The role of Energy Geostructures for Heating and Cooling in the UK

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Presentation Outline

- About me
- Geothermal energy
- Shallow and deep geothermal
- Energy geostructures and their advantages
- Energy Geostructures in the UK, potential and uptake barriers
- National Buried Infrastructure Facilities at the UoB
- Current research project on energy piles

About me

My research focuses on Smart and Sustainable Civil Infrastructure, integrating computational mechanics and experimental modelling. I specialise in geo-energy infrastructure, including energy piles and offshore wind turbine foundations as well as novel sensing technology to monitor geo-structure, transportation geotechnics.

Key areas of my work include:

- Novel supporting structure for offshore renewables (e.g., offshore wind turbines both fixed and floating)
- Digital twins for geo-energy systems (e.g., energy piles)
- AI applications in the design, analysis, and maintenance of transportation geo-structures

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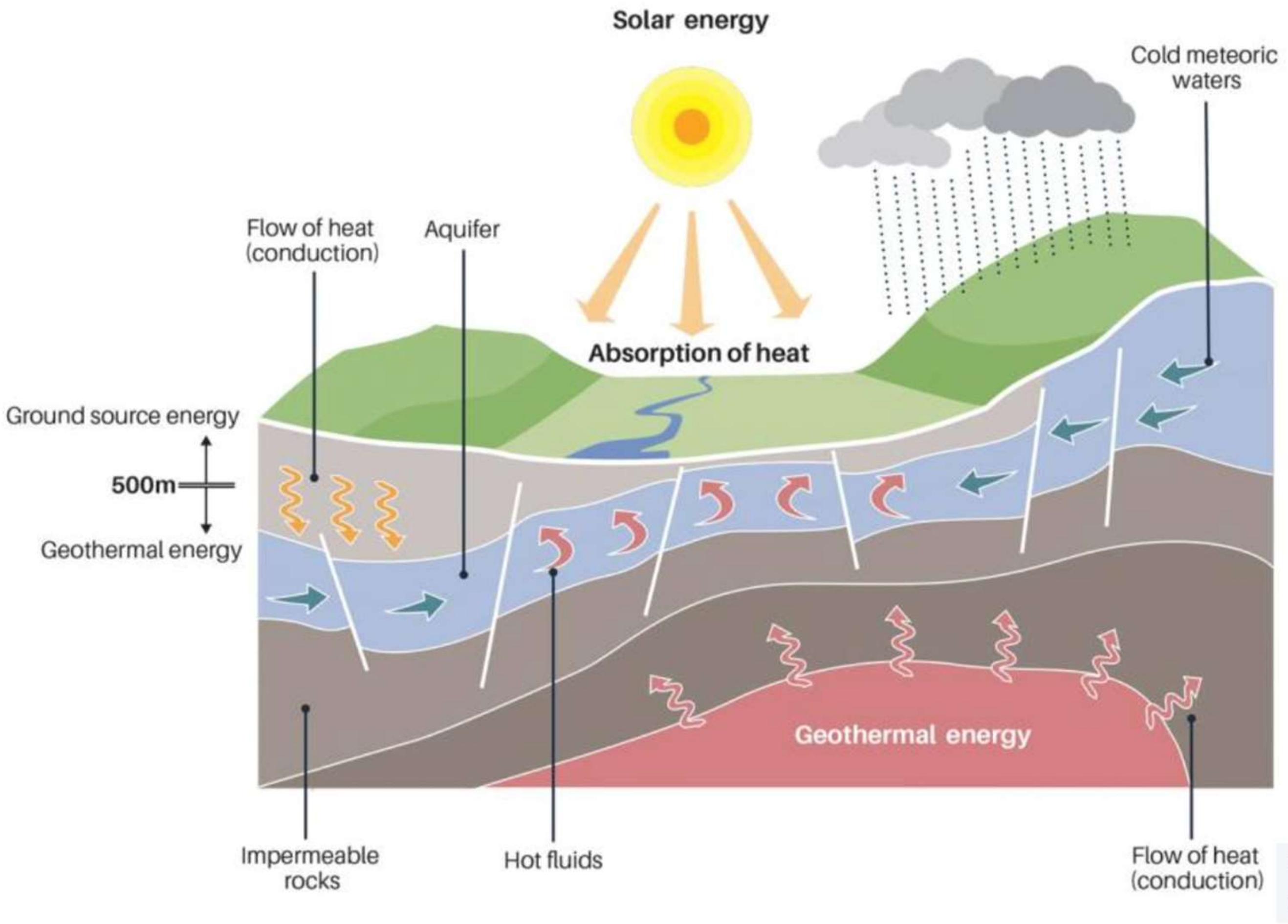
What is Geothermal Energy?

- Geothermal energy is all energy stored in the form of heat beneath the surface of the solid earth. It is a reliable and constant source of low-carbon, renewable heat that is not dependent on weather conditions.

- It is available across the UK at depths from a few metres to several kilometres from where it can be extracted using different technologies.



Factors affecting the flow of heat in the UK crust. BGS © UKRI.

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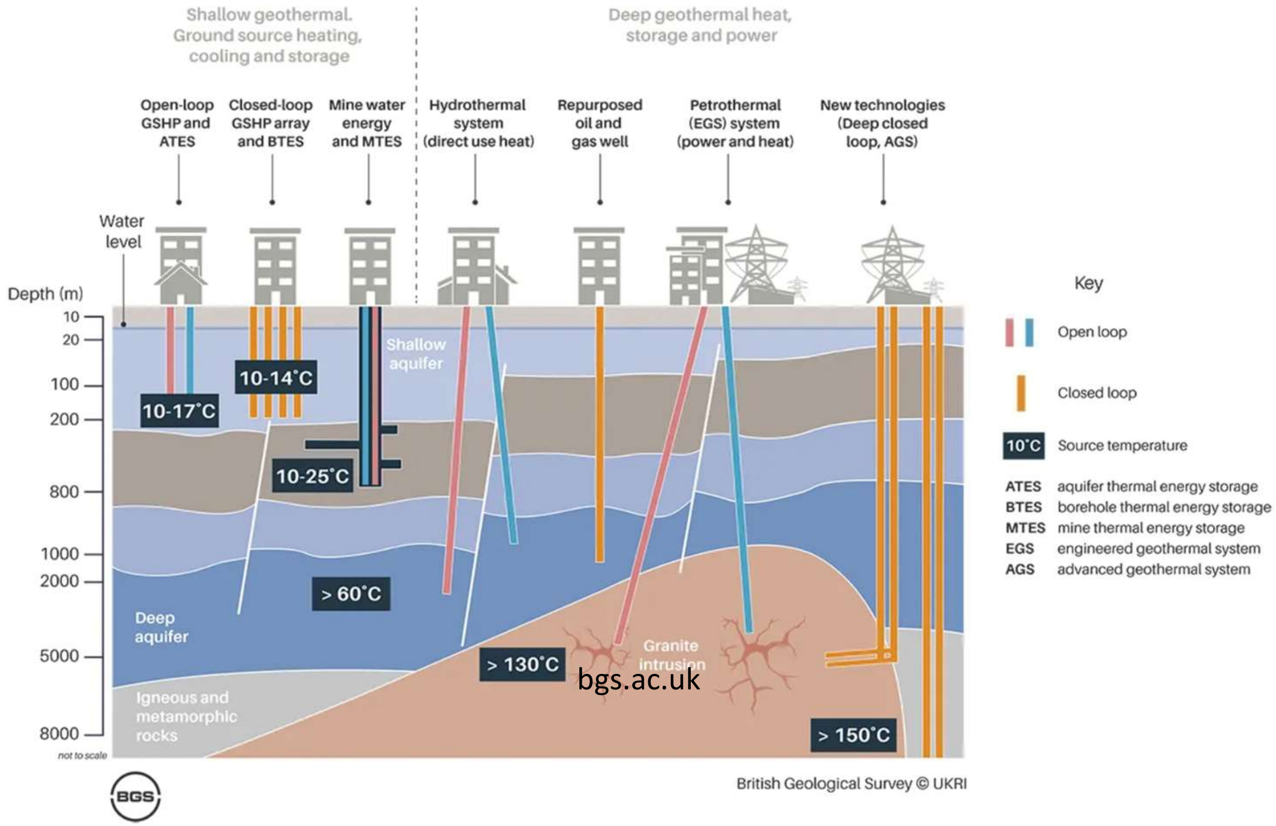
Shallow & Deep Geothermal

Shallow geothermal energy is the low-grade heat (10 to 25°C) that is stored in the shallow subsurface at depths of up to 500 m. It requires the use of ground-source heat pumps and can be used in most parts of the UK for the heating of buildings.

Deep geothermal energy is the heat stored at depths greater than 500 m. Temperatures within the Earth increase with depth in line with the local geothermal gradient, which averages around 27°C/km in the UK.



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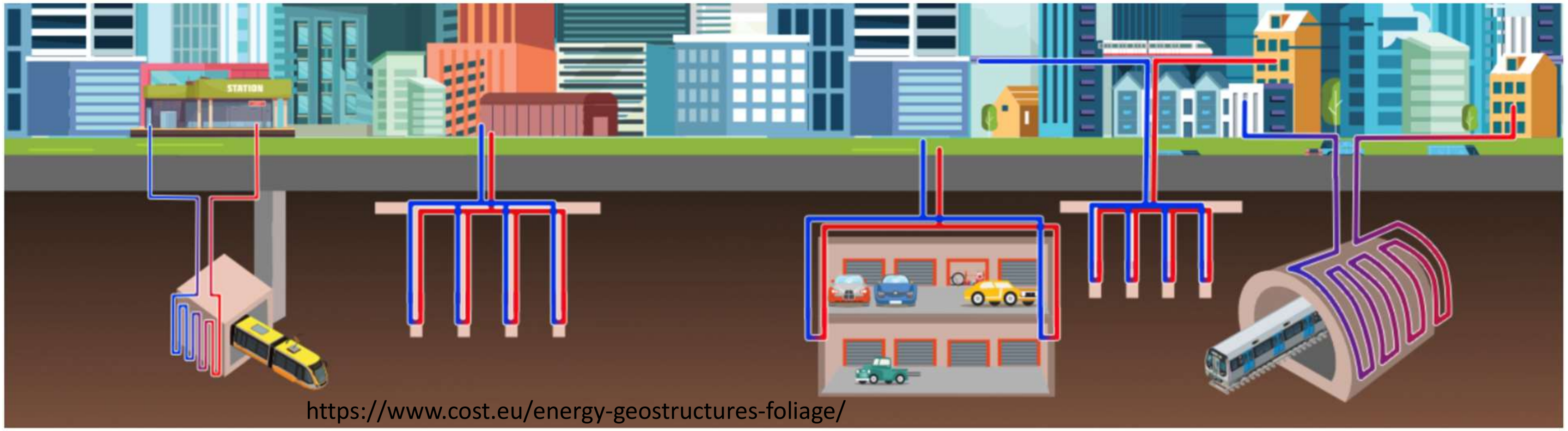
What are Energy Geostructures?

- Energy geostructures are a type of shallow geothermal energy technology where building foundations, or other buried infrastructure (such as metro stations, tunnels and sewer pipes) are used to access heat from the ground for both heating and cooling purposes, as well as for their original structural function.

- Energy geostructures constructed as a part of ground-source heat pumps (GSHP) systems have seen increased growth in markets and research in the last few years. However, their wider potential to integrate to district heating networks has yet to be explored.



https://www.cost.eu/energy-geostructures-foliage/

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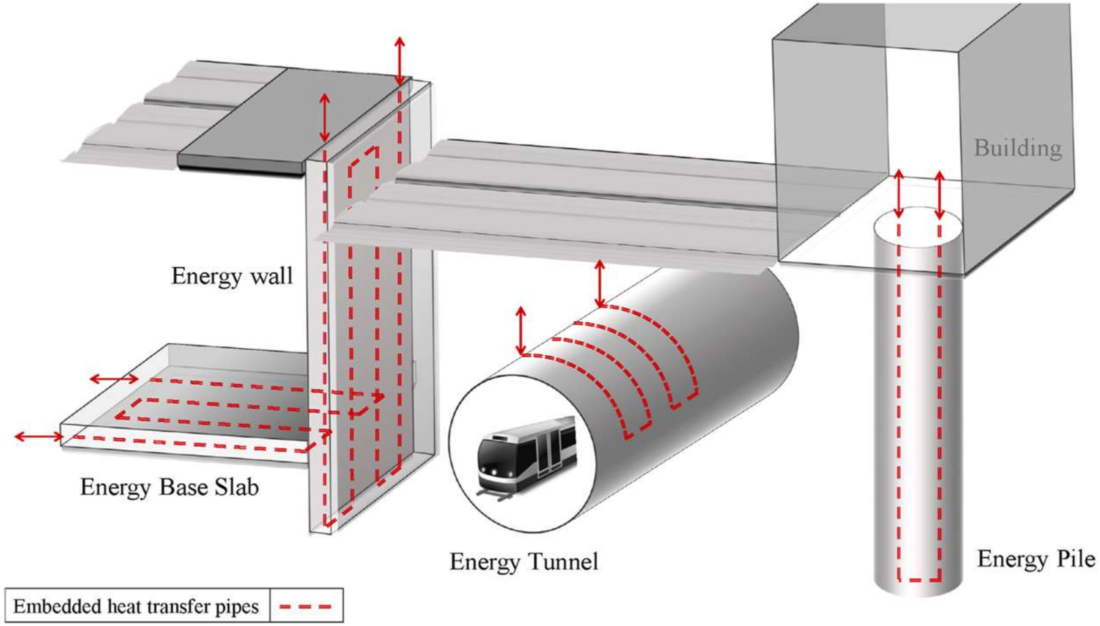
Advantages of Energy Geostructures

- Low-impact and space-efficient
- Alignment with national infrastructure
- Opportunity for repurposing
- Cross-industry innovation
- Efficient and scalable systems
- Cost-effective integration
- Thermal energy storage
- Sustainable and renewable
- Economic and environmental benefits



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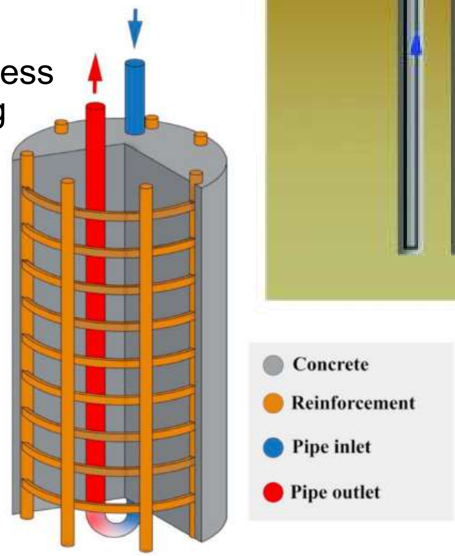
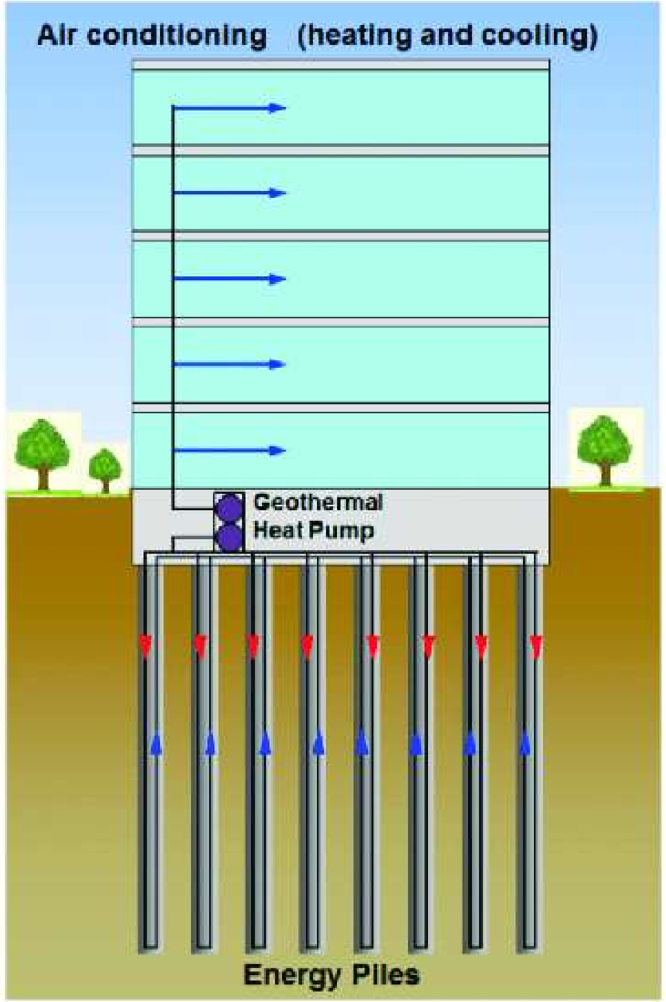
Energy Geostructures in the UK: Potential

- Energy geostructures can deliver low or zero carbon heating and cooling to buildings in one of the following two way:
    - By direct connection to a ground source heat pump system in an overlying or adjacent building;
    - By connection to a heating and cooling network, either via a central heat pump which feeds a high temperature network, or via an ambient loop network which requires individual buildings to operate their own smaller heat pump.
- A recent study by UKCRIC has highlighted the contribution which buried infrastructure converted to energy geostructures can make to decarbonising heating and cooling in the UK (Loveridge et al, 2022).
- Another research shows that energy geostructures could contribute in excess of 50 TWh/year of thermal energy to help decarbonise heating and cooling (Loveridge et al, 2021).





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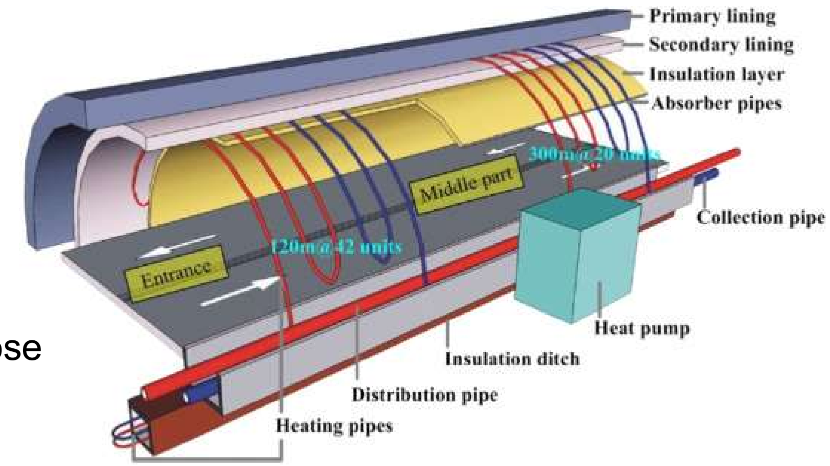
Energy Geostructures in the UK: Uptake Barriers



- Their uptake has been very slow in the UK compared with much of Europe and as a result accounts for less than 1% of renewable energies in the UK in September 2023.

- Broadly speaking, challenges associated with GSHP, particularly those relevant to the UK, can be divided into a number of broader categories:

  i. Financial and Economic challenges

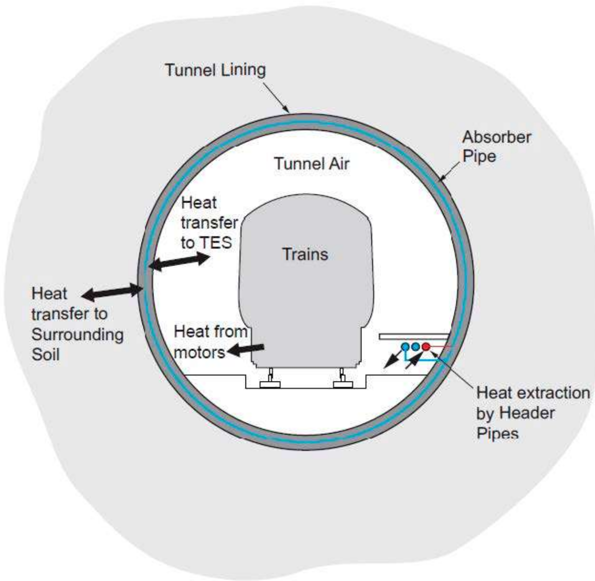
  ii. Policy and Regulations

  iii. Awareness, Knowledge and Social Acceptance

  iv. Sustainability, Environmental and Geographical considerations

  v. Technical and Infrastructure challenges

  vi. Research and Development



https://learninglegacy.crossrail.co.uk/

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Financial and Economic challenges

- High initial installation costs
- Market Uncertainty Challenges for their Adoption (GSHP in general)

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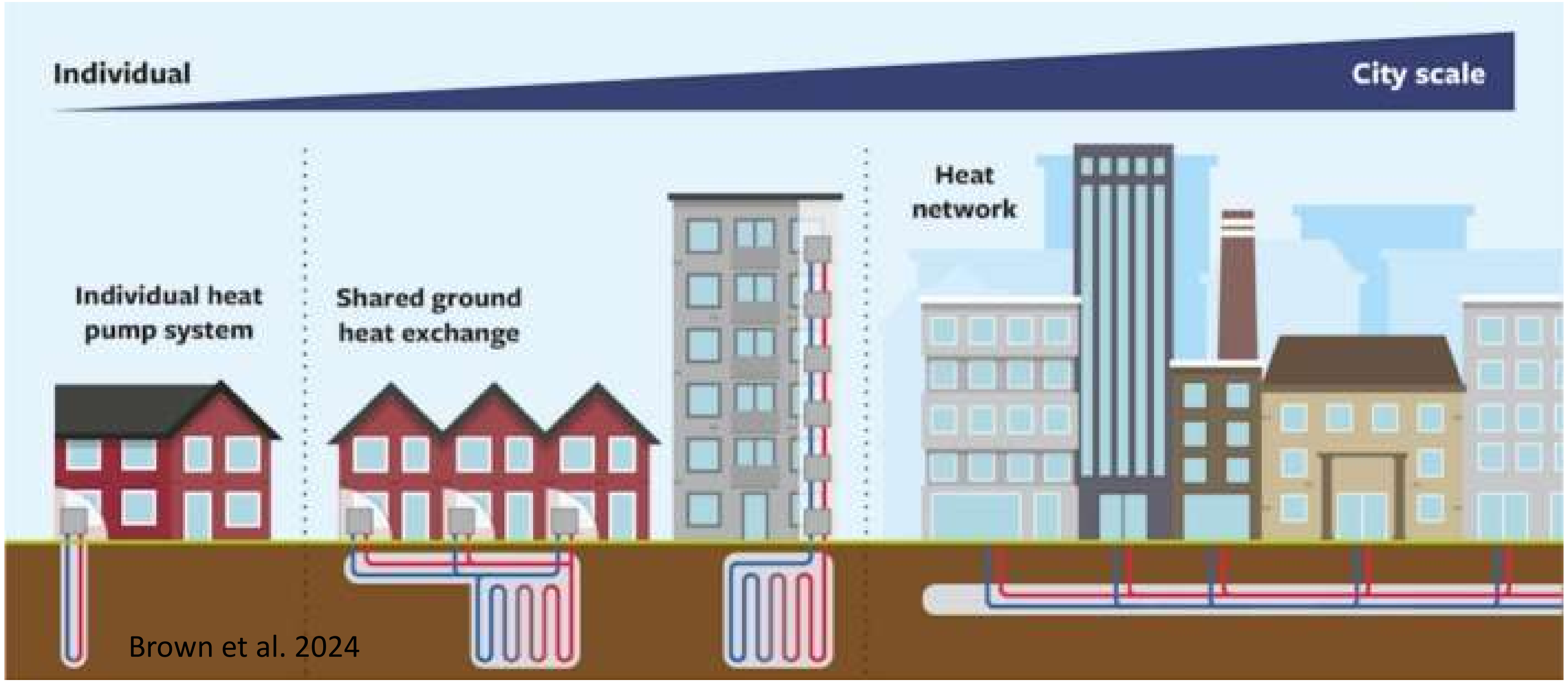
Policy and Regulations

- Regulatory and Planning Barriers to GSHP Deployment in the UK
- Urban Constraints and Bureaucratic Hurdles in GSHP Implementation



Brown et al. 2024

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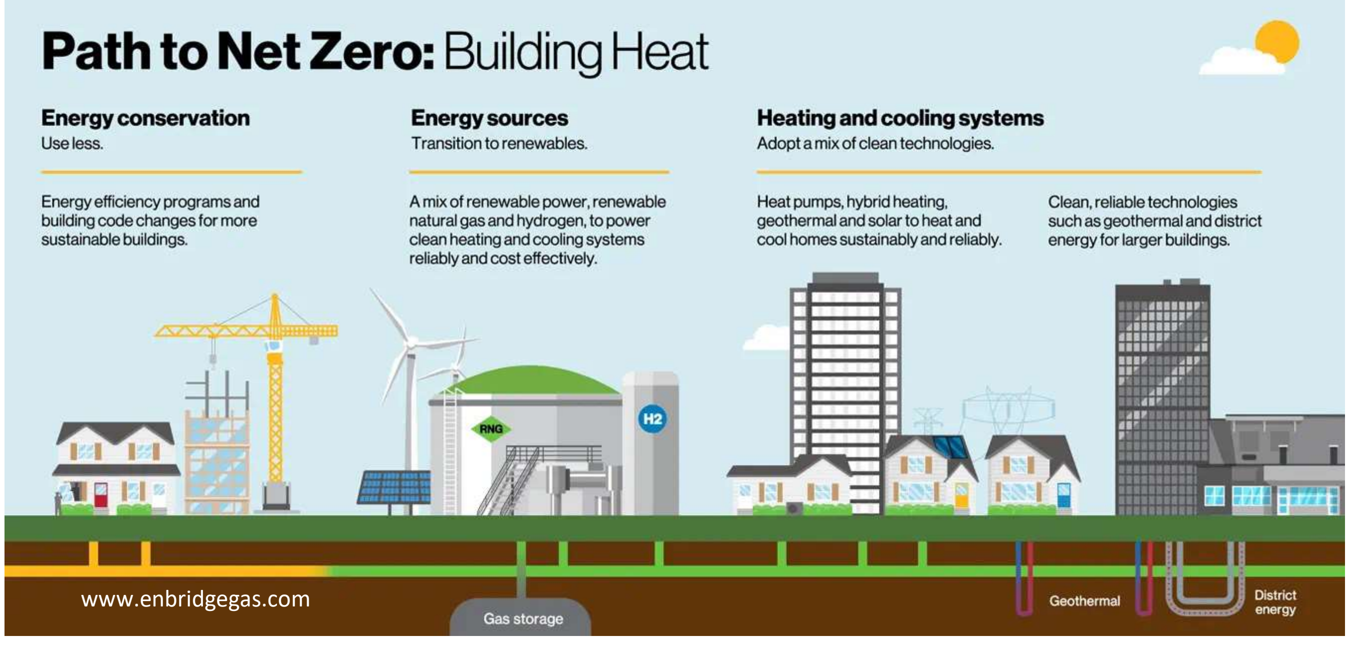
Awareness, Knowledge and Social Acceptance:

- Research published in 2020 showed that more than 60% of the public haven't heard of GSHP including energy geostructures .
- There's a significant knowledge gap concerning GSHP technology, levels of disruption and long-term benefits, and it is less and less understood by the general population compared to other renewable energy sources like solar panels. This lack of awareness can lead to misconceptions and a lack of confidence in the technology and its contribution to sustainability, hindering its social acceptance.
- There's a pressing need to better advocate the merits of GSHPs as a choice for low carbon energy supply (both for heating and cooling), especially when compared to other less dispatchable renewables like solar, wind, and air source heat pumps, highlighting financial-savings, life-cycle benefits, and efficiency .



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Environmental, Geographical, and Sustainability Considerations

- Environmental concerns exist around both the installation process and the potential impact of open loop GSHP systems on aquifers and wetlands.

But

- Energy geostructures are a closed loop shallow geothermal energy technology. As such they do not actively interact with groundwater, and any risk of pollution due to heat transfer fluid leakage is exceptionally low due to the high durability pipe materials used.

- Energy geostructures, can change the temperature of the sub-surface environment. In extreme cases this could be considered as pollution. However, well designed individual systems should operate at relatively low temperatures and cause little concern and more research needed to optimise the system and minimise this risk.

- In the future, with significant shifts to access of shallow geothermal energy, there is the potential for high densities of systems within urban areas to lead to higher temperatures due to adjacent system interactions. It is important to plan for this eventuality now to ensure future sustainability.

Technical and Infrastructure Challenges:

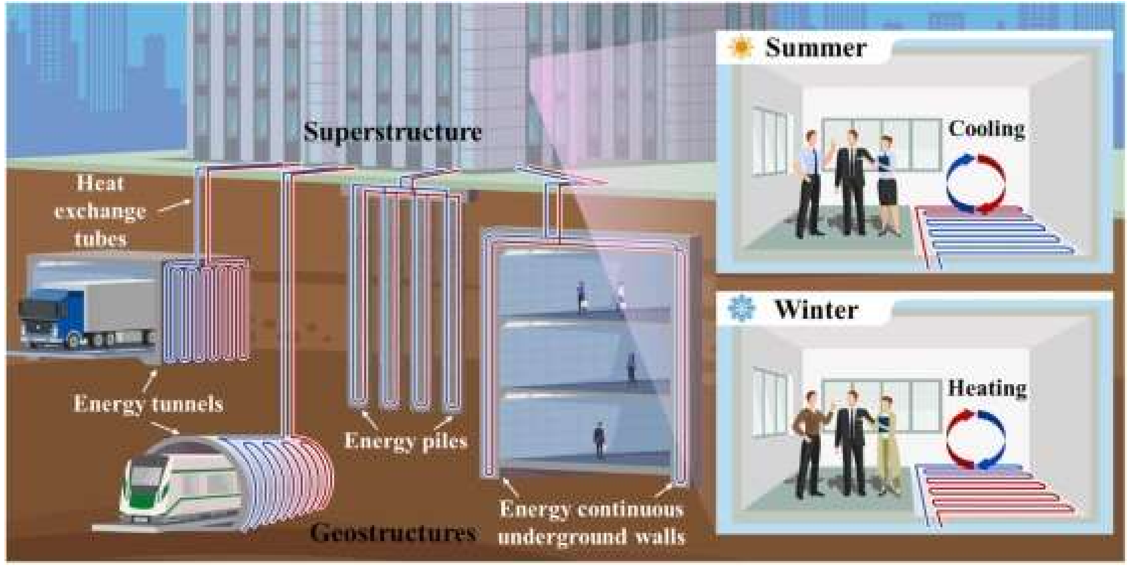
- In general, installing GSHPs in both new and existing buildings is complex, often requiring modifications to structures and careful navigation of subsurface infrastructure and sensitive environments.
- Underground components face durability challenges, especially in difficult ground conditions, highlighting the need for innovative materials and techniques.
- Structural design must consider thermal-induced forces and potential degradation of materials, yet available performance data remains limited.
- Maintenance demands and a shortage of skilled technicians, along with integration challenges with other renewables, hinder widespread adoption.

Research and Development

- A comprehensive research strategy is needed to improve GSHPs (e.g., energy geostructures), including better site assessments, tailored designs, cost-effective drilling, and advanced, eco-friendly materials.

- Smart monitoring, digital twins, AI, and low-cost sensors can enhance performance, integrate GSHPs with other renewables, and support efficient resource management.

- Economic uptake can be supported through innovative financing models and incentive schemes based on a full value assessment for society, the economy, and the environment.



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Our Current Research on Energy Geostructures

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National Buried Infrastructure Facilities (NBIF)

As part of the government investment for the UK Collaboratorium for Research on Infrastructure and Cities, the University of Birmingham has constructed the National Buried Infrastructure Facility (NBIF).

Based at the University of Birmingham, NBIF is a 'one of its kind' facility spanning research, innovation, education, CPD and training in buried infrastructure-ground interaction and ground engineering:

- Buried infrastructure-ground interaction,
- Soil stabilisation and improvement,
- Geophysical sensing,
- Pipeline detection and condition assessment,
- Tunnelling,
- Trenching & trenchless technologies,
- Structural performance of transport-ground-pipeline systems and green-grey infrastructure interdependencies.

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NBIF Equipment examples

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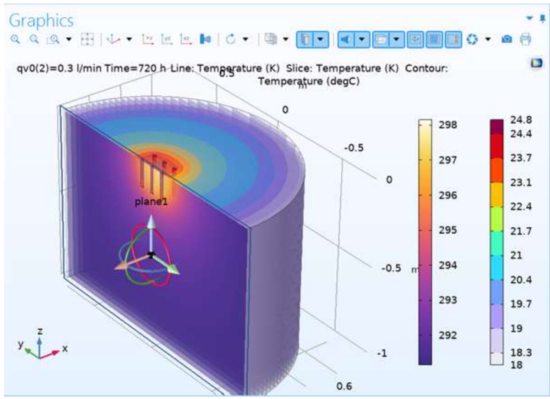
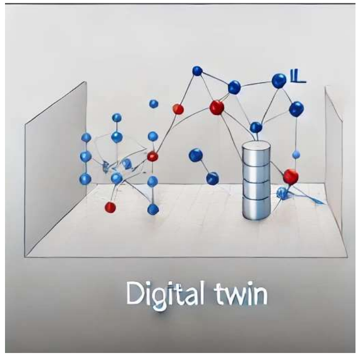
Improve heating & cooling efficiency and system resilience of shallow energy piles by developing a digital twin of the system

- Data Driven T-H-M **numerical** simulation
- Integrating **physical** experiments with computational modelling to simulate the **heat transfer, fluid flow, and soil-pile interactions**
- Development of a **Digital Twin** of the system
- **Real-time data** processing to train and inform ML algorithms and refine the digital twin, allowing for **optimisation** of **heating** and **cooling** performance.





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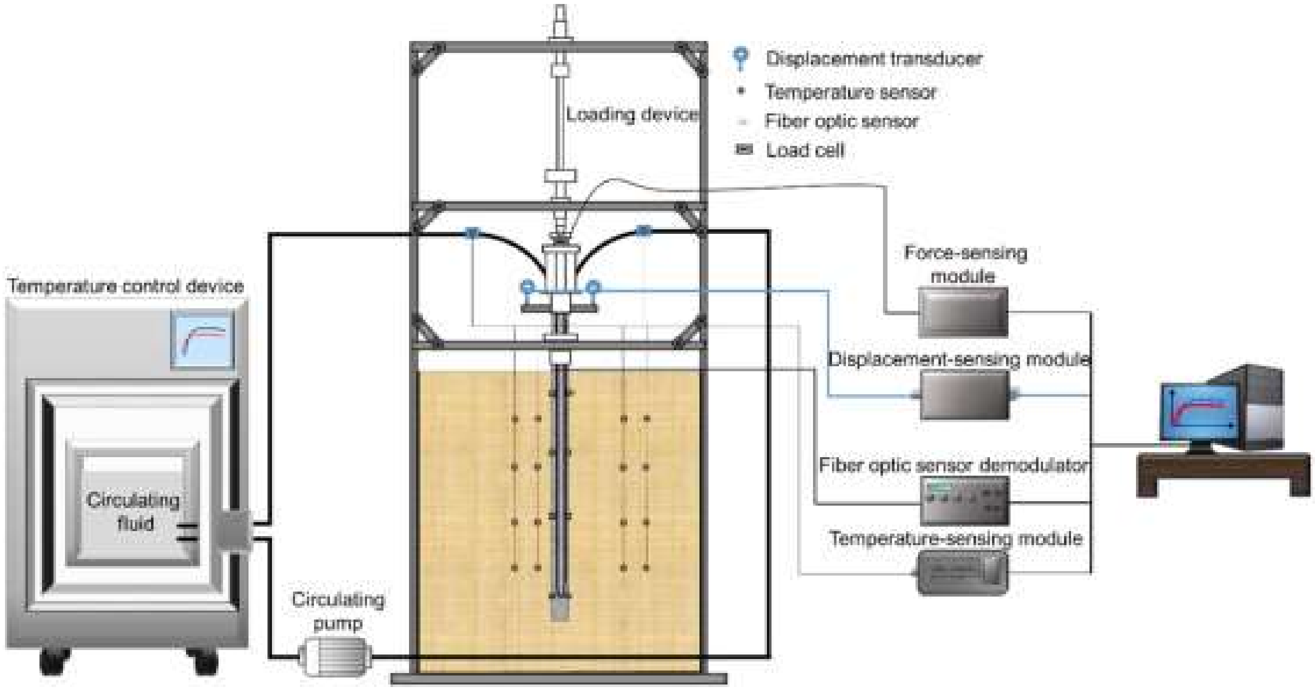
Improve heating & cooling efficiency and system resilience of energy piles by developing a digital twin of the system



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Danke
Merci
Gracias
Thank you
Grazie
謝謝
Спасибо