PUSH-IT: Outlook on piloting underground seasonal heat storage in Delft
(and many other places)

Urban energy institute
Dr.ir. M. Bloemendal
2022-11-09

TU Delft

WHY do we need heat storage?

Heat is challenging
..specially in the built environment

NOS.nl, 1-3-2021


deVolkskrant

NIEUWS

Minister De Jonge noemt dwang onvermijdelijk bij huizen van het gas halen

Dwang is uiteindelijk onvermijdelijk bij het van het gas afhalen van huizen. Dat heeft Hugo de Jonge dond gezegd in zijn nieuwe rol als minister van Ruimtel Ordening. De invasie van Oekraïne maakt de energietransitie volgens hem urgenter dan ooit.

Jurre van den Berg 10 maart 2022, 14:09


Rijk moet gaan kiezen tussen warmtepompen of warmtenetten

Het Planbureau voor de Leefomgeving ziet een 'mismatch' in het warmtetransitiebeleid

Jurgen Tiekstra 08 november 2022

Twee warmtepompen bij een woning. - Shutterstock

De Rijksoverheid staat in de warmtetransitie voor een tweesprong: blijft ze mikken op individuele huishoudens die met subsidie overgaan op warmtepompen, of gaat ze vooral inzetten op hele wijken die collectief op een warmtenet overstappen? Die keuze moet worden gemaakt, schrijven twee onderzoekers van het Planbureau voor


nieuwsuur · KLIMAATTOP GLASGOW

NIEUWSUUR • BINNENLAND • 01-03-2021, 17:00

'Huizen aardgasvrij maken is complex en kost ook meer dan verwacht'


Energeia · Archief · Trilemma · Uit de hoek · Podcast · Meer

Hans van der Lugt • Energeia

NIEUWS

PBL: rijk traag in toepassen lessen uit Programma Aardgasvrije Wijken

Het omzetten van lessen uit het Programma Aardgasvrije Wijken in wijzigingen in het overheidsbeleid verloopt traag. Het programma is onvoldoende onafhankelijk van het rijk en legt daardoor te weinig gewicht in de schaal. Ook is een obstakel dat het nu eenmaal veel tijd en inzet vergt om gewenste wijzigingen door te voeren.

Planbureau voor de Leefomgeving naar lessen geleerd uit het Programma Aardgasvrije Wijken (PAW): *Tussen uitvoering en beleid in de warmtetransitie.* In de studie onderzoekt het PBL hoe binnen het programma op rijksniveau wordt omgegaan met de knelpunten waar gemeenten tegenaan lopen bij de uitvoering van het PAW. In dit programma werken gemeenten sinds 2018 aan het aardgasvrij maken van 27 wijken die zijn aangewezen als proeftuinen.

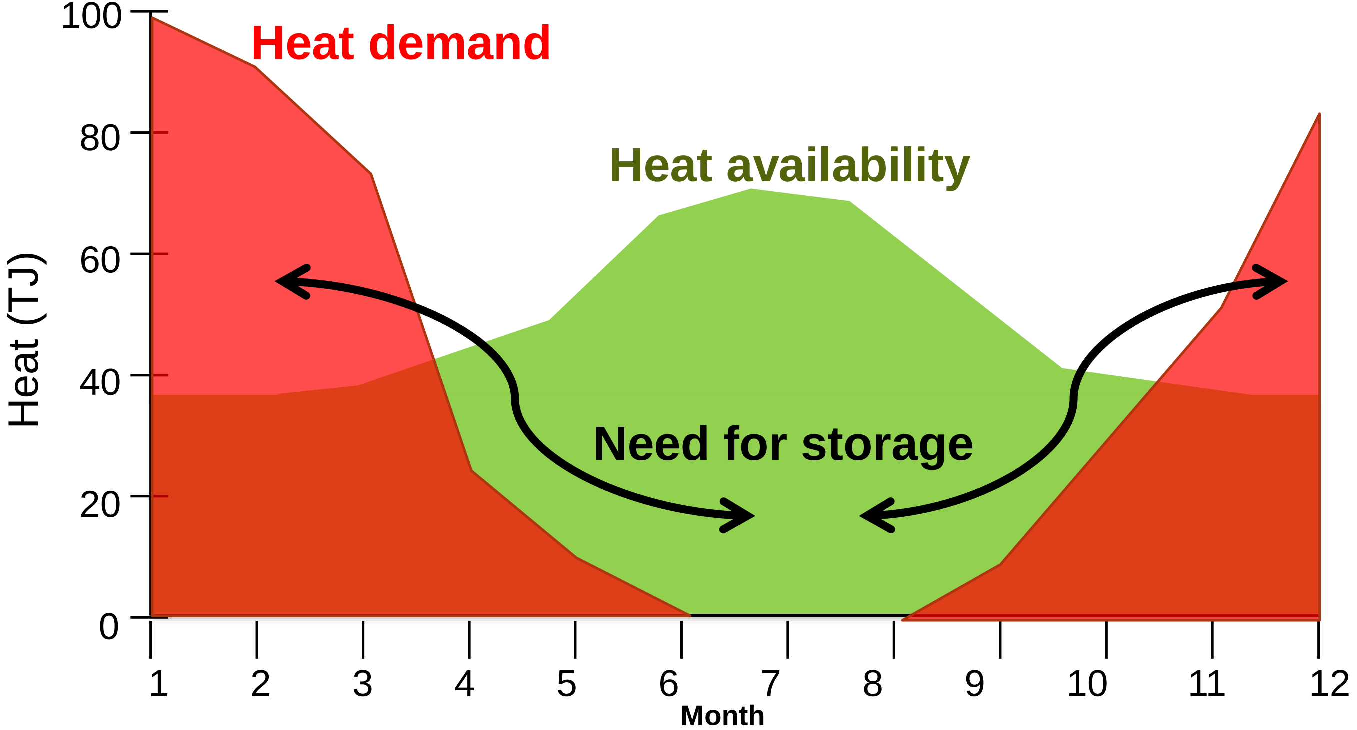
PBL | Tussen Uitvoering en Beleid

Nieuwsoverzicht

A hot topic for deep research

TU Delft

The need for heat storage



Heat demand and availability at Northern hemisphere

HOW can we store heat?

TU Delft

Options for heat storage

SENSIBLE HEAT STORAGE

- Most widely used
- Most often water is used for energy storage

PHASE CHANGE MATERIAL (PCM)

- Store latent heat via heat of fusion
- Heat of fusion is higher than heat capacity of material
- Eg: Paraffin, Nitrates etc.

THERMOCHEMICAL MATERIAL (TCM)

- Reversible endo/exothermic chemical reaction
- Volumetric energy content higher than PCMs

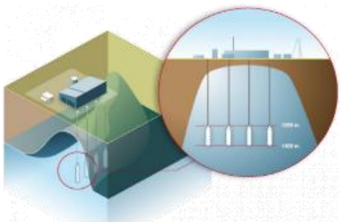
Small scale and short cycle storage

- High volumetric storage
- High efficiency

- Specific temp operation → Less flexible
- Expensive

Large scale – seasonal heat storage ? → Sensible heat storage

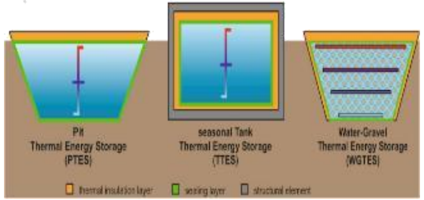
MINES/ CAVERNS



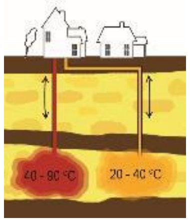
- Salt deposits in mines/caverns can be used to store energy.

- Availability is limited
- Losses can be high

TANKS/PITS



Underground



https://www.agbzw.nl/over-ons/aardgasbuffer-zuidwending

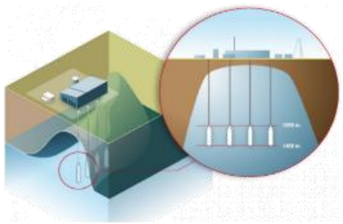
State-of-technology review of water-based closed seasonal thermal energy storage systems, Christoph Bott et al.

Mijnwater Heerlen

http://roelmeertens.nl/

Large scale – seasonal heat storage ? → **Sensible heat storage**

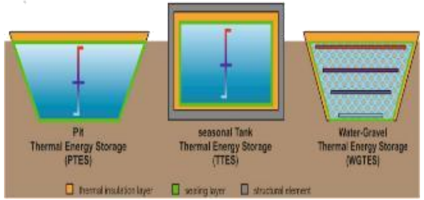
MINES/ CAVERNS



- Salt deposits in mines/caverns can be used to store energy.

- Availability is limited
- Losses can be high

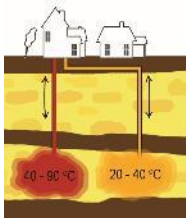
TANKS/PITS



- Offers good insulation and flexibility

- Expensive & limited capacity
- Not always possible in dense urban settings

Underground



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.

Tank at Diemen CHP

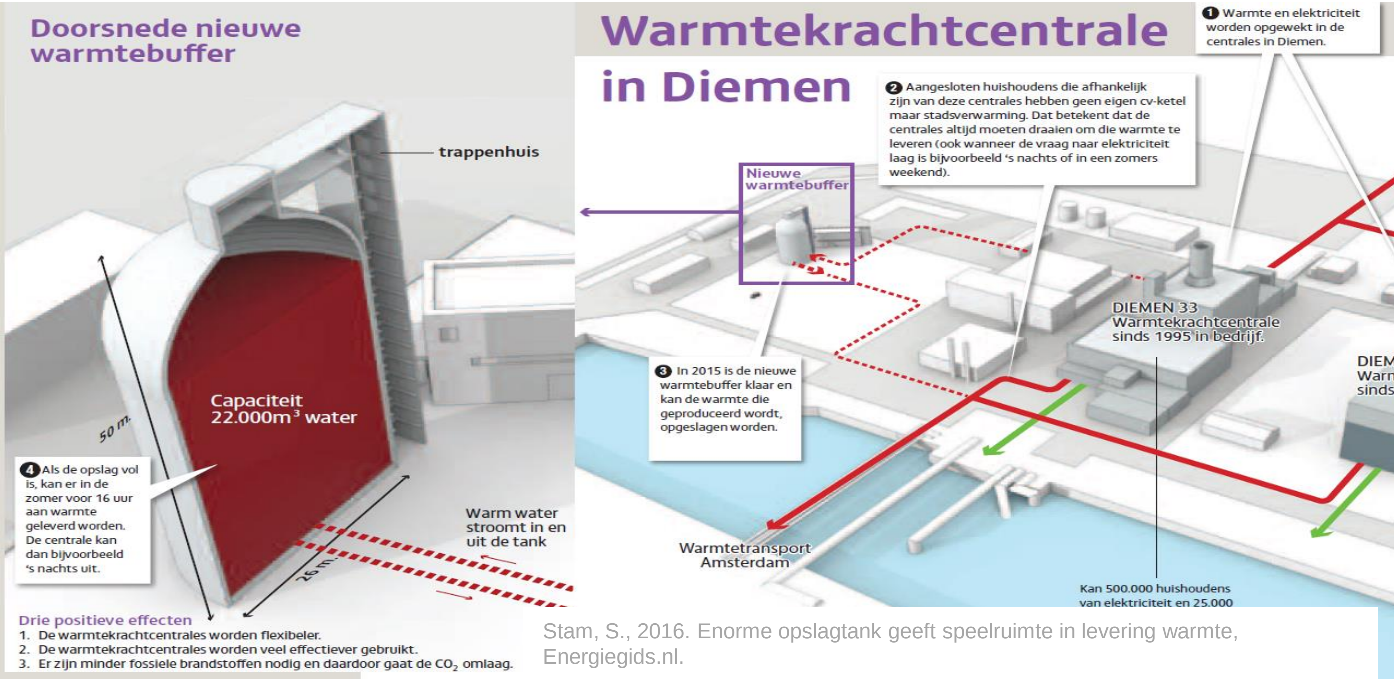
22,000 m^3 enough for a hot weekend in Amsterdam 😘

Water tank Diemen 22000m3

Radius = 26m

Height = 50 m

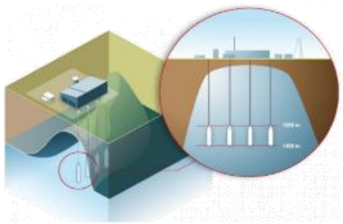
Source: Vattenfall.nl



Stam, S., 2016. Enorme opslagtank geeft speelruimte in levering warmte, Energiegids.nl.

Large scale – seasonal heat storage ? → **Sensible heat storage**

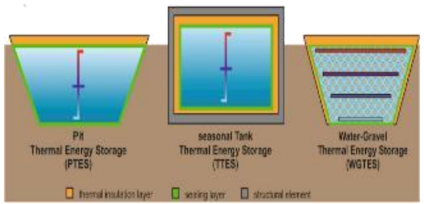
MINES/ CAVERNS



- Salt deposits in mines/caverns can be used to store energy.

- Availability is limited
- Losses can be high

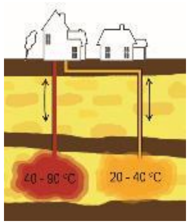
TANKS/PITS



- Offers good insulation and flexibility

- Expensive & limited capacity
- Not always possible in dense urban settings

Underground



- No space requirement above ground
- Large capacities

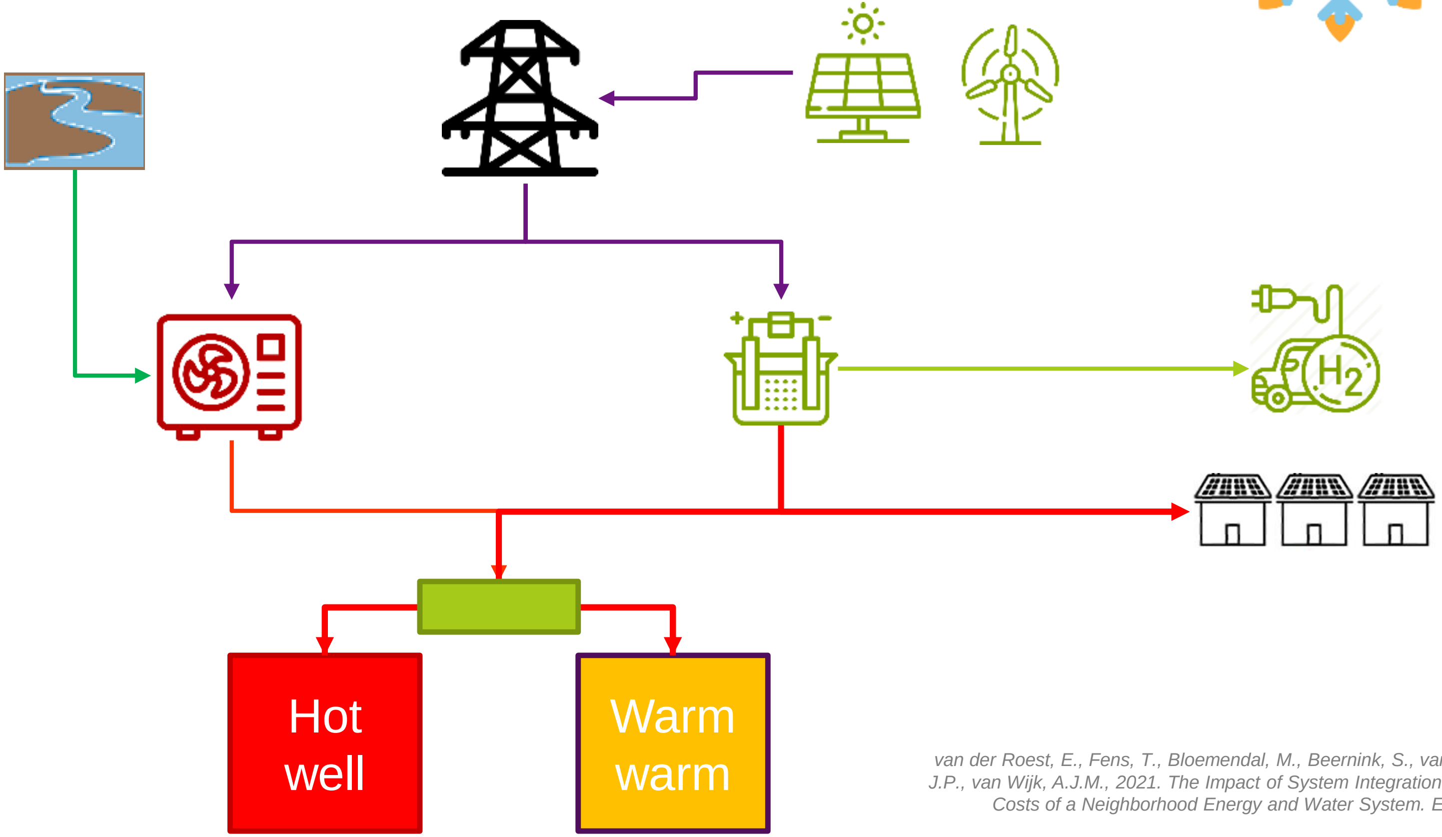
- Subsurface infrastructure needed
- Dependent on local geological conditions

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.

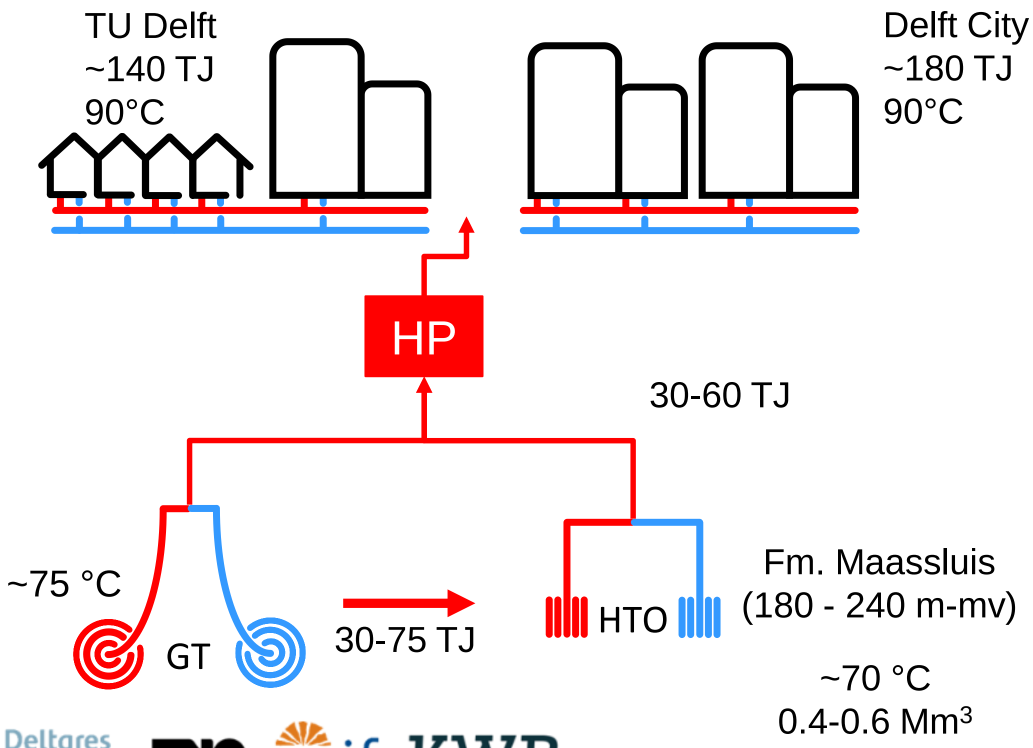
TU Delft

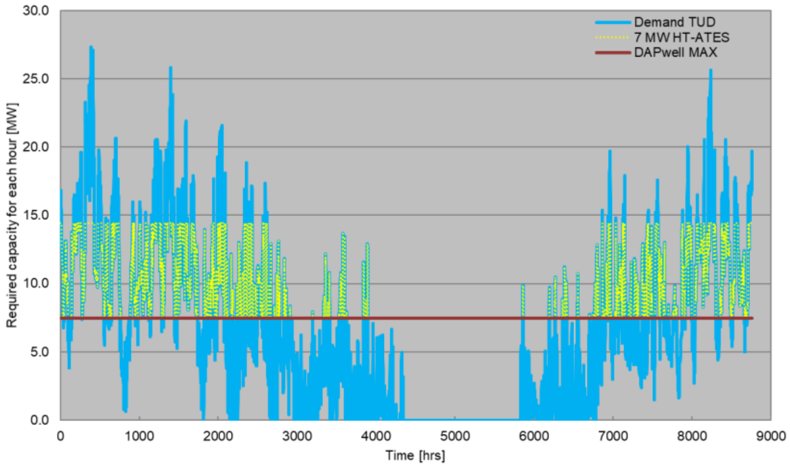
Multi energy systems



van der Roest, E., Fens, T., Bloemendal, M., Beernink, S., van der Hoek, J.P., van Wijk, A.J.M., 2021. The Impact of System Integration on System Costs of a Neighborhood Energy and Water System. Energies 14.

HT-ATES Delft – Lay-out/concept





Deltares Enabling Delta Life TNO if KWR

WINDOW – Pilots

22 sites quick-scan → 7 sites feasibility → 2-4 sites Design & pilot drilling → 2-3 sites demo project

Nr	Case (i
1	Nieuwe
2	Utrecht
3	H
4	Alkmaa
5	IJmond
11	Voorne
12	Bleiswi
13	Harnas
14	Het Gro
15	Bomme
16	Braban
17	Breda (
18	Tilburg
19	Eindhov
20	Ensche
21	Leeuwa

heatstore

Deltares Enabling Delta Life · TNO · if · KWR

WARMING UP

PUSH-IT

- Innovation action
- Heat storage
- up-to 90°C
- In geothermal reservoirs

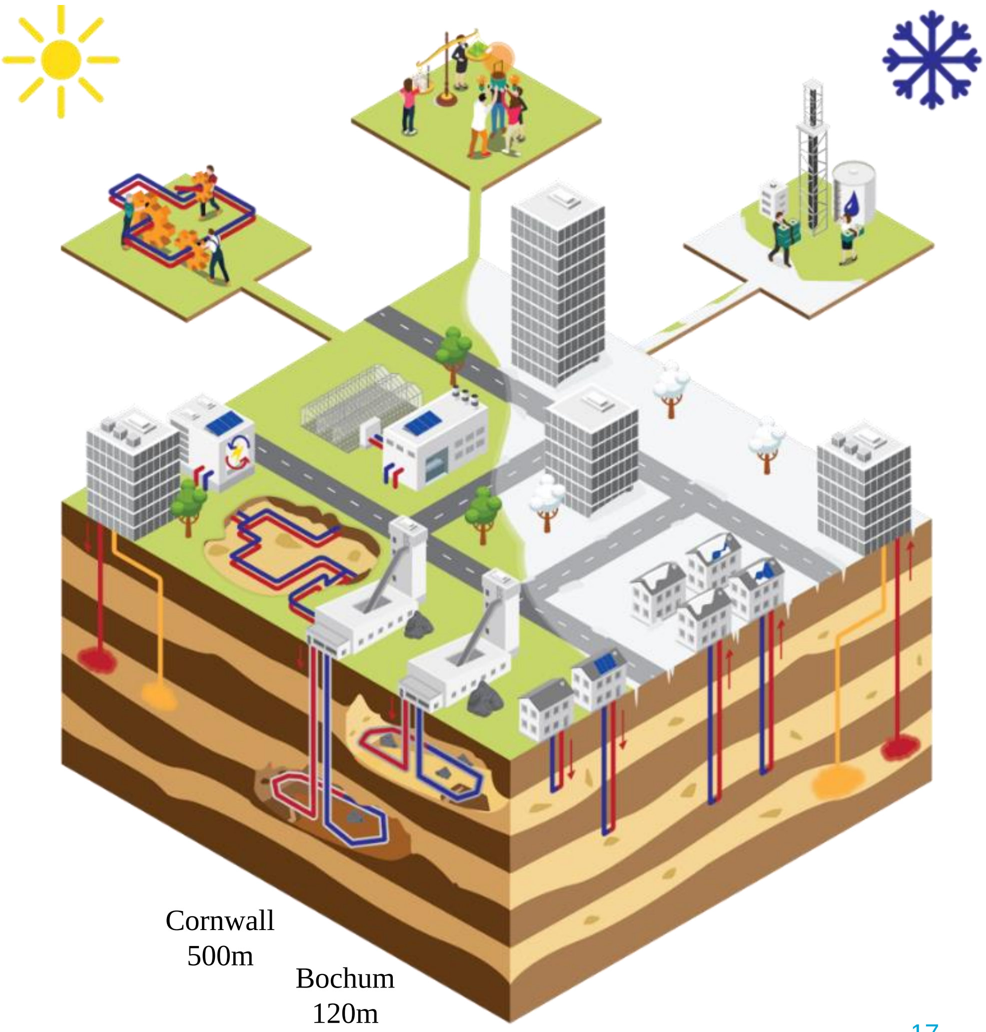
TU Delft

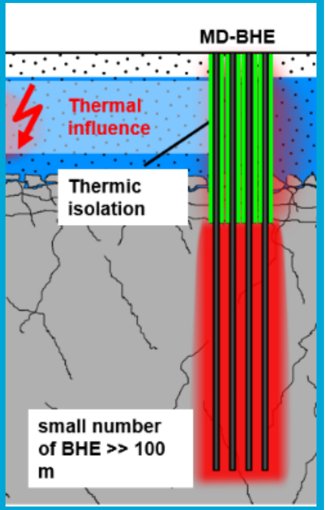
WHICH developments are needed?

j.m.bloemendal@tudelft.nl

PUSH-IT

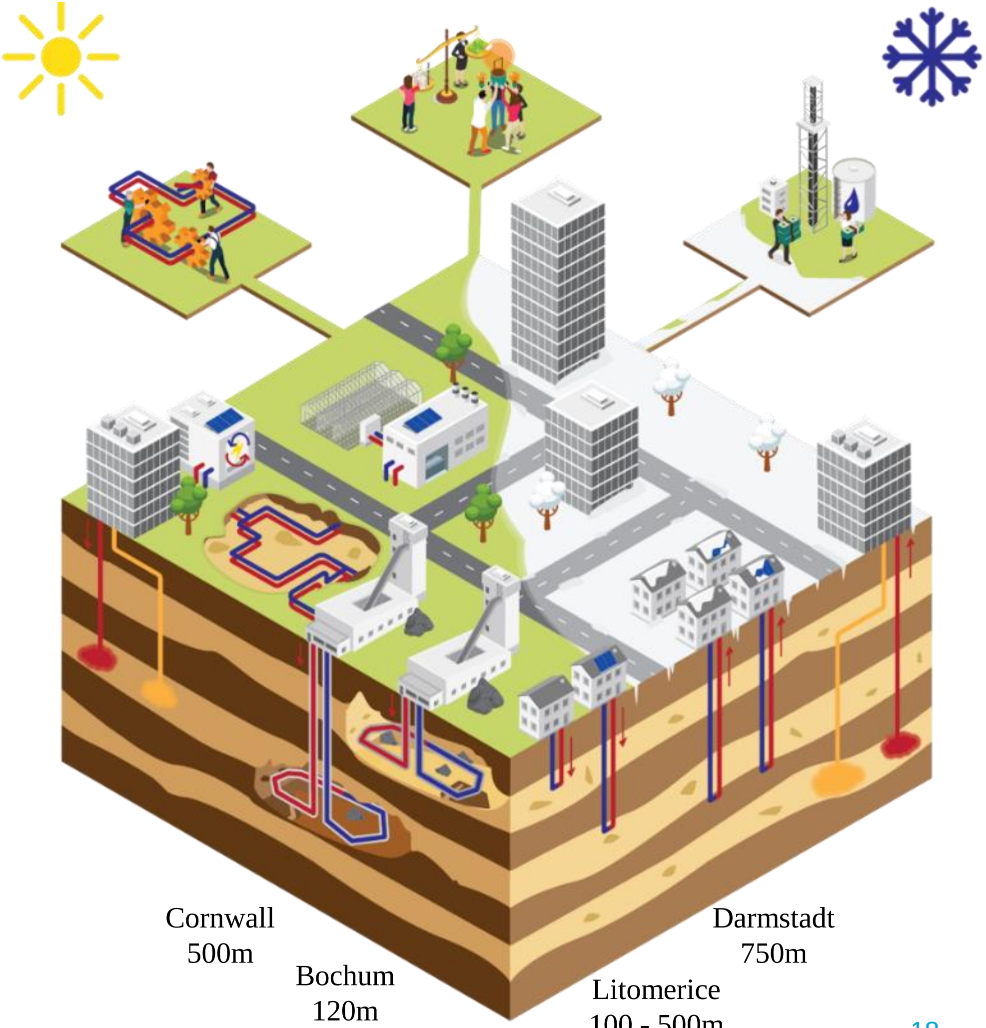
- Mines
  ~0.5 MW
  ~5 TJ
- Heat losses
- Targeted drilling
- Water quality





PUSH-IT

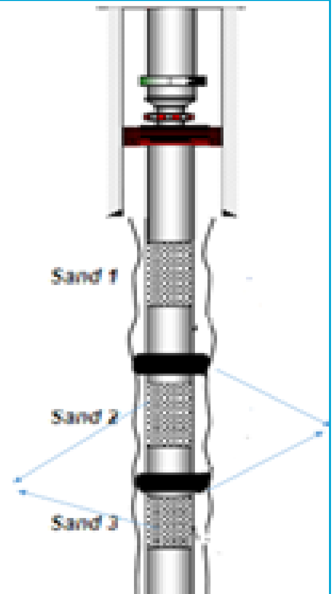
- Boreholes
  1 MW
  20 TJ
- Completion
  Coax / vacuum
  backfill materials
- Impact
- Depth

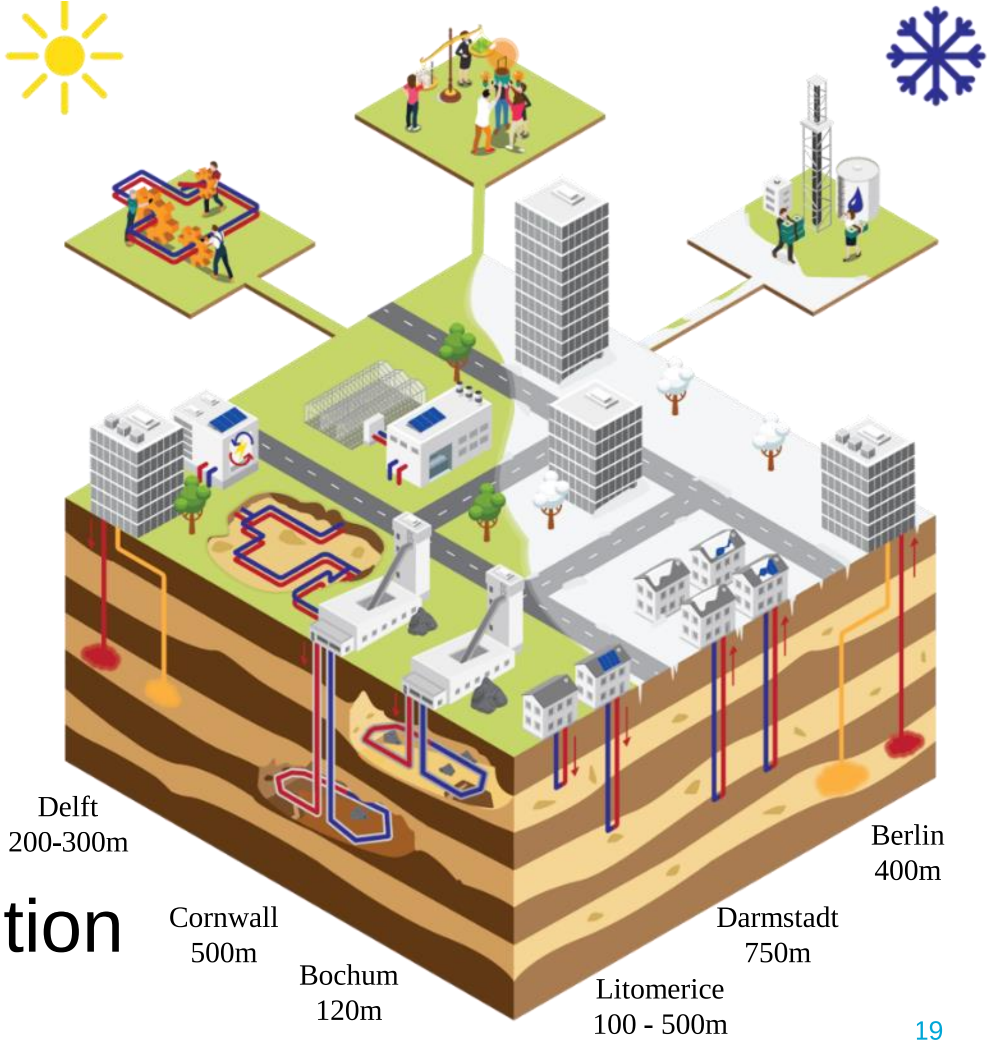


PUSH-IT

- Aquifers
  5-10 MW
  ~60 TJ

- push-pull tests
- ESP
- Impact
- Drilling/completion





PUSH-IT

- Mines
  ~0.5 MW
  ~5 TJ
- Boreholes
  1 MW
  20 TJ
- Aquifers
  5-10 MW
  ~60 TJ

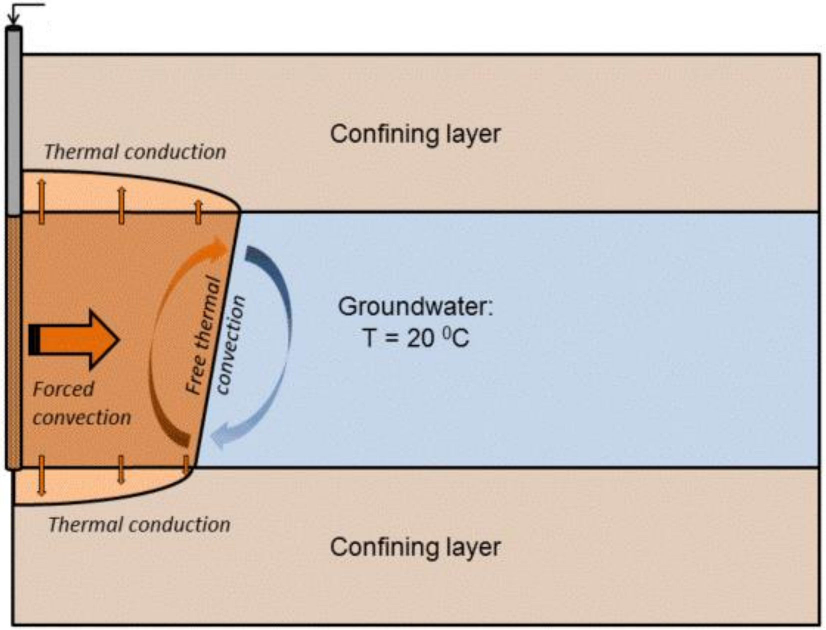
Innovation Highlights Delft

1. Impact
   – Chemical & micro-biological effects
   – Heat distribution / losses

Heat distribution in / around aquifer

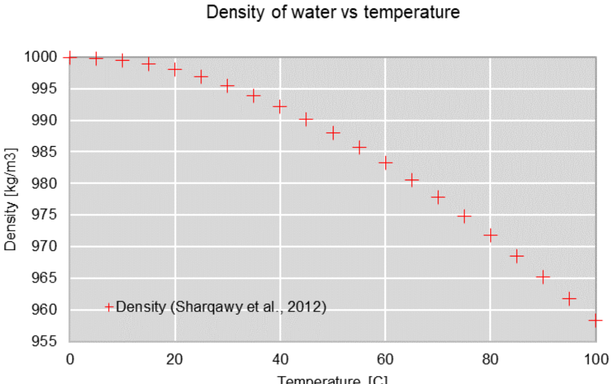
Storage temperature (T)

Screen length (L)

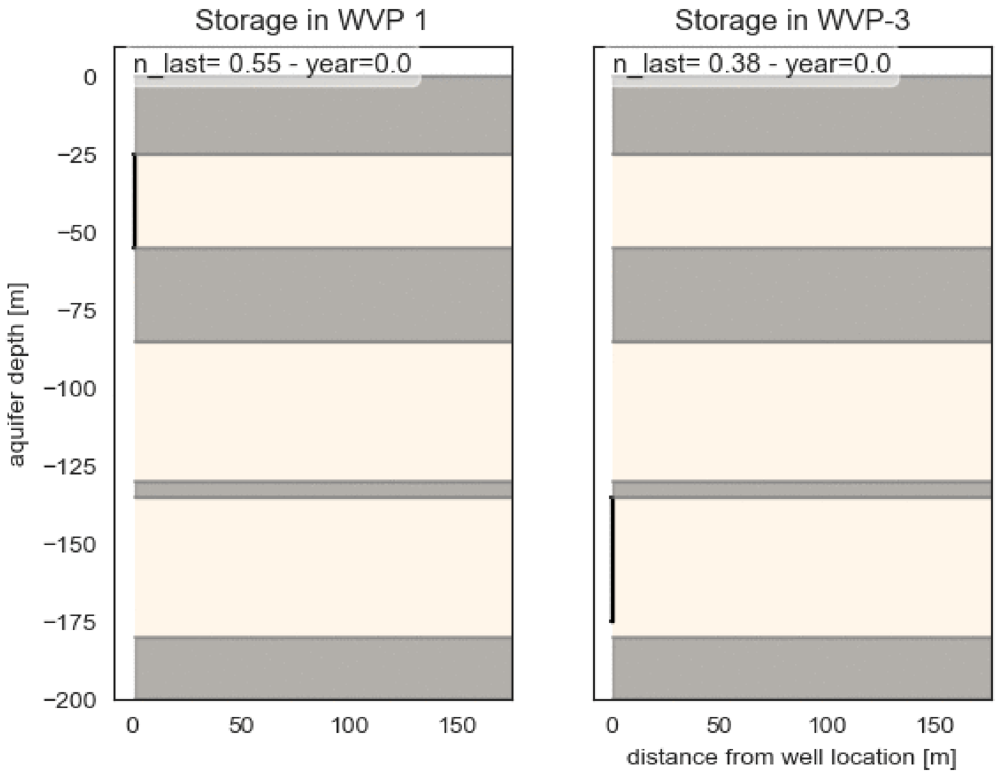


Thermal radius (R_{th})
Depends on volume and L

Lopik, J. H. v., N. Hartog and W. J. Zaadnoordijk (2016). "The use of salinity contrast for density difference compensation to improve the thermal recovery efficiency in high-temperature aquifer thermal energy storage systems." Hydrogeology Journal.



Impact depends on conditions

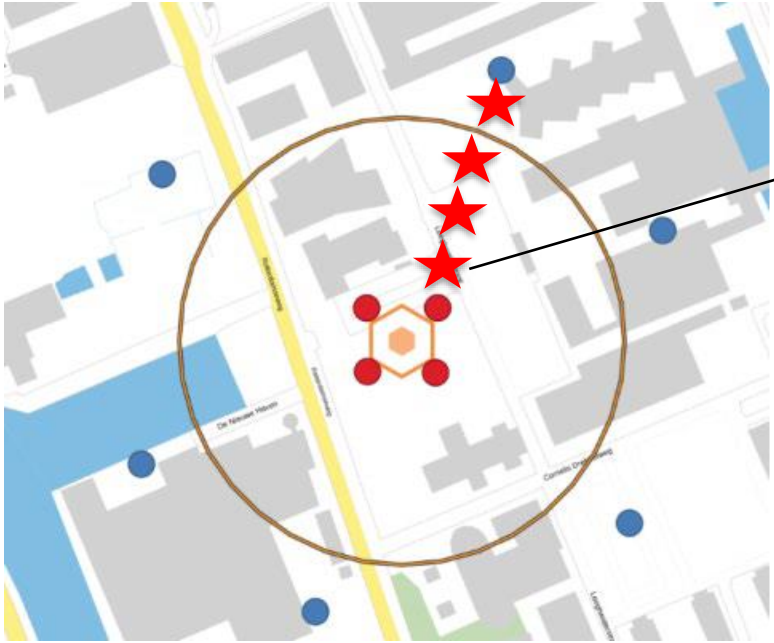


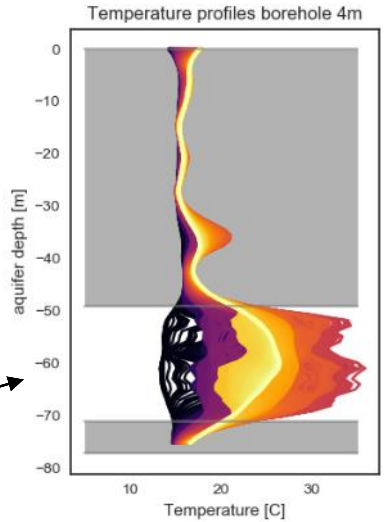
Dooren, T., Beernink, S., Timmers, P., Bloemendal, M., 2019. Prestaties en effecten van ondergrondse warmteopslag: Een verkenning voor het P2X project. KWR, Nieuwegein.

TU Delft

Temperature monitoring

DTS monitoring



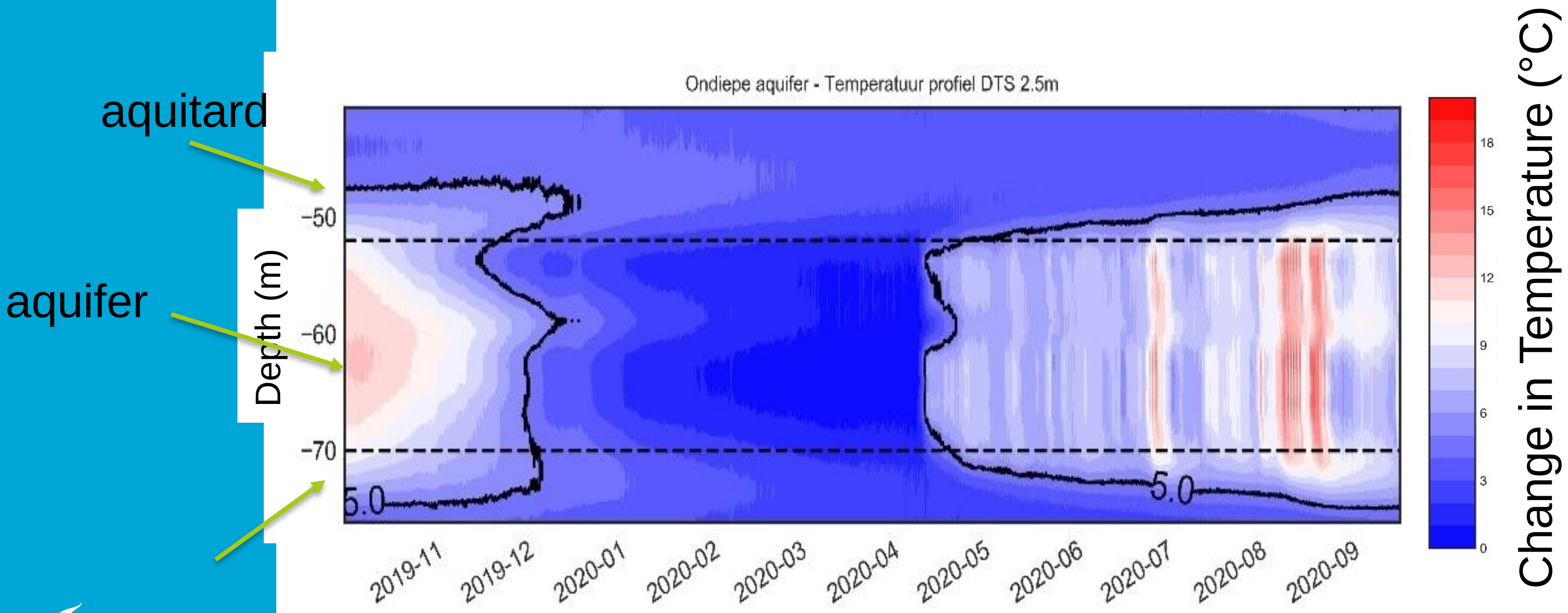


Underground heat transport

- Temperature distribution
- Buoyancy / conduction
- Heterogeneities, uncertainties

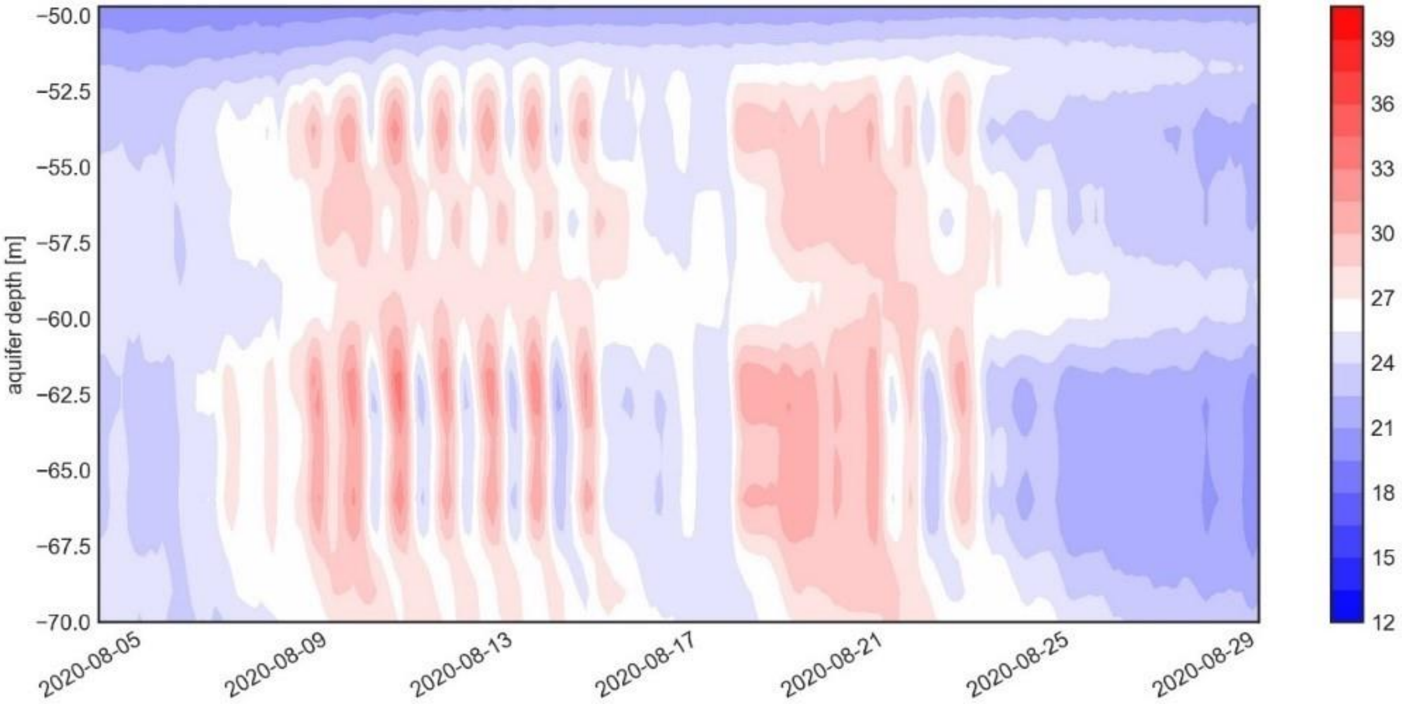
j.m.bloemendal@tudelft.nl

Distribution of heat



Bloemendal, M., Beernink, S., Bel, N.v., Hockin, A., Schout, G., 2020. Transitie open bodemenergiesysteem Koppert-Cress naar verhoogde opslagtemperatuur. KWR water research Nieuwegein

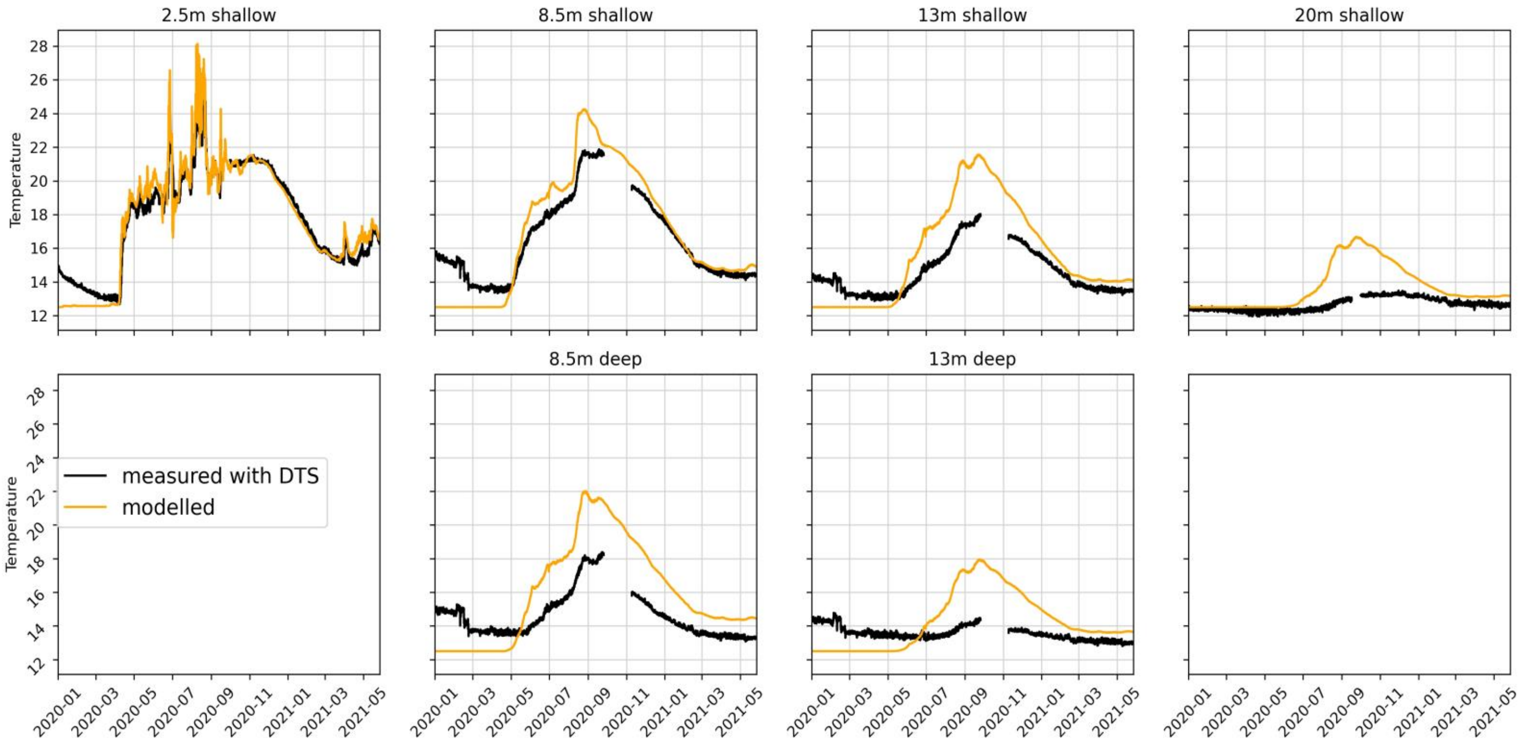
Heterogeneities and dynamics



Bloemendal, M., Beernink, S., Bel, N.v., Hockin, A., Schout, G., 2020. Transitie open bodemenergiesysteem Koppert-Cress naar verhoogde opslagtemperatuur. KWR water research Nieuwegein

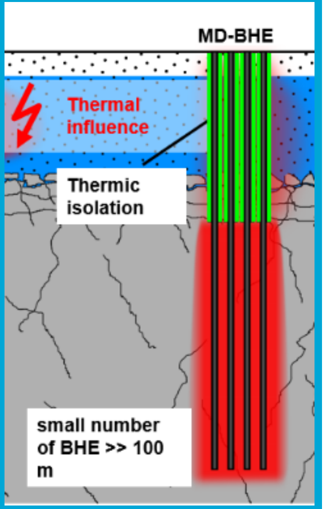
TU Delft

Model improvements



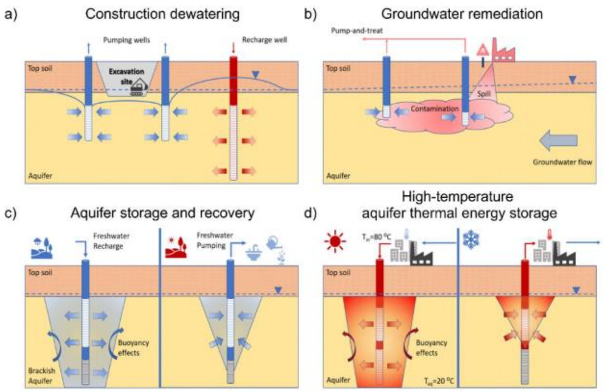
TU Delft

Innovation Highlights Delft



1. Impact
   - Chemical & micro-biological effects
   - Heat distribution / losses
2. Wells
   - Drilling method
   - Completion

Problem



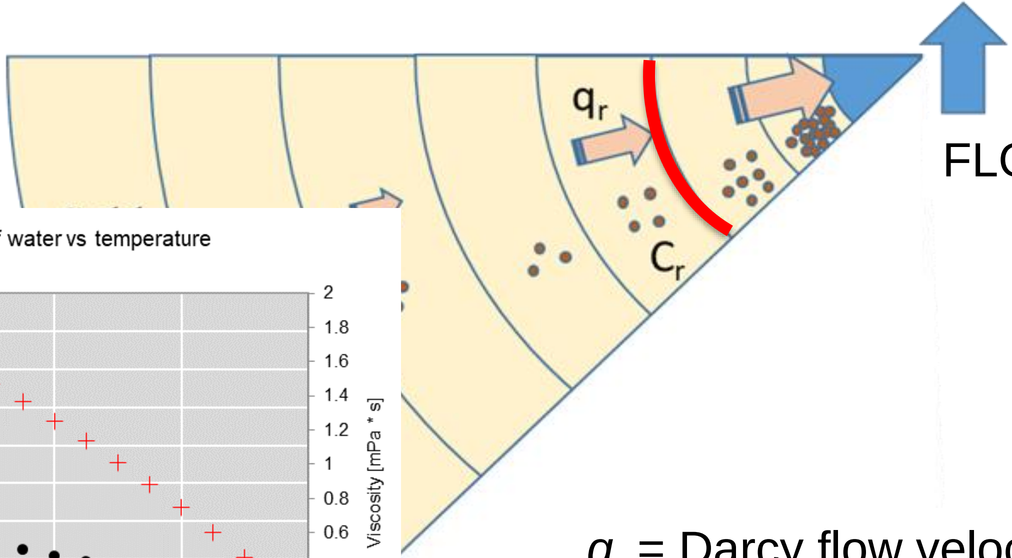
Lopik, 2020

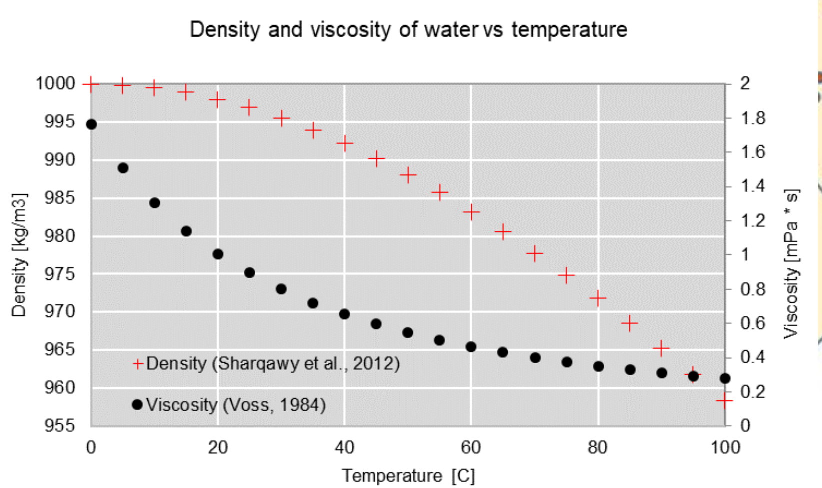
- Busy in the underground
- Utilise more “challenging” aquifers
  i.e. thin, fine grained, deep
- Hence, capacity, clogging and costs are an issue

j.m.bloemendal@tudelft.nl

Particle transport to wells

- Radial flow → particle cumulate near well

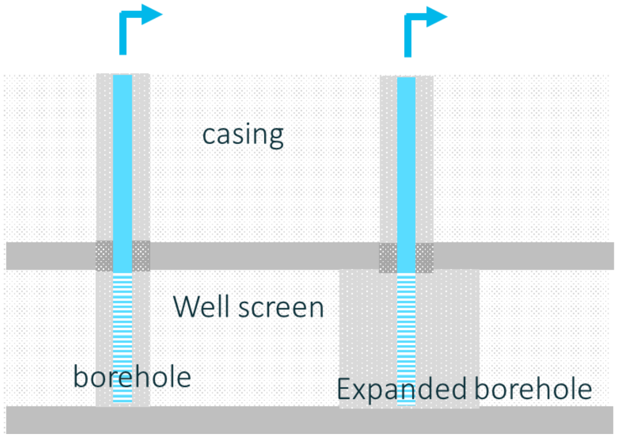




q_r = Darcy flow velocity at distance r
c_r = concentration particles

Why expand borehole diameter

- Potential benefits
  - Reduce drawdown i.e. pumping costs
  - Reduce borehole clogging
  - Reduce drilling costs



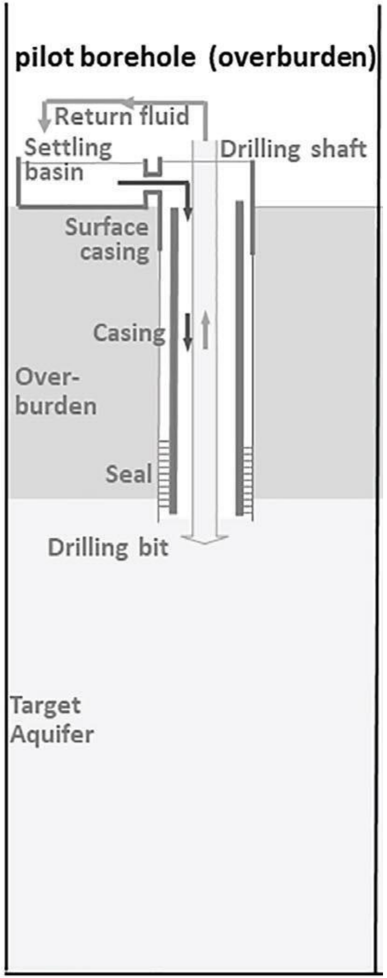
- Aim: expansion of borehole in unconsolidated formations

haitjema grondboorbedrijf

KWR

TU Delft

Pilot borehole + casing



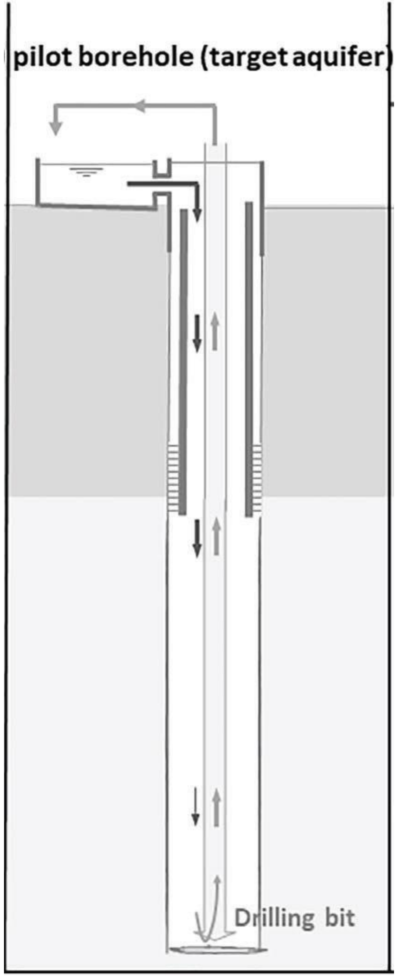
Schans, M.v.d., Bloemendal, M., Robat, N., Oosterhof, A., Stuyfzand, P.J., Hartog, N., 2022. Field Testing of a Novel Drilling Technique to Expand Well Diameters at Depth in Unconsolidated Formations. Groundwater

haitjema grondboorbedrijf

KWR

TU Delft

Pilot borehole



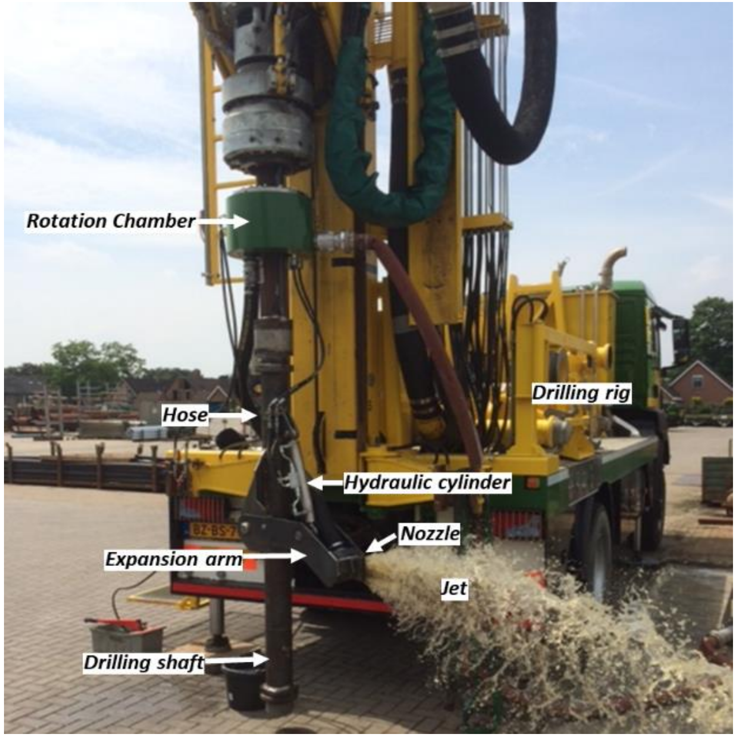
Schans, M.v.d., Bloemendal, M., Robat, N., Oosterhof, A., Stuyfzand, P.J., Hartog, N., 2022. Field Testing of a Novel Drilling Technique to Expand Well Diameters at Depth in Unconsolidated Formations. Groundwater

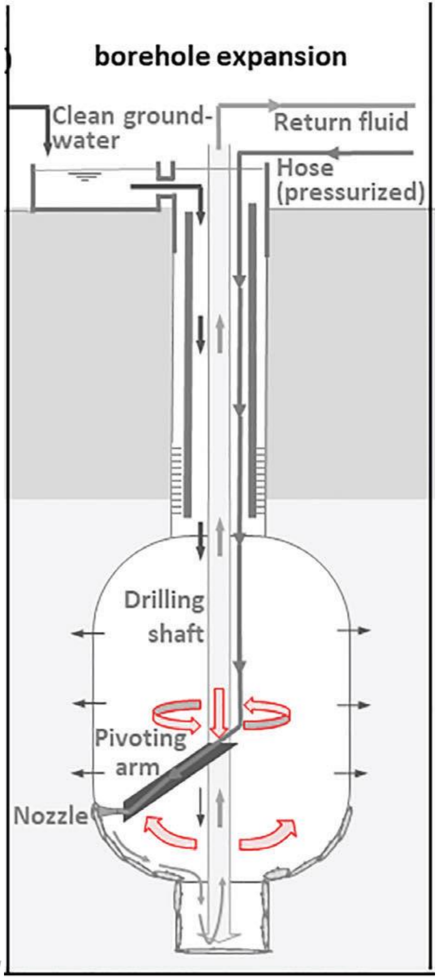
haitjema grondboorbedrijf

KWR

TU Delft

Borehole expansion

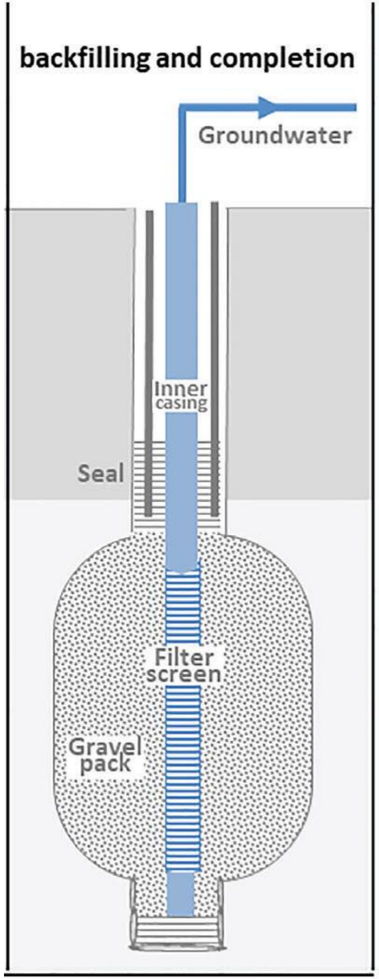




Schans, M.v.d., Bloemendal, M., Robat, N., Oosterhof, A., Stuyfzand, P.J., Hartog, N., 2022. Field Testing of a Novel Drilling Technique to Expand Well Diameters at Depth in Unconsolidated Formations. Groundwater

Completion

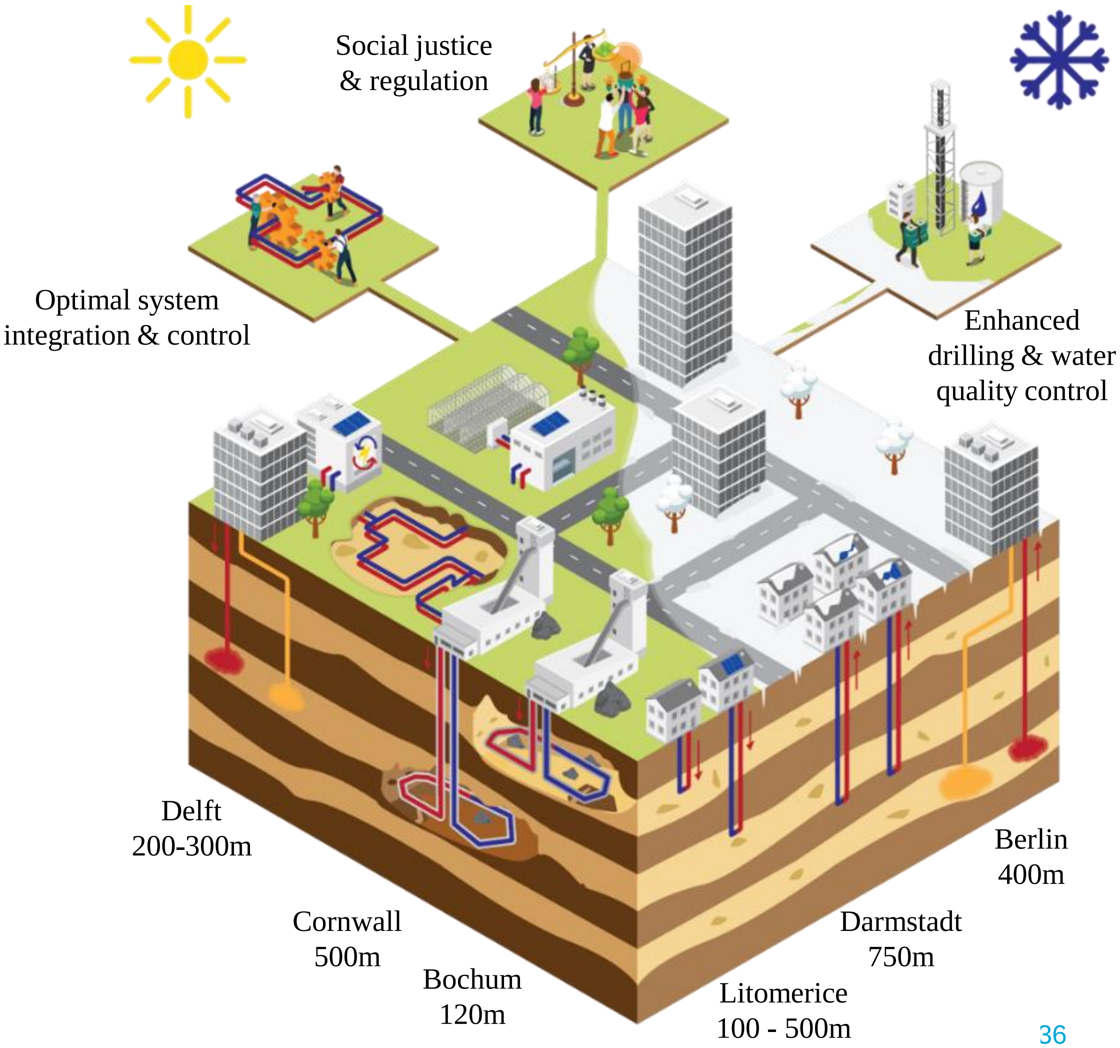
- Ø1.7m
- Ø2.5m



Schans, M.v.d., Bloemendal, M., Robat, N., Oosterhof, A., Stuyfzand, P.J., Hartog, N., 2022. Field Testing of a Novel Drilling Technique to Expand Well Diameters at Depth in Unconsolidated Formations. Groundwater

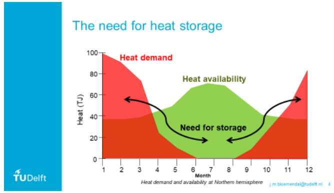
PUSH-IT

- **Mines**
  ~0.5 MW
  ~5 TJ
- **Boreholes**
  1 MW
  20 TJ
- **Aquifers**
  5-10 MW
  ~60 TJ

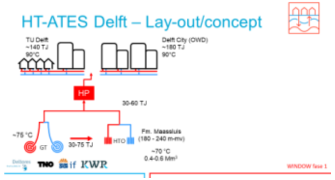


TU Delft

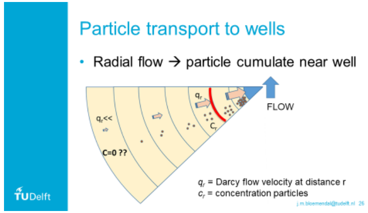
Take home

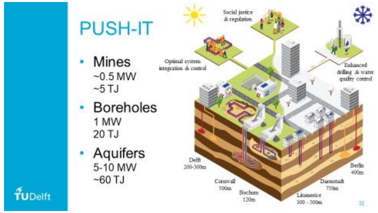


- Large scale seasonal heat storage is needed
- Various ways to store and integrate → underground accommodates capacity for seasonal

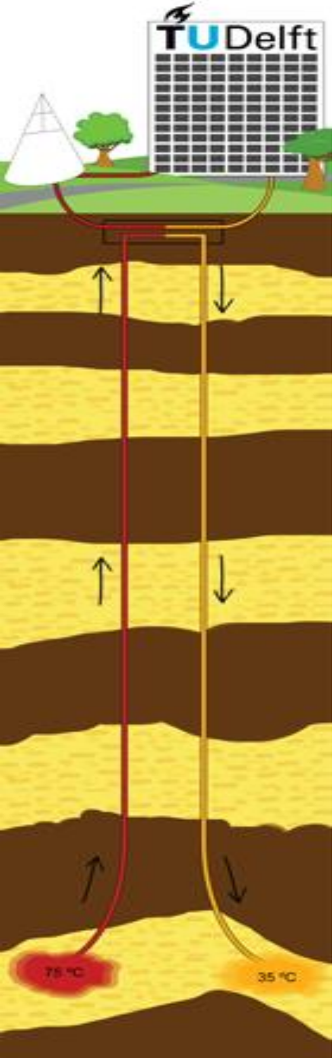


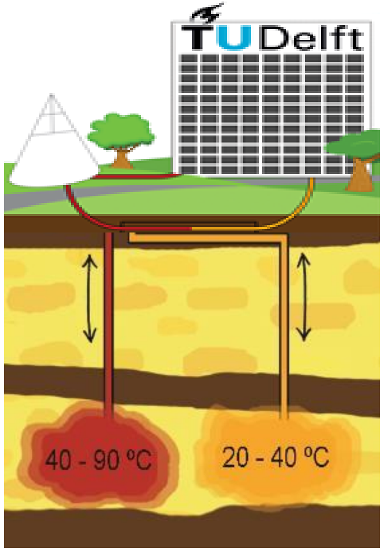
- Via fundamental research at demo's towards stable and robust seasonal heat storage in the underground





TU Delft PUSH-IT Team:
-Martin Bloemendal
- Phil Vardon
- Alexandros Daniilidis
- David Bruhn
- Danitsja van Heusden
- Jan Schiereck
- Anne Medema
- m.m.





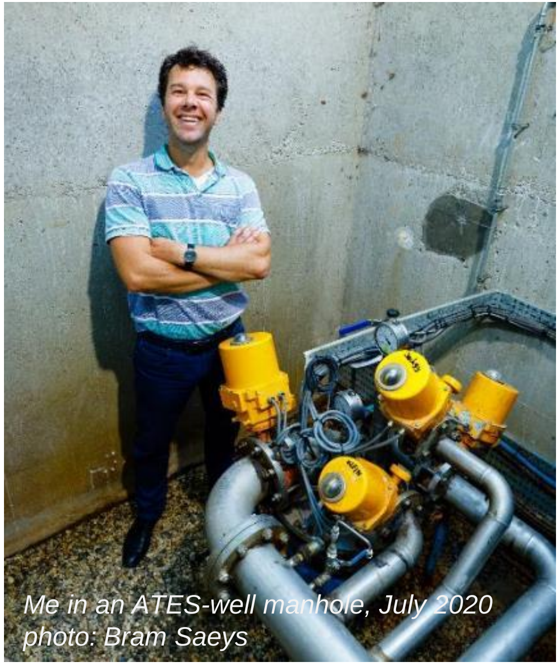
Novel combination of
geothermal energy and HT-ATES
&
World-wide unique research & education infrastructure

PUSH-IT: Outlook on piloting underground seasonal heat storage in Delft
(and many other places)

Dr.ir. M. Bloemendal
2022-11-09
j.m.bloemendal@tudelft.nl

More info:
www.heatstore.eu
www.warmingUp.info
Webinar geothermal & HT-ATES
EBN week of subsurface storage

Contributions from:
Stijn Beernink, Martin v.d. Schans, Phil Vardon


Me in an ATES-well manhole, July 2020
photo: Bram Saeys

TU Delft

Innovation highlights

- · Water treatment: One of the goals is to experiment on water treatment with CO_2 instead of hydrochloric acid and to monitor the results of the application of CO_2 injection.
- · Drilling and completion: ATES differs from geothermal wells in a technical sense. We will reduce costs identifying novel materials for making the wells and pipes. Pump selection: Experience shows that pump selection is an important aspect. Attention will be made to select the right pump to increase lifetime, while keeping total cost of ownership as low as possible.
- · System integration / control: Co-simulated model of the district heating grid and of the subsurface storage. This model will be used to deliver data for the machine learning techniques training the models of the smart district heating network controller prototype. This will be demonstrated in a cluster of buildings at the demo site to optimize network operating for the ATES system. The co-simulation platform will be used to extrapolate the performance of the controller to the entire network.
- · Monitoring: Push-pull test will be used for reservoir monitoring to characterize dynamic reservoir behaviour. Multi method monitoring will be used to quantify reservoir behaviour storage efficiency in 4D.
- · Teaching and research facility to increase contact of users/ scientists to the technology and enhance the awareness.

TU Delft

PUSH-IT: Learning by doing [TUD]

WP2: Public engagement, societal benefit and risks [UXT]

- T2.1: Societal engagement and social acceptability [UXT]
- T2.2: Supporting regulations and governance [BGS]
- T2.3: LCOE generating a sustainable energy economy [UU]

WP1: Demonstration and Follower Sites [F-IEG]

- T1.1: Delft – ATES (NL)
- T1.2: Darmstadt – BTES (D)
- T1.3: Bochum – MTES (D)
- T1.4: Berlin – ATES (D)
- T1.5: Litomerice – BTES (Cz)
- T1.6: United Downs – MTES (UK)

Social sciences

Preparation → Installation & commissioning → Monitoring & assessment

Enabling technologies

WP3: Enabling technologies [TUD]

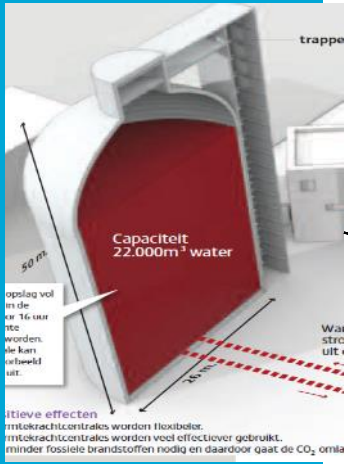
- T3.1: Enhanced well Drilling and completion [TUD]
- T3.2: Smart district heating network control [VITO]
- T3.3: Water quality and environmental impact control [BRGM]
- T3.4: System performance assessment and optimisation [TDA]

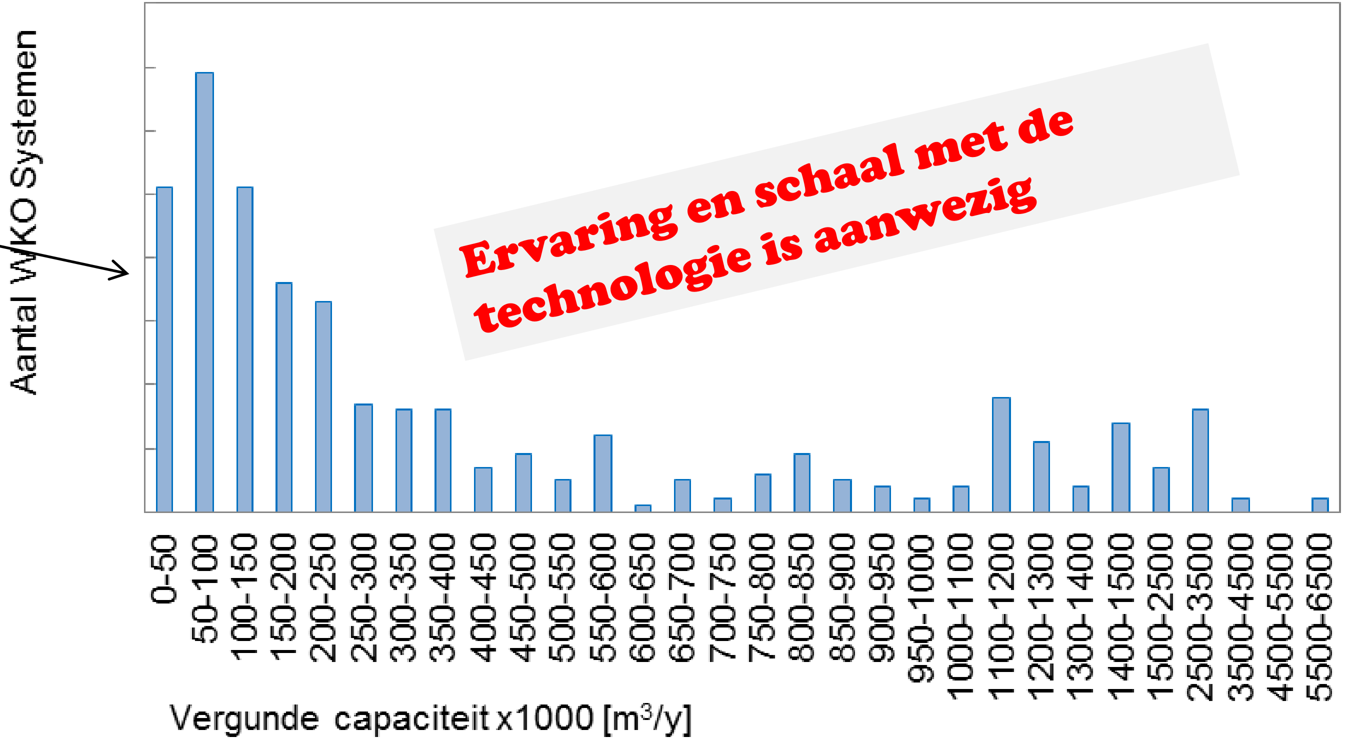
WP4: Dissemination, Exploitation and Communication [EQS]

- T4.1: Dissemination of methods and workflows [TDA]
- T4.2: Exploitation and fast track market upscaling [EQS]
- T4.3: Communication: Public information [UGN]
- T4.4: Communication: stakeholder network [EQS]
- T4.5: Spatial Multi Criteria Analysis for sustainable development of UTES [UGN]

WP5: Project coordination [TUD]

- T5.1: Technical coordination [TUD]
- T5.2: Non-technical coordination [TUD]
- T5.3: Quality Assurance & Risk management [TUD]
- T5.4: Open Science & Innovation management [TUD]





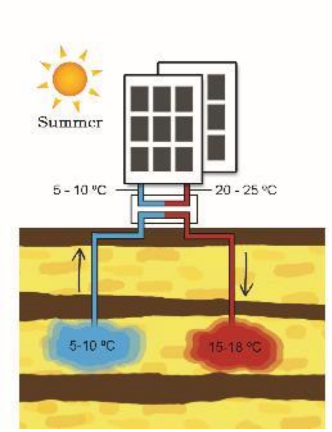
5 TJ ----------------50 TJ--------------------0.5 PJ

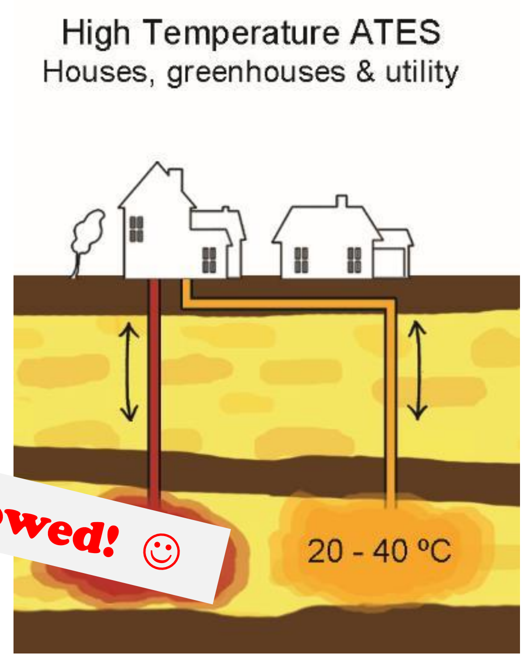
20 --- 100 ---------------------------------- 2000

Bloemendal, M. and N. Hartog (2018). "Analysis of the impact of storage conditions on the thermal recovery efficiency of low-temperature ATES systems." Geothermics 17(C): 306-319.

HT-ATES

- <25°C standard regulatory framework
- >25°C Permitted as pilot / research projects

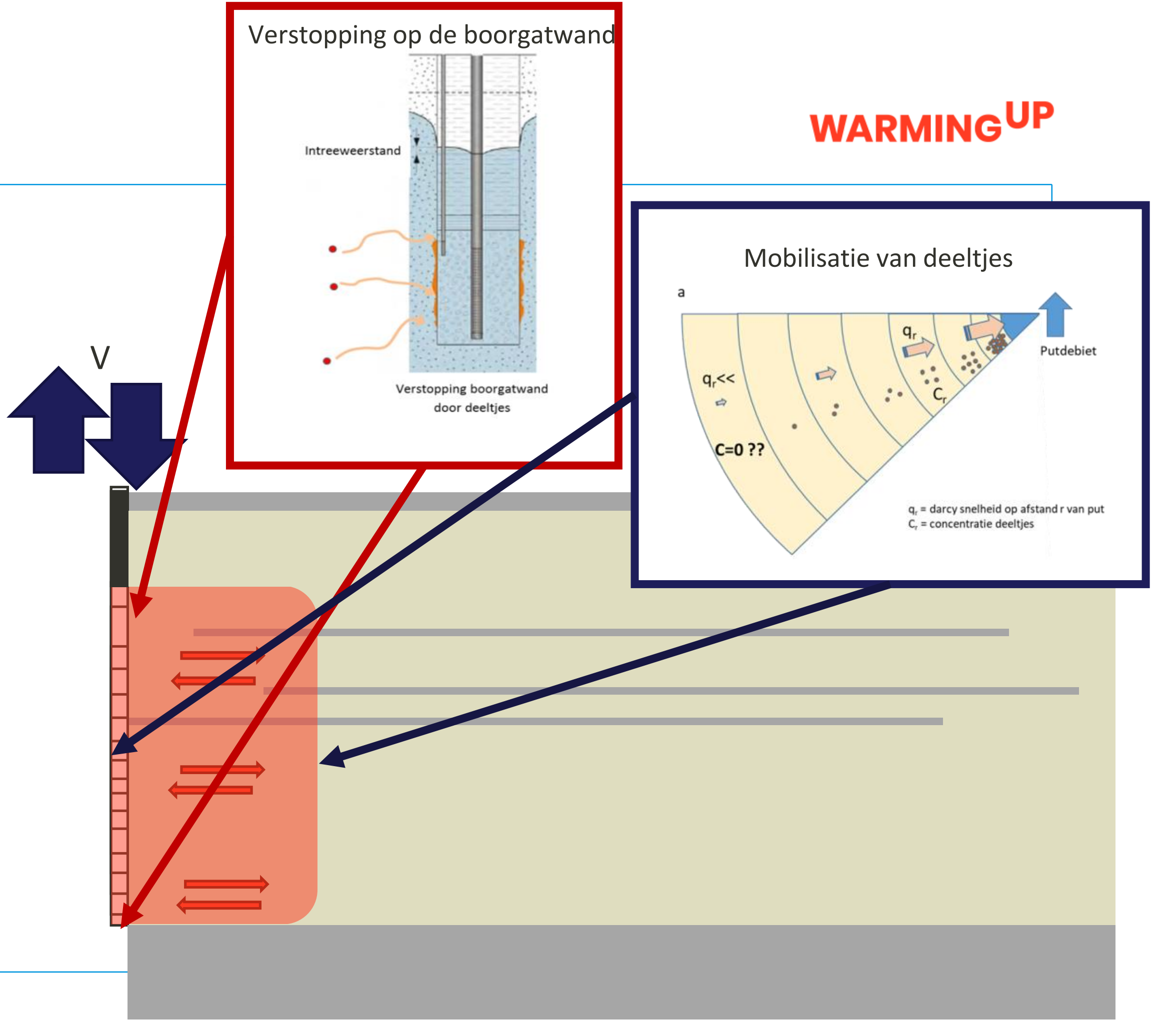




WARMING UP

Onderzoeksvragen

- Wat is de invloed van temperatuur op
  (1) mobilisatie van deeltjes en
  (2) verstopping van putten.
- Nevenvraag: Wat is de invloed van grotere diepte (druk, pakking) op de mobilisatie en verstopping?

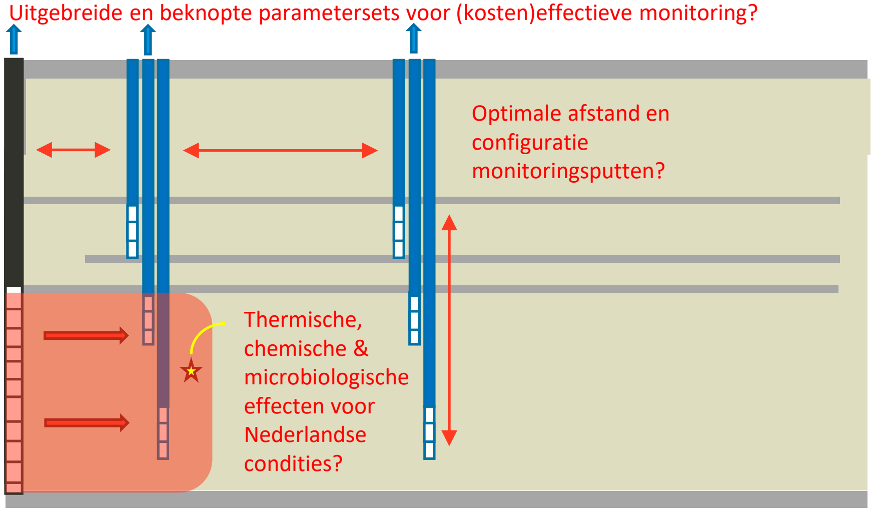


Milieueffecten en monitoring

WARMING UP

Onderzoeksvraag

- Wat zijn in de Nederlandse omstandigheden verwachtte thermische en chemische/ en microbiologische effecten?
- Waar en wat moet er gemonitord worden?



Minimaliseren van verliezen

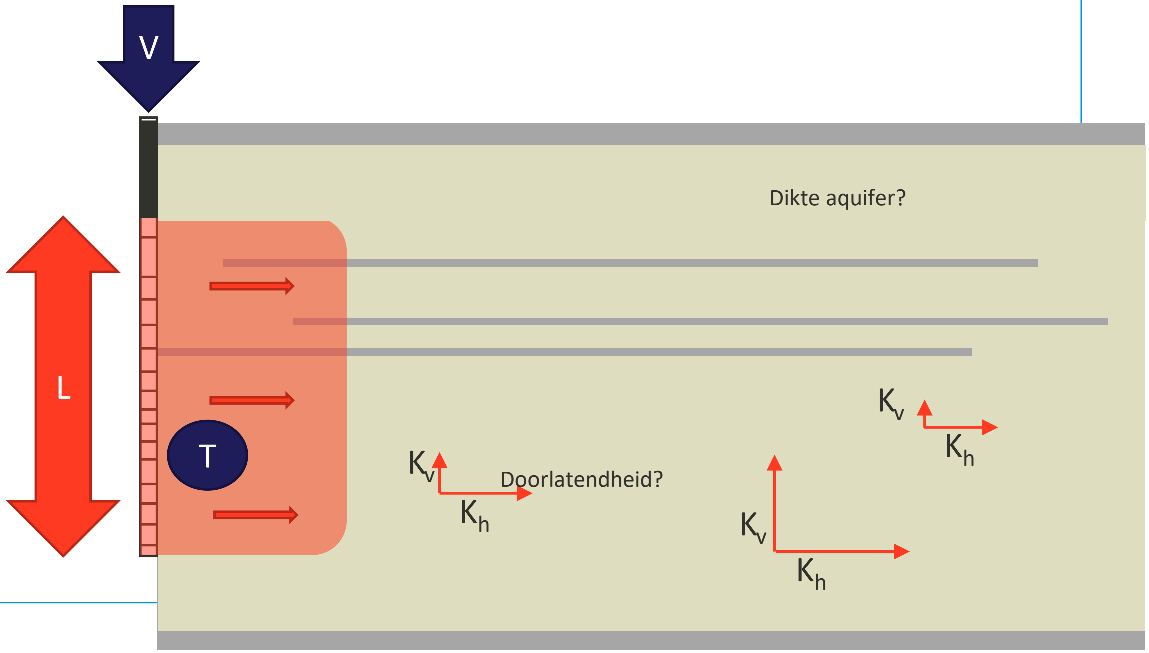
WARMINGUP

Opslagcondities

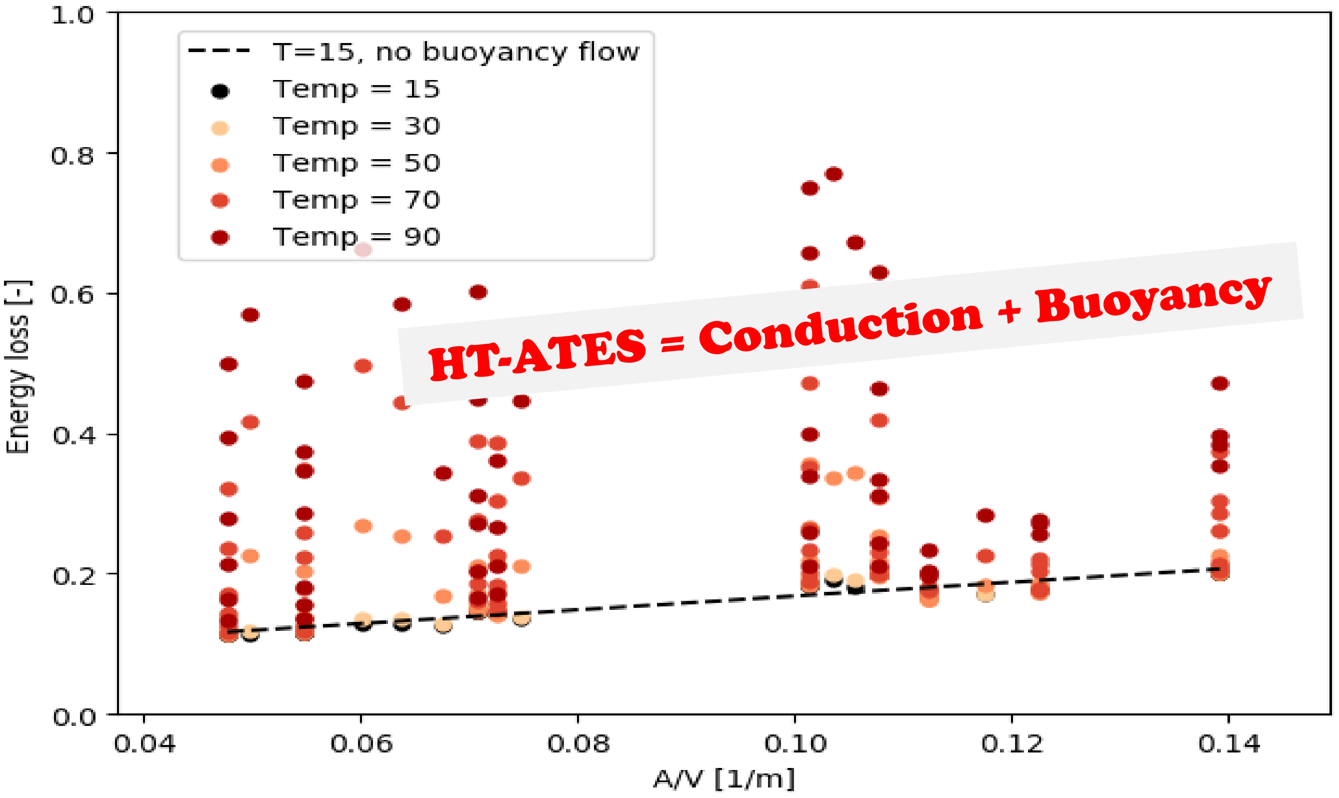
- Opslagvolume [V]
- Opslagtemperatuur [T]

Karakteristieken ondergrond

- Dikte aquifer [L]
- Doorlatendheid [K]
- Gelaagdheid
- Heterogeniteit



Buoyancy and conduction losses



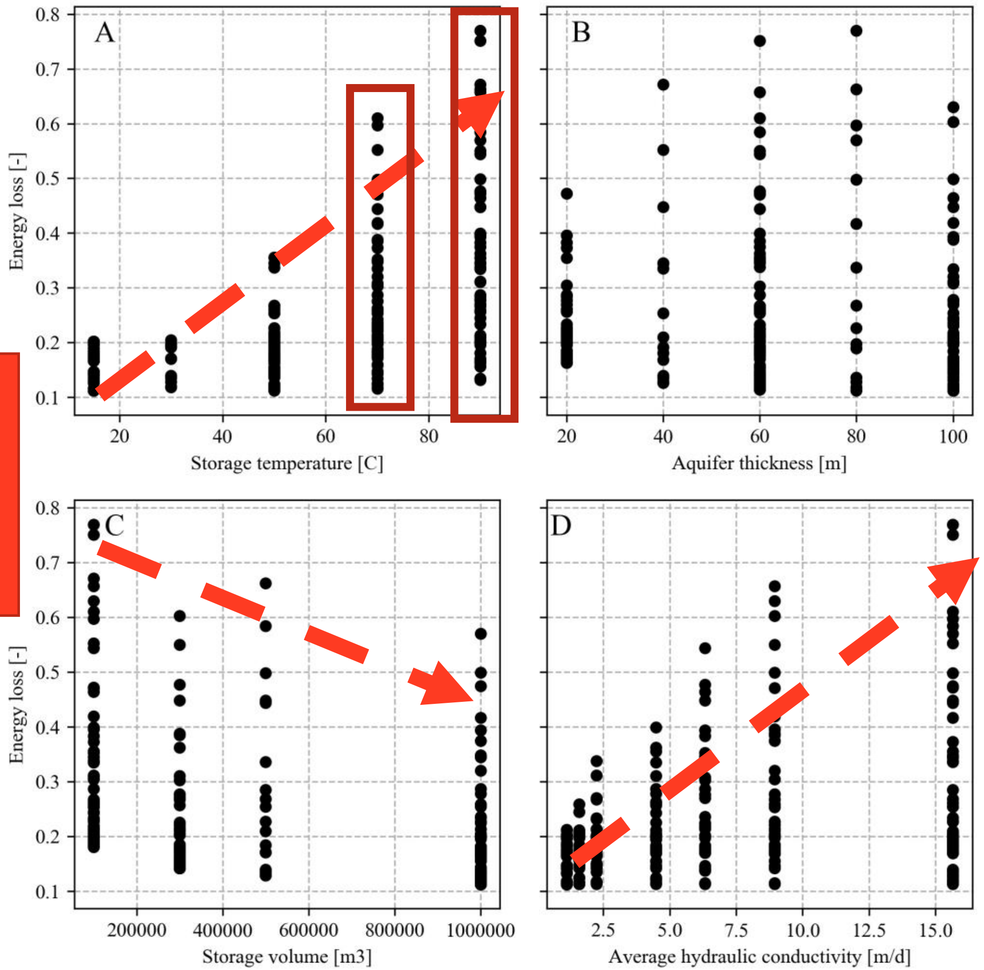
Minimaliseren van verliezen

Opslagcondities

- Opslagvolume [V]

Waarom is er een brede range aan energie verlies?

- Doorlatendheid [K]
- Gelaagdheid
- Heterogeniteit



Results

Heat demand and availability

- There is potential for HT-ATES to significantly contribute to the sustainable heat delivery to the TU Delft and City

Subsurface: 2 suitable layers

- *Maassluis -200m*
- *Ommelanden -400m*

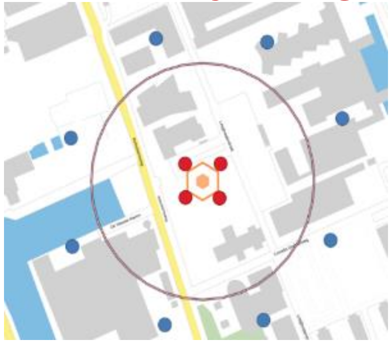
Policy & permits

- No showstoppers

Business Case

- Connect the city and HT-ATES with preference for the Maassluis formation

Preliminary design



0.7Mm^3,
4 hot wells, 6-8 warm wells

CO2 savings

~30%