Carbon Storage in the Ocean

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Summary

Nations are finding it difficult to limit the generation of carbon dioxide and as a consequence the concentration of CO_2 in the atmosphere is rising. This increase is causing both heating of the Earth and acidification of the surface ocean. The ocean, occupying 70% of the surface of the globe, is a promising place to store the liberated carbon dioxide away from the atmosphere. The issues involved have recently been reviewed by a Working Group of the Engineering Committee for Oceanic Resources, an ICSU affiliated body. The report of this group will be released in 2009.

The ocean already stores much carbon and the addition of all the estimated reserves of fossil carbon would increase the carbon content of the ocean by only 10%. If the fossil fuel generated carbon dioxide is left in the atmosphere, much of it will end up in the ocean, if it is not stored elsewhere by processes such as carbon capture and geological storage. The ocean has lots of capacity to store additional carbon and unlike the densely populated land, storage in the ocean has a low opportunity cost.

The ECOR Report considers three main categories of storage of carbon. They are direct injection, changes in alkalinity and ocean fertilisation. None have been commercialised at this time but all could be demonstrated at pilot plant scale in the near future.

Direct injection relies on capturing carbon dioxide, usually from intense sources, and injecting the concentrated CO_2 into the deep ocean. At mid depth the carbon dissolves in the sea water and can be stored for long time. Alternatively liquid carbon dioxide can be injected in deep topographical depressions in the sea floor to form a carbon dioxide lake.

Changing the alkalinity by increasing the bicarbonate content of the ocean allows carbon to be stored indefinitely. Most proposals involve using carbonic acid formed from carbon dioxide, to dissolve calcium carbonate either in ambient sea water or in reactors at elevated pressure and temperature.

Ocean fertilisation exploits the fact that the biological carbon pump is limited by one or more nutrients in the surface ocean. These can be either micronutrients, e.g. iron, or macronutrients, e.g. nitrogen and phosphorous. Nitrogen can be provided to the surface ocean either by pumping up nutrient rich waters from the thermocline, by generating nitrogen using the Haber Bosch process or by encouraging cyanobacteria to fix nitrogen.

Direct injection of carbon dioxide involves capture of carbon dioxide and its compression. Changing the alkalinity needs carbon dioxide rich mixture to be economic. Ocean fertilisation does not require carbon capture and so can store already emitted CO_2.

With varying rainfall patterns as the climate changes, agricultural costs can be expected to rise creating a serious problem for the many subsistence farmers worldwide. A technology such as ocean fertilisation holds out the promise of a significant increase in the supply of economical marine protein as well as storage of carbon away from the atmosphere for thousands of years. More protein will be needed over the next 30 years to satisfy the demands of the presently malnourished people as well as the expected additional 2 billion people. The collateral benefit of increasing the marine food web may be of greater value to humanity than the cost of providing the nutrients. This is known as a *no regrets* option.

Ocean storage of carbon is a somewhat neglected opportunity that deserves further development. The costs are less than or comparable with other large capacity options to reduce net emissions of carbon dioxide to the atmosphere. The environmental risks, while uncertain, do not appear unacceptable.

The price at which carbon can be stored is a critical factor, when market mechanisms are used to limited net emissions, in determining which technologies are adopted. There are many factors contributing to the estimate of the cost of avoiding the equivalent of releasing one tonne of carbon dioxide into the atmosphere. Not all of the carbon dioxide emitted will remain in the atmosphere. Some will be taken up by plants and some will flux into the ocean. Input prices fluctuate with time. The overheated economies of the first years of the 21st century have sharply cooled in the 2008 American recession. These changes lead to fluctuations in construction and feed stock prices in addition to varying interest rates. This report tries to express costs in US dollars of the year 2000, before the sustained period of unusual global economic growth. Representative inflation rate between 2000 and 2008 for the US is 20%. Those prices that have a wide range of possible values and are quoted in dollars near the year 2000 have not been adjusted. Prices for the three technologies are shown in Table 1.

Table 1 Carbon dioxide capture and storage costs

Category	Type	Cost,US$ per tonne CO2 avoided	Capacity CO2
CCS	IPCC (2005)	30 – 70	2000Gt
Direct Injection	Lake	13-15*	large
	Midwater	11-13*	large
Alkalinity shift	CCOS	30 (70)	Small (large)

Ocean fertilisation	Iron	5 (for 100 yr)	medium
	Macronutrient	20-30	50-500Gt?
	Cyanobacteria	10 -20	50-500Gt?

*capture only, IPCC (2005)

International discussions of climate change need to keep in mind that the UNFCCC commitment deals with sinks of greenhouse gases in the ocean as well as other terrestrial, coastal and marine ecosystems. The subsequent protocols should not exclude potentially lower cost emerging technologies designed to store carbon in the ocean.

Reference:

IPCC (2005) IPCC Special Report on Carbon Dioxide Capture and Storage.…ISBN 13978-0-521-68551-1, 442pp.