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Institute for Energy and Environmental Flows:

A RESEARCH UPDATE

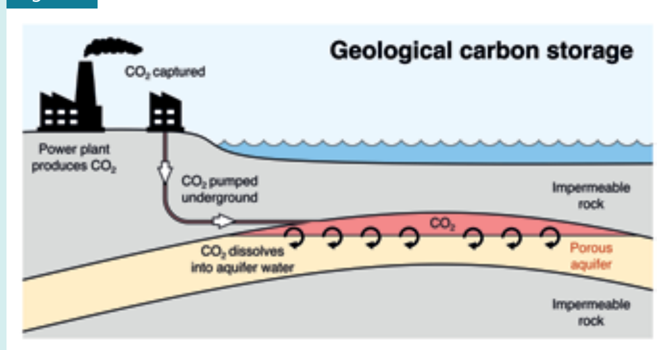
Exciting new projects in the Institute are focussing on the long term geo-storage of hydrogen, carbon dioxide and thermal energy, all vital to the energy transition. Renewable energy generation from wind and solar power is intrinsically intermittent. Solar radiation has both a daily and an annual cycle, complicated by the more random cloud cover associated with weather patterns. Wind power is highly coupled to weather systems on time scales of days to weeks, and systematically increases in winter. These fluctuations lead to week- to month-long periods of over- or under-supply of renewable energy. Such intermittency needs to be actively managed. Solutions include the use of gas fired power, linked to carbon capture and storage, during periods of low renewable generation and large-scale energy storage during periods of over-supply of renewables; stored energy is reused in periods of low-supply.

Carbon capture and storage

Scientific research and technology can be deployed to improve the efficiency of carbon capture and storage in subsurface aquifers. One aim is to enable liquefied CO_2 to access a greater fraction of the injected subsurface porous reservoir. A second aim is to understand the long-term fate of CO_2 whether trapped by geological structures such as anticlines, by capillary trapping in the water-filled pore spaces between sedimentary grains, or by dissolution into the pore water. Our research focusses on the dynamics of CO_2 transport through porous layers, and on controls on the rate and mechanisms of trapping of the CO_2 (Figure 1).

We have evolved a fascinating suite of analogue experiments to model the dissolution of trapped CO_2. They use bead packs containing salt powder and unsaturated water, which provide an analogue system for trapped CO_2 and CO_2-unsaturated brine.

Figure 1



Hydrogen storage

Hydrogen storage represents one response to the challenge of large-scale energy storage. Hydrogen is produced through electrolysis in periods of excess renewable generation. This hydrogen is stored at pressure in a salt cavern or on a larger scale in a saline aquifer. The hydrogen is then recovered in periods of low generation, typically over seasonal time scales (Figure 2). Our research into hydrogen storage focusses on the potential use of aquifer storage in anticlines (Figure 3).

Figure 2

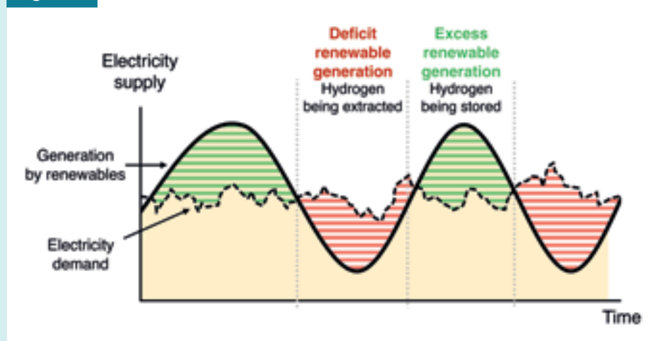
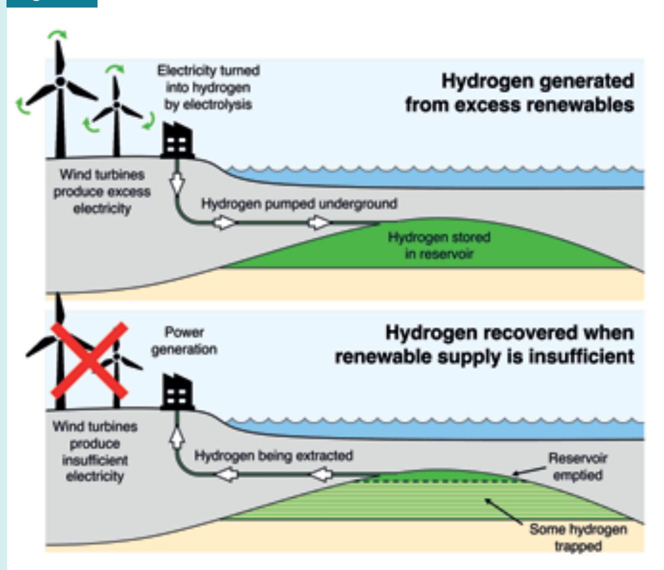


Figure 3



A suitable aquifer for CO_2 or hydrogen storage: Bridport Sand Formation, West Bay, Dorset.

Key questions concern the efficiency of aquifer storage in that some hydrogen may not be recovered from the system owing to capillary trapping or buoyancy trapping. Our new models and experiments have identified that capillary trapping may lead to 5-20 % of the injected pore space continuing to host hydrogen. A plume of hydrogen may remain trapped in the aquifer unless the production rate is low or the reservoir permeability is high (Figure 3).

Thermal energy storage

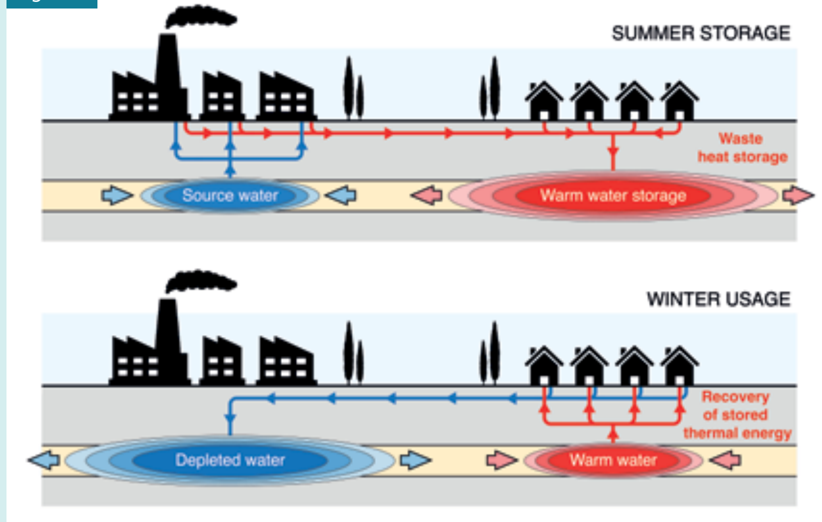
A third programme of our research explores the potential for thermal energy storage in aquifers or arrays of boreholes. Excess thermal energy in the summer or waste industrial thermal energy can then be used for heating applications in the winter (Figure 4). Waste heat represents over 10% of global primary energy use, so recycling this heat has enormous potential for reducing the energy load required for heating. The value of the thermal energy depends on the temperature at which is it collected. However, combining stored low temperature waste heat with heat-pump technology can reduce by a factor of four the energy cost and carbon emissions of heating in winter or cooling in summer. Our research models the distribution of thermal energy stored in the subsurface through circulation of warm or cold water, and how this can be used in complex heating and cooling systems.

Such modelling also helps to ensure that thermal losses in the subsurface are minimised and that the use of the ground as a store of thermal energy is optimised. As the depth of the thermal store is increased, its potential to generate power and heat increases. So too does the elasticity of the thermal storage, in the sense that it can better accommodate inter-annual fluctuations in the heating or cooling demand. Moreover, at these higher temperatures, the thermal energy can be converted to electricity using thermo-mechanical conversion techniques, creating a hybrid geothermal power – energy storage system.

Other IEEF research

Our projects on long-term energy and carbon storage are vitally important for future schemes to buffer fluctuations in the supply of renewable power. However, the Institute is involved in a host of other research projects relating to energy transition and the environment. These include ice dynamics, deep ocean mixing, pollutant transport in rivers and research into processes of enhanced weathering. The IEEF is proud to be successfully applying fundamental scientific research to some of the most important practical issues on Earth.

Figure 4



Acknowledgements: The research described in this article includes research carried out by Andy Woods, Nicola Mingotti, Emma Lepinay, Thierry Menand.

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