Developing and demonstrating HT Aquifer Thermal Energy Storage in Delft

Dr.ir. M. Bloemendal

2025-09-10

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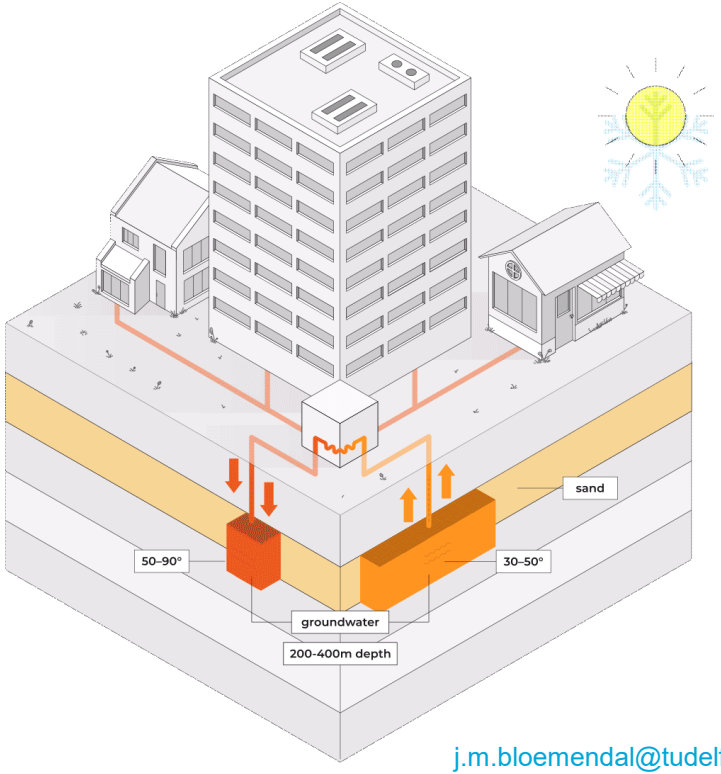
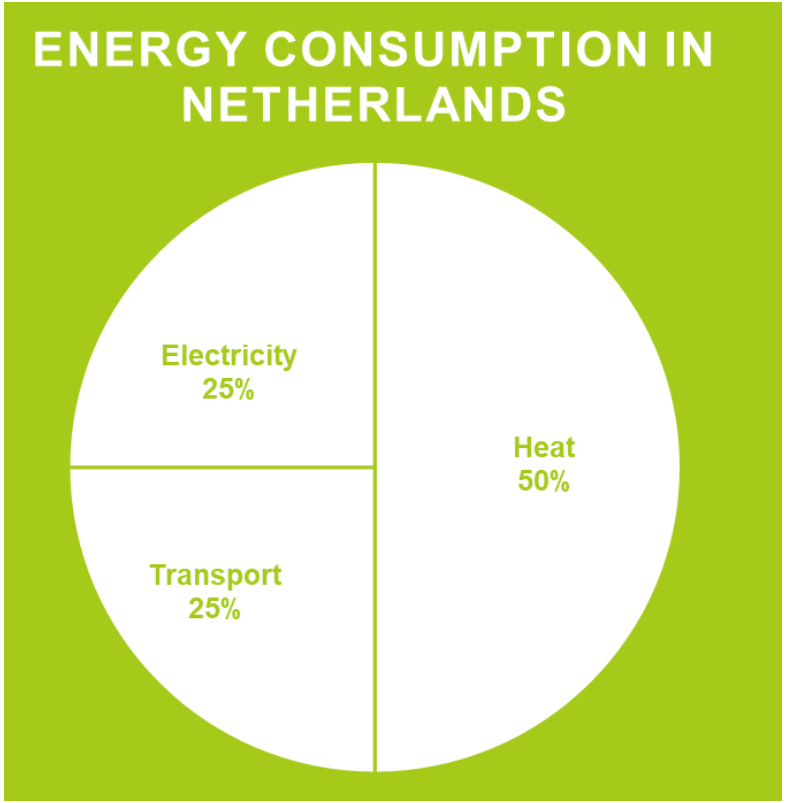


TNO

TU Delft

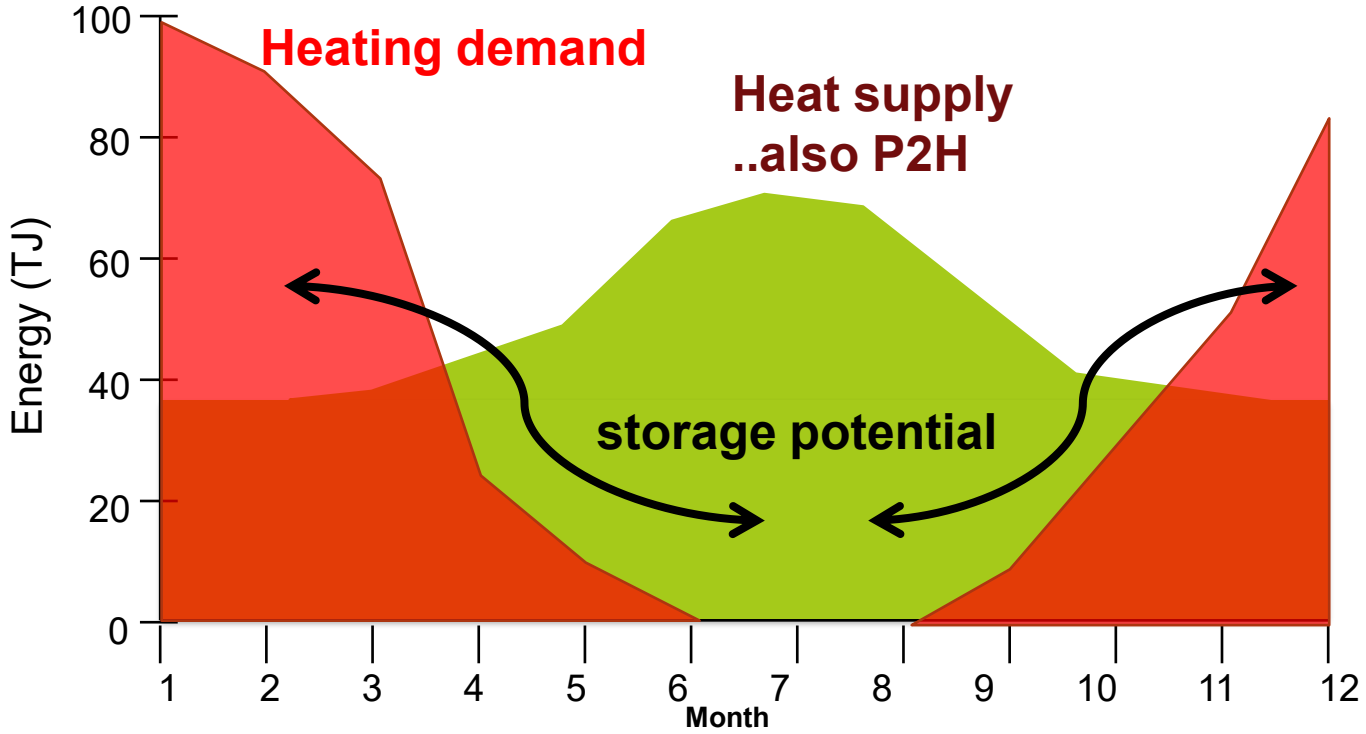
Need for HT-ATES + characteristics

Why heat buffering?



Source: CBS, 2019. Figures slightly simplified.

Why buffering / storage?

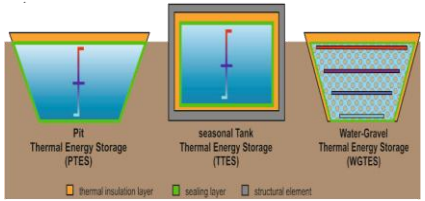


Heating/cooling demand in buildings in the northern hemisphere

Heat storage options: Sensible heat

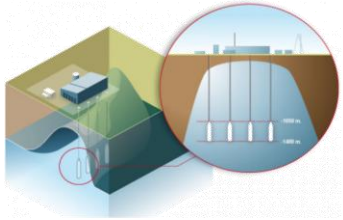
Large scale seasonal thermal energy storage → Sensible Heat Storage

TANKS/PITS



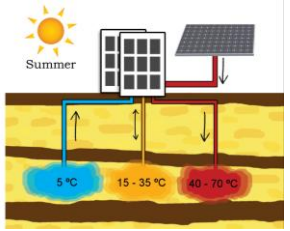
- Offers good insulation
- Expensive & limited capacity
- Unsuitable in dense urban settings

MINES/ CAVERNS



- Salt deposits in mines/caverns can be used to store energy
- Availability is very limited
- Expensive

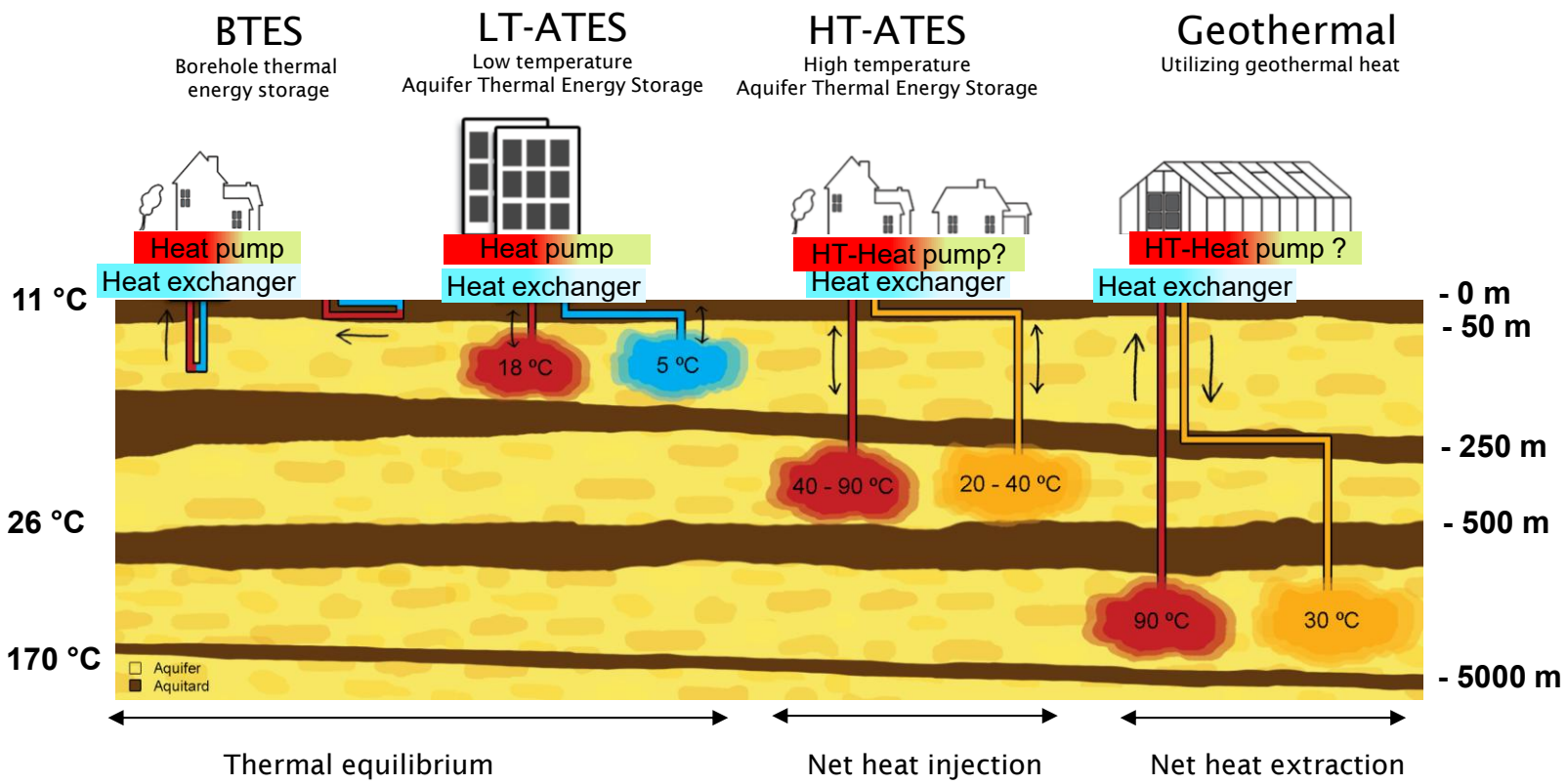
UNDERGROUND



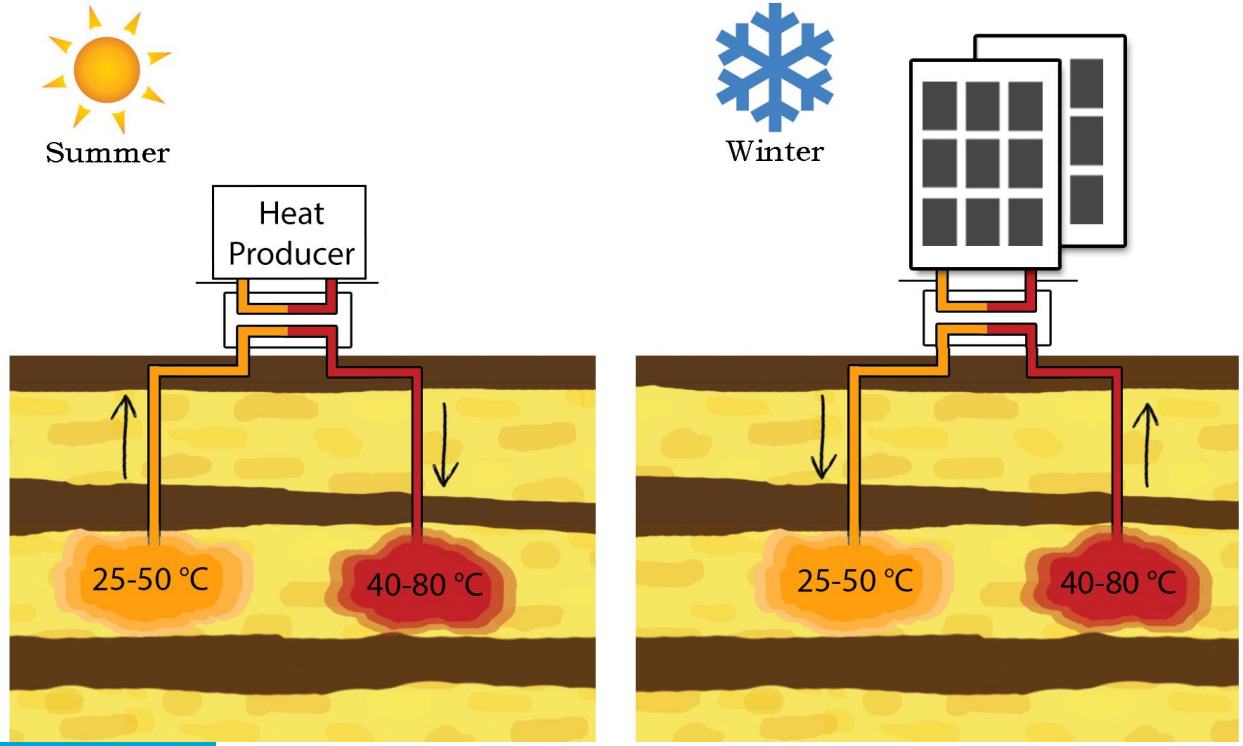
- No space requirement above ground
- Large capacities
- Subsurface infrastructure needed

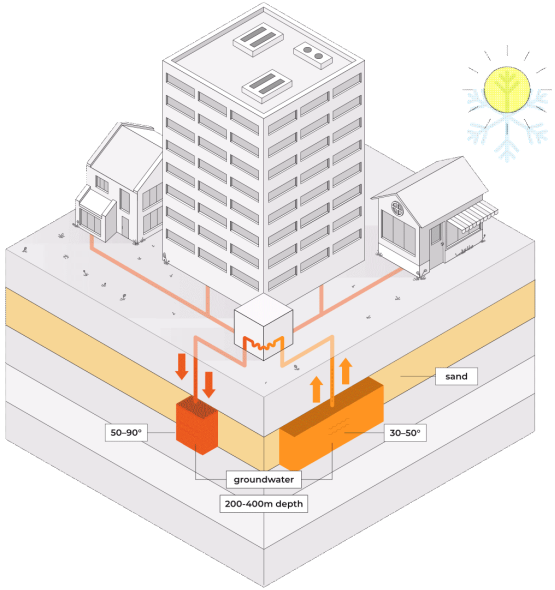
https://www.agbzw.nl/over-ons/aardgasbuffer-zuidwending
State-of-technology review of water-based closed seasonal thermal energy storage systems, Christoph Bott et al.

Geothermal energy in NL



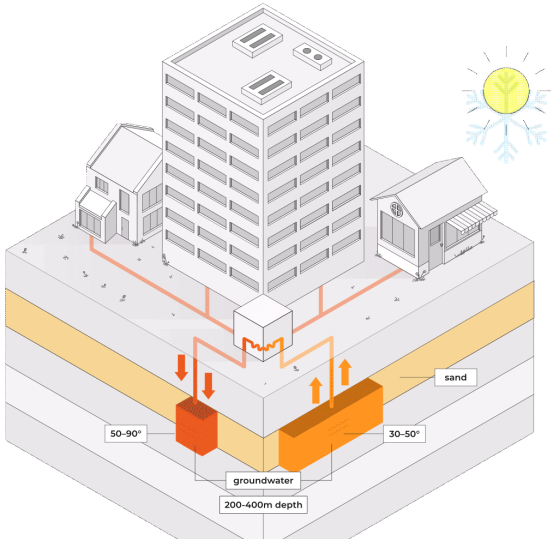
HT-ATES >25°C


Summer
Heat Producer
25-50 °C
40-80 °C
Winter
25-50 °C
40-80 °C


sand
50-90°
30-50°
groundwater
200-400m depth

HT-ATES legality in NL

- <25°C standard regulatory framework
- >25°C Permitted by provincial board (GS)
  often as pilot / research projects



Permitting

Authorities are geared-up for LT-ATES (<25 °C)

>25°C permitted as pilot/ research in ZH

- Clear thresholds in advance

Before 2024: Several licences (Waterwet, Activiteitenbesluit, etc.)

After 2024: Single license (Omgevingswet)

- Formal thresholds not known in advance

omgevingsdienst Haaglanden

Zaaknummer : 01093173
Ons Kenmerk : -
Datum : 3 december 2024

Beschikking

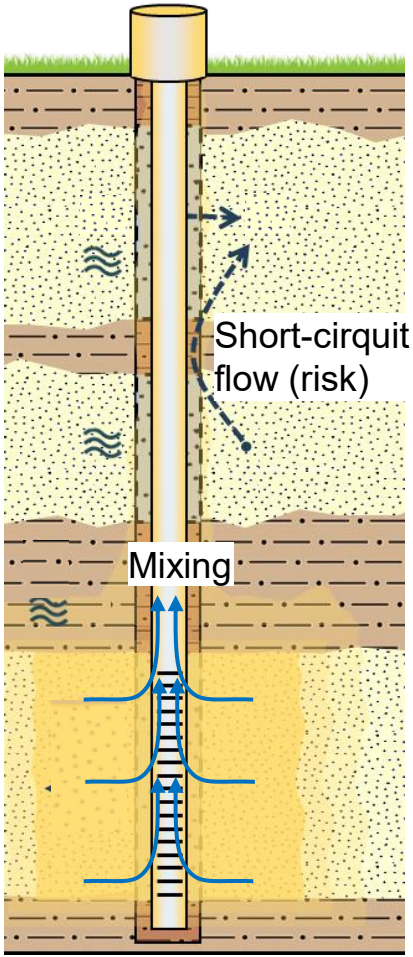
Waterwet Hoge Temperatuur Opslag (HTO)

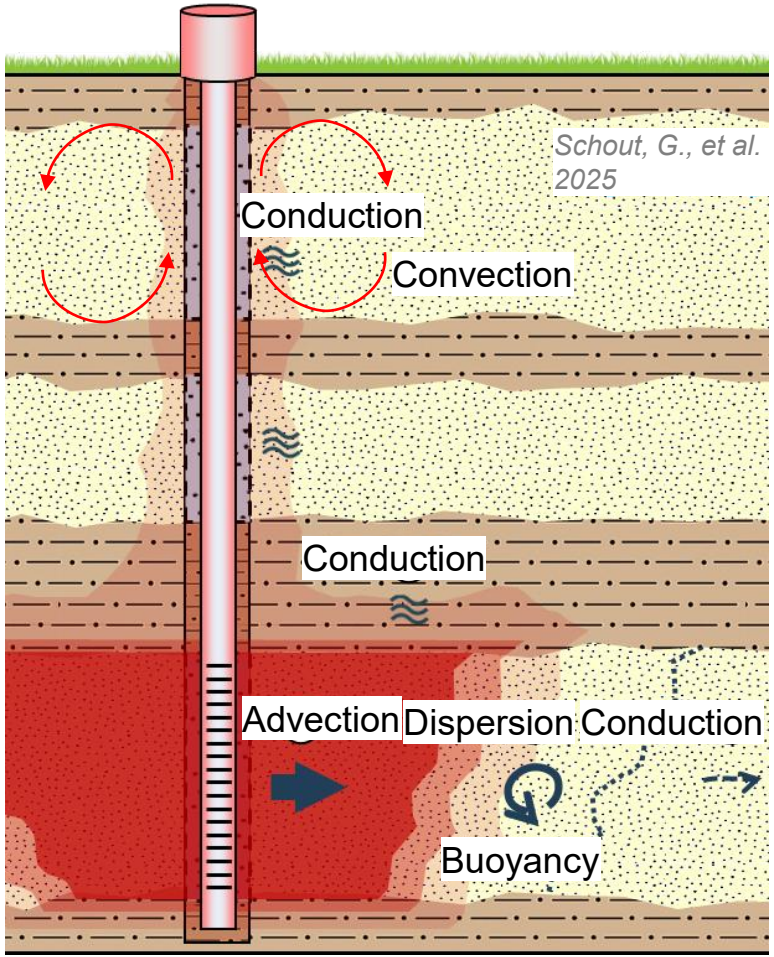
Onderwerp

Op 22 december 2023 hebben wij van Technische Universiteit Del
bedoeld in artikel 6.4 van de Waterwet. De aanvraag betreft het on
grondwater ten behoeve van een open bodemenergiesysteem (pilo
voor de klimatisering van de campus van de TU Delft (TUD) via he
toekomst het Open Warmtenet Delft (OWD). De bronnen voor het
groenstrook ten noorden van de Balthasar van der Polweg, gelegen
de Rotterdamseweg, alsmede op een terrein bij de inrit van de huid
de kruising van de Rotterdamseweg en de Cornelis Drebbelweg. He
maximaal drie hete bronnen en vier warme bronnen met een totaa
00 m³ grondwater per etmaal, 204.600 m³ grondwater per
deze hoeveelheden zal bij aanleg eenmalig maximaal 30.0
van de ontwikkeling van de bronnen en jaarlijks maximaa
uud van de bronnen.

Thermal and hydrological process

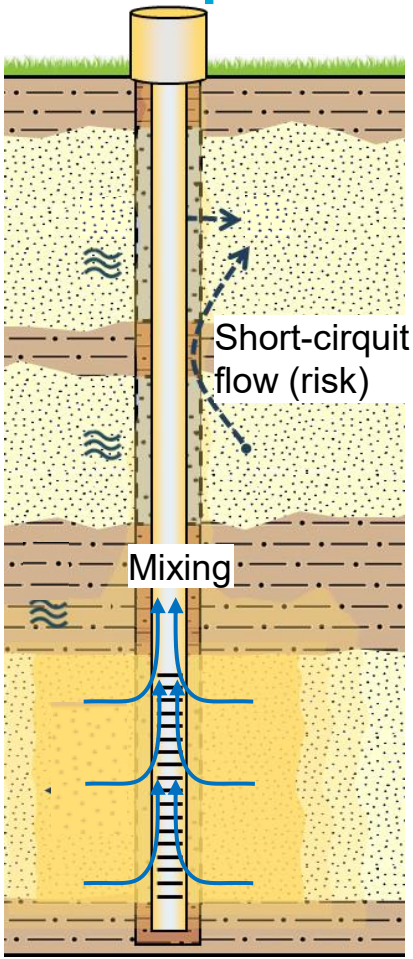
- Mixing of water from different depth
- Heat losses

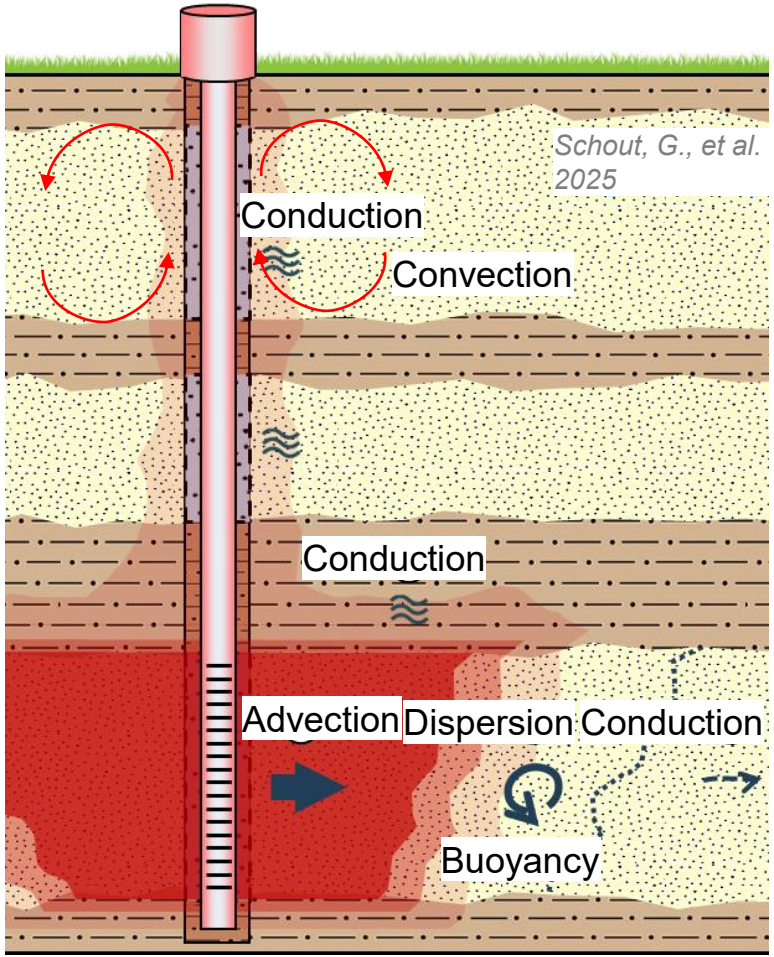




Information requirement

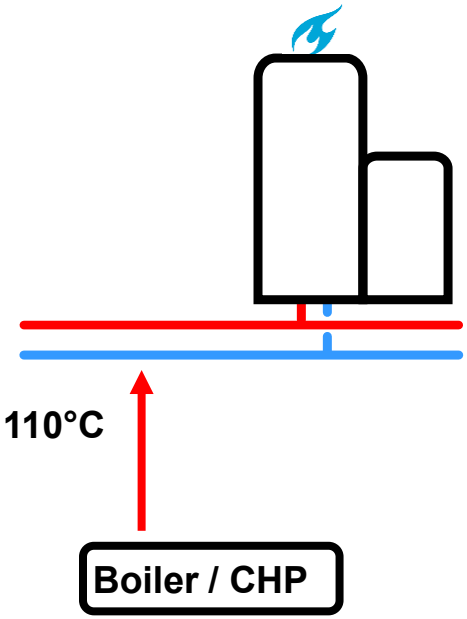
- Detailed subsurface composition
- groundwater quality
- Neigboring subsurface uses

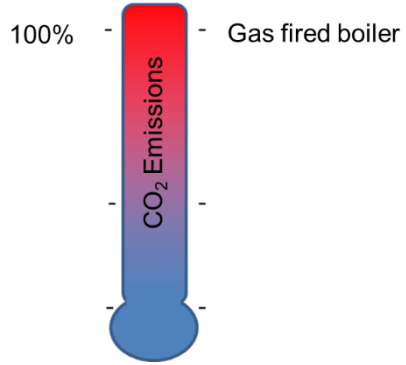




HT-ATES Delft

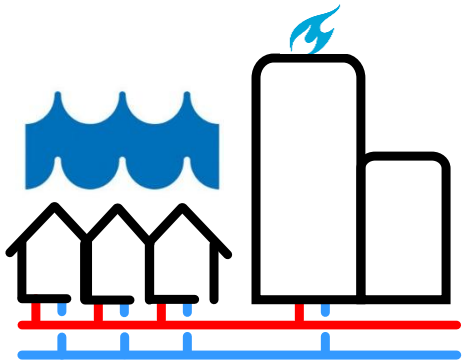
Current





~2024

Also deliver to city

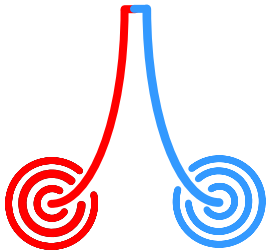


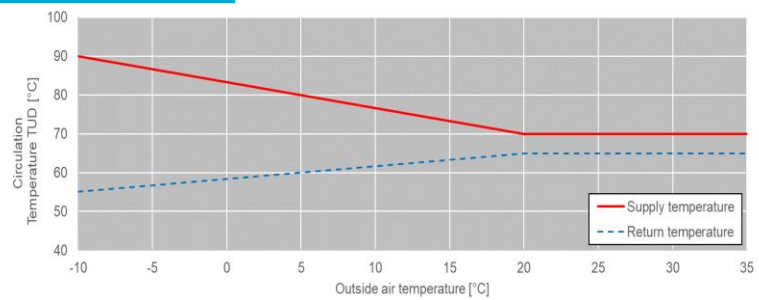
Maximise power
Minimise injection temp

HPC

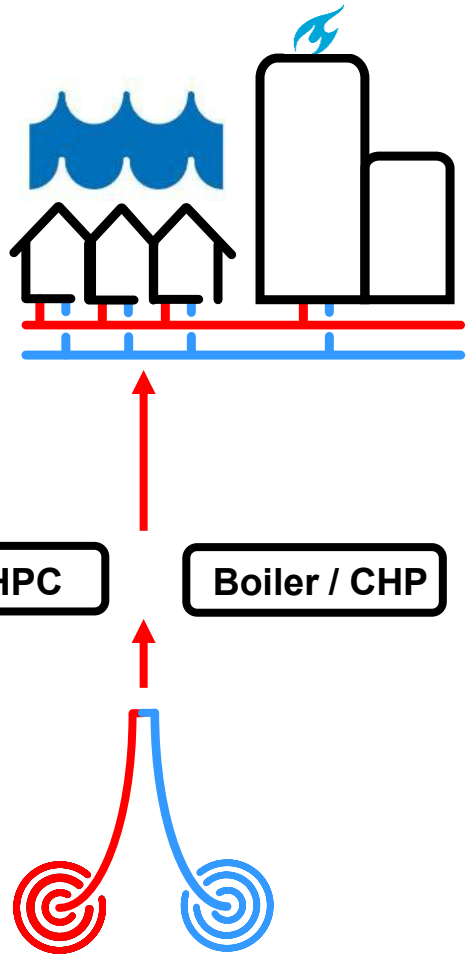
Boiler / CHP

Backup for peaks





>2025



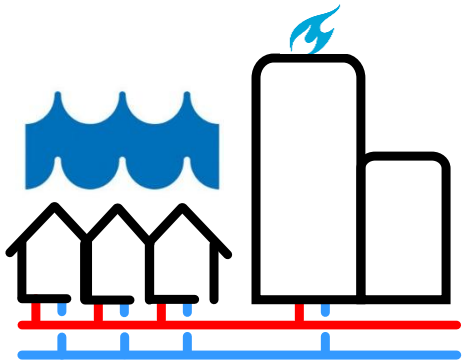
Maximise power
Minimise injection temp

HPC

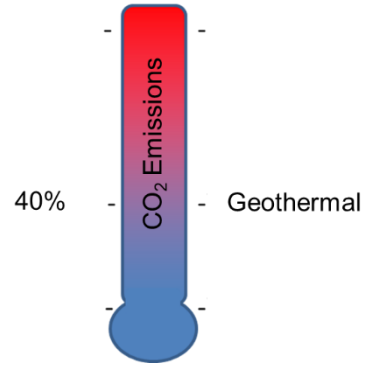
Boiler / CHP

Backup for peaks

~2025



Also deliver to city

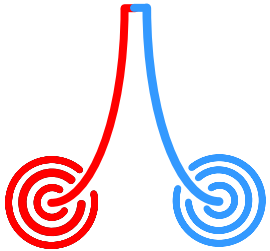


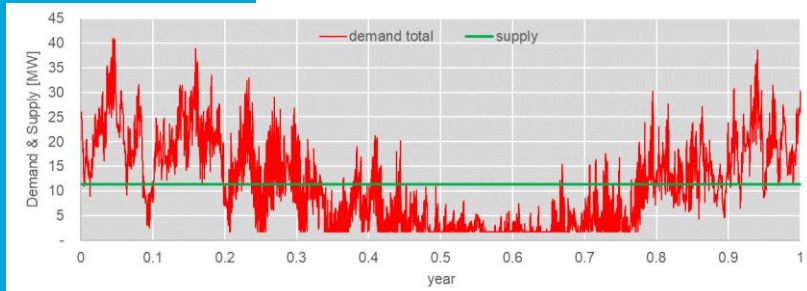
Heat pump to
Maximise power
Minimise injection temp

HPC

Boiler / CHP

Backup for peaks

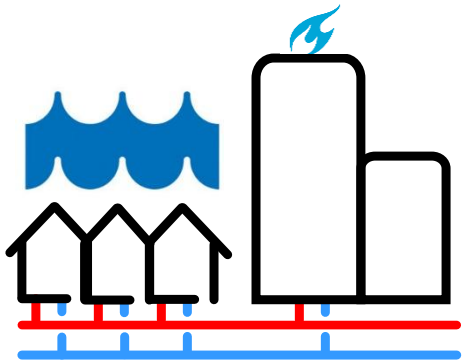


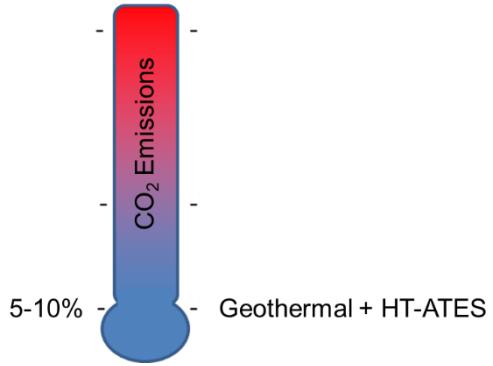


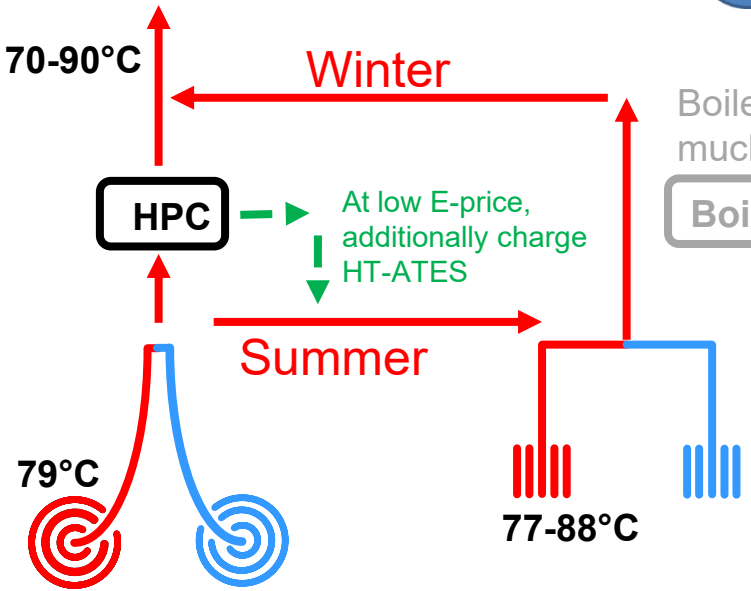
>2025

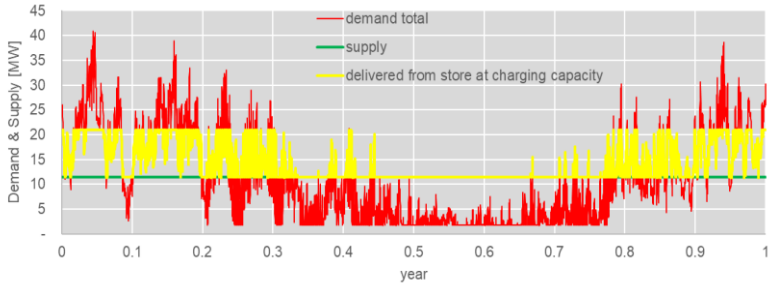
Novel combination of geothermal & HT-ATES

World-wide unique research & education infrastructure

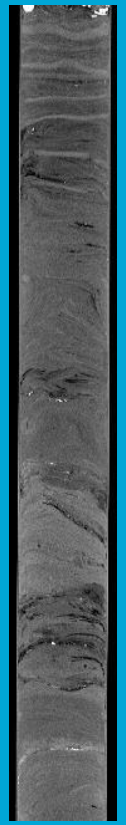






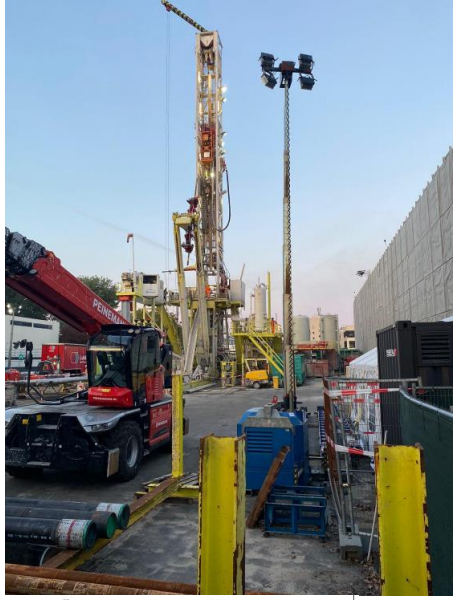


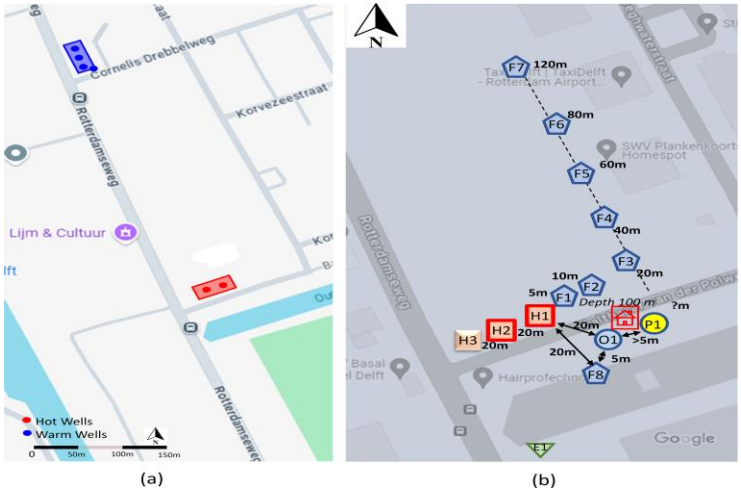
PUSH IT



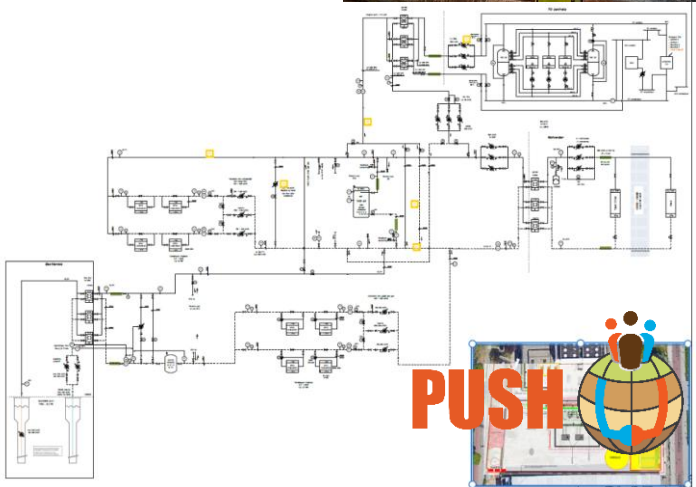
Innovation Highlights

1. Impact & performance
2. Wells
3. Societal
4. System integration and control





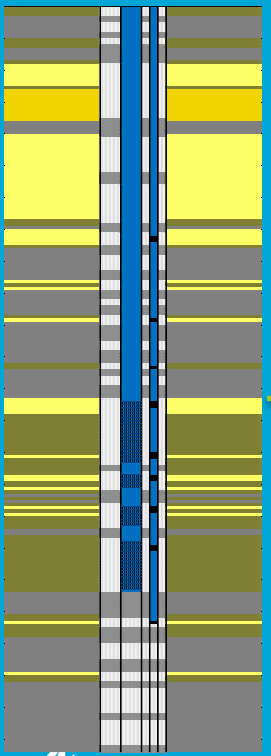
(a) (b)



Information need for HT-ATES design

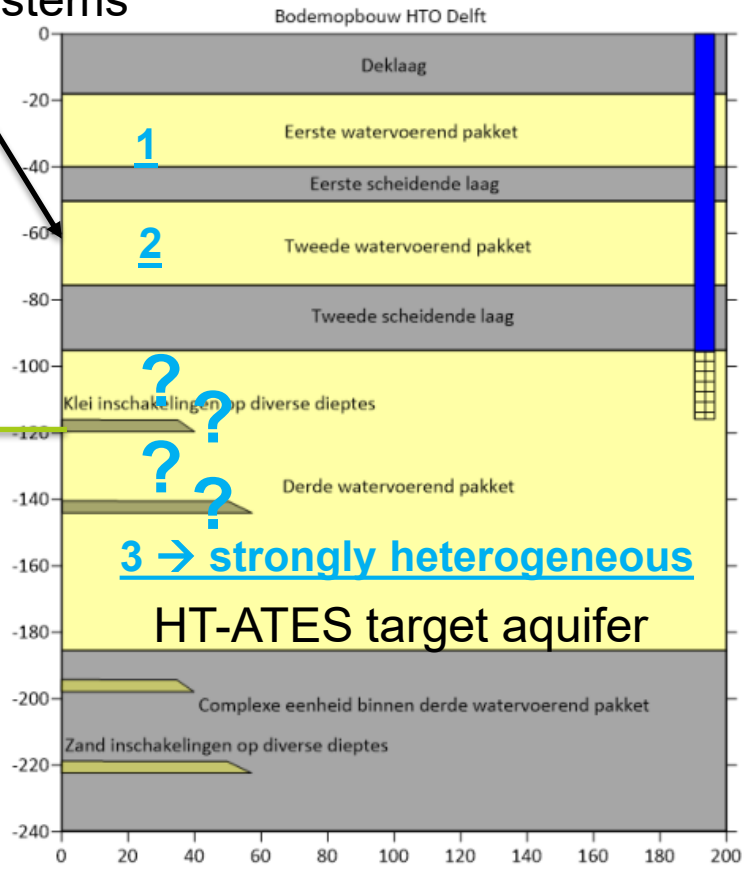
Aquifers present

REGIS, Offset-wells



Campus LT-ATES systems

- Typically, little information (other wells, drillings) in aquifers suited for HT-ATES.
- Uncertainy about hydraulic characteristics



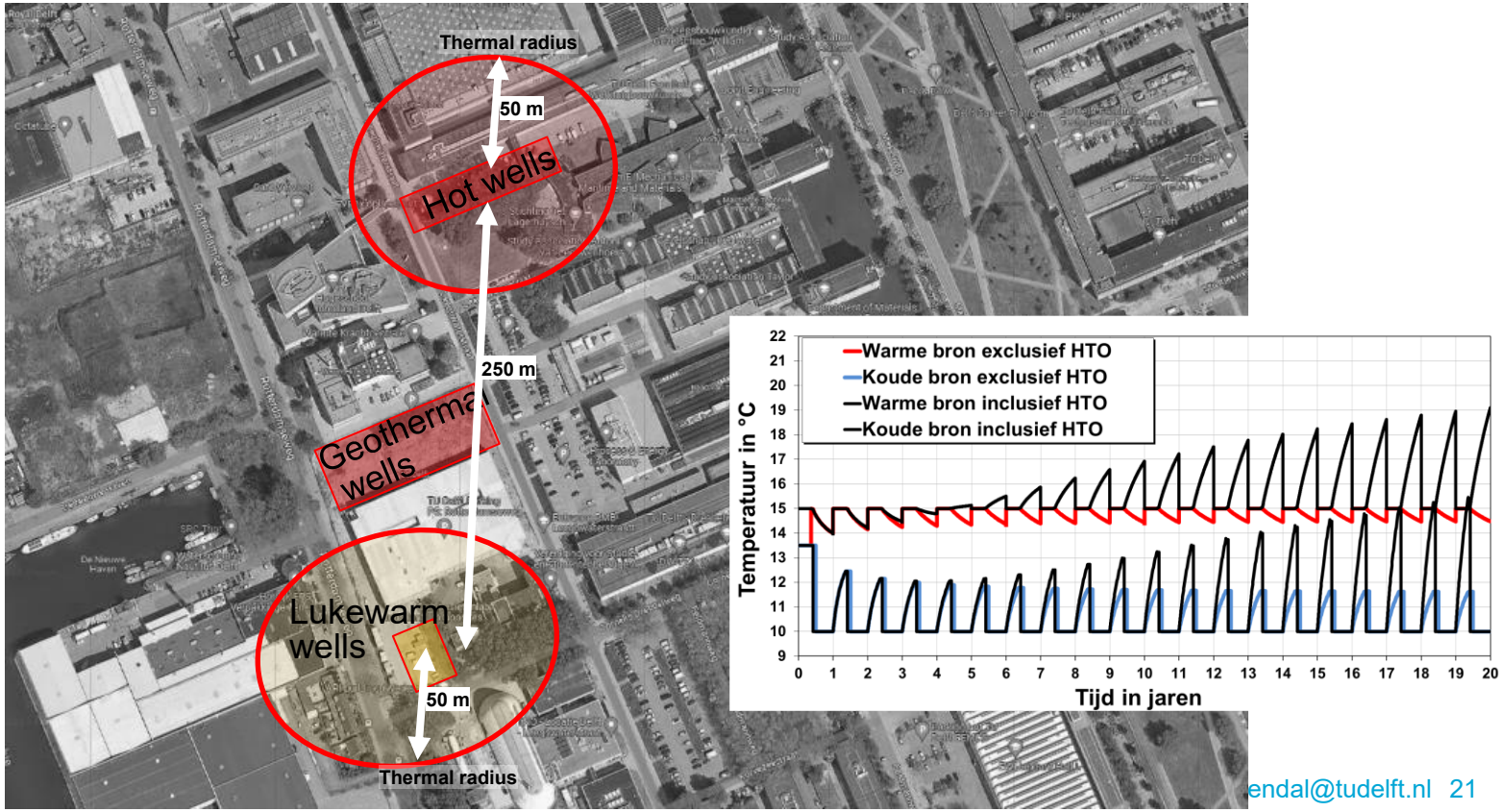
Consequence/ solution

- Uncertainty on thermal efficiency, feasablity unclear
- Need for pilot borehole

TU Delft

Placement puzzle at Delft campus

Initial Well locations



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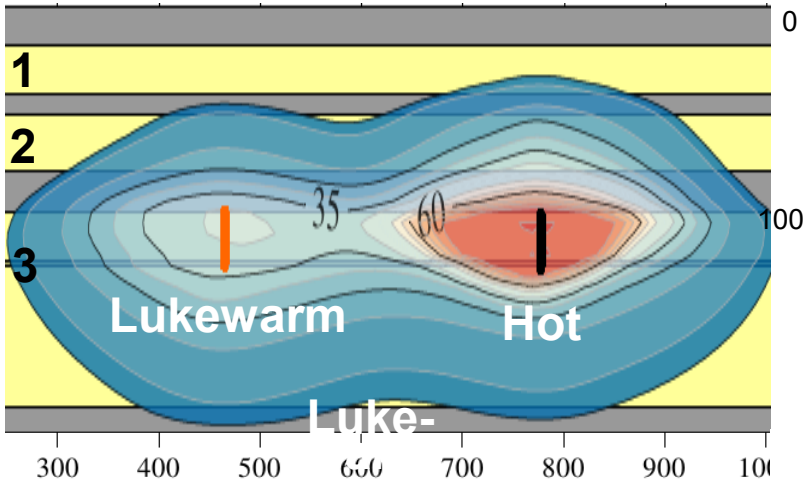
Placement puzzle at Delft campus

Thermal Impact on surrounding systems

- TUD systems were known
- Others not

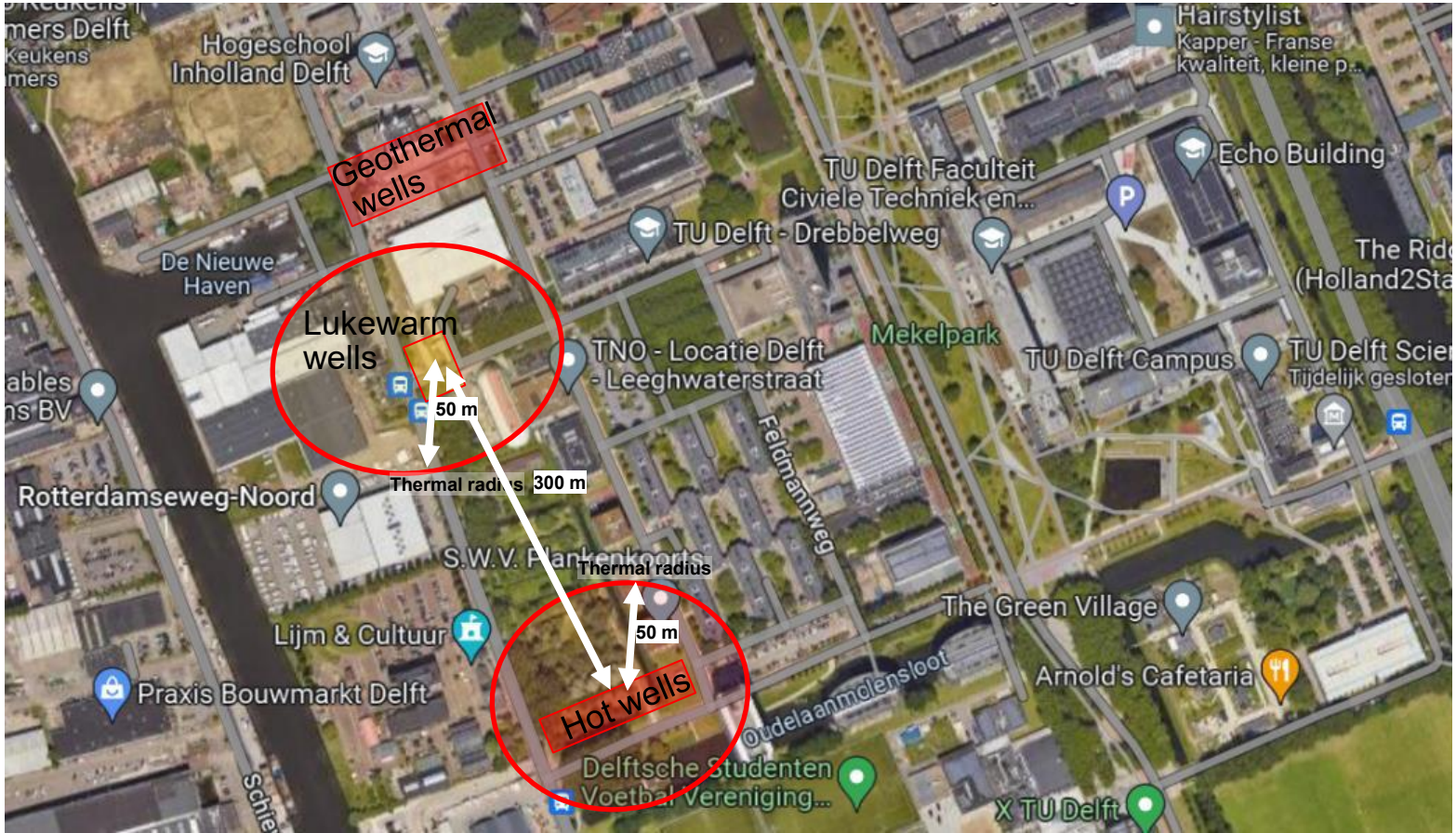
Consequence / solutions

- Move to different location
- Lower cut-off temperature in hot well
- Use heat pump to lower return temperature in lukewarm well
- Place warm wells of shallow ATES systems at HT-ATES
- Monitoring, temperature cut-off points

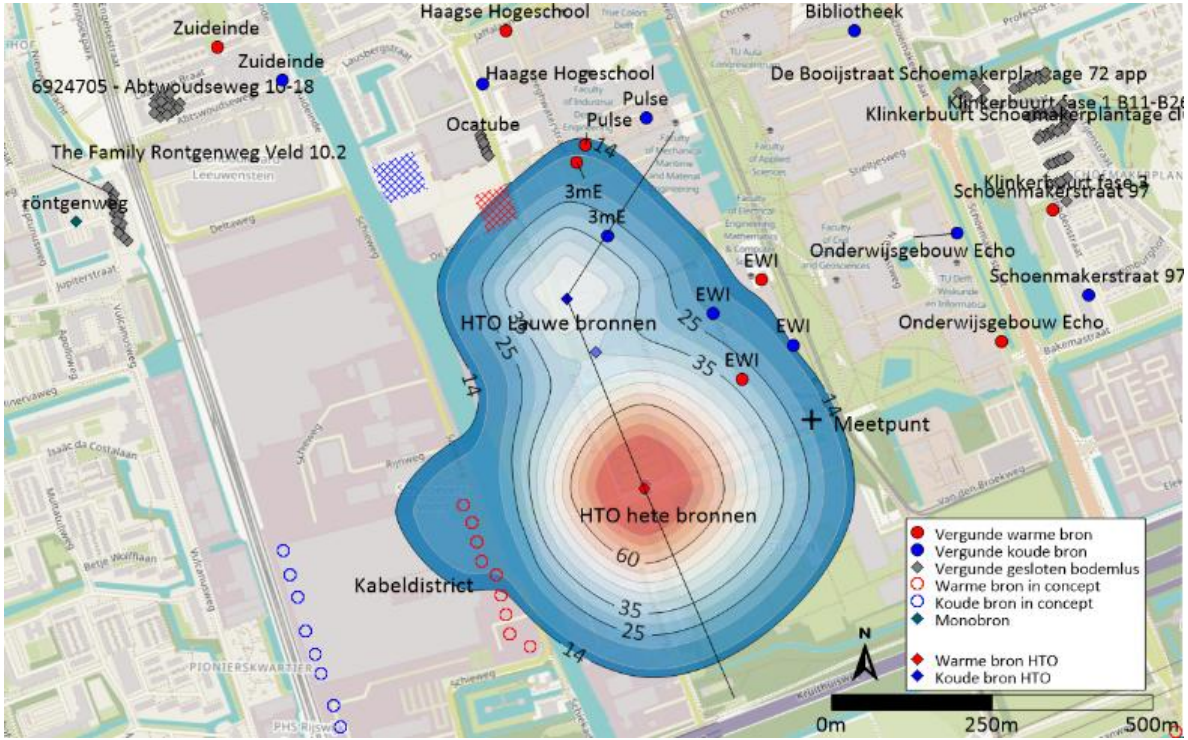


Placement puzzle at Delft campus

New well locations



Effecten nieuwe bronlocaties 150 m



Biochemical processes

Heating + Mixing water from different depth

<u>Chemistry</u>

Changes in water quality (partly reversible)

- Calcite precipitation, weathering of silicates, mineralisation of organic manner, faster redox reactions, mobilisation of sorbed trace metals (e.g. arsenic), …

Scaling (clogging of installation)

$$CaCO_3 \leftrightarrow [Ca^{2+}] + [CO_3^-]$$

$$CO_2 + H_2O + CaCO_3 \rightarrow Ca^{2+} + 2\,HCO_3^-$$

$$SI = \log\left(\frac{[Ca_2{}^+][CO_3{}^{2-}]}{K_{sp}}\right)$$

- SI = 0: Chemisch evenwicht
- SI > 0: Oververzadigd
- SI < 0: Onderverzadigd

Schout & Hartog 2025

<u>Consequence / solutions</u>

- CO2 dosing → additional cost, difficult to predict dosage, uncertain long term effects,

Biochemical processes

Heating + Mixing water from different depth

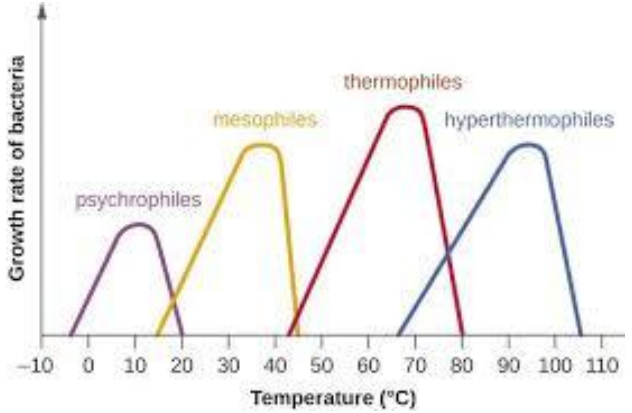
<u>Microbiology</u>

Remnants of drilling fluid

Supply of nutrients (higher flowrate, mixing)

Shift to meso/ thermofilic species

Temperature influences microbial growth rate



https://microbeonline.com/psychrophiles-mesophiles-thermophiles/

<u>Consequence / solutions</u>

- More extensive (and expensive) monitoring compared to conventional LT-ATES (5 – 25 °C).

Take home

- Temporal mismatch between heat availability and demand require large scale seasonal thermal energy storage
- Underground offers time and space for large scale heat storage helps to utilise local renewable energy sources
- Via research and demo's towards cheap and robust TES in the underground

- Challenges regarding information availability:
  - Detailed characteristics unknown/uncertain
  - Details on other uses needed
  - Water quality unknown

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Co-funded by the European Union

TNO

TU Delft

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2025-09-11
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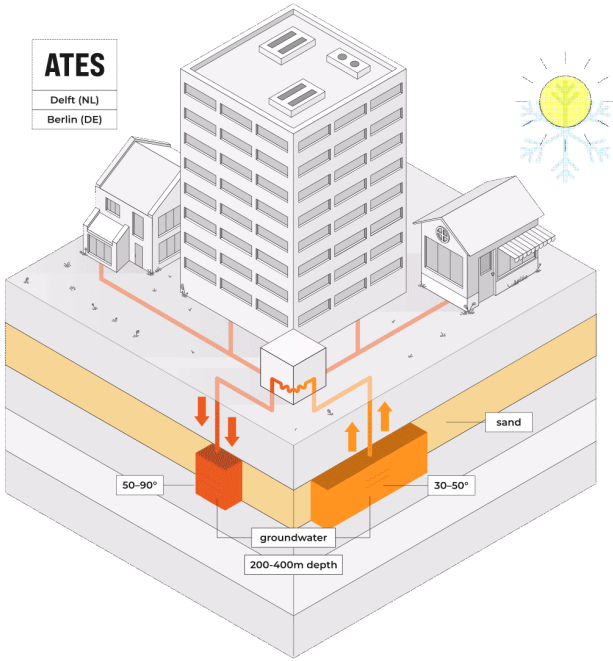
PUSH IT

www.push-it-thermalstorage.eu

Stay in touch / connect?

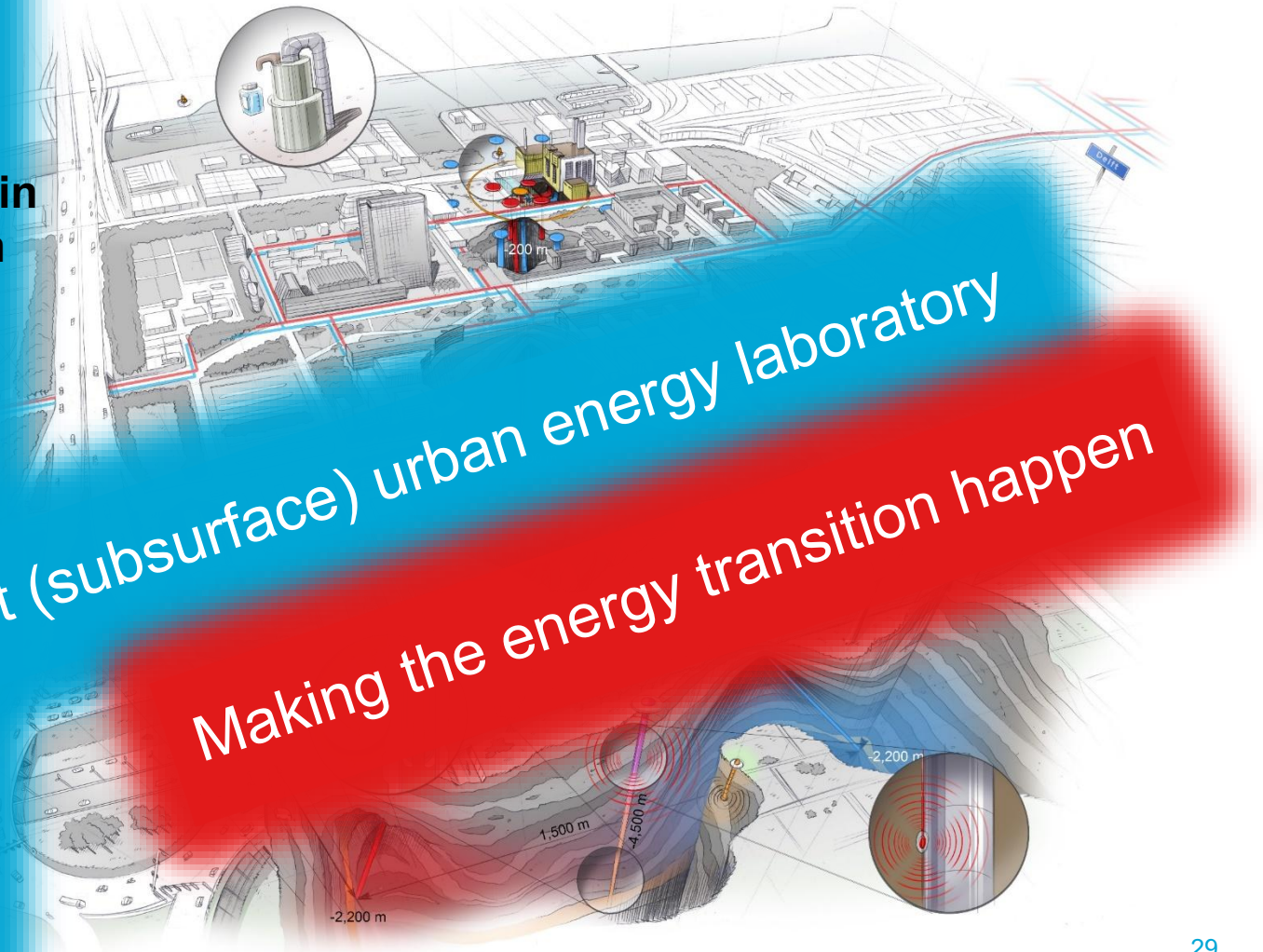
TU Delft geothermal get together
TU Delft Urban energy institute
Delft Aardwarmte project

Contributions from:
Tessel Grubben, Alexis Koulidis, Stijn Beernink, Martin v.d. Schans, Phil Vardon, Niels Hartog, Anne Medema, Ergin Kukrer, Amirhossein Hashemi



Novel combination of geothermal & HT-ATES in complex energy system

World-wide unique infrastructure for research & education



Delft (subsurface) urban energy laboratory

Making the energy transition happen

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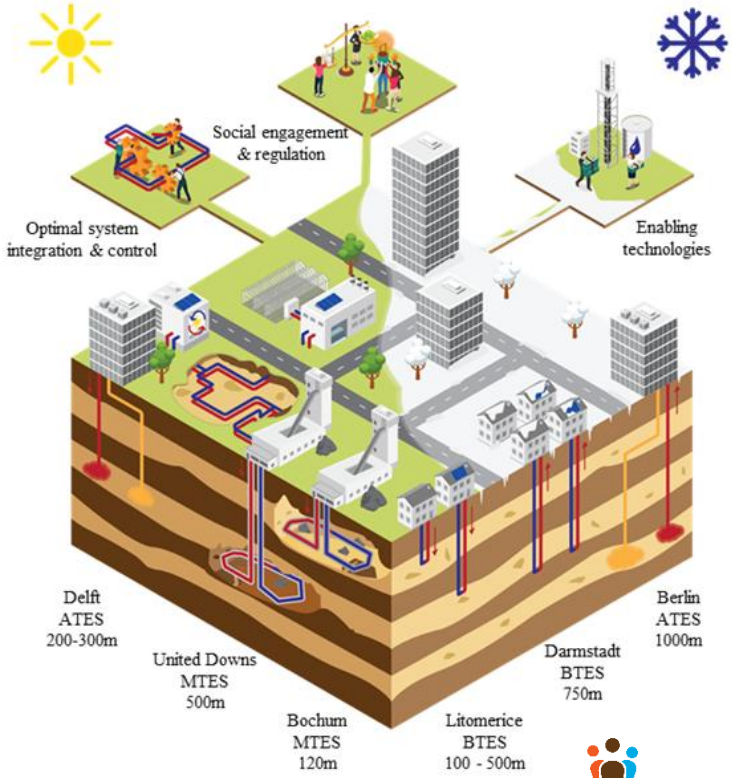
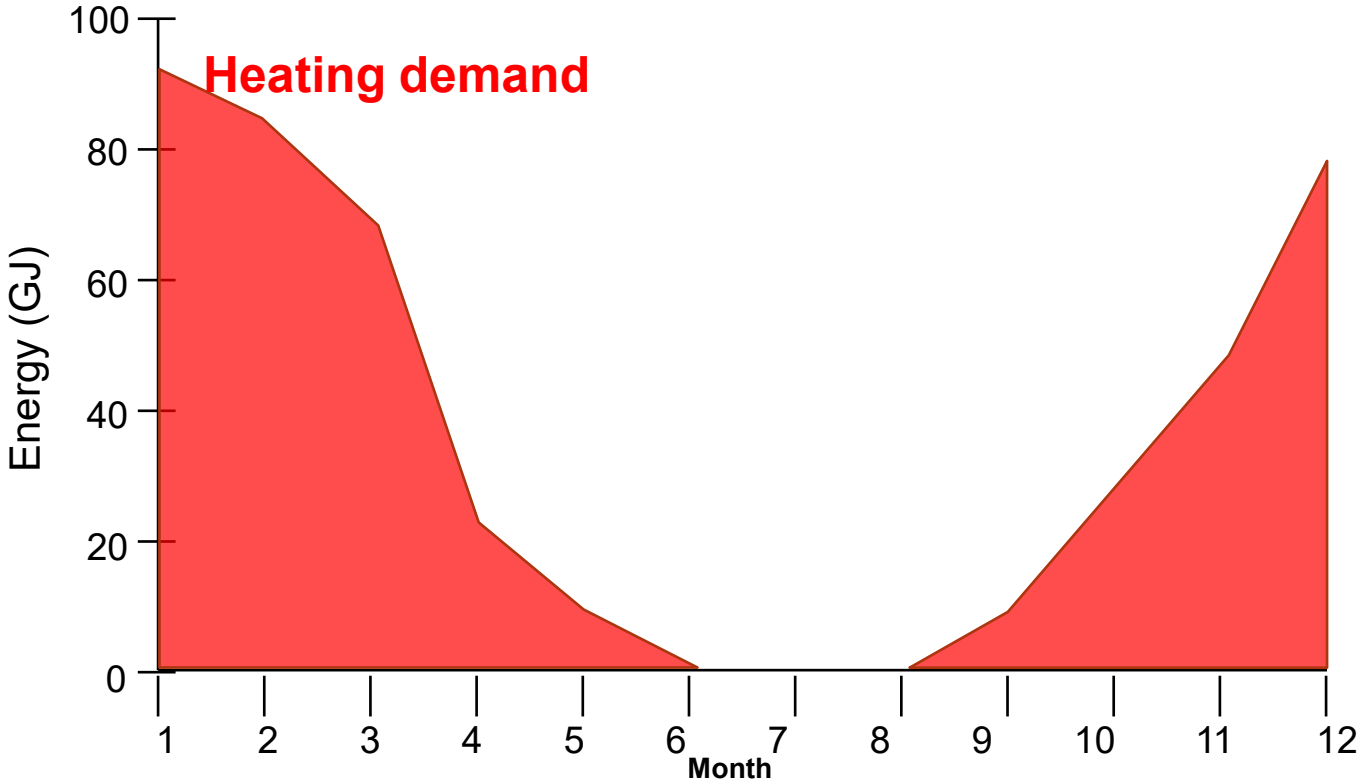
PUSH-IT project:
Intensive monitoring en research

Technical
- Drilling and completion
- System control & integration with district heating network
- Monitoring, optimization & mitigating impact

Societal:
- Public perceptions
- Regulation
- Techno-economics



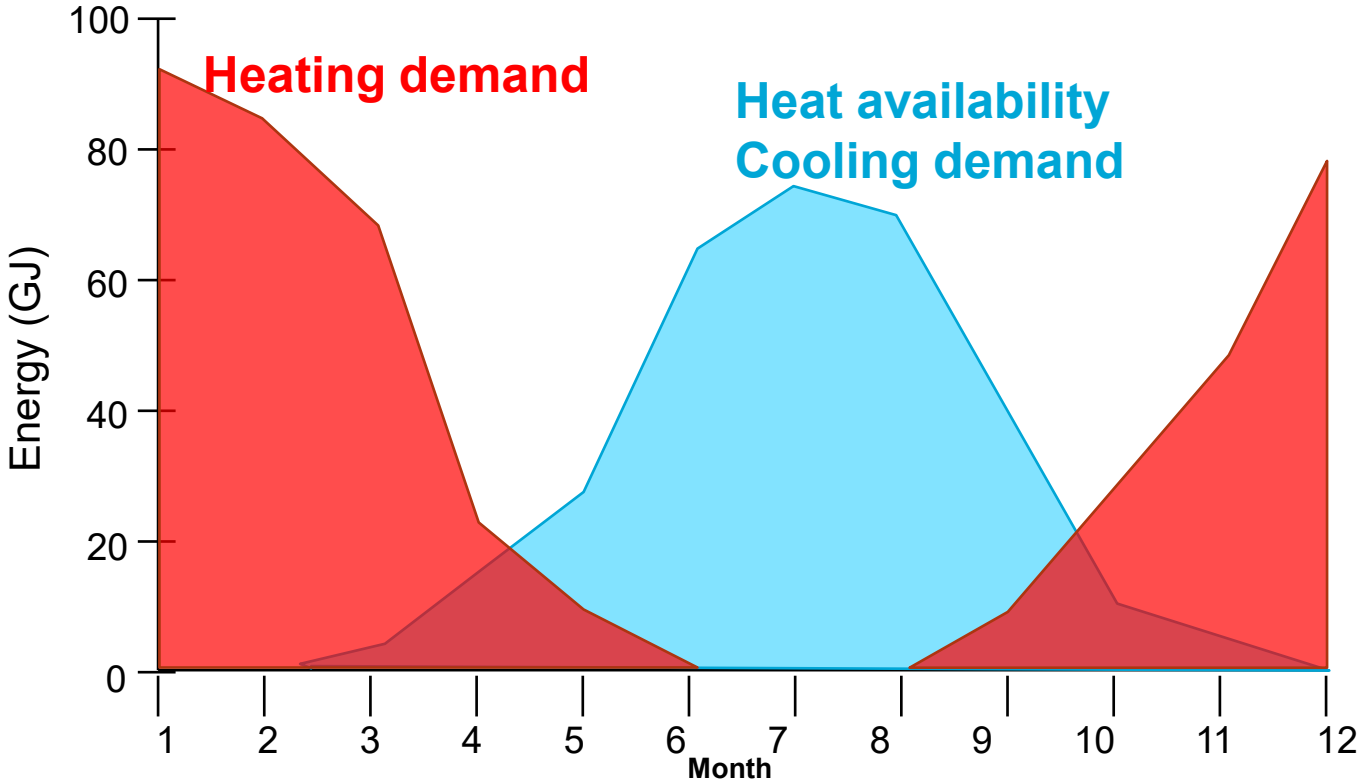
Why buffering / storage?



Heating/cooling demand in buildings in the northern hemisphere

Why buffering / storage?

Temporal mismatch heat availability and demand



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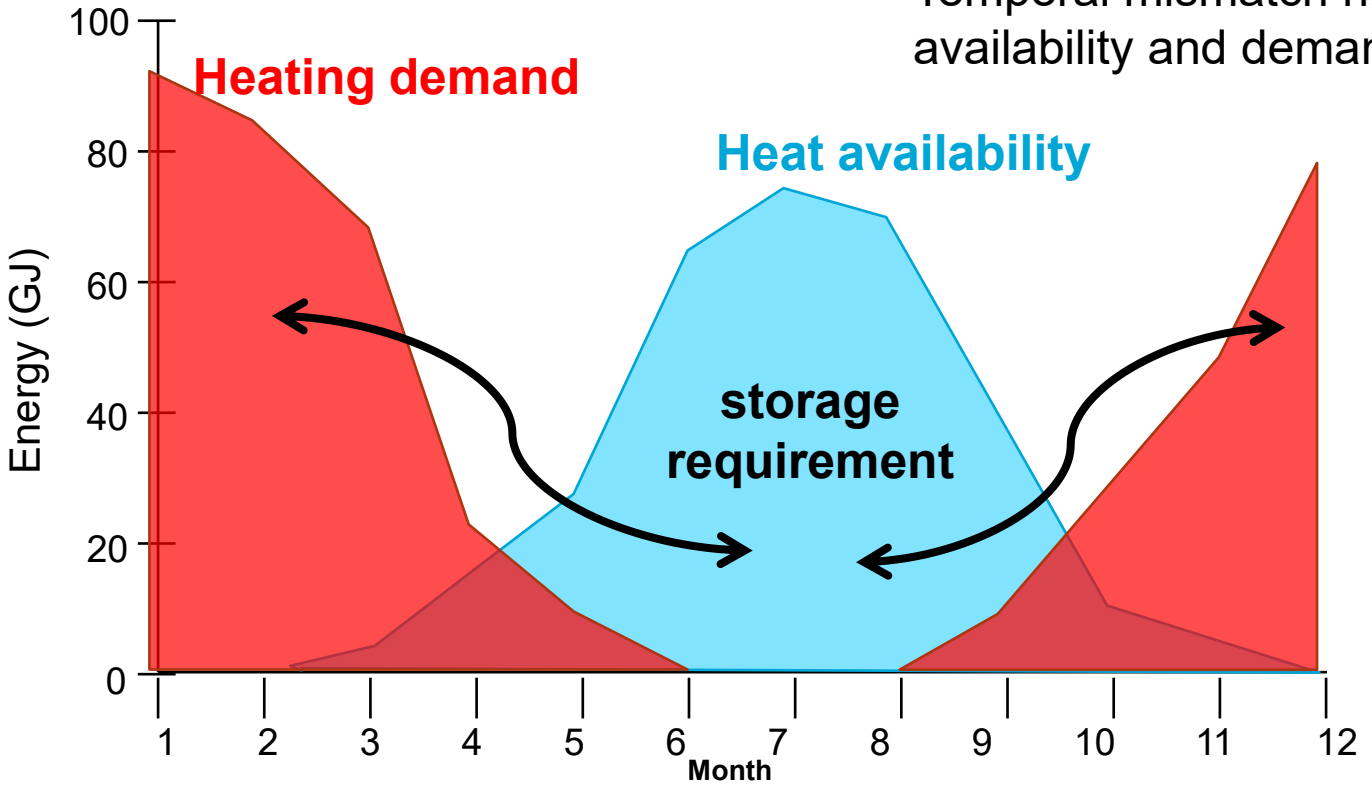
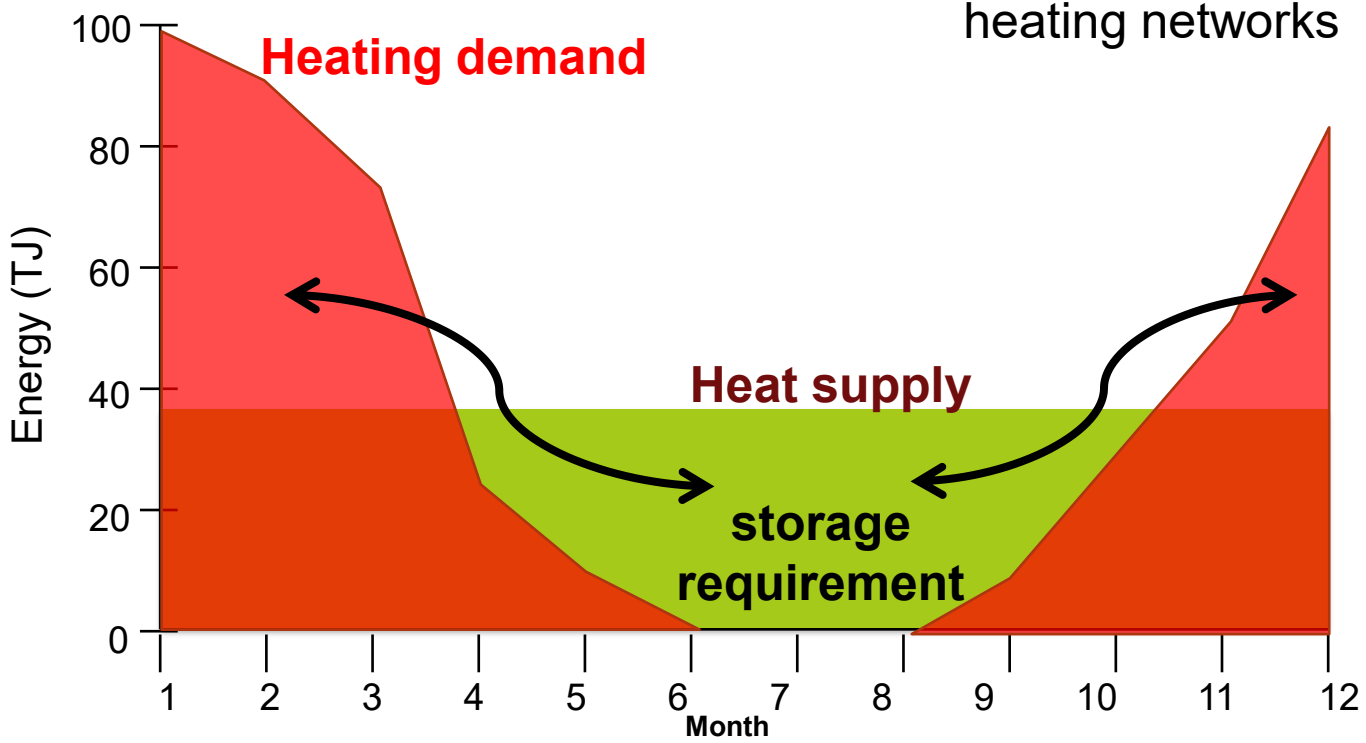


Heating/cooling demand in buildings in the northern hemisphere

Why buffering / storage?

Also useful in district heating networks



Heating/cooling demand in buildings in the northern hemisphere