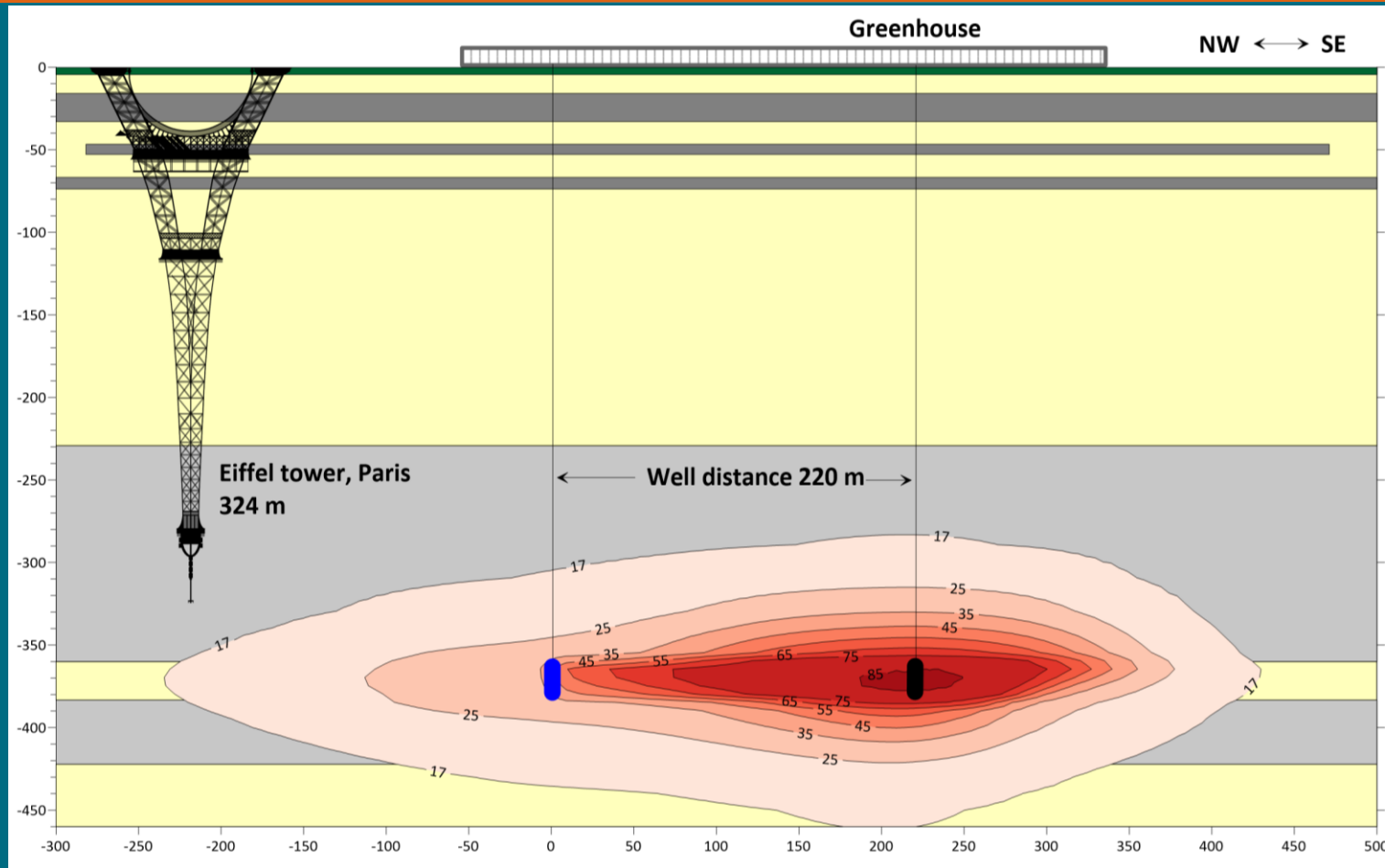
Performance of HT-ATES in practice

Lessons learned from 2 years of successful HT-ATES operation in Middenmeer, NL

Peter Oerlemans, GEOtherm 2024

1 March 2024



Content

- Why Heat Storage?
- Why Heat Storage with HT-ATES?
- HT-ATES system Middenmeer
  - System configuration
  - Monitoring setup
  - Results on performance & effects
- Outlook

IF Technology

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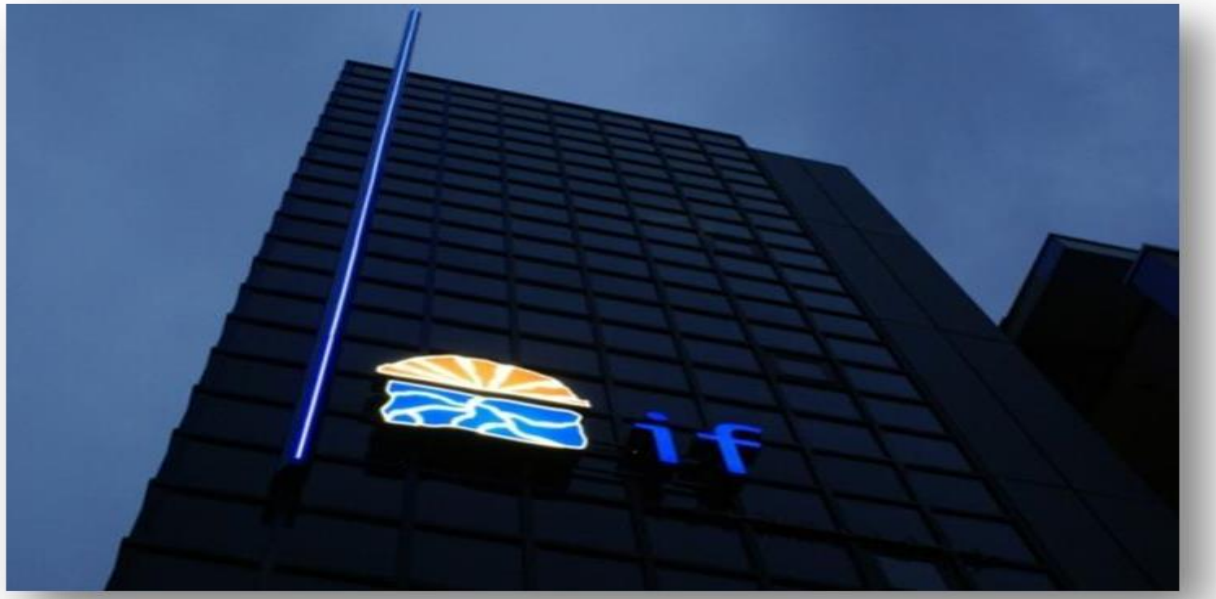
IF Technology

- ATES Consultancy and Engineering
- Total ATES spectrum: Feasibility – permitting – system design & realization – exploitation - monitoring
- >35 years experience in NL and abroad,
- > 3,000 projects
- 80 employees: energy consultants, (hydro)geologists, mechanical engineers, well engineers
- Arnhem, the Netherlands
- www.iftechnology.nl | www.iftechnology.com



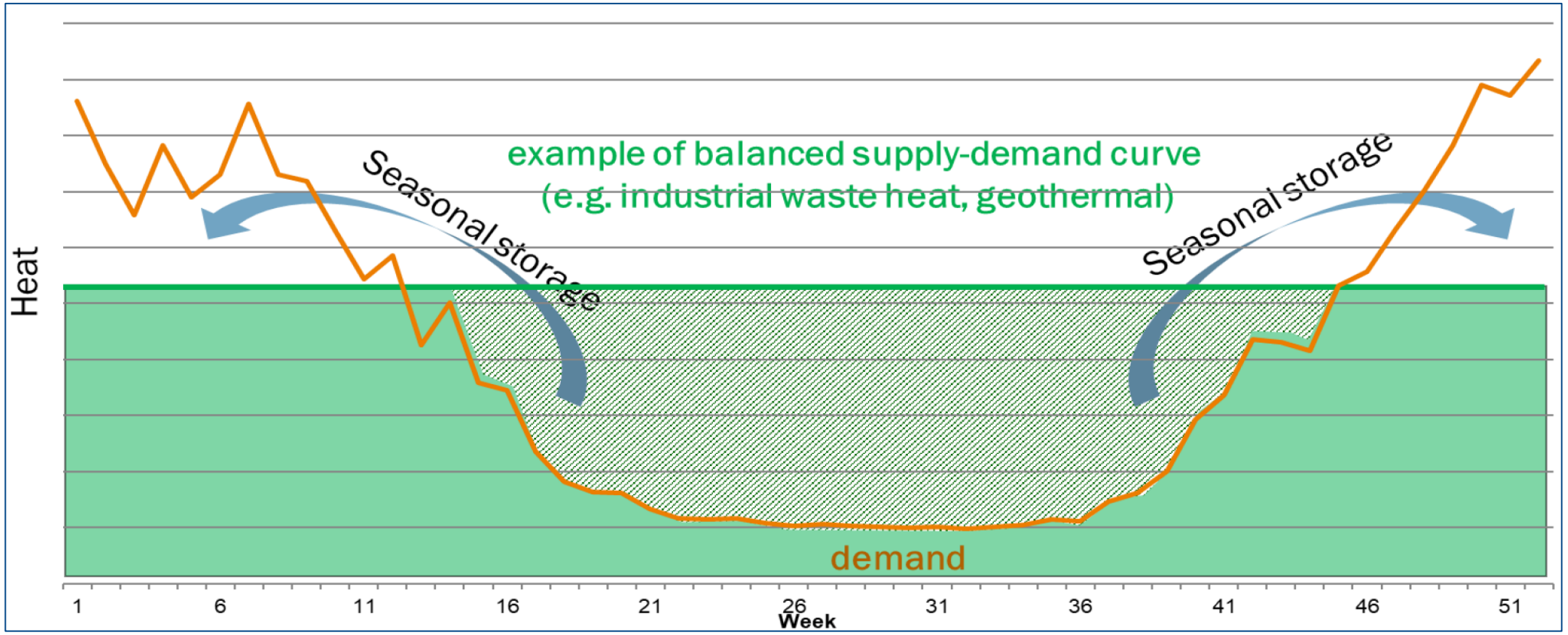
Why Thermal Energy Storage?

The Bathtub

Summer: **Heat surplus**

Winter: **Heat shortage**

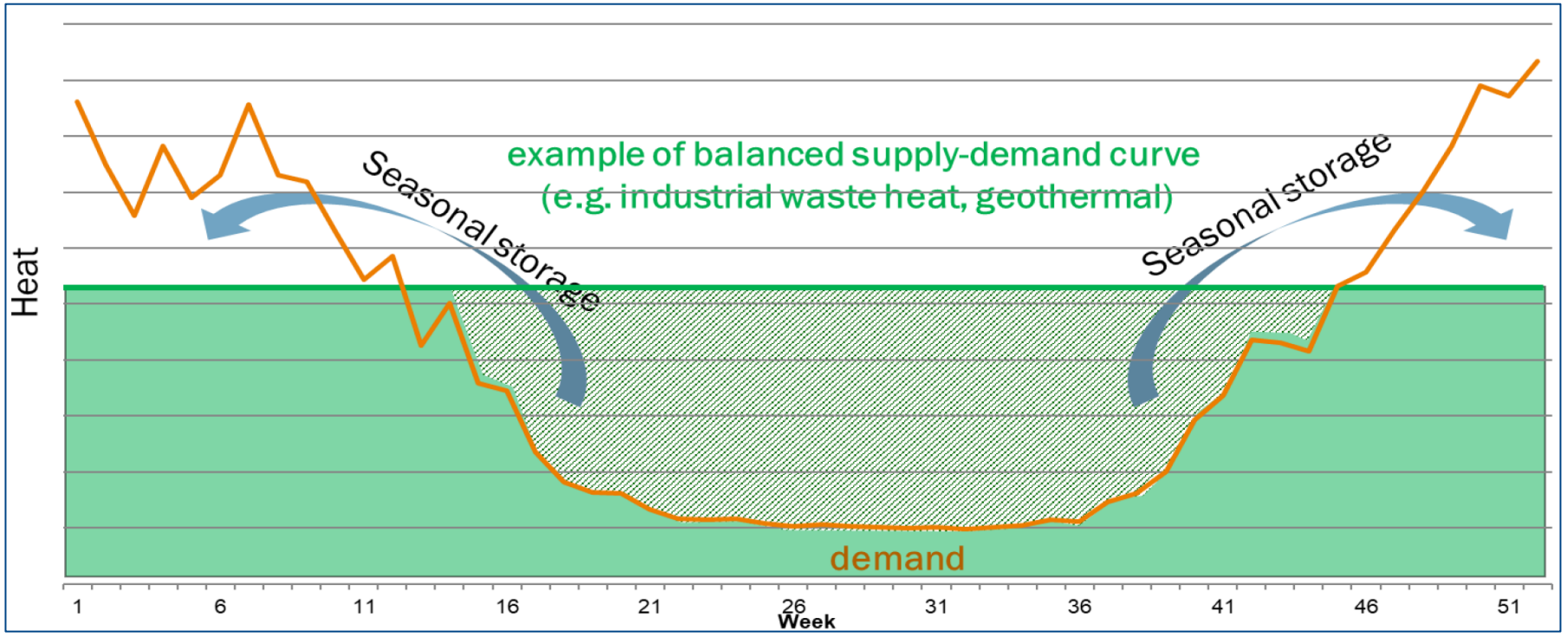
} **Solution = Heat Storage**



Why Thermal Energy Storage?

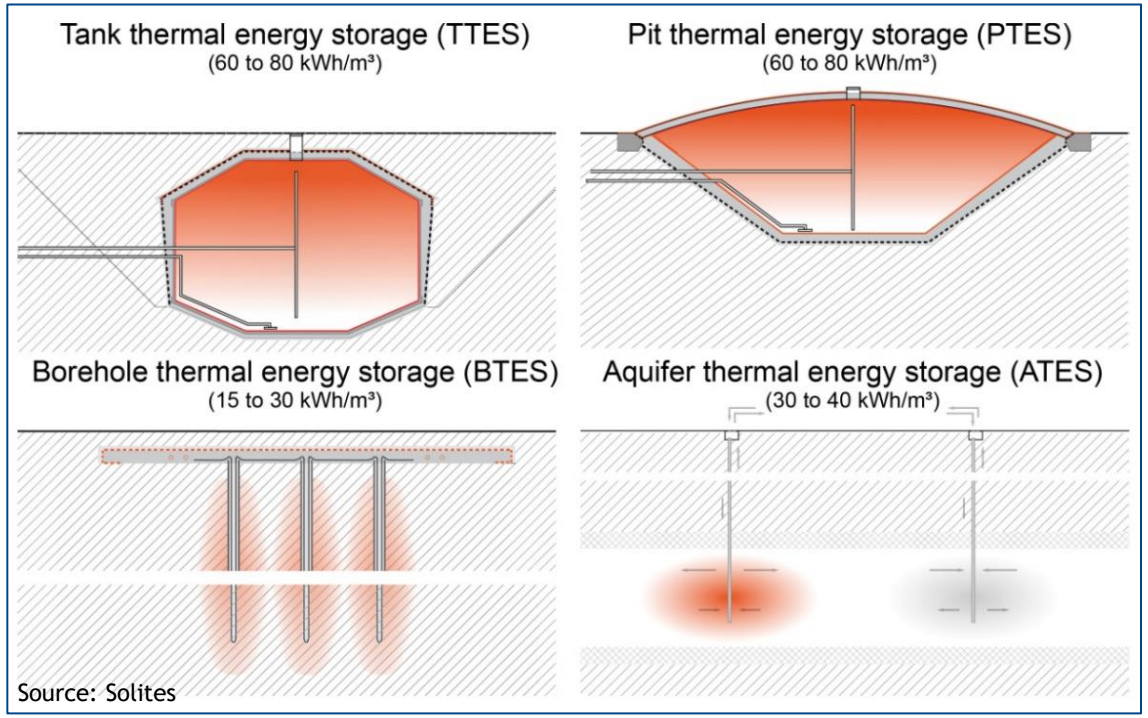
Advantages of Thermal Energy Storage

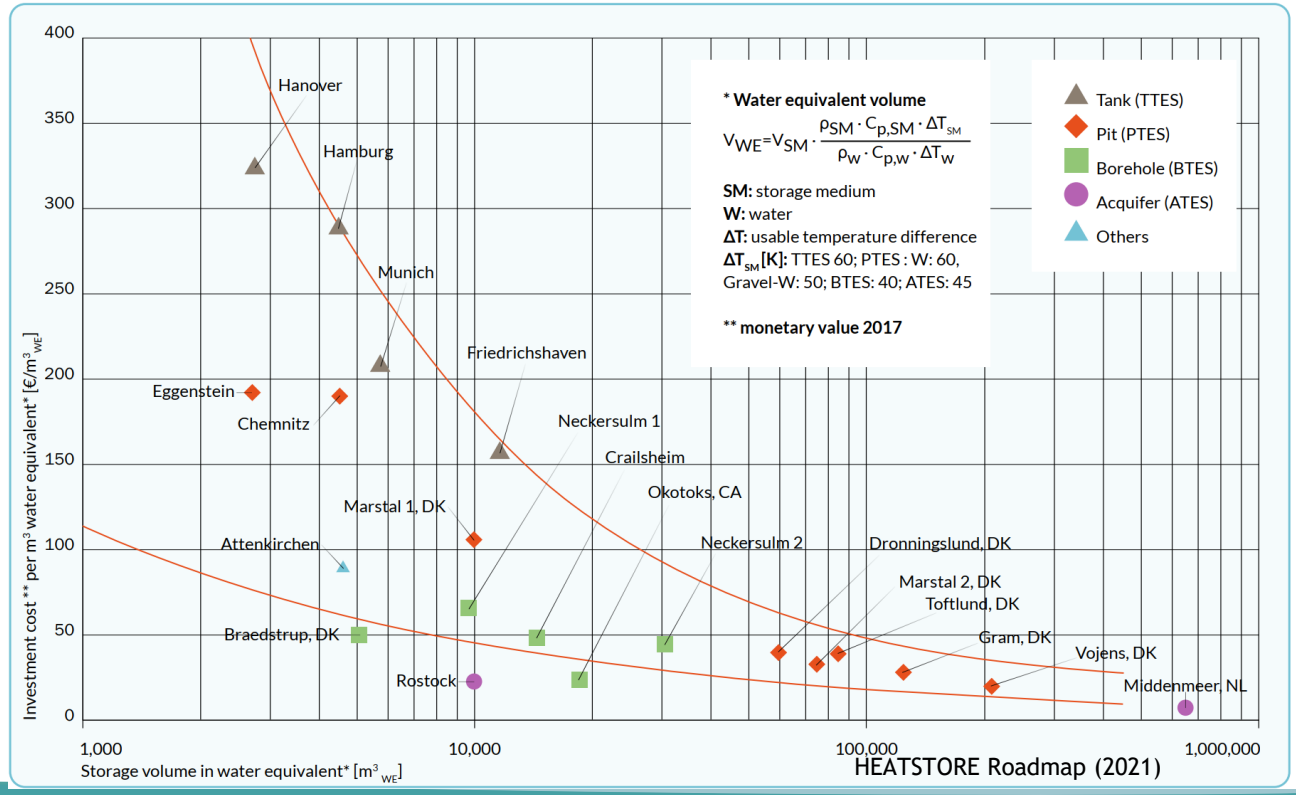
- Increased yields from sustainable heat sources (geothermal, solar, residual)
- Decreased use of fossil heat
- Enhanced flexibility
- Security of supply



Why Aquifer Thermal Energy Storage?

- Scale advantages (costs)

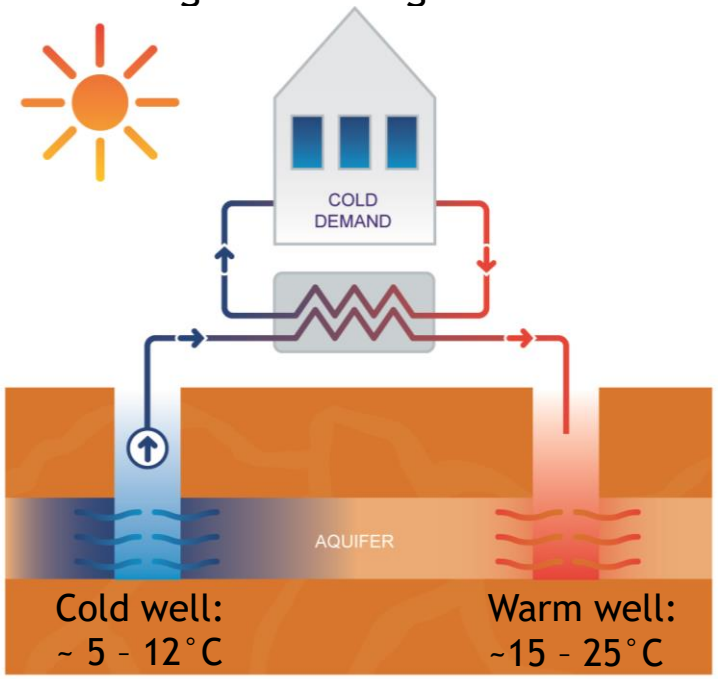




What is ATES? Aquifer Thermal Energy Storage

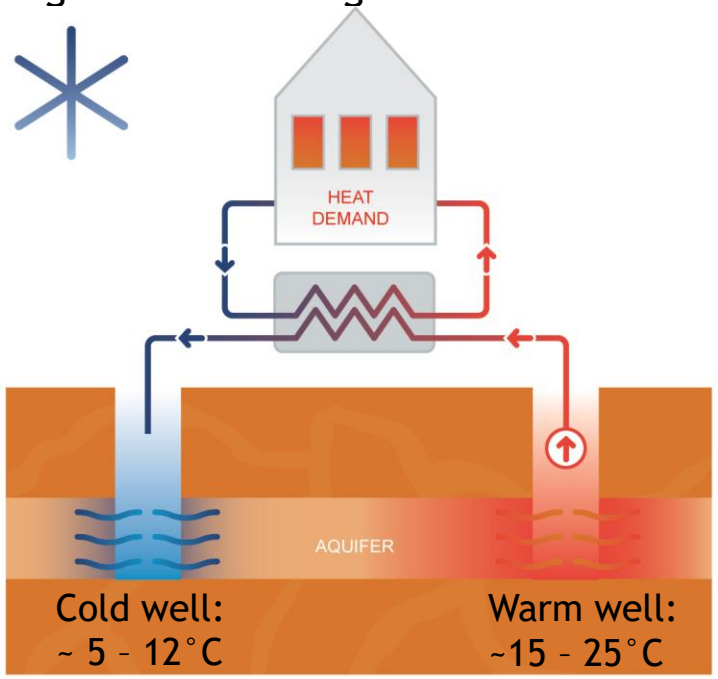
Summer

Effective cooling with cold groundwater

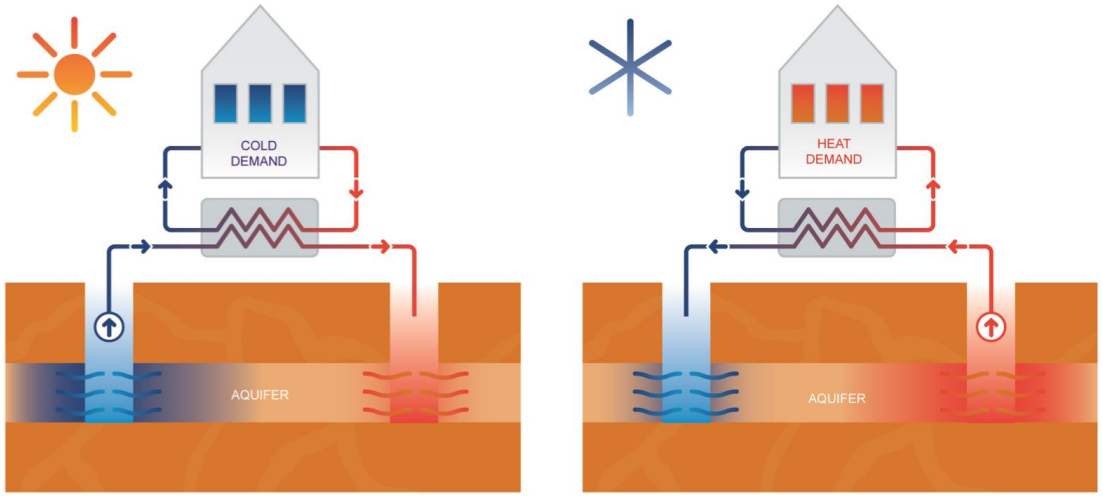


Winter

Heating with warmed groundwater + heat pump

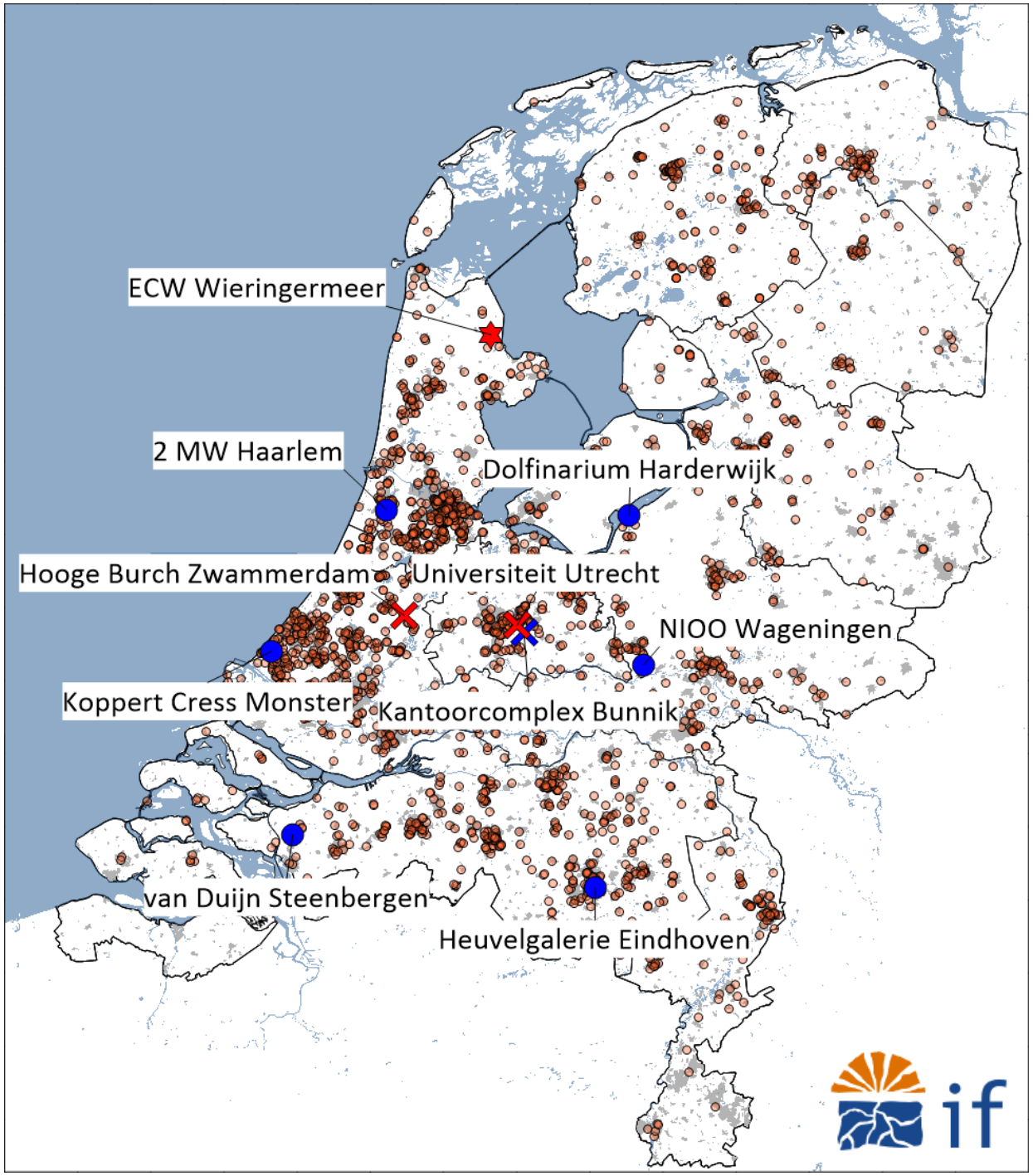


ATES in the Netherlands



Temperature ranges ATES in NL

• 15-25 °C	LT-ATES	Low	>99%
• 25-50 °C	MT-ATES	Medium	< 1%
• 50-90 °C	HT-ATES	High	1 operational



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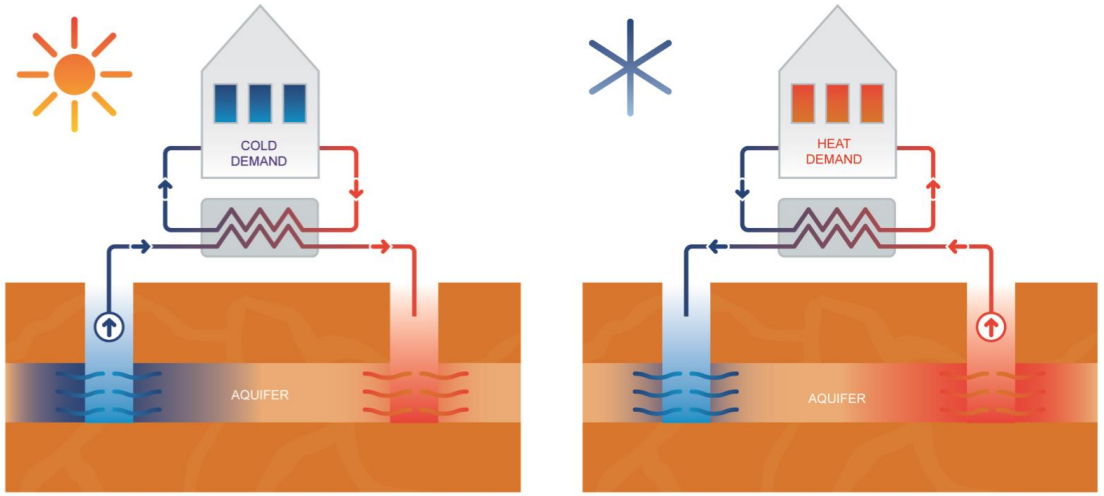

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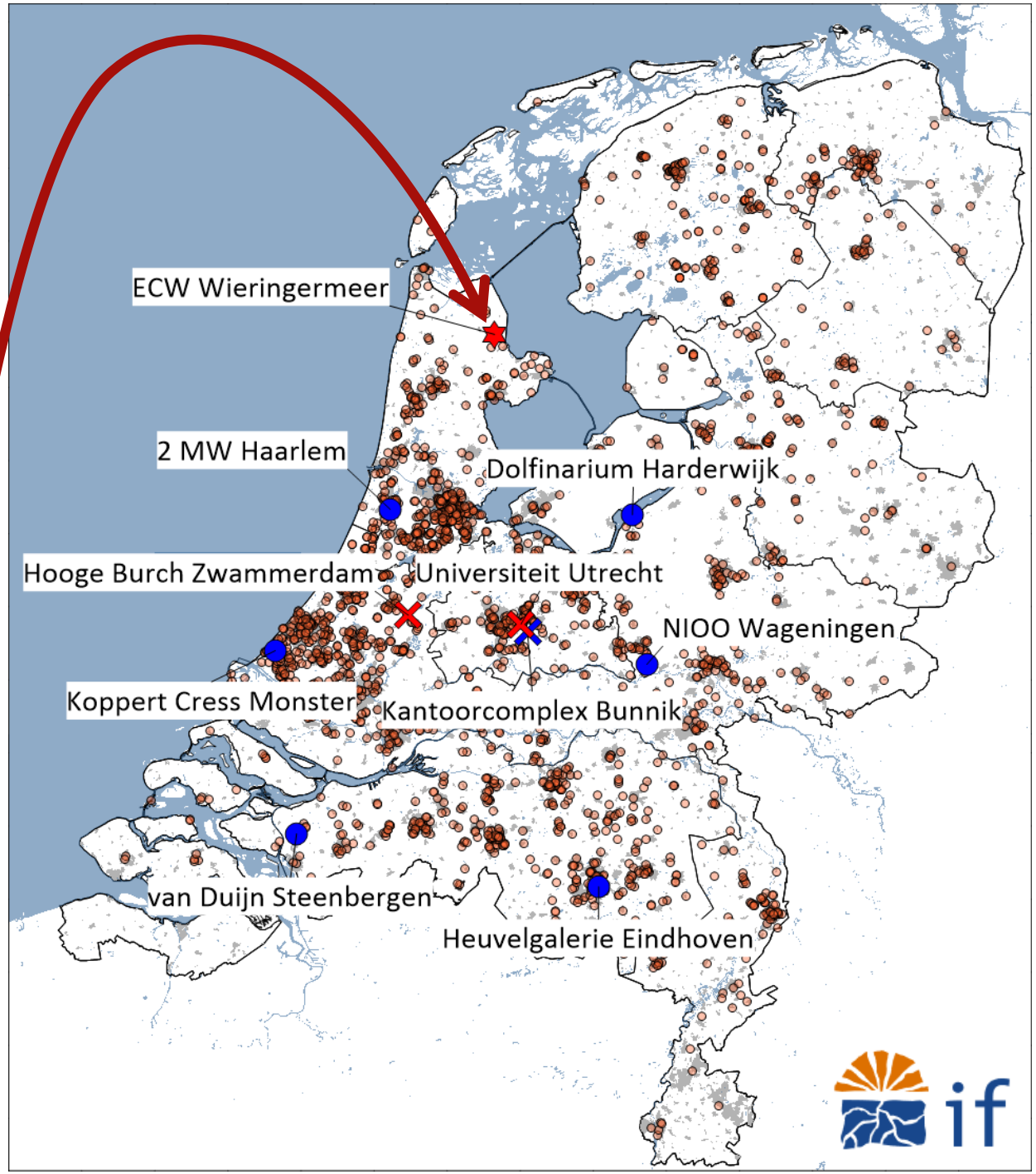
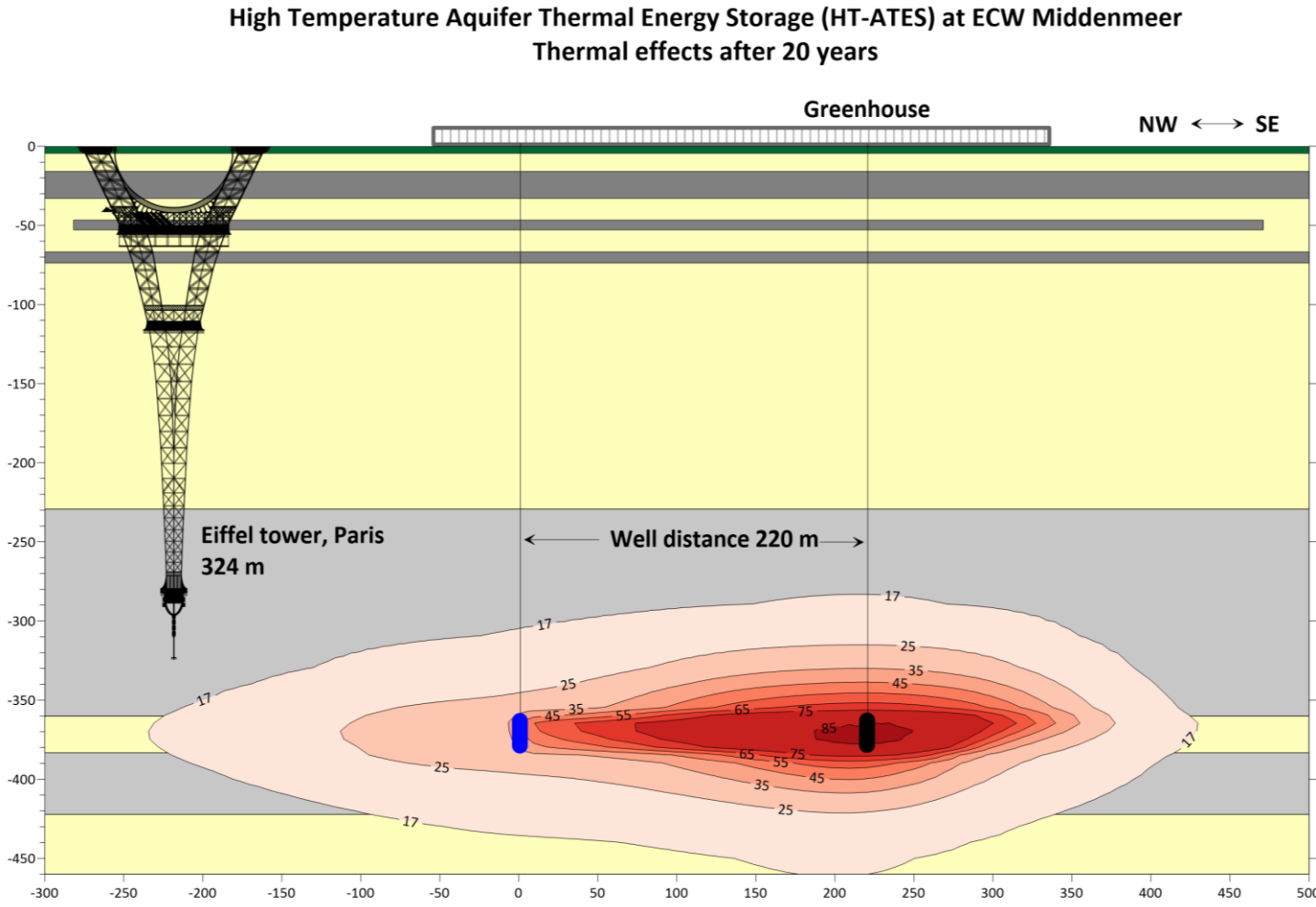


High Temperature ATES

Features

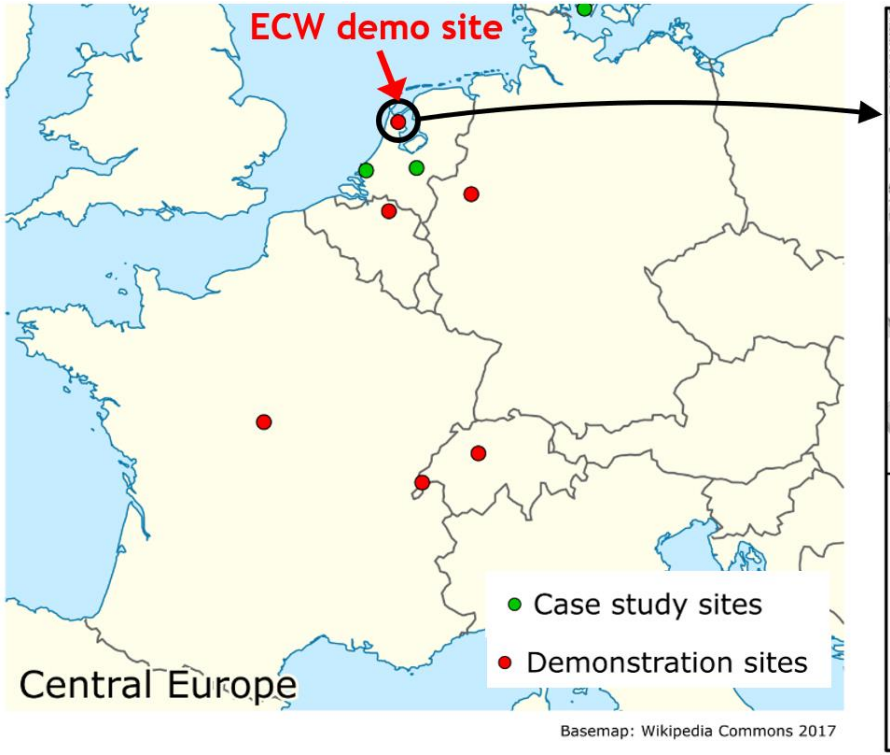
- High storage temperatures (e.g. 85 °C)
- Large scale (> 15 GWh)
- Storage in subsurface aquifer (sand layer)
- Storage interval: seasonal

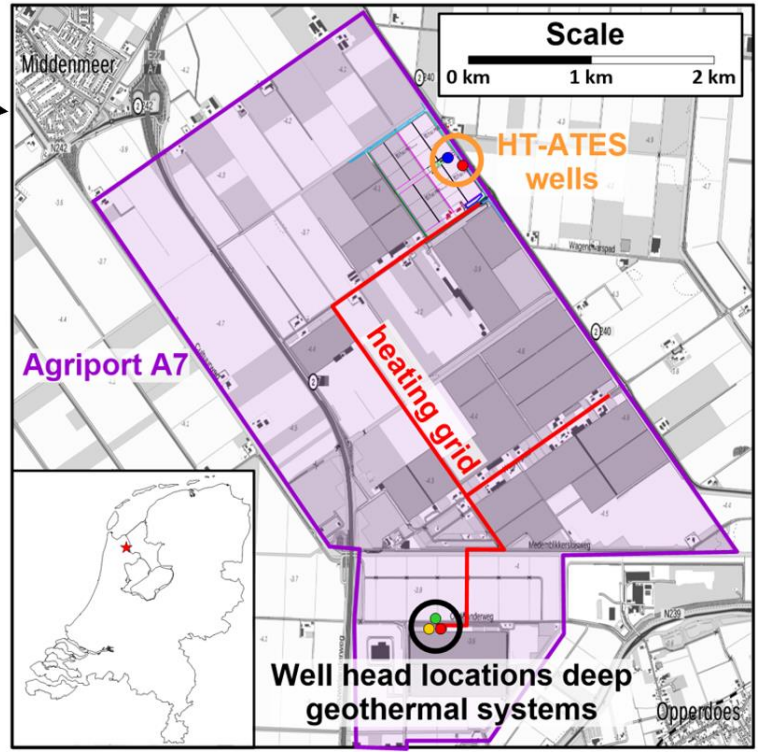


Source: IF Technology

HT-ATES Middenmeer

- Developed during GEOTHERMICA HEATSTORE

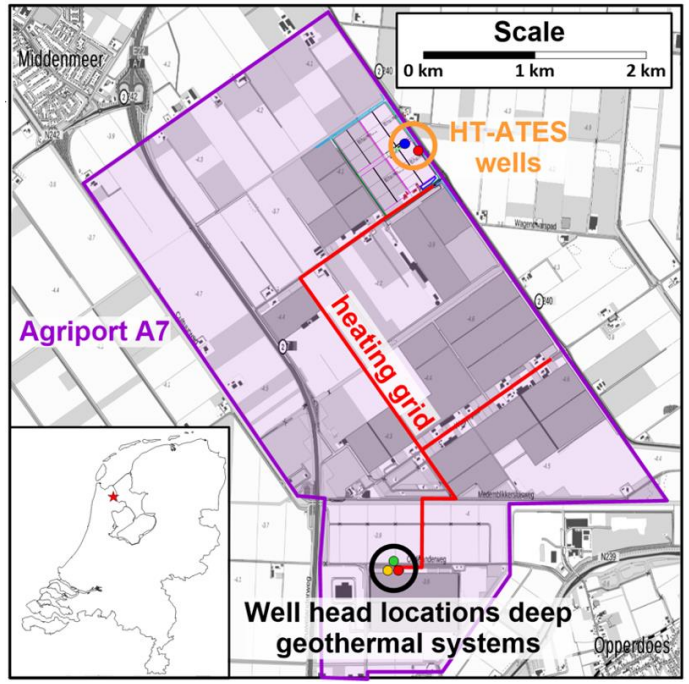




- 2018 • Permit
- 2019 • Test Drilling
- 2020 • Doublet realization
- 2021 • Start of operation

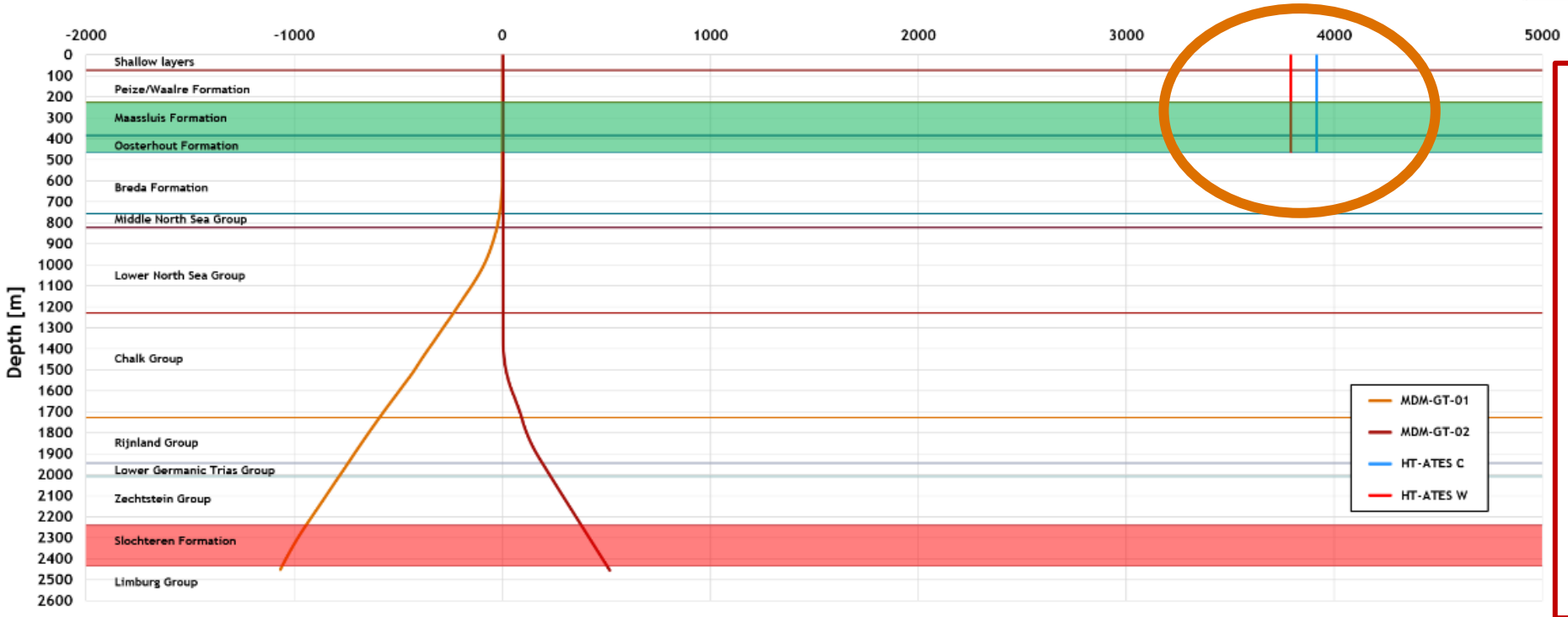
HT-ATES Middenmeer

- Geothermal production wells and HT-ATES storage system



Geothermal doublets (2,3 km, 90 °C)

HTATES Doublet (360m, 85°C)



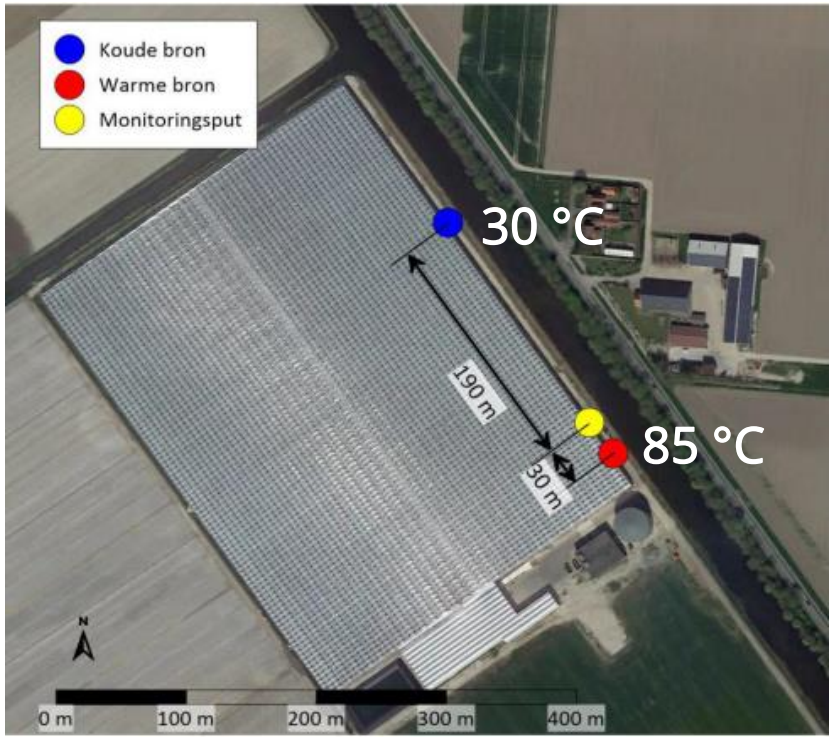
HT-ATES Aquifer (~400 m depth)

- ~ 25 m thick Aquifer
- Unconsolidated sand aquifer
- Between thick clay layers

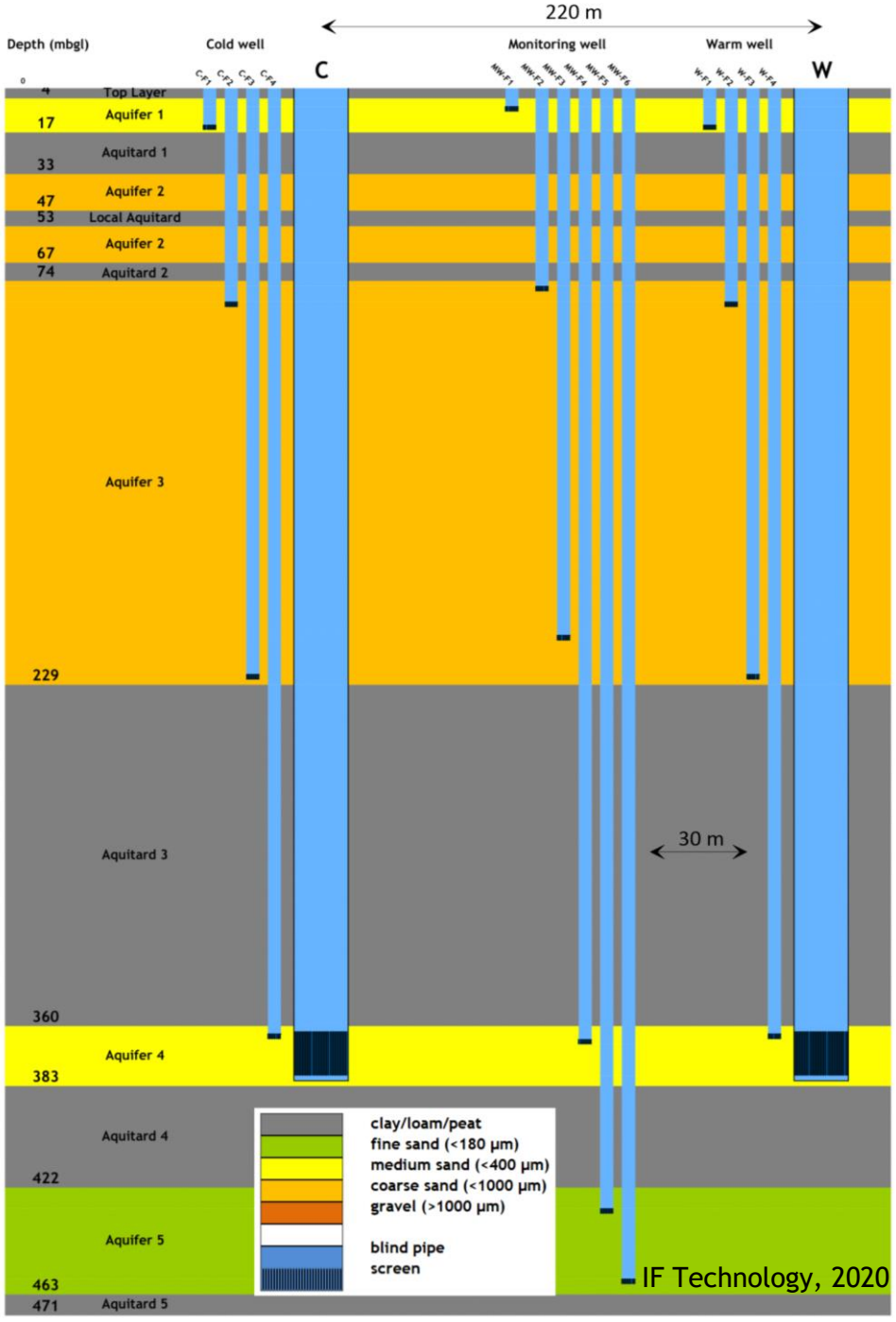
Geothermal Reservoir (> 2km)

- Sandstone
- Slochteren Formation

HT-ATES Middenmeer



Parameter	Unit	Summer	Winter
Flow Rate	[m³/h]	150	150
Injection Temperature	[°C]	85	30
Groundwater volumes	[m³/season]	440,000	440,000
Power (charge/recovery)	[MW]	10	2 - 8
Heat Storage/recovery	[MWht/yr]	28,000 (100 TJ)	20,000



HT-ATES Middenmeer

Drilling rig

Composite well (GRE) with fibre-optic DTS

Hot well with piezometers

Pictures by IF Technology

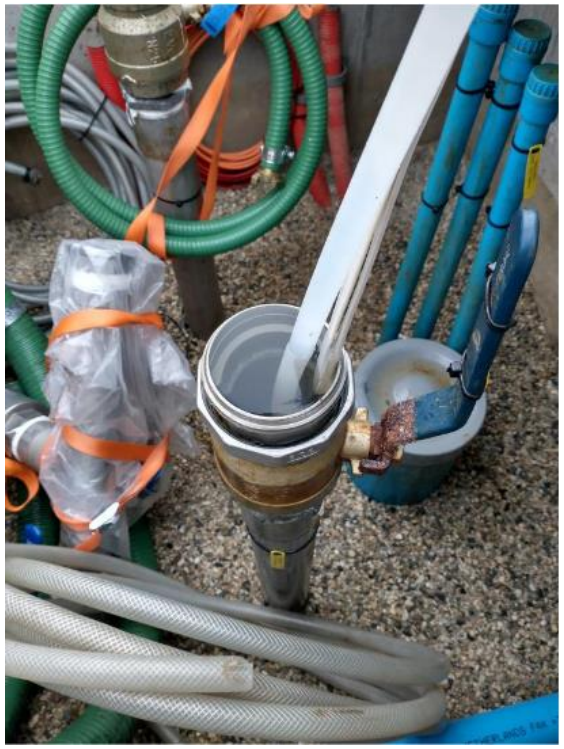
HT-ATES Middenmeer - Monitoring

Subsurface effects

- Temperature
- Groundwater composition (chemical, microbiological)

Operational performance:

- Thermal performance
- Well clogging risks



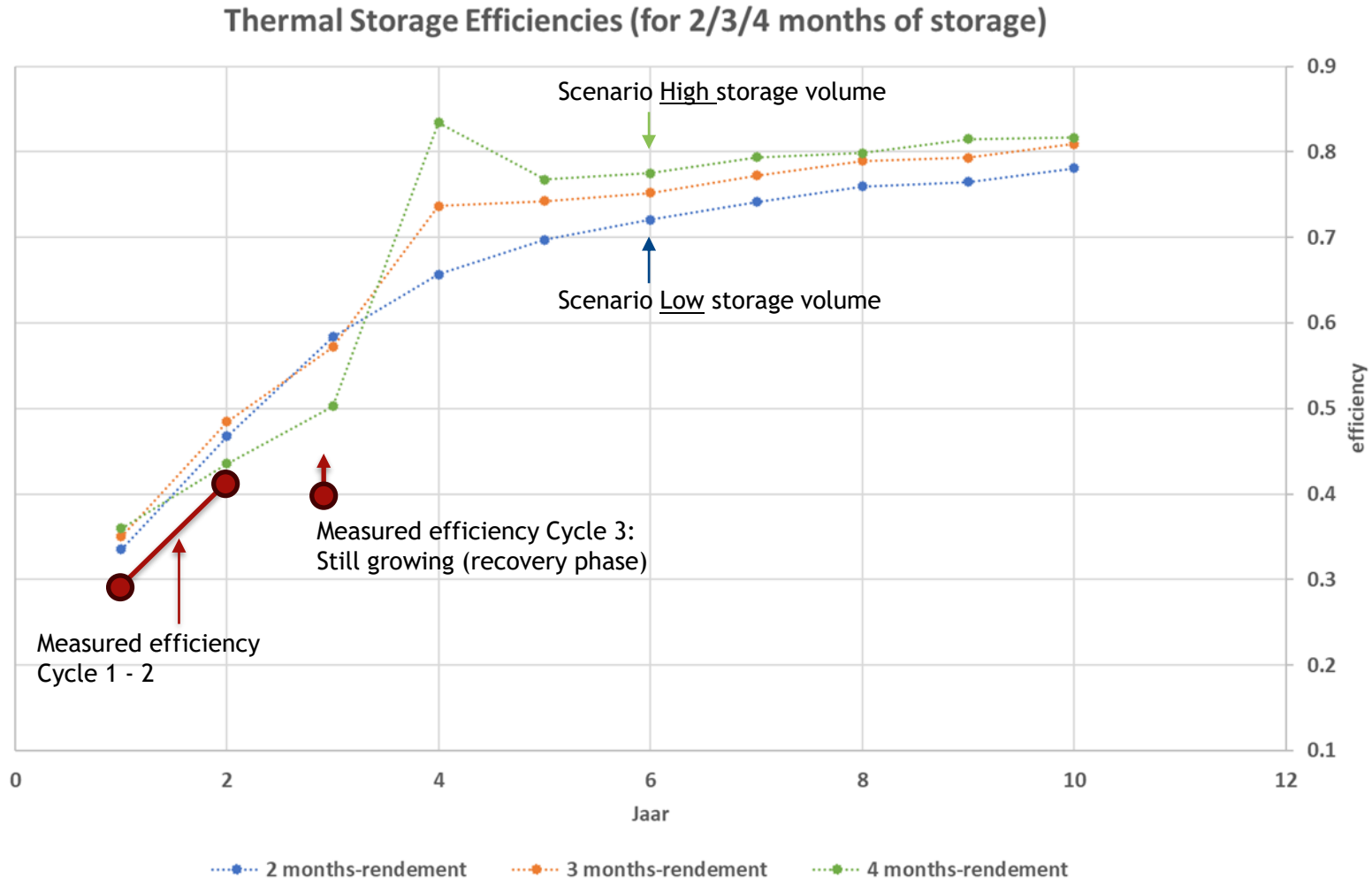
Pictures by IF Technology

HTATES Middenmeer - Thermal Performance

- $Storage\ Efficiency = \frac{Recovered\ Heat\ (cycle\ x)}{Stored\ Heat\ (cycle\ x)}$

- Simulated versus Measured

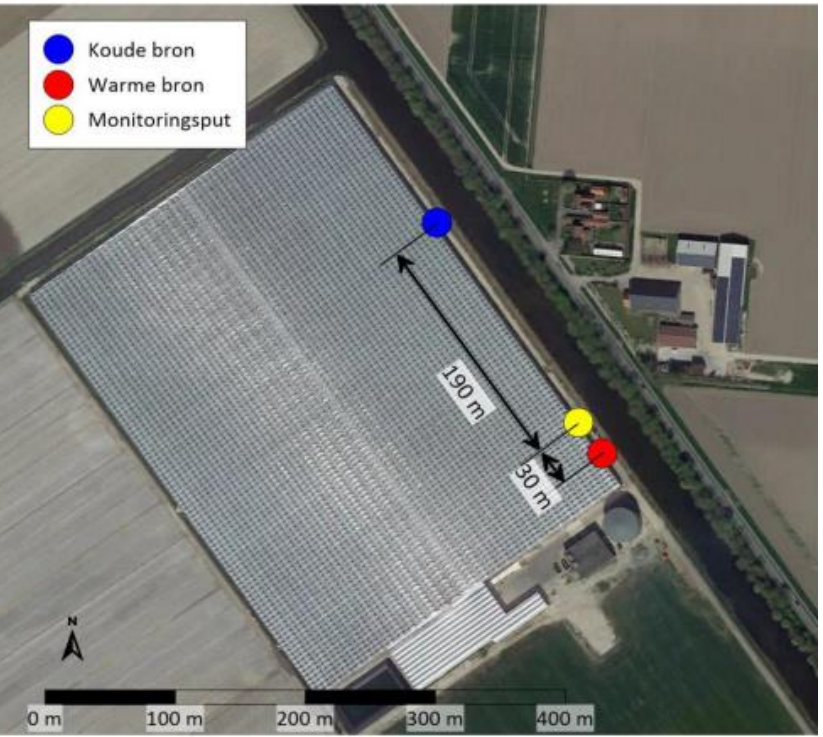
- Efficiency slightly lower than simulated:
  - Much smaller storage volume
  - Heat losses through the well casings

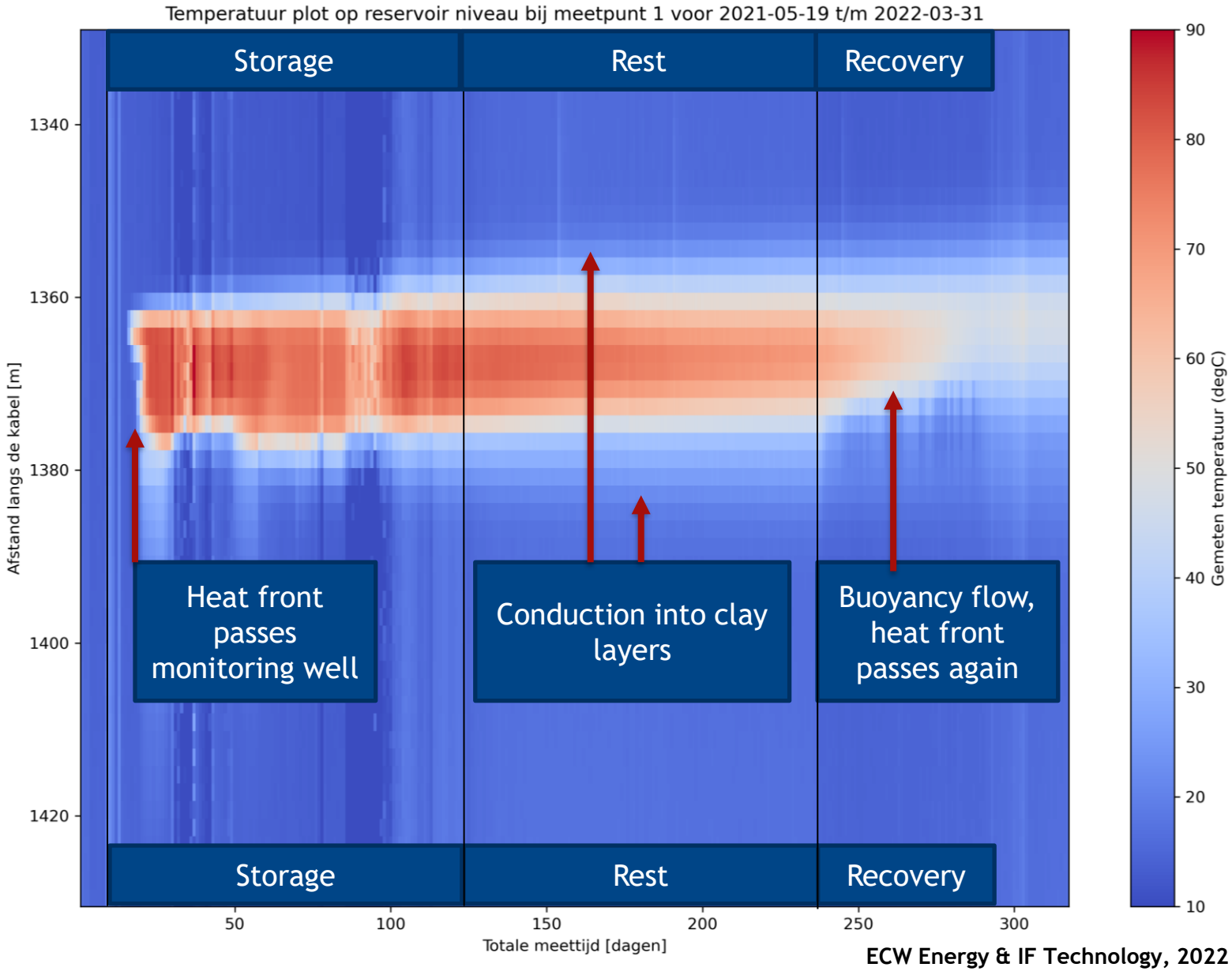


HTATES Middenmeer - Thermal Performance

Heat Transport processes in Aquifer

- Heat injection into hot well
- Heat front passing Monitoring well
- Conduction to clay layers
- Buoyancy flow in aquifer

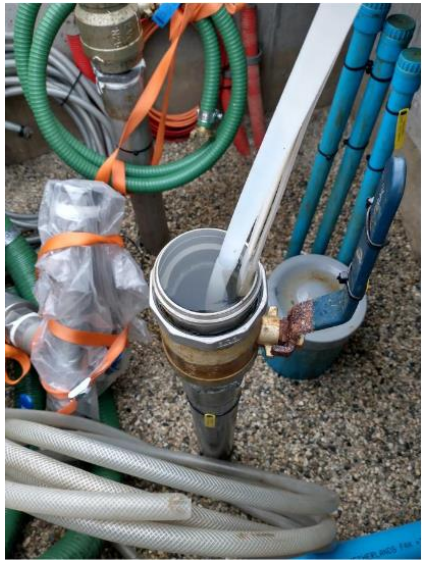




ECW Energy & IF Technology, 2022

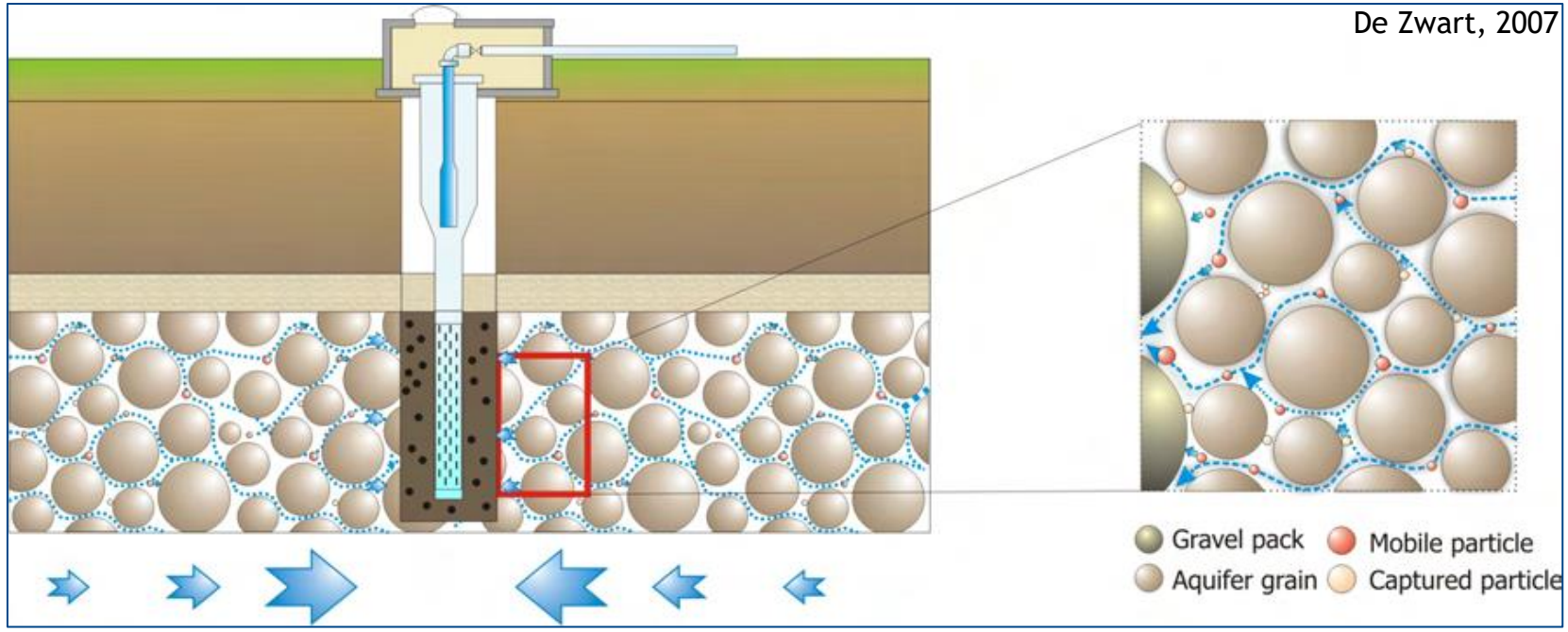
HTATES Middenmeer - Well clogging risks (1)

Risk:	Well clogging by calcite scaling
Mitigation measures	Water treatment (CO_2-dosing) Monitoring groundwater and well performance
Results	CO_2-dosing unit worked properly No indications for scaling/clogging. CO_2 increase visible in monitoring well (no consumption of CO_2)
Optimizations	Minimize dosing in order to contain CO_2-pressure on long term



HTATES Middenmeer - Well clogging risks (2)

Risk:	Well clogging by particles due to high flow rates
Mitigation measures	Well development Filtering of production water and analysis of material
Results	Few particles produced. No indications for well clogging
Optimizations	Continue filtering and analysis



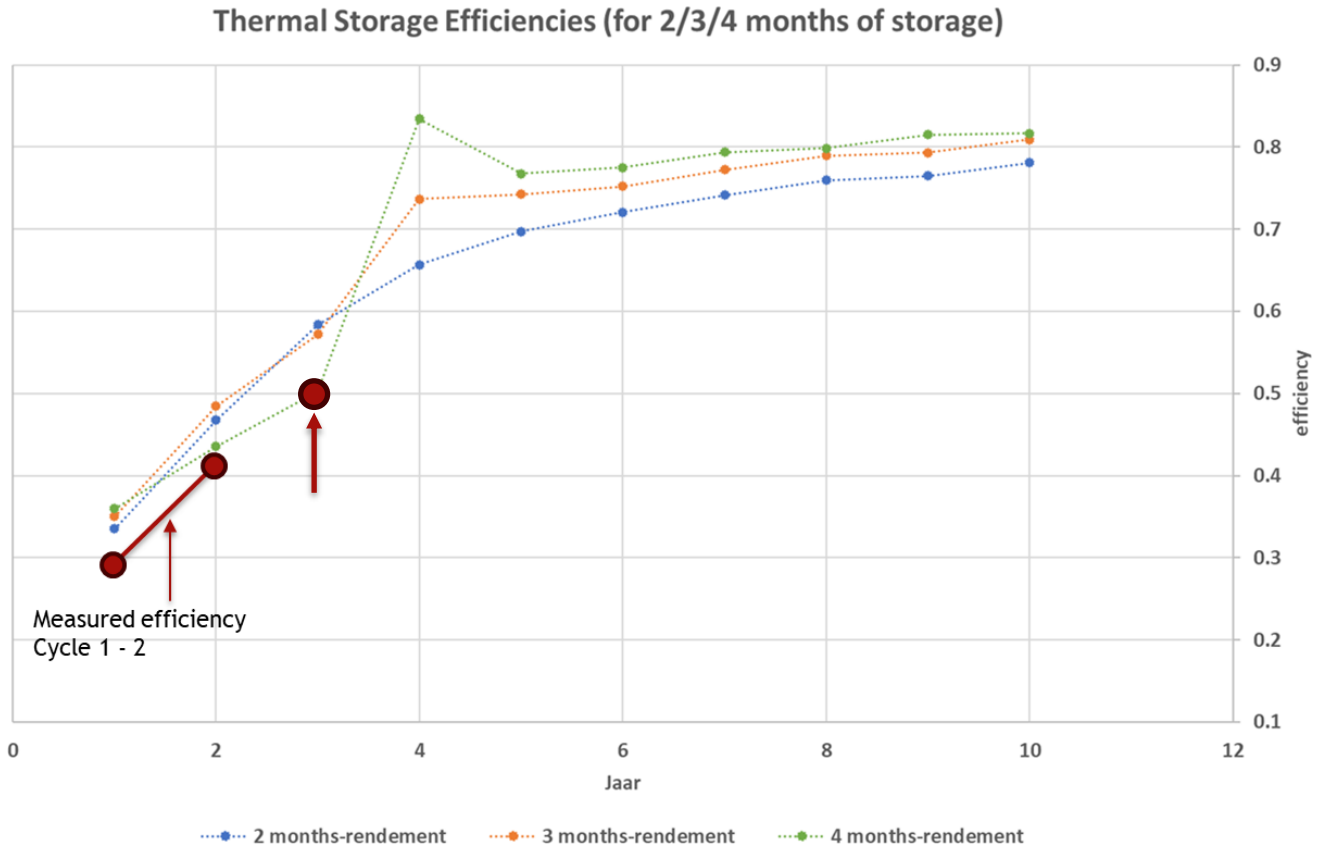
HTATES Middenmeer - Groundwater effects

What are the effect of HT-ATES on groundwater composition?

Parameter	Hypothesis (literature)	Observation at HT-ATES	Interpretation
Calcite	Precipitation due to higher temperatures	No considerable changes	Water treatment (CO_2) effectively mitigates precipitation
DOC	Mobilized at higher T	No considerable increase	Little solid organic matter to be mobilized. Mobilized DOC cannot be consumed by microbes, since low activity
Silicium	Dissolution at high T	Increased Si near hot well.	Dissolution of sediment near hot well (high T, low pH)
Arsenic	Mobilized at hot well, Concentrates at outer sphere of storage	Naturally: low conc. Hot well: low concentrations Monitoring well: slight increase	Limited As presence Mobilization at hot well, resorption near monitoring well
ATP	Decreases at highest T	Very low ATP near hot well	Biomass cannot thrive near hot well Research on 'cold' well (30C) continues

Outlook

- Monitoring is continued in ‘HTO-PEN’ research
  - Groundwater sampling
  - Temperature measurements with DTS (daily)
  - Inline measurements on P, T, pH
- Thermal recovery efficiency: >50% in cycle 3?!
- **Extensive evaluation of cycle 1 - 3 (summer 2024)**



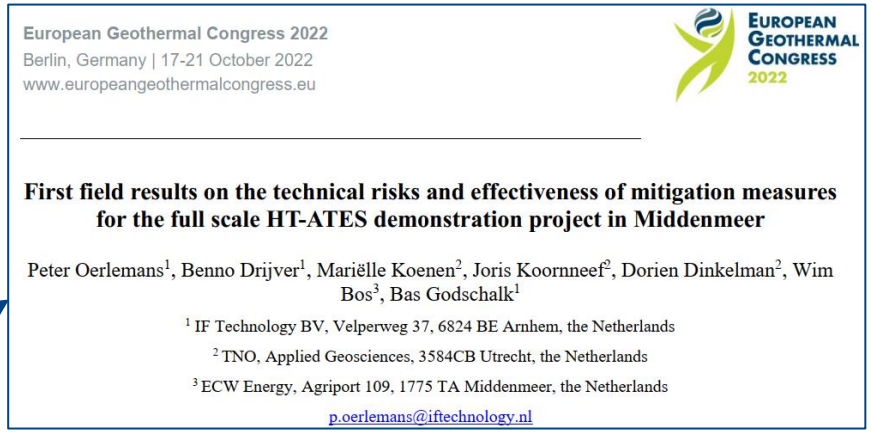
Relevant references and links

References

- HEATSTORE Roadmap (2021) (www.heatstore.eu)

Congress papers on HT-ATES Middenmeer, NL:

- ***EGC 2022***: *First field results HT-ATES Middenmeer*
- ***GET 2020***: *Full-Scale HT-ATES Tests Demonstrate that Current Guidelines Considerably Overestimate Sand Production Risks in Deeper Unconsolidated Aquifers*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EUROPEAN GEOTHERMAL CONGRESS 2022

First field results on the technical risks and effectiveness of mitigation measures for the full scale HT-ATES demonstration project in Middenmeer

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