Can enough CO_2 be stored to avoid dangerous climate change?

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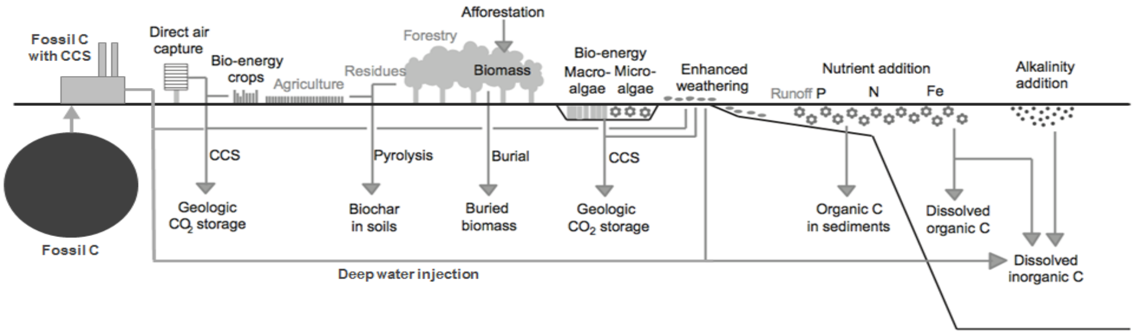
Project Background:

The cumulative quantity of fossil C combusted and released as CO_2 determines the expected mean peak warming of the Earth's climate. Supply and expected demand for fossil C vastly exceeds the CO_2 budget consistent with societal goals to limit warming. A possible strategy is to capture produced CO_2 either directly from sources – carbon capture and storage (CCS), or from the atmosphere – CO_2 removal (CDR). To mitigate climate change captured CO_2 needs to be isolated (stored) away from the atmosphere. CO_2 storage through injection into sedimentary rock formations is established with a current limited global injection of around 20 million tonnes CO_2/yr, mostly into depleted oil reservoirs to increase oil production, but in a few cases into saline aquifers. A number of other propositions for CO_2 storage in terrestrial, ocean and geological systems have been proposed but are not yet developed or tested at scale. Here we model the storage needed.



Proposals for the management of atmospheric CO_2 concentration through CCS and CDR (Figure adapted from Lenton 2014).

The success of CO_2 storage will depend on the balance between the amount of fossil C released and CO_2/C captured and stored, and the security of the CO_2/C storage mechanism. For CO_2 storage to have a useful impact on climate mitigation efforts, the amount of CO_2 injected and stored will have to increase by orders of magnitude. Global CO_2 storage capacity estimates indicate that sufficient storage capacity might exist, but the vast majority of this storage potential is unconfirmed and there is a considerable range in current estimates. The security of this scale of storage is also uncertain. Initial work has suggested that a relatively high leakage rate of up to 1% per 1,000 years can still be tolerated, with overall benefit to at least medium term climate mitigation efforts (Stone, Lowe et al. 2009; Shaffer 2010; Gerlagh and van der Zwaan 2011).

Research Questions:

In order to keep long term climate change to within 2, 3 or more degrees of pre-industrial values, on both 100 year and longer timescales:

1) How much of the fossil C supply could feasibly be balanced by CO_2/C storage?
2) How much of this total CO_2 would need to be stored in geological or other reservoirs?
3) What is a reasonable range of scenarios for stored CO_2/C to return to the atmosphere?
4) How do such scenarios compare to the performance of different types of storage?

Methodology:

Six principal parameters determine the potential role of CO_2 storage in controlling climate: the desired atmospheric concentration of CO_2, the climate sensitivity to CO_2, the fraction of CO_2 that is captured, the total quantity of CO_2 stored, the rate at which CO_2 could leak to the atmosphere from storage and the proportion of the stored CO_2 that could leak. Current assessments are simplistic, and take no account of abilities to identify secure storage sites, or to engineer against leakage. This project will develop a greatly improved model, which combines both storage and climate impacts and then use it to explore the above questions.

The School of GeoSciences contains a unique conjunction of CO_2 storage expertise and climate modelling research. These skills, along with academic and wider literature, will be used to establish plausible ranges and distributions of storage and climate parameters, which will lead to a model system based on realistic assumptions. The project will investigate multiple scenarios using different parameter combinations and different timescales to build an improved picture of the overall role that CO_2 storage could play in climate change mitigation.

The results of this project will be presented at international conferences, published in high-impact peer-reviewed journals, and will impact on debates concerning the legislation and funding of CO_2 storage as part of CCS and CDR. Current legislation such as the EU geological storage of CO_2 Directive (European Commission 2009) places difficult requirements for guarantees of total storage permanence, seen by some as a barrier to CO_2 storage being undertaken. Proper accounting inclusive of storage security considerations of less established storage methods is still to be developed. Better informing this debate with improved technical understanding of the options and trade-offs of different approaches to CO_2 storage is essential to improving the legislative framework under which CO_2 storage could be developed and undertaken.

The project will benefit from the world leading expertise within the School of GeoSciences in both CO_2 storage and climate modelling, and will collaborate with the large community of researchers working on related areas both in University of Edinburgh and elsewhere.

Training:

A comprehensive training programme will be provided comprising both specialist scientific training and generic transferable and professional skills. The student will be further trained in subsurface geoscience, the use and coding of climate models and parameter sensitivity analyses, and impacts of science to policy. The student will also benefit from supervisors existing collaborations with other carbon management groups in the UK and Germany.

Requirements:

This project would suit a student with a numerate background, ideally including some computer modelling experience and with a strong interest in climate science and techniques to mitigate climate change.

Further reading and references:

Haszeldine, R.S.H. and Scott, V. (2014): Storing Carbon for Geologically Long Timescales to Engineer Climate.
Lenton, T. M. (2014): The Global Potential for Carbon Dioxide Removal.
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Keller, D.P., Feng, E.Y. and Oschlies, A. (2014): Potential climate engineering effectiveness and side effects during a high carbon dioxide-emission scenario. Nature Communications, 5-3304.

European Commission (2009). Directive 2009/31/EC – Geological Storage of Carbon Dioxide.

Gerlagh, R. and B. van der Zwaan (2011). "Evaluating Uncertain CO_2 Abatement over the Very Long Term." Environmental Modeling and Assessment: 1-12.

Shaffer, G. (2010). "Long-term effectiveness and consequences of carbon dioxide sequestration." Nature Geoscience **3**: 464 - 467.

Stone, E. J., J. A. Lowe, et al. (2009). "The impact of carbon capture and storage on climate." Energy & Environmental Science **2**(1): 81-91.