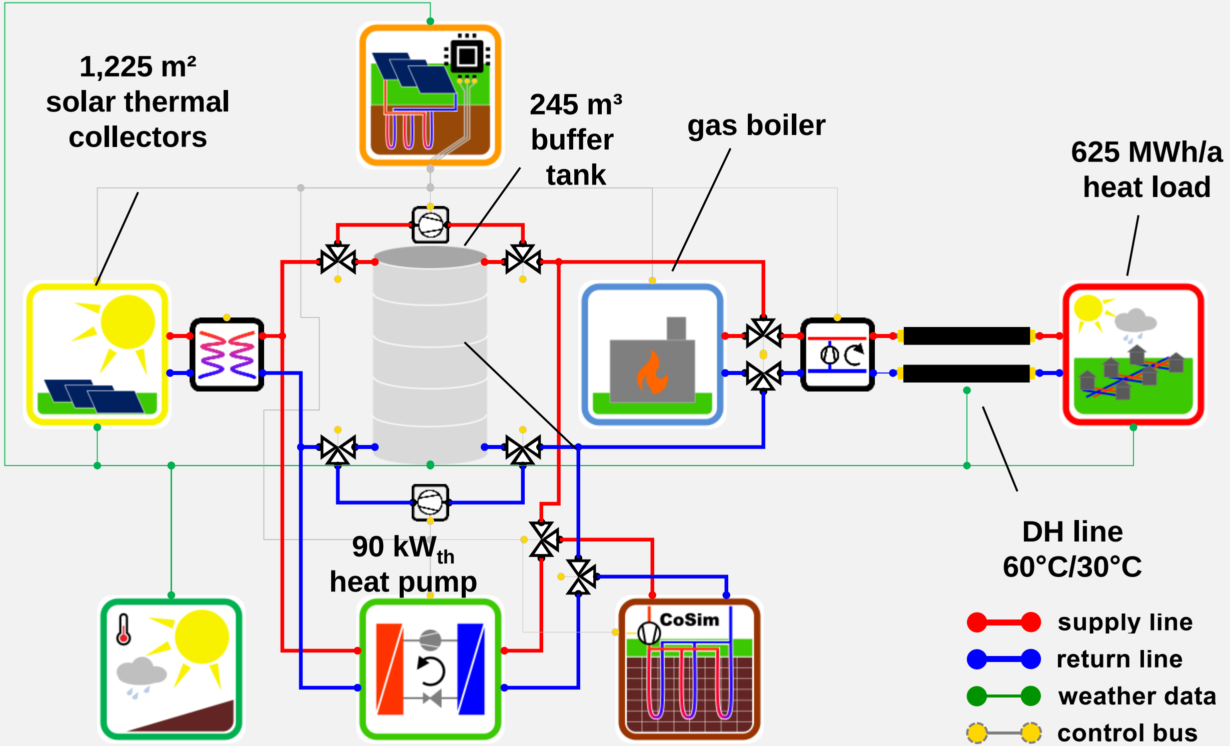
Recommended strategy: Gradual/42,000 m² solar & 37 BHEs

	2025	2030	2040
Solar	14,000 m²	28,000 m²	42,000 m²
BTES	-	19 BHEs	37 BHEs
CHP	3 MW_{th}	1,5 MW_{th}	0,5 MW_{th}
HPC cooling	HP→ret	HP→sup	dir→sup

Formhals et al. (2021)

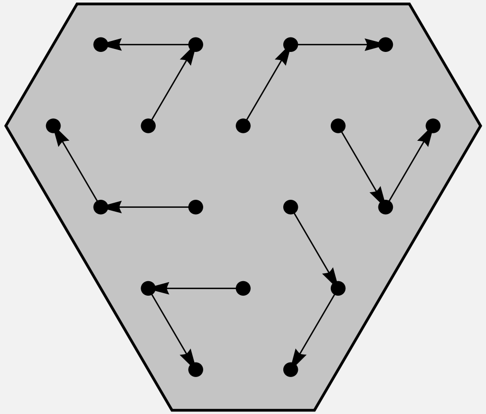
Case Study – Groundwater Flow

Is HT-BTES possible in regions with groundwater flow?



BTES

- 18 BHEs of 100 m
- 3 BHEs connected in series



Hydrogeology

- Hydraulic gradient: 0.01 m/m
- Hydr. conductivity: 10^{-8} – 10^{-4} m/s

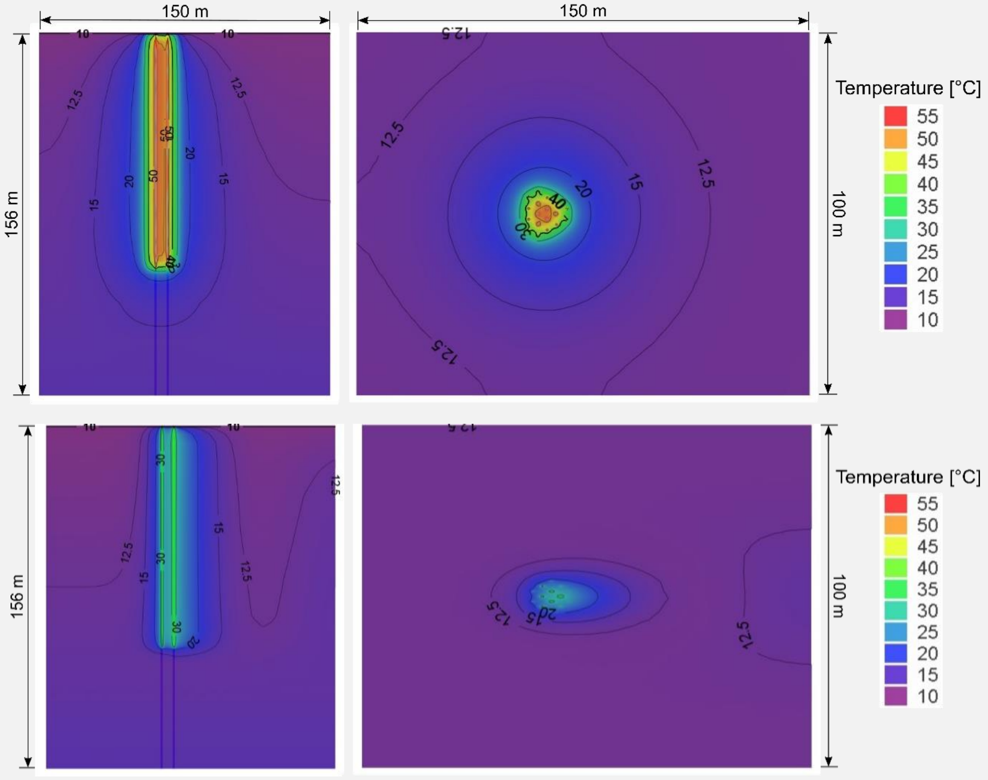
Formhals et al. (2022)

Case Study – Groundwater Flow

Flowing groundwater transports the heat out of the storage region

$k_f = 10^{-8}$ m/s
→ 3.2 mm/a

$k_f = 10^{-4}$ m/s
→ 32 m/a



hydraulic gradient

hydraulic gradient

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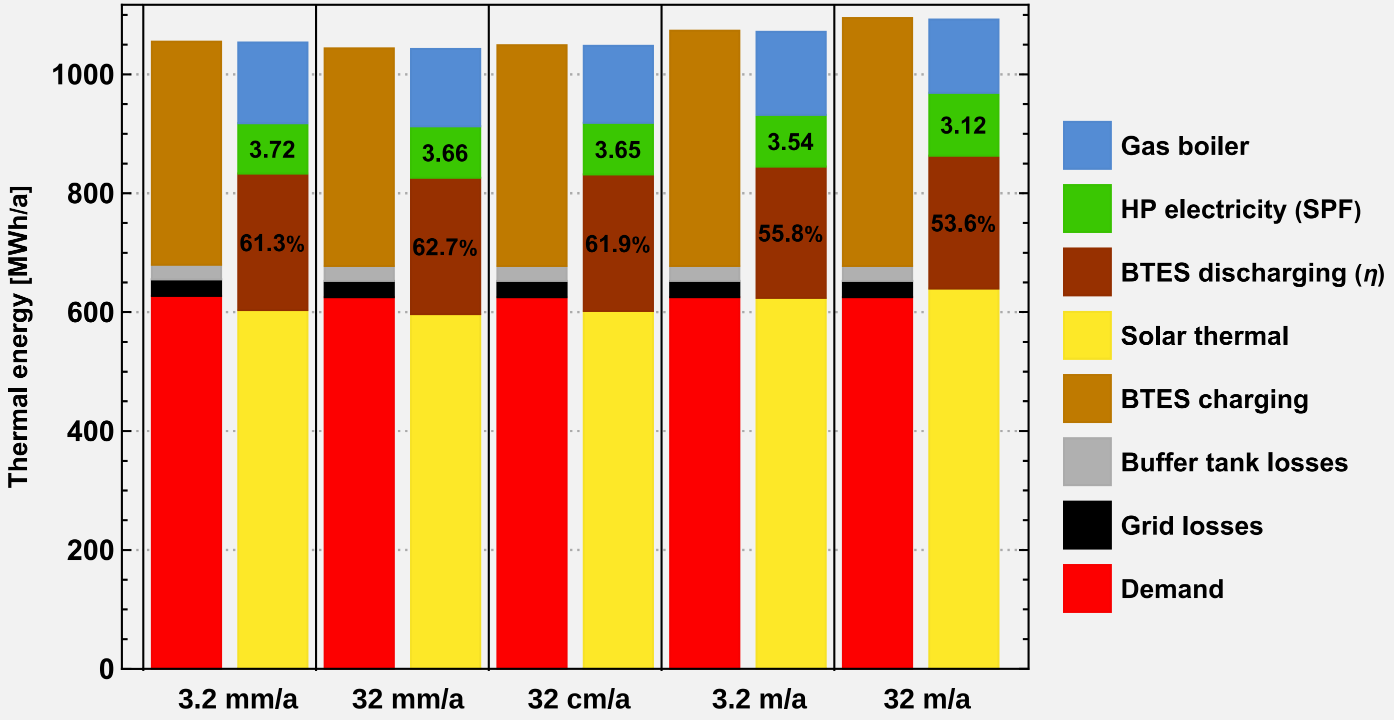
Formhals et al. (2022)

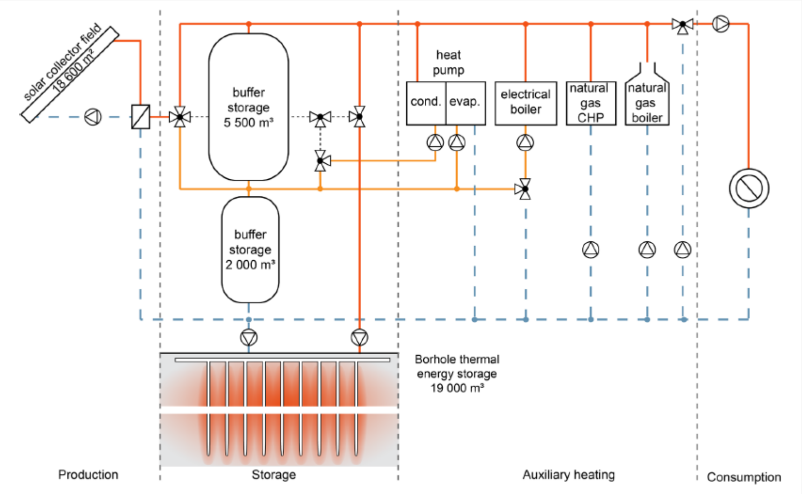
Strong groundwater flow reduces storage performance and heat pump COP



Formhals et al. (2022)

Brædstrup Solar DH system with HT-BTES

(Arcon-Sunmark, 2017)



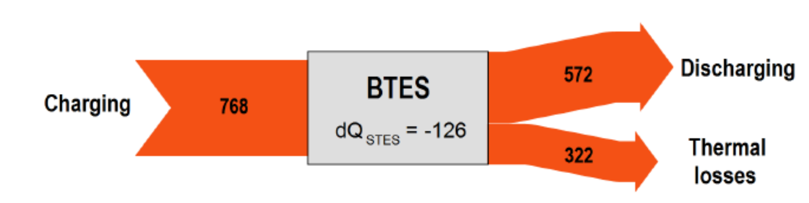
(Solites, 2019)

Brædstrup Fjernvarme supplies around 1,500 households with 37-42 GWh/a

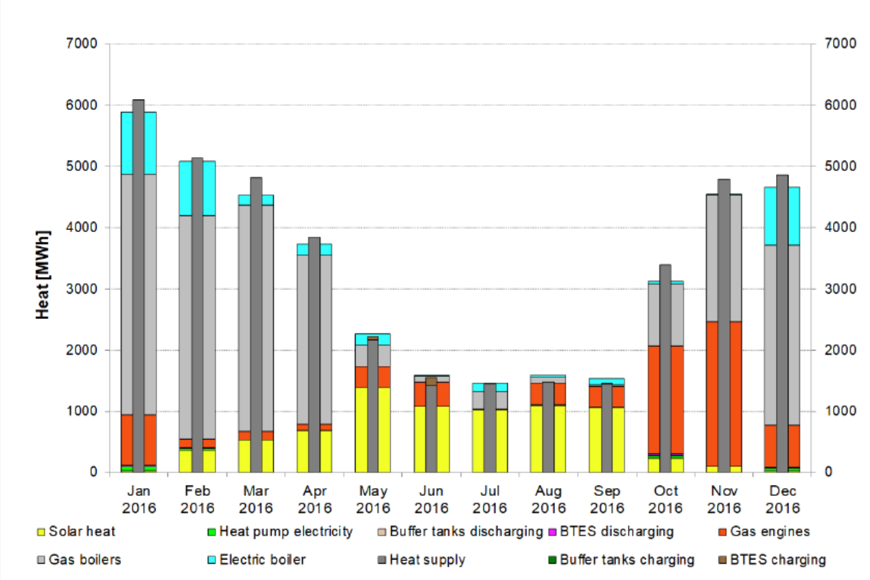
Brædstrup DH

Usefulness of seasonal storage is highly dependant of the overall system and availability of excess heat

Storage energy turnover for 2014-2017



Heat supply (broad) vs demand (thin)



- Storage efficiency of 74,4% in average
- Annual charging of 192 MWh
- Much lower than design number of 510 MWh
- Increased heat demand resulted in no solar excess during summer
- The seasonal storage was hardly used

(Solites, 2019)

Key take aways

- HT-BTES can store very large amounts of heat for reasonable storage costs
- Very high efficiencies are possible - even above 100%
- …but the integration into the system and temperature levels defines the overall efficiency
- A good combination is to have high temperature heat sources for storage (75-90 °C) and low grid temperatures (ideally 80 °C or lower)
- Significant groundwater flow reduces storage and system efficiency
- Storage performance and usefulness is highly dependant on the overall system (availability and temperature of excess heat, grid temperatures,…)

Bedankt voor jullie aandacht

Questions?

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References

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