Using thermal recycling to optimize short-term HT-ATES for DSM applications

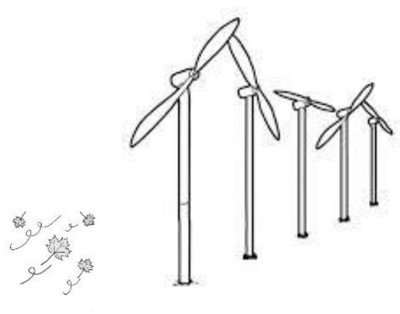
Tanguy Robert & Guillaume De Schepper

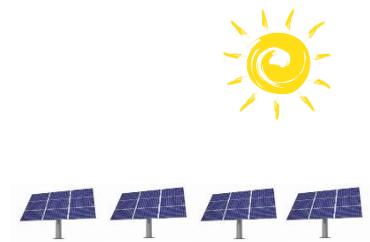
Tanguy.Robert@uliege.be

g.deschepper@aquale.com

Session HS8.2.3/ERE5.3
EGU2019-4159

What is demand-side management? (DSM)

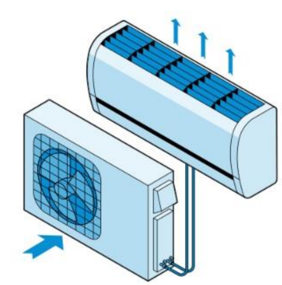




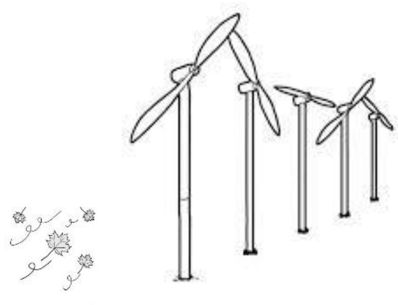
Energy production

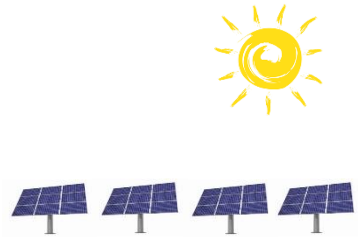
must be in balance with

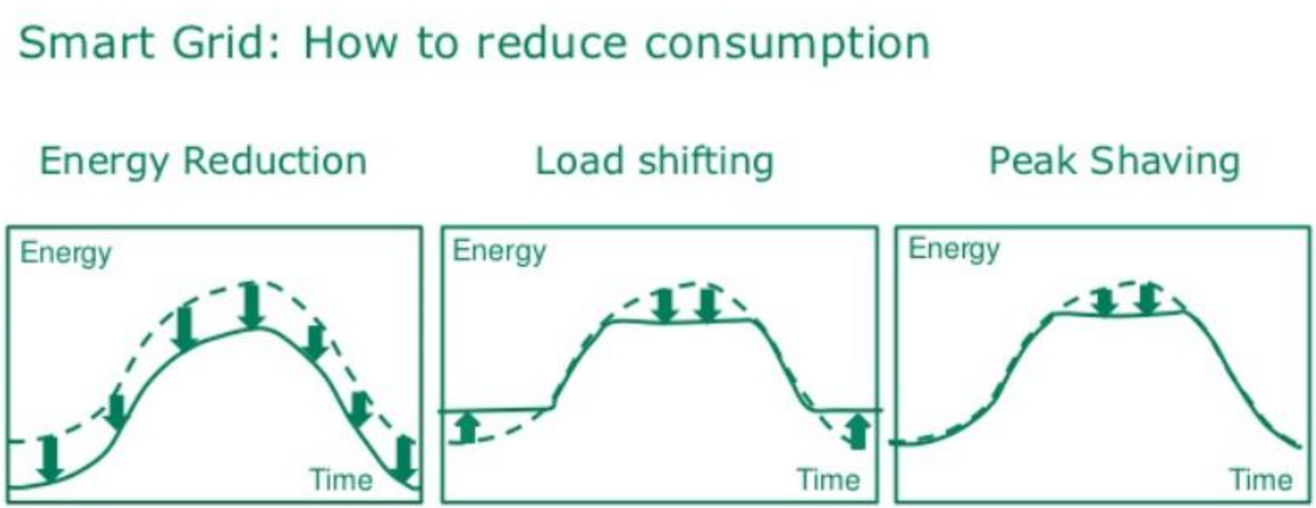
energy consumption

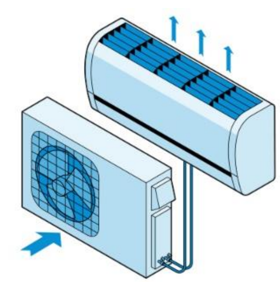


DSM offers flexibility
but storage strategies are needed …





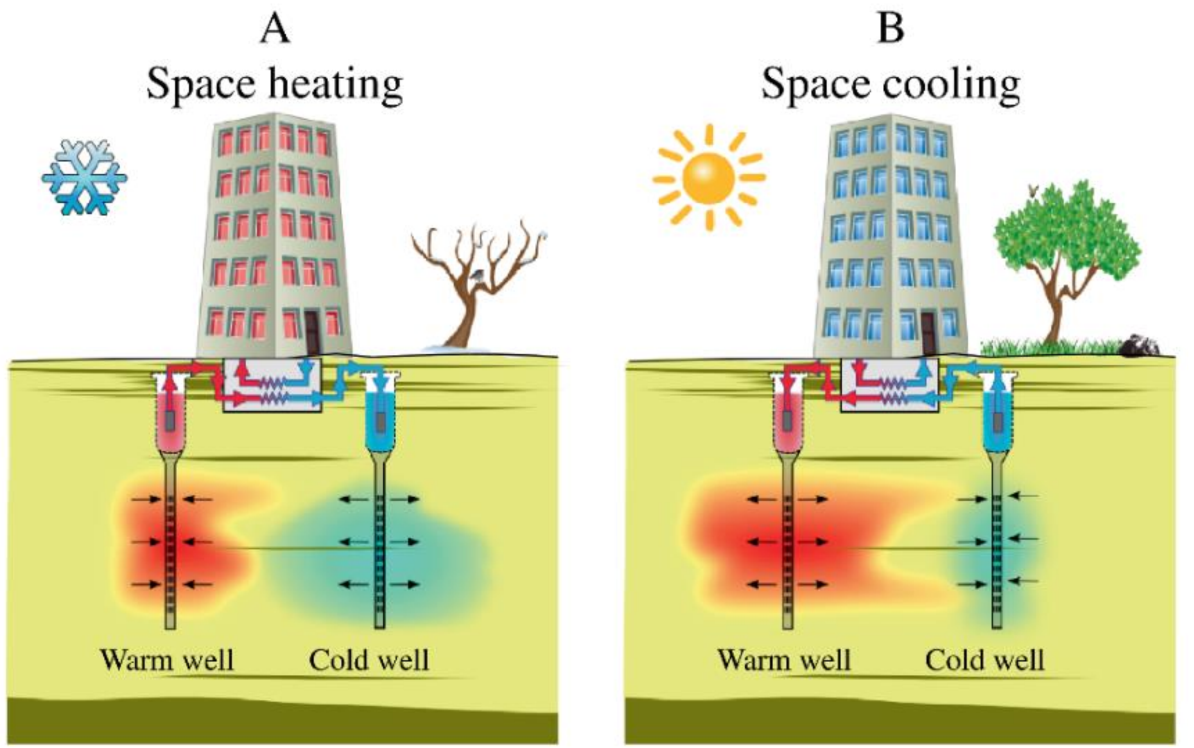




In the EU,
40% of total energy demand
is in the building sector

IEA (2013)

… ATES can provide this flexibility



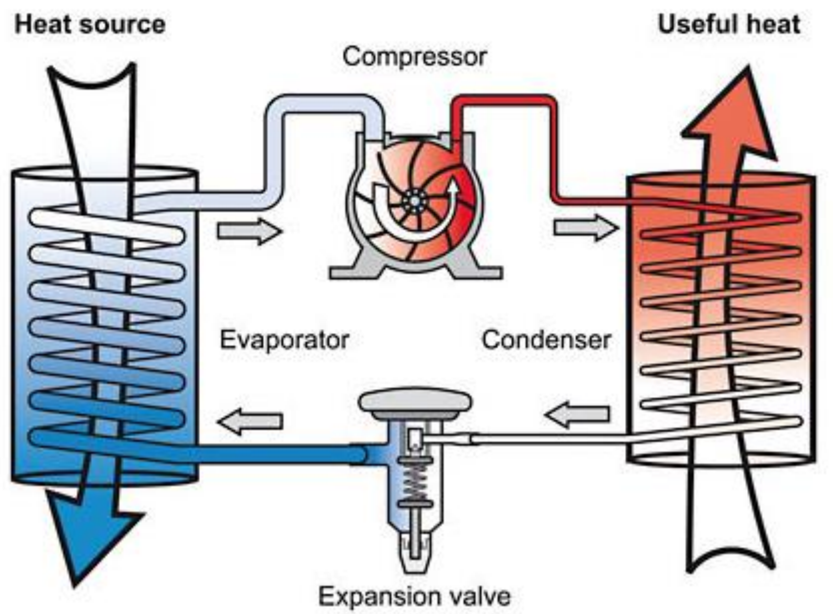
Modified after Bonte (2013)

ATES is Aquifer Thermal Energy Storage
Ability to decouple heat and electricity demand (at least partially)

How? With the groundwater heat pump!

Electrical grid

Groundwater

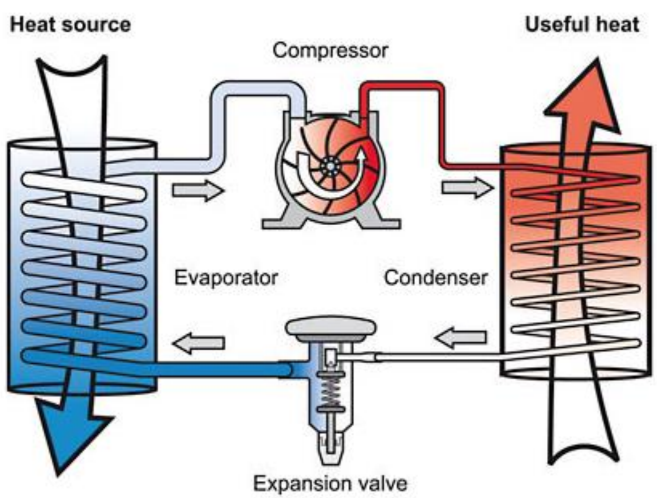


Building

Figure from Veolia Water$_2$Energy (2018)

The efficiency of GWHP depends on temperatures

T_c



T_h

Figure from Veolia Water$_2$Energy (2018)

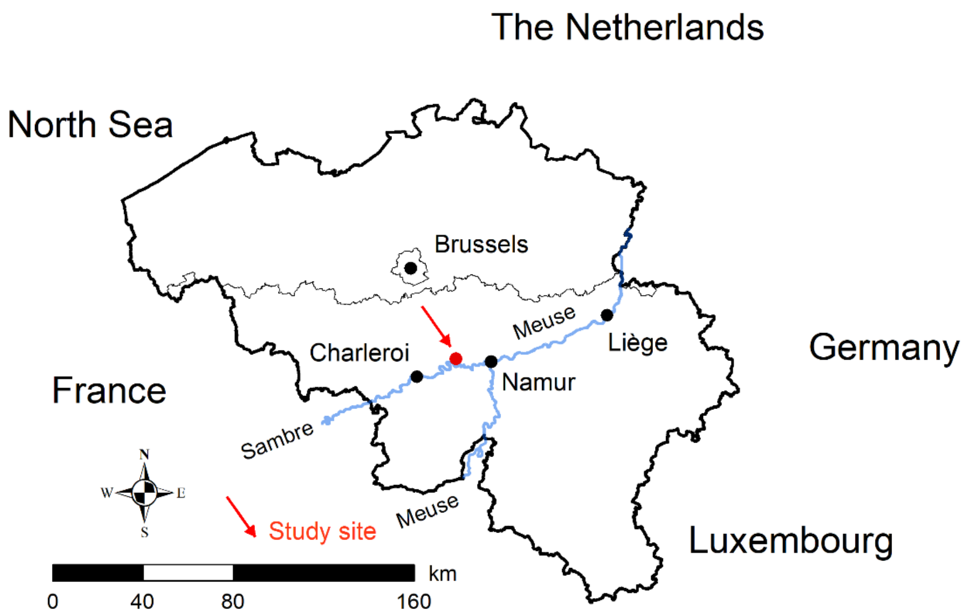
$$COP_{Heating} \propto \frac{T_h}{T_h - T_c}$$

$$COP_{Heating} = 4\ (@T_c = 10°C)$$

$$= 5\ (@T_c = 16°C)$$

And what if $T_c \geq T_h$?

Alluvial aquifers are our target



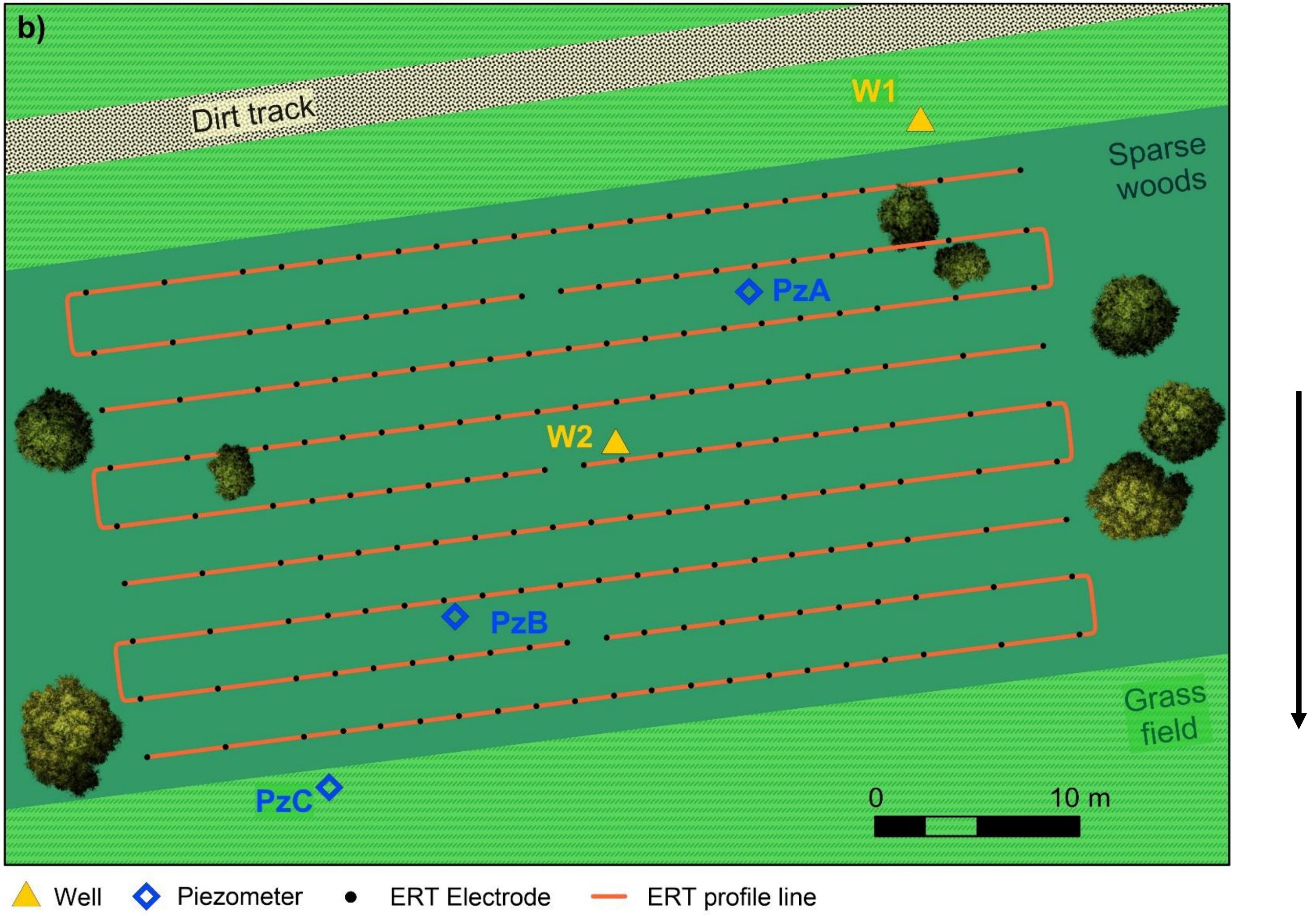
Major cities are built on alluvial deposits

Alluvial aquifers are often productive
→ High storage capacity

Alluvial aquifers are shallower
→ Low installation costs

Alluvial aquifers present (poorer) quality
→ No conflict with other applications

Our site is representative of shallow alluvial aquifers with slow ambient flow

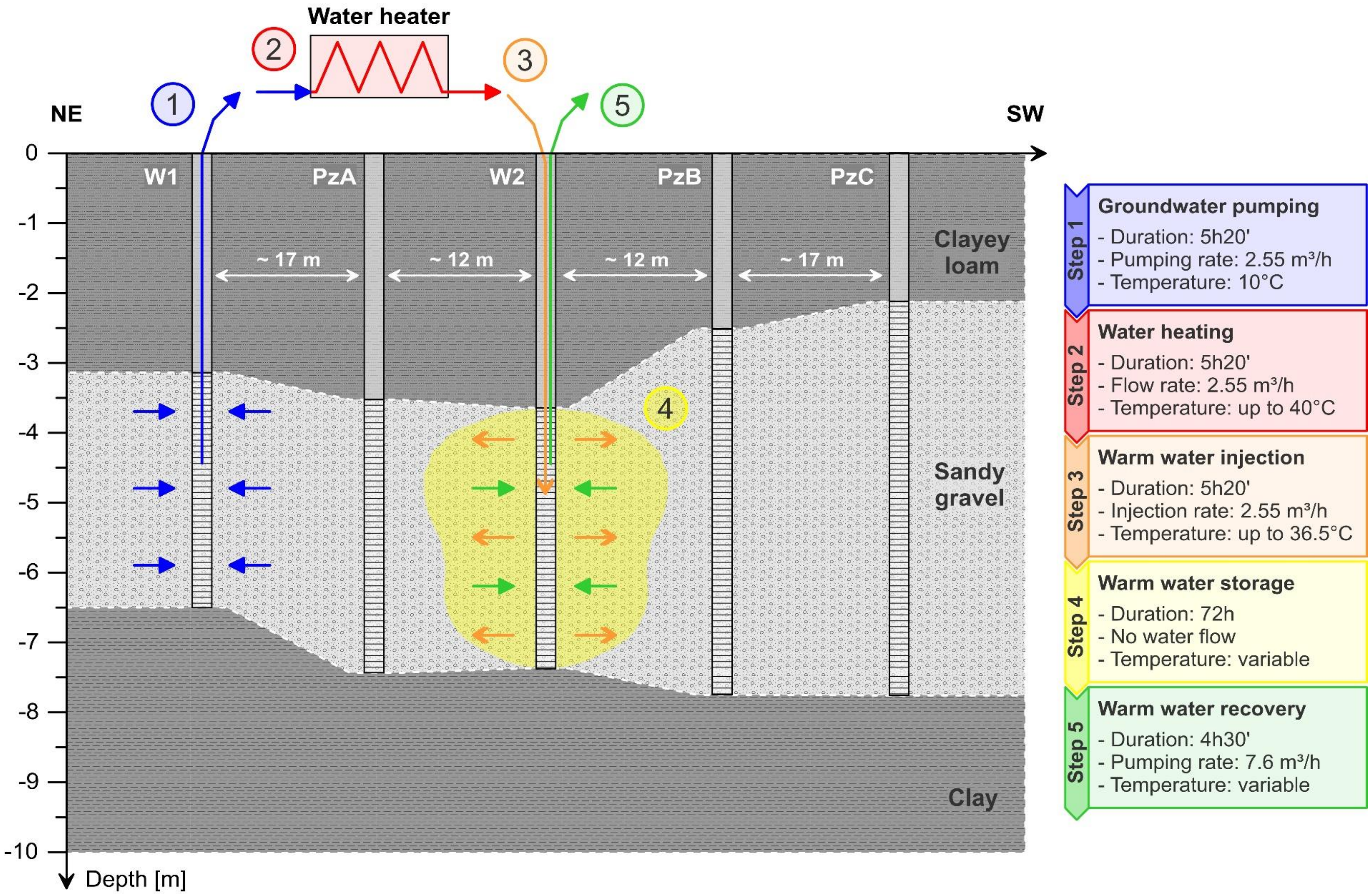


gw flow direction

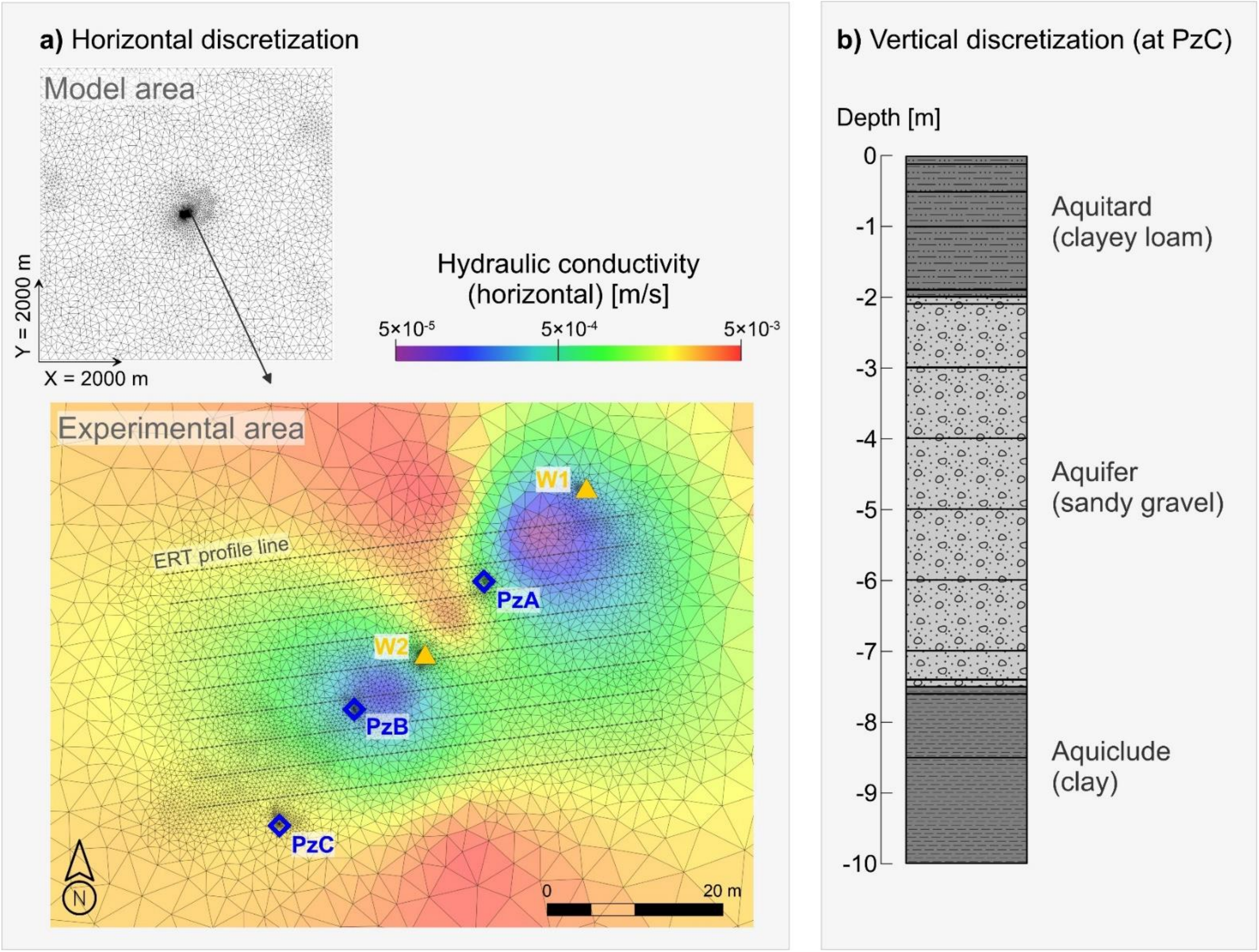
~10 m/y

10^{-3} m/s

We emulated an ATES & recovery cycle



We used experimental data to conceptualize, build, & calibrate a numerical model in Feflow



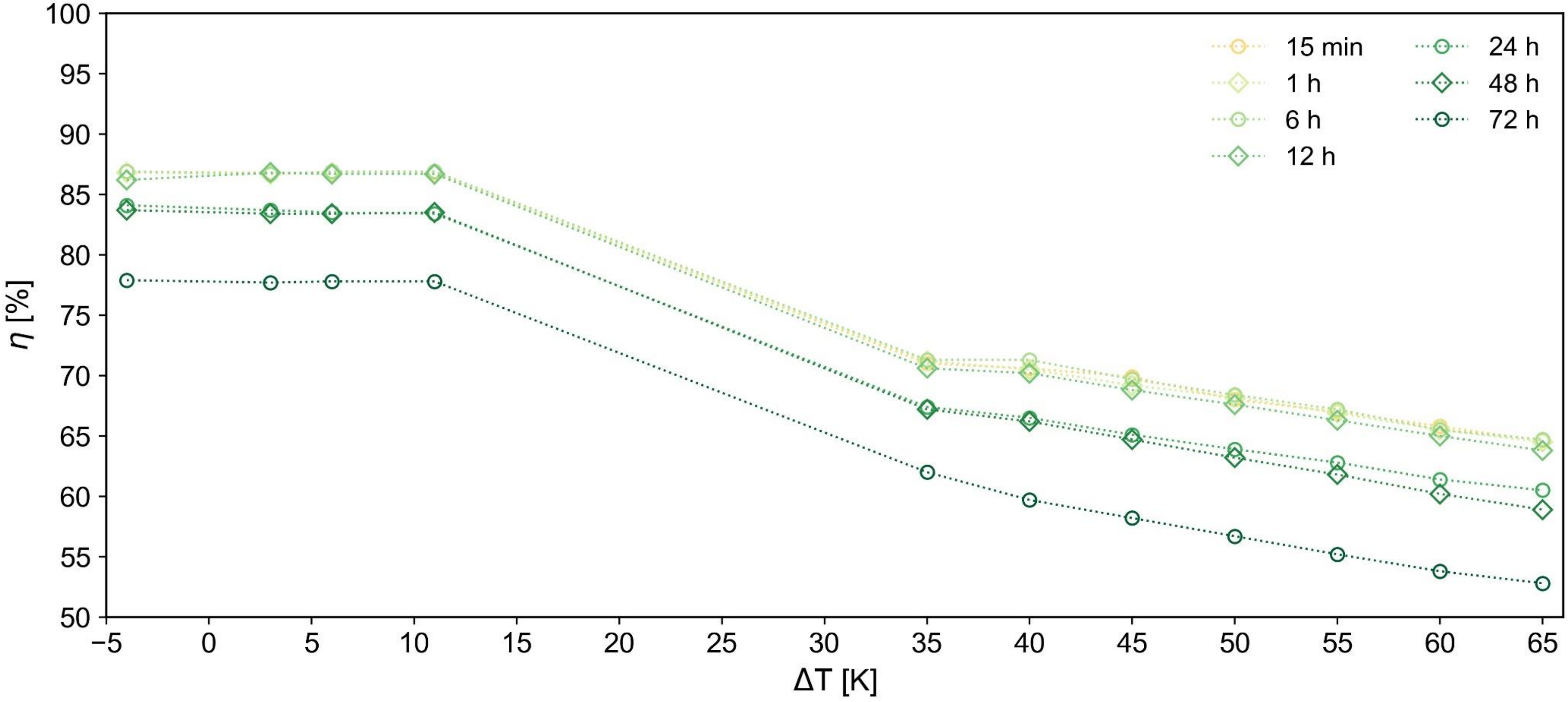
We ran 77 simulations

1st idea: Slight increase in water temperature to improve the COP of GWHP

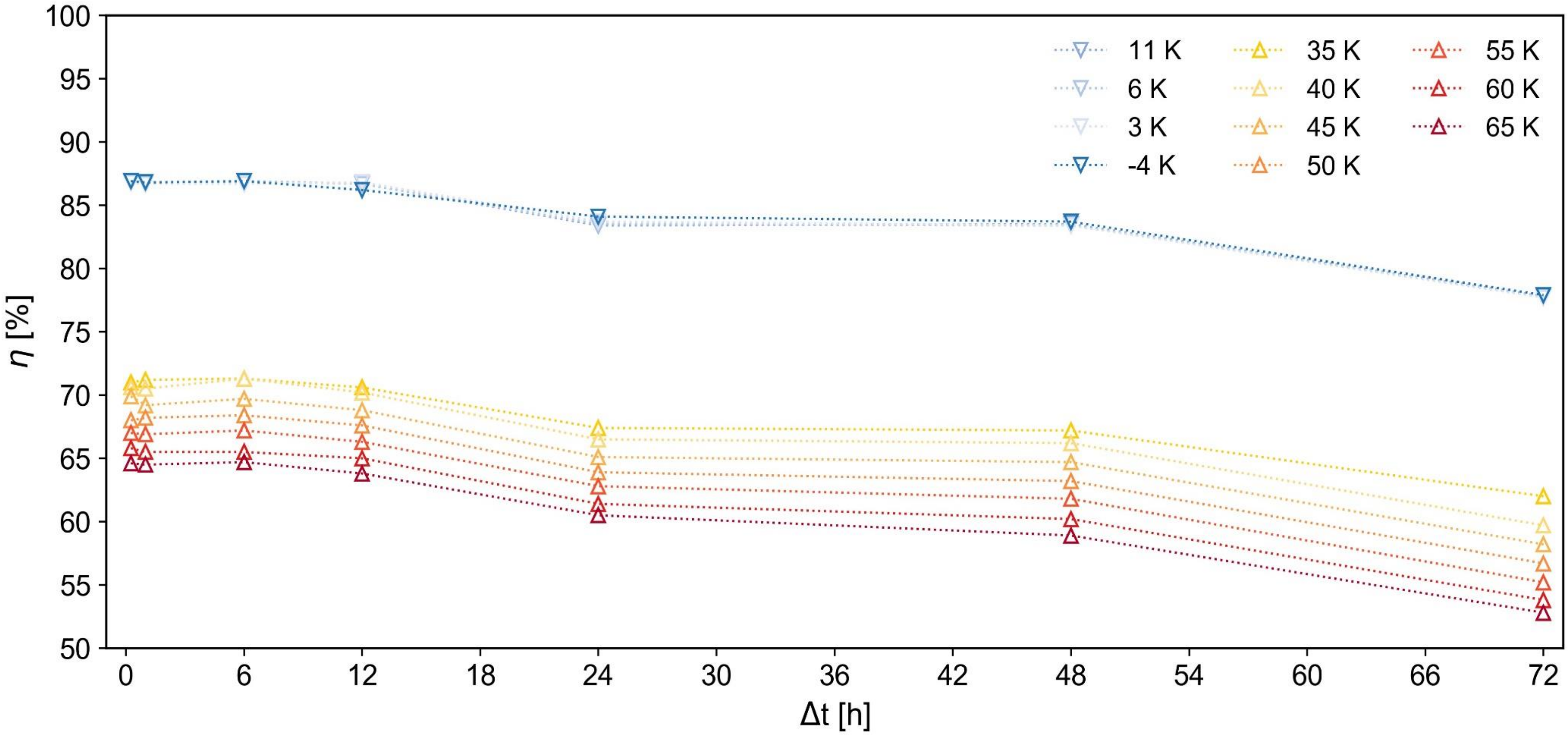
2nd idea: Strong increase in water temperature to get rid of GWHP

For now, just one cycle for comparison purposes

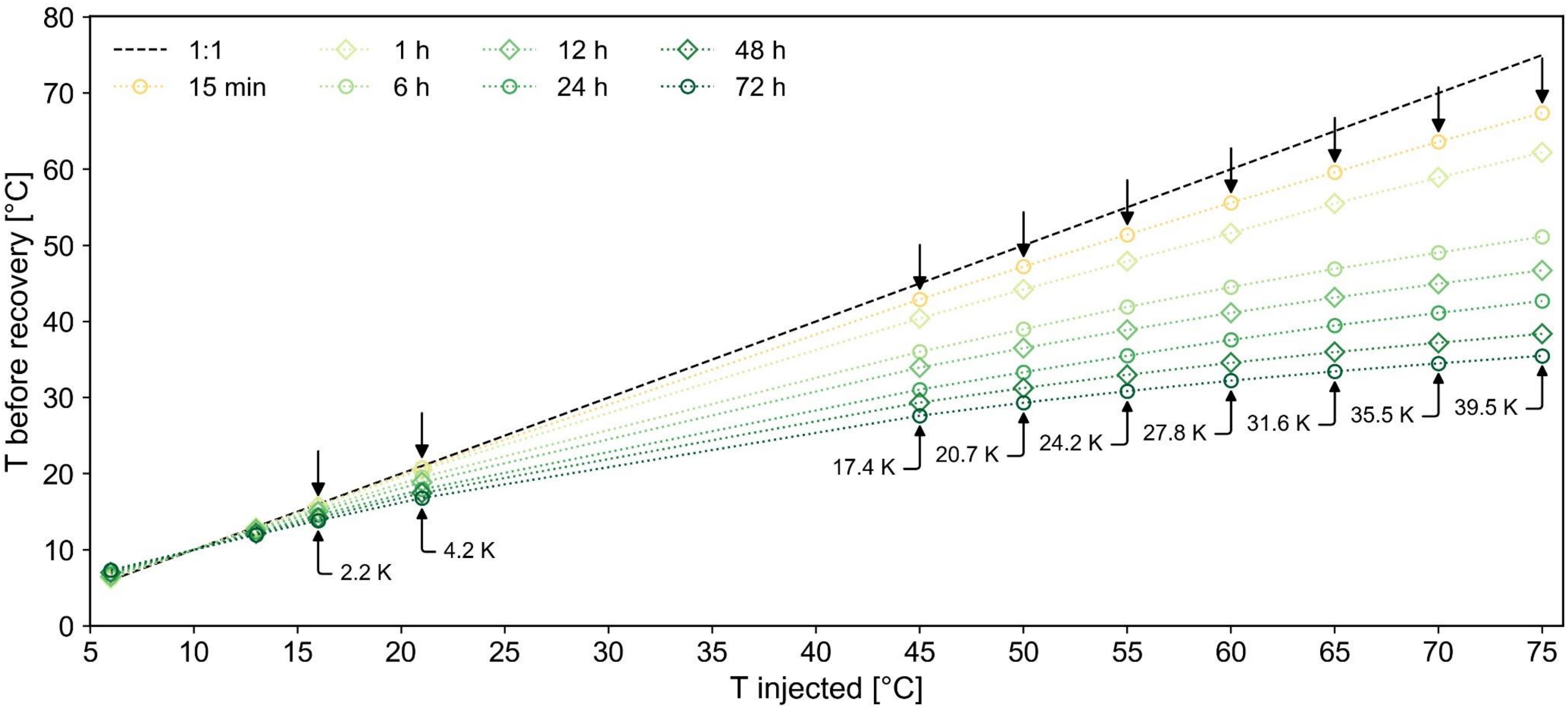
Energy recovery rates (η) decrease with increasing temperatures



Energy recovery rates (η) decrease with longer storage duration



For HT-ATES, optimization is needed to get rid of GWHP

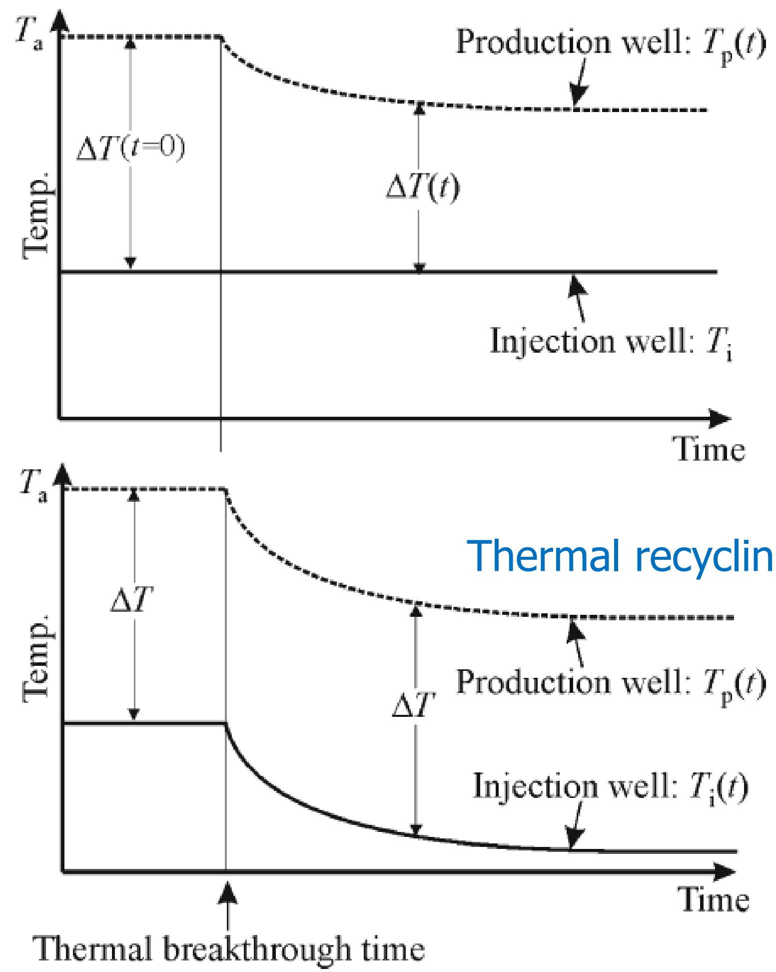


Other simulations

Idea:
Repeat ATES
& recovery cycles

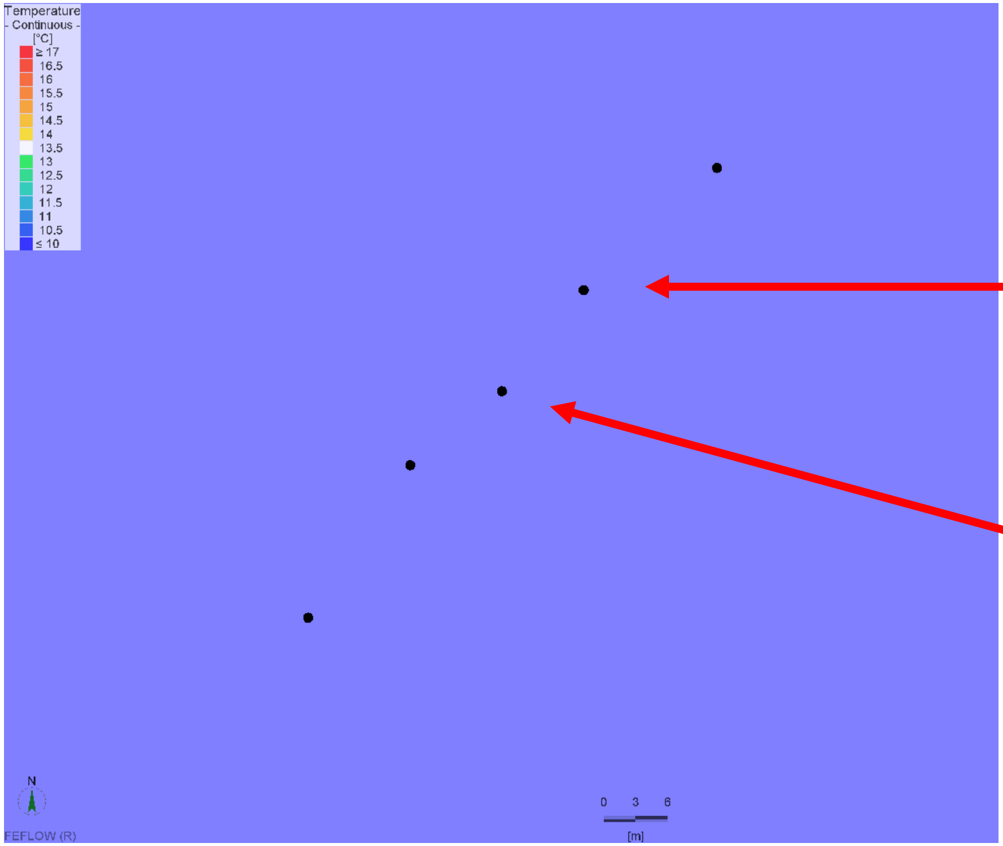
This time,
with thermal recycling

Thermal feedback



Figures from Milnes & Perrochet (2013)

Thermal recycling helps containing the heat plume in the area of interest

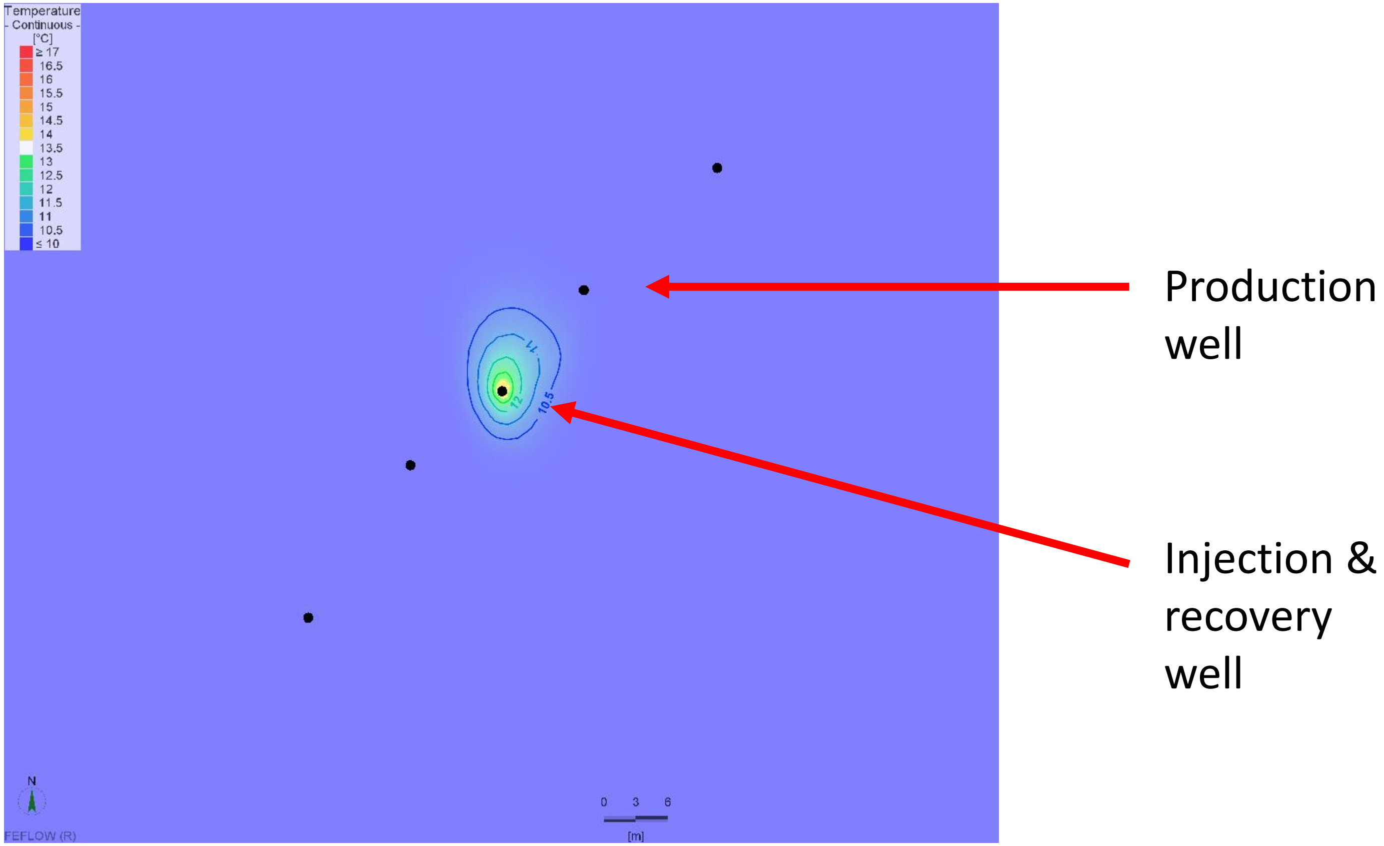


Production well

Injection & recovery well

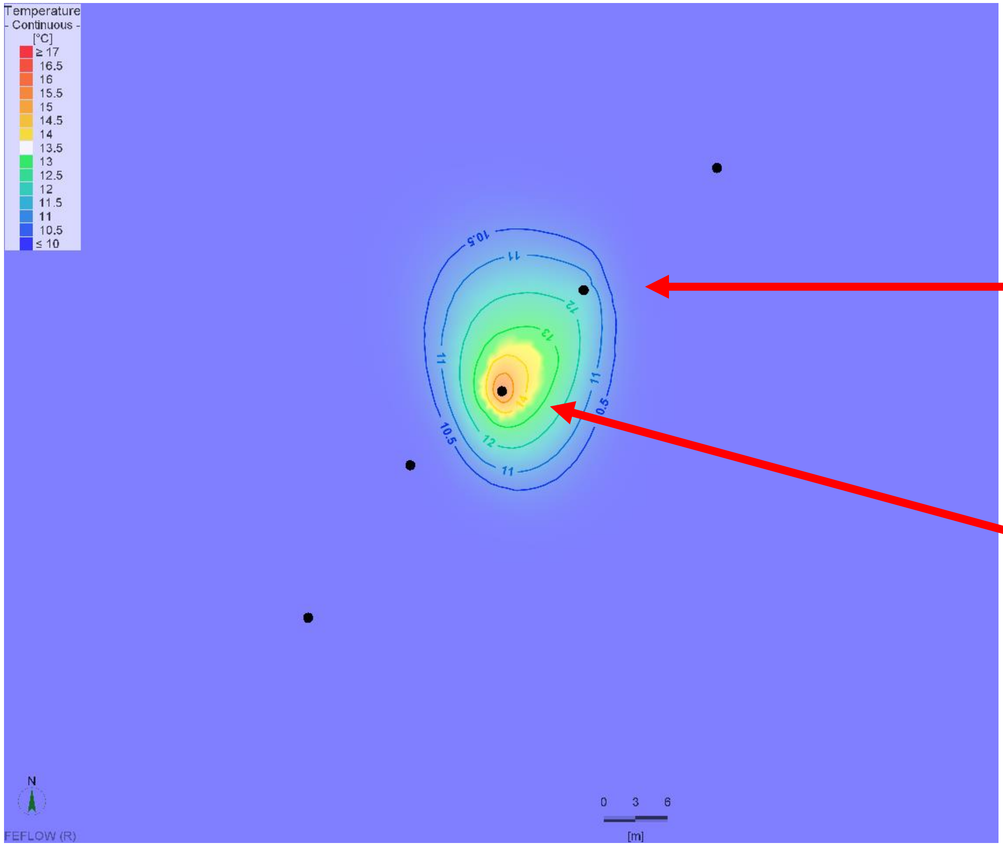
Example of LT-ATES (ΔT = 6K) – Day 0

Thermal recycling helps containing the heat plume in the area of interest



Example of LT-ATES (ΔT = 6K) – Day 1

Thermal recycling helps containing the heat plume in the area of interest

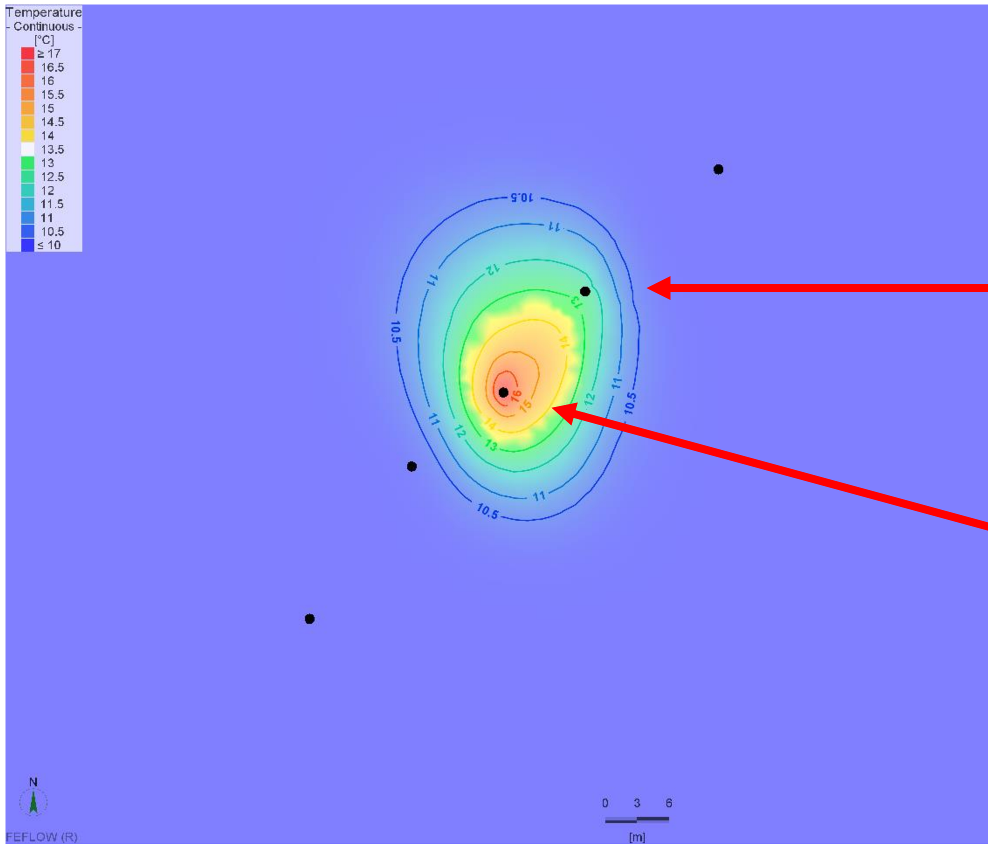


Production well

Injection & recovery well

Example of LT-ATES (ΔT = 6K) – Day 7

Thermal recycling helps containing the heat plume in the area of interest

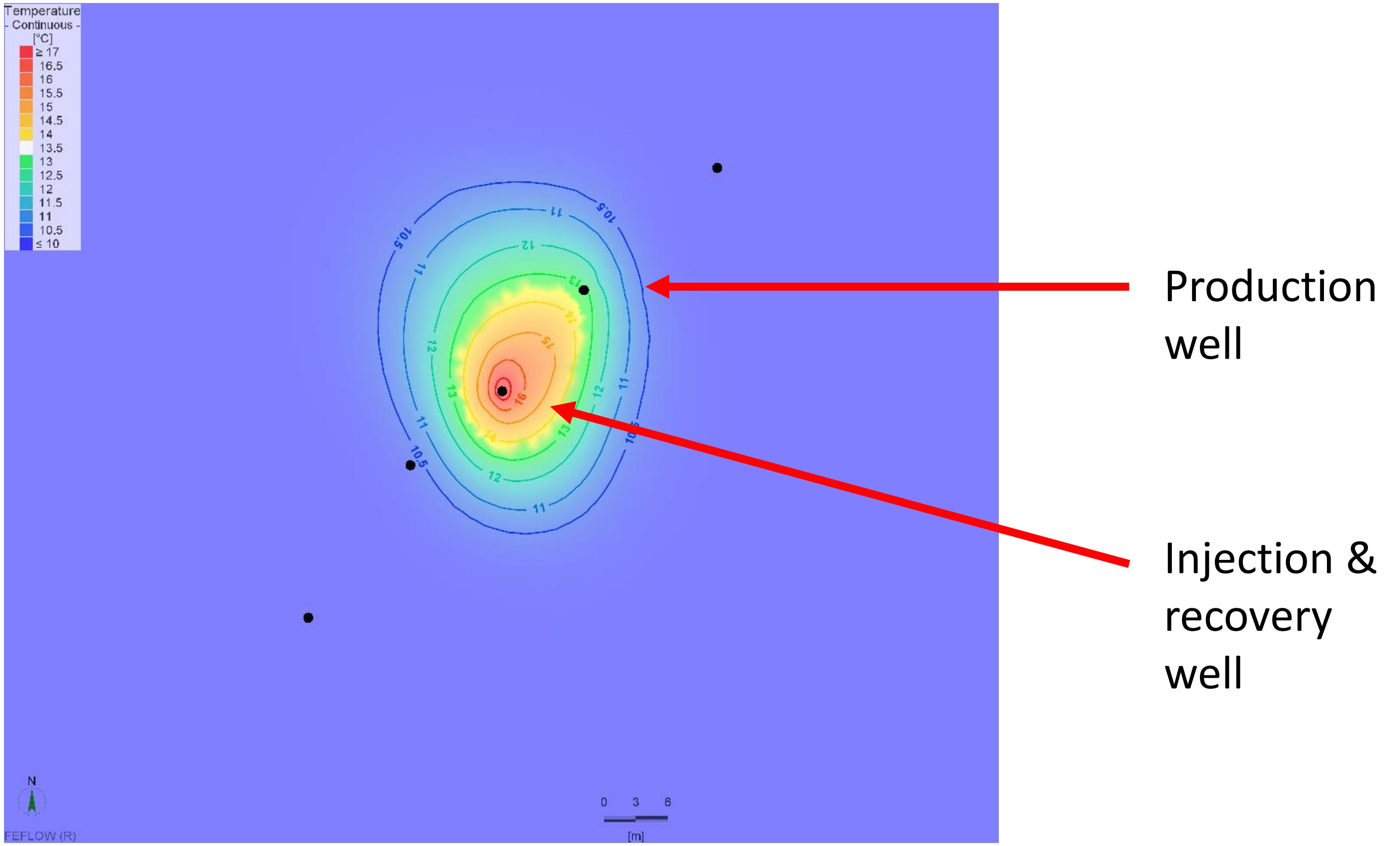


Production well

Injection & recovery well

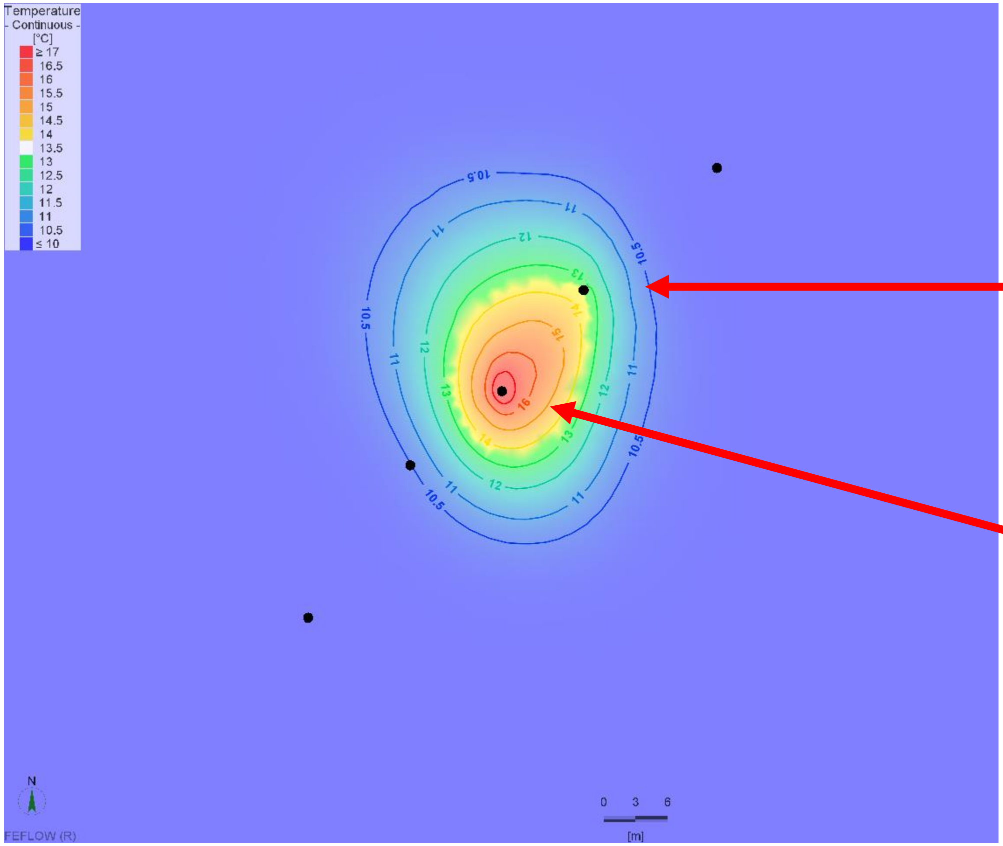
Example of LT-ATES (ΔT = 6K) – Day 14

Thermal recycling helps containing the heat plume in the area of interest



Example of LT-ATES (ΔT = 6K) – Day 21

Thermal recycling helps containing the heat plume in the area of interest



Production well

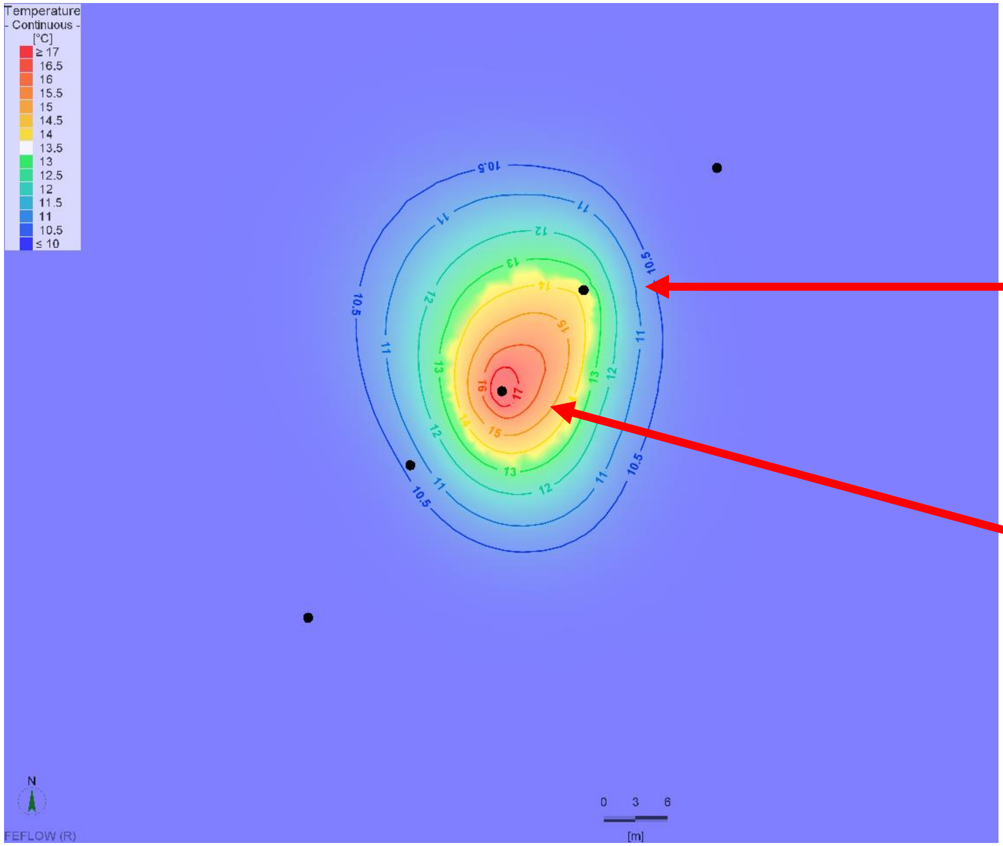
Injection & recovery well

Example of LT-ATES (ΔT = 6K) – Day 28

Thermal recycling helps containing the heat plume in the area of interest

gw flow direction

~10 m/y

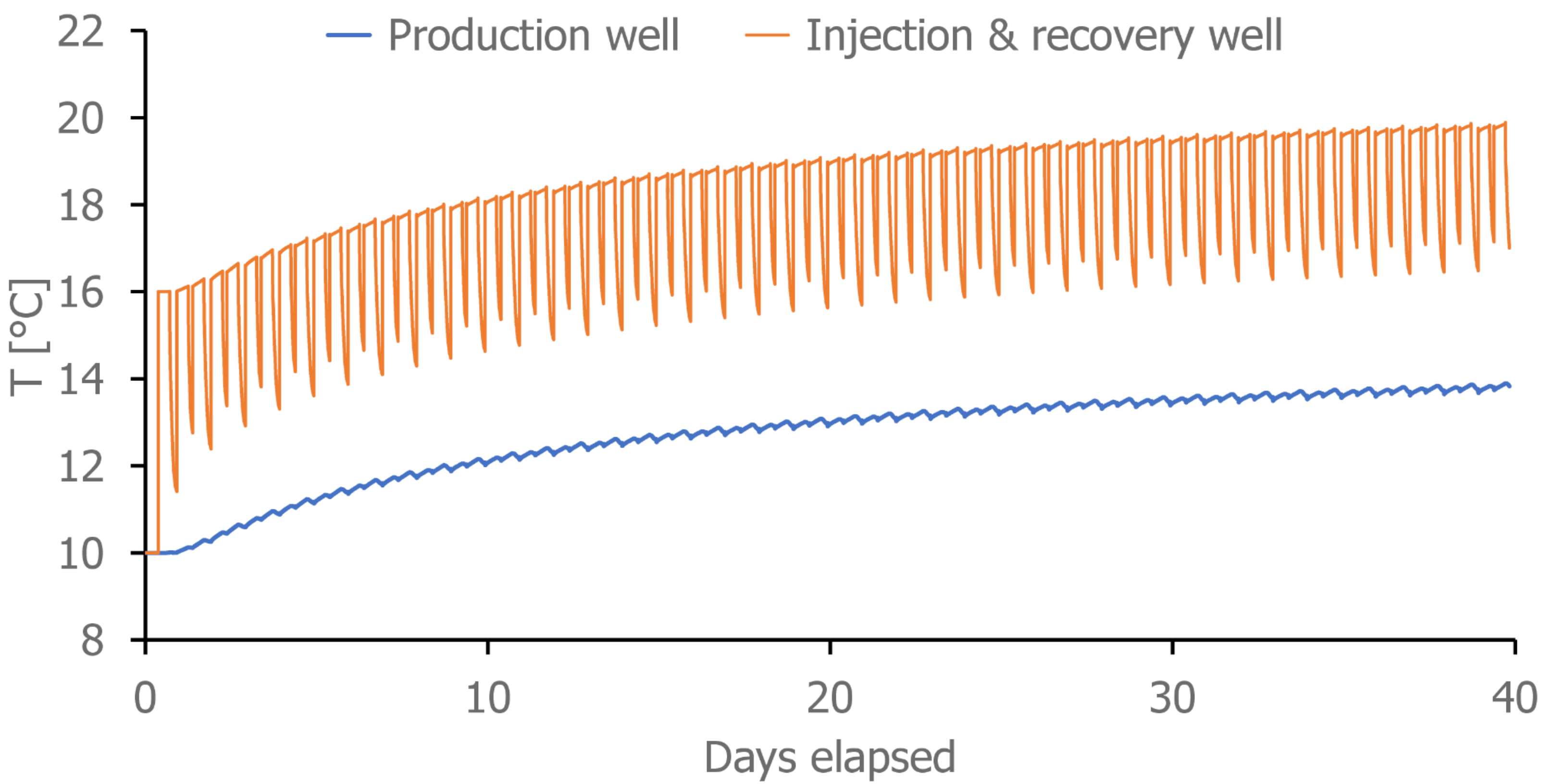


Production well

Injection & recovery well

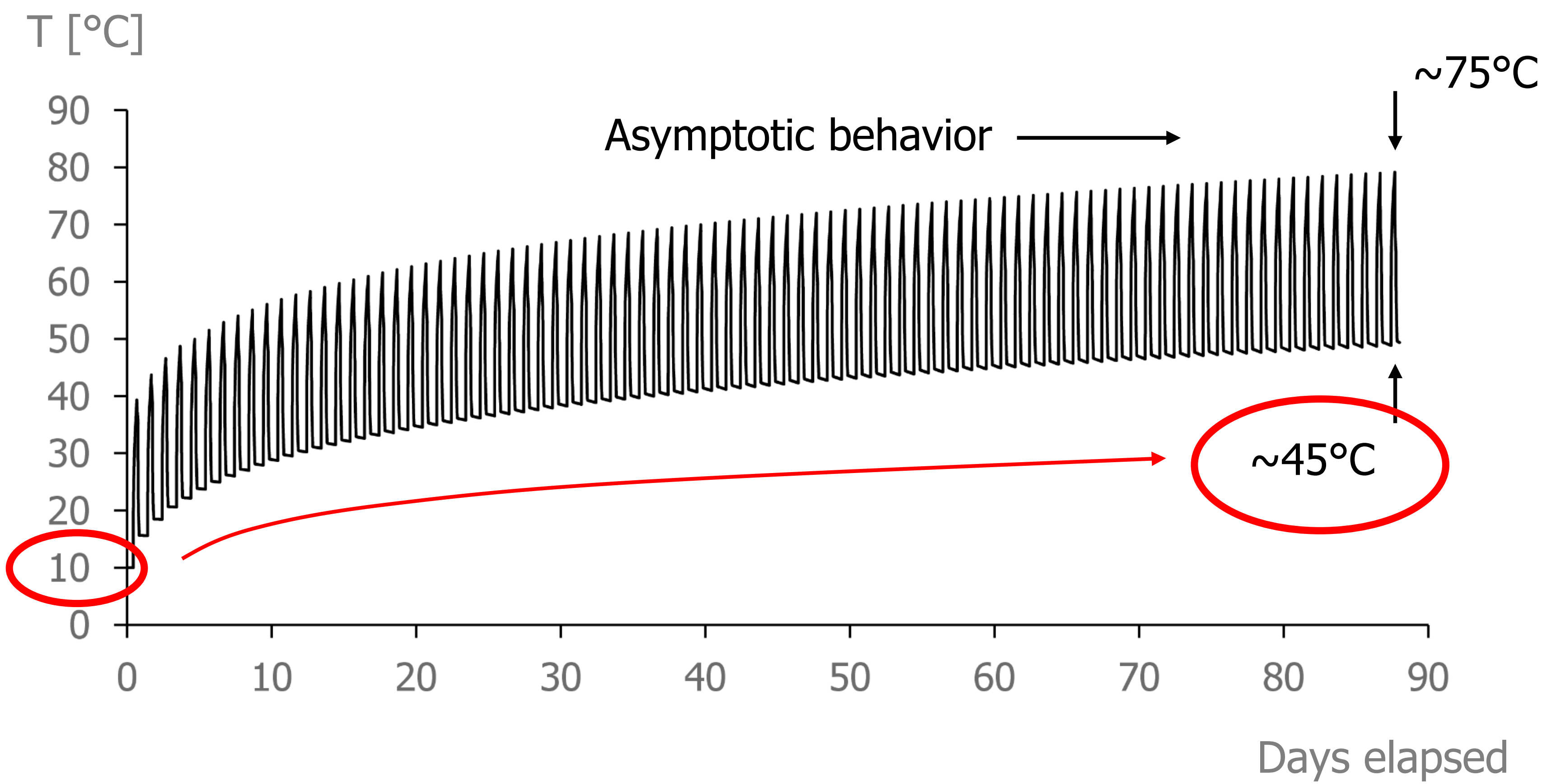
Example of LT-ATES (ΔT = 6K) – Day 35

For LT-ATES ($\Delta T = 6K$), this strategy works



Heat is stored during off-peak periods and recovered during peak periods (of heat demand)
Heat is then either stored or recovered for heating applications

For HT-ATES (ΔT = 30 K), thermal recycling allows to get rid of GWHP



Similar scenario but with a different ΔT

3 key messages

Alluvial aquifers are good targets for ATES

Thermal recycling contributes to increasing energy efficiency and its quality

Thermal recycling can be used to contain the heat plume near its injection point

More information…

Applied Energy 242 (2019) 534–546

Contents lists available at ScienceDirect

Applied Energy

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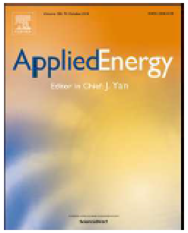
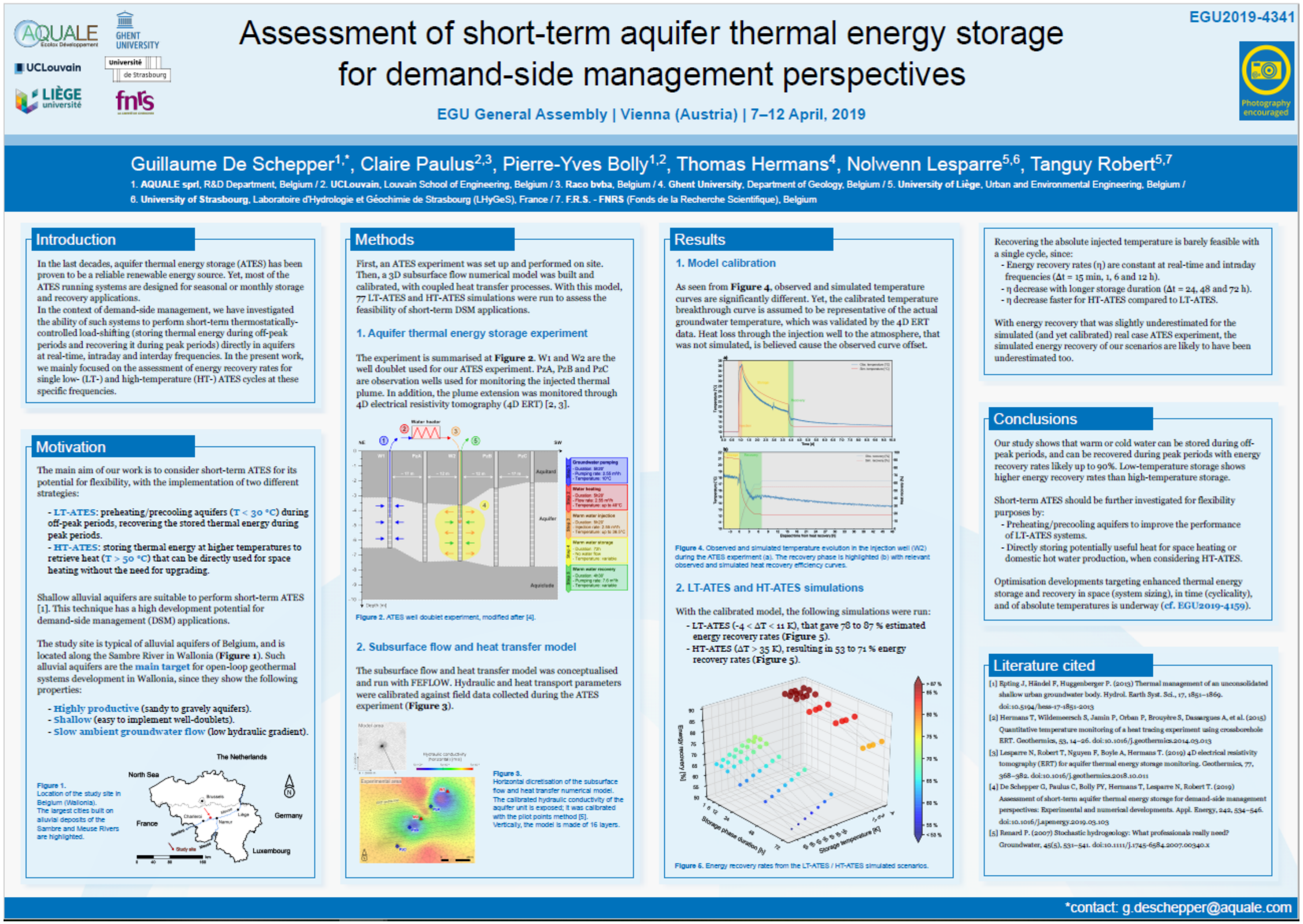


Assessment of short-term aquifer thermal energy storage for demand-side management perspectives: Experimental and numerical developments

Check for updates

Guillaume De Schepper[a,*], Claire Paulus[b,c], Pierre-Yves Bolly[a,c], Thomas Hermans[d], Nolwenn Lesparre[e,f], Tanguy Robert[e,g]

… & Guillaume's poster in the next session



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Thank you!

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More information on ATES

Full review: Fleuchaus et al. (2019) – RSER 94
Worldwide application of aquifer thermal energy storage – A review

HT-ATES: Wesselink et al. (2018) – Energy 147
Conceptual market potential framework of high temperature aquifer thermal energy storage - A case study in the Netherlands

Status: Haehnlein et al. (2010) – RSER 14
International legal status of the use of shallow geothermal energy

Policy: Haehnlein et al. (2013) – Energy Policy 59
Sustainability and policy for the thermal use of shallow geothermal energy

& many more…

Other references

Bonte, M. [2013]. *Impacts of shallow geothermal energy on groundwater quality: a hydrochemical and geomicrobial study of the effects of ground source heat pumps and aquifer thermal energy storage*. PhD thesis, Vrije Universiteit Amsterdam, NL

Dahash et al. [2019]. *Advances in seasonal thermal energy storage for solar district heating applications: A critical review on large-scale hot-water tank and pit thermal energy storage systems*. Applied Energy, 239, 296-315

De Schepper et al. [2019]. *Assessment of short-term aquifer thermal energy storage for demand-side management perspectives: Experimental and numerical developments*. Applied Energy, 242, 534-546

International Energy Agency (IEA) [2013]. *Transition to Sustainable Buildings: Strategies and Opportunities to 2050, Paris, France: Organisation for Economic Cooperation and development (OECD)*

Milnes, E., & Perrochet, P. [2013]. *Assessing the impact of thermal feedback and recycling in open-loop groundwater heat pump (GWHP) systems: a complementary design tool*. Hydrogeology Journal, 21, 505–514

Veolia [2018]. http://www.veoliawater2energy.com/fr/references/heat-pumps/