Can CCS and radwaste find comon ground? Indeed they can, say Neil Chapman[1], Julia West[2] and Jordi Bruno[3]

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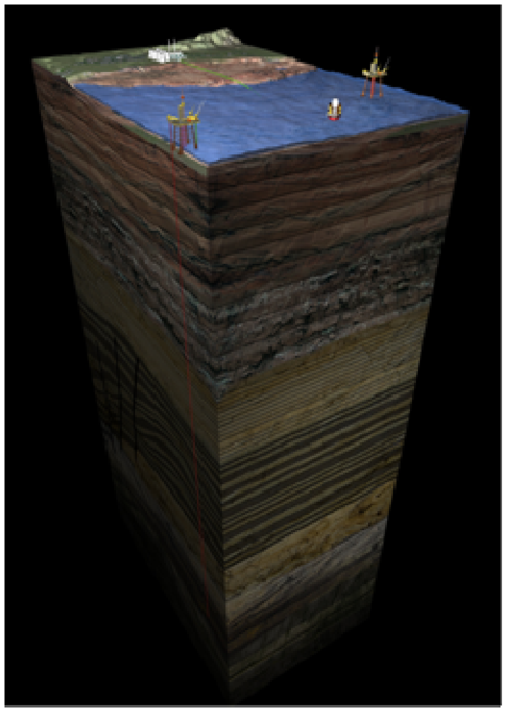
To a geologist, the analogies between the geological disposal of radioactive wastes and the sequestration of CO_2 deep underground are obvious. Both aim to isolate and contain waste products that come principally from the generation of electricity. Both focus on safety, and both are concerned with similar technical and non-technical issues. These include modelling fluid movement in and characterising deep rock formations, evaluating complex hydrogeochemical interactions, finding suitable sites and addressing associated public perception issues – particularly in communities where disposal facilities might be located. You could be forgiven, then, for thinking that scientists working on these topics communicate regularly, share experiences and work on common problems.

- Image: The falls at Meiringen, where Sherlock Holmes met his nemesis. © The Sherlock Holmes Museum, 221b Baker Street, London, England www.sherlock-holmes.co.uk.

But you would be wrong. Even before Fukushima, nuclear power had endured decades of bad press, and was only just becoming an acceptable conversation topic again, as people woke up to just how much our low carbon energy supply will depend on it. Projects to dispose of radwaste deep underground have met opposition in most countries and have regularly failed to get approval. Only in the last five years or so have geological repositories featured in two or three European countries. It will be a decade before any waste will be put in most of them.

So the nuclear business has never been regarded as the best of PR bedfellows by the hydrocarbons industry - the sector principally responsible for driving carbon storage projects ahead (since it aims to use depleted reservoir formations as hosts). Association with – even reference to – radioactive waste has been actively discouraged by parts of the carbon capture and storage (CCS) technical community and (perhaps especially) by those funding their work.



- Image: Source to sink: Concept for the capture and offshore underground storage of CO2. Chris Wardle, BGS © NERC 2011. All rights reserved.

One aspect of this distancing is the perception that while CCS can be seen as being 'on the side of the angels', geological disposal of radwaste (GD) is merely clearing up residues from an 'unwanted' and 'dirty' industry. The radwaste community has been on the back foot for most of the last 20 years, whereas the CCS community, relative latecomers, have felt they were promoting 'a good thing'. Though in fact, as CCS has stepped onto the shaky ground of onshore siting, it has realised that it may not after all enjoy so great a distance from GD.

On top of that, the apparently clear-cut environmental evils and benefits of different forms of power generation that have been exploited by two generations of activists are becoming blurred, as the real environmental and societal impacts become clearer. Both nuclear power and CCS are likely to make an important contribution to preventing temperature increases beyond 2°C for the 2020 horizon. So, it was with no small tepidation that a group of scientists involved in either GD or CCS or both, got together late last year for tentative discussions about establishing common ground and exploring what might be learned. The meeting took place in the pretty Alpine town of Meiringen in Switzerland, overlooked by the Reichenbach Falls, where Sherlock Holmes met his nemesis Professor Moriarty for the last time.

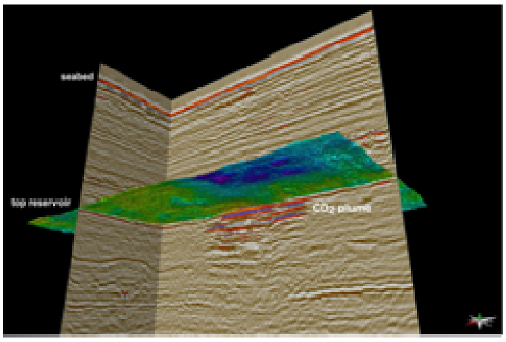
MIND YOUR LANGUAGE

- Image: Monitoring CO_2 storage projects. CO_2 storage regulations will require that storage operations are rigorously monitored for a number of reasons, including: verifying the amount and composition of CO_2 being put into underground storage; understanding how the CO_2 is behaving once underground; providing early warning if things are not going as planned; providing assurance of long–term storage integrity; measuring any leakage that might occur; Baseline surface gas flux measurements at the In Salah CO_2 storage site, Algeria.

First, we needed to get our words straight. Where GD talks about ‘disposal’ (sometimes, when it is feeling the need to be Delphic, ‘disposition’), CCS says ‘storage’ (with ‘sequestration’ its Delphic equivalent). Much was said about these fine distinctions.

For GD, ‘disposal’ means ‘final’ - not ‘indefinite storage’ (effectively, the policy of the current Scottish Government), because that is no solution. Probably because CCS has had to tackle the problem of offshore injection of CO_2, it talks of ‘storage’ because (until modified in 2006 to cater specifically for CCS) the London Convention prohibited waste ‘disposal’ offshore unless accessed from land. Consequently, not only is CO_2 not being ‘disposed’, neither is it described as ‘waste’.

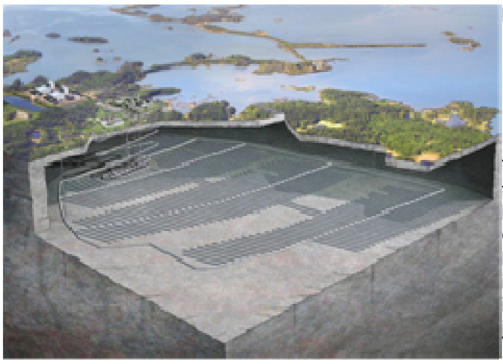
GD struggles with the fact that it could be used for materials that are arguably recyclable (e.g., spent nuclear fuel, or separated plutonium). The possibility of retrieval of disposed radioactive materials thus becomes more than just a matter of leaving options open for future generations in case final disposal becomes unacceptable. Finally, and despite the semantic contortions of policy-makers, it is unarguable that CO_2 and most radioactive materials destined for geological disposal are both ‘wastes’ and are being ‘disposed’ of.



- Image: 3D view of injected CO_2 plume at the Sleipner field, Norway. BGS © NERC 2011. All rights reserved.

The meeting worked hard to generate clear definitions of what GD and CCS are intended to achieve: an easier task for GD, because it has done it before. Thus, the objective of CCS is: “To protect the global environment and human health by effectively preventing CO_2 from entering the atmosphere and the oceans, as part of a wider programme of mitigation measures. To do this in a safe and sufficiently timely manner and on an appropriate scale, so that the global impact on emissions is significant.”

The objective of GD is: “To isolate radioactive wastes from people and the environment and contain them so that the natural processes of radioactive decay, retention and dilution prevent any radionuclide from returning in concentrations that pose a hazard.”



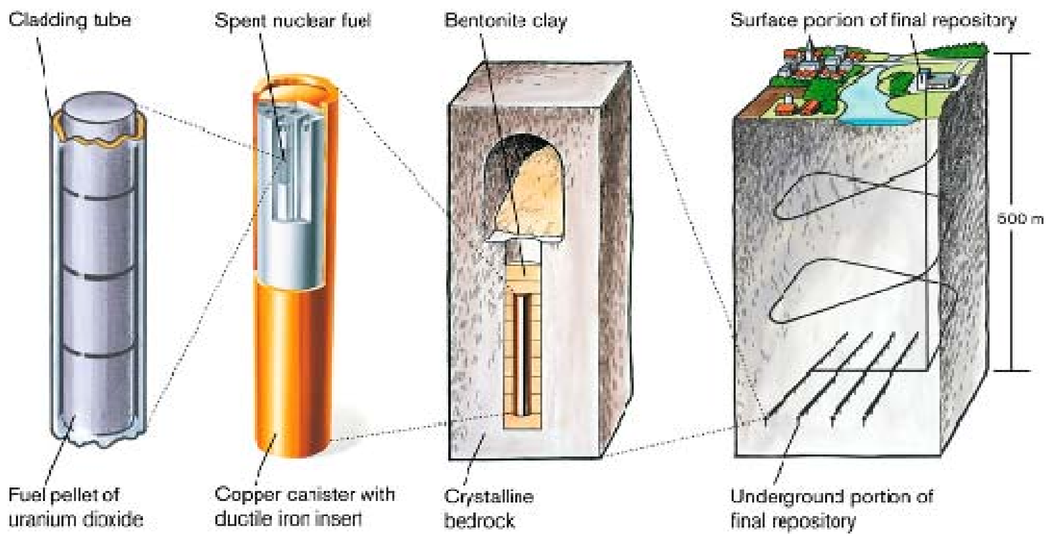
MITIGATION

- Image: 3D diagram of radwaste repository concept. SKB - Illustrator: LAJ Illustration. © NDA. Reproduced by permission.

The meeting observed that CCS exists only as a direct mitigation response to the threat of global warming, whereas GD is all about ensuring safety from hazardous materials. This distinction does not really hold much water: although CO_2 is a part of the natural carbon cycle and not hazardous in dilute quantities, human and environmental safety is paramount in both cases. The safety of GD is judged by estimates of radiation exposures to localised, hypothetical, individuals in the distant future, whereas the success of CCS is primarily judged by the ‘safety’ it delivers to the global environment.

Carrying out CCS ‘safely’ is thus simply a constraint on a technology with considerably greater objectives. The environmental consequence of failing to implement CCS are different in magnitude to that of, say, poorly executed GD – but both have their foundation in the provisionof safety. Nevertheless, CCS is also looking at the utility and feasibility of local safety targets for releases during the operational phase in terms of ‘admissible annual CO_2 release rates per unit area’. This stands in contrast to GD, where releases are judged in terms of exposure of people. CO_2 release targets are set more in terms of their impact on the health of ecosystems. Another aspect of this is the number of facilities that might exist worldwide over the next century. For GD this is likely mean tens, whereas for CCS to achieve its objective, it must be many hundreds.

Permanent containment below surface is the objective of both technologies; but geologists understand that 'permanent' has no real meaning, and is anyway unnecessary because of changing hazard potential through time. The way that this translates into achievable goals provides a clearer distinction between CCS and GD, in terms of containment timescales.

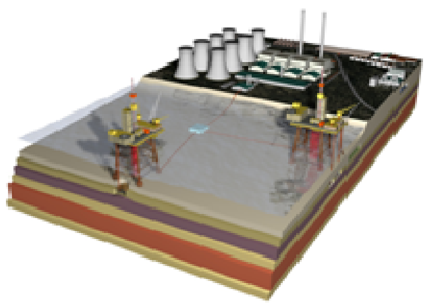


- Image: 11. Barriers: Source: SKB – Illustrator: Jan Rojmar © Svensk Kärnbränslehantering AB. Reproduced with permission.

GD aims to provide isolation and containment for tens to hundreds of thousands of years – until the radiotoxicity of even the most hazardous materials has declined to levels similar to natural uranium ore bodies. Even after this time, so long as both geological repositories and rich uranium ore bodies remain isolated deep in the rock, their hazard potential remains extremely low. For GD, the most critical containment objective must be for the period when the wastes are at their most hazardous – for some 100s of years after disposal. It is becoming recognised that the radwaste community's apparent obsession with geological timescales has distracted from that aim, inhibiting communication and progress.

For CCS, leakage figures of 0.1-0.01%/year are currently seen as acceptable, and would give residence times of c. 1000 to 10,000 years. In fact, CCS sites are not currently designed in terms of leakage rates or residence times but rather are expected to retain CO_2 indefinitely. However, both technologies have to address issues on timescales that are very long in terms of human experience and engineering practice. At present, there appears to be no real societal perspective on the absolute risks of either technology (especially in comparison with other environmental hazards) and, more importantly, of the risks of doing nothing as a result of failing to put risks in perspective.

Actually figuring out what the impacts are – how localised, how significant and when they occur - lies at the root of safety assessment (SA). Here GD enjoys a considerable lead, as the first SAs were date from the 1970s. GD has experience, not only of forward-modelling deep systems over long periods, but of assembling the necessary thermo-hydro-chemical-mechanical geoscientific data to evaluate the processes involved in containment, mobilisation and migration.



- Image: CCS involves the capture of CO_2 arising from the combustion of fossil fuels to provide energy, transporting CO_2 to a suitable site, and storing deep underground in geological formations. Images show injection in a marine environment. Chris Wardle, BGS © NERC 2011. All rights reserved.

Identifying release scenarios and likelihoods has been an important aspect of this work, as has dealing with the inevitable uncertainties involved in characterising and modelling natural systems at large scale. Both deterministic and probabilistic techniques aimed at estimating risks to individuals lie at the core of safety assessment for GD, along with clear definition of quantifiable safety functions of different components. Clearly, using similar approaches for CCS will help identify not only localised risks (especially important for on-land injection) but also the larger scale, longer-term risks if systems perform less well than expected. Generally, the Meiringen group considered that system understanding for carrying out SAs for CCS is much less developed.

Linked to safety assessment are the regulatory standards that are applied when licensing disposal facilities. For GD, national standards are based upon well-used principles and standards defined by the IAEA and are sufficiently quantitative (whether in terms of doses or risks to people) and generally agreed to be prescriptive. At present, CCS safety regulation is less developed and qualitative. The current EC directive (for example) is ambiguous about safety – talking, for example, only in terms of 'significant' risk. This should be tightened up in the anticipated 2012 revision.

The localised nature of safety assessments for GD means that site characterisation for repositories is an intensive matter. The recently completed site investigations for the spent fuel repository at Forsmark (Sweden) lasted almost a decade, leading to probably the most comprehensively characterised volume of crystalline basement rock (prior to excavation) anywhere in the world. This repository will have a footprint of about one square kilometre. For CCS, the volume of rock involved is considerably larger, with CO_2 possibly ending up several kilometres from the point of injection.

Given CCS's more limited containment objectives and the ability to rely on the evidence of past containment provided by the reservoir rocks being used, less site characterisation work is considered necessary, perhaps using only original hydrocarbon exploration and production data. However, for some on-shore sites and non-oil/gas reservoirs (such as saline aquifers) the scale and detail required is likely to be commensurate with GD.

DISPOSAL & MONITORING

Disposal facility monitoring is an area of overlaps and contrasts. In a CCS facility, the main risk of leakage occurs during and shortly after injection, but drops off thereafter. There is consequently a strong stimulus for monitoring the progress of injection and looking for signs of leakage during this period. In GD, while post-closure monitoring may provide reassurance, the passive nature of the GD concept, the sluggishness of processes at depth and the fact that a repository cannot fail catastrophically, mean that such monitoring will not be a management tool. Indeed, that safety must not depend upon the ability to monitor is a 'given'. No releases are envisaged and, even if some aspect of system behaviour were to deviate from expectation, it would be more hazardous (to the operators) to intervene than to do nothing.

DEPLOYMENT TIMESCALE

Perhaps the most critical difference between the technologies is their deployment timescales. There is actually little objective urgency to dispose of radioactive wastes, provided we are prepared to live with them in secure surface storage, and provided we know that a solution is definitely available – bearing in mind, always, that the most secure solution is to get the materials deep underground. Volumes are relatively small and storage is practical in the interim.

Nevertheless, policy-makers find it reassuring if a disposal solution (or a path to one) exists, especially when they are promoting nuclear power. In the UK, this has perhaps been the main reason why the GD programme has found itself back on track. Although the first European deep repositories will be available in about 10 years' time, it will probably be well into mid-century before most EU countries, UK included, have operational facilities expected to stay operational for up to a century or more.

In strong contrast, CCS on a very large scale is urgent - on a timescale of decades - if it is to be of any help in addressing climate change. Consequently, the promise of CCS has to be realised within a certain time-window or it will become progressively less worth doing. This sits uncomfortably with planning horizons. In the EU, the first commercial deployment is now not envisaged until 2030 - possibly too late to contribute significantly to the 30 Gt/a disposal target that some climate modellers consider necessary. This contrasts sharply with the 2020 objective of having 100 CCS plants in operation.

Siting has been the downfall of many GD projects and 'technically-led' approaches have destroyed both programmes and organisations, and led to decades of delay. Even in countries that have adopted the enlightened approach of calling for volunteer communities to host radwaste disposal facilities (e.g. Sweden, Japan, Belgium), the process has proved slow or littered with obstacles.

The UK is now in the early stages of this process and appears to be making good progress. Problems in the past have led to considerable self-analysis in the GD community, much experience-sharing and, it must be said, hand-wringing. There is much for CCS to learn from this, especially as it appears to be embarking upon the same road and that demonstration projects on-shore face similar obstacles.

WAYS FORWARD

The Meiringen meeting concluded that all energy-related technologies using the sub-surface should work closely together. From the CCS viewpoint there is a clear need for speed and a comprehensive programme; it cannot afford to stumble like GD. The group proposed a number of possible ways in which swapping experience could help move both technologies forward:

- establish a baseline of internationally accepted principles and standards to guide practices and assist regulators, informed by the long-standing IAEA approach to nuclear and radiation safety;
- collaborate on methodologies of safety-case development and safety assessment, sharing terminology where appropriate;
- compare internationally recognised best practices, including governance issues;
- compare model approaches to planning, integrating and evaluating the results of site investigation methods;
- develop equivalent systematic approaches to long-term data and knowledge management;
- discuss benefits to communities accepting the responsibilities of hosting facilities in their areas;
- open a wide public dialogue on the significance and perspective of short and long-term, local and global risks with respect to managing the by-products of energy generation;
- extend discussions to involve other industries relying on geological containment.

Altogether, this was an enlightening and encouraging meeting, particularly if the impetus can be maintained by further and spreading collaboration. There certainly seems little to be gained by maintaining a polite distance!

** [1]ITC School of Underground Waste Storage and Disposal and MCM Consulting, Switzerland; [2]British Geological Survey, UK; [3]UPC Barcelona and Amphos 21, Spain*