



## **Advisory Group on R&D on Ocean Sequestration of CO<sub>2</sub>**

**REPORT PH3/2  
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*This document has been prepared for the Executive Committee of the Programme.  
It is not a publication of the Operating Agent, International Energy Agency or its Secretariat.*

# SUMMARY

## 1. Introduction

In 1995-96, IEA GHG organised a series of four expert workshops, to address key aspects of ocean sequestration of CO<sub>2</sub>, with the twin aims of finding out what was known in this and related fields and identifying key challenges for future research. The subjects of these workshops were:

1. Ocean Circulation
2. Environmental Impact
3. International Links and Concerns
4. Practical and Experimental Approaches

The participants at these workshops were mainly scientists but experts with legal and policy perspectives were also involved. One of the recommendations of the third workshop was that an Advisory Group should be set up to advise on a strategy for R&D on ocean sequestration of CO<sub>2</sub> including identifying issues of public concern. It was recommended that this group should include representatives of other stakeholders with interests in this subject, including environmental non-governmental organisations (ENGOS).

In response to this recommendation, the IEA GHG Programme organised a meeting to establish such an advisory group. This was held at the Forte Crest Hotel, Heathrow Airport, London, on 26<sup>th</sup> and 27<sup>th</sup> of March 1998. The participants were:

Dr Eric Adams	Massachusetts Institute of Technology	USA
Dr Martin Angel	Southampton Oceanography Centre	UK
Dr Michael Bewers	Bedford Institute of Oceanography	Canada
Ms Alison Crowther	The Environment Council	UK
Mr John Davison	IEA Greenhouse Gas R&D Programme	UK
Dr Paul Freund	IEA Greenhouse Gas R&D Programme	UK
Mr Lars Golmen	Norwegian Institute for Water Research (NIVA)	Norway
Dr Paul Johnston	Greenpeace Research Laboratory	UK
Prof. Judith Kildow	Massachusetts Institute of Technology	USA
Mr James McCullagh	Legal consultant	USA
Dr Takashi Ohsumi	Central Research Institute of Electric Power Industry	Japan
Mr Brett Orlando	IUCN – The World Conservation Union	USA
Ms Delia Villagrasa	Climate Network Europe	Belgium
Mr Robert Warzinski	Federal Energy Technology Center	USA

This provides an overview of the meeting and summarises the recommendations arising from the discussions.

## 2. Conclusions

### 2.1 Summary of the meeting

Extensive discussions were held during the meeting to agree a mission statement for the Advisory Group, to agree the future composition of the Group and to identify areas of concern about ocean sequestration of CO<sub>2</sub>. The consensus view of the participants was that the meeting was productive, informative and came to an appropriate and satisfactory conclusion. All participants stated that either themselves or one of their colleagues would be involved in the future work of the Advisory Group.

## 2.2 Purpose of the Group

After detailed consideration of what needed to be done, the following statement was agreed:

*This group believes it is essential to achieve objective evaluation and comparison of options for prevention / mitigation of atmospheric CO<sub>2</sub> build-up.*

*To this end, the group will aim to ensure the objective evaluation of the feasibility, benefits, effects and risks of ocean sequestration of CO<sub>2</sub>.*

This will help to put the R&D on ocean sequestration of CO<sub>2</sub> in context. The group decided that it should *provide oversight and guidance to relevant parties* about ocean sequestration of CO<sub>2</sub> but, in the time available, no further definition of the future activities of the group could be achieved. This would be continued at the next meeting.

## 2.3 Recommendations

Specific recommendations resulting from the discussions were:

- The number of participants in the Advisory Group should be increased to around 16, mainly by increasing the number of ENGOs and including industry representatives.
- IEA GHG should publish the proceedings of the Heathrow meeting, and later meetings of the Advisory group, on the World Wide Web, and distribute via e-mail, as well as through the usual channels, to help elicit feedback.
- A larger meeting should also be arranged, to inform a wider range of stakeholders about ocean sequestration of CO<sub>2</sub>, to obtain their views and to agree future actions of the Advisory Group. The current members of the Group should help to identify appropriate participants.
- IEA GHG should produce one page and ten page publications summarising ocean sequestration of CO<sub>2</sub>, which could be provided to potential participants and others interested in the subject.
- The analysis leading to US support for R&D on ocean sequestration of CO<sub>2</sub> would be of interest to the Advisory Group. If similar information is available in Japan and Norway, this would also be of interest.
- The Advisory Group will not become directly involved with outreach activities in Hawaii, related to the Japan/US/Norway CTI experiment.

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# 1. Introduction

Emissions of greenhouse gases are increasing the risks of major climate change. By extrapolating the rates at which fossil fuels are being used it has been estimated that all currently known fossil fuel reserves will have been used within 150-200 years. This fossil fuel consumption is projected to result in an atmospheric concentration of CO<sub>2</sub> about four times the pre-industrial level. The atmospheric concentration is then predicted to decline gradually to about double its pre-industrial concentration in the long term (about 1000 years), as the ocean and atmosphere come to a new natural equilibrium. Although mankind will ultimately have to survive without large-scale use of fossil fuels, it may not be possible for us to make sufficiently deep and rapid reductions in fossil fuel use to avoid the potentially harmful near-term peak in atmospheric CO<sub>2</sub> concentrations. In these circumstances, separating CO<sub>2</sub> from large point sources, such as power stations, and sequestering it in the deep ocean may be beneficial to the global environment, as this activity will reduce the peak of atmospheric CO<sub>2</sub>.

The ocean already contains a large amount of CO<sub>2</sub>, about 146,000 Gt (about 40,000 Gt of carbon), mostly in the form of bicarbonate. For comparison, the atmosphere contains CO<sub>2</sub> amounting to about 750 Gt of carbon and annual CO<sub>2</sub> emissions from the use of fossil fuels contain about 6 Gt of carbon.

In 1997 Japan, the USA and Norway began a 5 year, \$3.8 million R&D project on ocean sequestration of CO<sub>2</sub>, organised under the Climate Technology Initiative (CTI). This is an initial, limited project to investigate CO<sub>2</sub> plume physics. It will consist of an experiment off the coast of Hawaii in the summer of the year 2000, involving injection of around 100 tonnes of CO<sub>2</sub> through a pipeline into the ocean at a depth of around 1000m, over a three week period. A possible follow-on project could involve injecting a larger quantity of CO<sub>2</sub> into an enclosed ocean basin, such as a Norwegian fjord, to investigate environmental impacts.

The IEA Greenhouse Gas R&D Programme<sup>1</sup> (IEA GHG) is evaluating a wide range of greenhouse gas mitigation options, including ocean sequestration of CO<sub>2</sub>, and aims to provide an independent perspective on the various alternative options. IEA GHG is not part of the CTI project, or part of any other development work associated with this concept, and is therefore in a good position to provide informed but unbiased advice about the aims and objectives of such practical research projects.

In 1995-96, IEA GHG organised a series of four expert workshops, to address key aspects of ocean sequestration of CO<sub>2</sub>, with the twin aims of finding out what was known in this and related fields and identifying the key challenges needing future research. The subjects of these workshops were:

1. Ocean Circulation
2. Environmental Impact
3. International Links and Concerns
4. Practical and Experimental Approaches

Proceedings of these workshops are available from IEA GHG. The participants were mainly scientists but experts with legal and policy perspectives were also involved. One of the recommendations of the third workshop was that an Advisory Group should be established, to provide a forum to examine the strategy for R&D on ocean sequestration of CO<sub>2</sub> from all relevant points of view. It was recommended that this group include representatives of other stakeholders who have an interest in this subject, including environmental non-governmental organisations (ENGOS).

In response to this recommendation, IEA GHG organised a preliminary meeting at the Forte Crest Hotel, Heathrow Airport, London, on 26<sup>th</sup> and 27<sup>th</sup> of March 1998. This report provides an overview of this meeting and summarises the recommendations arising from the discussions.

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<sup>1</sup> IEA GHG is an international collaborative programme to evaluate technologies for mitigation of greenhouse gas emissions and identify necessary research and development. The programme is sponsored by 15 countries, the European Commission and 6 industrial organisations.

## 2. Participants

The meeting was set up to discuss issues of public concern and to agree the terms of reference and membership of an Advisory Group on CO<sub>2</sub> Ocean Sequestration R&D. The number of participants was set at 12-15 to ensure effective dialogue. IEA GHG invited participants from a broad range of countries, backgrounds and organisations, including scientists involved in R&D on ocean sequestration of CO<sub>2</sub>, scientists involved in other international ocean and climate change programmes, experts on policy and law, and ENGOs. Participants included scientists from the main countries involved in R&D on ocean sequestration of CO<sub>2</sub>, i.e. Japan, the USA and Norway, as well as countries with relevant marine, policy and legal expertise (e.g., the UK, Canada and USA) and ENGOs based in Belgium, the USA and the UK. Scientists comprised a relatively large proportion of the participants, in order to provide expertise in the many aspects of ocean sequestration and to ensure that questions from other participants would be competently answered. The ENGOs at the meeting included two 'umbrella' ENGOs (Climate Network Europe and IUCN<sup>2</sup>), who will be able to act as a channel to a large number of other ENGOs, and Greenpeace, who are particularly interested and influential regarding the ocean environment and climate change. Other environmental NGOs were invited to the meeting, including WWF<sup>3</sup>, Friends of the Earth, Environmental Defense Fund, Natural Resources Defence Council and Bellona but for various reasons they were unable to attend. A representative from a charitable organisation involved in environmental facilitation and mediation, The Environment Council, attended part of the meeting, as their services may be useful for future activities of the Advisory Group.

The participants at the meeting are listed below. Contact details, including postal and e-mail addresses and telephone and fax numbers are contained in Appendix A.

<b>Name</b>	<b>Organisation</b>	<b>Country</b>
Dr Eric Adams	Massachusetts Institute of Technology	USA
Dr Martin Angel	Southampton Oceanography Centre	UK
Dr Michael Bewers	Bedford Institute of Oceanography	Canada
Ms Alison Crowther	The Environment Council	UK
Mr John Davison	IEA Greenhouse Gas R&D Programme	UK
Dr Paul Freund	IEA Greenhouse Gas R&D Programme	UK
Mr Lars Golmen	Norwegian Institute for Water Research (NIVA)	Norway
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Mr James McCullagh	Legal consultant	USA
Dr Takashi Ohsumi	Central Research Institute of Electric Power Industry	Japan
Mr Brett Orlando	IUCN - The World Conservation Union	USA
Ms Delia Villagrana	Climate Network Europe	Belgium
Mr Robert Warzinski	Federal Energy Technology Center	USA

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<sup>2</sup> IUCN - The World Conservation Union

<sup>3</sup> World Wide Fund for Nature

### 3. Presentations

The first day of the meeting consisted of presentations, including preliminary discussions. The presentations enabled all participants to become familiar with the main issues associated with ocean sequestration of CO<sub>2</sub> and provided an opportunity for the presenters to express their views. The subjects of the presentations and names of the presenters are given in the following table. Slides and summaries of the presentations are included as Appendices B to J.

1. Welcome and introduction to the IEA Greenhouse Gas R&D Programme	Paul Freund
2. Aims of the meeting	John Davison
3. Public outreach efforts for CO <sub>2</sub> ocean storage project	Judith Kildow
4. Use of the oceans and environmental impact	Martin Angel
5. Proposals for ocean storage of CO <sub>2</sub>	Takashi Ohsumi
6. CO <sub>2</sub> ocean storage R and D programmes	Eric Adams
7. CO <sub>2</sub> experiments in a deep enclosed seawater basin	Lars Golmen
8. Influence of science on environmental policy	J. Michael Bowers
9. Ocean sequestration of CO <sub>2</sub> - legal issues	James McCullagh

Paul Freund presented an introduction to the IEA Greenhouse Gas R&D Programme (IEA GHG) and explained why the Advisory Group was being formed. The IEA GHG Programme is a collaboration of 15 countries, the European Commission and a number of industrial organisations. Its aims are to evaluate technologies for reducing greenhouse gas emissions, to disseminate the results and identify any necessary R&D. The major anthropogenic greenhouse gas is carbon dioxide so this has received the most attention. Options for reducing CO<sub>2</sub> emissions include:

- improved energy efficiency and fuel switching (both of which are cost-effective today);
- substitution of energy from renewable sources and nuclear power offer the possibility of making deeper reductions in emissions;
- capture and disposal of CO<sub>2</sub>, an option that has received relatively little attention but could offer deep reductions in emissions whilst avoiding the need for a precipitate switch away from fossil fuels.

The IEA GHG Programme has been concentrating on ensuring this option is sufficiently well understood, so that any decisions about its application could be taken with confidence. Captured CO<sub>2</sub> could be stored in various natural reservoirs, such as disused oil or gas fields, deep saline reservoirs or the deep ocean. The focus of this meeting was the ocean option. IEA GHG work on ocean sequestration of CO<sub>2</sub> was briefly summarised - this included the initial assessment of the option, which showed the potentially large capacity, a series of expert workshops to define the boundaries of current knowledge and recommend necessary research, and subsequent studies and research work.

John Davison said that deep reductions in CO<sub>2</sub> emissions will be required to avoid the risk of harmful climate change. Ocean sequestration of CO<sub>2</sub> is a possible option for achieving these reductions. The concerns regarding ocean sequestration of CO<sub>2</sub> highlighted at IEA GHG's earlier workshops were summarised. The broad aims of this meeting were proposed; to identify issues of public concern regarding R&D on ocean sequestration of CO<sub>2</sub> and to recommend steps to address these concerns. To

achieve these aims it will be important to involve all stakeholders, listen to and understand their needs, interests and opinions, identify and build on areas of common agreement and look for solutions that all stakeholders can support.

Judith Kildow discussed public outreach activities, particularly associated with the CTI project in Hawaii. The growing role of the public over the last 40 years was described in relation to a number of scientific and technical activities. Nowadays, the question is not whether to include the public in decision making but how? The socio-political context in Hawaii was described and a strategy to address issues at local, national and international level was presented.

Martin Angel summarised the environmental impacts of using the deep ocean for CO<sub>2</sub> sequestration. The long term impact of discharging CO<sub>2</sub> into the ocean will be similar to discharging it into the atmosphere except for the near-field effects. The impacts of high concentrations of CO<sub>2</sub> on marine animals has received little scientific attention, so data are available for only a very few species. He suggested criteria whereby the use of the ocean for sequestration might be evaluated; these are:

1. No living species should be driven unnecessarily into extinction
2. Living resources should not be affected deleteriously
3. Other legitimate uses of the ocean should not be excessively inhibited
4. The extent and impacts should be limited in time and space.

The possibility of meeting these criteria is discussed in Appendix E.

Takashi Ohsumi gave an outline description of the overall global carbon cycle and sinks. Approximately 70 Gt C could be sequestered in the mid-depth ocean (1000-3000m) at an atmospheric CO<sub>2</sub> concentration of 550 ppm. The involvement of different Japanese organisations in CO<sub>2</sub> ocean sequestration R&D was described. Total annual Japanese expenditure on this option is about 1450 million Yen (about US\$11 million at the present exchange rate). Advantages of ocean sequestration proposed by Dr Ohsumi included a reduction in climate change and a reduced risk of an irreversible switch in climate occurring during the peak in the atmospheric CO<sub>2</sub> concentration. Disadvantages included the scientific uncertainty and the unpredictability of the ocean-climate system.

Eric Adams provided a summary of the CTI experiment. He described the aims and benefits of the experiment and the types of measurements which will be made. The aim of the experiment is mainly to understand the physics of CO<sub>2</sub> discharge plumes. The benefits are that data will be generated which could be used in environmental impact assessments, design and feasibility studies and to help define future field experiments. Factors leading to the selection of Hawaii as the site for the experiments and the budget and administration were also described.

Lars Golmen described possible benefits and drawbacks of CO<sub>2</sub> experiments in a deep enclosed seawater basin. Such experiments may be the next stage after the Hawaiian experiment. Benefits include the availability of deep water near to the shore, the possibility of conducting baseline studies, the possibility to study processes and effects over longer timescales because of limited dispersion, a reasonably good knowledge of the physics and biology, and logistic and economic issues. Drawbacks include somewhat different biota and physics compared to the open-ocean, difficulties in finding an equivalent undisturbed "reference fjord", uncertainties about long term impacts and public and local concerns and conflicts of interest.

Mike Bewers provided a personal perspective on the influence of science in environmental policy, based on his involvement in relevant international organisations, including the London Convention, GESAMP<sup>4</sup>, IAEA<sup>5</sup>, ACMP<sup>6</sup> and AMAP<sup>7</sup>. The philosophy behind the development of marine environmental conventions and the derivation, application and consequences of the precautionary principle were described. The thesis of the presentation was that the increasing influence of public perception on marine environmental protection policy and the neglect of the concept of “net benefit” and multi-sectoral approaches is leading to the adoption of simplistic and unnecessarily extreme approaches to marine pollution prevention and to reduced reliance on science.

Jim McCullagh provided a broad review of legal issues associated with ocean sequestration of CO<sub>2</sub> (Appendix J). This included a general overview of international law, the potential impacts of CO<sub>2</sub> sequestration, the major international conventions such as the UN Framework Convention on Climate Change, the UN Convention on the Law of the Sea and the London Convention 1972, different formulations of the precautionary principle and a discussion applying the major international legal controls to questions raised by ocean sequestration of CO<sub>2</sub>.

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<sup>4</sup> Group of Experts on the Scientific Aspects of Marine Pollution

<sup>5</sup> International Atomic Energy Authority

<sup>6</sup> Advisory Committee on Marine Pollution

<sup>7</sup> The Arctic Monitoring and Assessment Programme

## **4. Discussions**

On the second day of the meeting two separate discussion groups were formed and charged with recognising concerns about ocean sequestration in general and R&D programmes. They were also asked to identify other groups or points of view that should be involved in the discussions. Having listed their views, the two groups came back together for a round table discussion. The focus of the discussion then shifted to agreeing on the purpose and membership of the Advisory Group.

### **4.1 Concerns**

The lists generated by the two discussion groups are reproduced in Appendix K. These covered a wide range of issues; a summary of the concerns is provided below, together with suggested actions which arose from the subsequent discussion.

#### **1. Impacts of raised oceanic CO<sub>2</sub> concentrations**

Participants expressed concerns about the impacts of CO<sub>2</sub> on the marine environment, living resources, biodiversity and ocean circulation. Details of these issues are contained in the appendices to this report and the proceedings of IEA GHG's earlier workshops. As much of the CO<sub>2</sub> generated from use of fossil fuels will end up in the ocean anyway, these concerns are relevant to the future of the oceans in general and not just the ocean sequestration concept. It is important to increase our knowledge of the environmental impacts of increased oceanic CO<sub>2</sub> concentrations, as this would be relevant to business-as-usual scenarios as well as scenarios involving ocean sequestration of CO<sub>2</sub>. This research could expect to receive support from a broad spectrum of society.

#### **2. Timescale for retention of CO<sub>2</sub> in the Ocean**

There is uncertainty about the length of time which sequestered CO<sub>2</sub> would remain in the ocean.

#### **3. Rationale for R&D on ocean sequestration of CO<sub>2</sub>**

The rationale for carrying out R&D on ocean sequestration has not yet been clearly demonstrated to a wide audience. Some participants questioned the prudence of proceeding with field experiments without first prioritising the various mitigation options. They expressed interest in seeing the detailed analysis leading to US support for R&D on ocean sequestration of CO<sub>2</sub> and if similar information is available in Japan and Norway, this would also be of interest. Some participants also expressed concern that carrying out research on ocean sequestration to avoid the transient problem of a peak in atmospheric CO<sub>2</sub> concentrations may reduce the urgency of action on other measures for dealing with rising CO<sub>2</sub> concentration.

An impartial comparison of ocean sequestration of CO<sub>2</sub> and other greenhouse gas abatement options would help to put the merits and concerns regarding ocean sequestration R&D in context. The criteria to be used in this comparison need to be agreed. IPCC has a responsibility to compare different options. The IEA GHG Programme provides evaluations of many different options against standard criteria. It is important that scenarios involving ocean sequestration are compared against business-as-usual scenarios as well as scenarios involving alternative mitigation options. There was some concern that any R&D programme may acquire a momentum, hence evaluation should be carried out as soon as possible. However, one of the difficulties regarding evaluation of ocean storage of CO<sub>2</sub> is the lack of data. The proposed R&D programme will provide some of the data necessary for a thorough and meaningful evaluation.

#### **4. Scientific objectivity and public scepticism**

It was acknowledged that there is a general scepticism in society about the trustworthiness of science and the impartiality of scientists, particularly applied research sponsored by industry and special interest groups but also government sponsored research. Efforts should be made to correct the negative public perception of applied environmental research. The objectivity and perception of objectivity of any evaluation in this area is paramount. People from a range of affiliations should be involved in the evaluation of ocean sequestration. This should minimise any possible criticism of bias and should help to avoid groups having different interests and mandates carrying out independent evaluations, resulting in adversarial disputes.

#### **5. “Unknown unknowns” and the precautionary principle**

Science should be able to address gaps in knowledge in a particular field but there is concern about the ‘unknown unknowns’, particularly in relation to long term impacts. On the one hand, the ocean environment is complex and relatively poorly understood, which has resulted in a general tendency to be cautious in relation to activities affecting the ocean. On the other hand, the precautionary principle should not be used simply as a reason for foreclosing options, since these options may have as yet unperceived overall environmental benefits.

#### **6. Use of R&D resources**

There was concern among some participants about the cost of ocean sequestration R&D. Could the resources planned to be used for ocean sequestration R&D be used more effectively on R&D for other options, such as energy efficiency? Others pointed out that, because funding for these different activities is likely to come from different government departments, a reduction in expenditure on ocean sequestration R&D may not result in increased funding for other mitigation options.

This is a summary of some of the statements made in wide ranging debates in the two discussion groups. A detailed list of concerns expressed is given in Appendix L.

#### **4.2 Membership of the Advisory Group**

It was suggested that the present group contained too high a proportion of scientists and technologists. The difficulties of attracting ENGOs to this meeting were discussed. Reasons for not participating included prior commitments, prioritisation of activities and the lack of current public awareness of the issues. It was decided that the number of non-scientists involved in the group should be increased, even perhaps reducing the number of scientists involved although there was a range of views about this. It was decided to aim to attract at least two more ENGOs with a global presence and an active interest in ocean and climate change issues; WWF was considered to be a prime candidate. Industry representatives, including one from Japan, should be included in the core Advisory Group. In this context, industrial NGOs such as E&P Forum might also be useful participants. An economist, but not one associated with an interested party, should also be included. Contact should be made with UNEP, which is internationally active in issues affecting marine pollution from land-based activities.

It was emphasised that no interested group should be precluded from joining the Advisory Group and information should be made widely available to help ensure that all interested groups are informed. It will be important to emphasise the independence of the Advisory Group to attract new members.

It is important that the Advisory Group is able to influence policy makers effectively, particularly in the three countries involved in R&D on this option, i.e. Japan, the USA and Norway. Policy makers from these countries therefore need to be actively involved in the Advisory Group.

Members of the Group should be encouraged to listen to, understand and respect the needs, interests and opinions of others, identify and build on areas of common agreement and look for solutions that all stakeholders can support.

#### **4.3 Next meeting**

It was agreed that the next stage should be to hold a larger meeting, involving a wider range of stakeholders. The purpose of the meeting would be to inform a wide audience about R&D on ocean sequestration of CO<sub>2</sub>, involve them in discussion about concerns and start to build a consensus. Brief and targeted presentations should be included to provide information to new participants.

Other organisations which were suggested as candidates for involvement in this meeting, in addition to those mentioned above, included developing country representatives, UN and other international bodies, the media, labour unions, representatives of fisheries, tourism and shipping and tax payers (through consumer groups).

#### **4.4 Information for potential participants**

IEA GHG has published the proceedings of the four earlier workshops, which provide comprehensive reviews of the state-of-knowledge about ocean sequestration of CO<sub>2</sub>. These proceedings were made available to all participants at the meeting. It was agreed that IEA GHG should produce a more condensed (about 10 pages) version of these reports, with appropriate up-dates, for distribution to stakeholders and potential participants in future meetings. IEA GHG should also produce a 1-2 page summary note. These summaries should be impartial summaries, not publicity 'fliers'. The Advisory Group will offer comments on the drafts of these summaries.

#### **4.5 Interaction with the CTI project**

Public outreach activities are currently being carried out in Hawaii, related to the Japan/USA/Norway CTI project. The Hawaiian outreach activities involve many issues which are specifically local, related solely to the CTI experiment. These activities should remain separate from the Advisory Group, although the group remains keenly interested in the current and future CTI experiments and is willing to provide feedback where appropriate. It is important that the Advisory Group is, and is seen to be, independent of the CTI project.

## 5. Purpose of the Advisory Group on CO<sub>2</sub> Ocean Sequestration R&D

After detailed consideration of what needed to be done, the following statement was agreed by those present:

*This group believes it is essential to achieve objective evaluation and comparison of options for prevention / mitigation of atmospheric CO<sub>2</sub> build-up.*

*To this end, the group will aim to ensure the objective evaluation of the feasibility, benefits, effects and risks of ocean sequestration of CO<sub>2</sub>.*

The group decided that it should *provide oversight and guidance to relevant parties* about ocean sequestration R&D but, due to time constraints, was unable to further define the group's future activities. This would be continued at the next meeting. Mike Bewers' preliminary suggestion of the objectives of the group, which provided a focus for discussions at the meeting, is given in Appendix L.

IEA GHG will act as facilitators, enabling the group to function, but the group will decide its own programme of activities and recommendations. The IEA GHG Executive Committee, representing the members of IEA GHG<sup>8</sup>, has agreed to support the activities of the group, as part of an overall programme of work on evaluation of greenhouse gas mitigation options.

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<sup>8</sup> The members of IEA GHG are currently Australia, Canada, Denmark, Finland, Japan, Korea, The Netherlands, New Zealand, Norway, Poland, Sweden, Switzerland, UK, USA, Venezuela, The European Commission, BP, DMT-FP, EPRI, Mobil, RWE and Shell.

## 6. Recommendations

The consensus view of the participants was that the meeting had been productive, informative and had come to an appropriate and satisfactory conclusion. All participants stated that they would like either themselves or one of their colleagues to be involved in the future work of the Advisory Group on CO<sub>2</sub> Ocean Sequestration R&D.

The following specific recommendations were agreed at the meeting:

- The number of participants in the Advisory Group should be increased to around 16, mainly by increasing the number of ENGOs and including industry representatives.
- IEA GHG should publish the proceedings of the Heathrow meeting, and later meetings of the Advisory group. Drafts of the meeting reports will be circulated to participants of the meeting for comments, prior to publication. To facilitate and encourage feedback and a broad audience, distribution should be through the World Wide Web and e-mail, as well as through the traditional channels.
- A larger meeting should also be arranged, to inform a wider range of stakeholders about ocean sequestration of CO<sub>2</sub> and the role of R&D, to obtain their views and to agree on future actions of the Advisory Group. The current members of the Group should help to identify appropriate participants.
- IEA GHG should produce one page and ten page publications summarising R&D on ocean sequestration of CO<sub>2</sub>, which could be provided to potential participants and others interested in the subject.
- The analysis leading to US support for R&D on ocean sequestration of CO<sub>2</sub> would be of interest to the Advisory Group. If similar information is available in Japan and Norway, this would also be of interest.
- The Advisory Group will not become directly involved with outreach activities in Hawaii, related to the Japan/US/Norway CTI experiment. However, the group remains keenly interested in the current and future CTI experiments and is willing to provide feedback where appropriate.

# APPENDIX A

## Contact Details Of Participants

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# **APPENDIX B**

## **Introduction to the IEA Greenhouse Gas R&D Programme**

**P. Freund**

**IEA Greenhouse Gas R&D Programme**

# **APPENDIX C**

## **Aims of the Workshop**

**J. Davison**

**IEA Greenhouse Gas R&D Programme**

# **APPENDIX D**

## **Public Outreach Efforts for CO<sub>2</sub> Ocean Storage Project**

**J. Kildow**

**Massachusetts Institute of Technology**

# **APPENDIX E**

## **Use of the Oceans and Environmental Impact**

**M. Angel**

**Southampton Oceanography Centre**

# **APPENDIX F**

## **Proposals for Ocean Storage of CO<sub>2</sub>**

**T. Ohsumi**

**Central Research Institute of Electric Power Industry**

# **APPENDIX G**

## **CO<sub>2</sub> Ocean Storage Research, Development and Demonstration Programmes**

**E. E. Adams**

**Massachusetts Institute of Technology**

# **APPENDIX H**

## **CO<sub>2</sub> Experiments in a Deep Enclosed Seawater Basin**

**L. Golmen**

**Norwegian Institute for Water Research (NIVA)**

# **APPENDIX I**

## **Influence of Science on Environmental Policy**

**J. M. Bowers**

**Bedford Institute of Oceanography**

# **APPENDIX J**

## **Ocean Sequestration of CO<sub>2</sub> - Legal Issues**

**J. McCullagh**

**Legal Consultant**

# APPENDIX K

## Discussion Group Reports

### Group A

#### 1. Members:

Martin Angel  
Michael Bowers  
Alison Crowther  
John Davison  
Takashi Ohsumi  
Delia Villagrasa  
Robert Warzinski

#### 2. Concerns

Note: The group categorised concerns as general ('G') and specific to ocean sequestration of CO<sub>2</sub> ('S'). Some concerns are both general and specific ('G/S').

Inadequate science (G/S)

Inadequate scientists (G/S)

pH change (S)

Effects on biodiversity (G/S)

Effects on living resources (G/S)

Effects of ocean circulation (S)

What is the capacity (S) - fate of CO<sub>2</sub>

- how long does it stay?

- how secure is it?

Is it practical? (G/S)

Catastrophic risk element (G/S)

Is it legal? (S)

Unknown unknowns

Cost in R&D as well as when up and running (S)

- cost effectiveness

Balance of cost of this option to other options (S)

Can we get the data we need? (S)

- with acceptable uncertainties

Are there sufficient scientists around to do the above work? (S)

- atmospheric

- oceanic

- modelling

What is the right thing to do with this data? (G/S)

- presentation

- communication

Need a balanced overview of options against each other (S)

Need a balanced overview of this option (S)

- multi-sectoral
- multi-disciplinary
- group of people - what are their concerns
  - what are their scientific concerns
- no change business as usual scenario needs to be flagged

Speed of injection - comparisons (S)

Key is to chop off the transient

- the need to preserve the short term future

Can society survive the reduced consumption of fossil fuels which will make end of pipe mitigation options unnecessary?

- if no then comparison of end of pipe solutions is crucial

Relationship between Advisory Group and power to inter-relate with stakeholders and vice versa

How do scientists interact with the public?

Must be definition between

- locally specific
- and generally specific
- and when both may be brought together

Since this is a transient solution, is there a risk of not adopting policies and research on longer term problems?

### **3. Who needs to be involved?**

Independent people

Interested advisory group

Lawyers

Scientists

Social scientists

Economists

Environmental NGOs, especially marine and climate

Media

Policy makers - wide ranging

Ethics and value specialists

Developing countries representatives

Churches

Labour unions

Fisheries

Tourism

State representatives

Shipping

Tax payers - through consumer groups

Youth groups

## Group B

### 1. Members:

Eric Adams  
Paul Freund  
Lars Golmen  
Paul Johnston  
Judith Kildow  
James McCullagh  
Brett Orlando

### 2. Concerns

Don't make assumptions which preclude people joining the dialogue  
- availability of information  
How does this option compare with others?  
Greatest bang/\$  
What are the criteria to be used for (iterative) evaluation procedures?  
Whether to do the research?  
- a bigger question than detailed design of experiments  
Need to be convinced it is a robust proposal  
Make available to the group critiques of R&D needs assessment  
Experimental design appears to have out-run justification for the R&D

Status in relation to international legislation (eg Kyoto, Law of the Sea etc)  
Broaden participants in discussion  
More than just Norway, US, Japan, IEA GHG  
Not on the 'radar' of many other groups  
Need to do multi-media evaluation  
How to take the negative bias off applied environmental research?  
Commercial interests - raises questions about motives  
Can't believe government funded research either  
R&D - is it to overcome the obstacles?  
- or is it to decide whether it is feasible?  
Environmental impacts on deep ocean  
How effective is it as a mitigation option?

Concerns will span whole spectrum  
Give confidence to others that should contribute

'Integrity' of the measurements for Kona experiment  
Research results not (much) published in marine science journals  
Representativeness of the experimental site

### 3. Who to involve?

NGOs, e.g. NRDC, EDF  
IPCC  
Other agencies, e.g. EPA, State

#### **4. Stakeholders**

FOE, WWF, NCC

Trade associations

Utilities

Governments and government agencies

Scientific organisations, e.g. RSOC, Soc. Env. Toxicology, ECOR

UN and other international bodies

General public

# APPENDIX L

## Proposed Objectives and Terms of Reference

drafted by J. M. Bowers

*This group believes it is essential to achieve objective evaluation and comparison of options for prevention / mitigation of atmospheric CO<sub>2</sub> build-up. To this end it will aim to:*

- *Ensure the objective evaluation of the feasibility, benefits, effects and risks of ocean sequestration of CO<sub>2</sub>.*
- *Provide oversight and guidance to relevant parties regarding:*
  - *the nature of concerns regarding deep ocean sequestration of fossil fuel CO<sub>2</sub> from scientific, social, economic and environmental perspectives;*
  - *definition of research and development activities to address such concerns, both in terms of improving the understanding of relevant processes and reducing uncertainties;*
  - *ensuring the objectivity and multi-sectoral and multi-disciplinary scientific information and its translation into addressing social, economic and environmental issues relevant to the topic.*