NET ZERO

Researchers view a computer-assisted, virtual subsurface geothermal energy model *(Image credit: U.S. Department of Energy, Public domain, via Wikimedia Commons)*

STRUCTURAL GEOLOGY FOR A SUSTAINABLE WORLD

The transition to net-zero carbon emissions requires innovative use of the subsurface. Colleagues from the Tectonic Studies Group argue that structural geologists have the knowledge and skills to effectively support the net-zero transition

TECTONICS and structural geology have been at the core of Earth resource development for decades, helping to build and shape the world we live in today. Resource revolutions of the past, including mining of coal for the industrial revolution, the extraction of minerals and metals and the unlocking of hydrocarbons, were enabled and supported in large part by the know-how of tectonics and structural geologists. But many of these activities, and the developments that they have powered, have led to the climate and ecological crises that we face today. Given this, one might assume that structural geology will become obsolete in the net-zero carbon-circular economy of the future. On the 50th anniversary of the Tectonic Studies Group of the Geological Society, we look at some of the ways structural geologists will remain relevant, if not crucial, to the realisation of the net-zero carbon revolution.

A changing Earth

Our use of Earth resources is changing through necessity. As a society we have consumed, produced and polluted ourselves into a position where we must fundamentally change how we do business for the ecosystems that support us to survive. Climate scenarios modelled by the International Panel on Climate Change indicate that we can avoid the most dangerous impacts of climate change if we work hard to limit global temperature rise to 1.5°C above pre-industrial levels. To achieve this, we need to move to a 'net-zero carbon' world by 2040, and crucially, we must also reduce non-CO_2 greenhouse-gas emissions.

Action is required. We need to slash greenhouse-gas emissions, and deploy negative-emissions technologies to balance the books, while enabling sustainable global development, too. As a result, we will use the subsurface in innovative ways, such as fluid cycling through injection and storage, CO_2 disposal and waste management. Resource extraction will diversify and its environmental footprint will shrink. These new uses of the subsurface mean structural geological expertise will be in high demand.

Unlocking the future

Geological storage of CO_2 plays two roles in achieving net zero: reducing emissions from industry and enabling negative emissions, for example, by storing CO_2 captured from the atmosphere. Revived focus on hydrogen could see increased hydrogen geological storage, whether in engineered salt caverns or in porous rock formations. Other potential technologies include compressed air energy storage. The success of these technologies will require new data acquisition with reinterpretation of existing subsurface data, characterisation of the architecture of geological structures and subsurface fluid migration, as well as geomechanical approaches to characterise fault stability.

Growth in geothermal resource development is anticipated, in particular as a low-carbon solution for heating and cooling. Low-temperature resources, such as abandoned coal mines, can supply district heating, while higher temperature resources ('hot rocks') offer both heat and

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power options. The vast back catalogue of geoscience knowledge of coal systems, and the geological structures that partition them, is proving valuable to identify, assess and de-risk coal-mine geothermal energy. In higher energy systems, whether they be granite-hosted, fault-controlled reservoirs such as those in Cornwall, UK, hot sedimentary aquifers or active geothermal systems, we need structural geologists to carry out fracture mapping and modelling, as well as reservoir geomechanical analysis, characterisation, and model parameterisation. For this fledgling UK industry, structural geology know-how is essential to aid resource optimisation, operation and monitoring.

Constructing anything – whether wind turbines to generate energy, direct air capture units to remove CO_2, dams for hydroelectricity, or pipelines to create a connected CO_2 network – requires the expertise of engineering geologists who can assess ground stability, and here the understanding of geological structures is key. The need for critical raw materials will continue to rapidly increase to meet the demand of the growing green-technology revolution. Finding and extracting new deposits, optimising further utilisation of existing ones, and even revitalising or repurposing abandoned resources that may hold previously overlooked potential requires the expertise and skills of structural geologists who can understand the tectonic controls on fluid flow and mineralisation processes. Further, mining these metals will need to be more efficient and there are roles for structural geologists in mineral exploration and deposit modelling, resource estimation, 3D mine design and geotechnics.

Skills for the future

Structural geology skills and understanding are far from obsolete; they are key for delivering net zero. The past is the key to the present — and future.
A range of net-zero solutions are grounded in the subsurface, meaning that structural geologists have a crucial role to play in the energy transition. Our market is evolving: while some traditional avenues will close, there are many new and exciting opportunities within our grasp. A successful transition depends on our realisation that the knowledge, understanding, approaches and data common in a traditional structural geologist's wheelhouse translate to many developing and emerging industries. We do not need to reinvent the wheel, just adapt it with some new net-zero spokes. There is much to do – we face a period of innovation and adaptation to a new future that needs us if it is to succeed.

Despite the need for more structural geologists, there is a worrying downturn in student uptake of geoscience subjects. To avoid a future skills gap, we need advocacy to support uptake of Earth science in society and education in the years to come. Such advocacy must be coupled with action to break down barriers to inclusivity; diversity amongst the geoscience community is not only a matter of justice, but will support the innovative, cooperative and representative development needed for sustainable solutions.

Geoscientists are excellent at whole-systems integrated thinking. This approach is essential for a net-zero world, where a sustainable circular future is an integrated future, a 'system of systems' that combine to improve efficiencies, design out waste, and maximise benefits. We already see the vision of integrated geothermal power, heat, and metals production at United Downs in Cornwall, UK, a project that demonstrates the circular economy principles that must underpin the energy transition.

All net-zero solutions must be place-sensitive. Many of the approaches underpinned by geoscience are embedded in issues of social and environmental justice, and ignoring them will only propagate the negative impacts and public concern around the resource sector. Socio-scientific challenges are particularly prevalent for topics that are unfamiliar, uncertain, or emerging, and where change is needed fast – like most net-zero geoscience developments! So, we will need structural geologists who are comfortable integrating across disciplines, and who are able to communicate and collaborate with a range of stakeholders, including policy makers, the public and communities, so that our sustainable future will benefit everyone.

FURTHER READING
A full list of further reading is available at geoscientist.online.

- The Intergovernmental Panel on Climate Change Special Report: Global warming of 1.5 °C; www.ipcc.ch/sr15/
- The Tectonic Studies Group: http://tectonicstudiesgroup.org/

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