7180

THE 7TH CONFERENCE ON RESERVOIR MANAGEMENT

The New Petroleum Age

Clarion Admiral Hotel Bergen

18th - 19th November 1998

RESERVOIR MANAGEMENT AND ENVIRONMENTAL PROTECTION: THE MITIGATION OF CLIMATE CHANGE

Presented by:
Paul A. Johnston
Greenpeace Research Laboratories
University of Exeter, UK

RESERVOIR MANAGEMENT AND ENVIRONMENTAL PROTECTION: T HE MITIGATION OF CLIMATE CHANGE.

Paul A. Johnston & D. Santillo, Greenpeace Research Laboratories, University of Exeter, UK

Introduction

It is now widely accepted that human activities which produce greenhouse gases have had a discernible effect upon global mean temperatures over the last 50 years. 1997 was the warmest year on record and 1998 appears set to equal or exceed this. Since climatic processes are largely driven by temperature changes and differentials, these temperature changes will be associated with major climatic changes around the globe. In turn these changes will lead to marked changes in other of the Earth's physical and biological characteristics. Among the most important of these projected changes are a substantial rise in sea level and changes in oceanic circulation patterns. Changes in terrestrial habitats will affect food growing areas and hence food production on a regional basis. They will also severely impact the remaining world forests, threatening biodiversity. Changes of particular importance are predicted as a result of rapid temperature rises in polar regions. It has been suggested that in temperate regions, climatic change will result in the northward movement of vegetation zones at an effective rate of a metre an hour. Current predictions are that, at current emission rates, global temperatures will rise by an average of between 1°C and 3.5°C by 2100 relative to 1990. These projected increases in global temperatures will be larger than any recorded following the emergence of the earth from the last ice-age 10,000 years before present

A number of gases entering the atmosphere as a result of human activities can act as greenhouse gases. Of these, the most important is carbon dioxide and atmospheric concentrations have risen by around 30% as compared to pre-industrial concentrations. Energy related emissions from the use of fossil fuels account for more than 80% of the CO_2 released to the atmosphere each year with these fuels accounting for around 90% of the world's commercial energy production. Current global emissions of carbon dioxide (calculated as carbon) are estimated at around 7.1 billion tonnes annually, with carbon dioxide concentrations in the atmosphere currently rising at around 0.4% per annum. The precise impacts of increasing carbon dioxide concentrations and the concomitant global temperature changes are not entirely clear due to inadequacies in the mathematical models used for predictive purposes and incomplete understanding of potential feedback mechanisms. Nonetheless, the question is now not one of how climate change can be prevented but rather one of how the changes can be kept within certain limits. The inertia of climate and ocean systems means that there is a time lag between increased greenhouse gas concentrations and the manifestation of impacts. The full impact of historical emissions over the last two centuries has yet to be fully realised.

The provisions of the 1997 Kyoto Protocol go some way to promote reductions in emissions of greenhouse gases, and are an important first step. Nonetheless, by themselves they are not adequate to restrict the rate and scale of change to "manageable" dimensions, even if the provisions are effectively implemented. Against a background of rapidly increasing energy use in developing countries based upon coal, a carbon intensive fossil fuel, and slowly rising consumption in the developed world, clearly, more far reaching measures are required to reduce the possibility of catastrophic change. Even if current emission levels are held steady, atmospheric carbon dioxide concentrations will double by the end of the 21st century.

The Carbon Logic

The most pragmatic approach to reducing emissions of CO_2 from energy generation and utilisation contrasts with strategies designed progressively to reduce emissions themselves (with a heavy focus on downstream emission abatement or containment options) and concentrates instead directly upon the consumption of fossil fuels. The approach starts from the position that environmental changes need to be constrained within defined limits to avoid, as far as possible, "unmanageable" impacts. The following ecological limits have been proposed:-

- Restriction of the long term global temperature increase to less than 1°C above the pre-industrial average,
- Restriction of the average rate of temperature increase to 0.1°C per decade within the next few decades,
- Limit the rate of sea level rise to 20mm per decade
- Limit sea level rise to 20cm above 1990 levels.

It is predicted that these limits will permit the vast majority of vulnerable ecosystems to adapt, although clearly not without some significant changes. Beyond these rates, the extent of ecosystem damage is expected to rise rapidly.

It is then possible to estimate (albeit with substantial uncertainties) the amount of fossil fuel which may be burned in order that these constraints are not exceeded. Meeting these limits would imply that CO_2 levels will need to be stabilised at or below 350ppm, a figure below current levels. Assuming a climate sensitivity of 3.5°C (the temperature rise commitment associated with a doubling of atmospheric carbon dioxide) then relatively simple calculations suggest that 225Gt of carbon can be burned in total. Without an extensive reforestation programme, this carbon budget falls to 145Gt.

At current rates of growth in energy consumption from the existing baseline, this 225Gt amounts to around 30 years of fossil fuel consumption and less than 40% of the known economically recoverable reserves. Accepting this pragmatic solution to climate change implies far-reaching changes in energy efficiency and in the development of renewable energy sources. It also implies that the fossil fuel industry will need to leave around 95% of potential reserves and resources unexploited and requires a rapid shift away from the use of the most carbon intensive fuels. In turn this will require a strong political will to develop a completely new energy infrastructure and associated industrial framework.

Unsustainable Solutions

The "Carbon Logic" represents a pragmatic and logical approach to current unsustainable global energy use and defines path through which such use can be brought onto a sustainable footing. By allowing anthropogenic greenhouse gases systematically to accumulate in the ecosphere, and by disrupting natural ecosystems current global, fossil-fuel derived energy use is demonstrably in violation of the basic principles of sustainability. A number of technical solutions have been proposed for sequestering carbon dioxide and storing/dumping it in order to remove it from the atmosphere. This has direct relevance to oil reservoir management insofar as a growing dimension of this area of expertise relates to the potential for exhausted oil formations and sub-sea aquifers to be used for the disposal of carbon dioxide from industrial activities. This is but one of the superficially attractive, though poorly rationalised, options currently being explored for disposal (or euphemistically, "storage") of carbon dioxide. Such proposals are essentially "planetary engineering" solutions but many also have a counterpart in the "end-of-pipe" technologies often used to address unsustainable chemical discharges.

Broadly, proposals for the mitigation of climate change through the sequestration and disposal of CO_2 fall into three categories. Firstly, there are those involving the manipulation of terrestrial or aquatic biological systems on a large scale. A second category involves the trapping and disposal of carbon dioxide in solid, liquid or gaseous form. The third category involves engineering of weather or reflection of incoming solar radiation by *inter alia* placing giant reflectors in space. This last category of options will not be considered further in this discussion. The remainder of the current paper describes some of the options currently under investigation in the first two categories which involve sea-based activities. It places these in the context of existing international agreements and more broadly in the context of principles of sustainability.

<u>i) Biologically Based Processes</u>

Manipulation of marine ecosystems in order to increase biological production and hence to increase the uptake of carbon dioxide generally involve "fertilisation" of the sea with nutrients which normally act as limiters to primary production. The largest scale of these proposals involves adding iron to high nitrate/low chlorophyll oceanic waters to increase the production of phytoplankton, based on the assumption that productivity in these waters is limited by iron availability. In turn this is projected to increase dissolved (ionic and organic) and particulate forms of carbon at the same time reducing dissolved CO_2. The concept has been subject to trials in the Southern Ocean and while the basic hypothesis appears to be sound, the recorded effects were very short lived. Implementation, therefore, on a large scale would involve a commitment to continuing the process for a century or more and substantial investment in the large number of ships required to deliver the iron to the site.

Other schemes have proposed the addition of macronutrients in the form of nitrate and phosphate and also of ammonia produced from natural gas and atmospheric nitrogen . These schemes are designed to promote the growth of phytoplankton and of macroalgae when applied to the issue of carbon dioxide sequestration. More usually, however, addition of macronutrients is designed to increase the yields from aquacultural or fishery activities with the carbon dioxide issue being of secondary importance. In some studies, moreover, it has been found that much of the carbon dioxide bound in this way is derived from seawater through a shift in the carbonate/bicarbonate equilibrium rather than from the atmosphere. As with the use of iron, the operation would need to be carried out over many decades to have any likelihood of being effective.

In general, ocean fertilisation strategies must be viewed as very high risk. In addition to the possibility that they may not achieve the desired objective, there is the very substantial risk that they would be accompanied by undesirable ecosystem changes. These range from the possibility of causing widespread deoxygenation of the treated ocean areas to changing ecosystem dynamics. Shifting species composition towards nuisance species or those with lower commercial value implies the possibility of wholesale changes in marine community structure with unknown consequences. Such effects have been observed in waters receiving high inputs of nitrates and phosphates from sewage or inorganic agricultural fertilisers, and international efforts are being made to reduce nutrient inputs in many areas thus affected. In addition there are concerns about the impacts of such strategies on the nitrogen cycle, and thus may lead to increased production of nitrous oxide, itself a greenhouse gas. These concepts *de facto* compromise the principles of sustainability.

<u>ii) Capture and Dumping of Carbon Dioxide</u>

Proposals to capture carbon dioxide and directly introduce it into the deep oceans or into sub-seabed formations, in contrast to other options, have been the most extensively explored and are at the most advanced stage. The rationale behind these schemes is that their implementation may enable avoidance of the sharp peak in atmospheric CO_2 concentrations predicted for around the year 2100 under the "business as usual" scenario. A further (specious) stated justification for these proposals is that they merely represent an acceleration of the natural process of carbon dioxide entering the oceans from the atmosphere. Proof of concept experiments are now planned or are actually being conducted.

a) Direct ocean disposal

Plans fall into two categories. The first involves the direct introduction of the liquid gas or of dry ice into the deep oceans followed by dissolution and dispersion. Alternatively, it is proposed to form isolated lakes of liquid carbon dioxide on the sea floor. Various refinements have been suggested, including the fashioning of solid CO_2 penetrators designed to embed into the seafloor after discharge from the surface. The first direct disposal test is due to take place along the Kona coast of Hawaii in the year 2000 and other programmes under development include discharge of carbon dioxide into Norwegian fjord systems. Substantial scientific uncertainties are attached to these schemes. Most important is the scope of the exercise required if this is to mitigate climate change to a significant degree. Estimates suggest that to be effective, a large proportion of future CO_2 arisings from fossil fuelled power plants will need to be captured and disposed of in this way. A significant proportion of the gas would return to the atmosphere over a period of several hundred years. If release was to take place rapidly as a result of changes in ocean circulation or upwelling patterns it is possible that the sudden large pulse of CO_2 could trigger climate feedback processes, leading to a runaway greenhouse effect. The impacts upon the ocean carbonate cycle have not been fully evaluated.

There is no doubt that the acidic plume created by liquid carbon dioxide disposal would prove lethal to most organisms. Benthic systems could be severely disrupted by a seafloor lake of CO_2 while mid-water acidic strata could prevent movement of organisms through the water column. There is also the possibility that increased CO_2 concentrations could reduce the capacity of seawater for other gases causing anoxia and increased formation of methane. Hence ecological impacts could potentially be severe. Direct disposal of CO_2 into the oceans represents an irreversible practice. If unanticipated effects occur, then recovery and remediation will be impossible. The long term benefits are also in doubt and this raises intergenerational liability issues, in contravention of principles of sustainability. The scientific uncertainties are similar to those associated with dumping of any wastes at sea. Recognising these, such dumping activities have been prohibited internationally under the terms of the London Convention of 1972. The dumping of carbon dioxide at sea (directly into the water, on the seabed, or below it) would clearly be illegal under international law.

b) Injection into geological formations

The second category of proposals for CO_2 disposal stem from oil industry practice of reinjecting gas separated from oil at the well head into oil formations, often as part of enhanced oil recovery procedures. Other precedents include the injection of brines and hazardous wastes into deep geological formations. The concept has been developed considerably to embrace the possibility of injecting captured CO_2 from industrial plants into both exhausted oil formations and into geological formations bearing saline waters.

While reinjection of oil derived gas into oil formations may, within limits, be justified by industry as standard practice, the use of these and other formations for carbon dioxide disposal cannot. Currently, a large scale pilot study is underway in which 1Mt per year of CO_2 is being injected into the Utsira sandstone formation below the sea floor off the Norwegian coast. A similar project has been proposed for the Indonesian Natuna gas field. These clearly differ from normal operational procedures insofar as the gas is being injected into formations other than those from which it was derived. This difference will become more profound if combustion-sourced CO_2 is disposed of into such formations.

Concerns largely centre around the ability of these formations to provide secure long term containment of the carbon dioxide. Exhausted oil formations may undergo structural changes affecting their long term integrity. The potential for carbon dioxide migration into adjacent formations, arising from the different physical characteristics of CO_2 compared to those of oil, has not been fully evaluated. The necessary long term commitment to monitoring to assure formation integrity, in the order of 1000+ years, raises questions once again of intergenerational equity which are somewhat analogous to the generation and disposal of radioactive wastes. Remedies for failure of containment are far from clear. Leakage of gas from these formations could, as a sudden release, cause widespread damage. Chronic leakage could change biological systems over a wide area by changing overlying water chemistry. The liability arising from such damage could very substantial.

Finally, the legality of sub-seabed disposal is questionable. The London Convention prohibits the dumping of industrial waste at sea, taken to include the sub-seabed compartment. While operational re-injection of gas for enhanced oil recovery may fall outside of this prohibition, injection of operating wastes into different formations and the disposal of carbon dioxide from other industrial processes clearly does not.

Conclusion

Current energy production and consumption patterns violate principles of sustainability. As a result the world is committed to warming as a result of emissions of greenhouse gases from the use of these fuels. A pragmatic approach to mitigating the potential impacts is to simply accept the need to limit future fossil fuel use, and ultimately replace it. This should take place through continuous development of an energy infrastructure based upon renewable resources, combined with measures to increase overall energy efficiency. Given this, proposals to sequester and dump/store carbon dioxide, besides being an unsustainable solution in their own right, also perpetuate unsustainable energy use based upon fossil fuels. It is also probable that attempts to limit the impacts of climate change by the capture and disposal of carbon dioxide will result in undesirable and unanticipated impacts. In addition, attempts to develop such techniques may well result in an entirely misguided diversion of attention away from other, more robust, mitigation options. Furthermore, under existing legislation, such operations at sea are illegal. Accordingly, resources currently deployed in investigating such schemes would be better directed, as a matter of urgent priority at the development of technologies which contribute to renewable energy generation or increased energy efficiency.