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Chemical and microbiological effects of HT-ATES on groundwater composition

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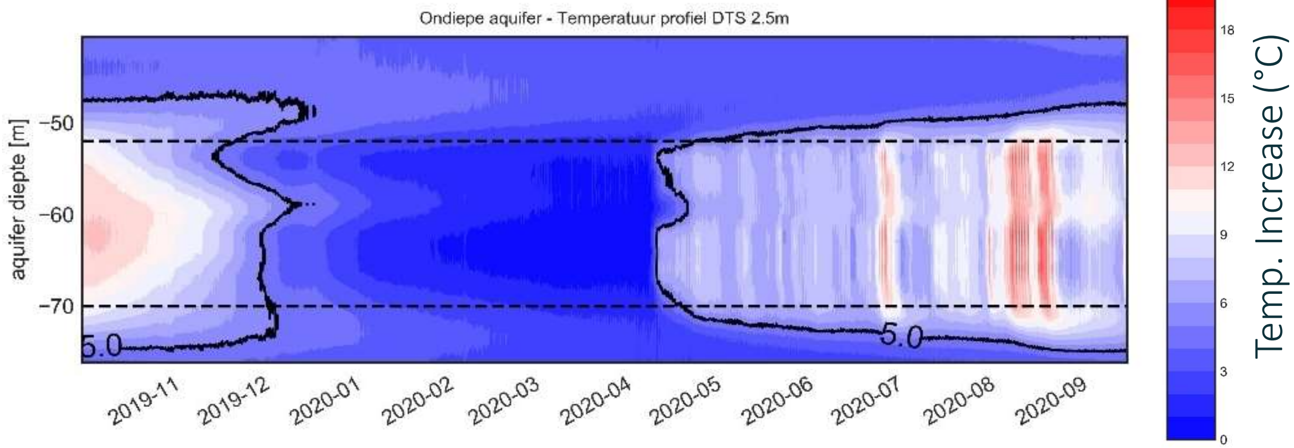
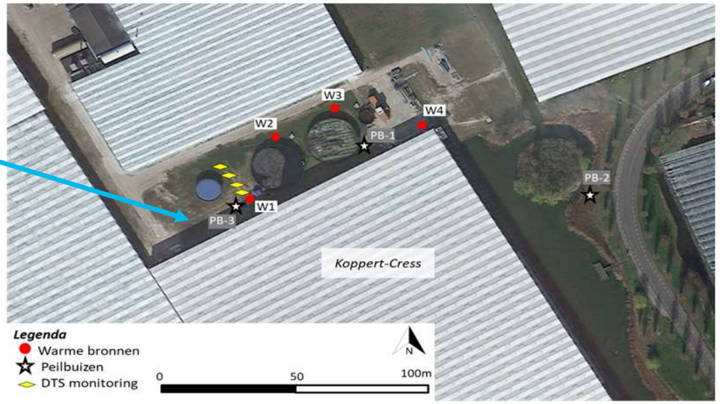
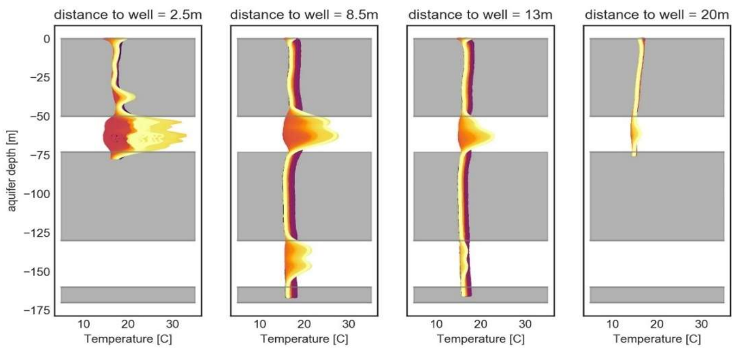
Bridging Science to Practice

Project examples

Harvesting heat in horticulture: LT-ATES → MT-ATES







Bloemendal et al, 2020

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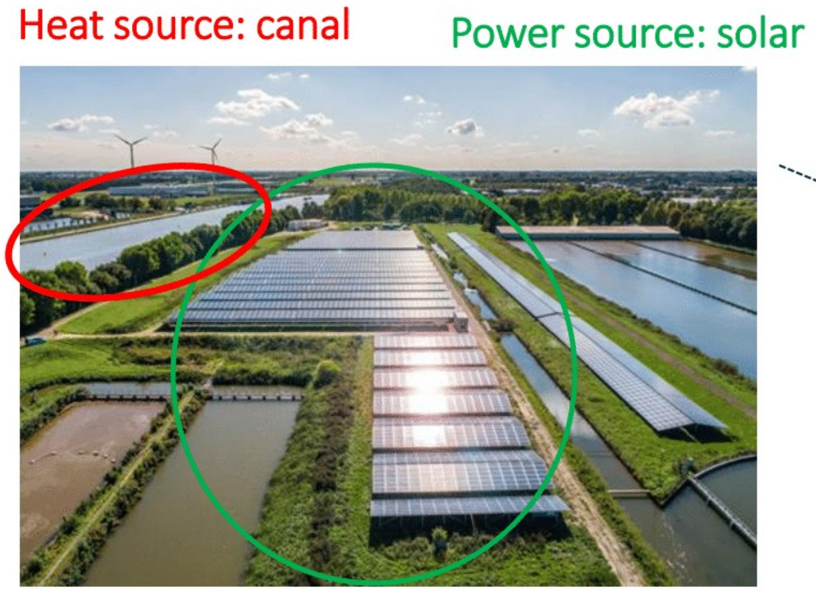
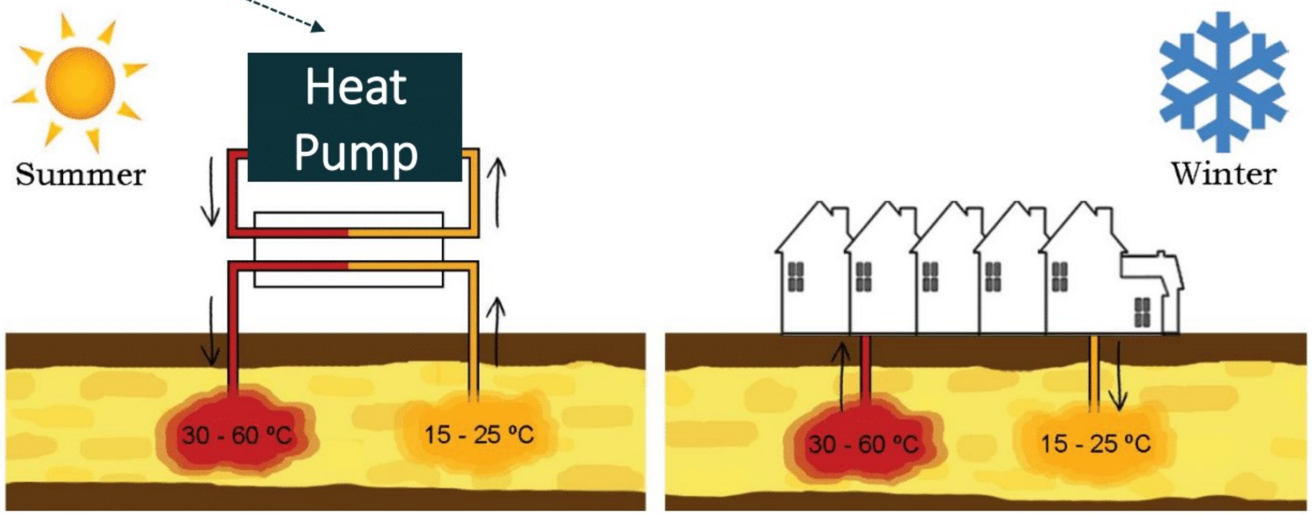
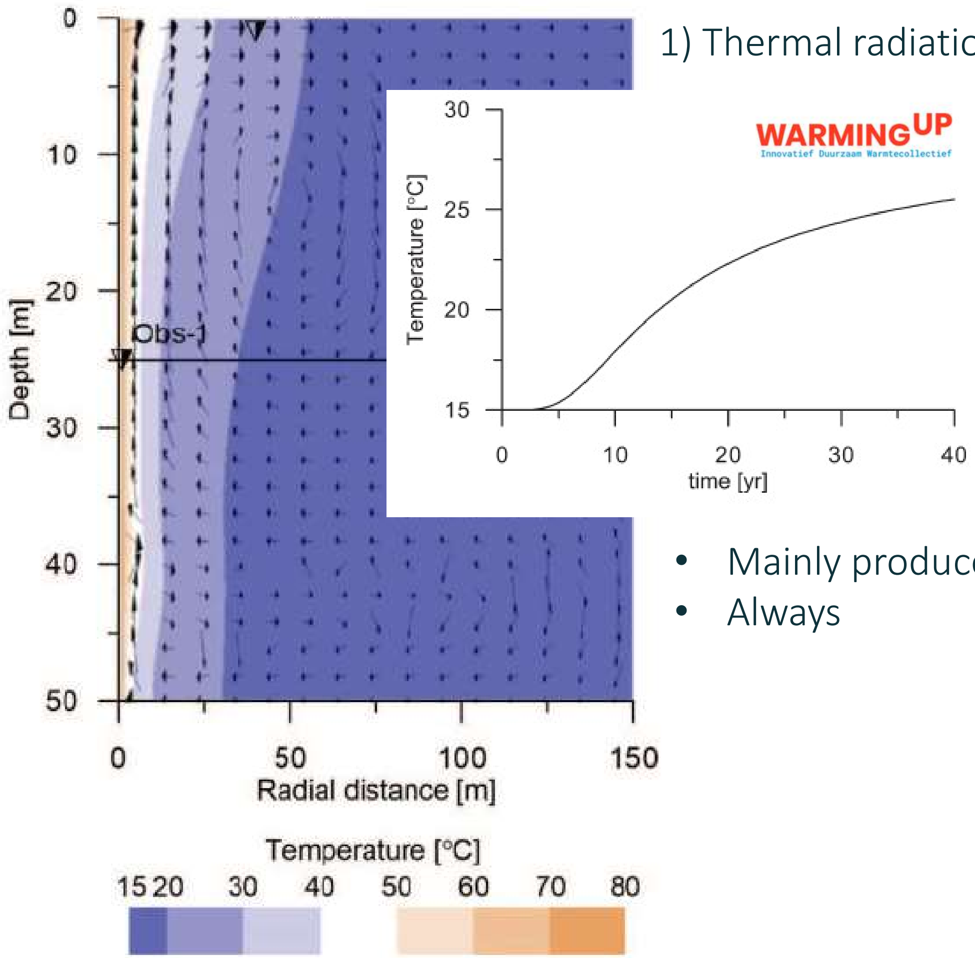
Greenpower to heat:
HT-ATES in a local energy system with Power-to-heat





Van der Roest et al. 2021

Subsurface effects: geothermal systems

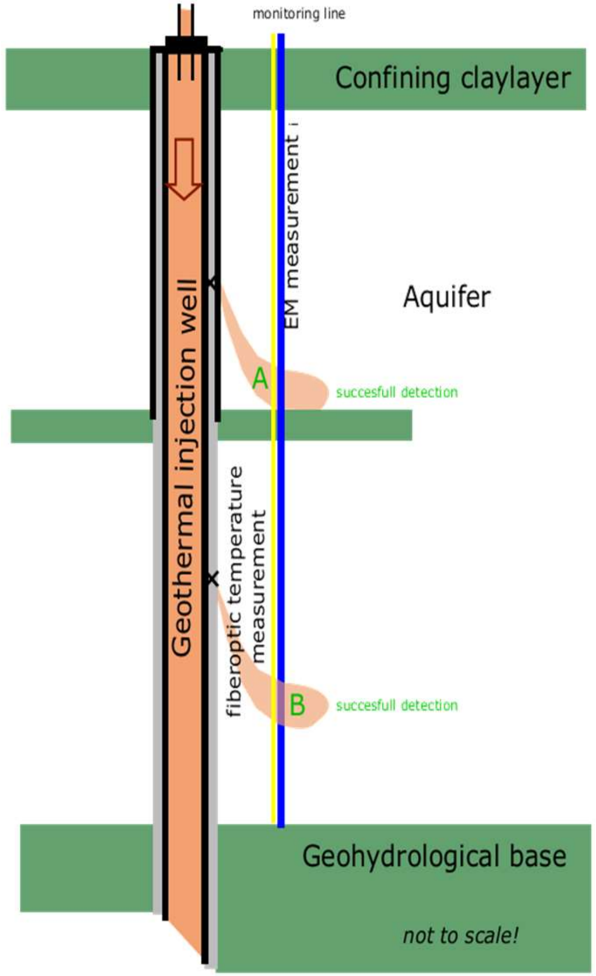


1) Thermal radiation

- Mainly producer
- Always

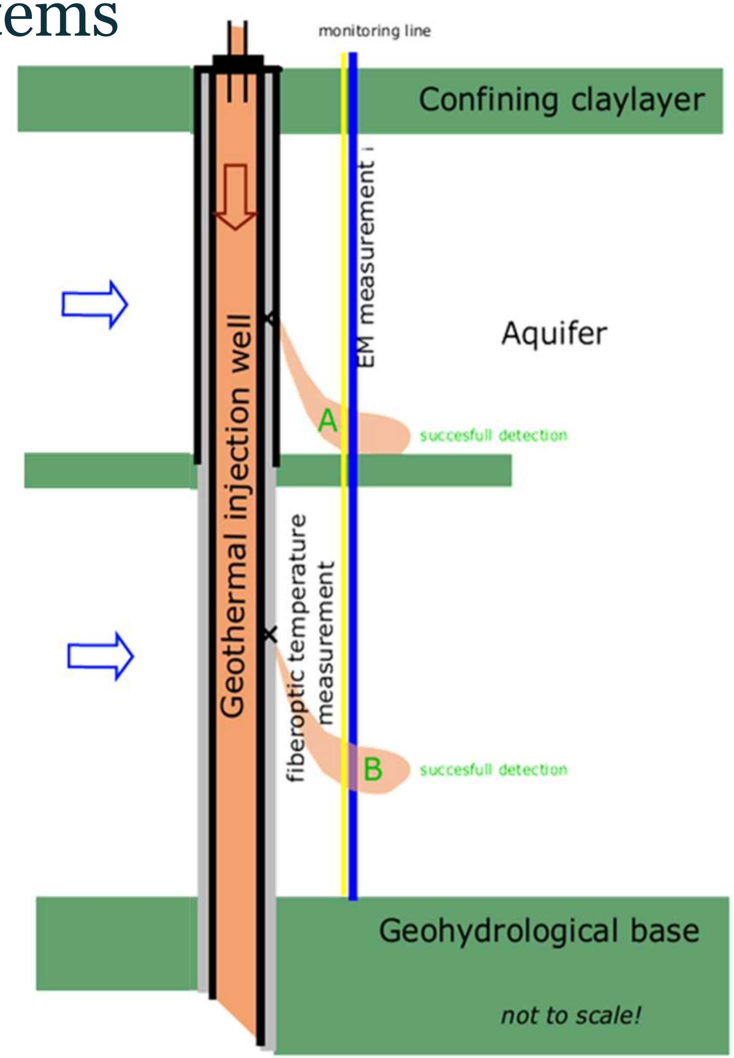
2) Brine leakage

- Injector
- Chance



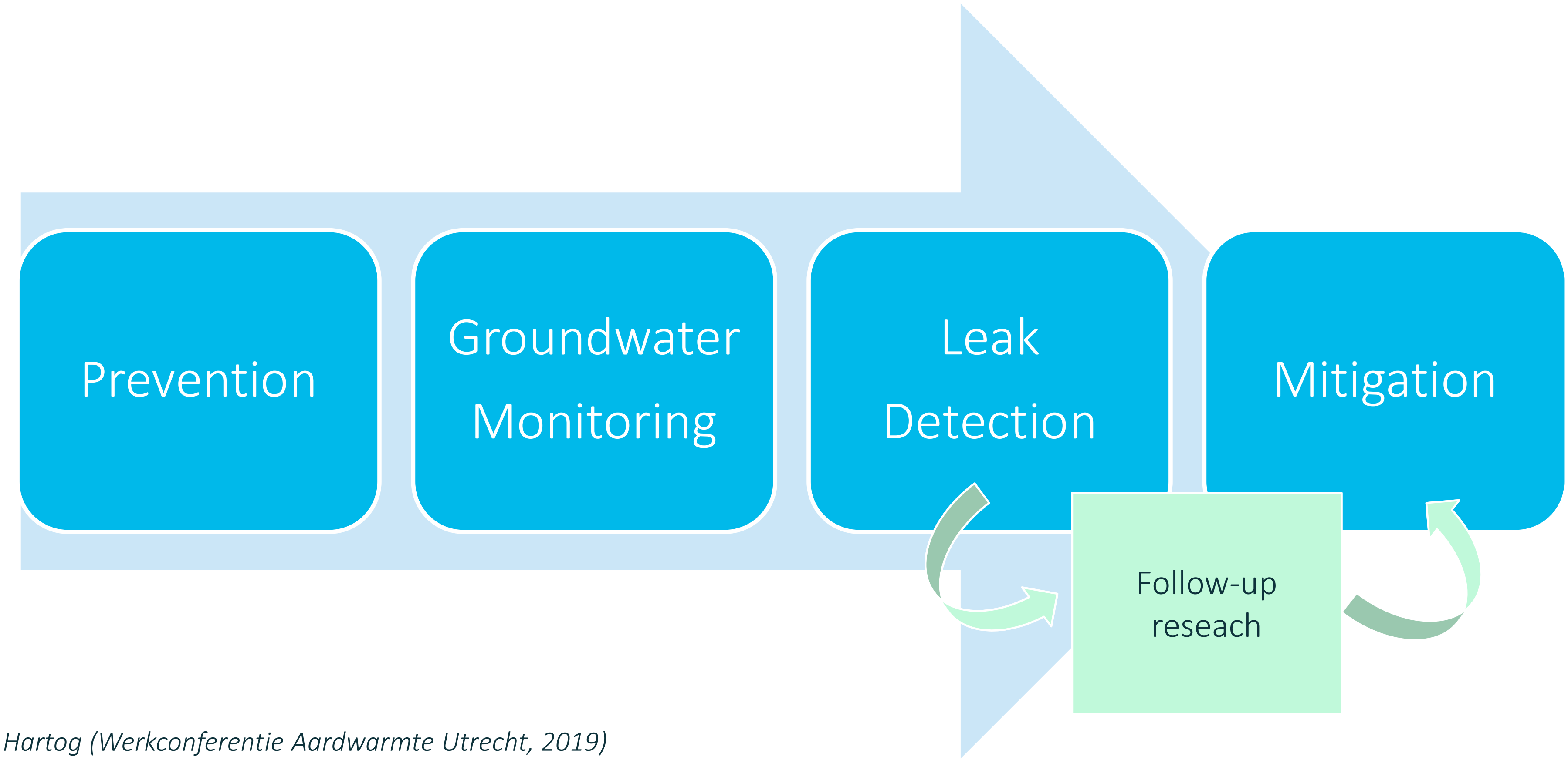
Groundwater monitoring: geothermal systems

- Strong contrast in both saltlevels and temperatures between geothermal brine and surrounding groundwater:
  - EC brine >> seawater
  - T brine >> 10-20°C groundwater
- Monitoring for temperature development and conductivity with time and depth (T + EC)
  - As close as possible to well: strongest contrast, fastest signal
  - Smallest chance for false positives & negatives
- Detection = trigger for follow-up research



Cirkel en Hartog, 2017

Preventing unintended groundwater impact



Hartog (Werkconferentie Aardwarmte Utrecht, 2019)

Subsurface effects: HT-ATES

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Subsurface effects: HT-ATES

- Concerns about effects on chemical and microbiological composition groundwater

- What do we need?
  - Knowledge to formulate science-based, pragmatic permitting policy

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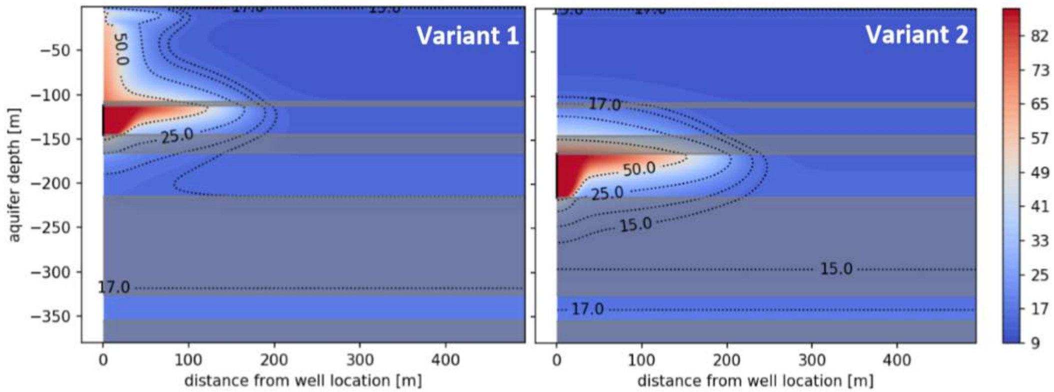
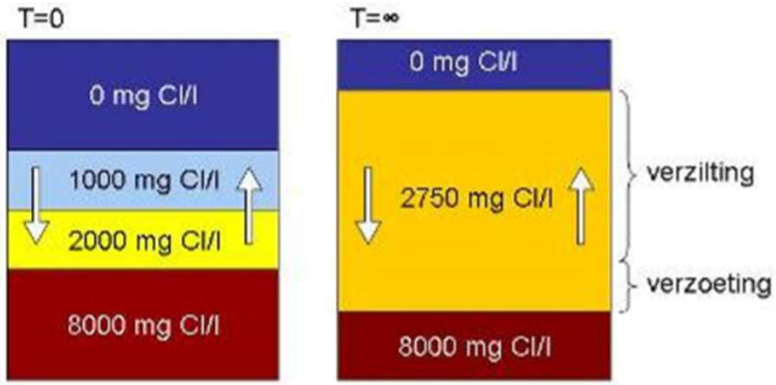
More than just thermal causes…

Thermal effects:



Beernink en Hartog, 2020

Mixing effects:



Meer met bodemenergie, 2012

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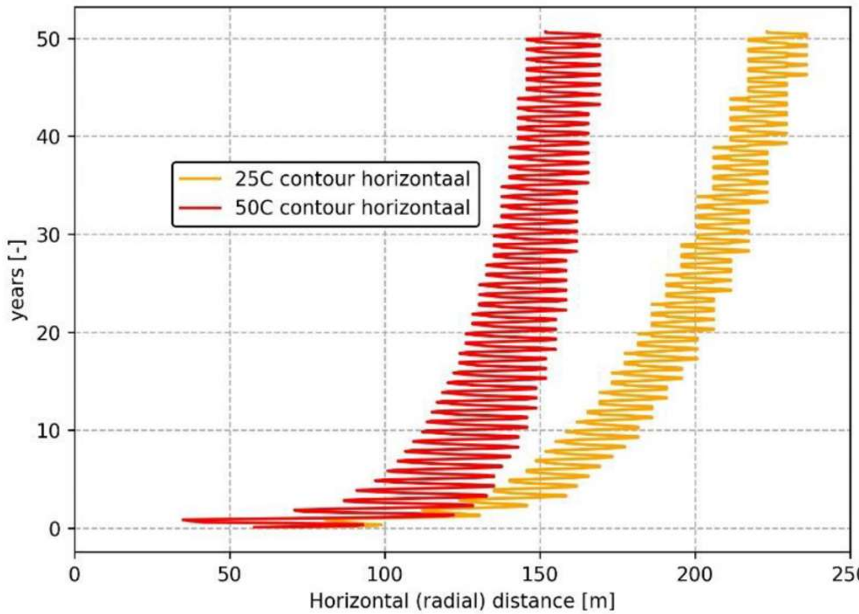
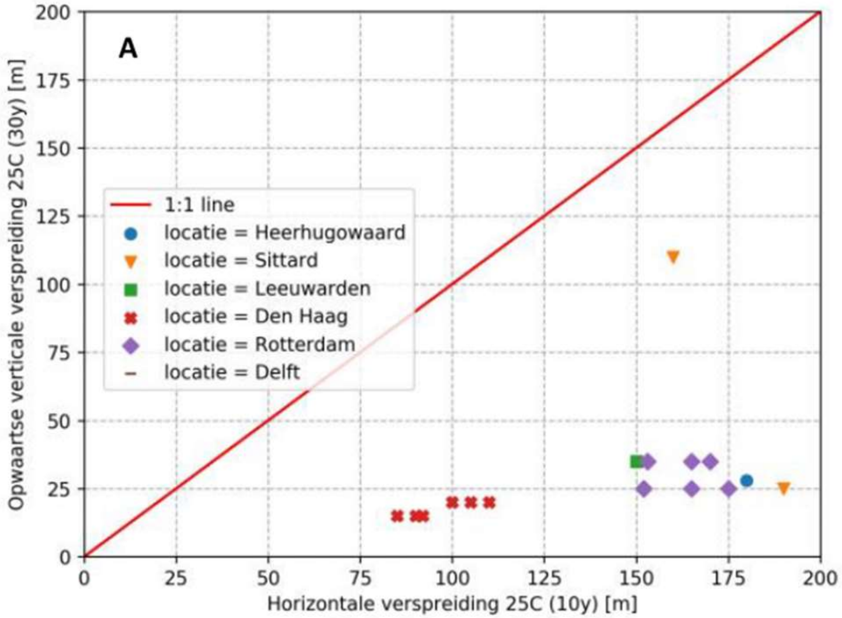
Thermal impact of HT-ATES systems

recovery efficiency ←→ thermal losses, thermal impact

thermal impact → chemical and microbiologal impact





Beernink & Hartog, 2020

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Temperature effects on chemistry: theory

1. Shifting geochemical equilibria
   impacts carbonate precipitation, silicate dissolution, (de)sorption, …

2. Changing geochemical reaction rates
   impacts redox reactions such as dissolution of iron oxides, reduction of sulphate

Mobilization of chemicals related to concentration in the sediment!

Net effect result of complex interplay of reactions!

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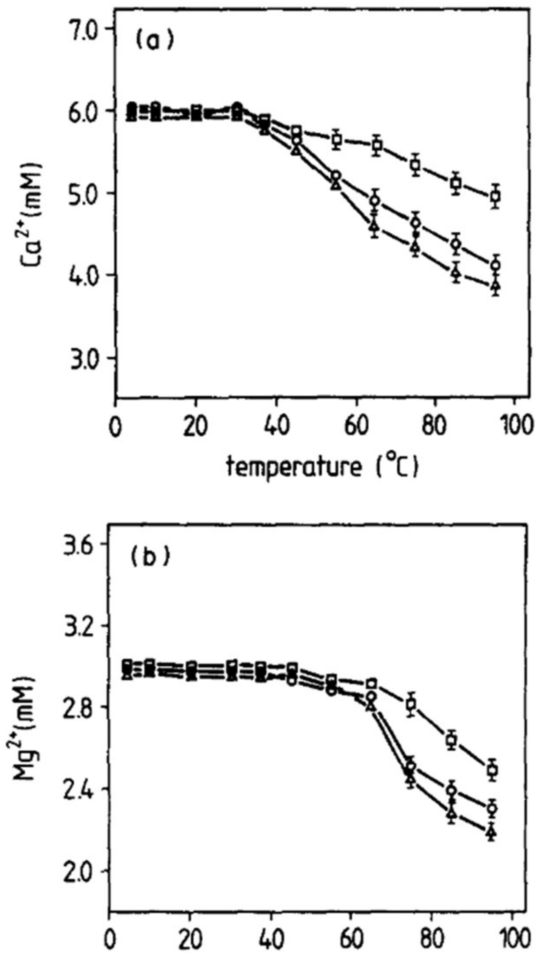
Temperature effects on macro chemistry

- Carbonate precipitation (decrease in hardness, Ca, Alkalinity)
    - From 40°C onwards
- Silicate dissolution (increase in Si, Ca, Na, K)
- Mobilization/weathering of sedimentary organic matter



Brons et al, 1991

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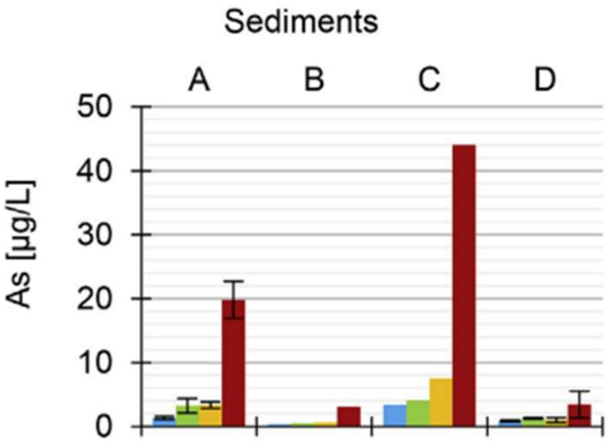
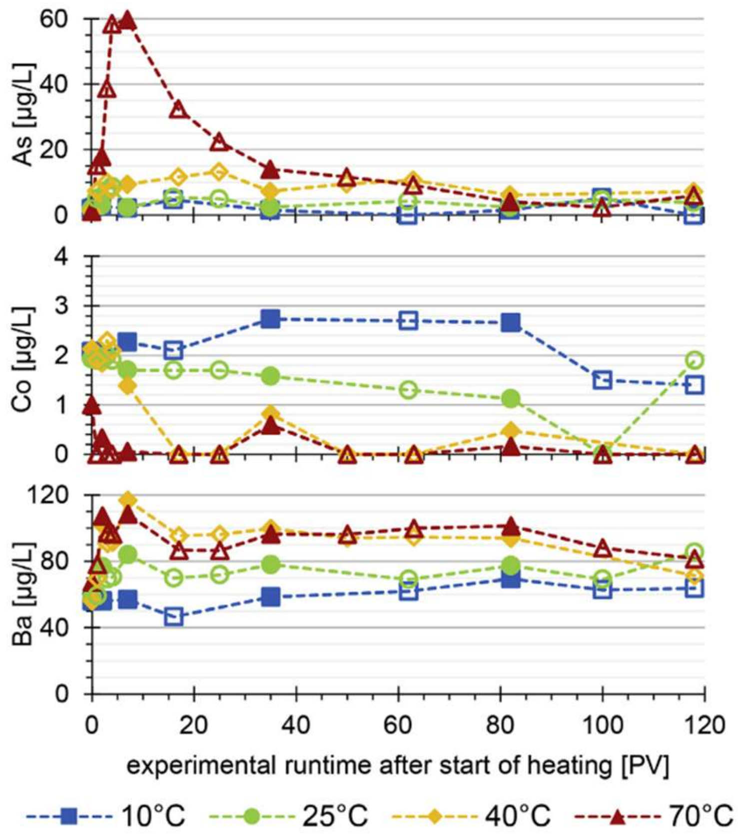
Temperature effects on trace element chemistry

- Studied in column and batch experiments
- Strongly dependent on temperature *and* sediment composition





Luders et al., 2020

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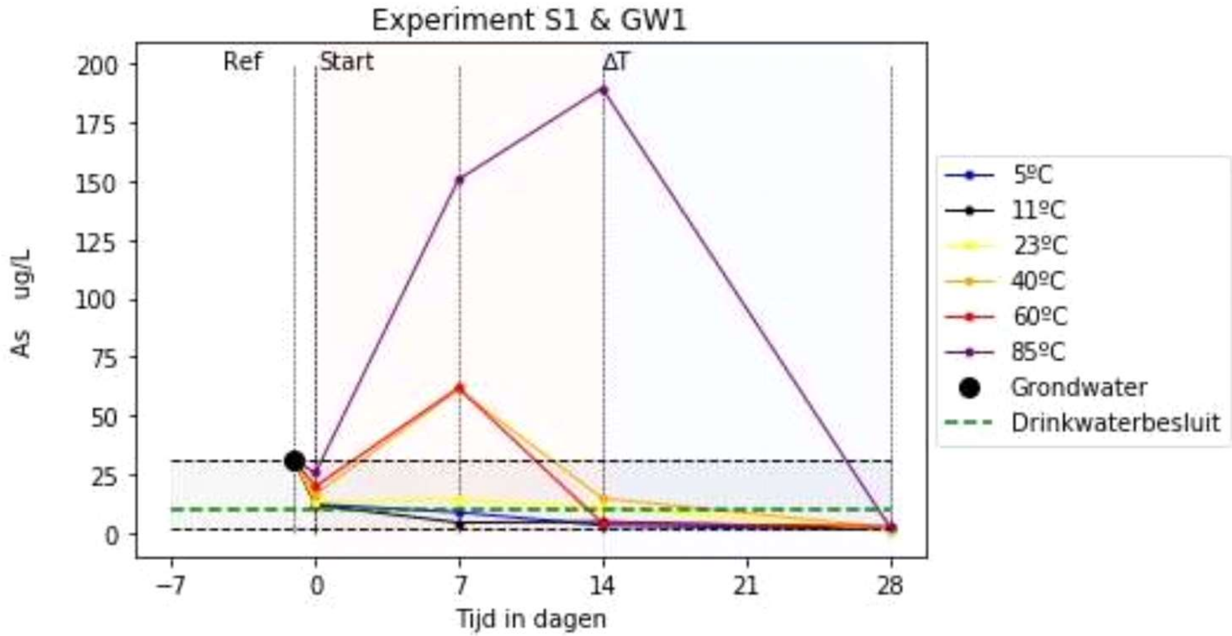
Reversibility of chemical effects

- Effects reversible when T decreases?
  - During storage
  - With distance from well
  - After abandonment

- Near complete reversibility observed for most trace elements



Van Dooren et al., 2019

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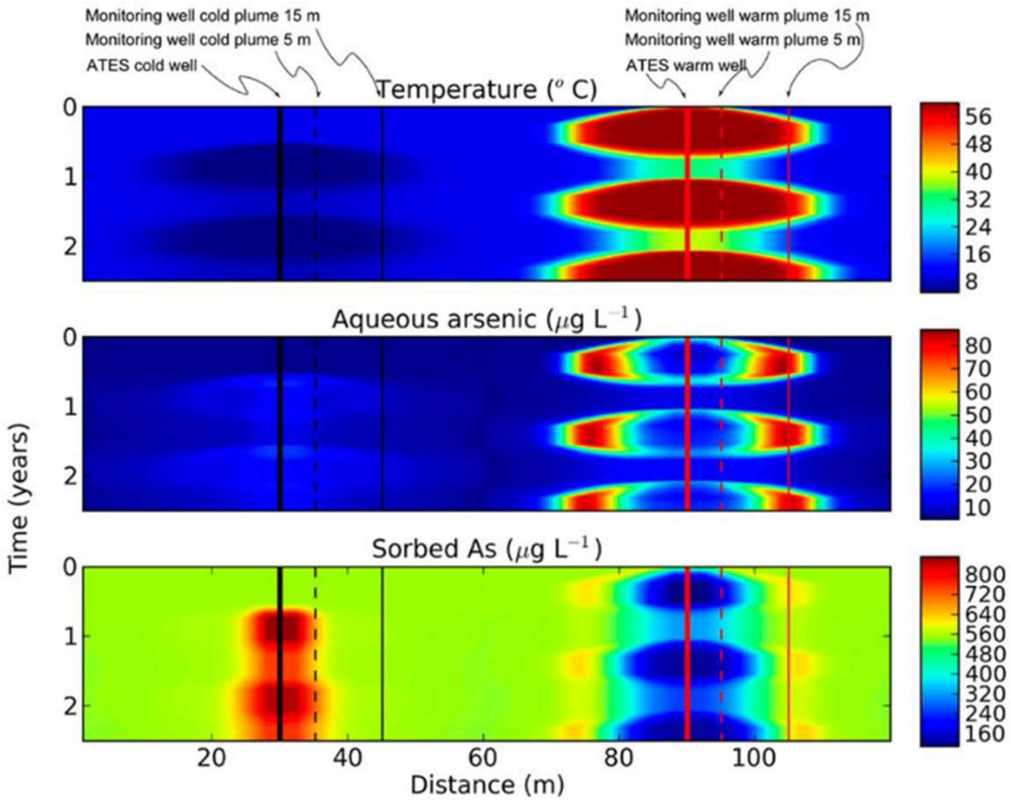
Mobility of mobilised chemicals

- HT-ATES may cause redistribution of sorbed chemicals
- Reversibility lower for changes related to mineral dissolution and precipitation
- Immobilization may occur outside thermally impacted area



Bonte et al., 2014

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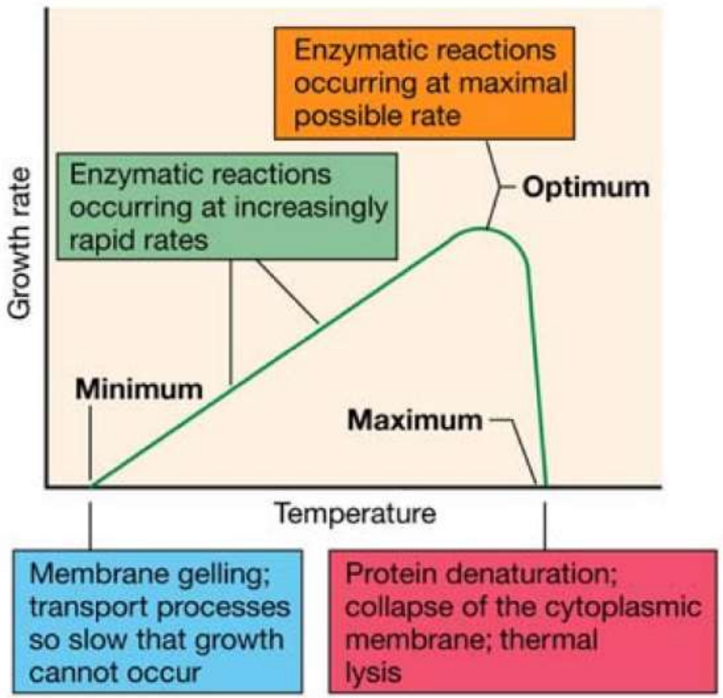
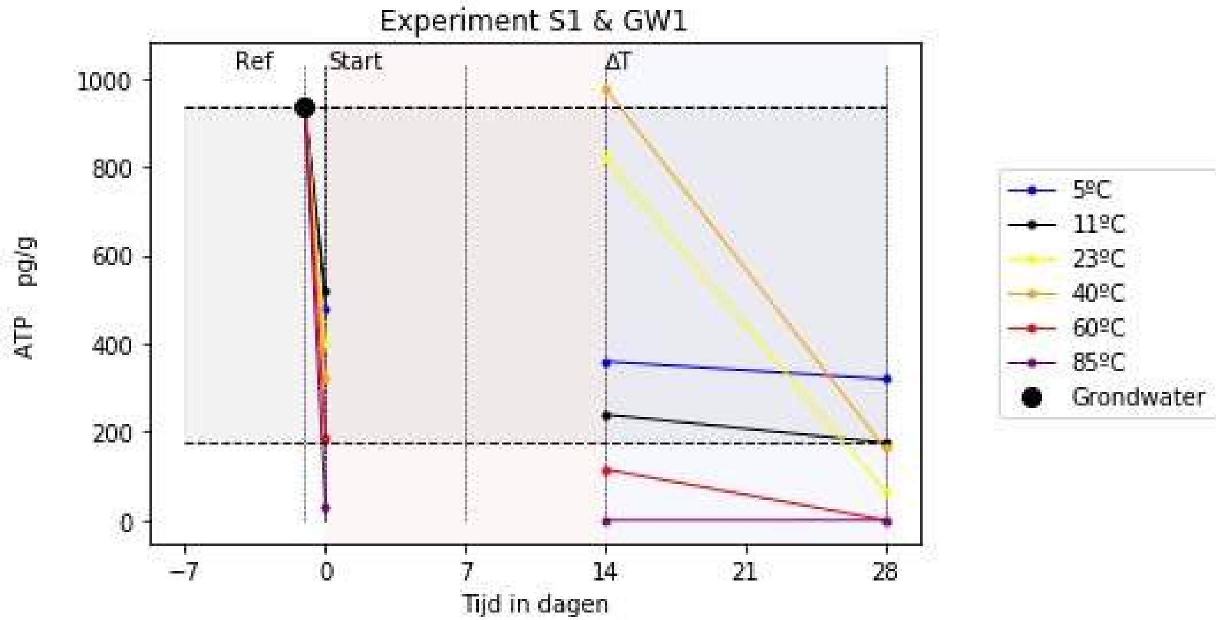
Temperature *may* impact microbial abundance



van Dooren et al., 2019



- Growth at intermediate temperatures (in some experiments)
- Die off at high temperatures (in core of thermal plume!)

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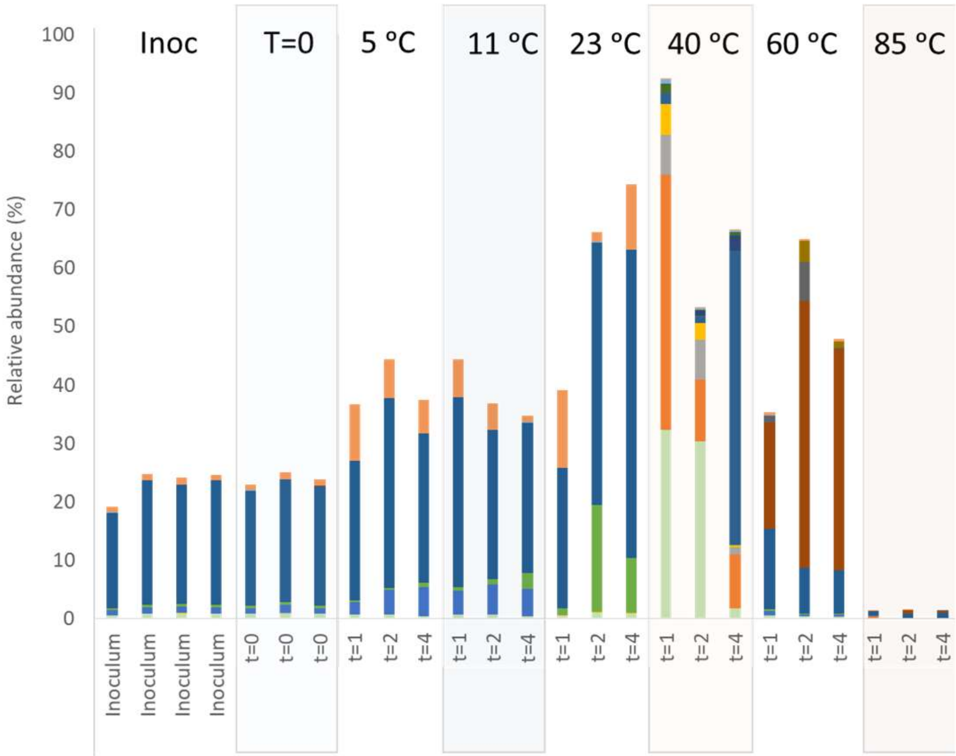
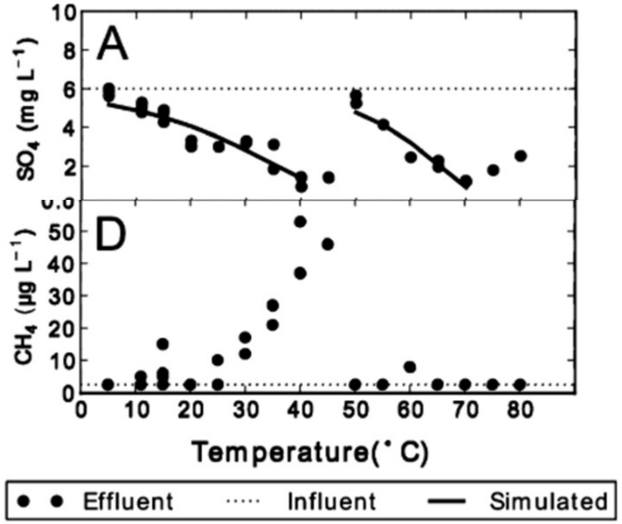
Temperature impacts microbial composition



Van Dooren et al., 2019



Bonte et al., 2013

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Way forward in current projects

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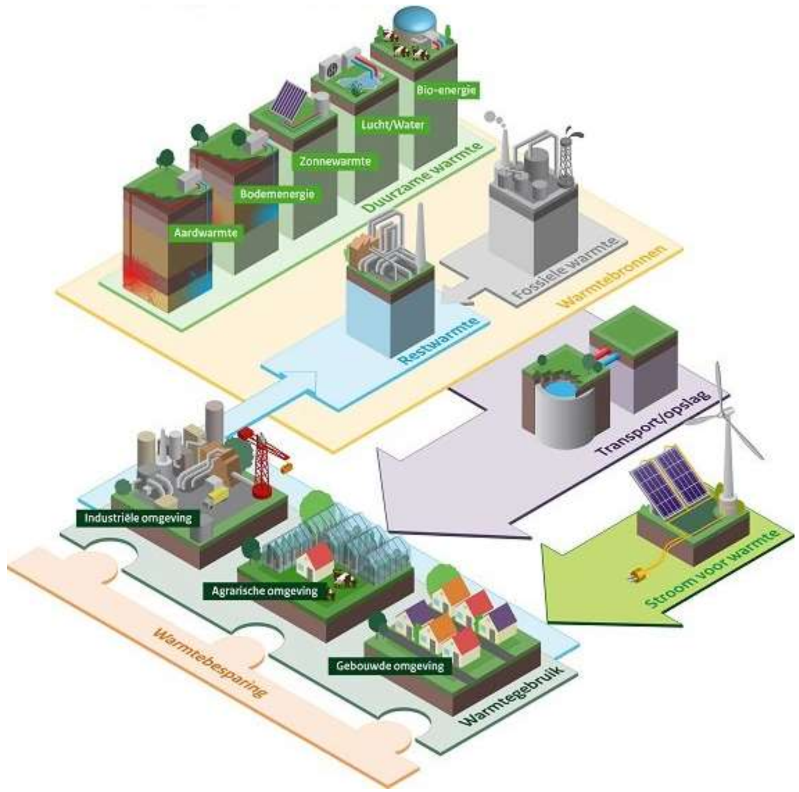
Ongoing: WarmingUP GOO seasonal heat storage project

- Upscaling to enable larger scale implementation of geothermal energy and HT-ATES in NL
  - Increase knowledge of midth-deep subsurface (100-1500 m)
  - Pilots, technological innovation and environmental impact HTO
  - Increased efficiency geothermal production
  - Improved social acceptance/involvement



Totaalbeeld warmtevoorziening
(Source: Stichting BEON)

Aardyn, Gemeente Almere, TU Delft, Deltares, Den Haag, ebn, ennatuurlijk, geothermie nederland, hvc, KWR, Shell, TNO, Tullip Energy, Universiteit Utrecht, WEP

Ongoing: PUSH-IT EU seasonal heat storage project

- Showcase the full-scale applications of heat storage (up-to 90°C) of 3 different technologies in geothermal reservoirs at 6 different sites with various societal, heat network and geologic conditions relevant across Europe:
  - Implement, develop and test thermal energy storage technologies (MTES, BTES, ATES) to store and recover heat
  - Enable joint decision making of citizens, regulators and operators to increase social acceptance
  - Enabling technologies to a wide range of geological conditions
  - Develop an open-source tool to assess and optimise LCOE reduction and costs of carbon emission reduction
  - Co-simulation and machine learning to optimised integration in heat systems