Government
Office for Science

Foresight

Future of the Subsurface

Progress Update

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Well and consciously governed underground resources may significantly increase the resilience of economy and society.

Hámor-Vidó et al, 2021. Underground space, the legal governance of a critical resource in circular economy. Resources Policy. Volume 73.

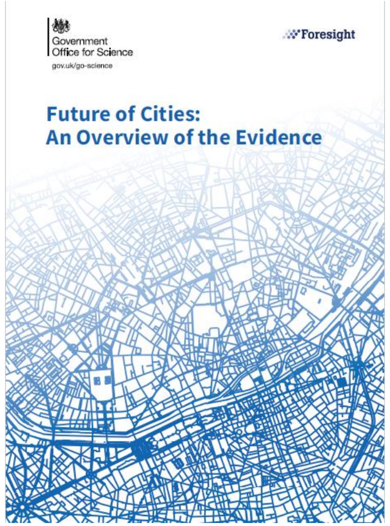
Go-Science and Foresight

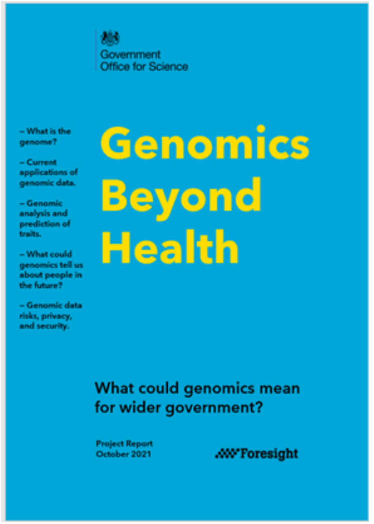
Who are GO-Science?

GO-Science advises the Prime Minister and members of the Cabinet to ensure that government policies and decisions are informed by the best scientific evidence and strategic long-term thinking.

What is a GO-Science Foresight project?

- Foresight projects take a big, cross-cutting issue, summarise the evidence, and explore future possibilities.
- They use the best available evidence and science advice by engaging GO Science's networks of experts.
- They identify challenges and opportunities for government to inform better policy that is resilient in the long-term.





How was the project selected?

Criteria for a Foresight project

Customer: *Clear identification of customer(s) within government*

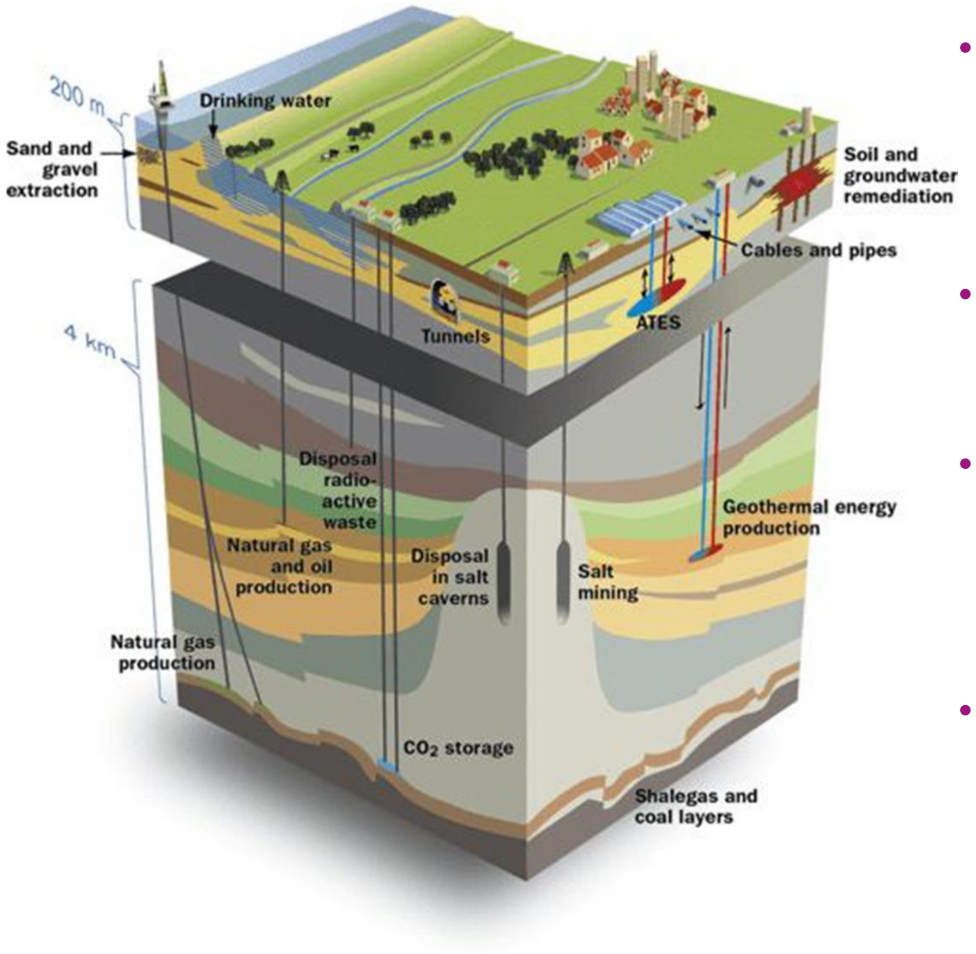
Value-add: *Clear added value from GO Science leading the work, e.g. the issue affects multiple departments and has a clear science or technology angle*

Long-term: *Project involves long-term thinking. Futures techniques can be used to inform government preparedness for potential changes on the horizon*

Timing: *Now is a good time for the project?, e.g. it fills a key evidence gap or informs an upcoming HMG strategy*

Impact: *There is scope for the project to inform a significant, identifiable policy outcome*

Why was the project selected?



Source: A technical investigation on tools and concepts for sustainable management of the subsurface in The Netherlands

- The subsurface provides society with a **wide range of essential services**, including space for infrastructure, transportation, and resources such as minerals, water and energy.
- Subsurface **space is finite** and can become congested, particularly in urban areas potentially **sterilising future uses**.
- **Competition** for subsurface space and resources is **set to increase** in the coming decades, due to changes such as increased urban populations and climate change adaptation and resilience.
- At the same time, subsurface **governance and ownership, decision-making and regulation are complex**, sector-dependant, and incomplete, leading to a lack of effective coordination and future-focused subsurface prioritisation.

Summary of Phase 1

Stakeholder engagement

- **Scoping workshops** – Held several interviews and workshops to determine scope of project, and key issues.
- **Systems mapping workshops** – Held two Systems mapping workshops, with a range of experts, to determine key subsurface systems interactions.
- **Additional meetings** – Engaged with stakeholders across government, academia and industry.

Outputs

- **Issues paper** - Combined stakeholder engagement with a literature review to produce an Issues paper, which is unpublished but available to share.
- **Case studies** – Conducted more in-depth looks at Competition for Space, Geothermal Heat, and Urban Water Management. Unpublished but available to share.
- **Systems map** – A visual depiction of the different elements of the subsurface and their interconnections, based on workshop outputs.

Key Findings: Current issues and challenges

Complex system interactions: Subsurface systems are complex and interconnected, resulting in a variety of feedback loops, which can be difficult to track. Subsurface elements are '**out of sight, out of mind**', exacerbating this.

For example, the uncontrolled extension of basements can interfere with groundwater levels, increasing the frequency of groundwater flooding.

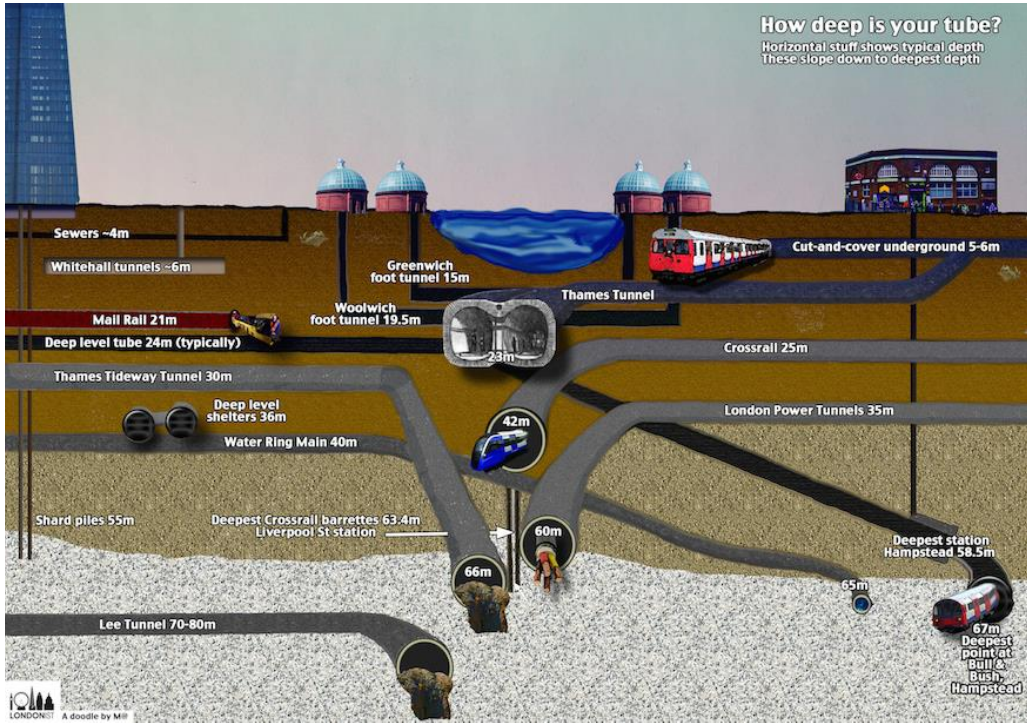
Data quality, availability and accessibility: Datasets are siloed between sectors and regions and are not usually shared, which hinders effective subsurface planning.

The image shows an incident where a third party accidentally cut through a fibre optic cable, leaving hundreds without internet connection for four days.
The establishment of a **National Underground Asset Register** demonstrated that barriers to integrating and secure sharing of national datasets can be overcome.

Source: https://www.dailymail.co.uk/news/article-7817277/Hundreds-furious-customers-left-no-internet-days-Virgin-Media-goes-down.htm

Key Findings: Current issues and challenges

Subsurface planning lacks coordination, direction and prioritisation: Stakeholders emphasised failures in coordination and planning of subsurface projects is a recurring issue, and the growing need for a stronger system of prioritising competing demands in an increasingly congested subsurface.



Source: https://londonist.com/2015/10/how-deep-does-london-go

Subsurface governance, regulation and ownership is complex, inconsistent, and incomplete: It is spread across national, regional and local bodies that can vary by sector and locality.

Although local government is largely responsible for subsurface planning, there are currently **no overarching subsurface policies** to govern or support initiatives such as climate adaptation at the local level.

Space can be used on first come first served principle, and the subsurface has been described as the **'final frontier**'.

Key Findings: Demand drivers and future challenges

Population increases and densification: Increased demand for infrastructure above and below ground, including utilities, transport tunnels and building foundations.

Climate change: Direct impacts include more frequent extreme heat and rainfall events. **Adaptation and resilience** measures involving the subsurface include incorporating sustainable drainage infrastructure, novel use of below-ground spaces for infrastructure, living and food production, tree planting for cooling and updating infrastructure to cope with heat.

Net Zero Transition: Many net zero solutions require new subsurface infrastructure, including EV charge points, district heating networks and ground sourced heat/cool. Future technologies that may help reach net zero include CCUS, hydrogen and compressed air storage.

Key Findings: Demand drivers and future challenges

Water: Impacts of climate change and population pressure are likely to continue to increase demand for groundwater and need to manage excess rainfall and alleviate flooding

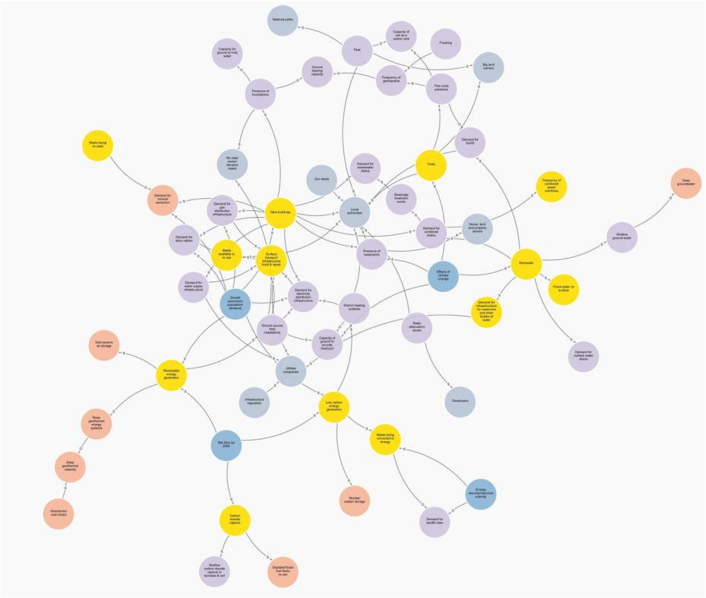
Subsurface technological innovation: Advances in tunnelling and excavation technology and improved scanning and mapping technology can reduce the cost of underground construction. The re-use of existing infrastructure is increasingly being considered to reduce costs and carbon usage.

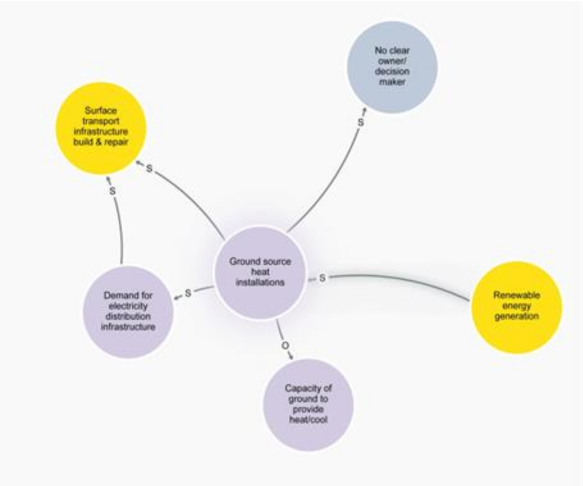
Tree planting projects: Trees can reduce heat effects and increase air quality, but a barrier to planting is uncertainty over ground conditions and buried services. Trees and utilities compete for urban space.

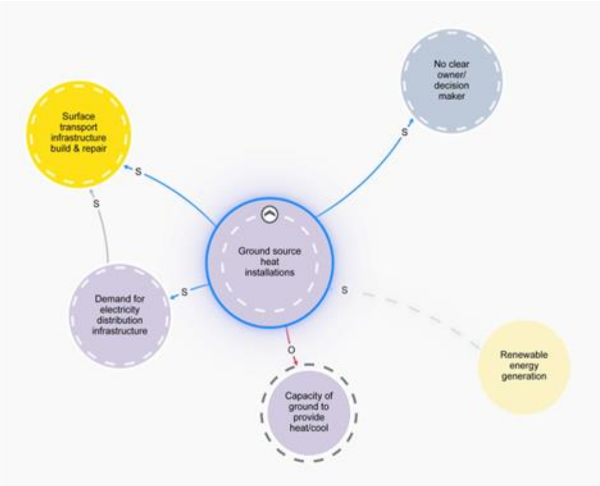
Other key challenges: Include ageing subsurface infrastructure, new digital roll-outs and protecting/reserving of ground for future Geological Disposal Facilities (GDF). The subsurface also contains critical resources and infrastructure relevant to national and international security and resilience.

Systems map

- Systems maps are a systems thinking approach which visually depicts the system, including relationships between different aspects and feedback loops.
- The systems map was developed through two workshops with 10-12 experts across a wide range of subsurface uses, and later refined within the team at GO-Science.
- The map splits the subsurface into five subsystems: the deep, shallow and surface physical systems, external drivers, and the institutional system.





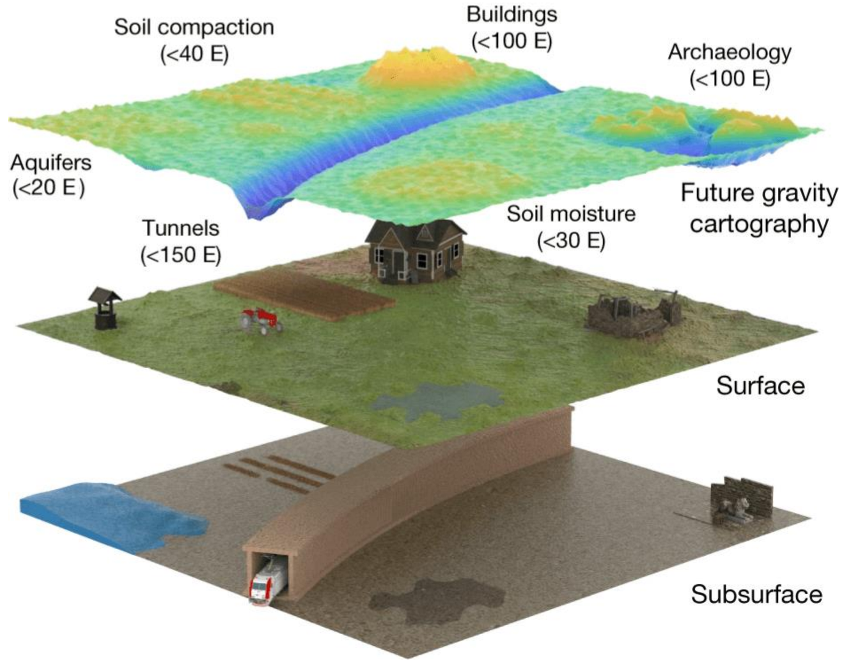


Example interaction

- Ground source heat installations (shallow physical) increase, causing the following interactions:
- Shallow physical: Capacity of the ground to provide heat/cool decreases; Demand for electricity distribution infrastructure increases
- Surface physical: Surface transport build and repair increases
- Institutional: There is no clear owner/decision maker for this

Use of Emerging Technologies

- **Quantum Sensing:** Ultra-precise sensors allow us to map under the surface and detect a variety of hidden infrastructure including mineshafts, sinkholes, pipes and tunnels. (Expand – Uni of Birmingham).
- **Fibre Optics to monitor ground behaviour:** Cambridge Centre for Smart Infrastructure has led to development and installation of optical fibre and conventional monitoring instrumentation on four major Crossrail sites.
- **Moun detection** an emerging technology to track and measure muons produced by cosmic rays, enabling the imaging and mapping of subsurface structures
- **Remote sensing:** increasingly detailed and real-time information from space such as InSAR (Interferometric Synthetic Aperture Radar) can be used to measure ground deformation with high precision.



Use of Emerging Technologies continued:

- **Digital Twins:** an emerging technology that creates virtual representations of a physical system or object with real time interactions between them. Geological Surveys and other organisations are building "twins/models" of the natural environment
- **Artificial Intelligence:** Tech start-up Exodigo promising to deliver AI-based scanners. Current project in UK with Colas Rail, using their technology as part of the light railway expansions for the Eastside Metro Expansion project in Birmingham.
- **Robotics:** vehicles and drones are getting increasingly smaller, autonomous and better connected. http://pipebots.ac.uk/ 'aims to revolutionise buried pipe infrastructure management with the development of micro-robots'

Stakeholder engagement

We have engaged widely with a range of stakeholders across government, academia and industry, including:

- **Government:** DESNZ, DSIT, DfT, Defra, DLUHC, Cabinet Office
- **ALBs/Local Gov/DAs:** National Protective Security Agency, British Geological Survey, Ordnance Survey North Sea Transitioning Authority, National Infrastructure Commission, Planning Inspectorate, Environment Agency, Nuclear Waste Services, Natural Resources Wales, Greater Manchester Combined Authority, Greater London Authority, Glasgow City Council, Transport for London
- **Academics:** Newcastle University, Manchester University, Aberdeen University, Imperial College London, Birmingham University, UCL, Oxford University, Oxford Brooks University, Lancaster University, Portsmouth University, University of Edinburgh, University of Cambridge, ETH Zuerich
- **External:** Arup, Atkins Global, Urban Design Group, Trees and Design Action Group, StreetworksUK, Highways Authorities Utility Committee

Key supporting quotes

Key stakeholder support:

DSTL Subterranean Team – "the subsurface presents enormous challenges but also significant opportunities, especially for science and technology to contribute to the benefit of UK interests"

DESNZ Clean Heat Team - "subsurface risks in many Heat Network (HN) schemes are putting-off contractors - providing accurate and detailed information on what is underground will reduce the risks and costs of constructing HNs

Greater London Authority Infrastructure Team – "there is a vital need for a more coordinated approach to management of the subsurface in order to decide how we can re-use abandoned assets, where new trees are planted, and Sustainable Urban Drainage Systems (SuDS) are installed.

Department for Transport – Highways Policy Team – "understanding how the space beneath our highways and railways is managed and used to facilitate decarbonisation and adaptation to Climate Change is essential"

National Infrastructure Commission – Economic Analysis Team – "very interested in the outcomes of Phase1 in particular how knowledge of the subsurface supports our aim getting infrastructure delivered in a timely fashion"

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Future of Tunneling

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