Carbon Dioxide Mitigation

Increasing emissions of carbon dioxide (CO_2) and other greenhouse gases, arising from the combustion of fossil fuels and other human activities, have triggered a debate over global climate change and spurred development of corrective strategies. The Hawaii Natural Energy Institute (HNEI) has been pursuing research on greenhouse gas mitigation technologies since 1989. Work in this area currently includes direct ocean sequestration of CO_2 and re-utilization of CO_2 for aquatic microalage production.

Sequestration Concept

"Sequester" means to remove or to set apart. Direct ocean sequestration of CO_2 attempts to isolate carbon released by the oxidation of fossil fuels away from the atmosphere by injecting it into the deep ocean. It is generally accepted that more than 80% of anthropogenic CO_2 emissions will eventually be absorbed naturally by the oceans, primarily through a slow exchange between the atmosphere and the surface waters. This exchange process behaves like a clog in a sink's drain: drainage occurs too slowly to prevent a large build-up, in this case of CO_2 in the atmosphere. To circumvent this restriction, it has been proposed to inject CO_2 from fossil fuel systems below the ocean thermocline.

As envisioned, CO_2 from fossil-fuel-burning power plants would be captured and liquefied. The liquefied CO_2 would be transported by a submerged pipeline to an undersea location away from upwelling sites and about 1,000 meters or more below the surface, where it would be released. The CO_2 would dissolve quickly into the seawater, producing carbonate and bicarbonate ions and reducing pH. The natural density stratification of the ocean would impede transport of the CO_2 back toward the atmosphere. Preliminary modeling indicates that the term of containment of the injected CO_2 could be on the order of centuries. This would reduce the peak value of CO_2 in the atmosphere that is expected to occur sometime between 2200 and 2400.

Direct ocean sequestration of CO_2 is a controversial concept because it proposes to purposefully discharge large volumes of greenhouse gas into the deep ocean to reduce the severity of changes to global climate. Sequestration strategies are predicated on the assumption that, for at least the next few generations, humans will not be able to forego the continued use of relatively inexpensive fossil fuels to satisfy our ravenous energy needs. Rather than doing nothing at all and allowing greenhouse gases to accumulate unabated in the atmosphere, sequestration may need to be considered as an interim, albeit imperfect, means to address a difficult and complex problem.

Given the gravity of the issue, policy decisions on strategies to mitigate global climate change must consider all options and be based on the best factual information. It is imperative, therefore, that research be performed carefully to assess the potential risks and benefits of ocean sequestration of CO_2. Specifically, the effectiveness of ocean sequestration in limiting the build-up of CO_2 in the atmosphere must be determined, as well as the associated costs, in terms of energy and economic penalties and relative impacts on the marine environment. Relative impacts on the marine environment consider that ocean sequestration will induce changes in sea water chemistry near the discharge site that may negatively impact the deep ocean ecosystem, while doing nothing may lead to warming and acidification of the surface ocean due, respectively, to the greenhouse effect and to steadily increasing levels of CO_2 absorbed at the air-ocean interface.

HNEI's Research

Research at the Hawaii Natural Energy Institute has focused on assessing the risks and costs of ocean sequestration of CO_2 and various associated engineering issues. This research program was initiated in 1989 under the auspices of HNEI and the Pacific International Center for High Technology Research (PICHTR), with funding support from Japan's Ministry of Foreign Affairs during the first three years of the effort. As a key part of this effort, the researchers constructed a deep ocean simulator [1] to investigate CO_2 injection phenomena and CO_2 hydrate formation.

The centerpiece of the laboratory is a fully instrumented pressure vessel that is partially filled with chilled sea water and pressurized to simulate conditions in the ocean at depths of up to 600 meters. Liquid CO_2 is released into the water through a removable injector.

Since its establishment, this program has attracted the funding support and/or collaboration of numerous organizations, including the U.S. Department of Energy; Government of Japan, through the Agency for Industrial Science and Technology of the Ministry of International Trade and Industry; RITE Japan; ABB Management of Switzerland; the University of Bergen (Norway); Norwegian Institute for Water Research (NIVA); Massachusetts Institute of Technology; and Institute for Ocean Sciences (Canada).

Results

HNEI has been a major participant in a landmark field experiment being conducted in collaboration with leading researchers representing the United States, Japan, Canada, Norway, and Australia. While this experiment has been the focus of significant controversy, it is expected to be concluded in 2002. The results will provide critical data on induced changes to sea water chemistry in the deep ocean and effects on benthic biota resulting from CO_2 injection.

HNEI's laboratory studies, meanwhile, have provided extensive data on the break-up of liquid CO_2 jets under deep ocean conditions and fundamental information on CO_2 hydrate formation. Studies of liquid CO_2 jet break-up and related investigations of oil jets in water have produced what is probably the most extensive database on liquid-in-liquid fluid instability. This information is relevant to a host of science and engineering applications.

Biological Sequestration

HNEI also is participating in a joint endeavor with Physical Sciences, Inc., and Aquasearch to investigate biological sequestration using aquatic microalgae. This study has tested the ability of a number of strains of microalgae to metabolize CO_2 from flue gas mixtures and to produce marketable products. One important finding suggests that microalgae can be used to produce solid carbonates that offer the potential for long-term sequestration of CO_2.

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Links:
[1] http://web41.its.hawaii.edu/www.hnei.hawaii.edu/facilities/deep-ocean
[2] http://www.hnei.hawaii.edu/staff/stephen-m-masutani