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Energy Transition

The Geological Subsurface and Its Potential for the Energy Transition

If Germany's geological subsurface is mentioned at all in public debate, then usually in the context of the potential exploitation of fossil energy resources such as natural gas. But the deep subsurface harbours many other opportunities that could be harnessed to build a more sustainable economy and reduce greenhouse gas emissions. Tapping into these opportunities will require immense efforts and quite likely some very difficult decisions. So what exactly does the geological subsurface have to offer?

1 Geothermal energy: An important enabler for the energy transition

Heat accounts for half of Germany's domestic energy consumption. Roughly three quarters of this demand is currently met through oil, gas and coal, which the German government plans to phase out completely over the next twenty years. Geothermal energy – the heat found within the subsurface of the Earth – is one possible substitute for these fossil fuels. Most people are already familiar with the subsurface heat exchangers used in domestic heat pump systems. "Deep" geothermal energy can be exploited on a much larger scale by drilling wells to a depth of 1,000 to 5,000 metres. Hydrothermal geothermal energy can be gained by tapping subsurface waters, which can reach temperatures of up to 170°C (these waters do not evaporate due to the pressure at these depths). This technology is already used extensively in the Munich metropolitan region. According to a report prepared by various Fraunhofer and Helmholtz institutes, about a quarter of Germany's current heat demand could be supplied using hydrothermal energy by 2040. Approximately 7,000 additional wells would have to be drilled and several thousand additional geothermal heating plants constructed to achieve this. Geothermal energy's clearest advantages are its sustainability, its ability to provide baseload power, and its small area footprint, making it particularly suitable for urban areas. The seismic risk posed by the operation of geothermal facilities can be minimized through proper design and management. However, tremors linked to geothermal facilities have caused damage to buildings in Germany (Landau) and Switzerland (Basel) in the past. These incidents could have been avoided with today's technologies and a precautionary approach to the development of geothermal resources. Nevertheless, such incidents have undermined public trust, and considerable efforts will be needed to restore confidence in utility-scale geothermal technologies. Modern well drilling technologies also make it highly unlikely that hydrothermal projects could contaminate groundwater sources. It is investors who face the greatest risk, as there is no guarantee that hydrothermal resources will be found at each well site.

2 Subsurface hydrogen storage

Energy storage solutions are crucial for Germany's energy transition. Excess electricity generated in periods of abundant wind and sunshine can be converted into green hydrogen through the process of

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electrolysis. Hydrogen can be used both to store energy from variable renewable sources and in different industrial processes (such as iron ore reduction in steel-making). In the distant future, hydrogen may also be used to fuel ships and aircraft. According to the think tank Agora Energiewende, hydrogen could supply 15-25 % of final energy consumption in the European Union. Hydrogen can be safely stored underground, primarily in salt caverns of the kind that are already used to store natural gas. While current storage capacities will be exhausted by 2030, depleted oil and gas fields could be repurposed in a next step. New storage facilities would not need to be developed in Germany until 2050. Currently, 23 billion cubic meters of natural gas, 30 % of the natural gas consumed annually in Germany, is stored underground at 40 sites nationwide. During the Cold War an 800-meter-deep porous rock storage facility was built here in Berlin close to the Olympic Stadium and remained operational until 2016. Subsurface hydrogen storage facilities could be developed in Germany with the support of this experience and further research.

3 Subsurface carbon dioxide storage (CCS)

It is also possible to store the greenhouse gas carbon dioxide underground. This is referred to as Carbon Dioxide Capture and Storage, or CCS. In the case of underground carbon storage solutions, CO2 is injected into a porous rock layer in the subsurface and trapped beneath an impermeable overlying layer. The CO2 mineralizes below ground and can be expected to remain stable for thousands of years. Deep saline aquifers offer the best potential for CO2 storage. Depleted natural gas reservoirs are also suitable for storing CO2, as the layers capping these formations have already retained natural gases for millions of years. According to the German Federal Institute for Geosciences and Natural Resources (BGR), saline aquifers in Germany have a maximum CO2 storage capacity of about 10 billion tons, which would be sufficient for only a portion of the emissions anticipated over the next decades. In light of this, reducing and avoiding emissions must remain the overriding priority for climate policy. Any attempt to change this would in all likelihood meet with considerable public opposition in any case. This makes CCS particularly attractive for those industrial processes for which CO2 emissions are unavoidable, such as cement production.

Of course, storing carbon dioxide underground is not without its risks. However, the operation of various CCS facilities around the world suggests that this is a controllable and low-risk technology. Carbon dioxide is non-flammable, non-toxic and can only cause asphyxiation in very high concentrations. Injecting carbon dioxide into the subsurface can trigger microearthquakes that are barely noticeable to humans. If CCS facilities are constructed in accordance with regulatory requirements at depths below 800 metres, there is very little risk of carbon dioxide upwelling that would contaminate groundwater aquifers. In northern Germany, plans to establish underground storage facilities met with considerable opposition due to both safety concerns and fears that the uptake of CCS would undermine climate policy ambitions. Ultimately, after the adoption of the Carbon Dioxide Storage Act in 2012, these plans were shelved by the states affected.

4 Mobilizing domestic mineral resources for energy transition technologies

Demand for various metals is set to grow as the energy transition gathers pace. According to scenarios developed by the German Mineral Resources Agency (DERA), global demand for copper for use in electrical equipment could almost double by 2040, and demand for lithium for use in electrical storage devices could increase fiftyfold, driven in particular by future e-mobility growth. However, Germany has relied on imports of metallic raw materials since the discontinuation of domestic metal mining operations in the early nineties. In the course of recent debates around the issue of energy, food and supply chain security in Germany, some have asked whether these metals could or should be mined in Germany once again. Some ventures are already in planning. According to estimates, around 1.5 million tons of pure copper metal could be extracted from ore deposits located at depths of 1,000-1,500 metres below ground near Spremberg in southeast Brandenburg. In Zinnwald-Georgenfeld in the Eastern Ore Mountains, as much as 2,900 tons of pure lithium has been located at depths of 400 to 700 meters. And in the Upper Rhine Graben, where drilling for geothermal energy is underway, lithium concentrations of 150 to 200 milligrams per litre have been measured in the thermal waters. Techniques to extract this lithium are currently being developed. The potential benefits and risks must be weighed carefully when planning new domestic mining operations. Mining consumes enormous amounts of water and is associated with a small but by no means negligible risk of earthquakes – buildings can be damaged as a result of underground blasting, for example. Waste water from mining also poses a risk for potable water resources. These risks and environmental impacts can be greatly reduced through proper planning and professional operative management, but they cannot be completely eliminated.

5 Storage and disposal of radioactive waste

Germany also plans to construct an underground facility for the safe storage of heat-emitting radioactive waste at depths of hundreds of metres within stable layers of rock. The German government has established an agency (the Bundesgesellschaft für Endlagerung (BGE)) that is tasked with identifying a site for a future repository and assessing the suitability of host rock formations. The time spans that must be considered in this undertaking are mind-boggling: a century will pass between the start of the site selection process in 2017 and the sealing of the repository. Radioactive waste materials will then be stored in the final repository over a period of one million years. Potential sites are carefully assessed by the scientific community to ascertain the stability of rock formations, their impermeability, and their capacity to withstand the corrosive effects of the heat emitted by radioactive waste as it decays. Studies will also be conducted to understand the potential effect of future erosion on possible sites over hundreds of thousands of years. The Federal Office for the Safety of Nuclear Waste Disposal (BASE) is responsible for facilitating public participation in various processes relating to this issue.

6 Political feasibility and the need for broad public debate

The potential uses of the subsurface outlined above promise to provide a range of benefits, especially when it comes to minimizing emissions of greenhouse gases harmful to the climate. It will be immensely difficult to transform our economy without harnessing some or all of them. At the same time, these uses entail health, environmental and financial risks. In each case, the engineering challenges and financial outlays are gigantic. It is vital that we engage in an informed public debate on these options in order to ethically weigh their benefits and risks in accordance with both the precautionary principle and the values that underpin our society. The findings of science, the interests of affected organizations and associations, and the concerns and interests of citizens must be systematically considered in this debate. Neither purely economic or technological considerations nor unfounded fears should determine its outcomes. Instead, in a first step we must determine as precisely as possible the opportunities and risks of each respective use. Then, applicable criteria and their weightings must be defined through public debate in order to arrive at a balanced and ethically justifiable decision. It will not always be possible to eliminate each and every concern. Even with the best preparation, some uncertainties and unknowns will remain. As with all policies affecting people and the environment, the benefits and risks will not be spread evenly – some will benefit more than others, and some will be exposed to more risks. We have no alternative but to make the best possible decision for our future, based on the knowledge currently available to us and applying criteria developed in an all-of-society debate to assess the opportunities and risks. After all, given the challenges we face in forging a sustainable future, not using the geological subsurface will not be an ethical option. What is needed, therefore, are new initiatives from politics and civil society to initiate this long overdue debate with all the organizations and individuals concerned.

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