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Novel Reservoir Modelling & Simulation

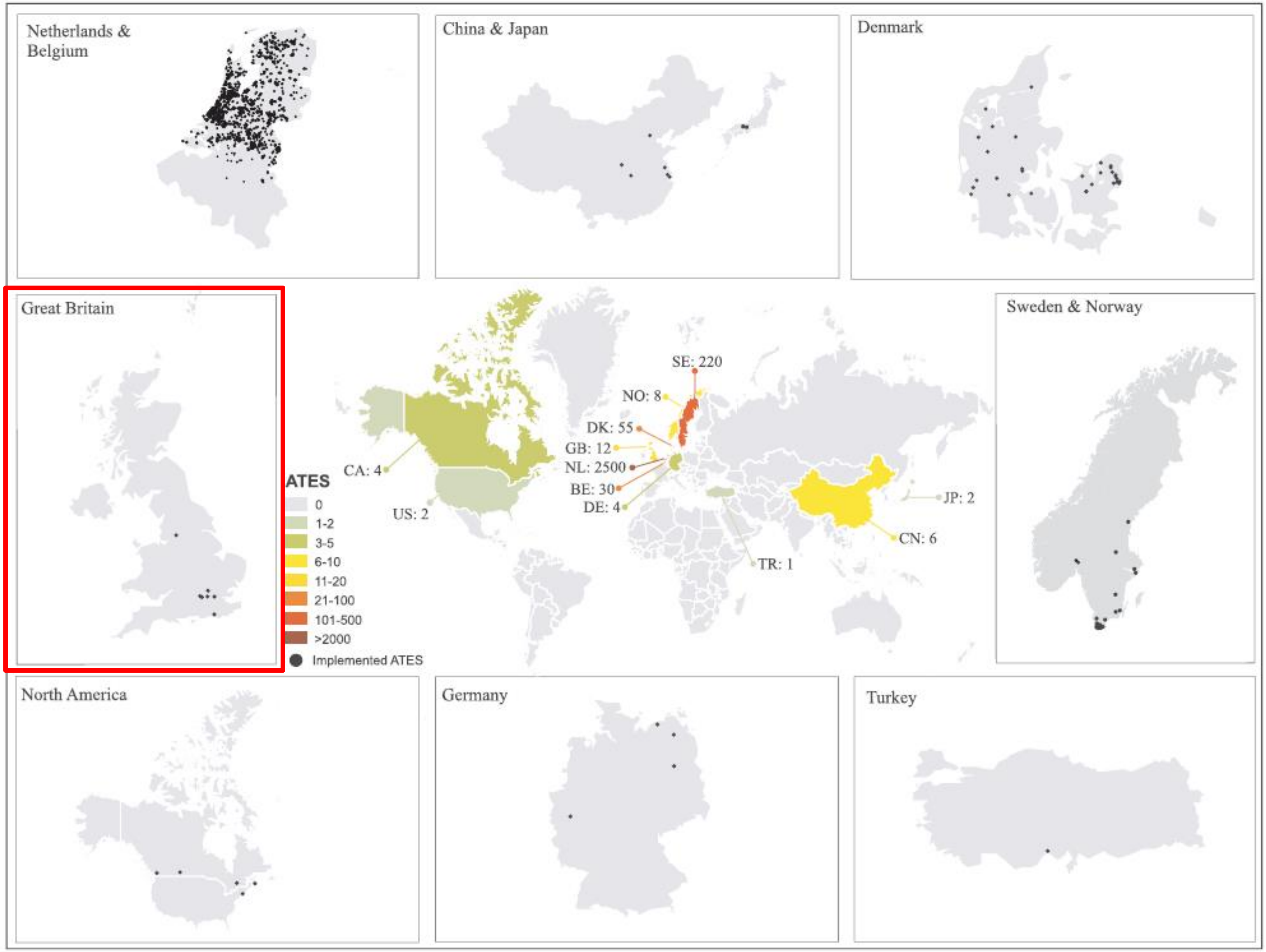
Aquifer Thermal Energy Storage in the UK: Current Status and Future Prospects

Carl Jacquemyn, Geraldine Regnier, Hayley Firth, Matt Jackson

2nd European Workshop on Underground Energy Storage
23-24 May 2023

GEOTHERMAL DHC
Towards Decarbonized Heating and Cooling!

ATES: Global spatial distribution



Fleuchaus et al. *Ren. Sust. Energy Rev.* (2018)

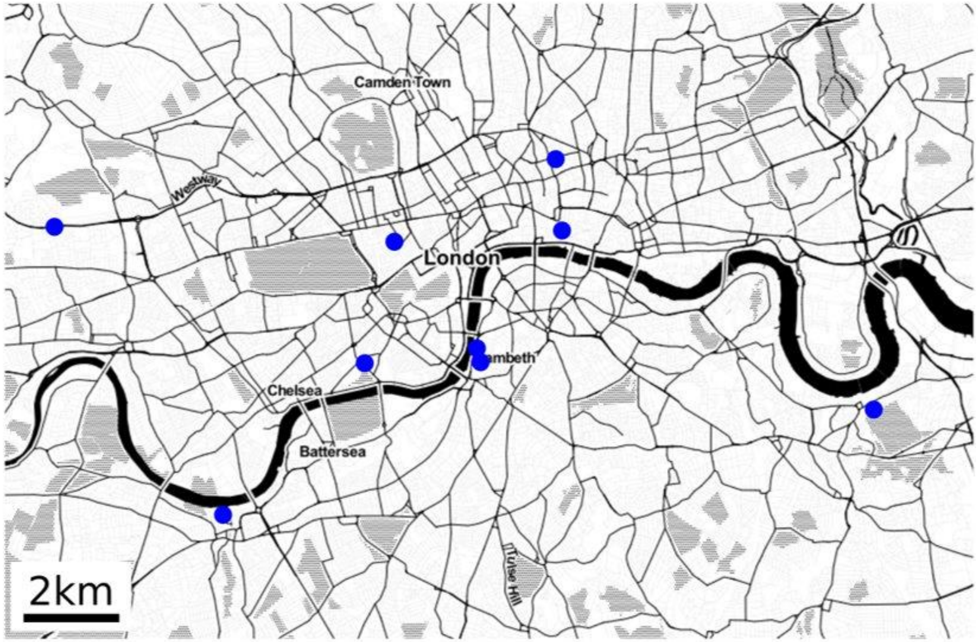
ATES in the UK

- 11 deployments identified plus one currently under development

- 9 in London
- 1 in Brighton

} Chalk

- 1 in Trafford } Permo-Triassic sandstone



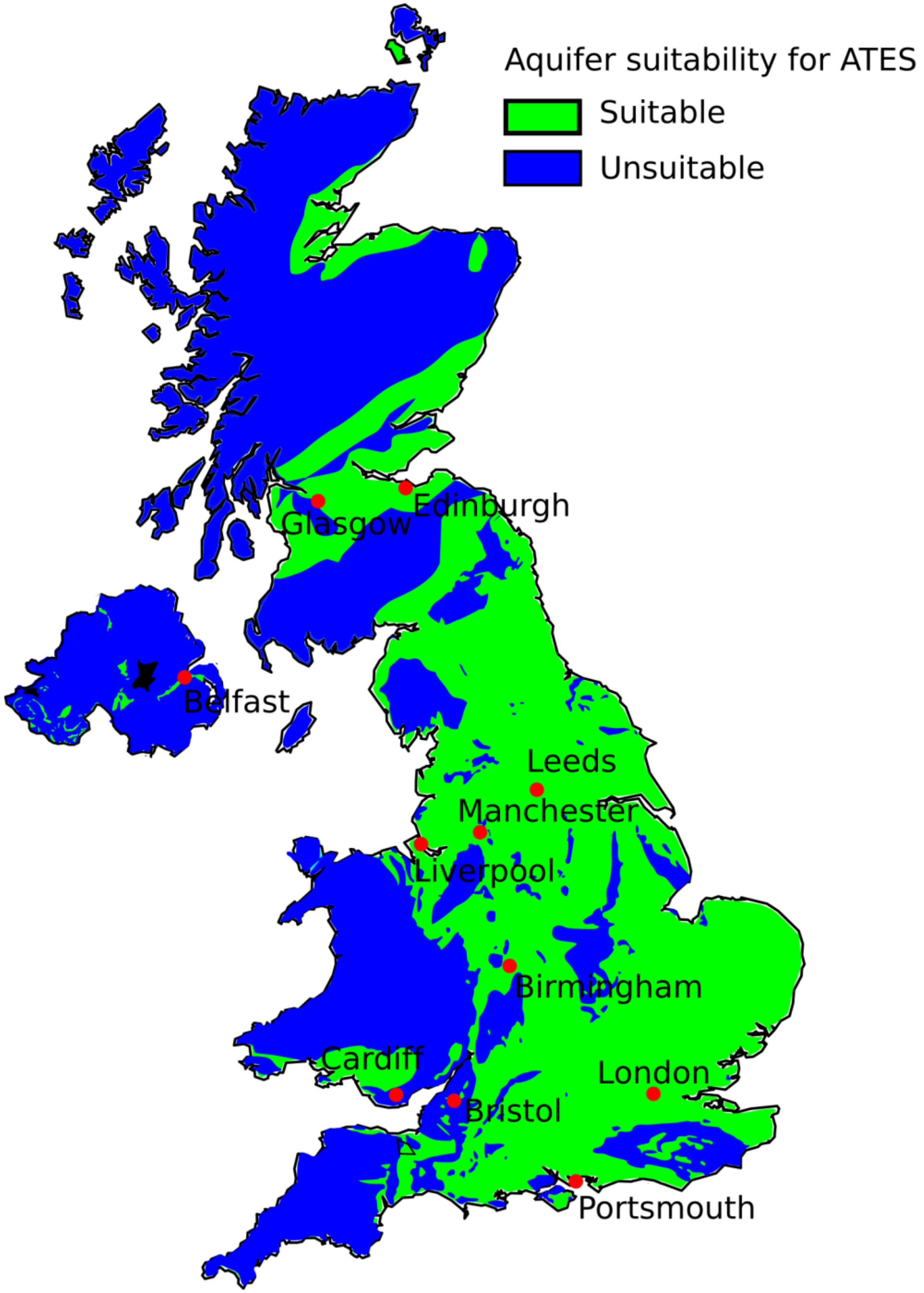
Regnier and Jackson, *Applied Energy* (in review)

ATES suitability in the UK

Composite aquifer map of the UK

Many major cities underlain by suitable aquifers for ATES

Seasonal variations in heating and cooling demand



Regnier and Jackson, *Applied Energy* (in review)

ATES in the UK

Table 1: ATES deployments in the UK and design characteristics

Project name	Date	Building type	Wells	Max flowrate (m^3/h)	Peak load heating/cooling (kw)
1. Westway Beacons	2006	Housing	2	25	250
2. Grosvenor Hill	2008	Housing	2	50	300/320
3. Riverside Quarter	2008	Housing	8	280	1800/2750
4. One New Change	2010	Shopping centre	2	40.5	600
5. National Maritime Museum	2011	Museum	2	46	300/350
6. Trafford Town Hall	2012	Offices	2	60	600
7. St James Riverlight	2015	Housing	8	58.3	1800/2900
8. Spring Mews Student Accommodation	2015	Housing	2	25	400/1204
9. Cockroft Building, University of Brighton	2016	University Building	2	99	703/546
10. Chelsea Barracks	2018	Housing	8	41.6	1062/650
11. City, University of London Law School	2019	University Building	2	72	600/590

Regnier and Jackson, *Applied Energy* (in review)

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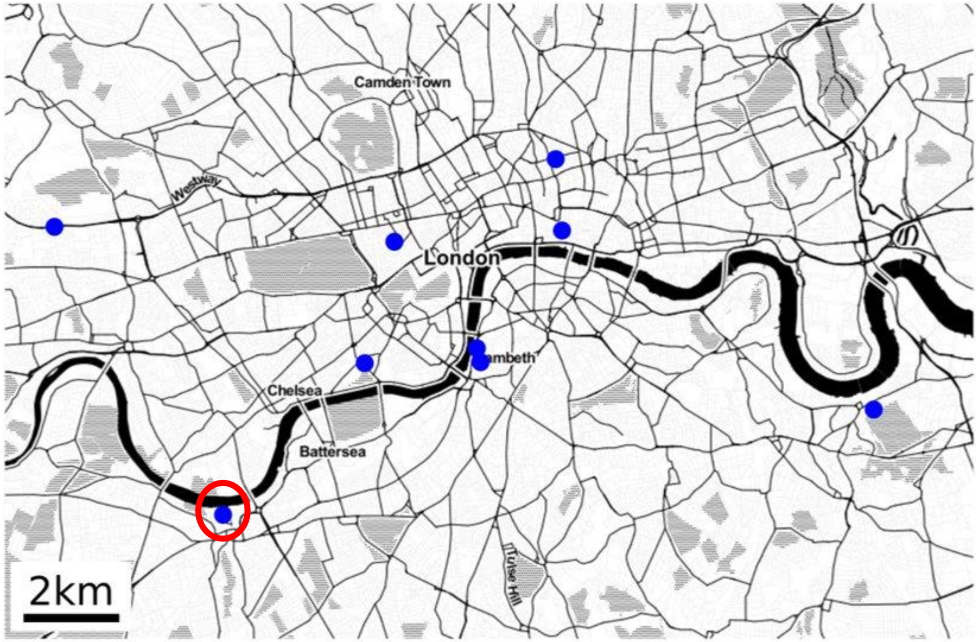
Regnier and Jackson, *Applied Energy* (in review)

Case study: Wandsworth Riverside Quarter



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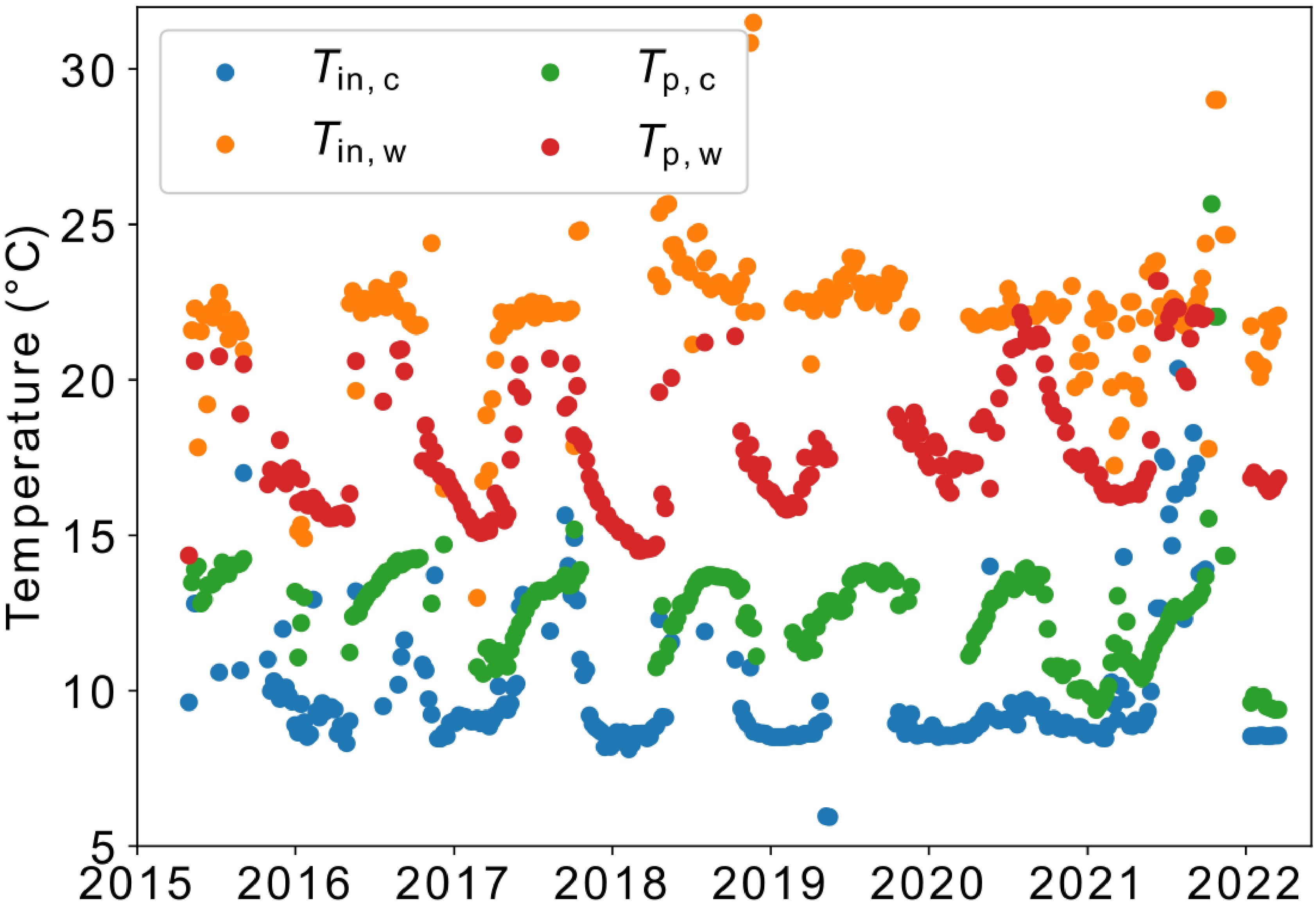

Regnier and Jackson, *Applied Energy* (in review)

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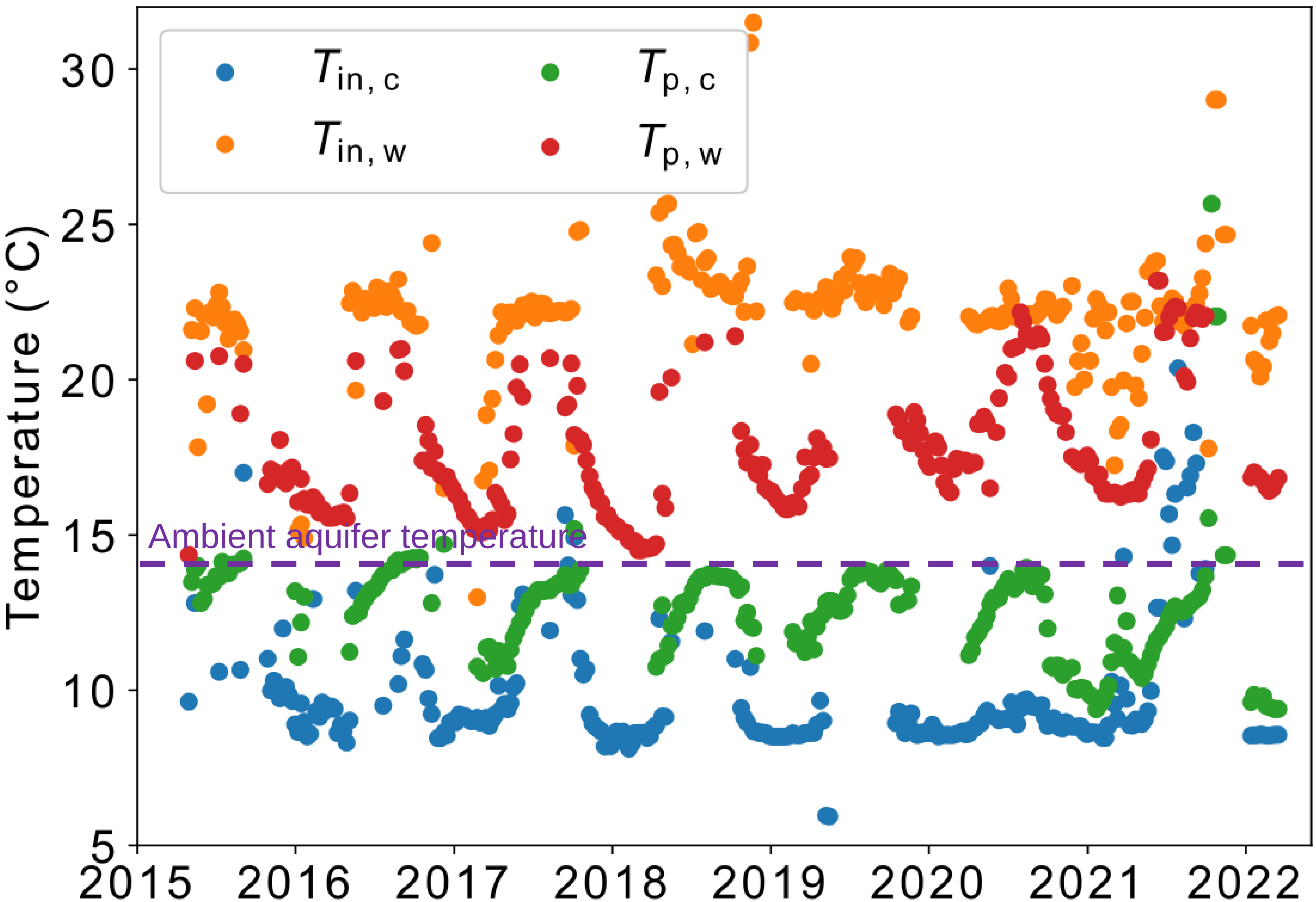

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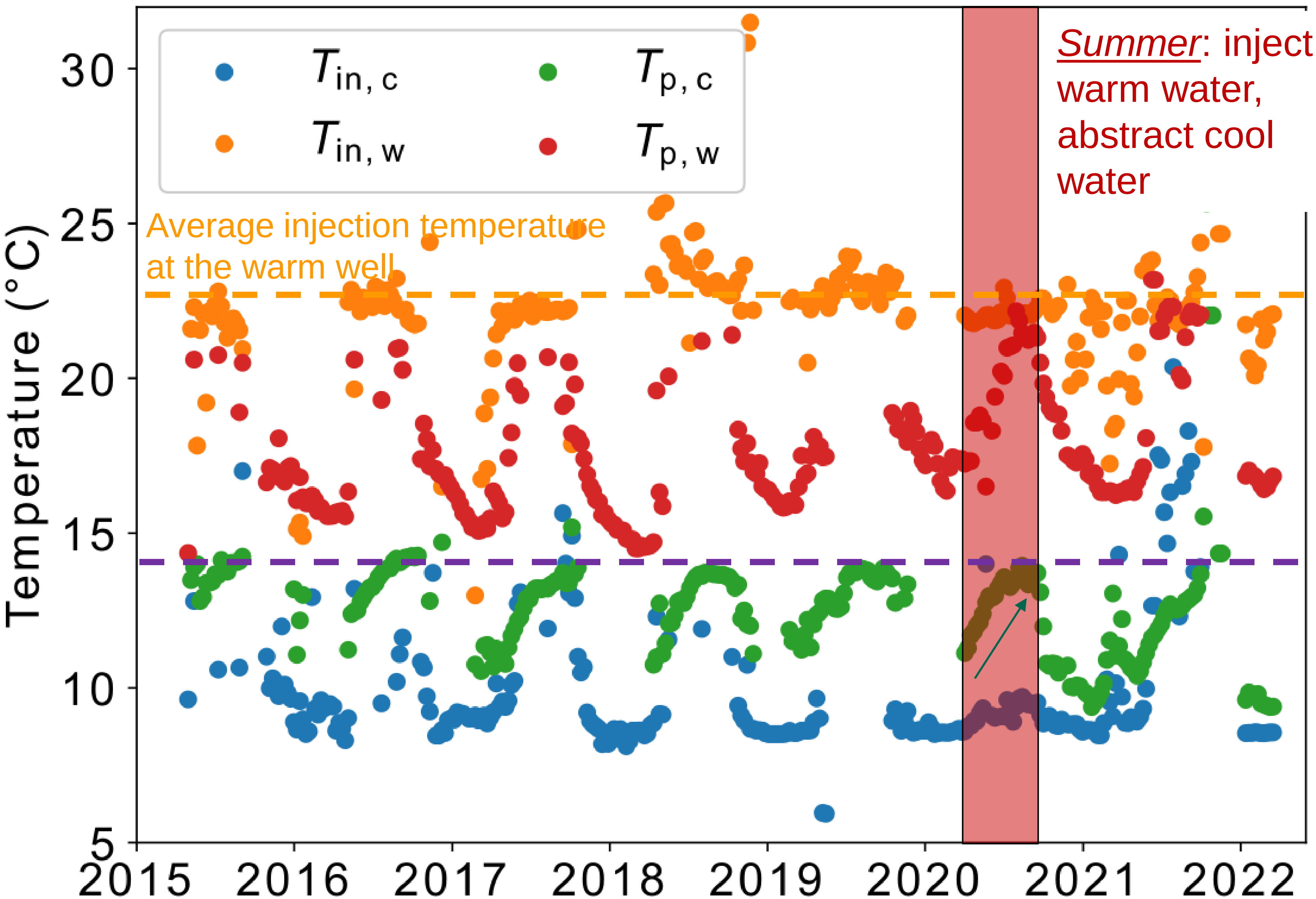

Regnier and Jackson, *Applied Energy* (in review)

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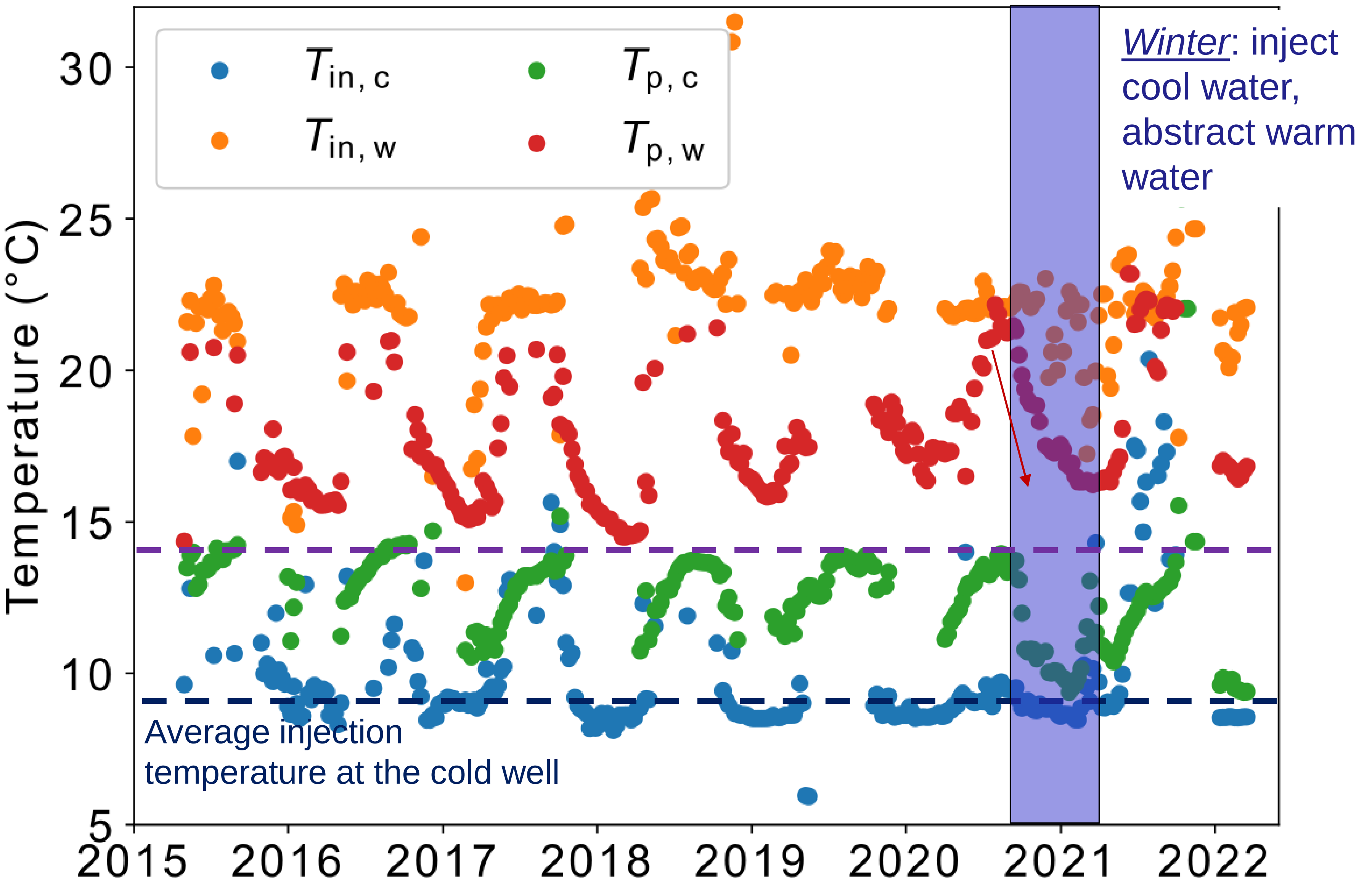


Regnier and Jackson, *Applied Energy* (in review)

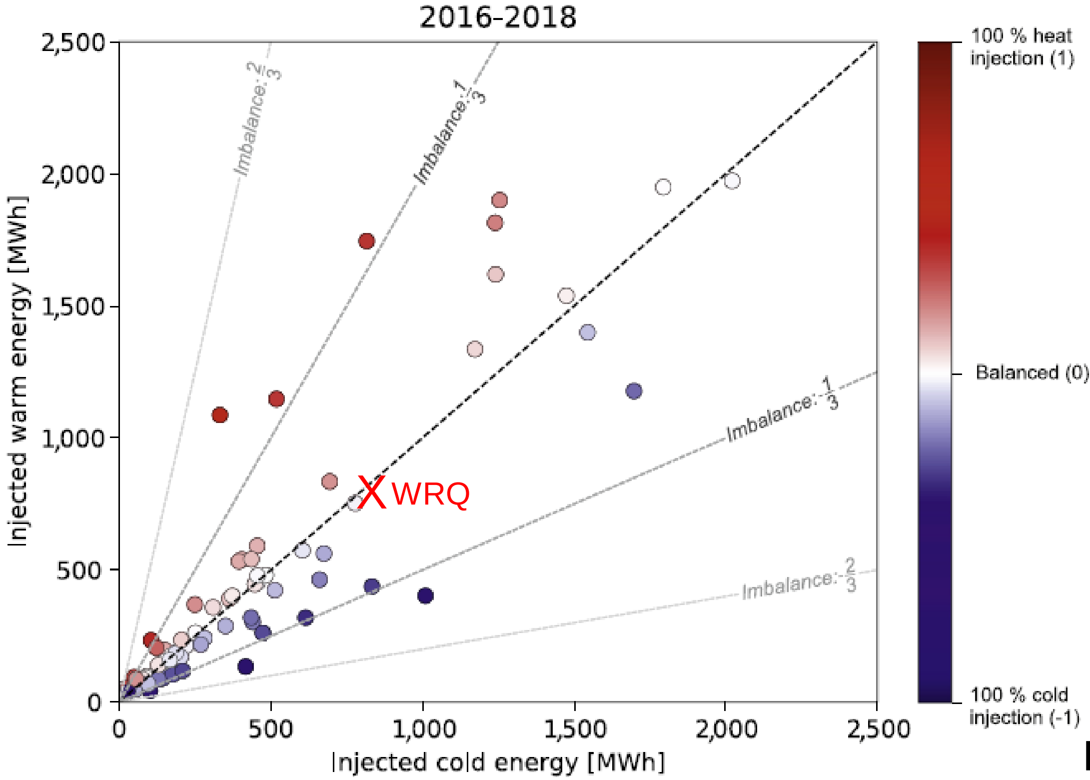
Case study: Wandsworth Riverside Quarter

- Is the installation *sustainable*?

Case study: Wandsworth Riverside Quarter

- Is the installation *sustainable*?

- Yes!
  - Energy balance ratio over operational period is 0.09
  - 20% more energy extracted for cooling than heating
  - Dry air coolers could be used to provide additional cool well recharge if imbalance further increases (but need to monitor)



Fleuchas et al., (2020)

Case study: Wandsworth Riverside Quarter

- Is the installation *efficient*?

Case study: Wandsworth Riverside Quarter

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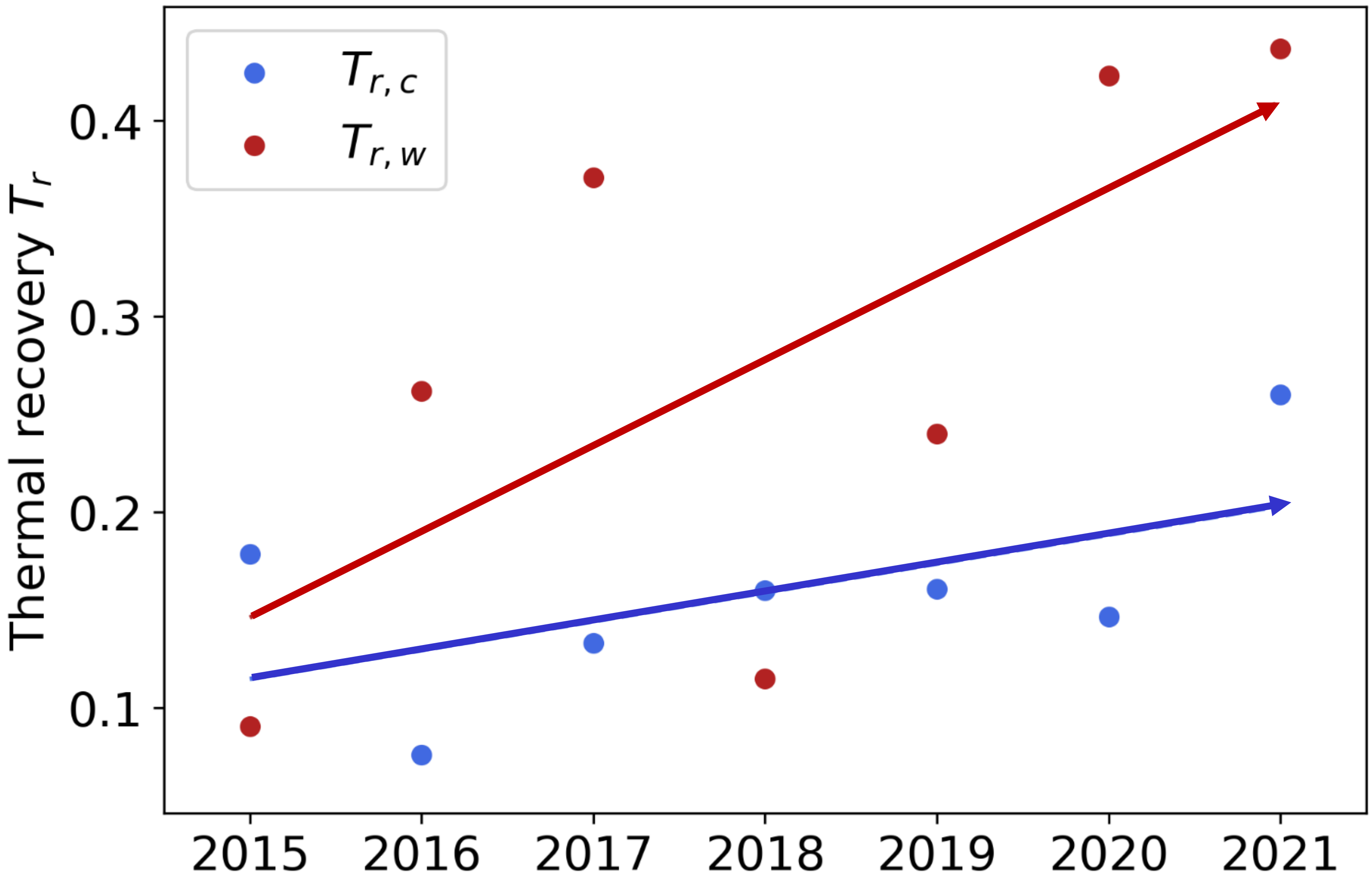
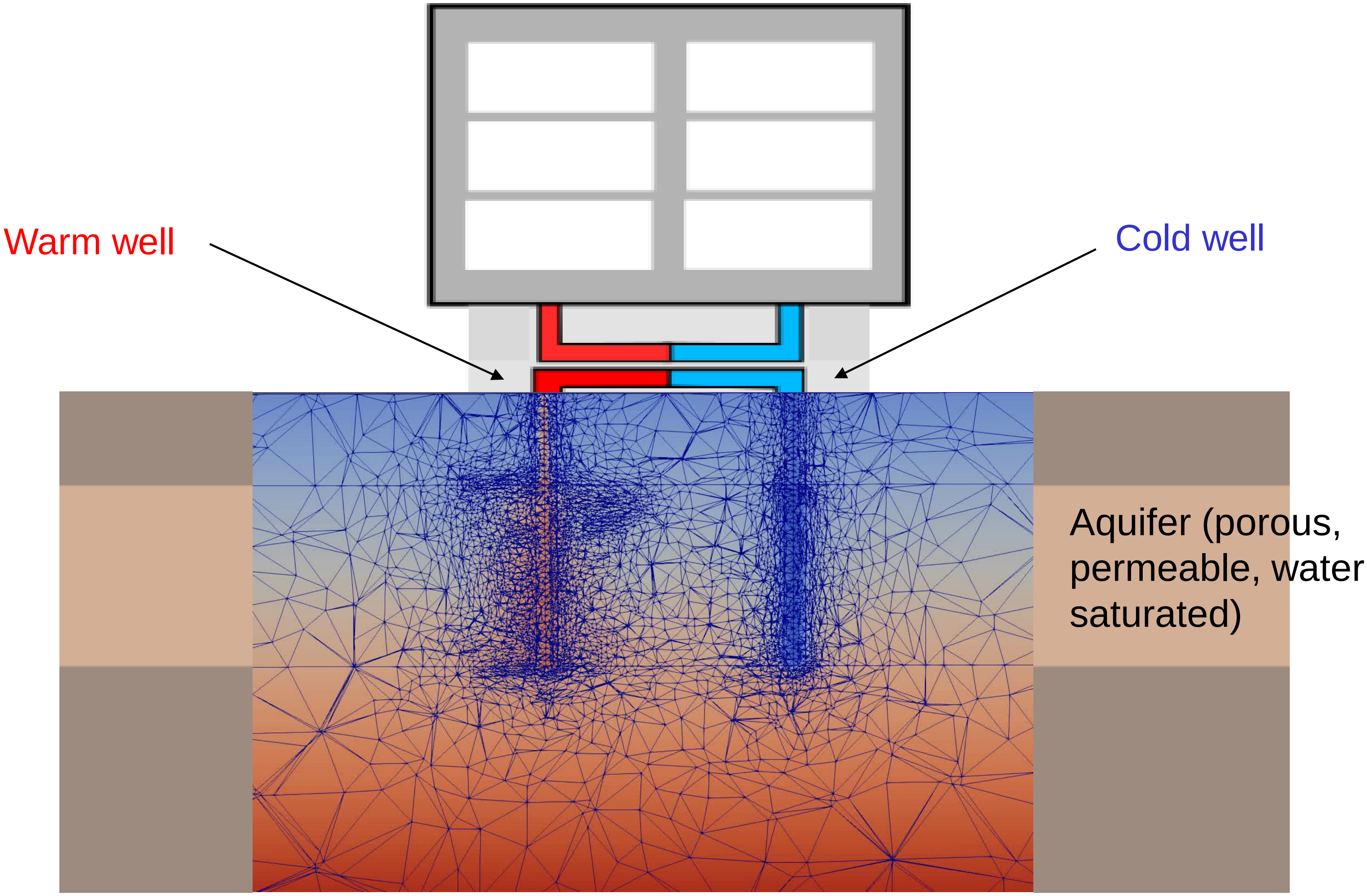


- Lower efficiency than Dutch systems (typically 0.6 – 0.9)

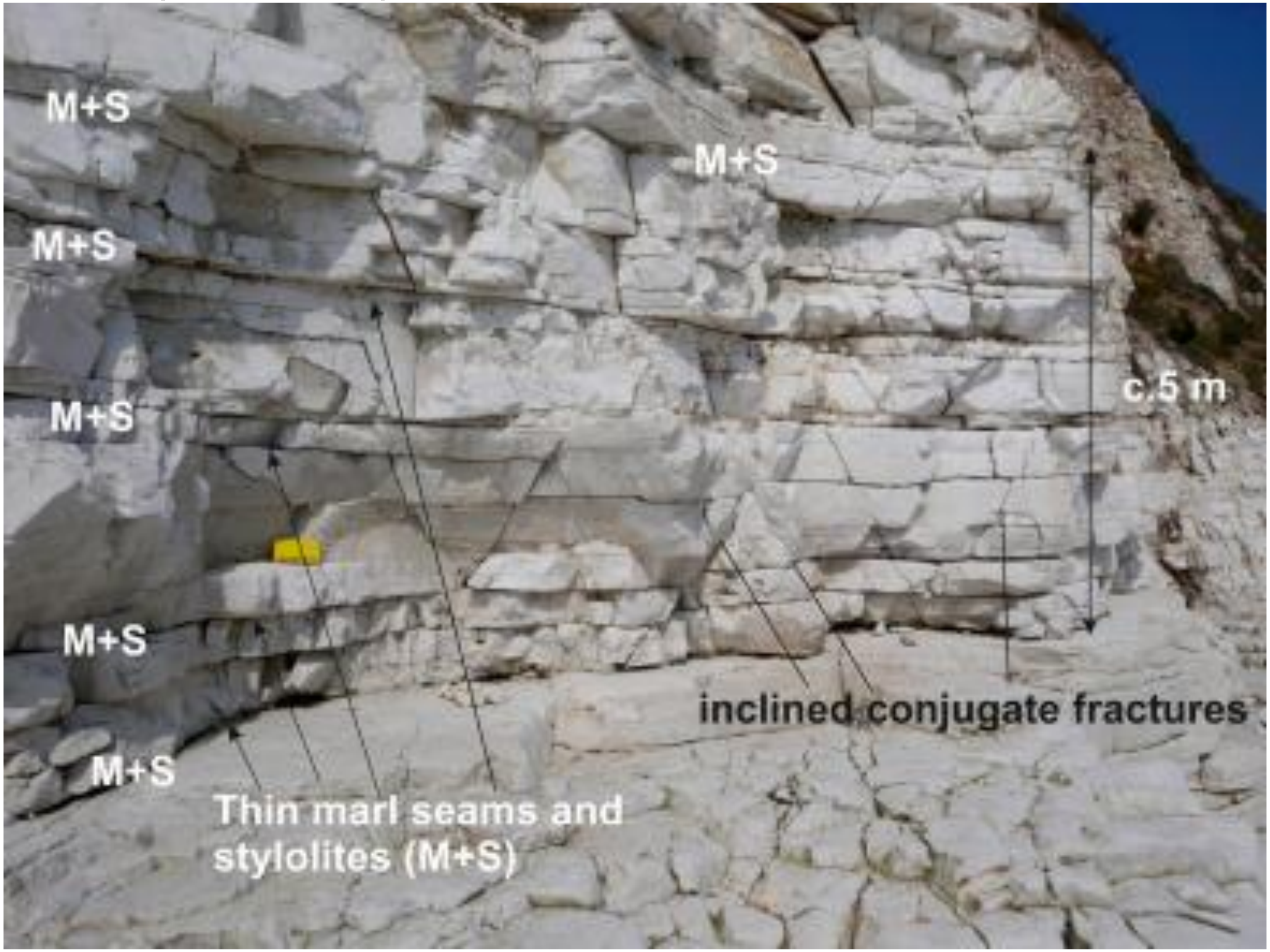
ATES thermal plumes in homogenous aquifers



Regnier et al., *Hydrol. J.* (2022)

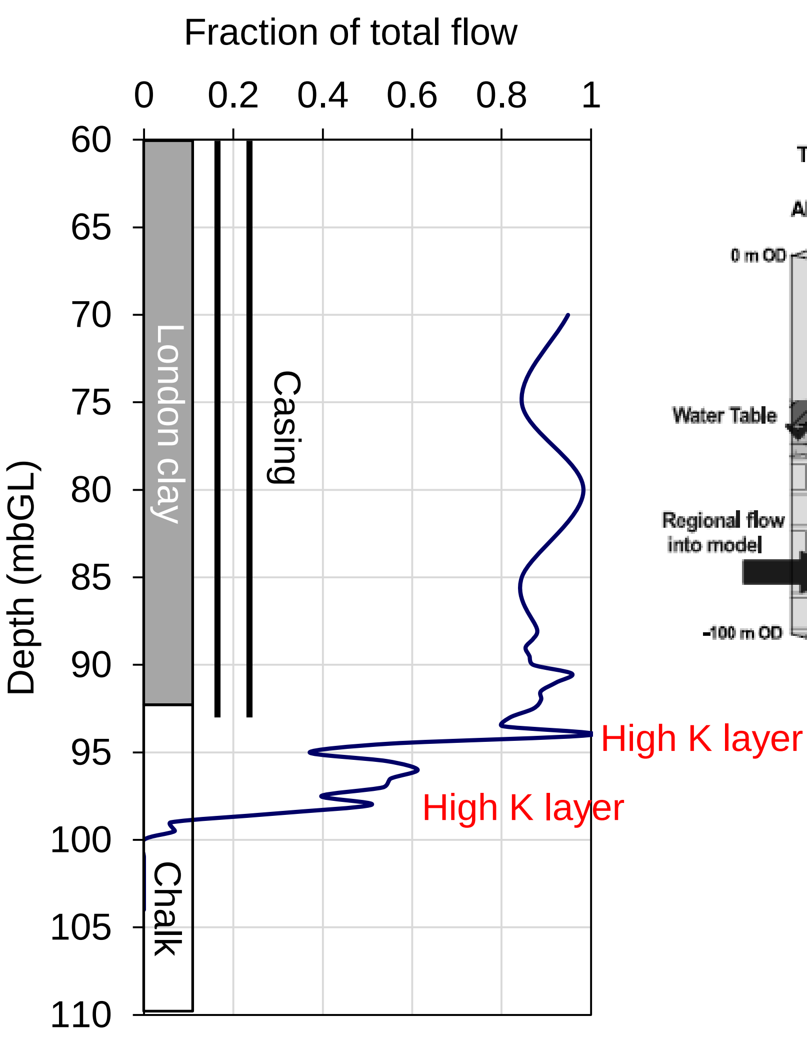
ATES thermal plumes in heterogeneous aquifers

Chalk aquifer outcrop, NE coast



ATES thermal plumes in heterogeneous aquifers

- Inflow into boreholes in Chalk aquifer, London



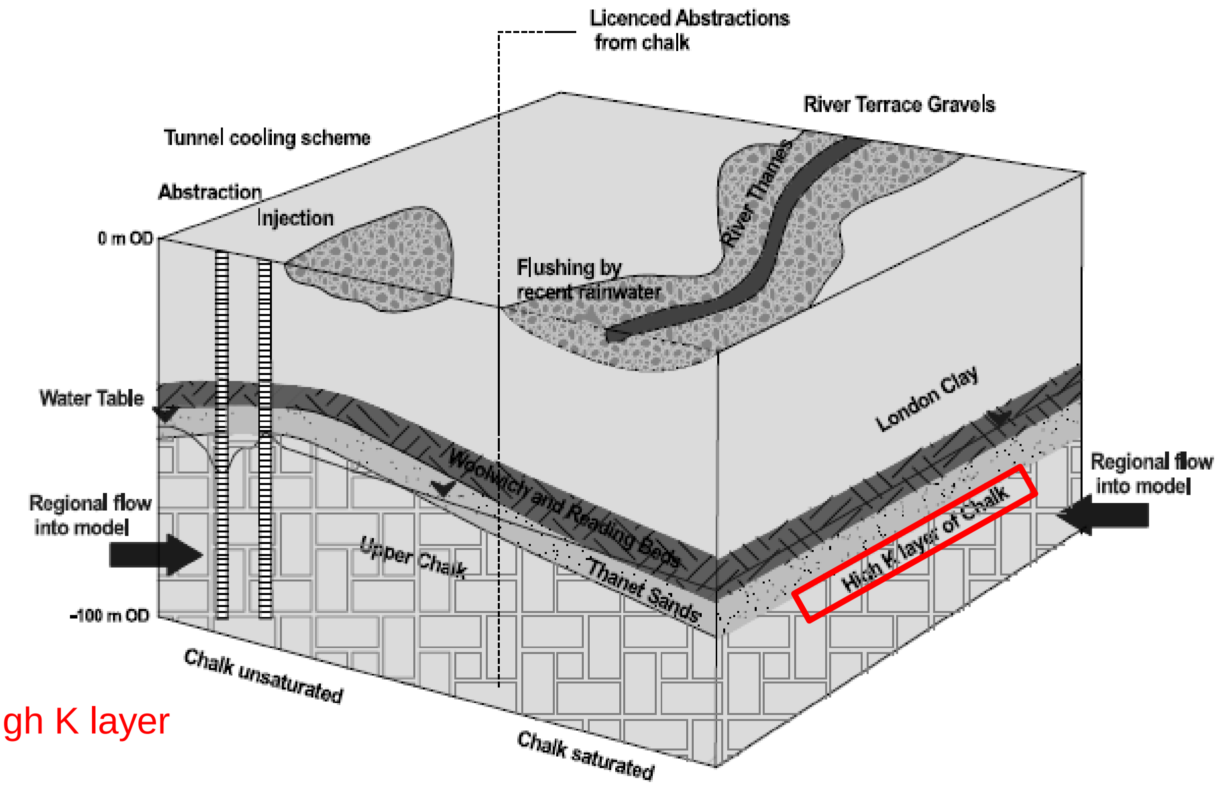
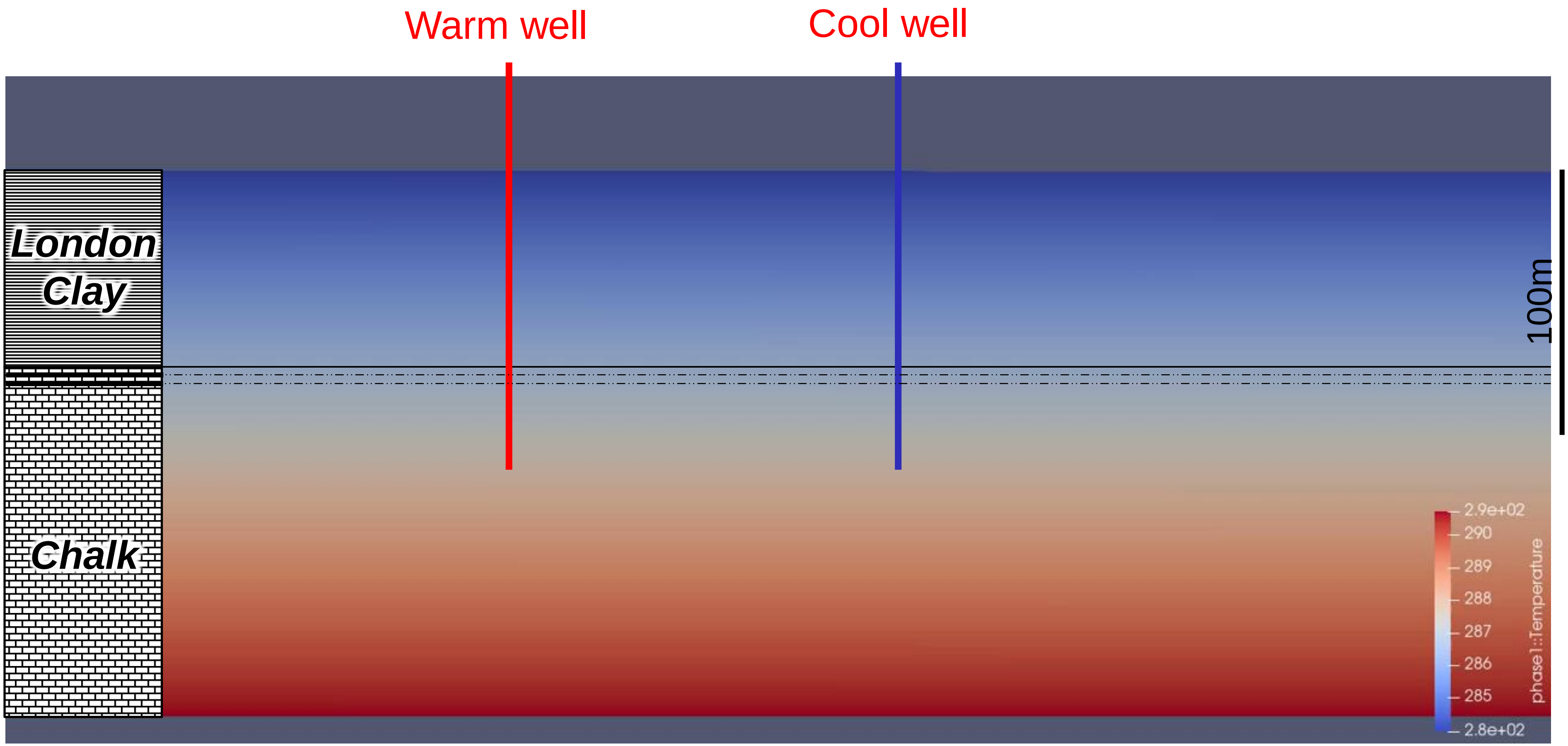


Fig. 2. Conceptual model.

Arthur et al., *QJEGH* (2010)

ATES thermal plumes in heterogeneous aquifers

- Simulated warm and cool plumes, ATES in Chalk aquifer, London



- ‘Pancake’ plumes exploiting high K layers at top of Chalk
- Vertically offset warm and cool plumes? Cf. Eaton Place

ATES thermal plumes in heterogeneous aquifers

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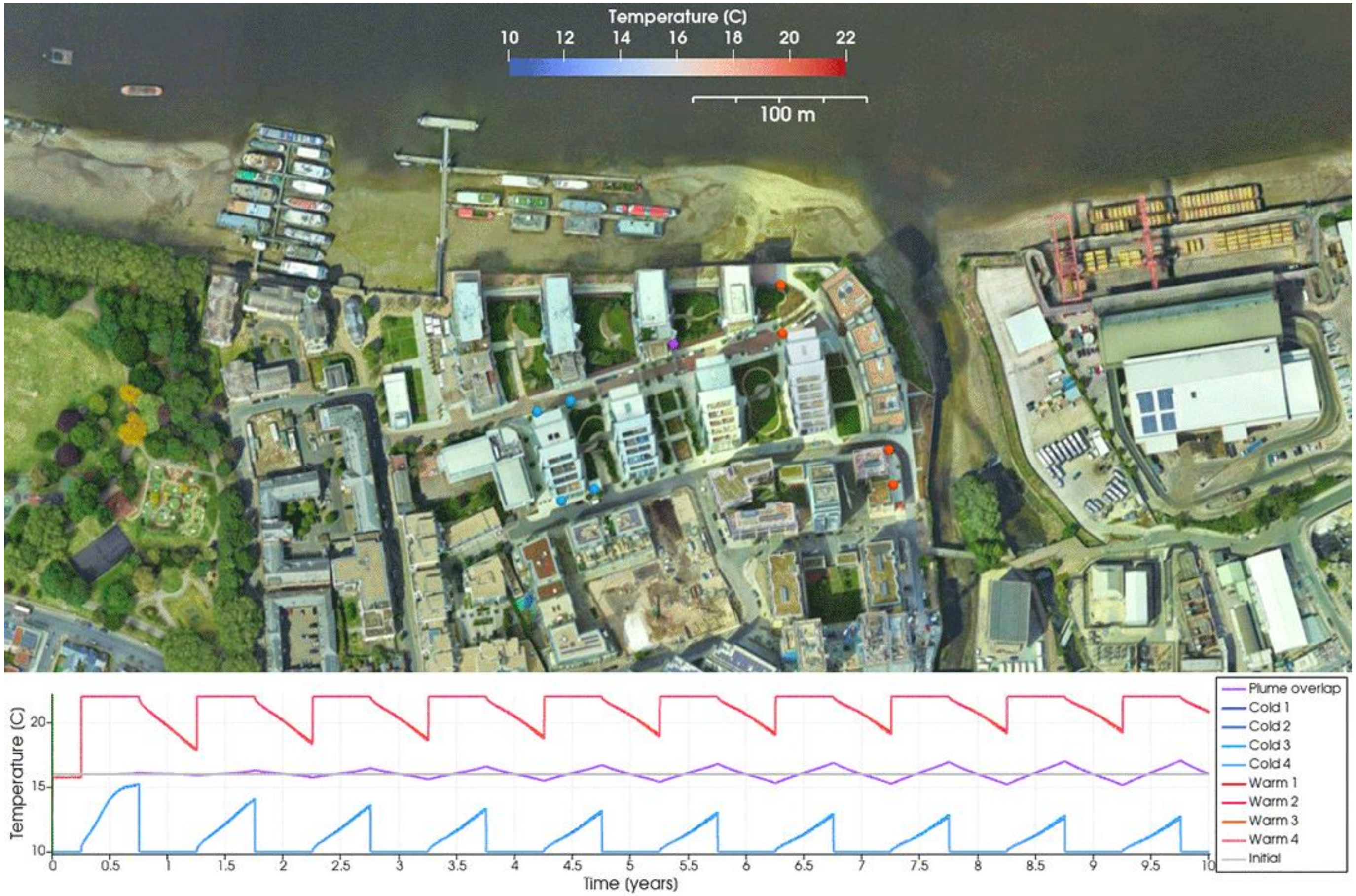

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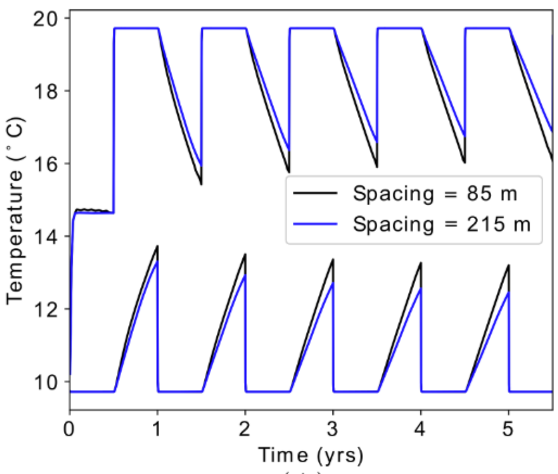
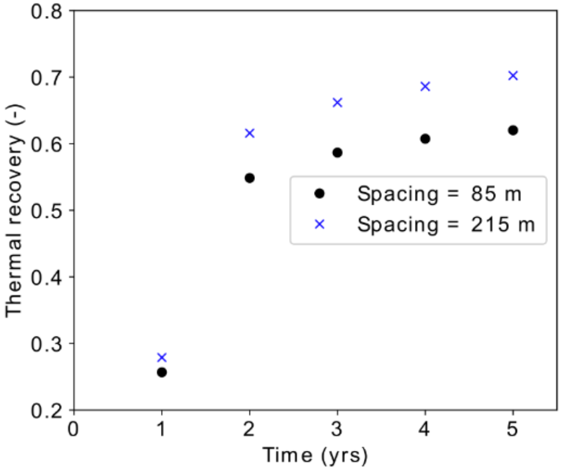
ATES plumes in heterogeneous aquifers

Permo-Triassic Sherwood sandstone aquifer at Ladram Bay, Dorset





- Higher predicted thermal recovery in other UK aquifers

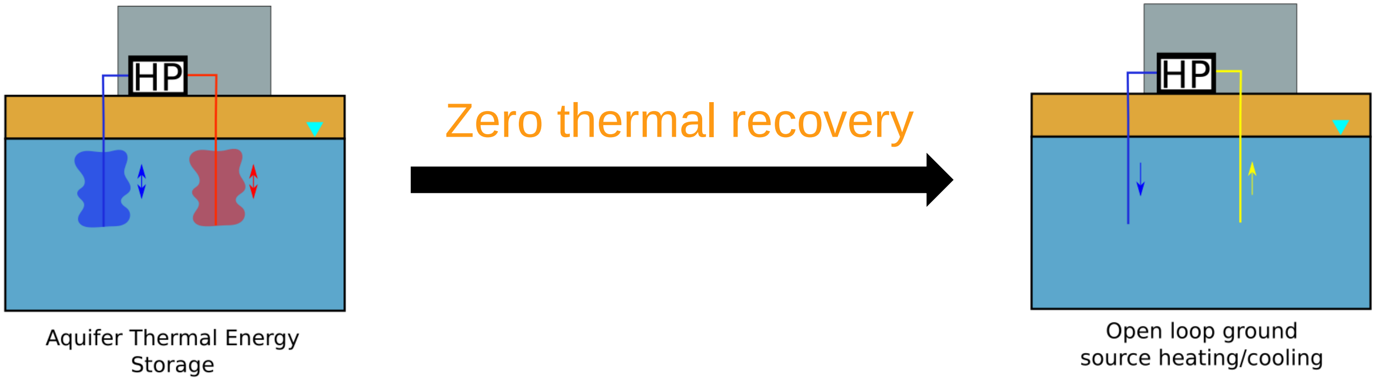
Case study: Wandsworth Riverside Quarter

- Is low thermal recovery efficiency a problem?

Yes and no…….

- In terms of energy extracted from the aquifer, a balanced ATES system with zero thermal recovery is identical to a uni-directional open-loop geothermal system used for heating and cooling

- The thermal recovery efficiency of a balanced ATES system can be thought of as a measure of the additional low carbon energy delivered by energy storage as compared to a uni-directional system without storage



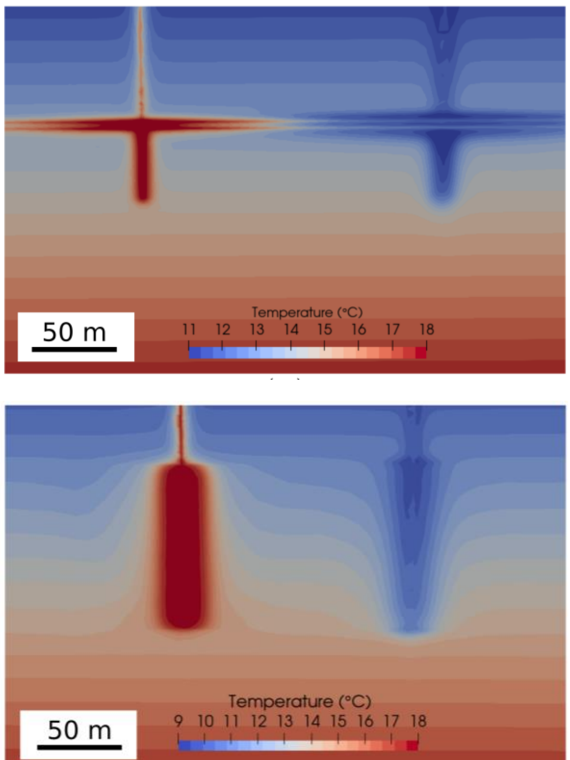
Regnier and Jackson, *Applied Energy* (in review)

Case study: Wandsworth Riverside Quarter

- Is low thermal recovery efficiency a problem?

Yes and no…….

- BUT….a larger subsurface plume impacts on how systems should be engineered for efficient deployment



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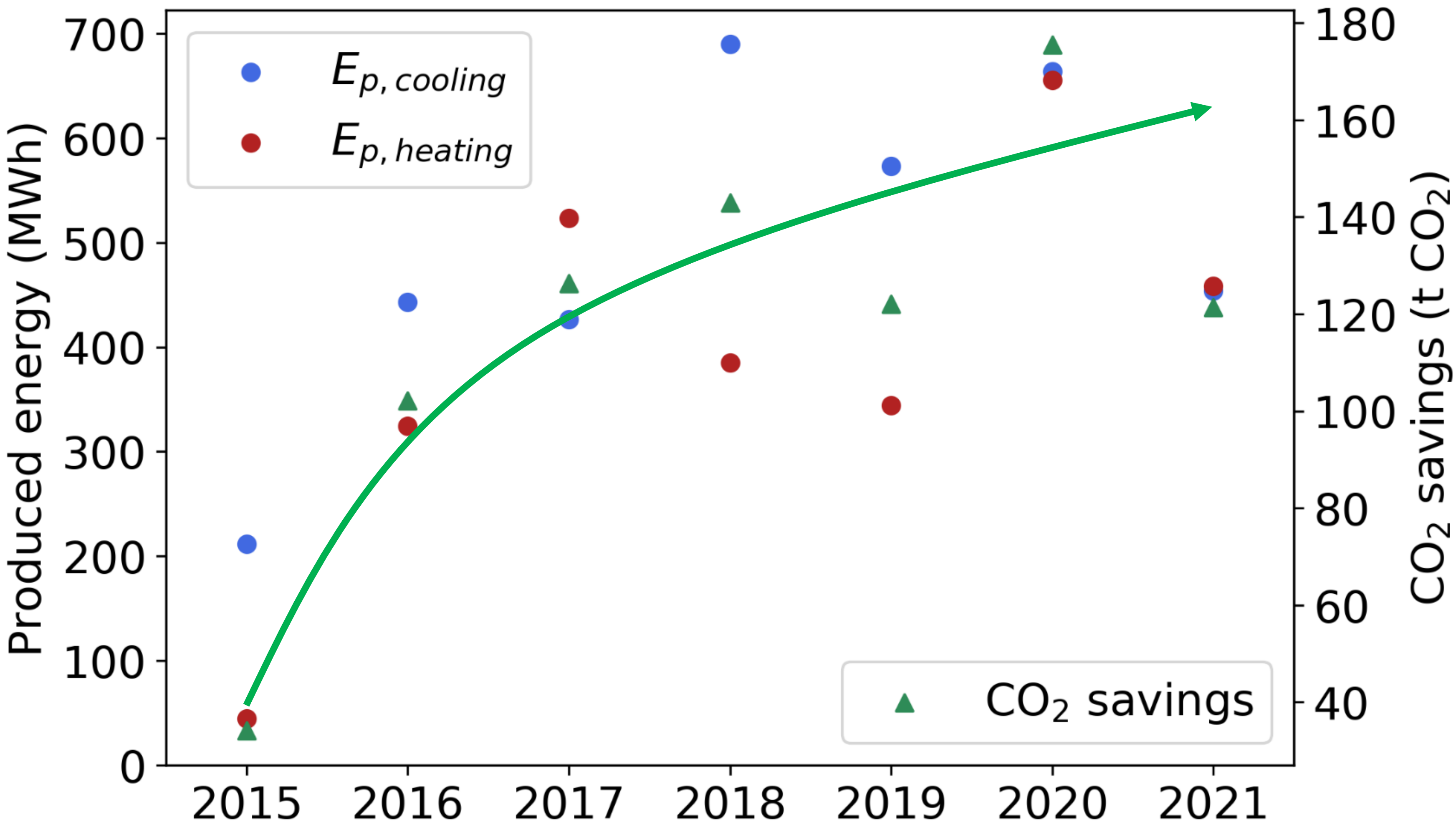
Bakr et al. (2013)

Case study: Wandsworth Riverside Quarter



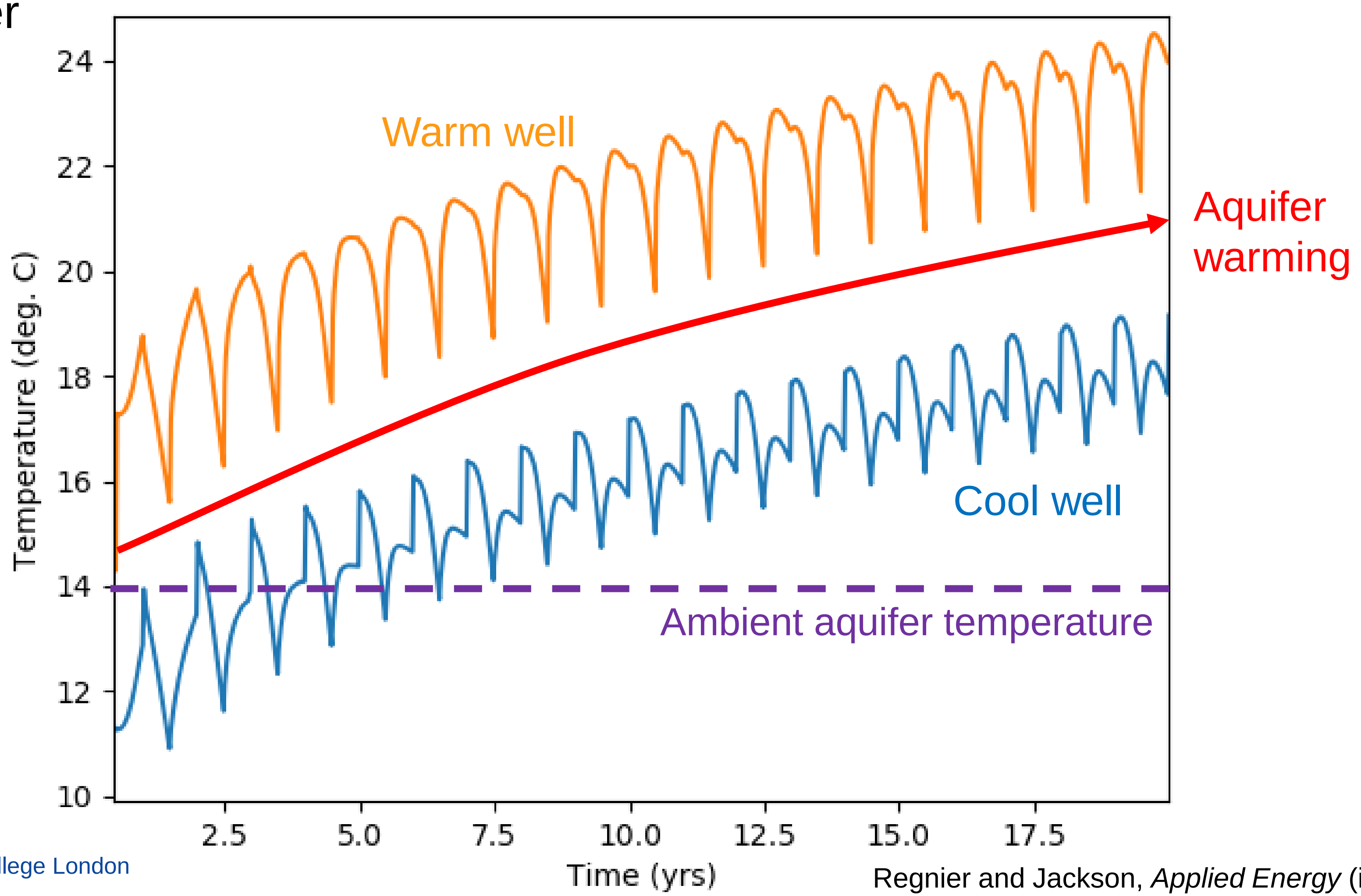
A 'good news' story!

Regnier and Jackson, *Applied Energy* (in review)

Temperature response in an unbalanced system

Operating ATES installation in London: Cooling demand exceeds heating demand

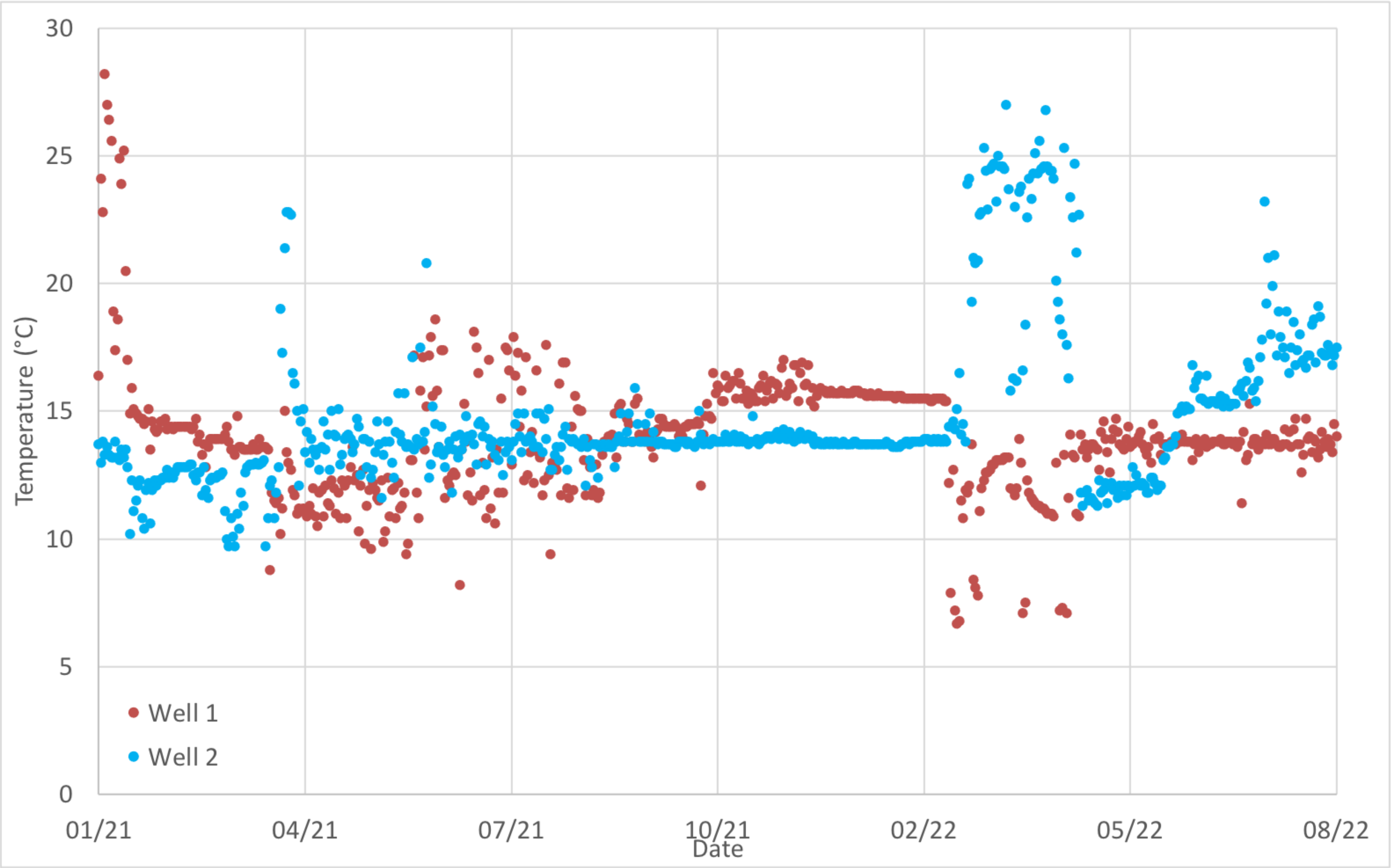
Groundwater produced at cool well now has higher temperature than initial aquifer



Regnier and Jackson, *Applied Energy* (in review)

Poor quality / difficult to interpret monitoring data

Operating ATES installation in London: Temperature monitoring



Challenges to ATES deployments in emerging markets

- Knowledge and skills divided between consulting and contracting companies and operational staff
- Unfamiliarity with the subsurface and its characteristics
- Lack of monitoring of the groundwater system:
  - actual pumped volumes are much smaller compared to the design values, on average 40% of the permitted capacity
- Lack of knowledge, experience of ATES installations
- Lack of awareness with policymakers, planners, public
- Lack of adequate legislation
  - in countries where ATES is widely applied, specific legislation has been designed or modified to regulate and/or stimulate the technology
  - long, laborious and uncertain permitting procedures
  - lack of knowledge at permitting authorities about ATES systems and their environmental impacts
- Economics and financial considerations
  - uncertainty on economic sustainability
  - high initial investment compared to conventional heating+cooling systems

Pellegrini et al. 2019

Some specific challenges we have observed/recorded

- Incorrect system operation / poor operator understanding
- Lack of system monitoring, real time analysis and expertise to identify problems
- Lack of streamlined permitting procedures
  - Separate permits for injection and abstraction
  - Temperature and other induced aquifer changes considered on a 'case-by-case' basis
  - ATES systems generally grouped with GSHP / GSHC
  - No requirement for balanced system
- Lack of awareness of the technology
- Little UK-based installation/service expertise
- Overly simplistic modelling of subsurface response
- Likely to be several failures of current (early) UK installations (or need to significantly re-engineer) – only one confirmed successful system to date
- The Dutch also experienced similar issues in early deployments
- Reichstag system in Germany operated for >15 years but now decommissioned (cool demand underestimated and never balanced)

Active research projects in shallow geothermal

Aquifer Thermal Energy Storage for Heating And Cooling: Overcoming technical, economic and societal barriers to UK deployment (ATESHAC)

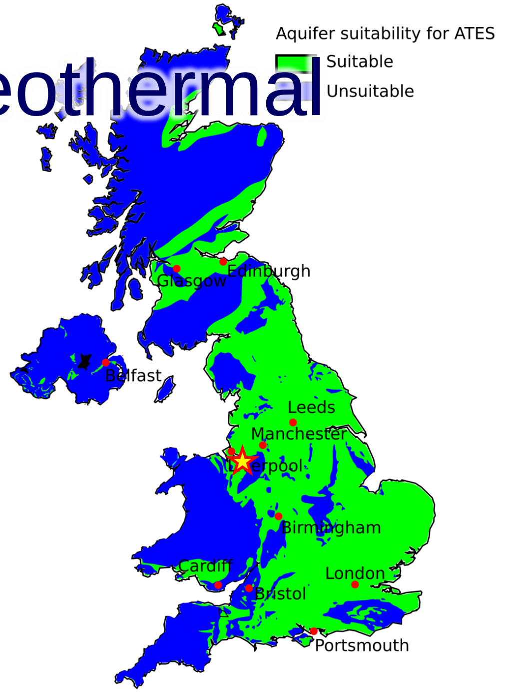
Imperial College, BGS, U Manchester

2021-2024

EPSRC, Decarbonising Heating and Cooling 2

- *ATES national capacity*
- *Aquifer response to heat and cool storage*
- *ATES operability & efficiency through numerical modelling*
- *Techno-economics*
- *Responsible ATES & public engagement*
- *Integration and policy/regulation recommendations*

Active research projects in shallow geothermal



ATESHAC

- BGS UKGEOS Cheshire Observatory
- Aquifer: Sherwood Sandstone
- Array of 21 wells
    - Logging
    - Heat and/or water injection/production
- Characterise aquifer at appropriate scale
- Link experiments with numerical models

Active research projects in shallow geothermal

Smart assessment, management and optimisation of urban geothermal resources (SMARTRES)

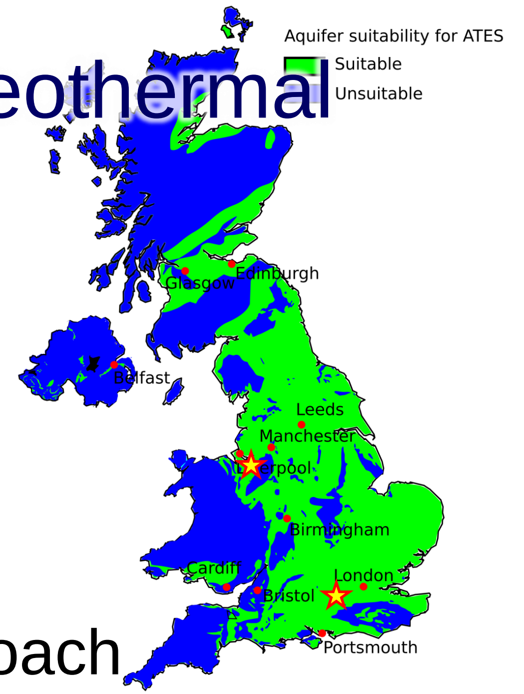
Imperial College, BGS, U Leeds, U Manchester

2023-2026

NERC, Highlight Topic

- *Stakeholder engagement*
- *Quantifying subsurface response*
- *Petrophysical and biogeochemical characterisation*
- *Storage and production capacity and cross-deployment interaction*
- *Monitoring and data management*
- *Long-term sustainability*
- *Recommendations for policy and regulation*

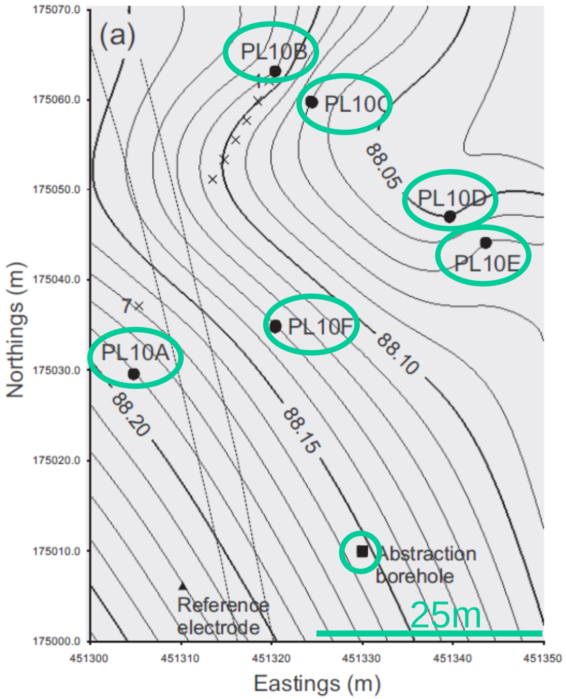
Active research projects in shallow geothermal



SMARTRES

- Sherwood Sandstone (matrix flow)
- Chalk (fracture flow)
- Deployment-scale physical experiments

- Digital twin approach



Conclusions

- Widespread geographic suitability in the UK aligned with high heating/cooling demand
  - Potential ATES storage and power capacity is very large (1-100's GWh / MW – 10's MW)
- ATES operation is sustainable in a well engineered and balanced system
- At least one successfully operating UK system
- Very little awareness of the technology in the UK
- High perceived risks due to lack of expertise
  - Installation/operation
  - Subsurface response
- Ongoing research to advance ATES in UK and overcome or bypass teething problems

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GEOTHERMAL DHC

Towards Decarbonized Heating and Cooling!

Thank you

Acknowledgements: The authors thank COST Action CA18219 “Geothermal DHC”, supported by COST (European Cooperation in Science and Technology), www.cost.eu; https://www.geothermal-dhc.eu/. Author Firth gratefully acknowledges funding from the UK Engineering and Physical Sciences Research Council (EPSRC). Authors Jackson and Jacquemyn gratefully acknowledge funding from the EPSRC via the ATESHAC project (Aquifer Thermal Energy Storage for Heating And Cooling), grant reference EP/V041878/1.