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Out of sight – out of regulation? Underground space governance in the UK

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Abstract: Underground space has been used by humans for thousands of years: for example, to extract mineral resources or water. Against the background of increasing populations, urbanisation, and energy demand, underground space has come back into focus, promising to ease pressure above the surface. However, geological underground models deliver only frameworks for possible uses and we do not know much about the context between geological characteristics and human uses, demands, and changes of underground space. Moreover, governing underground space can be complicated as it involves conflicting objectives and regulatory frameworks. One key objective, therefore, must be to conceptualise and implement new approaches to underground governance, taking into account its diverse uses and various stakeholders' claims. This article introduces the current situation of underground space governance and regulation in the UK, discussing different themes, such as property rights, regulation, planning, groundwater, fracking, and the future of underground space use exemplified by the storage of nuclear waste.

Keywords: Underground, governance, regulation, UK, sustainability, property rights.

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Introduction

When politicians, political ‘sherpas’, negotiators, NGOs (non-goverenmental organisations), and industry lobbyists gathered in late 2021 to discuss the future of climate change mitigation and adaptation at the annual United Nations Climate Change Conference COP26 (Conference of the Parties), they were talking about CO_2 emission reduction targets, fossil fuels, and water security among many other issues. However, they were talking less or not at all about where, for instance, fossil fuels or large amounts of water originate. Without using or exploiting underground space and resources, the world we live in would not be possible. Without iron ore there would be no iron, without coal or gas there would have been no large-scale industrialisation, without oil no plastics, without silicon no smartphone, without underground train systems no fast transport across the world’s largest metropoles. And in many areas of the world, without access to groundwater, life and settlements would not be possible. Underground space also plays a huge and important role in our cultural lives. The wall paintings of Lascaux are in a cave; humans settled underground; and still today, for instance, people in Coober Pedy, Australia live partially in caves known for their constant temperature. In many cultures we bury our ancestors underground or in catacombs; underground is almost synonymous with criminal activity (Tondo 2019); people hide underground during wars either to protect themselves or to escape from the enemy; and hell is of course a place underground.

The purpose of this article is to introduce the topic and to ask about the current situation of underground space governance and regulation in the UK using key themes and aspects related to underground space, such as property rights, regulation, fracking, and nuclear waste disposal. The question therefore is: how can an improved and sustainable governance of underground spaces in the UK be ensured? The article will therefore reflect on theoretical foundations and observations with regard to underground space use based on a literature and document review about the current legal and regulatory situation regarding underground space governance in the UK. This article is an introduction to a diverse issue and it is impossible to discuss all aspects of underground space use in detail here. The literature, as we will see, is dominated by civil engineers, architects, and urban planners and it focuses predominantly on urban underground space. Social science views or humanities’ perspectives on the underground have been scarce so far (Lee *et al.* 2016, Macfarlane 2019). The basis for this article is academic journals, policy documents, laws and regulations, and grey literature. This will include describing and defining underground governance and identifying themes and patterns. The literature and document review concentrates on the UK, but covers aspects and observations from other jurisdictions as well: for example, countries or cities known for their advanced approach on the issue, such as the Netherlands or Helsinki in Finland. The starting point for the literature review was a special issue of the journal *Tunnelling and Underground Space Technology* in 2016 (Bobylev & Sterling 2016). Further literature and documents were searched via a snowball search using cross-references and Web of Science and Scopus search engines. Articles were selected on the basis that they deal with underground space use, planning, or governance.

Although humanity has been using underground spaces for thousands of years (von der Tann *et al.* 2020)—for example, for extracting mineral resources or water—the systematic use of underground space, especially in urban areas, is a developing field and laws are not keeping pace with the demand for and opportunities of urban underground space (Bobylev & Sterling 2016). Construction, transport, groundwater, geothermal energy, geomaterials, storage, deposition, or mining are possible uses of underground space. Admiraal & Cornaro (2016) call it 'the final urban frontier waiting to be exploited by those who place the first stake and thereby claim their space'. An extreme case of this can be seen in London, where so-called iceberg houses are extended extensively underground (Baldwin *et al.* 2019, Batty 2018, Batty *et al.* 2018, Burrows 2018). The underground has become an economic and political arena.[1]

While geological underground models deliver only frameworks for possible uses, we do not know much about the interactions between geological characteristics and human uses, demands, and changes. Furthermore, the governance of underground space can be complicated as it involves conflicting uses and legal regulations. Whereas in the UK, coal, gas, minerals, silver, and gold belong to the Crown, groundwater is owned by the landowner, yet its use is limited to reasonable use or has been governed by abstraction licences since 1963. The *cuis est solum, eius est usque ad coelom et ad infernos* (whoever owns the soil, it is theirs all the way to heaven and all the way to the depths below) maxim has, according to Gray and Gray (2009): 'often been invoked in support of some notion of the sacrosanct nature of property rights'. Yet, in contemporary property law this has been substantially qualified. This might be evident for airspace above a property, yet as space beneath a property is out of sight, the regulation and responsibilities of landowners are a patchwork of various practices.

With the exception of nationally significant infrastructure projects, such as power stations, transport schemes, and national parks, planning in the UK falls under the responsibility of local government and is hence fragmented. Strategic regional planning was abolished in 2011 and the sole reference to the underground in the Department for Communities and Local Government (DCLG) 'National Planning Policy Framework' (DCLG 2019) is to encourage underground gas and carbon storage.

[1] For example, the SNL Metals + Mining database, which lists the profiles of 35,000 mines worldwide is under strict copyright and used as a commercial database for potential investors.

Public water supply is the responsibility of the Department for Environment, Food and Rural Affairs (Defra), the Environment Agency (EA) for England, or Natural Resources Wales (NRW), the Scottish Environmental Agency (SEA), and the Northern Ireland Environment Agency (NIEA), and also governed by water companies. Fossil fuels and mineral resources are under the auspices of the Department for Business, Energy and Industrial Strategy (DBEIS). This plethora of authorities could potentially lead to overlaps of governance functions and what and whose objectives should inform the governance of underground space. And, with so many different activities going on underground regulated by different authorities, agencies, and regulators, the bigger picture of underground use should not be forgotten. As above ground, things interact with each other and we should ask the question: how do we actually want to govern and regulate underground space in the future? Hence, a 'spatial dialogue' (Admiraal & Cornaro 2016) is required involving all stakeholders using an interdisciplinary approach (Besner 2016).

Population growth and climate change put stress on public water supply, which includes groundwater aquifers. While low river flows or decreasing reservoir levels are easily visible, the opposite holds true for decreasing groundwater aquifer levels. If further stress is put onto groundwater resources due to an intensified use of the underground for the extraction of shale gas, through hydrological fracturing ('fracking') or CCS technology (carbon capture and storage), this could add further stress on groundwater resources as both new technologies need large quantities of water and increase the risk of drinking water contamination. Therefore, a sustainable governance, understood as binding political decisions to the benefit of future generations that include state and non-state actors through steering mechanisms, cooperation, and coordination (Grecksch 2014), of underground space is needed.

It is striking that, although underground space is used daily by millions or that we are using products that rely on materials extracted from underground, we think so little about it, that we almost take it for granted. When climate change and its causes and effects are discussed, we easily mention words like fossil fuels, water security, etc, but we always omit 'underground', although the link is not in front of us but directly below our feet. Melo Zurita *et al.* (2017) subsume this phenomenon under 'surface bias' in their discussion about the Subterranean Anthropocene. Thus, it should enter the vocabulary of policymakers and those discussing the future responses to climatic changes at the annual COP negotiations.

The Anthropocene (Steffen *et al.* 2016), the new proposed geological epoch, which is defined by human impact on the Earth's geology and ecosystems, is more or less embodied by underground space; it is the future underground (Melo Zurita *et al.* 2017). A geological epoch differentiates itself from its predecessor by significant changes in the rock layers. Hence, the changes humans made and are making to underground space through extraction, usage, storage, etc will define this new epoch and what we leave behind.

What makes underground such an interesting space?

As mentioned before, humans have been using underground space for thousands of years. Industrialisation and colonisation are deeply linked with the exploitation of underground space for resources. However, with increasing populations and urbanisation around the world, the use of underground space has come into focus again. This is especially the case for cities where space and its efficient use are crucial, yet scarce and expensive. Moreover, the increased use of underground space could help cities to solve pressing issues such as overpopulation (Broere 2016). For example, we already find much infrastructure, utilities, and storage underground. Trains, urban and inter-urban, run underground through cities; broadband cables, electricity, water and wastewater pipes are hidden underground; and a lot of car parks are underground. In fact, without vital infrastructure and transport underground the modern city as we know it would not be possible. Outside of cities, in the countryside, underground space has come to prominence with large infrastructure projects such as the proposed high-speed railway HS2 in the UK, which includes the building of tunnels (Topham 2020). The second big issue in the UK's countryside is hydraulic fracturing, commonly known as fracking. Hailed as an energy source of the future by the UK government, it stirred up local protests at test drilling sites (Cartwright 2019). At the moment fracking has come to standstill in the UK after a series of earthquakes at test drilling sites (Ambrose 2019) and the government has put a moratorium on fracking (DBEIS & Oil and Gas Authority 2019). A later section of this article will take a closer look at and review the debate in the UK in more detail.

Carbon capture and storage (CCS) is a technology favoured by the UK government in its Clean Growth Strategy (HM Government, 2017). In brief, CCS is a process whereby CO_2 is separated from industrial and other energy-related sources, transported to a storage location and isolated long-term, usually underground. CCS technologies could reduce the lifecycle greenhouse gas emissions of fossil fuel power plants; however, CCS has not yet been applied at scale to a large, operational commercial fossil fuel power plant (IPCC, 2014). CO_2 leakage could be a potential issue; however, a growing body of experiments and literature (e.g., Roberts & Stalker 2020) addresses this issue.

Other developments with regards to underground space, which are worth mentioning briefly, relate to seabed rights for offshore windfarms. The Crown Estate, which manages the seabed around England, Wales, and Northern Ireland, in 2021 selected six new offshore wind projects (Crown Estate 2021). This affects underground space insofar as wind turbines have to be securely anchored into the seabed and pipelines laid to the shore. With regards to the subterranean biome, Sánchez-Fernández *et al.* (2021) emphasise that the subterranean ecosystem should not be forgotten in climate change agendas. And, recently the world's most precious metal, gold, has come into focus in Northern Ireland again (Carroll & Carrell 2020). However, local residents fear dust, air pollution, and water contamination resulting from the prospective gold mine and have submitted more than 40,000 representations to the public enquiry, most of them objections.

Hence, the demand for underground space is rising again, not least because of advances in tunnelling and excavation technology decreasing the construction costs of underground structures (Li *et al.* 2016). The same authors identify underground resources as a space for construction, groundwater, geothermal energy, and geomaterials. Bartel and Janssen (2016: 113) differentiate between *storage* (natural gas, oil, and storage of H_2 and compressed air); *deposition* (CCS; underground waste disposal including storage of radioactive waste, brine injection), *productive activities* (mining; the use of geothermal energy as geothermal heat pumps/shallow geothermal systems, hydrothermal geothermal systems, petrothermal systems/hot–dry rock technology; storage of heating and cooling energy; utilization of mineral springs and groundwater), and *underground structures* (tunnels, technical structures; underground pumped hydroelectric power plants). Apart from these, there are also interesting double-use examples of underground space: for example, road tunnels that can be used to retain flood water (Qihu 2016). The possibilities of underground use seem endless, and human engineering has already come up with a plethora of underground structures and uses. In Helsinki, we find a public swimming pool underground (Roth 2018, Vähäaho 2016) as well as a wastewater treatment plant (Vähäaho 2016). Furthermore, there are underground shopping centres, archives, restaurants, night clubs, etc. Data centres could be located underground, in areas not prone to flooding, saving space, and the excess heat produced by servers could be used to heat houses nearby (Admiraal & Cornaro 2016). In west London, there are plans to excavate gravel from underground creating a vast subterranean cavern while at the same time creating a public park on top (Wainwright 2017).

A special issue of the journal *Tunnelling and Underground Space Technology* in 2016 took stock of urban underground space use in the academic literature from 2006 to 2016 and found that Chinese researchers have the biggest interest in urban underground use, followed by those in the United States, Japan, and the UK. Regarding subject areas, Engineering, Earth and Planetary Sciences, and Environmental Sciences take the top three places followed by Social Sciences (Bobylev & Sterling 2016: 1). It is the Social Sciences perspectives that are of most interest in this article and this includes legislation and regulation. Bobylev and Sterling (2016: 3) conclude, for example, that laws are not keeping pace with the demand for and opportunities of urban underground space.

Underground space in law and regulation

Admiraal and Cornaro (2016: 215) write: 'As such underground space can be typified as the final urban frontier waiting to be exploited by those who place the first stake and thereby claim their space.' This may evoke the spirit of the Wild West; however, underground space is already heavily regulated. Yet, it is the plethora of different laws and regulations that may lead to conflicting interests and potential environmental damages: for example, to groundwater. However, let us start at the beginning and ask who actually owns underground space.

Without going into too much detail about property rights and property law, since this is not the core topic of this article, let us briefly define property law and property rights. Part of Private Law, Property Law is concerned with relationships over things often involving ownership of things and the rights that flow from that ownership (Fisher *et al.* 2019). Property rights are a social institution limiting, for example, the rights of access to a resource. Blackstone, in his *Commentaries on the Laws of England* said:

> There is nothing which so generally strikes the imagination, and engages the affections of mankind, as the right of property; or the sole and despotic dominion which one man claims over the external things of the world, in total exclusion of the right of any other individual in the universe. (Blackstone *et al.* 1844: sec. 2)

A statement that has lost little in meaning as the writer John Lanchester comments on empty, yet expansive, flats in London: 'a device for getting capital out of your home country, where it might be stolen or expropriated, to the UK, where the only true and universal object of worship is property rights' (Lanchester 2017). This is more so in the US where Goldstein and Hudak (2017) found a growing concern among the US right-wing about the need to defend individual private property rights against rules aimed at protecting the environment, whereas they found no such concern in the EU or among the US left.

Liberal Western democracies are unthinkable without property rights, and it is either a legal or an economics perspective, or both, that dominates the discussion about property rights (Grecksch & Holzhausen 2017). For instance, in the case of fracking, which will be discussed later, we can see how multinational corporations face a property regime which relates to national levels; however, in the age of a global economy, nationally defined property rights must be redefined or dismantled.

Multinational corporations therefore ask for the transformation of property rights into corporate rights and subsequently access to land and access to its resources (Teeple 1997). Braithwaite and Drahos (2000) also describe that globalisation's recent phase, that is, the 1990s, was to extend the security of property to non-citizens, especially transnational corporations.

> The sovereignty cost to nations of a global property regime is not simply a matter of economic adaptability. Property rights are not just economic tools, they are the product of broader social, cultural and philosophical traditions, and ideas. The rights of UK citizens to wander about in their countryside tell us as much about the social and political history of that country as they do about externality problems. Local property arrangements are the products of moral and cultural traditions, which are living traditions and which people do not necessarily want changed. The crucial issue is not the loss of traditions that carry and implement the moral values a society holds important. When governments exercise legislative power over property arrangements, they have to do so in ways that are consistent with the trust granted to them by the community they represent. This is a fundamental tenet of literal democratic traditions. (Braithwaite & Drahos 2000: 84)

We will see the relevance of this later in the section on fracking and how property can evoke more than a legal and economics perspective as, for example, demonstrated by Grecksch and Holzhausen (2017) for the case of narratives.

Riddall (2003), in his introduction to *Land Law*, states that in English law there is no such thing as absolute ownership of land. Instead, all land is held from the Crown by tenure. For instance, unmined gold, silver, and uranium belong to the Crown, as well as oil, gas, and coal (Morgan 2013). Its extraction, however, is possible through licensing. Gravells (2010) observes that the cases support in principle that the owner of land owns any natural or man-made structure below the surface of the land. While Roman law has the *superficies solo cedit* principle, meaning that whoever owns the land also owns what is placed on the land (Admiraal & Cornaro 2016), the common law maxim of *cuis est solum, eius est usque ad coelom et ad infernos* (whoever owns the soil, it is theirs all the way to heaven and all the way to the depths below) has often been invoked in support of some notion of the sacrosanct nature of property right despite it being 'in many ways discordant with the conceptual apparatus of the common law … today it serves a limited function reinforcing an owners exercise of all the rights required for reasonable enjoyment of his property' (Gray & Gray 2009: 14).[2] Gray and Gray (2009) continue to say that the maxim has limited definitional value and has virtually become worthless in contemporary law. For example, it would lead

[2] Sprankling (2008) delivers an interesting and elaborate discussion for the situation in the United States challenging the traditional view of the maxim.

to major problems in terms of air rights (Admiraal & Cornaro 2016) but also with regard to underground space it has been qualified, most recently in the UK, where the Infrastructure Act of 2015 created a new land access regime to use deep-level land below 300 metres (see the section on 'Underground and fracking' below). This enables fracking, as we shall see later, since fracking includes not only vertical drilling but also horizontal fracturing of the rock layers underground; hence the name.

In 1991, the International Tunnelling Association (ITA) conducted a survey among its member countries on legal and administrative issue in underground space use (Barker 1991). Regarding the limits of surface property ownership, four main conditions were identified. First, the surface owner owns to the limit of the earth. Second, the surface owner owns as far as a reasonable interest. Third, the surface owner owns only to a limited depth beneath the land (as little as 6 metres). Fourth, private landownership is almost non-existent and, hence, the underground is also publicly owned (Barker, 1991: 195–6). There are also restrictions on natural and mineral resource exploitation. They depend on the type of resource and often on whether the mineral has economic value. Hence, the survey found that resources can belong to the State which can issue concessions; resources can belong to the surface owner; resources may be developed by anyone who discovers them; mineral rights can be separate from surface ownership; or the State can reserve a share of the resource value (Barker 1991: 196).

The biggest challenge for underground regulation is conflicting uses: that is, transport vs. utilities vs. energy production vs. groundwater. These issues have conflicting priorities and different authorities with differing policies (Admiraal & Cornaro 2016: 217). Hence the authors name three aspects when considering the governance and legal challenges of underground space use: landownership, liability, and building codes (Admiraal & Cornaro: 2016: 218). With regard to landownership, they outline three approaches. First, effective landownership can be limited to a specific depth beneath the surface. Japan and Singapore have taken this route and limit space beyond the limit and deem it to be owned by the State and it may be used for public purposes (Admiraal & Cornaro 2016: 218, Kishii 2016, Zhou & Zhao 2016). The second approach is to acquire land based on a legal mandate through compulsory purchase, eminent domain, resumption, or expropriation. This usually requires compensation. The authors cite the UK Crossrail Hybrid Act 2008 as an example. Crossrail is a major transport infrastructure project crossing London from east to west. The Act determined that 'the Secretary of State had the right to acquire any land mentioned in the Act for up to five years after its passing with a further possible extension with five years' (Admiraal & Cornaro, 2016: 218). The third approach is an easement, a private agreement between two parties to access land (Admiraal & Cornaro, 2016: 218).

Water and underground

The human relationship with water has been a history of use and abuse (Grecksch 2019). Water and underground share a special relationship, as water infrastructure is mostly hidden underground (supply and wastewater pipelines, storage) and we find water in the form of groundwater stored in aquifers at various depths below the surface. Issues arise mostly for groundwater, although leakage of water supply pipelines is an issue haunting England's water companies (Plimmer 2020). First of all, an increasing population is demanding more and more water, putting pressure on water resources. Second, groundwater is mostly invisible and hence the true amount of water in an aquifer can at best be estimated based on weather cycles, precipitation patterns, streamflow, or previous abstraction data. Some hydrologists hence compare it to 'dark matter' because of its invisibility (Fogg 2015). Third, technologies like fracking and CCS require huge amounts of water for their operation. As do other major infrastructure projects:

> Major infrastructure programmes can also pose a threat to chalk streams and other delicate river environments. In the Chilterns, HS2 is likely to require over 10 million litres of water a day for its tunnelling operations. The Environment Agency told us that it will not give approval to any parts of HS2's plans until they have identified and set out any potential groundwater impacts and agreed acceptable mitigation actions. (House of Commons & Public Accounts Committee 2020: 14)

While the 17th-century True Leveller and Digger Gerrard Winstanley proclaimed that resources of the Earth are to be used in common by all (cited in Malcolm & Clarke, 2018), Malcolm and Clarke (2018) state that it is not an option to have no property rights for water as water cannot be left unregulated. Gray and Gray (2009: 51) say that it is:

> surprising the English property law remains relatively uncertain or incoherent in its conceptual treatment of the increasingly valuable resource of water. Although the ownership of water promises to become one of the critical questions of the 21st century, English law persists in regarding water as incapable of being owned.

Malcolm and Clarke (2018: 216) echo this notion:

> We are left with this situation in England as a result of the House of Lords decision in *The Mayor, Aldermen and Burgesses of the Borough of Bradford v Pickles*, where it held that, … , no one has any kind of property rights in or to percolating groundwater at common law. However, since 1963, there have been abstraction licences, issued by the Environment Agency for England that de facto trump property rights. Hence, without an abstraction licence that defines where and how many litres of water can be taken, no one is at liberty to take water from anywhere without a licence. (Malcolm & Clarke 2018: 218)

Planning and underground space

As mentioned in the Introduction, with the exception of nationally significant infrastructure projects such as power stations, transport schemes, and national parks, planning in the UK falls under the responsibility of local government and is hence fragmented. This fragmentation can cause tensions between national strategies and policies on the one side and local planning processes on the other side; however, this is nothing new in the UK (Grecksch & Holzhausen 2017: 103–4). Von der Tann *et al.* (2018) deliver a comprehensive overview of planning regulations in the UK for the subsurface. They conclude that:

> The current governance of subsurface space in England is largely sectoral and project centred rather than based on the premise to control all activities in a given volume. … However, each aspect is addressed separately and the interdependencies dealt with in a particular application are restricted to already existing or planned activities in the project vicinity. The effect of the individual regulations on plan making from the outset seems to be limited. (von der Tann *et al.* 2018: 34)

Furthermore, a conference on underground cities remarked that actual underground planning suffers from sectored tunnel vision:

> On the one hand, sectored planning result in the establishment of not connected 'underground islands' or 'underground patches'. On the other hand, permanent liveability of subterranean spaces faces numerous cultural, physiological and technical challenges. Lastly, traditional planning already relegated below the surface the technical facilities and devices that were supposed to be hidden (catacombs, sewers, transport systems, etc.) as well as the activities physiologically 'acceptable' without daylight (stores, logistics, etc.). Such a strategic bias coined underground areas primarily as service areas. (IRCS 2016)

As we will see below, a city or a whole country can develop a strategy or masterplan for underground space, thereby giving it more attention and focus and most of all the attention it deserves in the future development of resource governance, transport policies, and planning policies. The majority of the literature focusses on urban underground space use and planning, as a solution to overcrowding cities where space is scarce and expensive (Admiraal & Cornaro 2016, Bartel & Janssen 2016, Broere 2016, Dick *et al.* 2017, Hunt *et al.* 2016, Li *et al.* 2016, Price *et al.* 2016, Stones & Heng 2016, Volchko *et al.* 2020, von der Tann *et al.* 2020).

The Netherlands is the first country in the world to publish a national planning strategy for the subsurface (Government of the Netherlands 2018). This takes place in a larger framework of the Environment and Planning Act, an ambitious piece of legislation combining fifteen separate environmental acts into one (Volchko *et al.* 2020). The main reason for a national planning strategy for the subsurface is that the subsurface is important to the country's energy supply. For example, Europe's largest onshore gas field lies beneath the east of the Netherlands. Second, most of the Netherland's drinking water supply is produced from groundwater. Hence, the purpose of the plan is 'to think about long-term underground management now, in order to prevent problems in the future. For instance, we are making increasing use of alternative energy sources, which imply further utilization of our subsurface. And, of course, we will always need drinking water' (Government of the Netherlands 2018: 2). Other key points of the strategy include the exploration of the potential of geothermal energy, a 'no' to shale gas extraction, and CCS will only be possible offshore (Government of the Netherlands 2018: 2). According to the strategy, the guiding principle is sustainable, safe, and efficient use of the subsurface, balancing exploitation and protection. This will be ensured by deliberation and decision-making, which is based on involving all tiers of government, stakeholders, and NGOs (Government of the Netherlands 2018: 4). The development of the national strategy for the subsurface had already involved a variety of stakeholders with interest in the subsurface (Government of the Netherlands 2018: 18; see also Nouzari *et al.* 2019).

Helsinki is also at the forefront of underground regulation and governance. The city produced an Underground Master Plan which came into force in 2010. However, the planning process goes back to 1980 (Vähäaho 2016, 2018). The city hosts a whole variety of structures underground that go beyond the usual suspects like the metro, parking, utility tunnels, and road tunnels. The most prominent example is the Itäkeskus Swimming Pool, but the most interesting underground feature in Helsinki is the requirement of Finnish property owners to include emergency shelters in buildings of at least 1,200 m^2 (Vähäaho 2018: 16). Usually these spaces are designed to perform a different function during non-emergency times. Thus, the aforementioned swimming pool is constructed in a way that it can shelter 3,800 people in an emergency (Vähäaho 2018: 17). The Underground Master Plan of Helsinki shows both existing and future underground spaces and tunnels, as well as existing vital access links to the underground. It also includes rock resources reserved for the construction of as yet unnamed underground facilities, with the aim of identifying good locations for functions suitable for locating underground, and which would also reduce the pressures on the city centre's rock resources. As with the national strategy for the subsurface in the Netherlands, the Underground Masterplan was developed in a collaboration between public and private stakeholders (Vähäaho 2016).

Underground and fracking

As of November 2019, there has been a moratorium on fracking in England (DBEIS & Oil and Gas Authority 2019).[3] This does not mean the definitive end for fracking in England, but it is an important step for those who criticise the technology (Ambrose 2019). The moratorium was introduced after a report by the Oil & Gas Authority (2019) found that it was impossible to predict the probability or magnitude of earthquakes caused by shale gas extraction. Moreover, another report by the UK National Audit Office (NAO 2019) concluded that the government's 'plans to establish fracking across the UK was dragging years behind schedule and had cost the taxpayer at least £32m so far without producing any energy in return' (Ambrose 2019). And, even earlier in 2019, the UK High Court ruled the government's fracking guidelines unlawful. Scientific evidence had not been considered, and the design and the process of the public consultation were ruled to be unlawful (Harvey 2019).

Fracking in England turns out to be a prime example of why better regulation of underground space is necessary. It shows the interconnectedness of underground-related issues: it is seen as either or both bridging and future energy provider; there is evidence that it may contaminate groundwater; it is an example of the tension between central and local government in England regarding planning; it is a legal issue as fracking companies were able to invoke pre-emptive injunctions against protesters, that is, nip potential protests in the bud; and it is generally speaking an environmental protection issue, as protests could be observed across all test drilling sites fearing implications for the local environment, biodiversity, and water contamination.

Fracking (hydraulic fracturing) is a technology to access shale gas. Shale gas is natural gas trapped in low-permeability shales. The gas is held in pore spaces within the rock, or adsorbed onto minerals and organic material in the shale. New technology for gas production from shale formations, horizontal drilling and hydraulic fracturing, evolved first in the USA, and has led to the rapid exploration of shale formations worldwide (BGS 2020). The UK possesses considerable reserves of shale gas (Stuart 2012) and previous governments favoured the technology, arguing that it promises to help make the transition to a zero-carbon economy and support the UK's energy self-sufficiency (Clark 2018). In 2013, the former Chancellor of the Exchequer, George Osborne, proposed '"the most generous tax regime in the world" for shale gas,

[3] Decisions on fracking applications are a devolved matter. Scotland's government decided that fracking is incompatible with its climate policy and will not issue any licences (Scottish Government 2019). The Welsh Government came to a similar conclusion and will not support any applications for fracking (Welsh Government 2018). In Northern Ireland there is planning presumption against fracking (BBC News 2019).

saying he wanted "Britain to be a leader of the shale gas revolution"' (Bounds & Parker 2019).

Fracking has potential impacts on groundwater. This is important since groundwater is a vital source of freshwater in the UK and provides around 27 per cent of public water supply on average; in south-east England it is nearly 90 per cent of public supply (BGS 2020). Other uses of groundwater include bottled water, agriculture and irrigation, and food and drink production. And, groundwater is also vital for maintaining river flows especially during dry periods and so is essential for maintaining ecosystem health (BGS 2020). Stuart (2012), in his report for the British Geological Survey, summarises that:

> Groundwater may be potentially contaminated by extraction of shale gas both from the constituents of shale gas itself, from the formulation and deep injection of water containing a cocktail of additives used for hydraulic fracturing and from flowback water which may have a high content of saline formation water. (Stuart 2012: 19)

Moreover, fracking requires large volumes of water, putting pressure on groundwater resources with impacts on other uses and ecosystems. The author also lists 'unknowns' with regard to fracking, all three of them water related: shale gas fields could be overlain by aquifers; groundwater could be vulnerable to surface pollution and flowback water; and groundwater could be vulnerable to pollution from fracking operations and shale gas. He also mentions that examples of surface water contamination from releases of fracturing water or flowback water have been documented in the United States (Stuart 2012: 20).

Fracking involves not only drilling vertically but also horizontally, making it an issue for property rights. Stokes (2016), mentions the amendment of the Infrastructure Act in her critique of UK fracking governance, as one of the obstacles that needed to be removed to enable shale gas development. She places her compelling critique against the background of 'regulatory domain' versus 'regulatory dexterity'. The former involves analysing regulation in the abstract:

> It entails taking a synoptic view of the regulatory landscape and looking at regulation as a whole, rather than the individual parts of it. Government maps the general regulatory regimes applicable to fracking, providing a simplified illustration of the great expanse of legal provision. Because fracking is treated as analogous to conventional drilling technologies, it is said to fall within the remit of existing regulations on the protection of health and the environment. (Stokes 2016: 962)

In other words, the UK already has robust legislation and regulation for shale gas extraction and additional new rules would stifle the development. She concludes: 'The practice of resorting to existing legislative coverage gives the "regulatory domain" a sturdiness and panacea-like quality, and leaves little scope for reform in areas where "domain"-like arguments are invoked' (Stokes 2016: 974). Regulatory dexterity, on the other hand, involves the reverse:

> 'dexterity' is prompted by concerns over the lack of specific legislation and the corresponding need for reform. It prioritises the need to act quickly and with precision in adapting to changing technological circumstances. Rather than viewing regulation in the abstract, 'dexterity' has a narrower focus on concrete legal rules. In this case, government singles out rules governing finance, planning permission, and access to land. Within the confines of these rules, shale gas activities are seen not as analogous to, but as dissimilar from, conventional fossil fuel extraction. This opens up the possibility of fracking-specific regulation. (Stokes 2016: 962)

In other words, new regulation is needed for those elements in the regulation that are an obstacle for the development of fracking. Hence the government blamed the existing planning system and the system for access to land as obstacles for the development of the fracking industry (Stokes 2016: 979). Thus, three pieces of fracking-specific legislation were introduced. First, there was a new tax regime to attract fracking developers. The tax on profits from oil and gas extraction, which stood at 62 per cent was effectively reduced to 30 per cent. Second, there were changes to the planning process. The obligation on fracking operators to notify individual owners or tenants to whose land the planning process relates was removed and the planning application fee for fracking was reduced. Third, there were changes to the Infrastructure Act, creating a new land access regime (Stokes 2016: 981). The UK Infrastructure Act (2015) introduced deep-level land below 300 metres with an automatic right of access for petroleum and geothermal energy. Stokes (2016: 984) also notices that 'issues such as public participation in decisions relating to fracking and the human rights implications of shale gas extraction are conspicuously absent from government debate'.

Social aspects and the perception of fracking in the UK have been well researched (Bradshaw & Waite 2017, Cotton *et al.* 2019, Lloveras *et al.* 2021, Partridge *et al.* 2019, Roberts *et al.* 2021, Short & Szolucha 2017, Williams & Sovacool 2019). Williams and Sovacool (2019: 15) conclude that 'there is a perhaps surprising degree of contestation over shale gas, all the more so given that the UK has such a long history with natural gas and a history of extractive industries going back centuries'. They ask whether there is something new and sinister with shale gas, or whether this contestation associated with an emblematic shift in context. Partridge *et al.* (2019) conducted deliberation workshops in the UK and the US to evaluate conceptions of the underground with regard to shale gas extraction. They conclude that participants identified ecosystem links and described the underground as directly connected to life on the surface and related to human and other animal well-being (Partridge *et al.* 2019: 17). Short & Szolucha (2017), who worked with communities in Lancashire during the fracking application stage, speak of a collective trauma for the community, damaging or destroying the basic tenets of social life. Bradshaw & Waite (2017) cite surveys that measure the perception and awareness of shale gas extraction. They state that awareness has grown and that there has been a gradual decline in support and an increase in the level of opposition. Seventy-six per cent of the public are aware of fracking according to 'Wave 21', the most recent survey carried out by the Department for Business, Energy and Industrial Strategy (DBEIS 2017). Forty-nine per cent of the respondents neither supported nor opposed shale gas; 2 per cent did not know. This is likely to partly reflect a lack of knowledge about fracking. Thirty per cent of respondents are opposed to fracking; 19 per cent support it (DBEIS 2017: 7). Asked for reasons why people opposed fracking, respondents mentioned the loss or destruction of the natural environment (56 per cent); the risk of contamination to the water supply (32 per cent); that it is generally not a safe process (32 per cent); the risk of earthquakes (29 per cent); and that there is too much risk or uncertainty to support it at present (29 per cent). Reasons for supporting fracking are the need to use all available energy sources (35 per cent); reducing dependence on other countries for UK's energy supply (31 per cent); fracking being good for local jobs and investment (30 per cent); reducing dependency on other fossil fuels (28 per cent); and that it may result in cheaper energy bills (27 per cent) (DBEIS 2017: 7). Public opinion and public participation matter. The Climate Assembly UK, which is discussed further in the next section, is proof of the need for wide-scale public involvement in the future development of the country, especially with regard to matters of the environment. This extends to underground space as well. Public participation is a key constituent of environmental governance and hence a sustainable underground space use and its governance should reflect this.

Thus, following Stokes's (2016) observation that public participation was largely absent from the fracking discussion, it may be no wonder that, despite previous UK government's support for the technology, fracking has sparked a series of protests at the drilling sites across England (Cartwright 2019). The focus was often on a site in Lancashire near Preston. The Preston New Road site and the earth tremors caused by the drilling also led to the moratorium on fracking in England. The drilling site was operated by Cuadrilla Resources, a UK-based oil and gas exploration company.[4] In July 2017, three protesters managed to climb on lorries that were approaching the fracking site, rendering them unable to move any further. The men were sentenced to

[4] It is interesting to note that *cuadrilla* is a term originating in Spanish bullfighting. The *cuadrilla* is the entourage of the *matador*, the bullfighter, who help him to gore the bull eventually killing the animal. Since fracking requires vertical drilling into the earth one could make an analogy of 'goring' the earth until it dies. And in colloquial Spanish a *cuadrilla* is a name for a gang of thieves.

imprisonment of up to 16 months. This marked the first instance of imprisonment for environmental protest since the Kinder Scout mass trespass in 1932 (Curling 2019). UK fracking operators were also granted so-called pre-emptive injunctions, that is, an injunction in anticipation of breaching a legal right. INEOS, another fracking operator, was granted such an injunction, which is placed on unnamed individuals, even before the company received permission to drill (Curling 2019). Breaches of the injunction could be punished by a prison sentence of up to two years and/or a fine of up to £5,000. After a first challenge of the injunction failed before the High Court, the Court of Appeal ruled much of the injunction granted to INEOS unlawful in May 2019 (Curling 2019).

All of this seems historical against the moratorium on fracking in England since the end of 2019. However, the above showed how a controversial technology was fast-tracked by means of benign and industry-friendly legislation and regulation under the exclusion of public perceptions and consultation, causing protests. A hint of irony remains, though. The government's own former shale gas commissioner resigned from her post in frustration about 'ridiculous' regulations (Booth & Topham 2019). In an interview with BBC Radio 4, she said: 'if you applied the same standards to anything else, you wouldn't build another school or a hospital, you probably wouldn't have any buses or lorries on the roads' (Booth & Topham 2019).

Underground space and the future: nuclear waste

I would like to end this exploration through different aspects and themes of underground space use with a journey to the underground. In 2019, I had the opportunity to visit an underground research laboratory in France. The laboratory is situated near the small village of Bure in the Département de la Meuse in the east of France. Far away from bigger cities, Nancy as the nearest big city is over an hour's drive away, close to Bure is the Meuse/Haute Marne Underground Research Laboratory. The purpose of the facility is to evaluate the potential as storage for high-level and medium-level radioactive waste. Low-level radioactive waste is stored above ground in France, covered by concrete and secured and monitored for 300 years. In the near future, the laboratory will also be open for experiments in the field of CCS.[5] The site will remain a research laboratory, while the actual storage of radioactive waste will be very close by. The site was chosen because there are hardly any natural resources

[5] Even within the geology community, there is competition about underground space: oil versus gas, gas versus geothermal, etc. And it is also about research money. If funds go into geothermal research, then there is less for oil research and so on.

nearby.[6] The site is approximately 500 metres deep. The rock formation is claystone (Oxfordian) and it costs between 25 and 30 million Euros per year to run the facility. It is a fascinating maze of tunnels filled with dusty, dry air. There is heavy and light machinery everywhere. Different sizes of tunnel diameters and tunnel shielding technologies are tested, but the most obvious things are over 10,000 measuring points. At the time of the visit, most of the research was on gas build-up in tunnels and fractures, both effects of tunnel ventilation. A fellow visitor explained to me that for a long time and currently gases have been the biggest problem for radioactive waste storage and CCS. In the future it will be about microbiology, clay after all is organic matter.

At the end of one tunnel shaft was what looked like a black hole from a distance. Looking at it closer, it turned out to be a steel-lined tube with a diameter of just 80 cm that reached 80 m into the rock. Equipped with measuring points, tests are carried out for corrosion and hydrogen, which the steel emits as it corrodes. Corrosion in small quantities is not problematic; however, in larger quantities it destabilises the system physically and chemically. This steel-lined tube, in fact many of them, will be used to store high-level radioactive waste. Only 3 per cent of radioactive waste is high level, yet it carries 97 per cent of the radiation. Before high-level radioactive waste can be stored underground, it needs to cool down on the surface. The process of transporting the waste underground and storing it will be fully automatic. The monitoring period after storage is an unimaginable 500 years. The nuclear waste storage facility will run for 120 years and at the end the site will be closed with a giant bentonite plug. However, a change in French law introduced the law of reversibility in 2016. All machines and robots need to be able to retrieve the waste during the 120 years of operation. Yet, during the visit, I was told that it was more about retrievability than reversibility, because it is not really reversible, as the process of retrieval takes much longer than the process of storage. ANDRA (Agence nationale pour la gestion des déchets radioactifs), the agency responsible for running the facility, also has a group that works on the issue of how to communicate the site to future generations so as not to open Pandora's box (Sebeok 1986). At the moment the idea is to place several layers of red stones scattered across the surface area of the storage facility. Hence, should future generations start digging and ignore the first 'warning', a second layer appears. But who knows if red will be recognised as a warning colour in 500 years or what language we will be using. Even today the colour red has different cultural meanings across the world. Wedding dresses in many Asian countries are red, because it symbolises good fortune, success, and fertility. And, many native English speakers would have trouble understanding and reading the English spoken 500 years ago.

[6] It should also be mentioned that the site is in an area with a very low population density and a high percentage of unemployment.

The visit to the underground research laboratory was fascinating and insightful. Yet, what seems like an elaborate technological undertaking is of course one of the most controversial issues in countries which operate nuclear power stations. Faced with the closure of nuclear power plants for political reasons, because they have reached the end of their lifecycle, or because they do not comply with security standards, a wave of high-level radioactive waste is coming towards countries like France, Germany, and the UK. Objects like nuclear waste need to be kept safe. One challenge, however, is to provide institutions that cater for the longevity that the storage of nuclear waste requires: 'Carbon sequestration and storage as well as nuclear waste, in general, require continued management within stable institutional safeguards and communication systems over centuries, if not longer' (Hanusch & Biermann 2020: 20). At the moment, however, the authors claim there are no concepts for long-time organisations and how they could function over time.

Altman (2019) calls the process of one generation leaving behind toxic legacies for its successors 'time-bombing'. Nuclear technology introduced a new kind of legacy, one read into the body and carried there through time, she writes. Evens (2020) discusses the intricate relationship of nuclear reactors and water. In the past, protests at the proposed German deep-storage site for high-level radioactive waste in Gorleben have caused widespread protests as the site is already used for interim storage. The arrival of casks with radioactive waste usually drew thousands of protesters and an equal number of police officers. The geological exploration of the underground storage was suspended in 2012 and was ended in 2013 (BGR 2020). The UK is looking for a Geological Disposal Facility and the siting process is open. It is expected to take fifteen to twenty years. Community participation is a key aspect, according to the Nuclear Decommissioning Agency (NDA); however, the process is also sweetened by financial promises: 'we will … invest up to £1 million per year in communities once a Community Partnership is formed; also, invest up to £2.5 million per year in communities where deep borehole investigations take place' (Nuclear Decommissioning Agency 2020a). It is expected that the first radioactive waste could be stored at the chosen site by 2040 (Nuclear Decommissioning Agency 2020b). A report produced by Climate Assembly UK (2020), a large-scale public participation project, highlights some assembly members' voices on the issue, ranging from asking whether it is moral to store nuclear waste outside of the country (400), to 'we need to work a lot harder on nuclear waste management to ensure safe and secure storage to manage the public perception for what is an efficient technology' (402) or that some assembly members 'would rather have a small amount of nuclear waste in the north sea than a load of carbon dioxide' (468), the latter hinting at a comparison to CCS technology.

Conclusion

A lot of underground spaces are often out of sight, while other underground spaces, especially those for transport, are in plain sight and used by millions every day. Yet from those 'hidden' underground spaces come the materials that make our modern life possible. Rare earths for smartphones and computers, oil and gas to provide electricity, petrol, and plastic, the artefact of our times. And, of course, groundwater for public water supply. Hence, because materials and resources extracted from the underground feature in so many products, we should pay more attention to underground space and how we use and govern it, making sure to avoid the mistakes we made and are still making governing materials and resources above ground.

Three key messages follow from this article. First, underground space is an already heavily regulated space. However, regulation is fragmented and does not look at underground space as a whole or govern it as an entity. Instead, regulation orientates itself on resources or matter: for instance, oil, groundwater, or planning regulations for private houses. The example of the Netherlands showed, however, that it is possible to develop a national subsurface strategy and the UK could follow suit.

Second, the example of fracking showed how not to do it: that is, regulating and governing a specific area of underground space use. Independent of what one thinks about fracking, the approach by the government, fast-tracking permissions, and making industry-friendly regulation yet lacking the necessary public consultation, was almost meant to fail. The government and advocates of CCS technology should learn from these mistakes. The Climate Assembly UK could be a good starting point, as it reflects a diversity of views on issues of future importance, such as climate change and energy supply. It could be the basis for any conversation about future technologies in the UK and public perceptions, no matter whether it includes the use of underground space or not.

Third, there is an interdependence and an interplay between the themes identified —property rights, regulation, groundwater, fracking, nuclear waste storage—requiring a coordinated, interdisciplinary, and integral approach. At the moment the field, especially urban underground space, is dominated by engineers, architects, and urban planners. However, a ' UK underground dialogue' is necessary that includes a larger and more diverse range of researchers, stakeholders, and the public. As mentioned a couple of times in this article, the exploration and use of underground space are nothing new in human history; however, the renewed interest is a chance to design and use underground space based on the ideas of sustainability. For example, shifting large infrastructure facilities such as wastewater treatment works or refusal collection and storage underground could free up necessary space above ground, space that could be used for social housing or parks.

The underground is humanity's archive, a treasure trove for archaeologists. In future years, centuries, and millennia, when archaeologists want to find out about the living conditions, culture, and artefacts we used, they will dig underground. Hence, casting back from the future to the present, we could ask ourselves what is it that we want them to find.

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