

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

Tanguy Robert & Guillaume De Schepper

Tanguy.Robert@uliege.be

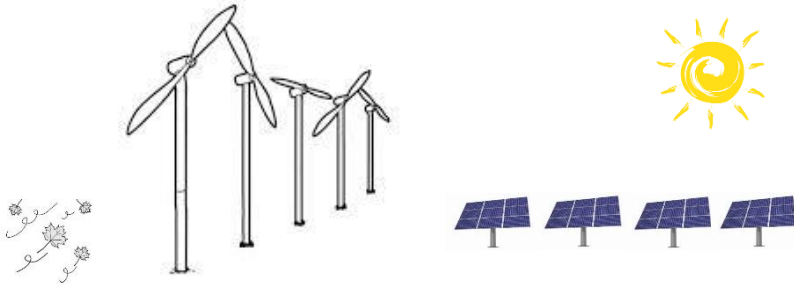
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Session HS8.2.3/ERE5.3
EGU2019-4159



What is demand-side management? (DSM)



Energy production

must be in balance with

energy consumption

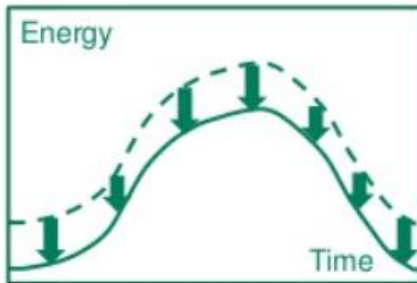


DSM offers flexibility but storage strategies are needed ...

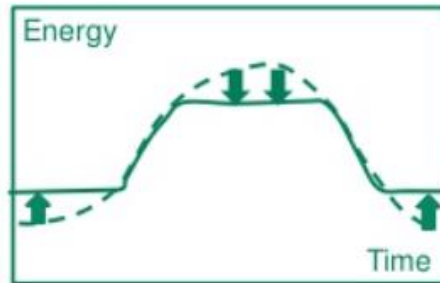


Smart Grid: How to reduce consumption

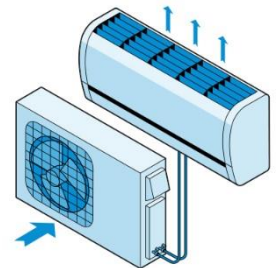
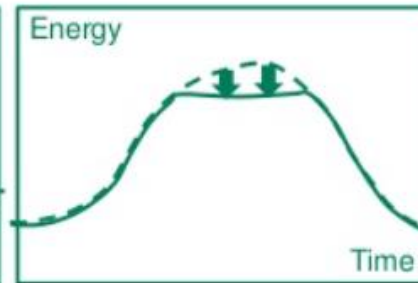
Energy Reduction



Load shifting



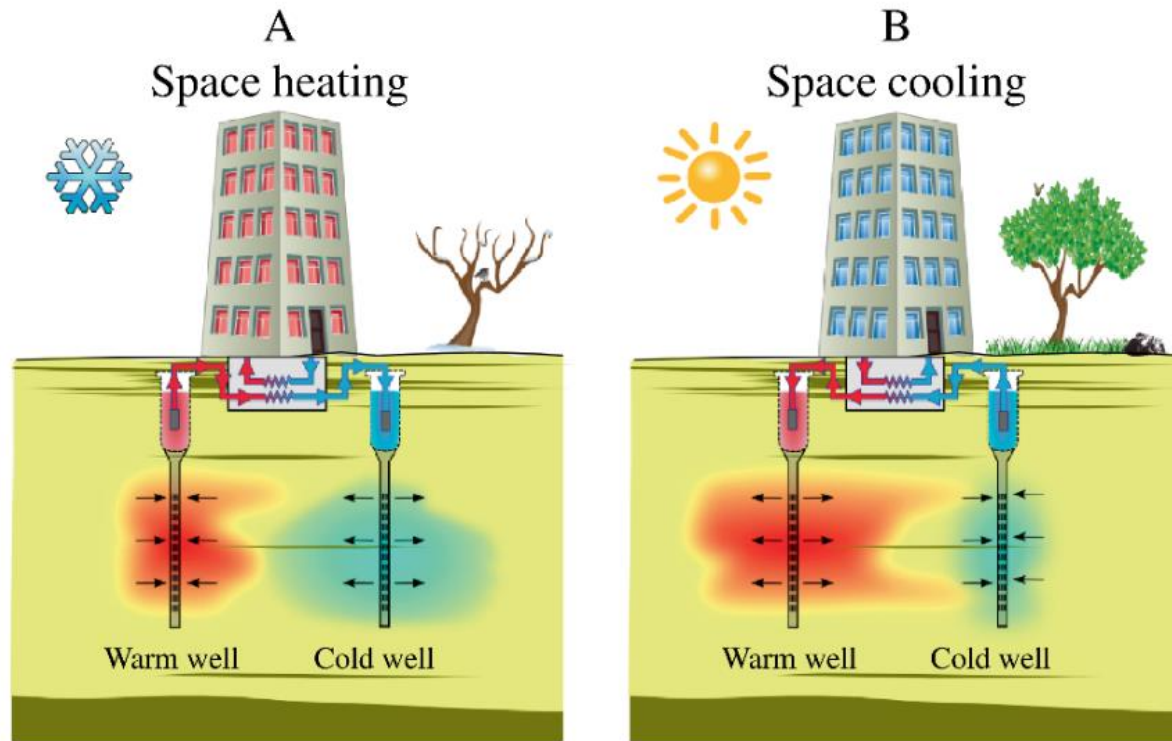
Peak Shaving



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

IEA (2013)

... ATES can provide this flexibility



Modified after Bonte (2013)

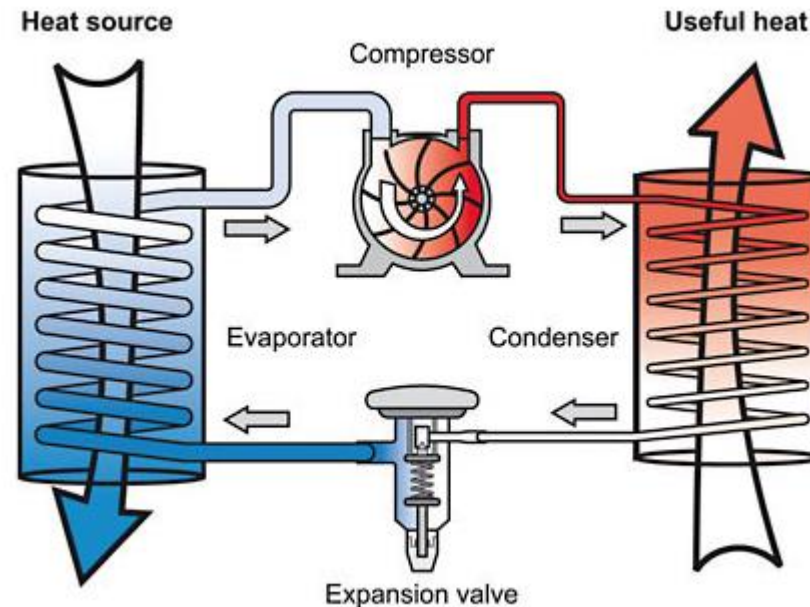
ATES is Aquifer Thermal Energy Storage

Ability to decouple heat and electricity demand (at least partially)

How? With the groundwater heat pump!

Electrical grid

Groundwater



Building

Figure from Veolia Water₂Energy (2018)

The efficiency of GWHP depends on temperatures

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

$$COP_{Heating} = 4 \text{ (@ } T_c = 10^\circ\text{C)}$$

$$= 5 \text{ (@ } T_c = 16^\circ\text{C)}$$

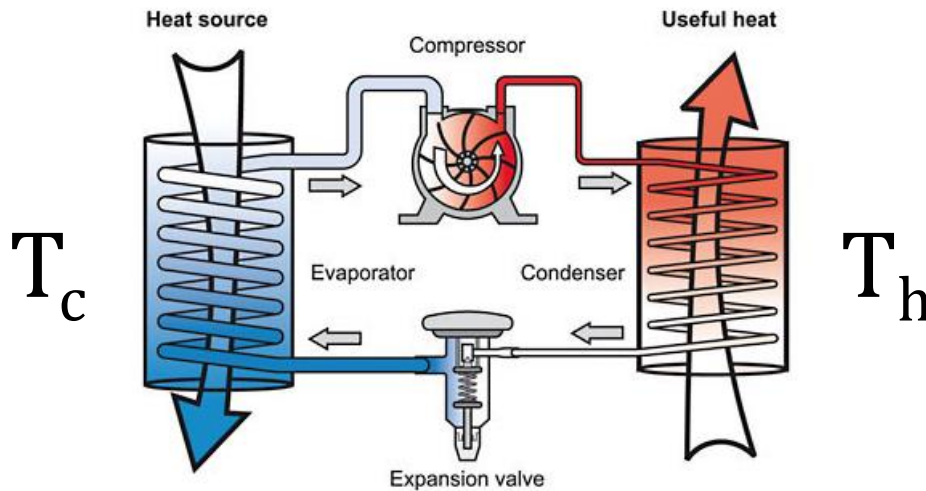
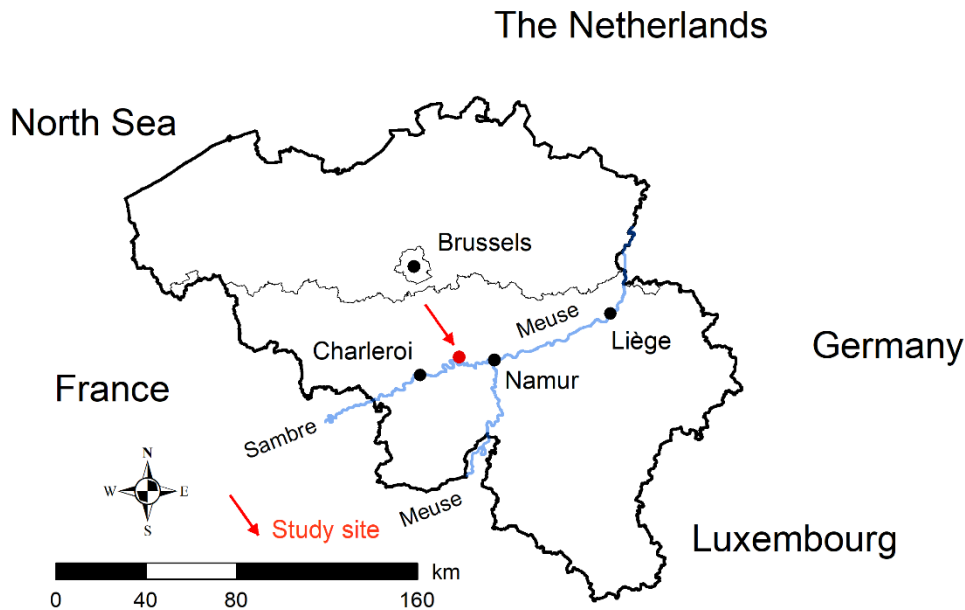


Figure from Veolia Water₂Energy (2018)

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

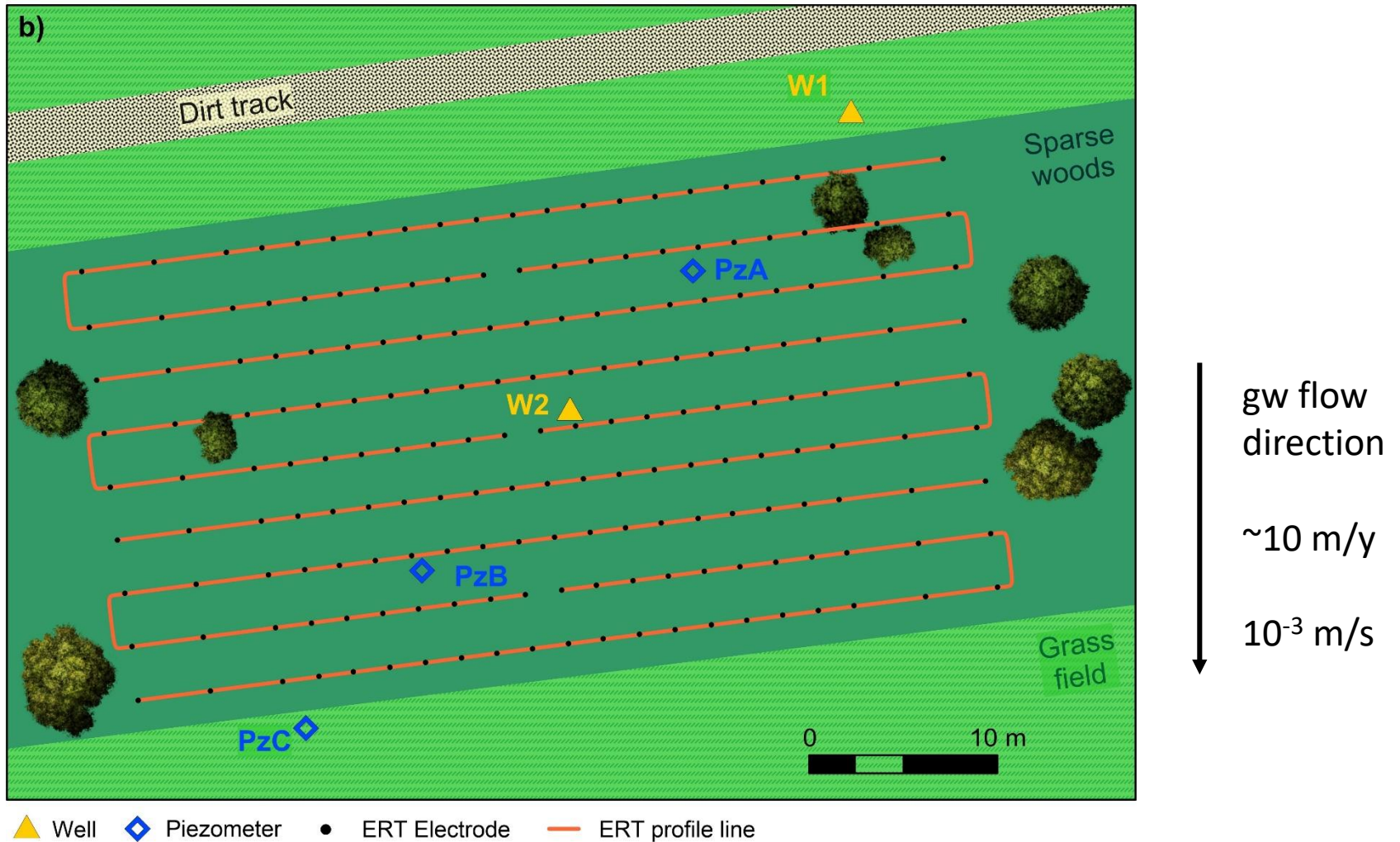
Alluvial aquifers are shallower

—————> Low installation costs

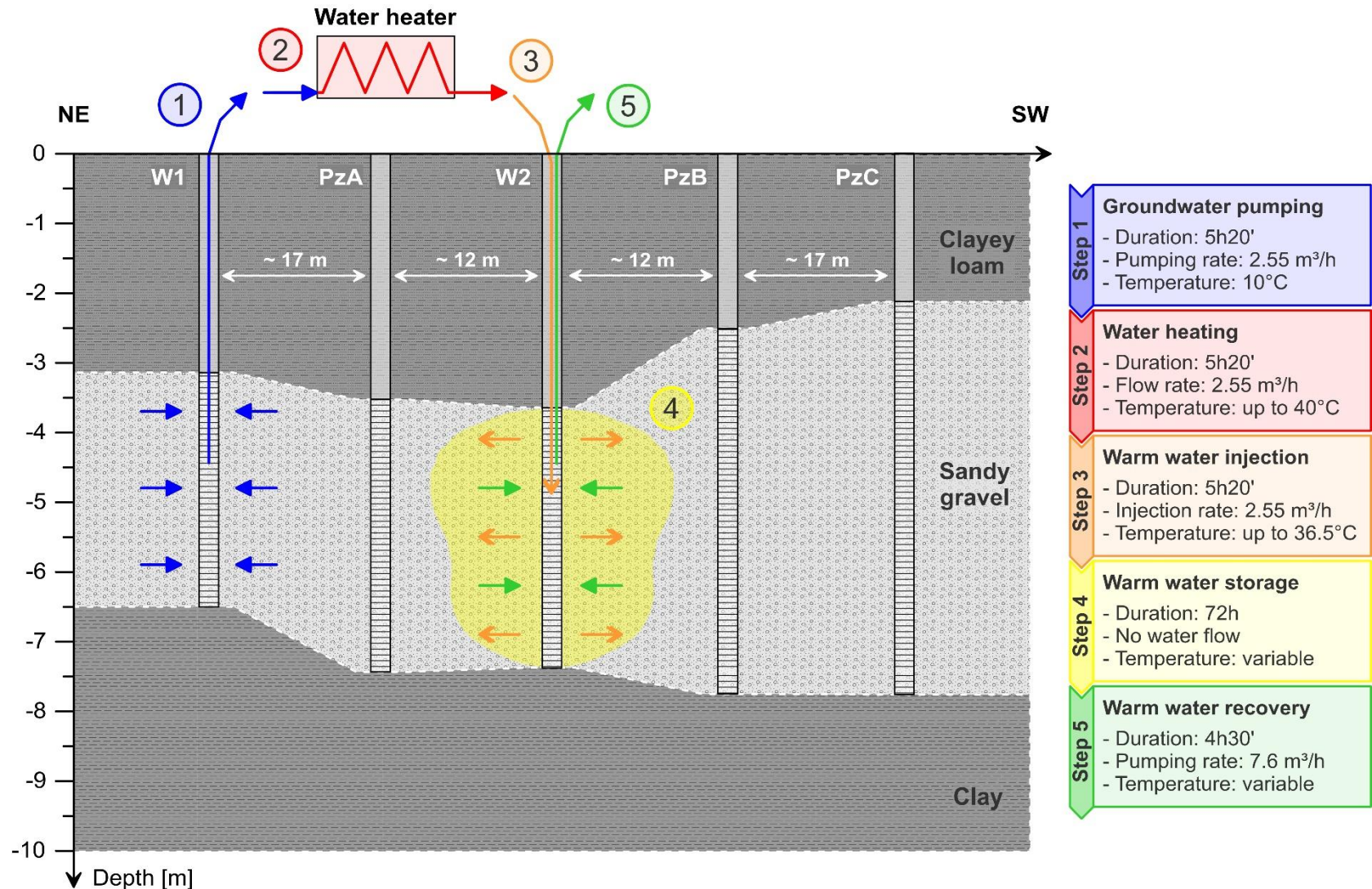
Alluvial aquifers present (poorer) quality

—————> No conflict with other applications

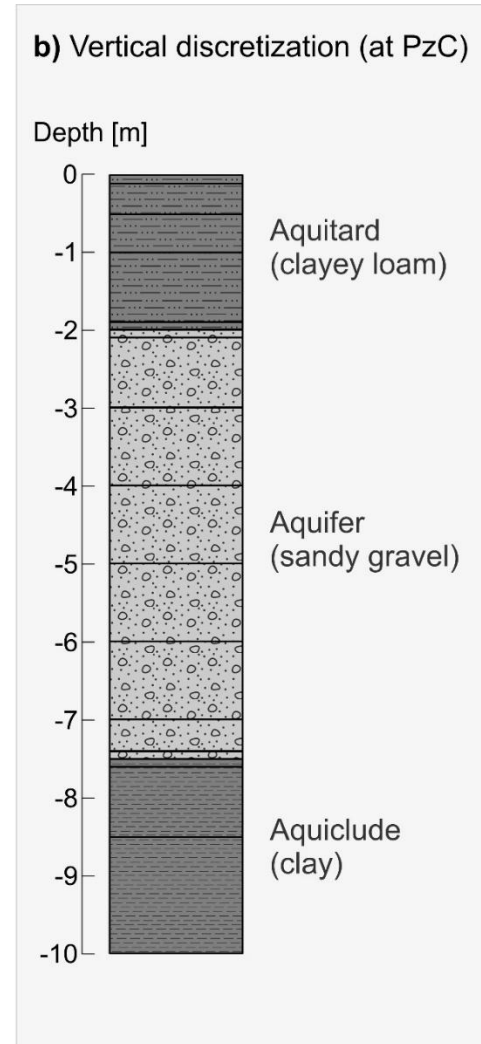
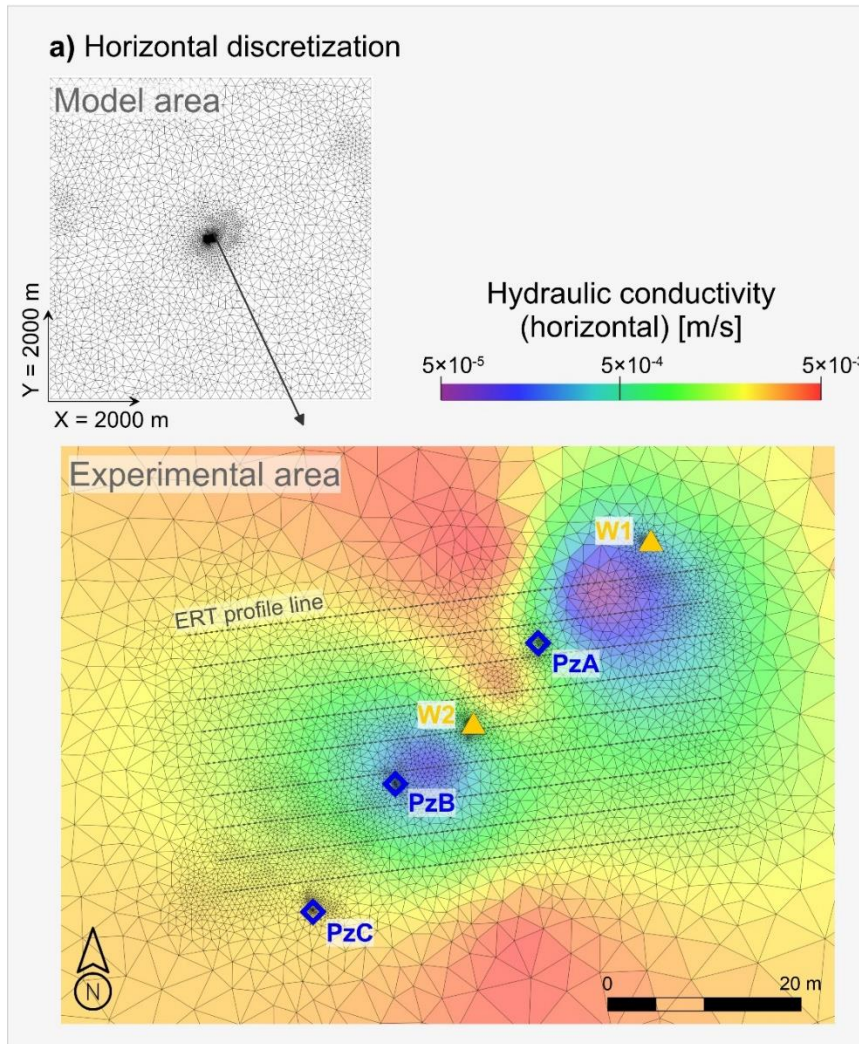
Our site is representative of shallow alluvial aquifers with slow ambient flow



We emulated an ATEES & recovery cycle



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



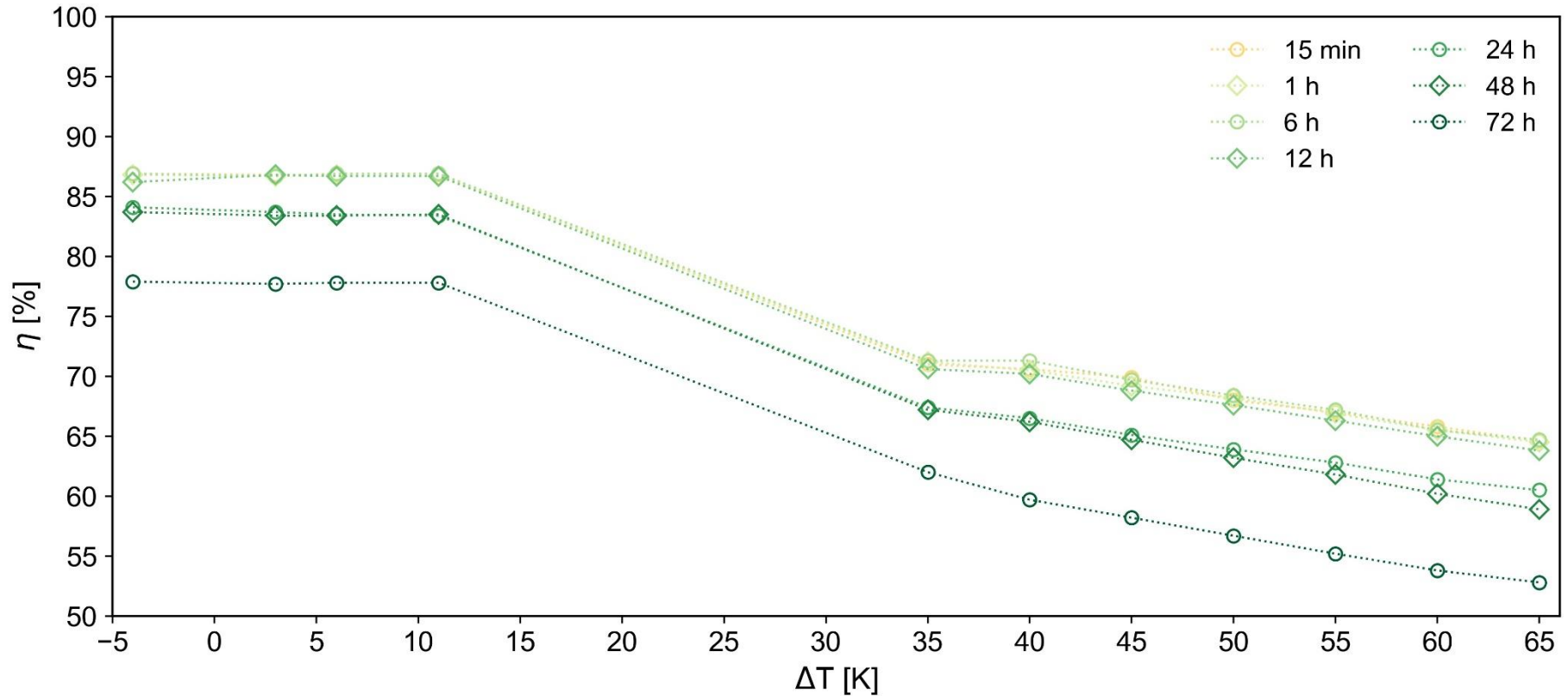
We ran 77 simulations

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

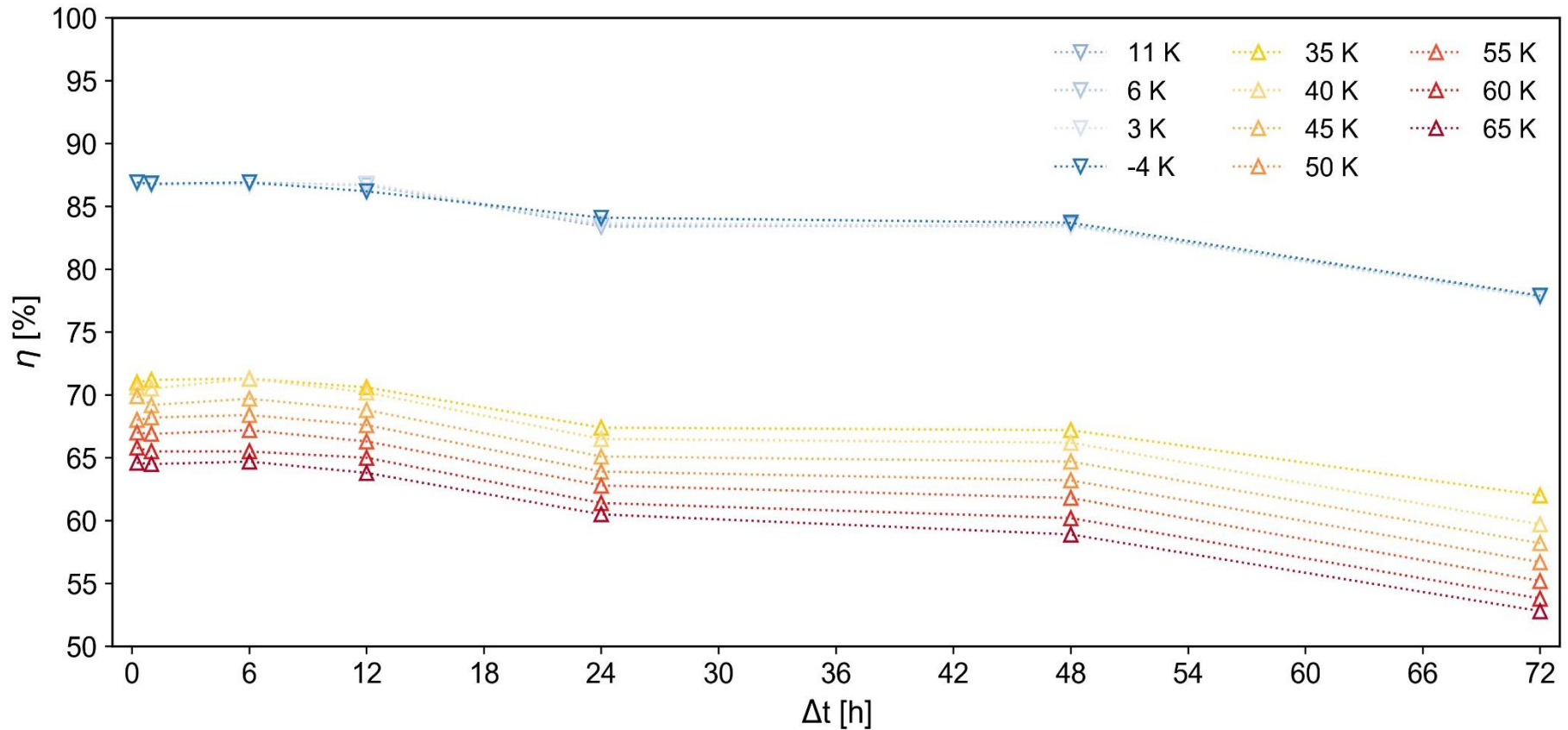
2nd idea: Strong increase in water temperature to get rid of GWHP

For now, just one cycle for comparison purposes

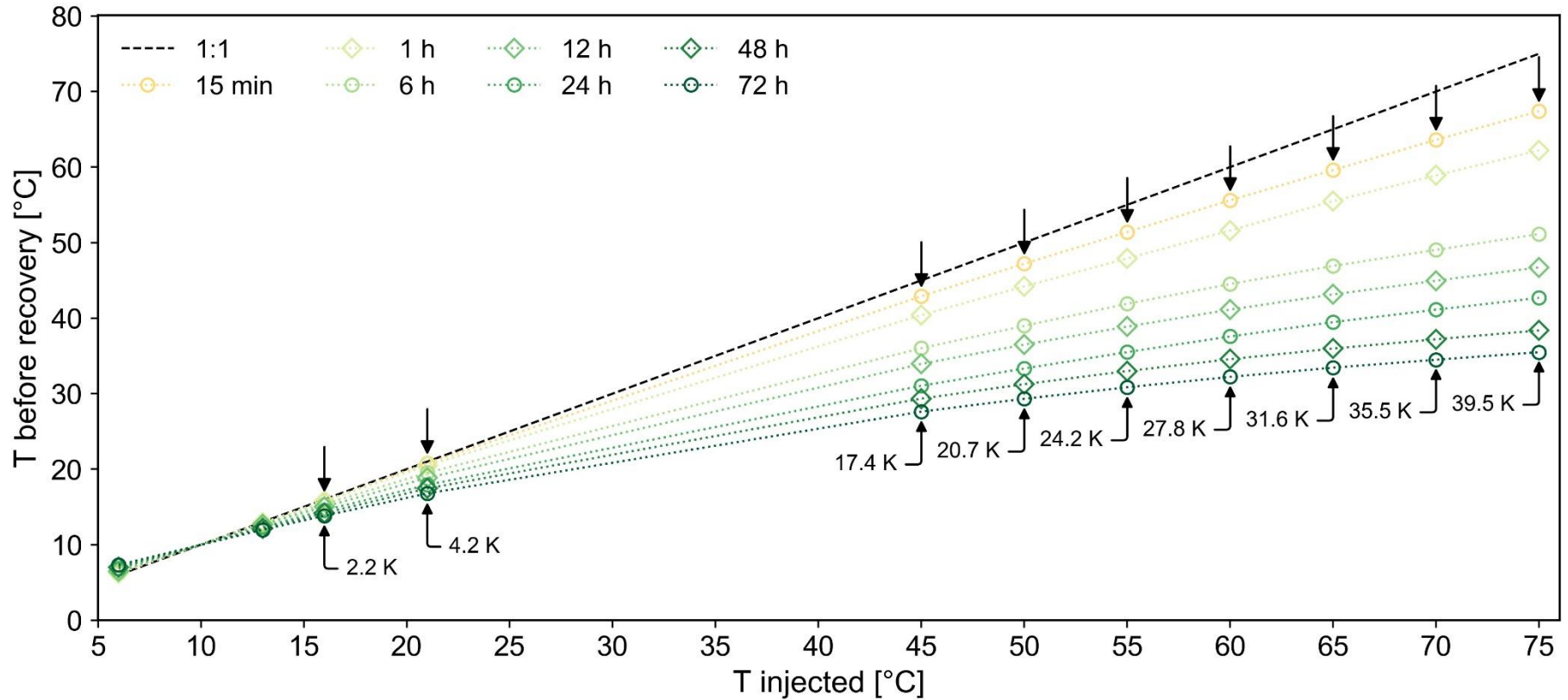
Energy recovery rates (η) decrease with increasing temperatures



Energy recovery rates (η) decrease with longer storage duration



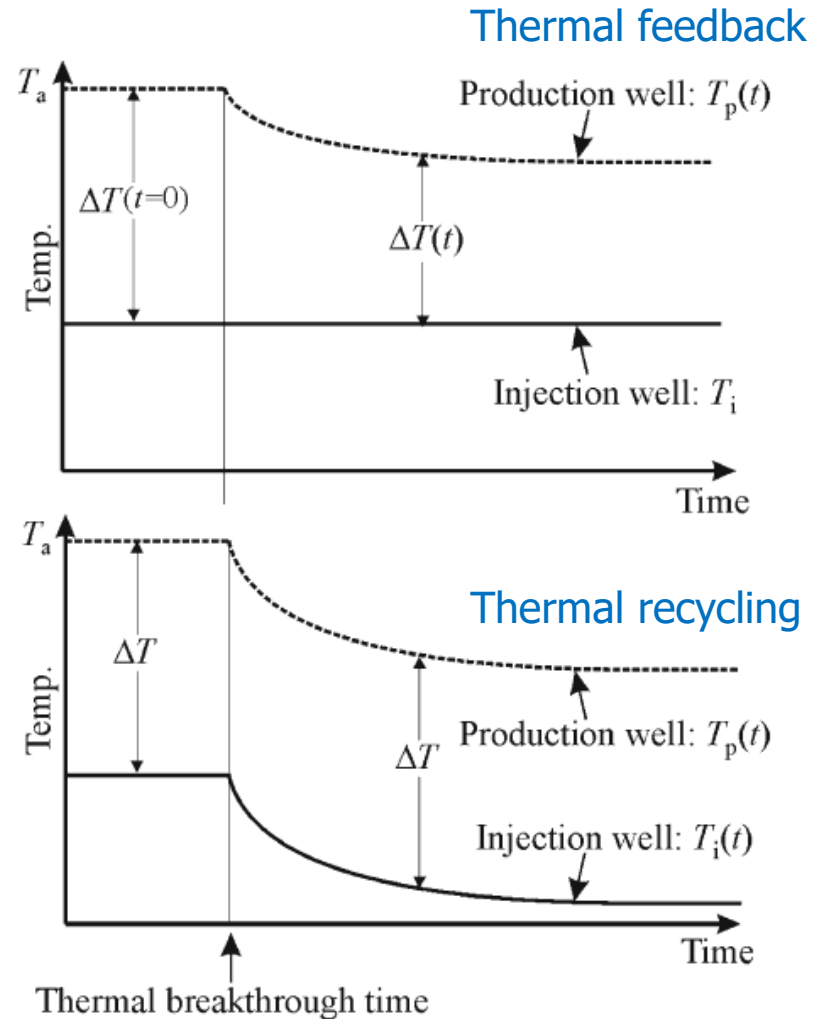
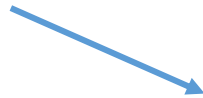
For HT-ATES, optimization is needed to get rid of GWHP



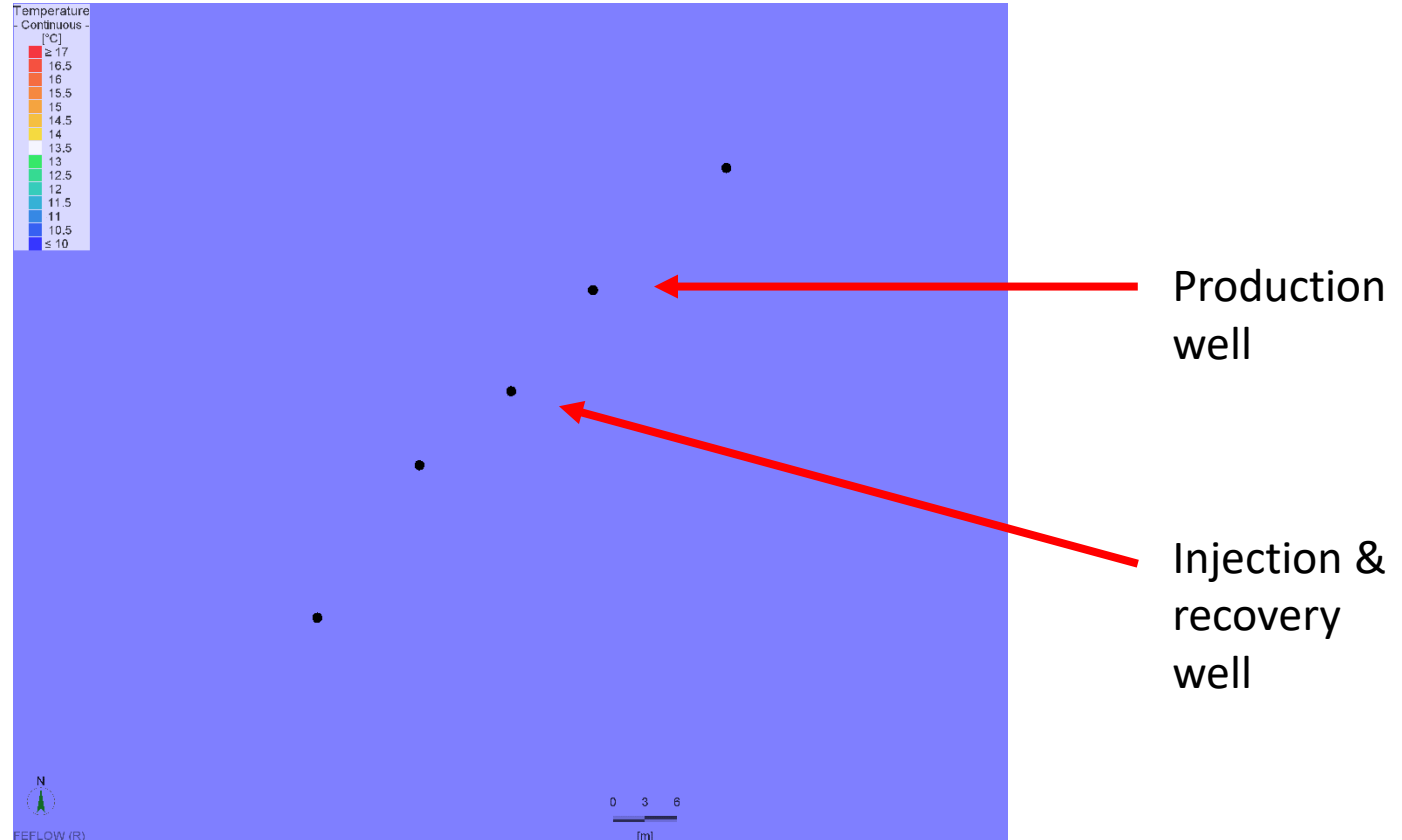
Other simulations

Idea:
Repeat ATES
& recovery cycles

This time,
with thermal recycling

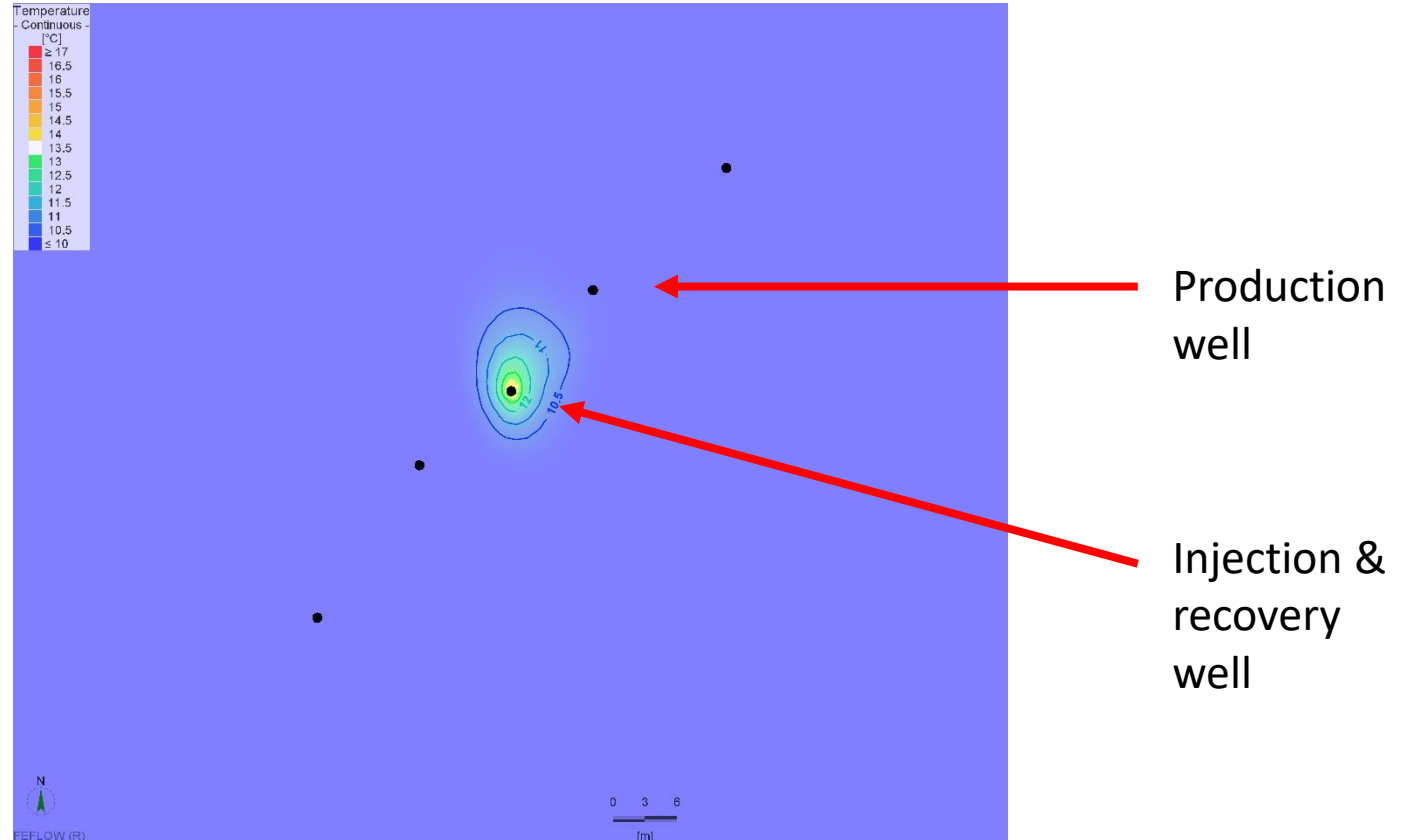


Thermal recycling helps containing the heat plume in the area of interest



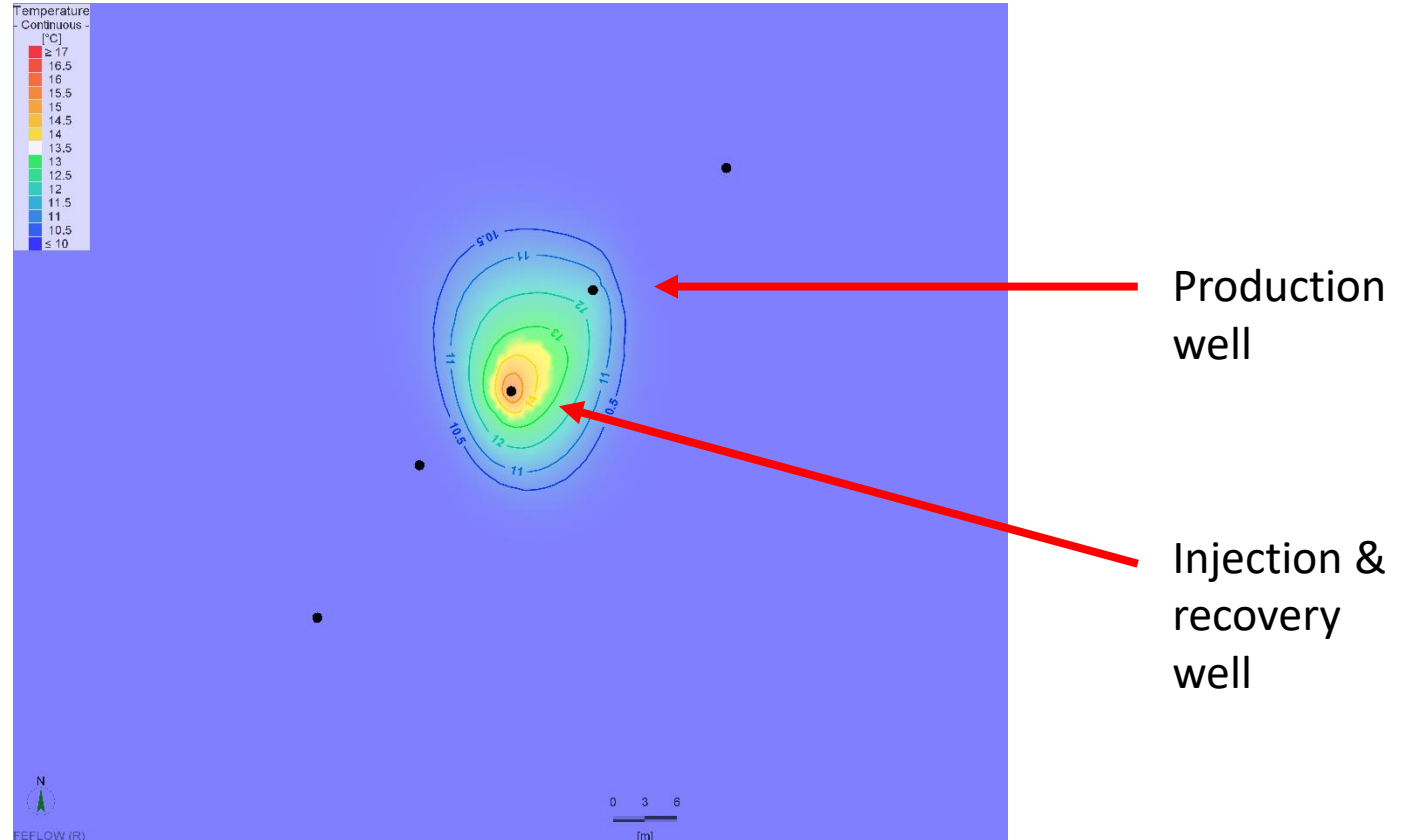
Example of LT-ATES ($\Delta T = 6K$) – **Day 0**

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



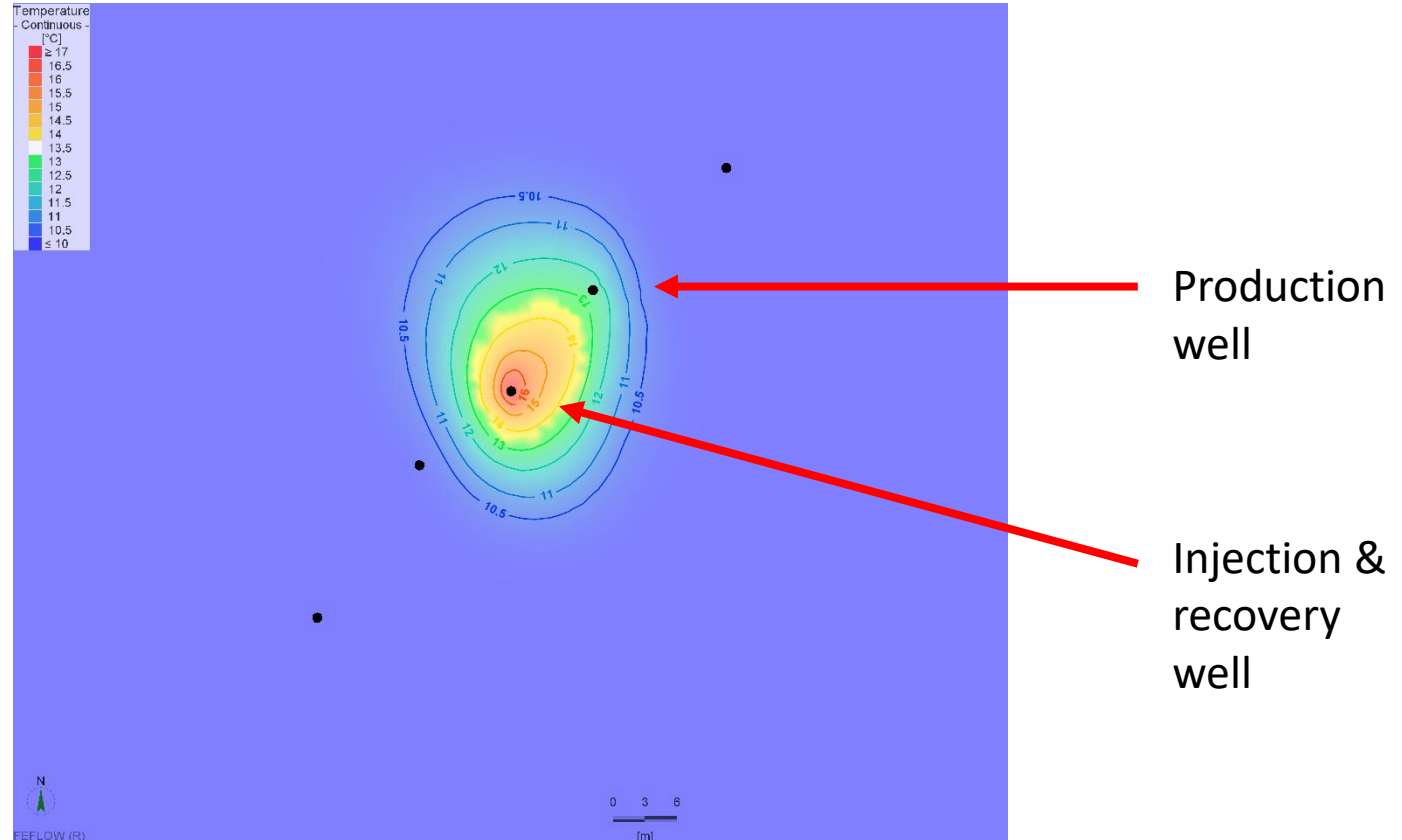
Example of LT-ATES ($\Delta T = 6K$) – **Day 1**

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



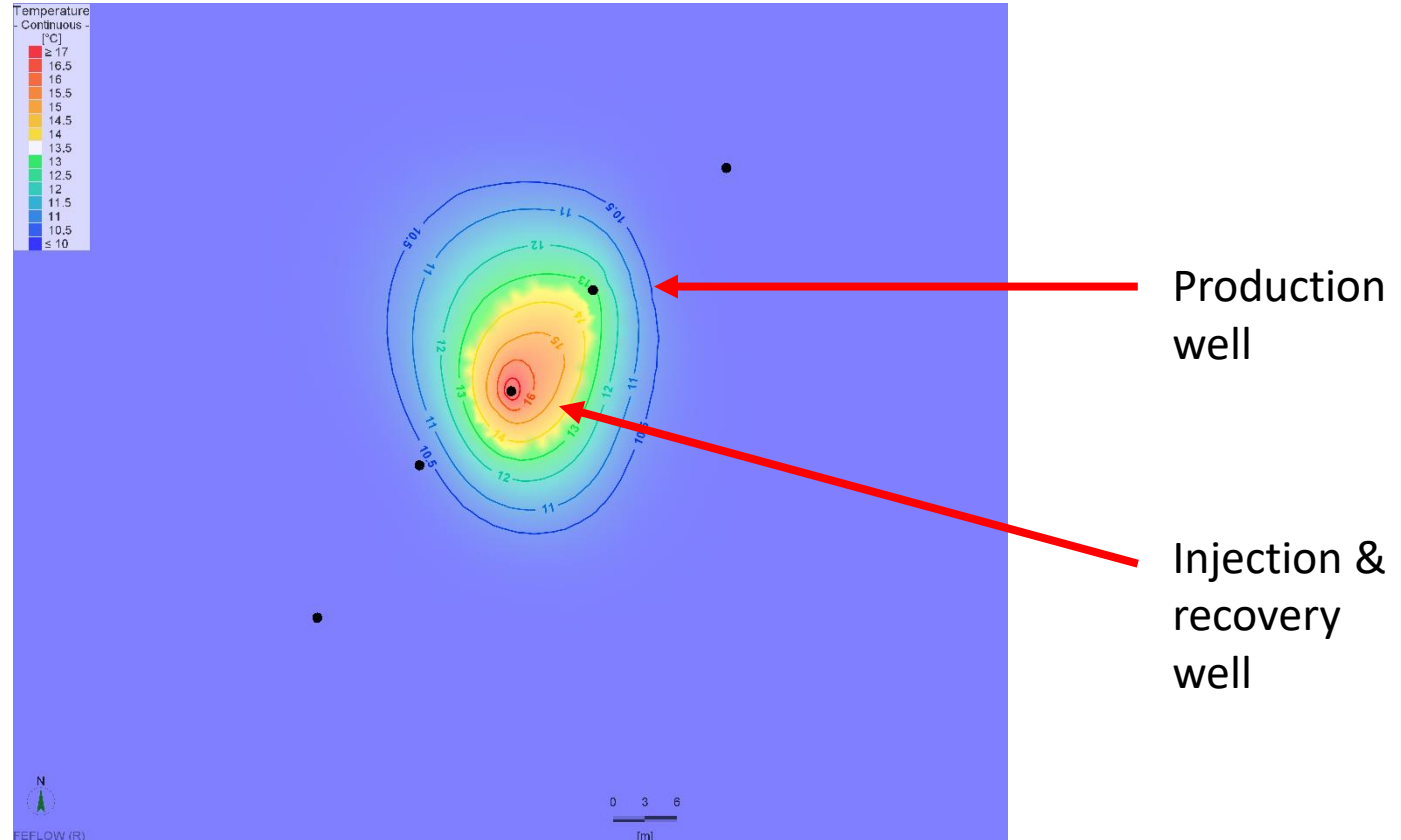
Example of LT-ATES ($\Delta T = 6K$) – **Day 7**

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



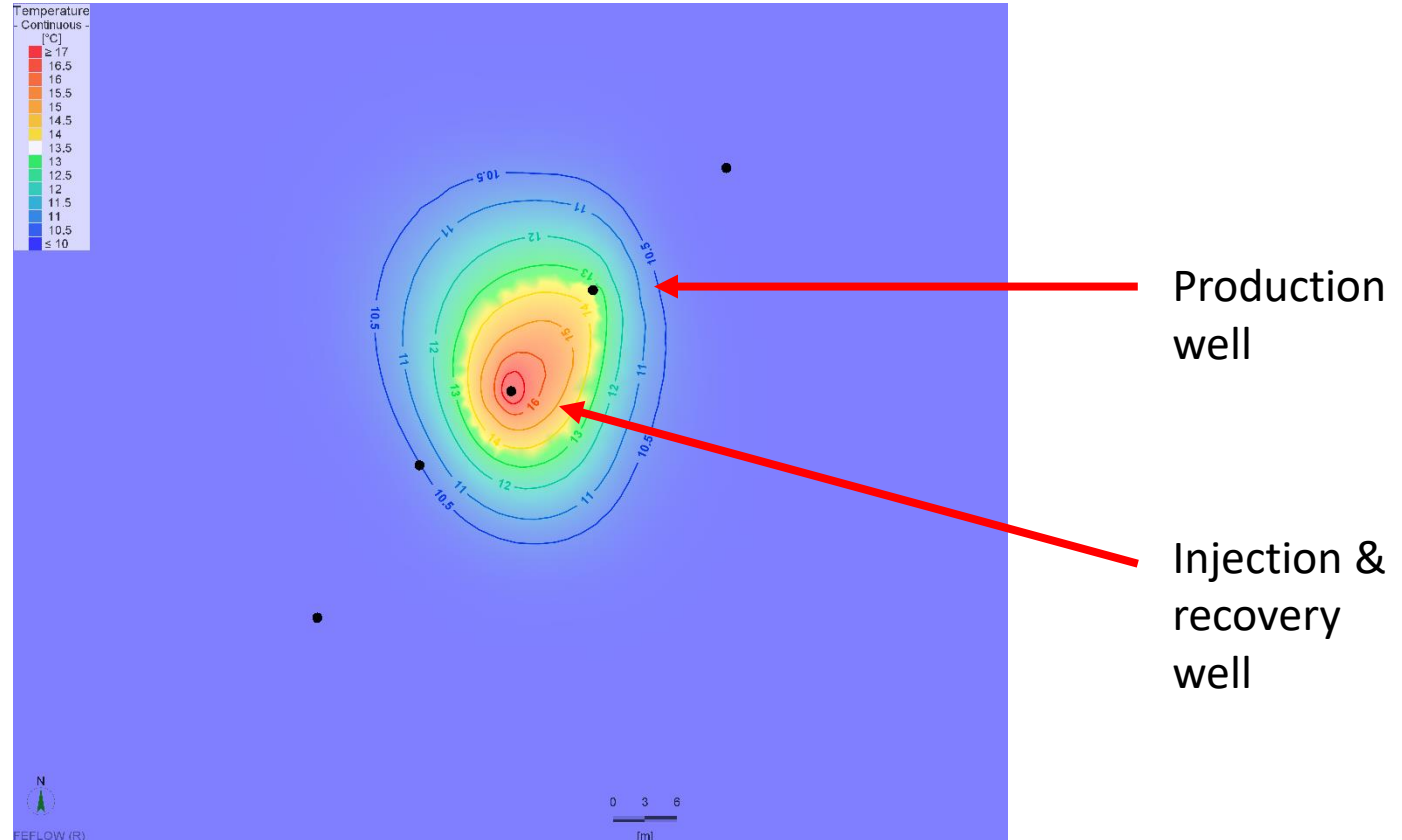
Example of LT-ATES ($\Delta T = 6K$) – **Day 14**

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



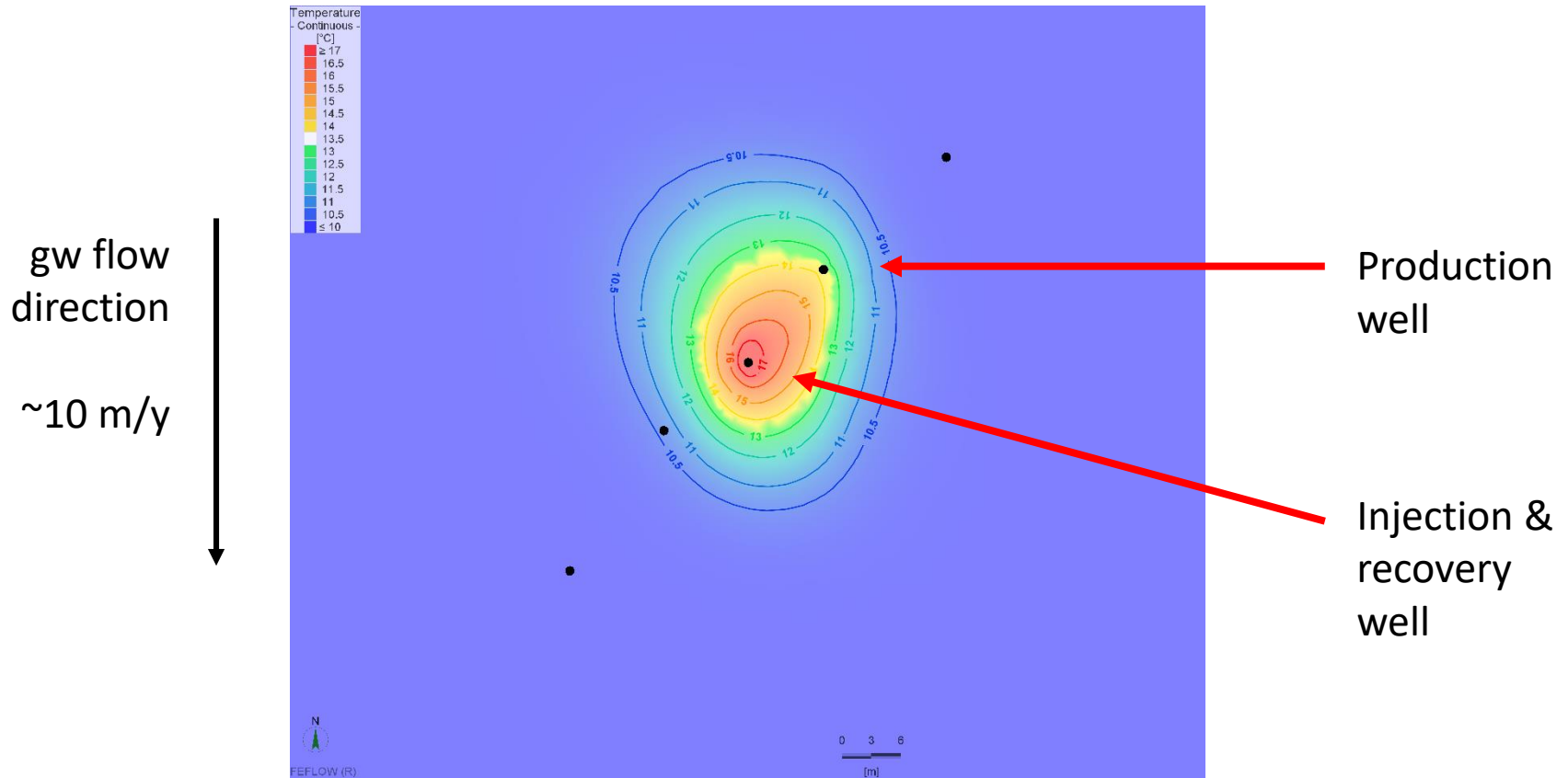
Example of LT-ATES ($\Delta T = 6K$) – **Day 21**

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



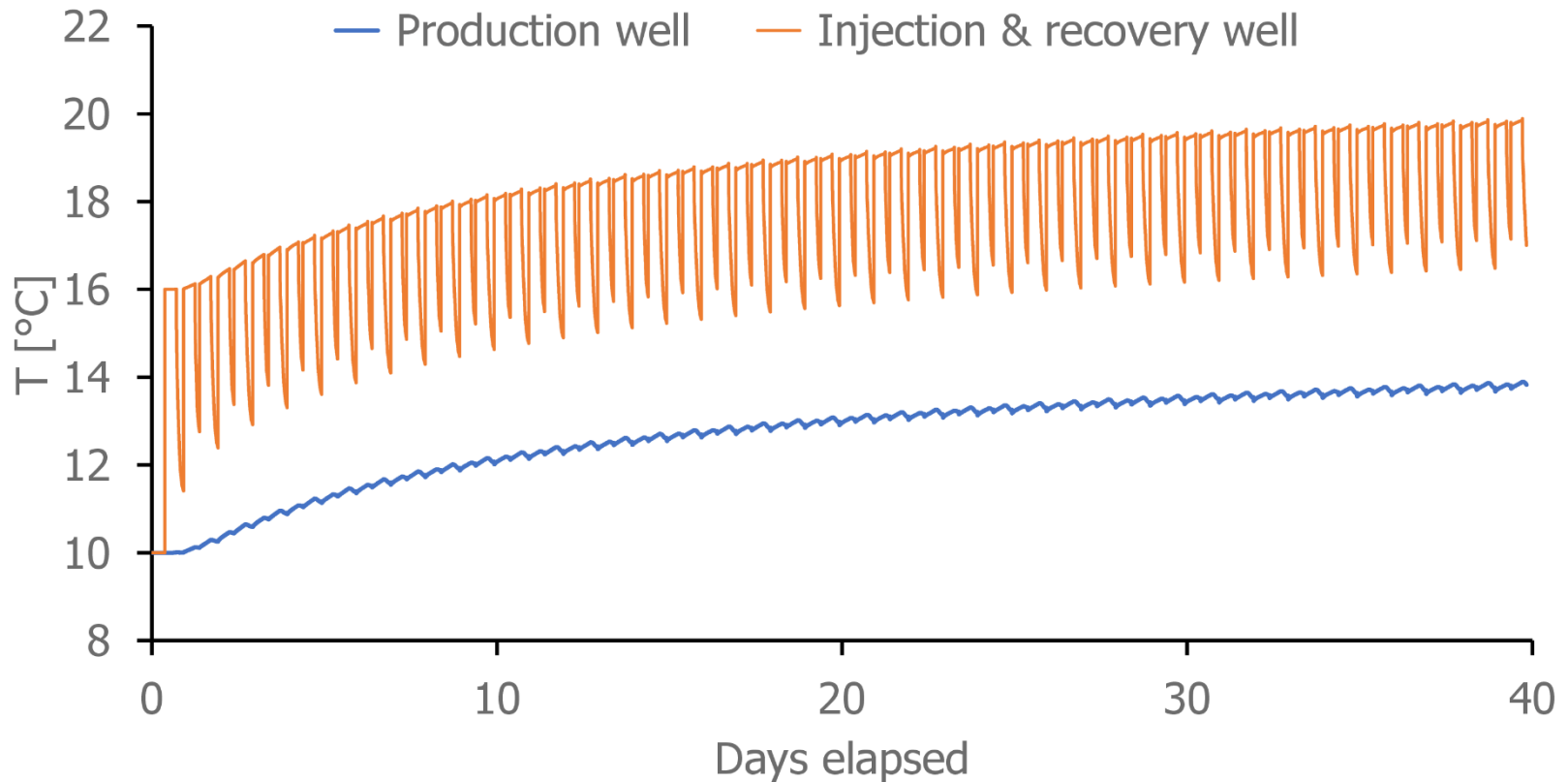
Example of LT-ATES ($\Delta T = 6K$) – **Day 28**

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



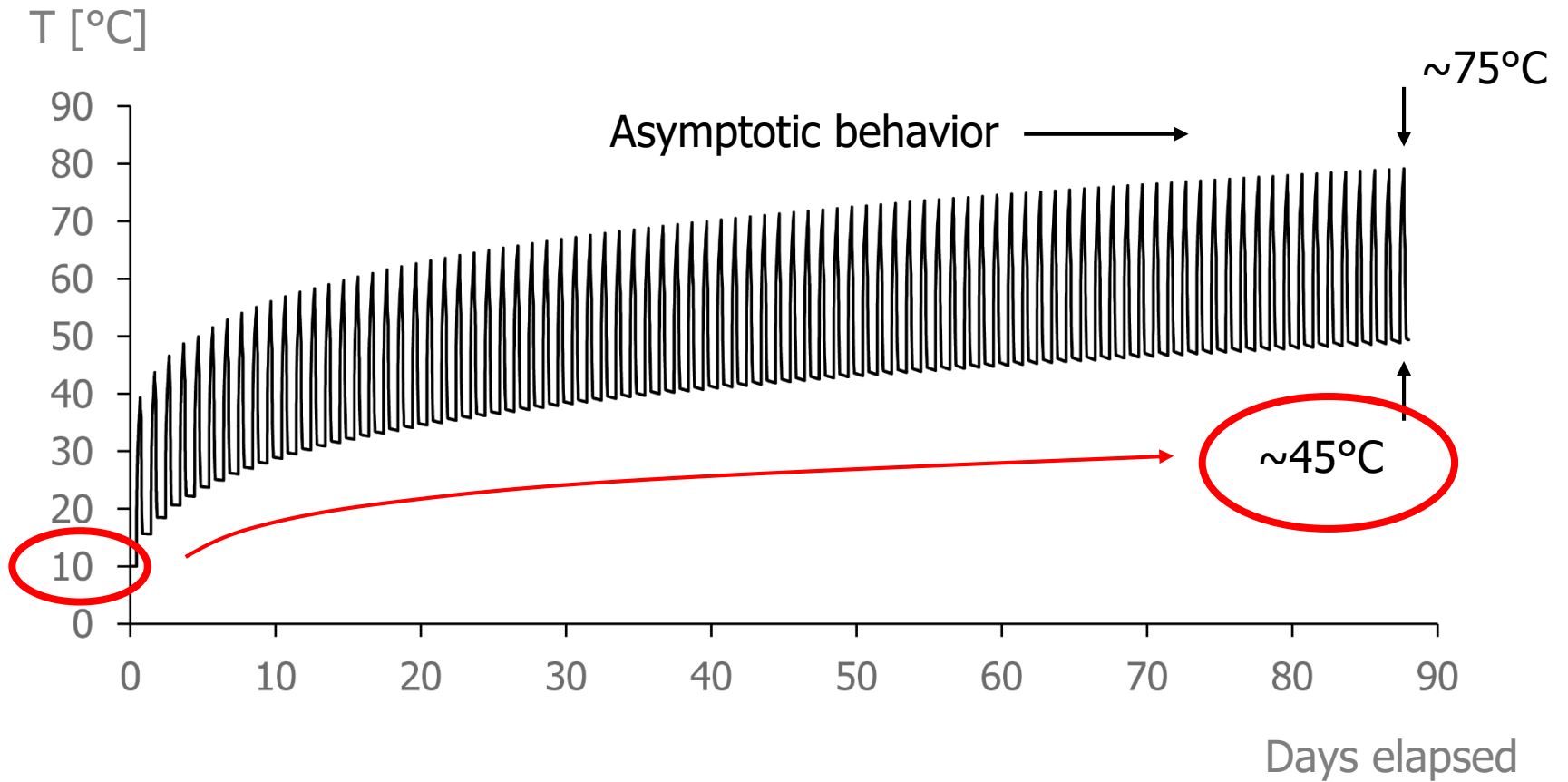
Example of LT-ATES ($\Delta T = 6K$) – **Day 35**

For LT-ATES ($\Delta T = 6\text{K}$), 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 ($\Delta T = 30$ 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...

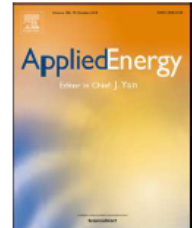
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Assessment of short-term aquifer thermal energy storage for demand-side management perspectives: Experimental and numerical developments

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

Assessment of short-term aquifer thermal energy storage for demand-side management perspectives

EGU General Assembly | Vienna (Austria) | 7-12 April, 2019

EGU2019-4341



Guillaume De Schepper^{1,*}, Claire Paulus^{2,3}, Pierre-Yves Bolly^{1,2}, Thomas Hermans⁴, Nolwenn Lesparre^{5,6}, Tanguy Robert^{5,7}

1. AQUALE sprl, R&D Department, Belgium / 2. UCLouvain, Louvain School of Engineering, Belgium / 3. Raco bvba, Belgium / 4. Ghent University, Department of Geology, Belgium / 5. University of Liège, Urban and Environmental Engineering, Belgium / 6. University of Strasbourg, Laboratoire d'Hydrologie et Géochimie de Strasbourg (LHyGeS), France / 7. F.R.S. - FNRS (Fonds de la Recherche Scientifique), Belgium

Introduction

In the last decades, aquifer thermal energy storage (ATES) has been proven to be a reliable renewable energy source. Yet, most of the ATES running systems are designed for seasonal or monthly storage and recovery applications. In the context of demand-side management, we have investigated the ability of such systems to perform short-term thermostatically-controlled load-shifting (storing thermal energy during off-peak periods and recovering it during peak periods) directly in aquifers at real-time, intraday and interday frequencies. In the present work, we mainly focused on the assessment of energy recovery rates for single low- (LT-) and high-temperature (HT-) ATES cycles at these specific frequencies.

Methods

First, an ATES experiment was set up and performed on site. Then, a 3D subsurface flow numerical model was built and calibrated, with coupled heat transfer processes. With this model, 77 LT-ATES and HT-ATES simulations were run to assess the feasibility of demand-side DSM applications.

1. Aquifer thermal energy storage experiment

The experiment is summarised at Figure 2. W1 and W2 are the well doublet used for our ATES experiment. PaA, PaB and PaC are observation wells used for monitoring the injected thermal plume. In addition, the plume extension was monitored through 4D electrical resistivity tomography (4D ERT) [2, 3].

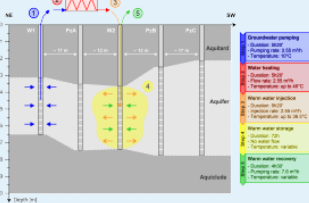


Figure 2. ATES well doublet experiment, modified after [4].

Results

1. Model calibration

As seen from Figure 4, observed and simulated temperature curves are significantly different. Yet, the calibrated temperature breakthrough curve is assumed to be representative of the actual groundwater temperature, which was validated by the 4D ERT data. Heat loss through the injection well to the atmosphere, that was not simulated, is believed cause the observed curve offset.

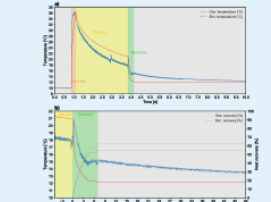


Figure 4. Observed and simulated temperature evolution in the injection well (W2) during the ATES experiment (a). The recovery phase is highlighted (b) with relevant observed and simulated heat recovery efficiency curves.

2. LT-ATES and HT-ATES simulations

With the calibrated model, the following simulations were run:

- LT-ATES ($\Delta T < 11$ K) that gave 70 to 87 % estimated energy recovery rates (Figure 5).
- HT-ATES ($\Delta T > 35$ K), resulting in 53 to 71 % energy recovery rates (Figure 5).

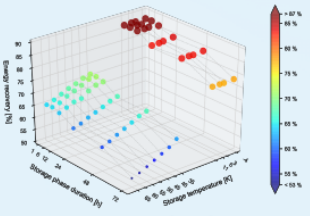


Figure 5. Energy recovery rates from the LT-ATES / HT-ATES simulated scenarios.

Motivation

The main aim of our work is to consider short-term ATES for its potential for flexibility, with the implementation of two different strategies:

- LT-ATES: preheating/precooling aquifers ($T < 30$ °C) during off-peak periods, recovering the stored thermal energy during peak periods.
- HT-ATES: storing thermal energy at higher temperatures to retrieve heat ($T > 50$ °C) that can be directly used for space heating without the need for upgrading.

Shallow alluvial aquifers are suitable to perform short-term ATES [1]. This technique has a high development potential for demand-side management (DSM) applications.

The study site is typical of alluvial aquifers of Belgium, and is located along the Sambre River in Wallonia (Figure 1). Such alluvial aquifers are the main target for open-loop geothermal systems development in Wallonia, since they show the following properties:

- Highly productive (sandy to gravelly aquifers).
- Shallow (easy to implement well-doublets).
- Slow ambient groundwater flow (low hydraulic gradient).

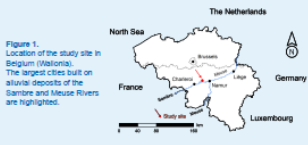


Figure 1. Location of the study site in Belgium (Wallonia). The largest cities built on alluvial deposits of the Sambre and Meuse rivers are highlighted.

Conclusions

Our study shows that warm or cold water can be stored during off-peak periods, and can be recovered during peak periods with energy recovery rates likely up to 90%. Low-temperature storage shows higher energy recovery rates than high-temperature storage.

Short-term ATES should be further investigated for flexibility purposes by:

- Preheating/precooling aquifers to improve the performance of LT-ATES systems.
- Directly storing potentially useful heat for space heating or domestic hot water production, when considering HT-ATES.

Optimisation developments targeting enhanced thermal energy storage and recovery in space (system sizing), in time (cyclicality), and of absolute temperatures is underway (cf. EGU2019-4159).

Literature cited

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[4] De Schepper G., Paulus C., Bolly PY, Hermans T., Lesparre N., Robert T. (2019) Assessment of short-term aquifer thermal energy storage for demand-side management perspectives: Experimental and numerical developments. *Appl. Energy*, 244, 534-545. doi:10.1016/j.apenergy.2019.05.005

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*contact: g.deschepper@aquale.com

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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...

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