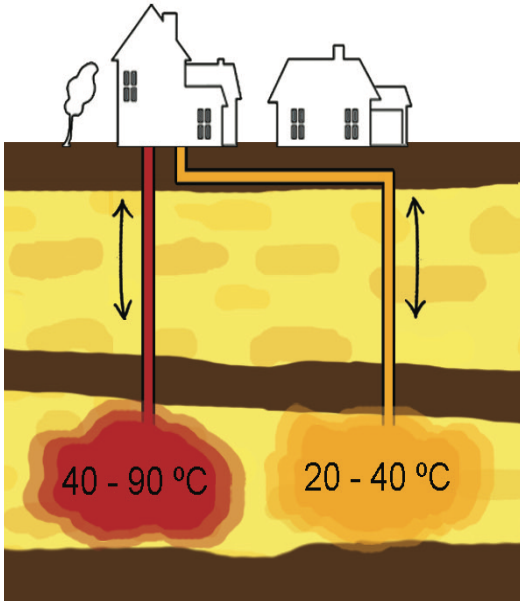
# Toepassingscondities en prestaties van HT-OBES (HTO): Van Potentie naar Realisatie

Dr.ir. M. Bloemendal
2022-05-19

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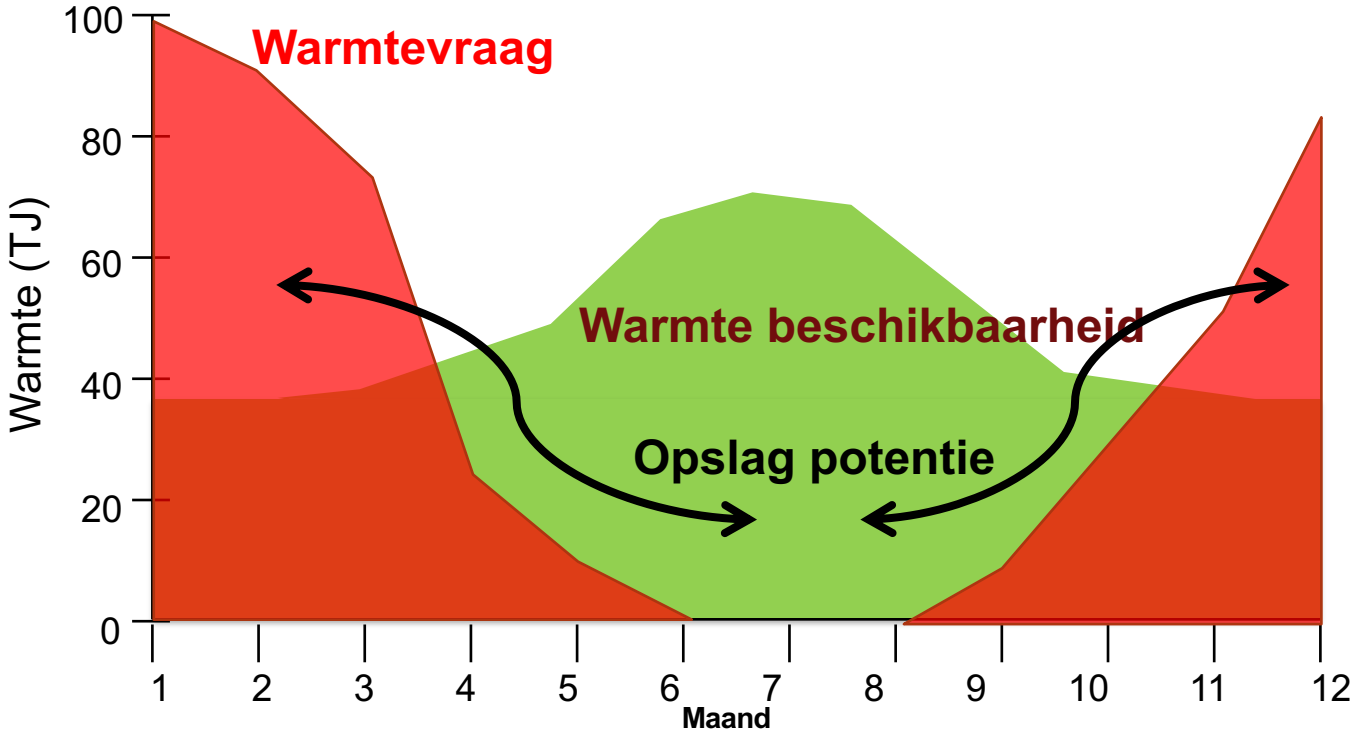
# De noodzaak voor opslag van warmte




*Warmtevraag in warmtenet op het noordelijk halfrond*

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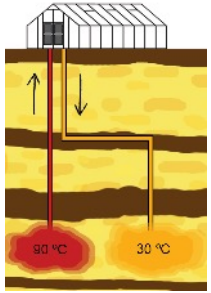
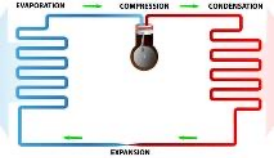
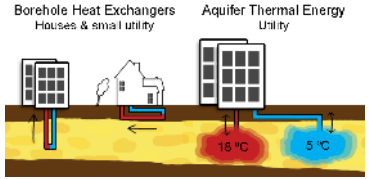
# HT-OBES is nodig in de energietransitie

- 8 000 000 gebouwen in NL (25% van totale energie gebruik) in 2050:
  - ~40% Warmtenetten




  - ~60% individuele/lokale oplossingen

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# Opties voor warmte opslag

## 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

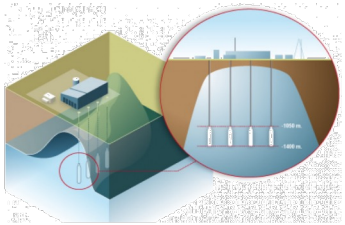
- High volumetric storage
- High efficiency

- Specific temp operation → Less flexible
- Expensive

# Voelbare warmte

Grootschalige warmte opslag → voelbare warmte

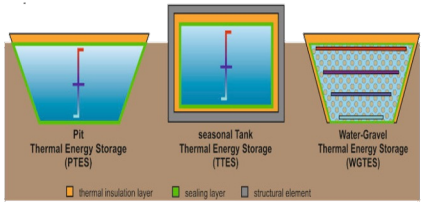
**MINES/ CAVERNS**



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

- Availability is limited
- Losses can be high

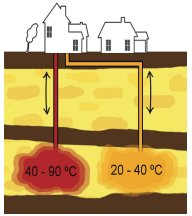
**TANKS/PITS**




- Offers good insulation and flexibility

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

**Aquifers**

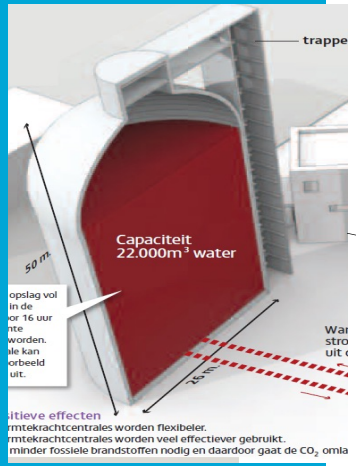


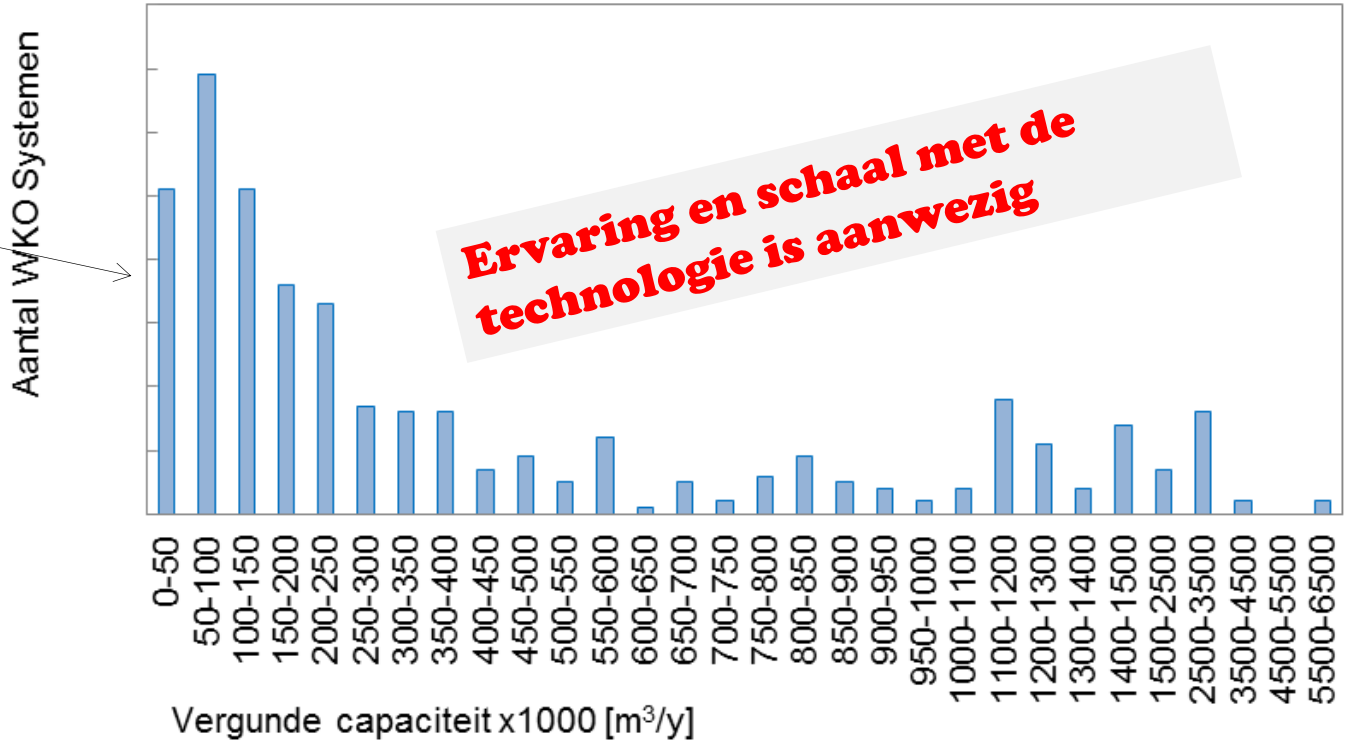

- No space requirement above ground
- Large capacities

- 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.



**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.

# WINDOW – Pilots

22 sites
quick-scan

→

7 sites
Haalbaarheid

→

2-4 sites
Voorontwerp +
proefboring

→

2-4 sites
demo project

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

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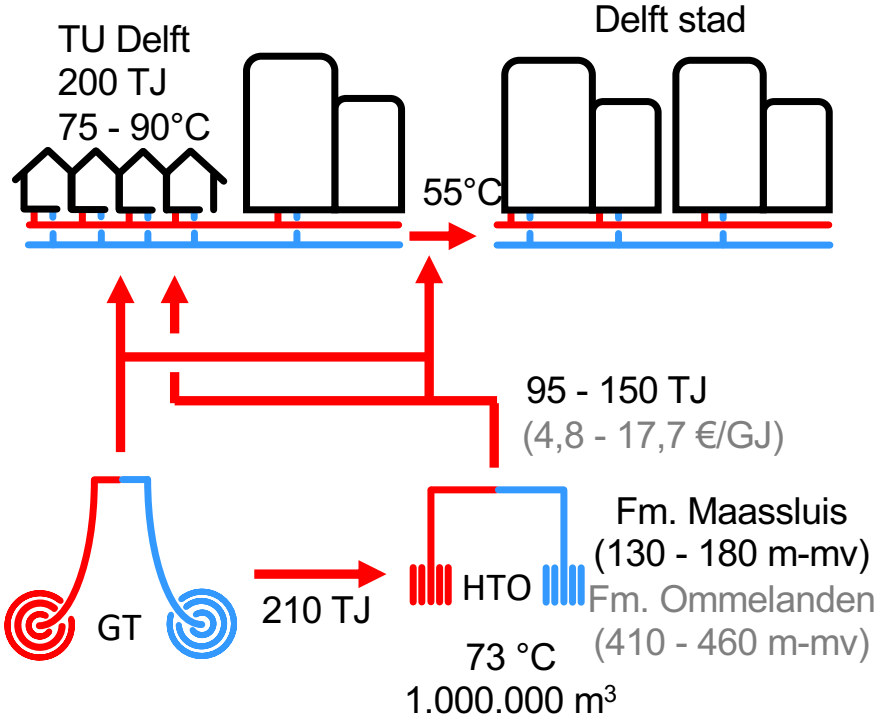
# Selectiecriteria

- Business Case
- Juridische haalbaarheid
- Risico's: technisch, geohydrologisch, milieu en veiligheid
- Commitment stakeholders
- Planning

| Case | BuCa | Juridisch | Risico's | Commit | Planning | Totaal |
|---|---|---|---|---|---|---|
| HAL | | | | | | |
| HHW | | | | No Go | | |
| HGN | | | | | | |
| LWD | | | | | | |
| NES | | | | | | |
| TIL | | No Go | | | | |
| TUD | | | | | | |

# Delft

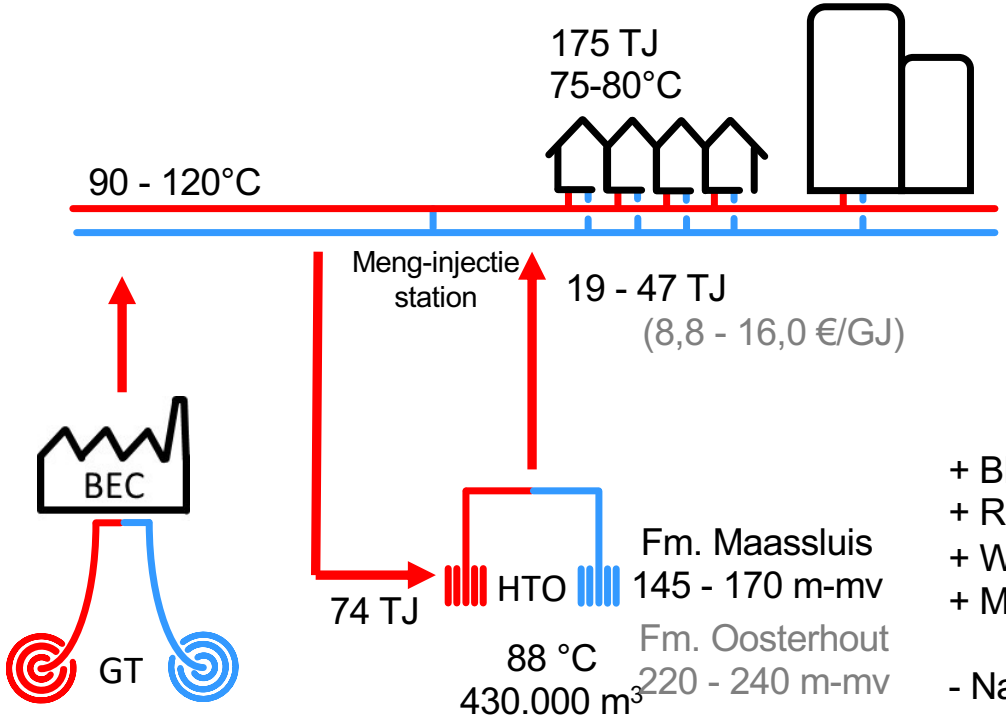



| Parameter | Eenheid | Waarde |
|---|---|---|
| CAPEX | M€ | 3,4 |
| OPEX | M€/a | 0,38 |
| Prijs warmte | €/GJ | 4,8 |
| Systeemrendement | % | 45 – 72 |

+ HTO op eigen terrein
+ Beoogde eindsituatie zeer groot (lage prijs warmte)
+ Betrokkenheid TU Delft onderzoek
+ Proefboring niet nodig

- Warmtenet(koppeling) nog in ontwikkeling
- Nog geen FID op geothermiebron

# Rotterdam - Nesselande




| Parameter | Eenheid | Waarde |
|---|---|---|
| CAPEX | M€ | 2,6 |
| OPEX | M€/a | 0,21 |
| Prijs warmte | €/GJ | 8,8 |
| Systeemrendement | % | 26 - 63 |
| $CO_2$ reductie | % | 85 |

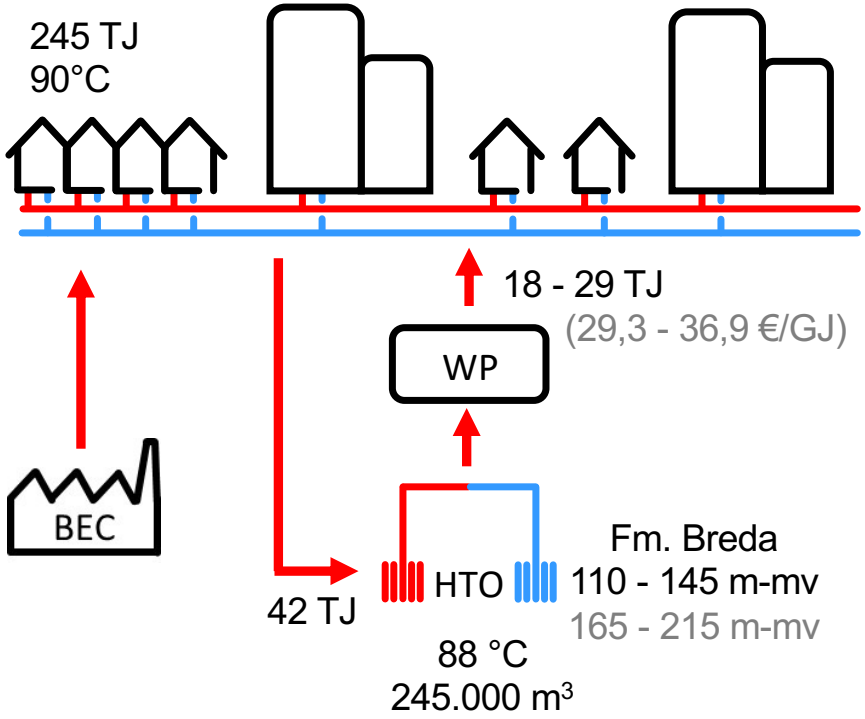
+ BEC (biomassa energie centrale) en warmtenet aanwezig
+ Relatief laag temperatuur warmtenet
+ Warmtepomp niet nodig door bijmengen
+ Mogelijk aanvullende geothermiebron in toekomst

- Nabijgelegen WKO-systeem

Deltares Enabling Delta Life TNO if KWR

WINDOW fase 1

# Sittard/Geleen – Het Groene Net



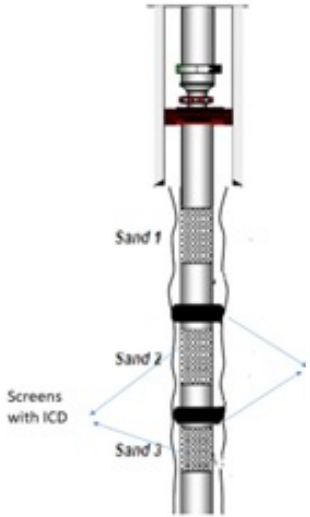

| Parameter | Eenheid | Waarde |
|---|---|---|
| CAPEX | M€ | 5,6 |
| OPEX | M€/a | 0,36 |
| Prijs warmte | €/GJ | 29,3 |
| Systeemrendement | % | 33 - 60 |
| $CO_2$ reductie | % | 65% |

+ Zowel bron als vraag reeds aanwezig
+ Groei vraag en bronnen in toekomst

- Opslag onder bruinkoollagen
- Omvang relatief klein
- Ennatuurlijk voorkeur voor andere locatie (Leeuwarden)

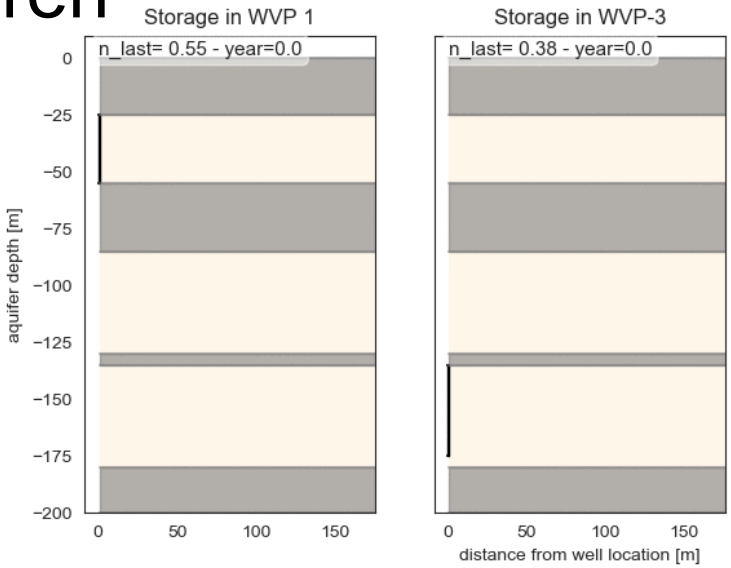
Deltares TNO if KWR

WINDOW fase 1




# Lopend onderzoek voor Stabiel en robuste werking HTO

1. Bronontwerp en afwerking
2. Monitoring & Control
3. Verliezen minimaliseren
4. Model optimalisatie
5. Beleid

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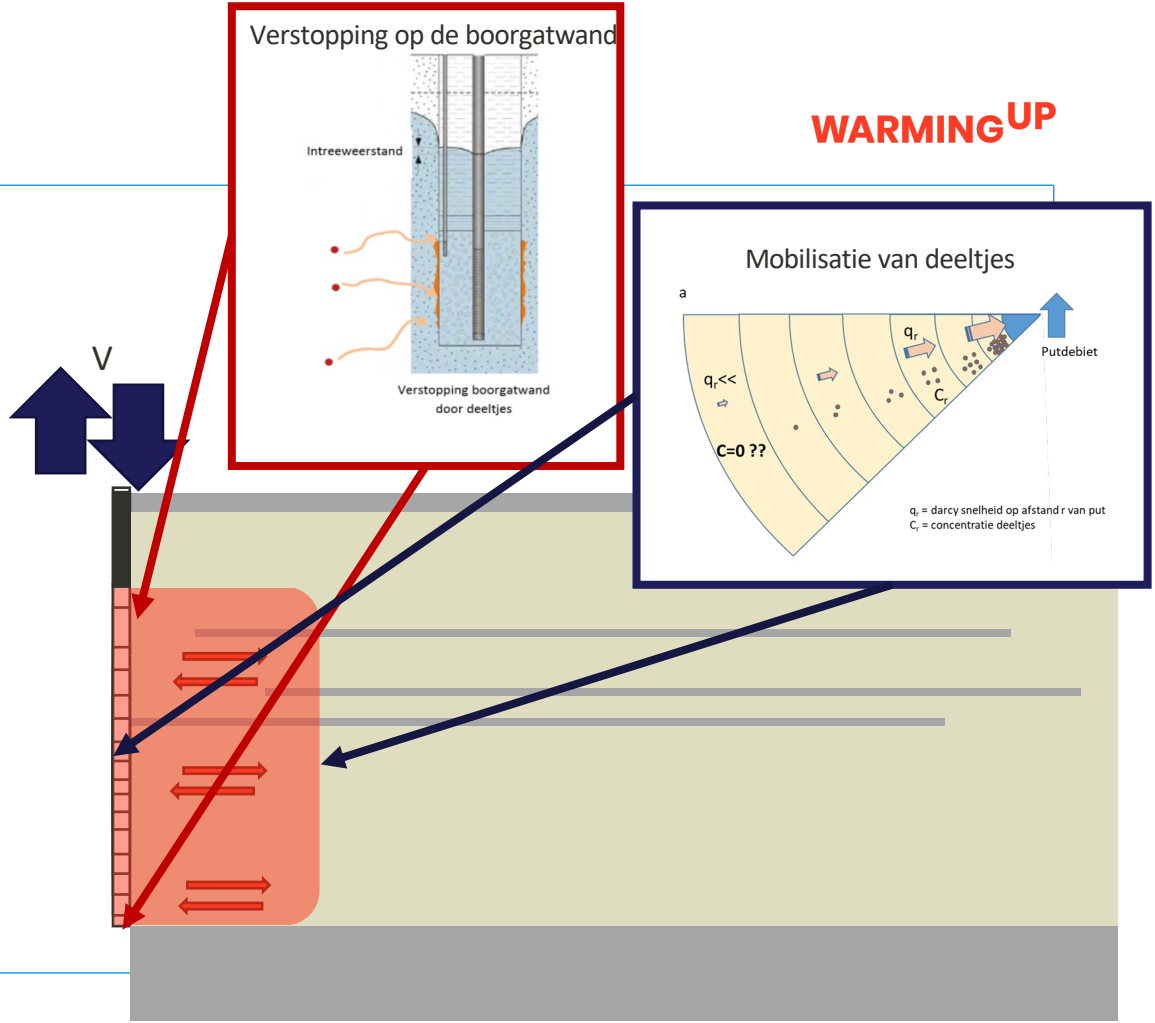
# Brontechniek

WARMINGUP

## 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?

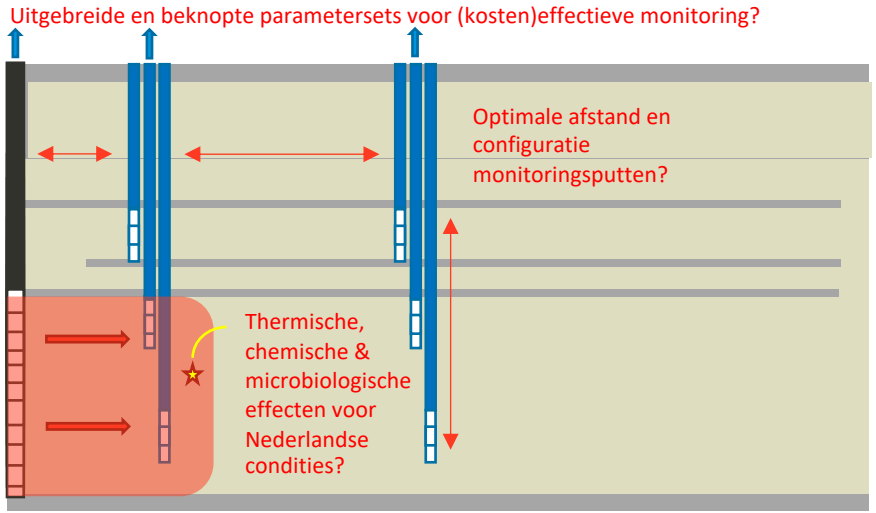


# Milieueffecten en monitoring

WARMINGUP

## Onderzoeksvraag

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



# Minimaliseren van verliezen

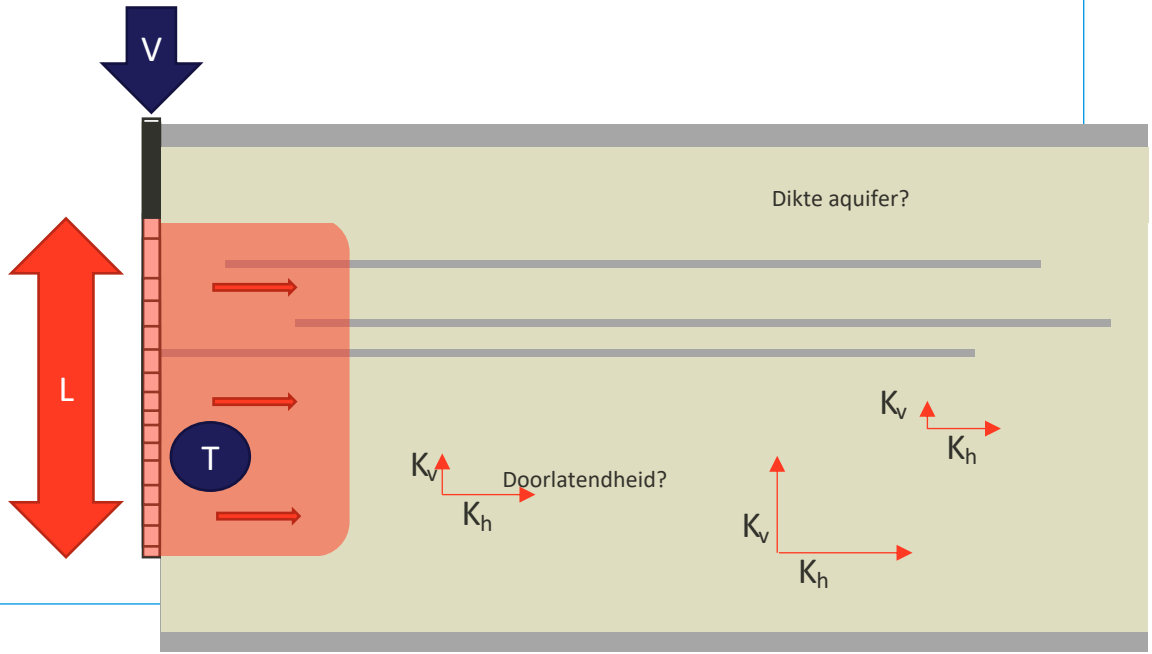
WARMINGUP

## Opslagcondities

- Opslagvolume [V]
- Opslagtemperatuur [T]

## Karakteristieken ondergrond

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



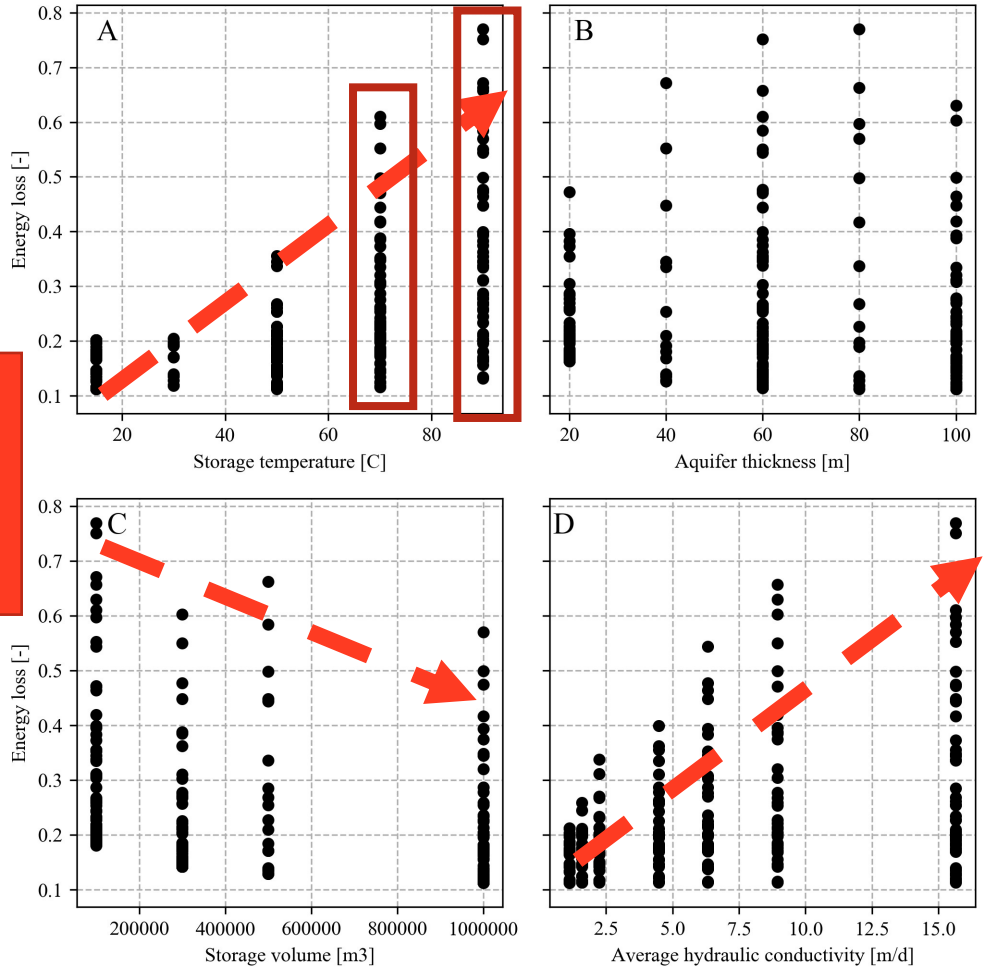
# Minimaliseren van verliezen

Opslagcondities

- Opslagvolume [V]

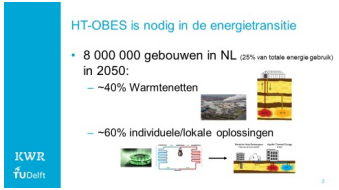
**Waarom is er een brede range aan energie verlies?**

- Doorlatendheid [K]
- Gelaagdheid
- Heterogeniteit

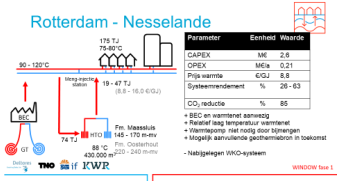


# Take home

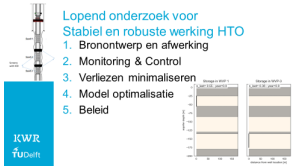
- Grootschalige seizoensopslag van warmte is nodig → HT-OBES

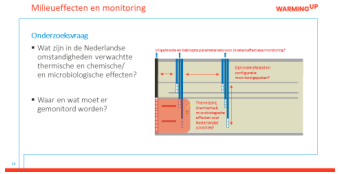


- Toepassingscondities en integratie verschillen sterk




- Via fundamenteel onderzoek i.c.m. pilots en demo's naar stabiele en robuuste HT-OBES

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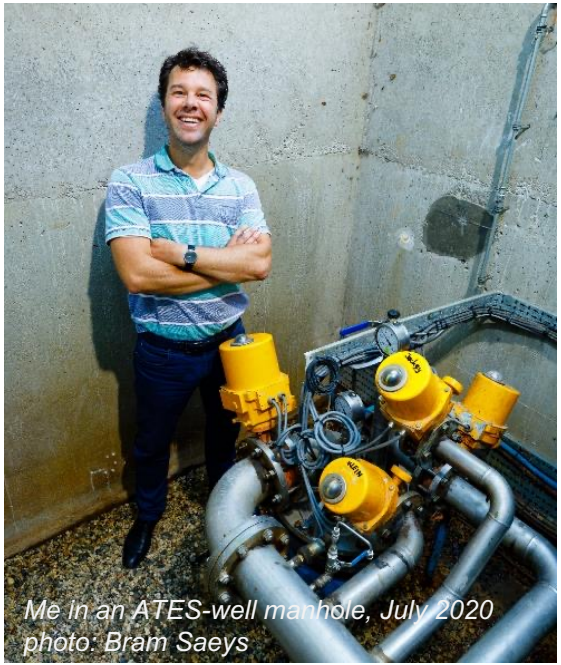
# Toepassingscondities en prestaties van HT-OBES (HTO): Van Potentie naar Realisatie

Dr.ir. M. Bloemendal
2022-05-19
j.m.bloemendal@tudelft.nl

Verder kijken/lezen:
https://www.ebn.nl/week-van-de-ondergrondse-energieopslag/
www.warmingUp.info
https://www.warmingup.info/actueel/59/warmingup-webinar-13-april-2021


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

Contributions from:
Niels Hartog
Stijn Beernink
Gilian Schout
Jan van Lopik

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# Project A: “Learning by doing” van verkenning tot demonstratieproject

**2019**

Ondergrondse warmteopslag beperkt toegepast

**A1. Fase 1 (TKI’s) Verkenningen**

Doel: Verkenning toepassingsconditie s en voo ntwerp

2020

**A2+A3. Fase 2 (WarmingUP) Nader onderzoek en voorbereiding demo’s**

Doel:
Minimaliseren projectrisico’s
Uitwerking ontwerp en opzet monitoring Voorbereiding besluitvorming demo’s

2022

**A4. Fase 3 (DEI/…) Demonstratie projecten**

- Aanleg, exploitatie
- Evaluatie

Doel: Belangrijkste lessen vóór 2025 geleerd.

**2025**

Ondergrondse warmteopslag bewezen techniek

## B Generiek onderzoek Potentie & inpassing

**B1. Systeemconcept en en -integratie**
- Keuze technieken
- Financiële kaders
- Rol in energietransitie

Temperatuurniveau s

**B2. Potentieel en toepassingscondities**
- Ondergrond
- Potentieel kaarten
- ThermoGIS-HTO

**B3. Koppeling warmtenetten**
- Koppeling in warmtenetten
- Regelstrategie
- Modellering WANDA

## C Generiek onderzoek Techniek & effecten

**C1. Brontechniek**
- Bronconstructie
- Waterbehandeling
- Materialen, filters
- Standaard uitwerking voor ontwerp, O&M

**C2. Geohydrologisch ontwerp**
- Ontwerpmethode
- Modellering
- Thermische effectbepaling

**C3. Milieueffecten en risico’s**
- Grondwaterkwaliteit
- Grondwaterbelangen
- Standaard monitoringsplan

**C4. Monitoringstechnieken**
- Kosteneffectieve meet-methoden temperatuur

## D Afwegingskader vergunningen

**Sociaal maatschappelijke inpassing**

**D1. Juridisch afwegingskader**
- Ontwikkeling afwegingskader ondergrondse warmteopslag

WARMINGUP
Innovatief Duurzaam Warmtecollectief

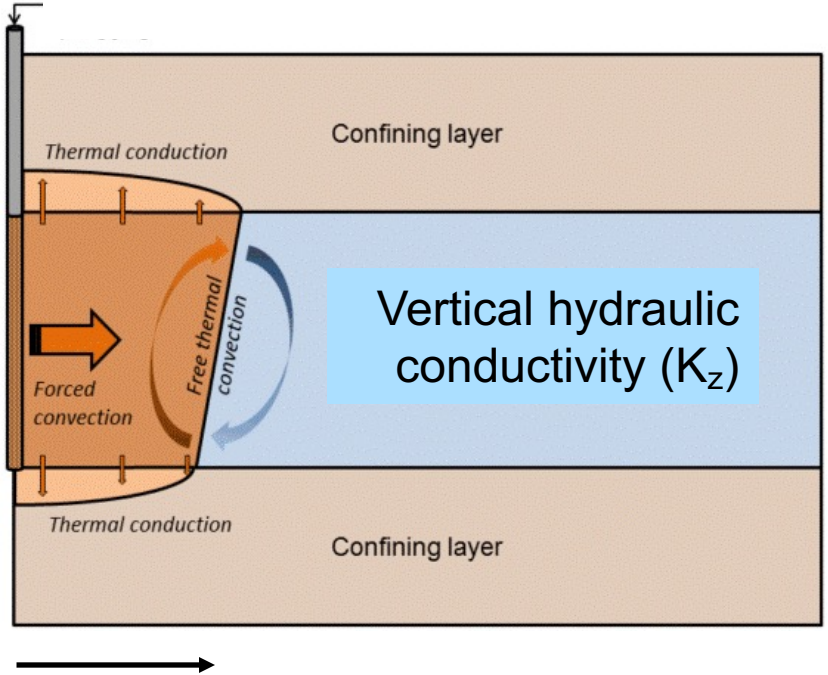
M Programma, organisatie en communicatie

# Exploratory simulations

## Identify optimal storage conditions

Storage temperature (T)

Screen length (L)




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

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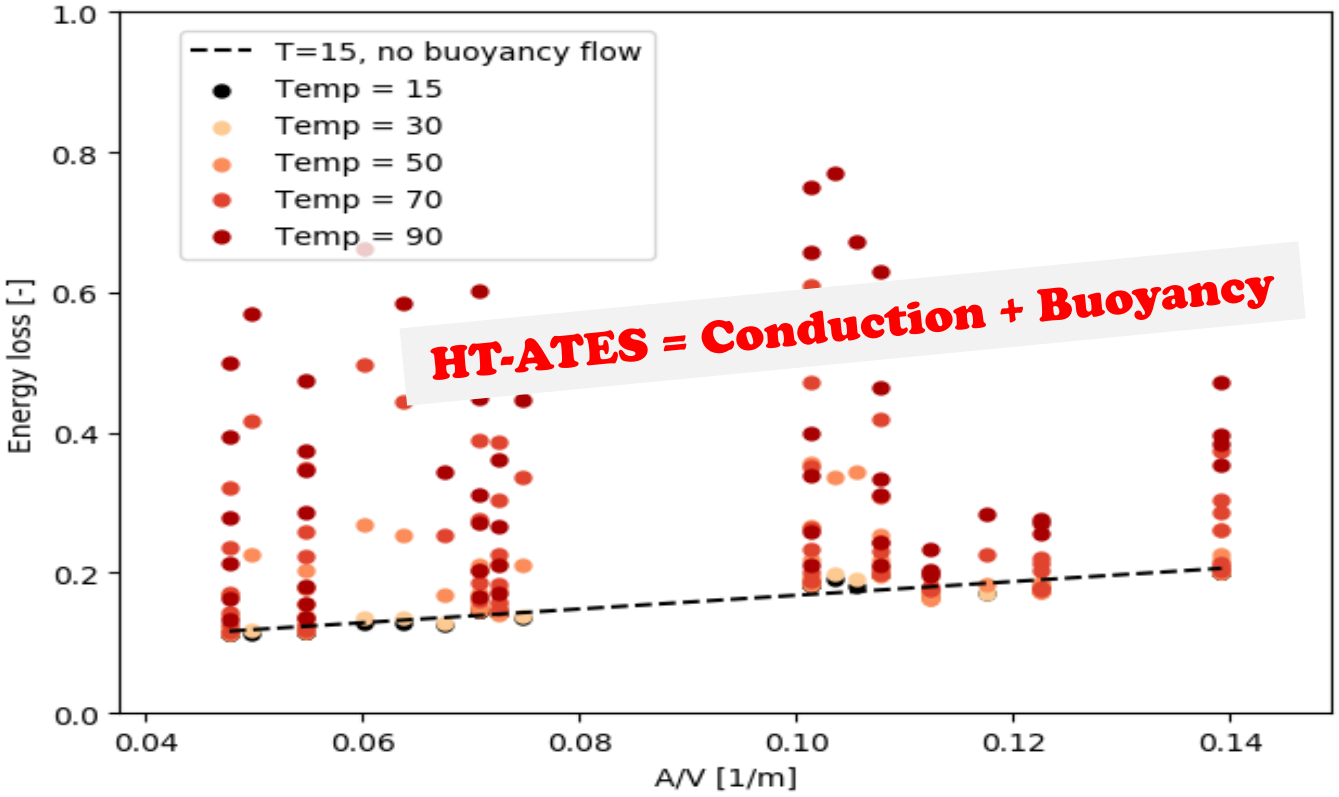
# Buoyancy and conduction losses

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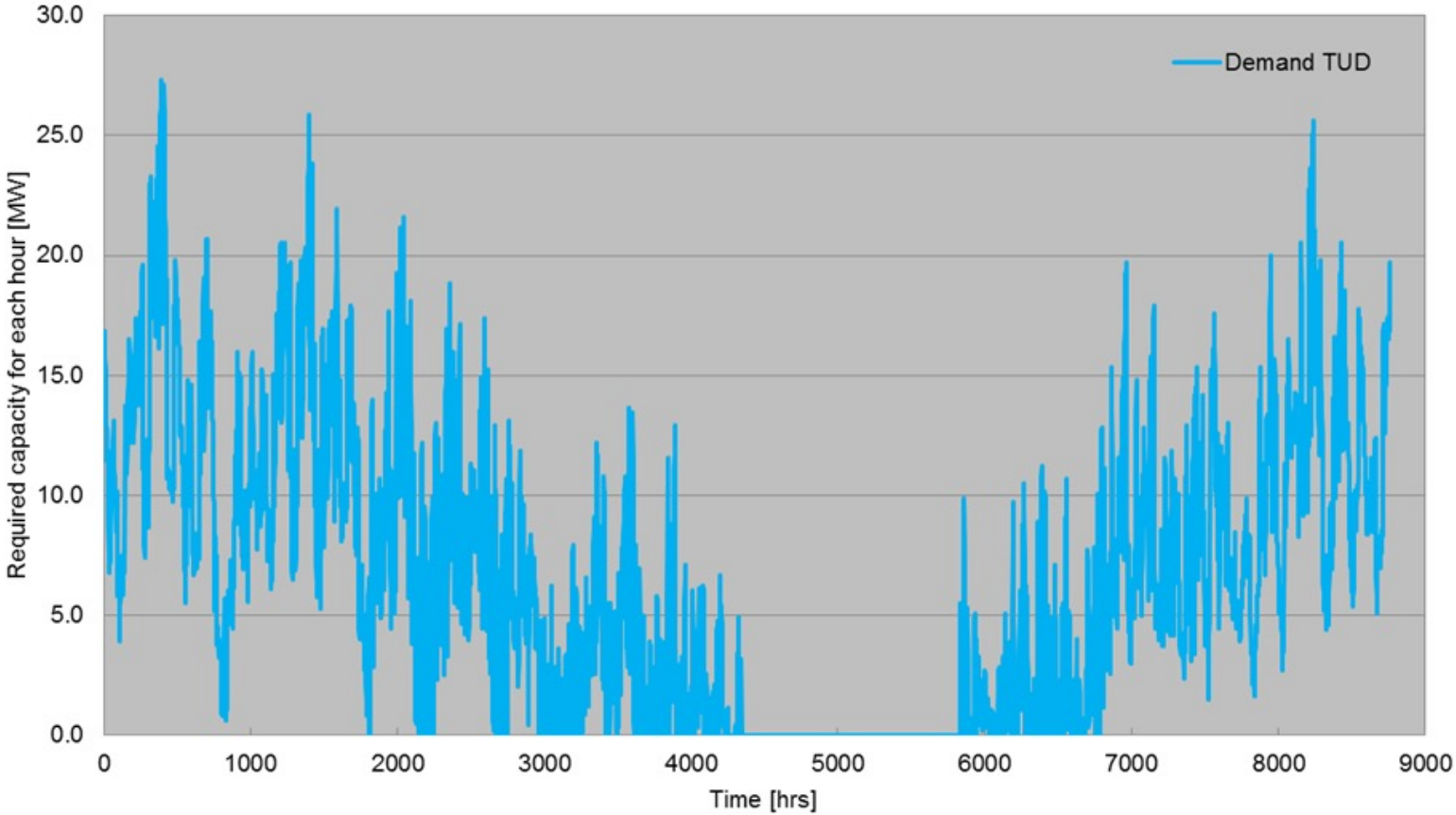
# Total demand = 200TJ

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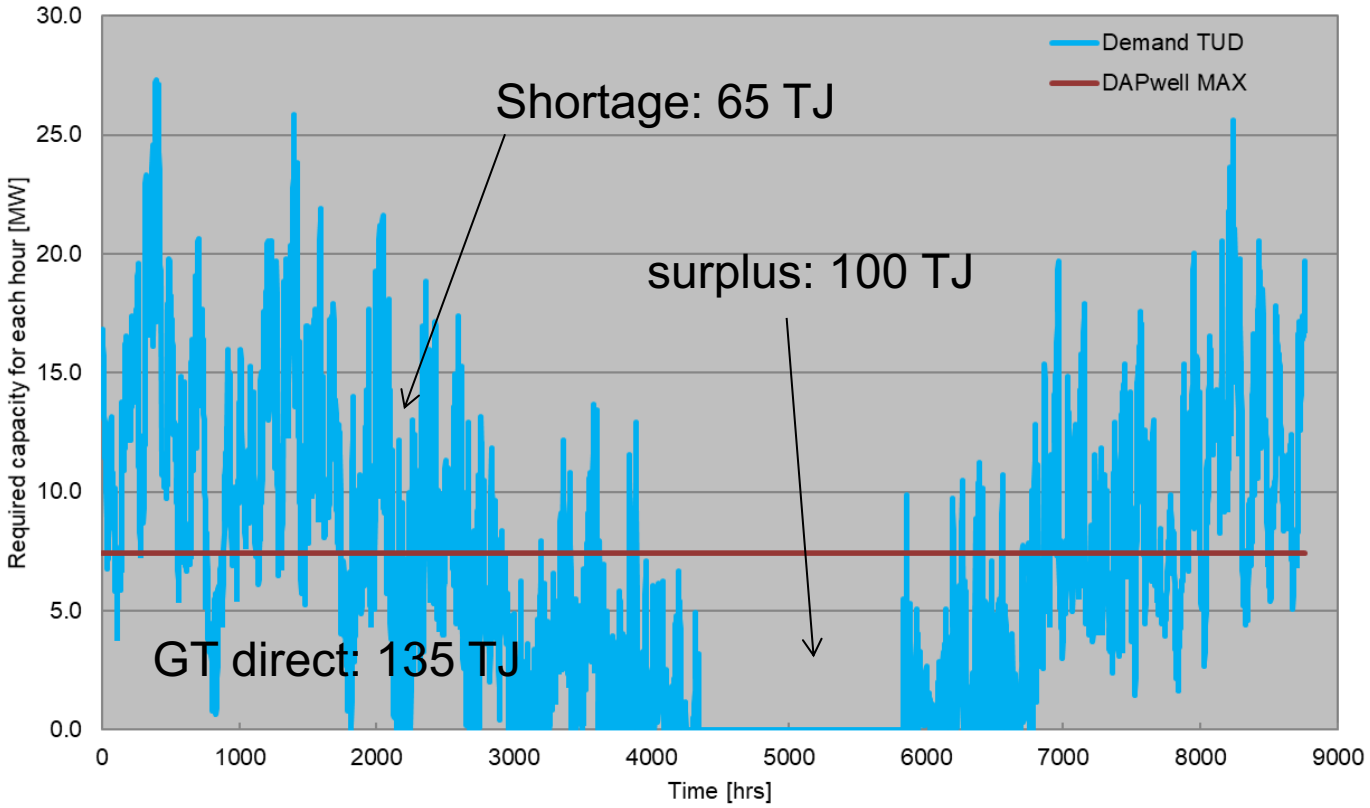
# Total production GT: 235 TJ

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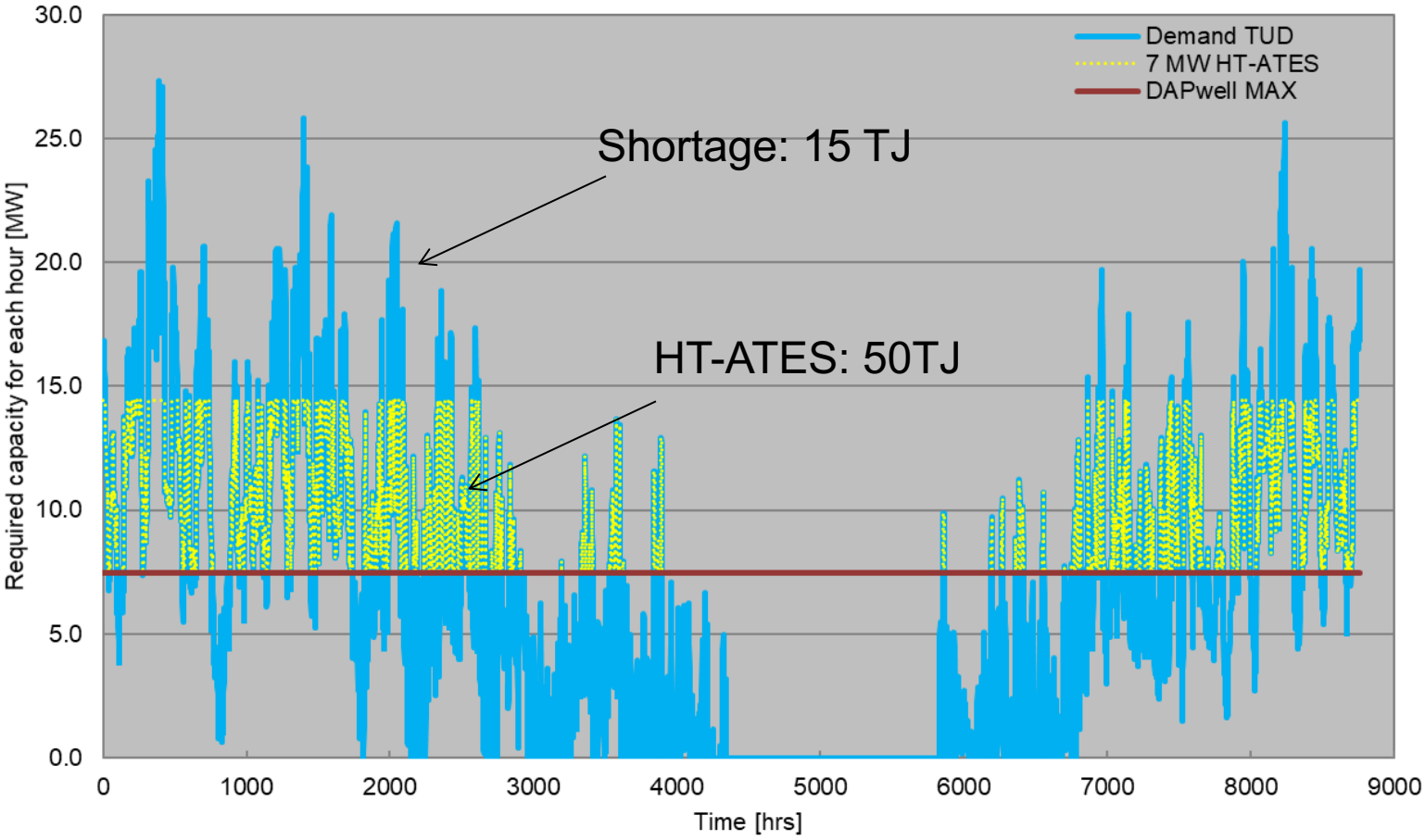
Demand TUD
7 MW HT-ATES
DAPwell MAX
Shortage: 15 TJ
HT-ATES: 50TJ
Required capacity for each hour [MW]
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
Time [hrs]

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# 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*

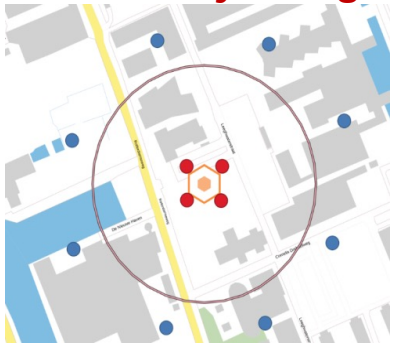
### *Policy & permits*

- 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%

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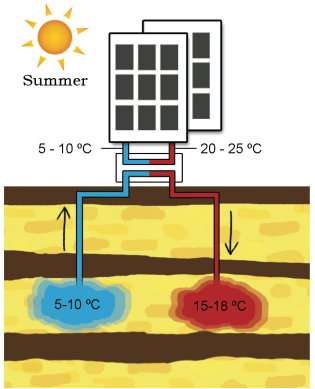
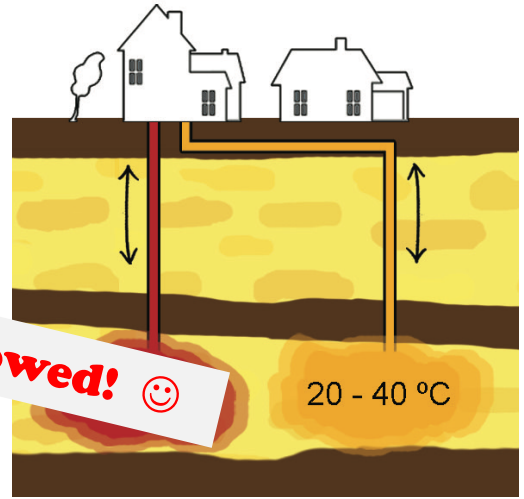
# HT-ATES

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




HT-ATES is allowed! ☺

High Temperature ATES
Houses, greenhouses & utility

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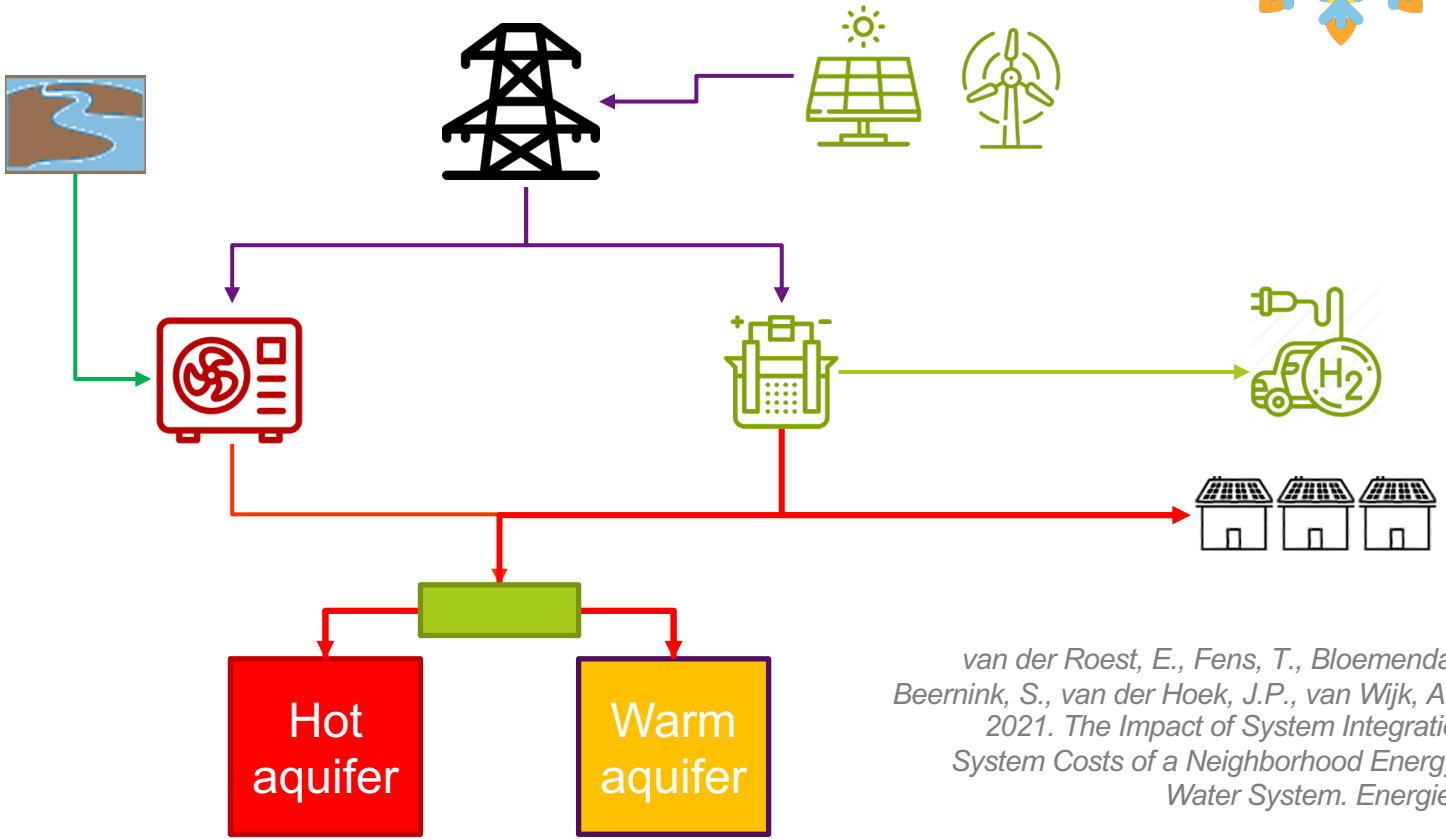
# Multi energy systems

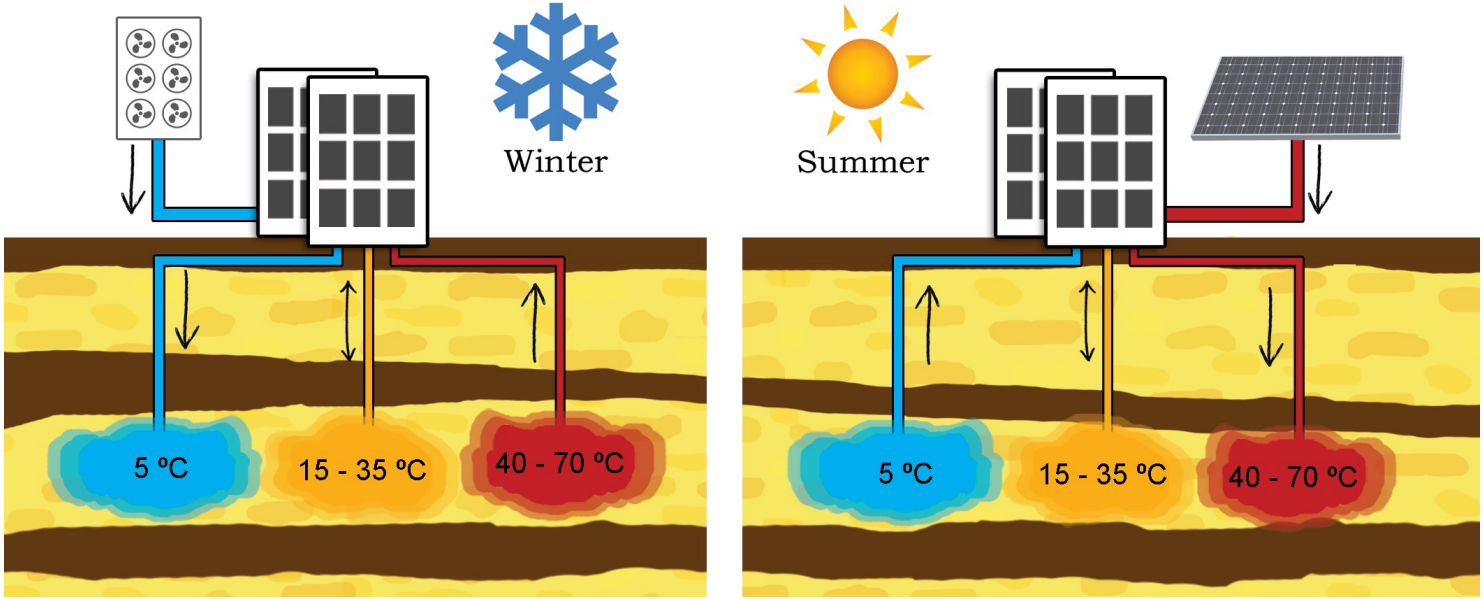



van der Roest, E., Fens, T., Bloemendal, M., Beernink, S., van der Hoek, J.P., van Wijk, A.J.M., 2021. The Impact of System Integration on System Costs of a Neighborhood Energy and Water System. Energies 14.

KWR

TU Delft

# ATES Triplet

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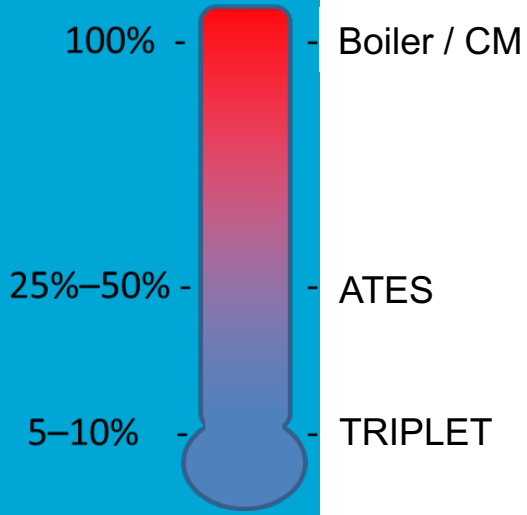
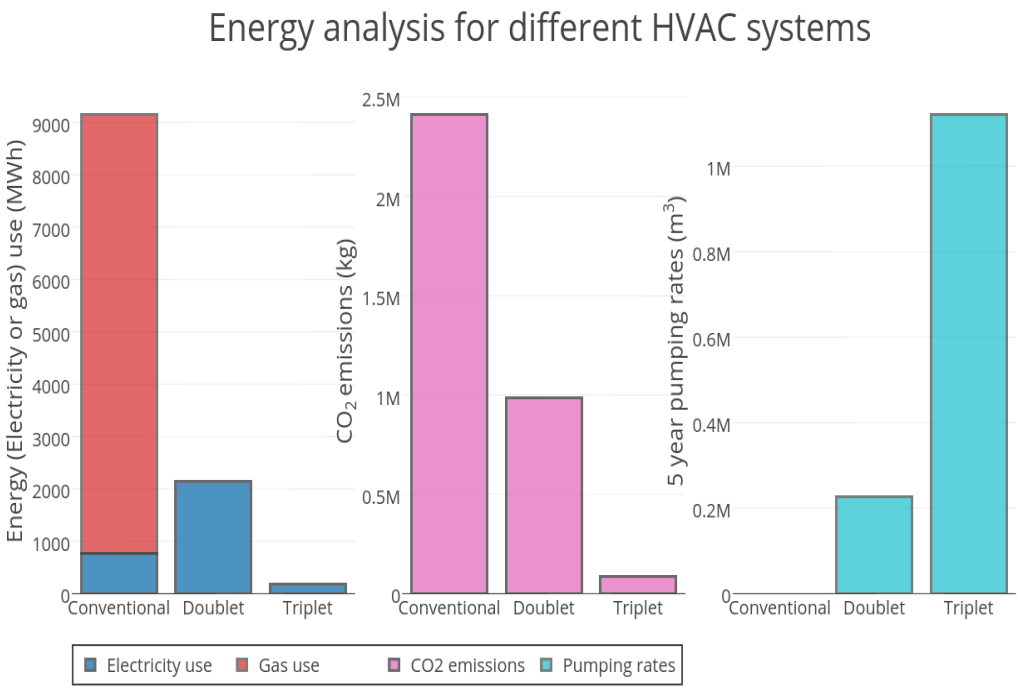
## Primary energy use




Bloemendal, J.M., Hartog, N., van Wijk, A. and Pape, J. (2018) Duurzaam Verwarmen met WKO zonder Warmtepomp — Triplet Systeem in Combinatie met Droge Koelers Maakt Gebruik van Hoge Temperatuur Opslag. VV+ Februari, 36-40.

# WINDOW

## Learning by doing

22 sites
quick-scan

→

7 sites
feasibilty study

→

2-4 sites
Full design,
pilot drilling

→

2-4 sites
demo projects

General research
- Technical potential
- Characteristics
- Optimisation and control, System integration
- Well design, materials
- Impact, Monitoring

Rules and regulation

if
Deltares
TNO innovation for life
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