Facing the main challenges in carbon capture and sequestration

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ABSTRACT
We discuss the main hurdles in implementing carbon capture and sequestration, these are (1) reducing the cost to a level that is comparable with the cost of steps towards energy efficiency and conservation, (2) upscaling the current technology with a factor 1000, and (3) monitoring leakage rates less than a percent per year. Unless we are able to address these question in a satisfactory way, carbon carbon and sequestration holds little promise for being helping curb anthropogenic global warming.

Key words: carbon capture and sequestration

Anthropogenic emission of greenhouse gases, notably CO_2, contributes significantly to global warming (Pachauri & Reisinger, 2007). Economic growth in developing countries, increasing reliance on non-conventional oil, and use of coal as a power source are all leading to increased emissions of CO_2 (Kerr, 2008). Carbon Capture and Sequestration (CCS) is viewed by some as a panacea. The US Department of Energy (DOE) made $3.4 billion available for fossil fuel research, a significant fraction for CCS (Charles, 2009), and DOE supports a number of trial projects for CO_2 sequestration (Litynski *et al.*, 2008).

Injecting CO_2 in the subsurface has an out-of-sight, out-of-mind appeal because the CO_2 is prevented from entering the atmosphere. This approach is, however, not without its drawbacks and research needs to focus on making CCS effective both technically and economically on the scale needed to mitigate anthropogenic contributions to global warming. In order to assess this issue it is essential to look at the numbers involved in CCS.

Let us assume that in order for CCS to have a significant effect, we sequester worldwide about 4 $GtCO_2$/year. This is about 1/6th of the current global production, and it is roughly the same as the amount of CO_2 sequestered as one of the seven steps needed for capping the CO_2 concentration at 550 ppm(Pacala & Socolow, 2004) (twice the pre-industrial level of CO_2). To put this in perspective, this is the same mass as the total annual global oil production (Central Intelligence Agency, 2009). To sequester such an amount in the subsurface takes an infrastructure that is comparable to the one used now for petroleum production worldwide.

Currently, CO_2 is injected at a number of pilot projects in countries that include Canada (Weyburn), the Norway (Sleipner), and Algeria (In Salah). In the multiple pilot projects supported by DOE in the continental USA, typically about 1 $MtCO_2$/year is to be injected. Therefore, the pilot-project technology currently used must be replicated or up-scaled by a factor of 1000 to be effective for mitigating global climate change. The current cost of CCS is between 40-70 $/ton CO_2 (Metz *et al.*, 2005). The annual cost of sequestering 4 $GtCO_2$/year at a cost of $50/ton CO_2 is 200 billion $/year. Even though this amount is not large compared to the global expenditure for energy, one may question whether society is willing to cover an expense of this magnitude in order to mitigate climate change. Moreover, the recent McKinsey report *Reducing U.S. greenhouse emissions: How much at what cost?* (McKinsey&Company, 2007) showed that the USA can avoid about 40% of its CO_2 emissions by taking actions such as driving more efficient cars and trucks, and implementing combined heat and power generation. Most of these actions are cheaper than CCS and actually pay for themselves in the long-term. Over the time-scale of several hundred years, CO_2 has the potential to react with the host rock in some geologic formations and to become permanently stored in the subsurface (Metz *et al.*, 2005). In order for CCS to be effective, CO_2 must be sequestered for several hundred years. Losing 0.5% of the

CO_2 per year over 200 years due to leakage amounts to a total loss of 64%. This means that in order to ensure that CCS is effective, one must be able to contain the CO_2, and to predict and measure extremely low leakage rates.

In order for CCS to be a viable option, it is essential that the following questions are answered.

(i) How do we reduce the cost of CCS? Currently, CCS is financially not competitive with other options for avoiding CO_2 emissions (McKinsey&Company, 2007), many of which also save energy. The current cost of CCS (between 40 and 70 \$/ton CO_2)(Metz *et al.*, 2005) makes it unlikely for this technology to be used at a scale that will make a difference in curbing global warming.

(ii) How do we upscale current technology by a factor of 1000? If pilot studies demonstrate the successful sequesterion of 1 Mt CO_2/year with current technology, how do we upscale the technology so that it is feasible to inject several Gt CO_2/year? Perhaps we simply need a thousand times as many injection sites, but is this the optimal way to implement CCS?

(iii) How can we predict and monitor extremely low leakage rates? In order for CCS to be effective, leakage rates of a fraction of a percent/year must be predicted and monitored. Monitoring such low leakage rates is beyond our current capability (Wells *et al.*, 2006).

CCS research that does not address these questions may provide valuable insights and develop useful expertise, yet ultimately falls short of a cost-effective implementation on the scale needed to significantly reduce greenhouse gas emissions. Because CCS is among the most expensive options for avoiding CO_2 emissions compared to alternative approaches that actually save energy and pay for themselves (McKinsey&Company, 2007), we may run the risk of repeating a mistake of the 1970s in the diversification of our energy portfolio; i.e., developing technical solutions that are not economically viable and therefore in the long run do not succeed. A critical evaluation of the various options for avoiding CO_2 emissions is essential for formulating and implementing a holistic policy that is successful not only in reducing CO_2 emissions, but also in saving energy, and creating jobs in the economy of the 21st century. By using appropriate CCS appropriately, but not placing too much emphasis on "injecting ourselves" out of the climate change problem, we will avoid being lulled into a sense of complacency that may prevent us from starting to work on additional approaches to reduce CO_2 emissions that may cost less and also save energy.

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