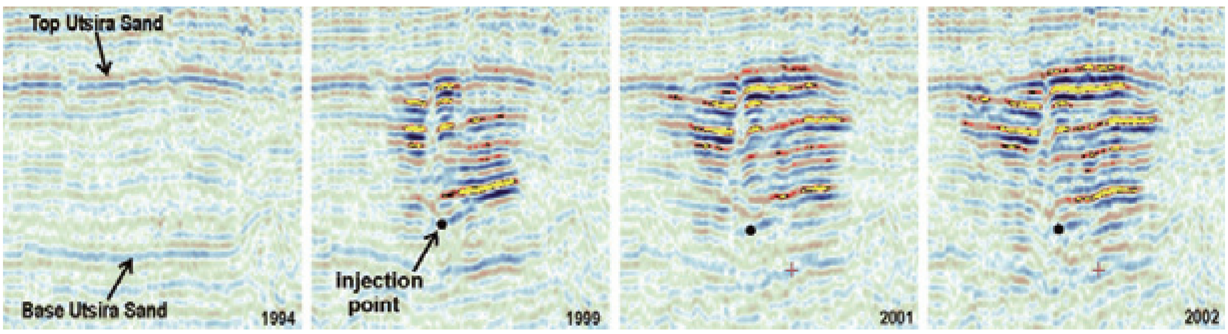
We may be able to reduce atmospheric carbon dioxide levels through greater energy efficiency and recourse to alternative energy sources. But what if we could just put the greenhouse gas somewhere else? As **Andy Chadwick** explains, perhaps we can.

Burying the problem

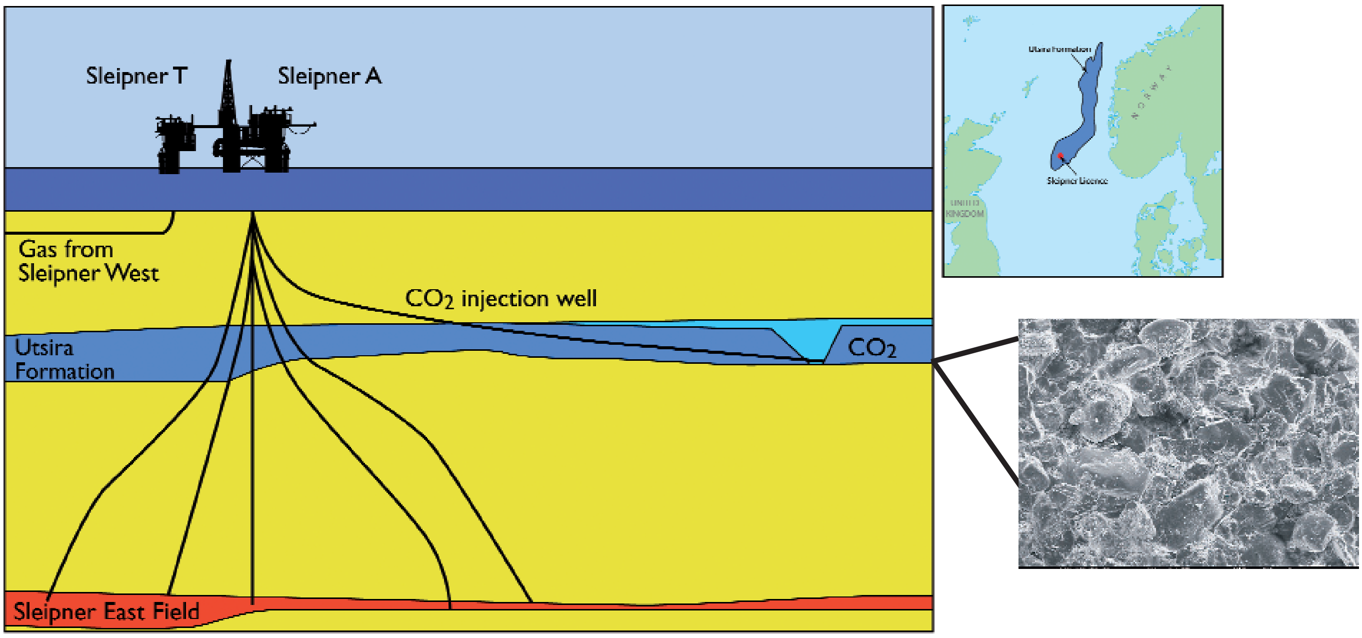
The burning of fossil fuels has resulted in the level of atmospheric carbon dioxide rising by more than a third since the start of the Industrial Revolution. The Intergovernmental Panel on Climate Change (IPCC) has estimated that, with the current growth in demand for fossil fuels, atmospheric concentrations of carbon dioxide could be more than three times pre-industrial levels by 2100 resulting in an increase in the global mean temperature of up to 5.8°C. Such an increase is predicted to result in climate change that is generally acknowledged to pose a major threat to the social and economic well being of all countries worldwide.

Our present dependency on fossil fuels may be reduced through greater energy efficiency and the development of alternative energy sources. However, fossil fuels will continue to dominate energy supply well into the twenty-first century. In fact, consumption seems set to rise as developing countries require more energy to support their industrial and social growth. Supporting the convergence of world economies, whilst maintaining the quality of life in developed countries and mitigating climate change, is a major challenge. A portfolio of measures will be needed including energy conservation, use of renewable energy and other low-to-zero carbon dioxide (CO_2) energy sources. Fossil-fuel-based carbon abatement technologies (CATs) are a group of innovative technologies that enable fossil fuels to be used with substantially reduced CO_2 emissions. They cover a range of alternatives for reducing CO_2 emissions from fossil fuel combustion including higher efficiency conversion. By switching fuel to lower carbon alternatives, such as from coal-fired power generation to natural gas, emissions of about 50% per unit of output can be achieved. CO_2 capture and storage (CCS) is where the carbon in fossil fuel is captured (as CO_2) either before or after combustion and placed in long-term storage in geological formations. This approach can reduce emissions by up to 85%.

CCS is the most radical of the CAT options. It involves the deployment of a chain of technologies for CO_2 capture, transportation and storage. It is the least commercially developed of the CAT options because there are no policy measures in place to achieve the high levels of CO_2 abatement that can be delivered. Nonetheless, most of the technologies needed to implement CCS are currently available through other applications.

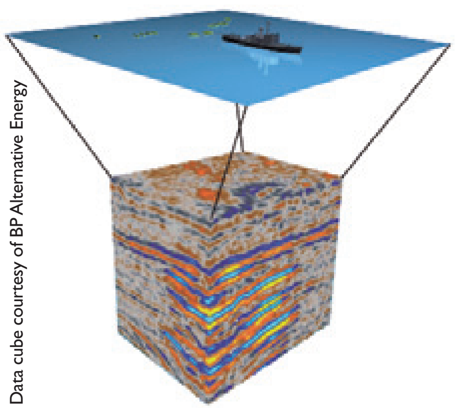


Time-lapse seismic images from Sleipner showing vertical slices through the storage reservoir in 1994 prior to injection and through the expanding plume in 1999, 2001 and 2002. The total height of the plume is about 250 metres, with a total width in 2002 of around 2 km. (Images courtesy of BGS involvement in the SACS, SACS2 and CO2STORE projects).



Sleipner summary showing location map, cartoon of injection operation, and scanning electron microscope image of the porous Utsira Sand reservoir rock (images courtesy of Statoil and BGS).

Started in 1996, the Sleipner project in the North Sea was the world's first demonstration of carbon dioxide capture and underground storage. Natural gas produced at the Sleipner West field naturally contains about 9.5% CO_2, which has to be removed to produce gas of saleable quality. Instead of venting the separated CO_2 to the atmosphere, where it would add to the greenhouse problem, Statoil, the operators of the field, and their partners decided to inject it down a three-kilometre-long well and store it in a porous and permeable reservoir rock called the Utsira Sand. About a million tonnes of CO_2 per year is prevented from entering the atmosphere in this way, and a total of over eight million tonnes has been injected so far.



Schematic view of a seismic survey operation with a 3D seismic 'cube' showing bright reflections corresponding to the CO_2 plume.

We are a partner in the project, contributing to the monitoring of the injected CO_2 in the Utsira Sand to check that it is behaving as predicted and is not migrating out of the intended storage site.

An important objective of the monitoring programme is to show that flow processes in the reservoir are well understood and that predictions of future, longer-term, plume behaviour are likely to be robust. A key issue is to understand the mechanism by which CO_2 is transported through the intra-reservoir mudstones and to assess the possibility that CO_2, either physically or chemically, may alter the flow properties of the reservoir and cap rock with time.

Time-series 3D seismic data were acquired in 1994, prior to injection of the CO_2, and again in 1999, 2001, 2002 and 2004 with, respectively, about 2.3, 4.3, 5.0 and 6.84 million tonnes of CO_2 in the reservoir. The spectacular seismic images show the plume of injected CO_2 as a number of bright subhorizontal reflections, above and around the injection point. The reflections are interpreted as wavelets from thin (just a few metres thick) layers of CO_2 trapped beneath intra-reservoir beds of mudstone.

The topmost layer of the CO_2 plume can be most accurately characterised, its rate of growth quantified, and CO_2 flux at the reservoir top estimated. The latter has been quite stable since 2001, which suggests that transport through intra-reservoir mudstones is via a limited number of discrete pathways that became established quite early in the evolution of the plume.

Looking ahead, the Utsira Sand has an estimated pore-space volume of about 600 billion cubic metres. If only about 1% of this were utilised for CO_2 storage, this would be sufficient to contain the annual output of over 900 coal-fired, or about 2300 gas-fired 500 megawatt power stations.

The possibility of storing CO_2 in exhausted oil- or gas-bearing structures, which form proven long-term traps for buoyant fluids and gas, is another option. Underground CO_2 injection is routinely used by the oil industry to assist with enhanced oil recovery in the effective exploitation of oilfields.

For further information, contact:

Andy Chadwick, BGS Keyworth,
Tel: +44(0)115 936 3183
e-mail: rach@bgs.ac.uk