Carbon Dioxide Capture for Storage in Deep Geologic Formations – Results from the CO_2 Capture Project

Capture and Separation of Carbon Dioxide from Combustion Sources

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Chapter 1

POLICIES AND INCENTIVES DEVELOPMENTS IN CO_2 CAPTURE AND STORAGE TECHNOLOGY: A FOCUSED SURVEY BY THE CO_2 CAPTURE PROJECT

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ABSTRACT

The CO_2 Capture Project organized a Policies and Incentives Team (P&I Team) in 2002 to begin studying the state of policies, regulations, incentives, and potential barriers around the world. The P&I Team had the primary mission to provide information and advice to the CO_2 Capture Project's Executive Board on these issues and any other external developments that may impact or benefit the technology program being developed by the CO_2 Capture Project. The team completed two key tasks with results that are described in this paper. They are:

- A comprehensive survey of existing policies, regulations, and incentives that impact or benefit CO_2 capture, injection and storage in geologic formations.
- Gap analysis necessary to formulate the regulatory and policy framework that will show how to get from "where we are" to "where we want to be" in deploying the technology.

The results of these tasks show:

- Clear momentum exists as projects are being deployed and technology continues to be researched and developed.
- The London Dumping Convention and the OSPAR Convention (Oslo Paris Convention) may apply to CO_2 capture and storage deployment offshore in geologic formations.[1] Issues for clarification may require several years of intergovernmental negotiations in order to accommodate such deployment.
- In general, there is little policy and regulatory development specifically addressing CO_2 capture and storage in individual countries.
- Specific countries (Netherlands, Norway, Canada, United Kingdom (UK), and the United States (US)) are moving in the direction of policy development specific to CO_2 capture and storage.
- Public awareness is low to non-existent. Some non-government organizations (NGOs) will likely play key role in the public acceptance of the technology.
- Some NGOs and the public in the European Union are becoming slightly less skeptical of the technology. However, it is still too early to assess the level of public skepticism, which will become clearer when specific projects are reviewed for permitting or licensing.

[1] In the context of this paper, deployment of CO_2 capture and storage offshore means CO_2 that would be stored in geologic formations under the seabed.

- Existing and emerging financial incentives in Australia, Canada, the European Union, Denmark, Germany, Italy, Netherlands, Norway, the United Kingdom, and the United States are focused principally on research and development. Such incentives are needed to improve the cost-effectiveness for deploying CO_2 capture and storage technology.
- CO_2 capture and storage technology is becoming recognized and credited in some regulatory regimes, though it is not yet widely recognized nor credited. A monitoring and verification framework is needed to achieve wide recognition and crediting.

INTRODUCTION

The CO_2 Capture Project realized from its beginning that technology development, policy and regulatory developments, incentives, and public acceptance of the technology are interdependent. In 2002, the CO_2 Capture Project organized a team of member company representatives for the purpose of studying potential issues, concerns, and barriers that would be raised as policies and regulations develop. The team had the charter to:

> …provide information and advice to the CO_2 Capture Project's Executive Board on national and global policies, regulations and legislation, incentives and any other external developments that may impact or benefit the technology program being developed by the CO_2 Capture Project.

TASKS AND METHODOLOGIES

The team had the specific tasks to:

- Complete a survey of existing policies, regulations, and incentives that impact or benefit CO_2 capture and storage in geologic formations. Survey is conducted by literature review, telephone interviews, and meetings with government officials and stakeholders.
- Conduct gap analysis needed to formulate the economic, legal and policy framework that will show how to get from "where we are" to "where we want to be" in deploying the technology.
- Establish a network monitoring function for the team and share information about proposed regulations, policies, and incentives that can affect the CO_2 Capture Project. Through this monitoring function, identify potential opportunities to inform the debate on CO_2 capture and geologic storage.

The results of the first two tasks will be described in this chapter. The third task has been completed through individual outreach efforts, engagement in forums where policy issues relevant to the technology have been discussed. For example, preliminary results of the first two objectives from 2002 were presented at the Workshop on Carbon Dioxide Capture and Geologic Storage at the invitation of the International Petroleum Industry Environmental Conservation Association (IPIECA).[2]

RESULTS AND DISCUSSION

Clear Momentum Exists as Projects are Being Deployed and Technology Continues to be Researched and Developed

In addition to the collaboration among the member companies that formed the CO_2 Capture Project, the momentum for CO_2 capture and storage technology development clearly exists. The International Energy Agency's Greenhouse Gas Research and Development Programme (IEA GHG R&D Programme) has

[2] Inventory and review of government and institutional policies and incentives potentially influencing the development of policy in CO_2 capture and geological storage: provisional results of work conducted for the P&I Team, CO_2 capture project, by ERM, presented by Cécile Girardin of ERM, IPIECA's Workshop on Carbon Dioxide Capture and Geologic Storage: Contributing to Climate Change Solutions, Brussels, 21–22 October 2003.

detailed information or brief descriptions in a database of most if not all of the projects around the world that are:[3]

- Capturing or are planning to capture CO_2 for injection.[4]
- Demonstrating or will be demonstrating CO_2 storage.
- Conducting CO_2 monitoring projects.

According to the data (Figure 1) from the IEA GHG R&D Programme, there are 51 current projects capturing CO_2 for re-injection. Further, there are additional projects planning to capture CO_2 for injection.

The IEA GHG R&D Programme's data (Figure 2) also show three current commercial projects that are demonstrating CO_2 storage in geologic formations. Additional projects are planning to demonstrate CO_2 storage. See Figure 2.

The IEA GHG R&D Programme's data (Figure 3) show two commercial projects that are also carrying out research projects related to CO_2 monitoring in the subsurface. Additional projects are being planned or are getting underway that will incorporate research in establishing CO_2 monitoring technologies.

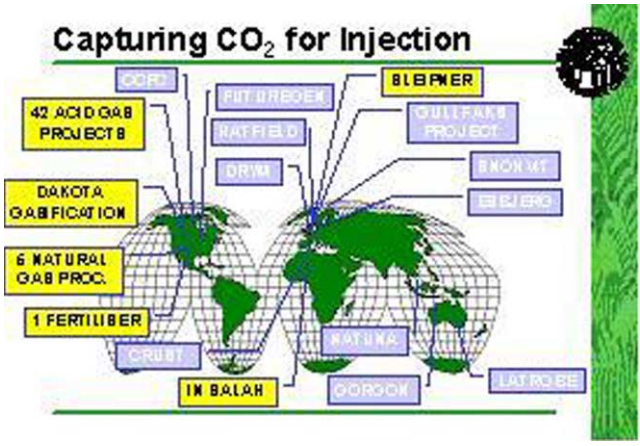

Figure 1: Current projects capturing or projects planning to capture CO_2 for injection. The project names in yellow are current projects. The others are projects planning to capture CO_2 for injection.

The London Dumping Convention, the London Protocol, and the OSPAR (Oslo Paris) Convention may Apply to CO_2 Capture and Storage Technology Deployment Offshore in Geologic Formations. Issues for Clarification may Require Several Years of Intergovernmental Negotiations in Order to Accommodate Such Deployment.

The definition and handling of CO_2 geological sequestration in multilateral environmental agreements and treaties will be an important determinant for the framework and limitation for implementation of these techniques particularly in offshore locations. Three factors are relevant:

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[3] Approaches and technologies for CO_2 capture and storage, presented by Paul Freund of the IEA Greenhouse Gas R&D Programme, IPIECA's Workshop on Carbon Dioxide Capture and Geological Storage: Contributing to Climate Change Solutions, Brussels, 21–22 October 2003. Details of the projects can be found in the database, which is accessible through http://www.co2sequestration.info. IPIECA is the International Petroleum Industry Environmental Conservation Association.

[4] In these projects, CO_2 is captured mainly from gas processing, integrated gasification combined cycle power plant, and a fertilizer that uses gasification to make the feedstock.

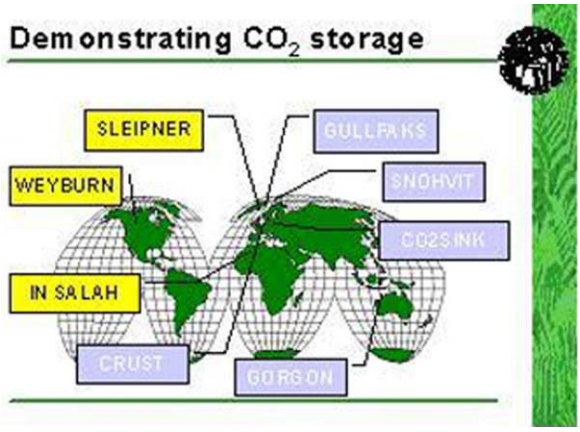

Figure 2: Current projects that are capturing or planning to demonstrate CO_2 storage. The three current projects are in yellow. Additional projects are in blue.

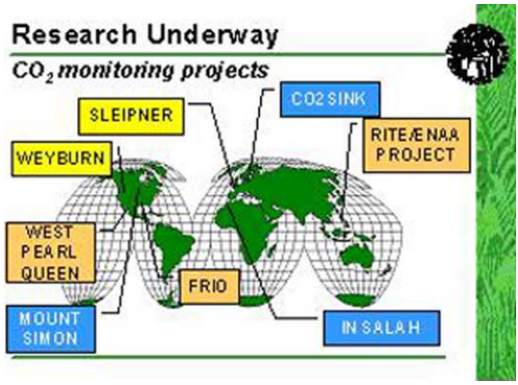

Figure 3: Research underway for CO_2 monitoring. The two current projects are in yellow. Additional projects are in other colors, in various stages of planning or are already getting under way. For example, the RITE/ENAA Project (by the Research Institute for the Earth and the Engineering Association of Japan) in the Nagoaka Prefecture in Japan began CO_2 injection in 2003 and CO_2 monitoring has also got under way.

- whether the captured CO_2 is being stored or is, in effect, being disposed of;
- whether the CO_2 is being placed in the water column or in the seabed and its subsoil as part of a scientific experiment as a prelude to CO_2 capture and storage or as part of the CO_2 capture and storage process;
- whether the CO_2 contains impurities resulting from the capture stage (e.g. H_2S).[5]

[5] CO_2 capture and storage: the position under international treaties, presented by Jolyon Thompson, United Kingdom's Department for Environment Food and Rural Affairs, IPIECA Workshop on Carbon Dioxide Capture and Geological Storage: Contributing to Climate Change Solutions, Brussels, 21–22 October 2003.

These issues are addressed at different national, regional and global levels under the 1972 London Dumping Convention and its 1996 Protocol, and the OSPAR convention. The overall intent of these treaties is to prohibit the dumping of wastes. See a summary of the Conventions in Box 1.[6]

Box 1. Summary of the London and OSPAR Conventions

The London (Dumping) Convention

The 1972 International Convention makes provisions for wastes that can be dumped at sea. The new "Guidelines for the assessment of wastes and other matter that may be considered for dumping," adopted in 2000, provide specific guidance for specific classes of wastes, including offshore platforms. The Convention deals with the dumping of industrial waste, sewage sludge, dredged material, incineration at sea, radioactive materials, and other wastes. It administers a blacklist containing substances, the dumping of which is prohibited and a grey list containing substances the dumping of which is only permitted under strict control and provided certain conditions are met. There are 80 government parties to the Convention. As with other international conventions, responsibility for enforcement lies with individual governments.

The London Protocol

The London Protocol of 1996 is designed to be the successor of the London Convention. When the 1996 Protocol enters into force, it will be binding on those London Contracting parties that are also Parties to the 1996 Protocol.

The OSPAR Convention

This international convention governs marine disposal in the North East Atlantic (from the Arctic to Gibraltar and from the East coast of Greenland to the west coast of continental Europe). It came into force in 1992 and replaces the 1972 Oslo Convention on dumping from ships and the 1974 Paris Convention on discharges from land, hence the acronym OSPAR. The Convention provides for the specific areas of prevention and elimination of pollution from land-based sources (especially toxic substances; by dumping or incineration and from offshore sources, and assessment of the quality of the marine environment. Since 1998 and following the Brent Spar affair, any disposal at sea of offshore structure is no longer permitted. Currently, the main working issues are: (a) the protection and conservation of ecosystems and biological diversity; (b) hazardous substances; (c) radioactive substances; (d) eutrophiication. Similar Conventions govern other seas, such as BARCOM for the Mediterranean and HELCOM for the Baltic Sea.

Sources: http://www.londonconvention.org; http://www.ospar.org/

In Europe, the OSPAR Convention will have the strongest implications for individual countries in the deployment of CO_2 capture technology. Issues include:

[6] Update and Studies of Selected Issues Related to Government and Institutional Policies and Incentives Contributing to CO_2 Capture and Geological Storage: Final Report to the CO_2 Capture Project, prepared by Lee Solsbery, Cécile Girardin, Scot Foster, David Adams, Peter Wooders, Janet Eccles, Charlotte Jourdain, Leiping Wang, January 2004.

- The maritime area: whether there will be a distinction between pumping CO_2 into the sea, as opposed to into the seabed. In the case of offshore oil and gas and land based sources, this distinction is very relevant.
- Possible methods and purposes of placement: three separate regimes for CO_2 storage were identified under OSPAR. These are from land-based sources; dumping from ships and aircrafts; and offshore oil and gas installations. The purpose of placement of CO_2 will be relevant to whether CO_2 storage is consistent with the convention.
- Considerations relating to land-based sources: the transport of CO_2 from a land-based source, by pipeline could be allowed, although this is not stated in the convention, which states that discharges into sea or seabed[7] should be subject to regulations preventing the discharges to harm the environment. CO_2 is regulated under the same provisions as the discharge of sewage into the sea. Consequently, as long as it cannot be proven that the placement of CO_2 by pipeline from a land-based source has adverse effects on the environment, this should be permitted under the Convention.
- Considerations relating to the dumping from vessels: shipment of CO_2 for placement from a vessel will be described as deliberate disposal of CO_2 and prohibited, unless it is clearly done for the purpose of a scientific experiment.
- Considerations relating to offshore installations: two activities would be acceptable under OSPAR. CO_2 re-injection for the purpose of enhanced oil recovery (EOR) should be acceptable as included in oil and gas production, which is accepted under OSPAR. Similarly, immediate injection of CO_2 which was emitted on site only, appears to be consistent with the Convention, provided that there is no evidence that this will harm the marine environment.

Dialog between nations that are parties to OSPAR will be ongoing. In summary, there is still a lack of clarity with respect to the applicability of OSPAR to offshore CO_2 geologic storage. If OSPAR is applicable, some experts believe that offshore geologic storage is inconsistent with the Convention while other experts disagree. This lack of clarity is creating a potential barrier to offshore CO_2 geologic storage. Amendments may be needed to develop the appropriate regulations of CO_2 storage within the frameworks of the OSPAR Convention.

Outside the OSPAR area, the London Convention (1972) and its 1996 Protocol may apply to CO_2 capture and geologic storage technology deployed offshore. The London Convention defines dumping as: “any deliberate disposal at sea of wastes or other matter from vessels, aircraft, platforms or other man-made structures at sea, but not placement for a purpose other than the mere disposal thereof, provided that such placement is not contrary to the aims of the Convention” (Article III.1, London Convention).

The main issues of interpretation of the London Convention with respect to CO_2 storage and “dumping” are:

- the Convention does not define where (water column or seabed) “disposal” is made. It only refers to pollution of the marine environment by dumping (Article 1.1(4)(5), Article 210). Therefore, it can be argued that disposal can be made either in the water column or in the seabed and its subsoil;
- there is debate as to whether “storage” is equivalent to “disposal”. Storage suggests a temporary activity with a potential further ultimate use for the stored CO_2, while disposal suggests something more permanent. CO_2 may fall under the “industrial waste” category in the list of wastes prohibited for disposal under the London Convention but is currently not classified. If classified as industrial waste, CO_2 disposal for geologic sequestration will be prohibited.

The discussions around the relevance of the London Convention to CO_2 capture and storage have only just begun. To make changes to the language of the Protocol or to clarify the intent of specific provisions will require long negotiations between nations that are parties to these international treaties. Therefore, the lack of clarity in these issues poses a potential barrier to the offshore deployment of CO_2 capture and storage. Amendments may be needed to develop the appropriate regulations of CO_2 storage within the frameworks of the London Convention.

[7] In a recent draft report by the “jurists and linguists” group operating under the OSPAR Convention, the group of legal experts described the seabed as including everything below the seabed as well (i.e. extending far below the mere seabed). Consequently, this applies to operations taking place 1000 m or more under the sea bed. At this writing, the draft report by the jurists and linguists is scheduled to be finalized in February 2004.

In General, there is Little Policy and Regulatory Development Specifically Addressing CO_2 Capture and Storage in Individual Countries

The CO_2 Capture Project's P&I Team requested the assistance of Environmental Resources Management Ltd (ERM) to conduct the survey of existing policies, regulations, and incentives that impact or benefit CO_2 capture and storage in geologic formations. ERM conducted this study from 2002 to the end of 2003. The findings from the ERM study are summarized here.[8] The work of this ERM study was carried out through a combination of document research and review, email exchange of information, telephone and face-to-face personal interviews. ERM interviewed representatives of government agencies, non-government organizations (NGOs), and people involved in research and development and demonstration projects for CO_2 capture and storage.

No country has yet fully developed strategies that include CO_2 capture and storage as part of an overall national energy or climate change strategy.

In most countries, the lack of regulatory framework may delay the application of CO_2 capture and storage. However, this lack of specific regulations is not expected to present a serious obstacle to the development of the technologies involved. Indeed, the expectation is that the regulatory framework will evolve in a generally positive manner, through cooperation between government, industry, and other stakeholders as the number of demonstration and commercial projects increases.

Governments have clearly not given full attention to this technology at the political and legislative levels. The knowledge of the technology and any associated policy implications is growing, though still limited, even in the executive or administrative sectors of national governments, government agencies and institutions with responsibility for climate change. So far, government policy and regulators appear to be broadly supportive, but opinions vary according to:

- the relative significance of the oil and gas sector;
- climate change mitigation commitments;
- public attitudes to risk and to the construction of new industrial facilities in each country.

This section, therefore, summarizes the development of policies in specific countries where CO_2 Capture Project member companies have interest.

Determining whether CO_2 will be considered (and regulated) as waste is one of the key issues to be resolved. If CO_2 is considered as waste, laws on discharge of effluents to groundwater will likely apply in order to protect the integrity of freshwater aquifers. This would increase the level of difficulty to obtain permits for storage of CO_2 in aquifer zones.

In Europe, the EU Water Framework Directive aims to "maintain and improve the aquatic environment in the Community". The Directive has two main objectives:

- Achieve and maintain water quality ("good status") by the deadline of 2015.
- Ensure that the quality of all ground and surface water does not deteriorate below present status.

The Directive defines a pollutant as:

"the direct or indirect introduction, as a result of human activity, of substances or heat into the air, water or land which may be harmful to human health or the quality of aquatic ecosystems or terrestrial ecosystems directly depending on aquatic ecosystems which result in damage to material property, or which impair or interfere with amenities and other legitimate uses of the environment."

[8] Update and Studies of Selected Issues Related to Government and Institutional Policies and Incentives Contributing to CO_2 Capture and Geological Storage: Final Report to the CO_2 Capture Project, prepared by Lee Solsbery, Cécile Girardin, Scot Foster, David Adams, Peter Wooders, Janet Eccles, Charlotte Jourdain, Leiping Wang, January 2004.

The list of possible pollutants is listed in Annex VIII of the Directive, and CO_2 is not on the list. In addition to the list of pollutants, there is a list of dangerous substances ("priority substances") and CO_2 is not included.

The Directive does not specifically mention CO_2 capture and storage, however it addresses all impacts on waters. The Directive may be triggered if there is potential impact on water resulting from CO_2 capture and storage, particularly if the CO_2 capture and storage involves storage in aquifer zones regulated under the Directive.[9] For example, the Directive does allow storage of natural gas in aquifer zones under certain conditions:

- injection of natural gas or liquefied petroleum gas (LPG) for storage purposes into geological formations, which for natural reasons are permanently unsuitable for other purposes;
- injection of natural gas or LPG for storage purposes into other geological formations where there is an overriding need for security of gas supply, and where the injection is such as to prevent any present or future danger of deterioration in the quality of any receiving groundwater.

This suggests that the Directive may be interpreted to allow the storage of CO_2 in certain reservoirs (e.g. former oil or gas reservoirs) subject to certain conditions.

There is another potential trigger for regulation under the Directive. The purpose of the Directive is to prevent any significant and sustained upward trend in the concentration of any pollutant in groundwater. When identified, such pollutant's concentration should be reversed. According to one European Commission official, CO_2 has the potential to change the chemistry of groundwater if it is in contact with it. The change in chemistry has the potential to dissolve other substances that may be harmful, which would then trigger Article 11 of the Directive.

Therefore, in summary, geologic storage in oil and gas reservoirs not located in fresh water aquifer zones would likely be considered acceptable under the EU Water Framework Directive as long as certain conditions are met. Further, existing regulations for the oil and gas production, pipelines, and natural gas storage would provide a convenient framework to develop regulations specifically addressing the deployment of CO_2 capture and storage.

At the individual national level and at the regional level, ERM reviewed the status of policy developments in these countries or the European Commission's policies that are of interest to the member companies of the CO_2 Capture Project. They are: the European Union (focusing on the Commission), Denmark, the Netherlands, Italy, Germany, United Kingdom, Norway, USA, Canada, Australia, and China.[10] Several important developments in CO_2 capture and storage policy are highlighted below. Table 1 is a comparison table that gives a simple overview of the dimension of policy developments between nations and also dimensions of:

- applicability of OSPAR and the London Convention;
- climate strategy or energy policy;
- existing regulations applied to gas storage, pipelines, aquifers, and mining;
- implications from lack of regulations;
- tax exemption;
- European Union's Framework Programme 6 activities or projects;
- R&D initiatives from government and from companies;
- pilot and demonstration projects.

[9] It should be noted that CO_2 storage in aquifers is not being considered for freshwater or potable aquifers, rather it is contemplated only for saline aquifers.

[10] Although China is included in the study, ERM found that China has neither existing policies, regulations, nor taxes and incentives with respect to CO_2 capture and storage. Although China is a member of the CSLF, they have limited to no awareness of this type of technology. Therefore, China has not been included in Table 1.

TABLE 1
POLICIES AND INCENTIVES OVERVIEW AND COMPARISON

Country	EU	Netherlands	Italy	Germany	UK	Norway	Denmark	USA	Canada	Australia
OSPAR (P is party; N/A means "not applicable")	Covers all EU members	P	P	P	P	P	P	N/A	N/A	N/A
London convention (P is party; N/A means not applicable)		P	P	P	P	P	P	P	P	P
Energy white papers/climate strategies (✓ means has white paper or climate strategy; × means none)	Netherlands, UK, Norway	✓	×	×	✓	✓	×	×	×	×
Existing regulations relating to gas storage (✓ means has regulations; × means none)	EU Water Framework Directive subject to interpretations; waste regulations may apply if CO_2 is deemed a waste; other potential interpretations. See text in Section "Conclusions"	✓	×	×	✓	✓	✓	✓	✓	✓
Existing regulations relating to pipelines (✓ means has regulations; × means none)		✓	×	×	✓	✓	✓	✓	✓	✓
Existing regulations relating to aquifers (✓ means has regulations; × means none)		×	×	×	✓	✓	✓	✓	✓	✓
Existing regulations relating to mining (✓ means has regulations; × means none)		✓	×	×	✓	✓	×	×	✓	×
Tax exemptions (✓ means has regulations; × means none)	See Netherlands and Norway	✓	×	×	×	✓	×	×	✓	×

(*continued*)

TABLE 1
CONTINUED

Country	EU	Netherlands	Italy	Germany	UK	Norway	Denmark	USA	Canada	Australia
Implications of lack of regulations (✓ means not a barrier to CCS; × means a barrier to CCS; – means neutral)	Those who were interviewed said the lack of a unified regulatory framework at the EU level hinders development of CO_2 capture and storage: reaching a consensus on OSPAR would be a major step for the development of CO_2 capture and storage	✓	–	×	×	✓	✓	×	×	×
EU 6th R&D framework programme (✓ means has activity or project; × means none)		✓	✓	✓	×	✓	×	N/A	N/A	N/A
Government R&D initiative (✓ means has activity or project; × means none)		✓	✓	✓	✓	✓	×	✓	✓	✓
Industry R&D initiative (✓ means has activity or project; × means none)		✓	✓	✓	✓	✓	×	✓	✓	✓
Pilot or demonstration project in place? (✓ means has activity or project; × means none)		✓	✓	✓	×	✓	×	✓	✓	✓

In Denmark, the government officials interviewed believe that the Danish Subsoil Act and the Offshore Installations Act will be extended to cover CO_2 capture and storage in offshore geologic structures; CO_2 storage on land will encounter more difficulties as there is very high pressure for groundwater protection in Denmark.

The issue of CO_2 capture and storage is currently a topic receiving significant level of attention in Germany; whereas the Federal Ministry of Environment expressed its fundamental opposition to the use of the technology in 2002, the Federal Ministry of Economics and Labour accepts that the German economy will be based on fossil fuel energy in the foreseeable future and sees the need for this type of technology.

Although Italy has no existing regulations on CO_2 capture and storage technology, ERM found that the Italian oil and gas industry has developed a significant focus on refinery and hydrocarbons processing R&D, including CO_2 capture and storage technology. This lack of regulatory development may present a problem for the deployment of the technology.

In the Netherlands, a new Electricity Act came into force on 1st July 2003. The Act suggests that a tax exemption worth approximately US$31–50 million (€25–40 million) in the first year and increasing every year by between US$31 and 37 million (€25–30 million) will be established to support renewable energy, energy efficiency and climate neutral electricity, including CO_2 capture and storage.

In Norway, the government adopted a strategy to realize gas power including CO_2 capture and storage. The strategy is based on the following elements:

- government support for technology and product development, including support for a pilot plant for gas power with CO_2 capture and storage;
- investment support for full-scale gas power with CO_2 capture and storage from 2006 onward;
- initiative of a governmental funded innovation center for environmentally friendly development of gas technology;
- potential participation by government in the development and operation of an infrastructure for CO_2 including preparations for use of CO_2 for EOR and for storage.

The UK White Paper on Energy Policy published in March 2003 recognizes the need for investing in CO_2 capture and storage. Also, the UK CO_2 Capture and Storage Feasibility Study Advisory Group published its first study (September 2003). This paper is a significant step for CO_2 capture and storage in the UK—it includes recommendations for the long-term implementation of the technology in the UK.

Canada has no existing regulations or policies specific to CO_2 capture and storage. However, there are current regulations applicable to the oil and gas industry that will likely be extended and modified to become applicable to CO_2 capture and storage. Further, on 16th May 2003, Alberta announced a new royalty program to promote the development of a CO_2 enhanced oil/gas recovery industry in Alberta. The Minister of Alberta Energy has announced a maximum of CAD $15 million is being provided over 5 years in the form of royalty credits to offset up to 30% of companies' approved costs in approved CO_2 projects.

Interest in geologic sequestration in Australia is growing; the Australian Prime Minister recently stated: "the production of electricity using coal gasification and sequestration of CO_2 in geological structures appears to offer the best chance of large scale greenhouse GHG mitigation." Research and development funding continues to receive new funding. For example, the Cooperative Research Centre for Carbon Dioxide (CO_2 CRC) has been formed with government funding of AUD $11.6 million (US$8.9 million) over 4 years.

Although the United States withdrew from the Kyoto Protocol negotiations, the US is strongly encouraging its industries to commit to voluntary levels of greenhouse gas emissions reductions. As part of the US initiative, the "1605(b)" voluntary registry program is currently being revised. The proposed revisions to the 1605(b) program would allow companies and organizations to report and register emissions reductions. As one part of its Technical Guidelines, the US Department of Energy (DOE) plans to publish guidelines

to encourage and guide industry in establishing monitoring and verification processes for CO_2 injection and geologic storage.[11]

In general, at a domestic level, regulations developed for protection of aquifers and development of oil and gas and mining facilities apply to CO_2 capture and storage. The relevance of these existing regulations to CO_2 capture and storage has been studied (e.g. Netherlands, Denmark) but is only starting to be applied to CO_2 capture and storage. Laws and regulations already applicable to oil and gas production, pipelines, enhanced oil and gas recovery will likely be extended and modified to cover future deployment of CO_2 capture and storage in Canada, Denmark, Netherlands, and the US.

At the international level, there are two significant multilateral initiatives that will play important roles in shaping policy development. They are:

- Intergovernmental Panel on Climate Change's (IPCC) Special Report on CO_2 Capture and Storage.
- Intergovernmental Panel on Climate Change (CSLF).

The first initiative is a special report to be prepared by experts from industry, academia, national research institutions, consultancies, governments, and environmental groups in the area of CO_2 capture and storage. The report will be produced as the work product of IPCC Working Group III and is scheduled to be completed in 2005. The experts have already identified the lack of consistent criteria for establishing a tonne of CO_2 in a geologic structure as one major issue to be addressed in the report. The technical criteria, principles, technology development status, and cost assessments to be examined in the report will be relevant for policy and regulatory developments.

The second initiative was launched in June 2003 by the United States to begin a forum for information exchange and potential collaborations on CO_2 capture and storage projects between nations. Sixteen nations, including the European Commission signing on as an individual entity, have signed the charter of the CSLF. The members are: Australia, Brazil, Canada, China, Colombia, European Commission, Germany, India, Italy, Japan, Mexico, Norway, Russia, South Africa, United Kingdom, and the United States. A second meeting was held from 20 to 22 January 2004 to begin preparations of:

- project selection guidelines;
- scoping a legal, regulatory, and financial issues paper to survey the state of such developments among the members.

A third meeting is being planned at the ministerial level for September 2003, where major announcements on the progress of the CSLF would be made.

Public Awareness is Low to Non-existent. Some NGOs will Likely Play a Key Role in the Public Acceptance of the CO_2 Capture and Storage Technology

Attitudes of informed NGOs and the general public may be critical to determining the future acceptance of the technology. At this time, public awareness of CO_2 capture and storage is very low in all countries covered by the P&I Team. It is not possible on the basis of the preliminary work done by the team to assess how the public will react to a large-scale deployment of the technology.

NGOs in general have a negative outlook on the issue,[12] as they believe that CO_2 storage will extend the usage of fossil fuels and divert resources from the development of renewable energy and the eventual emergence of an ideal energy future (e.g. hydrogen economy). However, some NGOs are developing a more positive opinion on carbon capture and storage, realizing that a transition phase is likely to be

[11] Sarah Forbes and Melissa Chan, US DOE's National Energy Technology Laboratory, private communications with Arthur Lee, 3rd September 2003. At this writing, the US DOE plans to publish the Technical Guidelines in June 2004.

[12] The CO_2 Capture Project conducted a survey of NGOs' attitudes and opinions towards CO_2 capture and storage in 2001, followed by two workshops. It concluded that NGOs did not exhibit positive attitudes towards CO_2 capture and storage, although most groups took an open attitude.

needed before renewable energy can become more cost-effective and widely implemented. Further, some now realize the importance of CO_2 capture and storage as an enabler to the emergence of a hydrogen economy.

Howard Herzog and Tim Curry of the MIT Laboratory for Energy and the Environment have shared the preliminary results of an ongoing study entitled *Public Survey of Opinions on Carbon Capture and Storage* with the CO_2 Capture Project's P&I Team. The report essentially concludes that public awareness of CO_2 capture and storage technology is low to non-existent; therefore gaining public acceptance will be a very steep uphill effort.

Figure 4 illustrates the limited public understanding of the benefits of "carbon capture and storage". When asked whether "carbon sequestration" or carbon capture and storage can reduce each of the environmental concerns listed, the survey shows that most of the public neither understand nor clearly distinguish which environmental issue carbon capture and storage helps to mitigate. The survey was conducted in the United States across a demographically diverse group of about 1200 respondents. There is no reason to believe that the situation in Europe or other countries is different from the results shown in the US study.

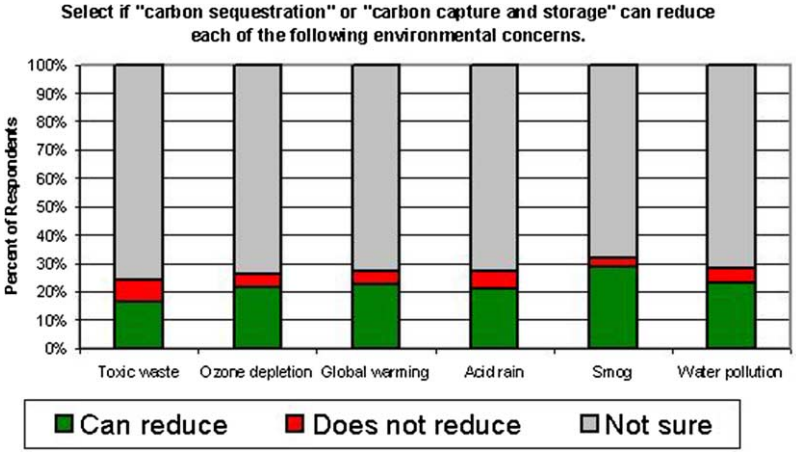

Figure 4: Public awareness of "Carbon Capture and Storage" is low to non-existent.

The CO_2 Capture Project's P&I Team is aware that attitudes and opinions will develop as more information on the technology becomes available. Therefore, developers of CO_2 capture and storage technology face significant challenges of communication and outreach. CO_2 capture and storage technology experts and developers will need to demonstrate and explain to governments, the public and the NGOs that the technology is expected to be safe and will play a necessary role in a transition to a hydrogen economy.

Existing and Emerging Financial Incentives in Australia, Canada, the European Union, Denmark, Germany, Italy, Netherlands, Norway, the United Kingdom, and the United States are Focused Principally on Research and Development. Such Incentives are Needed to Improve the Cost-Effectiveness for Deploying CO_2 Capture and Storage Technology

Existing and emerging financial incentives in Australia, Canada, the European Union, Denmark, Germany, Italy, Netherlands, Norway, the United Kingdom, and the United States are focused principally on research and development. In general, where there is a firm position that technology plays and will continue to play a vital role in practical climate protection and a clear momentum for developing CO_2 capture and storage, governments are providing the incentives to encourage such development.

European Union
In very broad terms, financial incentives in the EU will continue. As an update to the 2003 budget €25 million (US$31 million) will have been added to the existing EU budget €30 million to date (US$37 million) for three or four additional R&D projects on CO_2 capture and storage.

In addition to the budget increase, there are several ongoing funding programs for R&D under the EU's Sixth Framework Programme (FP 6) for Research and Technological Development that may be applied to CO_2 capture and storage. The FP6 Programme is intended to run from 2002 to 2006 and is worth €17.5 billion (US$21.7 billion) to be invested in seven key research areas: genomics and biotechnology for health; information society technologies; nanotechnologies and nanosciences; aeronautics and space; food safety; sustainable development; and economic and social sciences. The intent of the program has relevance for CO_2 capture and storage. The aim "…[is to] have a priority for medium to long term energy research on CO_2 disposal associated with cleaner fossil fuel power plants" and will look to foster cooperation between Member States on the issue. However, it should be noted that there are still no specific funding allocations for CO_2 capture and storage under FP 6.[13]

Denmark
The Danish Government has yet to articulate a clear policy on CO_2 capture and storage, and has not introduced any fiscal/regulatory incentives on the issue. At present, the Government is participating in IPCC and European Union discussions on CO_2 capture and storage, and is likely to support the use of the technology as a CO_2 reduction measure, but so far has adopted a "wait-and-see" policy rather than taking a proactive stance on the issue.

The Danish Government's "Proposal for a Climate Strategy for Denmark" states that more investment is needed in CO_2 capture and storage technology and that the technology is currently too expensive to implement. According to the Proposal, CO_2 capture and storage technology is more expensive to implement as a mitigation option, compared to emission reduction at the source. The Government has given a cap of 120 DKK (US$20) per metric ton CO_2 for initiatives that reduce GHG emissions. The same report established that the cost to implement CO_2 capture and storage is between 60 DKK (US$10) and 310 DKK (US$51.5) per metric ton CO_2, where CO_2 capture and storage is listed as an initiative with large potential.

Germany
CO_2 capture and storage historically has not been an important topic in Germany stemming from the fact that Germany has very little oil and gas production. Therefore, EOR and enhanced gas recovery (EGR) have not developed.

Recently, however, a few authorities (such as the General Parliament of the Energy Liberalization Committee, a cross party organization), have been discussing the issues surrounding CO_2 capture and geological storage in more detail. This is due to the development of several international research projects and has been elevated within several German Ministries. Some of the projects that have elevated the status of CO_2 capture and geologic storage are R&D projects of the EU commission with German partners such as a "CO_2 SINK" funding proposal €8.7 million (US$10.7 million) over 5 years supported by the 6th R&D Framework Programme and the IEA Zero Emission Technology Strategy where Germany is a member of the Working Party on Fossil Fuels. CO_2 SINK is a project focusing on CO_2 sequestration, and the project has been accepted by the EC. "CASTOR" is a project focusing on CO_2 capture in power plants, "COORETEC" is a project with the concept aiming to improve the efficiency of steam cycle power plants or gas turbines, development of new power plants processes and other similar operations. The COORETEC concept will be funded with €15 million (US$19 million) annually by the Federal Government and an additional €15 million (US$19 million) is expected to be funded by industry.[14]

[13] At the time of this writing in January 2004.
[14] At the time of writing, however, it is not possible to assign any amount of these funds to CO_2 capture and storage.

Netherlands
CO_2 capture and storage is regarded as part of the long-term solution by the government of Netherlands and is viewed as a transition mechanism in the process towards a sustainable society where there is a focus on energy efficiency and renewable energy.

To facilitate this vision, a number of CO_2 capture and storage R&D and pilot projects have been funded through government programs, with increasing EU financial assistance, where a principal driver is a new Electricity Act that came into force on 1st July 2003. Current drafts of the Act suggest that a tax exemption worth approximately €25–40 million (US$31–50 million) in the first year and increasing every year by between €25 and 30 million (US$31–37 million) will be established to support renewables, energy efficiency and climate neutral electricity, including CO_2 capture and storage.

Italy
In Italy, CO_2 capture and storage is viewed as a significant opportunity for industry to achieve GHG emissions reductions. In particular, there is interest in developing CO_2 capture and storage and applying it to deep saline aquifers, depleted oil and gas fields, and geothermal fields. Thus, the technologies associated with CO_2 capture and storage are one among the key R&D activities captured in the priority theme "New Technologies for Energy Generation and Management" of the Public National Plan that provides about €90 million (US$112 million) of government funding.

In addition to the above, other incentives may emerge from the "Fund for R&D on the Electricity System" with funding derived from electricity tariffs ($<$c€0.052 kW^{-1} h^{-1}) ($<$0.065 cents US kW^{-1} h^{-1}). As part of the tariffs program, the Ministry of Productive Activities will ask for demonstration projects in the field of new technologies for power generation.

United Kingdom
There is a clear momentum towards giving the area of CO_2 capture and geological storage serious consideration in the UK as a longer term means of reaching the Government's target of a 60% reduction in greenhouse gas emissions by 2050. The recent UK Energy White Paper recognized the strategic importance of CO_2 capture and storage technology as a potentially valuable contribution to the achievement of the reduction target. Therefore, research and development is currently being carried out to assess whether CO_2 capture and storage projects are feasible in the UK context. Financial support for R&D on capture and storage is also under consideration by DTI.

There are several small grants available from the Tyndall Centre (University of East Anglia) and the Carbon Trust. However, additional funding is being restrained until the EU makes a decision as to whether some funding would constitute State Aid, which is prohibited.

The Tyndall Centre has funds set aside to support young climate change research students at the beginning of their research careers as well as funding available for established international researchers who wish to work alongside Tyndall research teams on short-term research projects. The Tyndall Centre will fund, on a competitive basis, climate change research led by researchers based at UK research institutions outside the Tyndall Centre consortium. These funds, when compared to those of the CO_2 Capture Project are quite small in nature.

The Carbon Trust's total funding amounts to approximately £50 million (US$85 million) a year in grants from the Department for Environment, Food and Rural Affairs (Defra), the Scottish Executive, the National Assembly for Wales and Invest Northern Ireland. In addition, the Carbon Trust promotes the Government's energy efficiency Enhanced Capital Allowances scheme which could be worth up to £150 million (US$255 million) per annum, depending on take-up.[15]

[15] Carbon Trust's 2002/2003 Report, http://www.thecarbontrust.co.uk.

Australia
The level of interest in CO_2 storage in Australia will depend upon the degree to which carbon and carbon emissions are regulated. The Australian Government has made clear that it does not intend to ratify the Kyoto Protocol, though the nation is committed to achieving the target of reduction negotiated by Australia in the Kyoto Protocol. In January 2004, the Australian Greenhouse Office (AGO) officially stopped any development of a national emissions trading system.

At present, there are a number of financial incentives for CO_2 emissions reductions, at both the Commonwealth and State Government levels that may be applicable to CO_2 capture and storage. Existing Commonwealth incentives that may apply to CCS include the Greenhouse Gas Abatement Program (GGAP), which funds selected projects.[16]

In the 2003 Australian Budget, AUD $11.6 million (US$8.7 million) of new funding to be allocated over a 4-year period is still intact. The intent of this funding is to identify specific sites and implement demonstration projects for geologic sequestration of CO_2, through a special CO_2 CRC under the Department of Industry, Science and Resources.

Canada
There is significant interest in the issue of CO_2 capture and geological storage at the Canadian federal and provincial level (particularly in Alberta and Saskatchewan). CO_2 capture and storage is expected to become an important part of Canada's Climate Change portfolio of mitigation options.

The development of CO_2 capture and storage technology is likely to commence with the use of EOR, and progress to enhanced coal bed methane recovery, as the technology develops and CO_2 capture costs are reduced.

To facilitate technology development, a number of programs aimed at supporting the development of CO_2 capture, geological storage R&D, pilot tests, and demonstration projects are available both at the federal and provincial level in Canada, for example:

- Sustainable Development Technology Canada (SDTC) has CAD $100 million (US$77 million) targeted towards developing CO_2 emissions reductions technologies.
- Action Plan 2000, allocated CAD $15 million (US$11.5 million) to the Pilot Emissions Removals, Reductions and Learning Initiative (PERRL) administered through Environment Canada.
- Natural Resources Canada, has developed the NRCan initiative. CAD$25 million (US$19 million) is available for the development of private sector's CO_2 initiatives, essentially, CO_2 capture and geological storage. NRCan also developed an Incentive Programme aiming to fund new capture and storage demonstration projects, which will run in parallel to the Alberta CO_2 Project Royalty Credit Program discussed below.

CO_2 project royalty credit program in Alberta. This is a new royalty program intended to promote the development of a CO_2 enhanced oil/gas recovery industry in Alberta. In May 2003, the Alberta Minister of Energy announced that a maximum of CAD $15 million would be provided over 5 years in the form of royalty credits to offset up to 30% of companies' costs in approved CO_2 projects, whereby a maximum of CAD $5 million in credits may be applied to a single project. Further, the Alberta DOE is also revising royalty deductions available under the Enhanced Recovery of Oil Royalty Reduction Regulation.

Norway
The Norwegian Government places a lot of importance on the use of CO_2 capture and storage technology, as a means to curb CO_2 emissions. A primary tool for driving this development is the existing CO_2 taxes (offshore natural gas and fuel oil) which is equivalent to approximately €34.8 per tonne CO_2 (US$40); the CO_2 tax in transport (gasoline) is similar to offshore (about €34 per tonne CO_2) (about US$42 per tonne CO_2); for mineral oils it is generally €22 (US$25) with exemptions and special rates for some.

[16] Noteworthy is the fact that at the time of writing, neither capture nor geological storage projects have been funded under GGAP. The GGAP program is administered by the AGO.

Existing regulations state that CO_2 stored in geological structures is exempt from the Norwegian CO_2 tax and thus presents an incentive for CO_2 capture and storage.

Programs such as the 1997 KLIMATEK program established through the Research Council of Norway, a 5-year US$70 million Norwegian National Technology Programme aimed at promoting technology development for reducing greenhouse gas emissions. For Norway, this is an example of the level of importance placed upon the development of CO_2 capture and storage technology.

Included in the Norwegian 2004 budget is a proposal to allocate NOK 50 million (€6 million) (US$7 million) for an "increased commitment" to research related to carbon sequestration for gas-fired power plants. This includes efforts on CO_2 capture and storage R&D, pilot and demonstration projects.

The Government provided NOK 40 million (€4.9 million) (US$6 million) in 2003 for CO_2 capture and storage, a compromise from the initial budget proposal which suffered major cutbacks during the period of budget negotiations.

United States
In February 2003, President George W. Bush announced the Climate VISION program, an initiative which supports the goal of reducing greenhouse gas emissions intensity by 18% over from 2002 to 2012 without sacrificing economic growth. The initiative encourages industry to take voluntary actions using available, cost-effective technologies and best practices to reduce greenhouse gas emissions intensity.

The US DOE has been tasked with developing and implementing a strategy to achieve the President's objectives. The DOE approach involves technology development and mitigation strategies to: (1) create more energy efficient systems and (2) capture and sequester CO_2 and other greenhouse gases.

The DOE strategy builds upon the existing Carbon Sequestration Program, which has been in place since 1997, presently housed within the DOE's Office of Fossil Energy. The Office of Fossil Energy has overall responsibility for geologic sequestration programs.

While the injection of CO_2 for EOR is a well-established practice in oil-producing states, regulations are in place in all oil-producing states for CO_2 used in EOR projects under individual state and/or federal underground injection control (UIC) programs. At this time, CO_2 injection into geologic repositories for reduction of atmospheric greenhouse gases does not have widespread acceptance as an economically viable alternative. This is highlighted by the fact that there are no significant financial incentives, such as tax benefits or subsidies, at the state and federal levels for industry to undertake CO_2 capture and storage in commercial projects.

Prior to 2004, there are a limited number of state-funded and/or federally funded research grants specifically earmarked for developing and deploying CO_2 sequestration projects in the United States. Included among these are several small pilot programs funded largely by the US DOE. The CO_2 Capture Project is a recipient of such funding.

There are increases in the 2004 budget for sequestration research and development, the Administration has sent a clear signal that it intends to fund and pursue this area of technology development. The budget includes funding of USD $62 million (an increase of US$18 million over 2003) to the capture and storage of CO_2 emissions. This covers the funding of R&D and demonstration projects. Of the US$62 million, the focus area for carbon sequestration science will see a slight decrease from the 2003 budget.

CO_2 Capture and Storage Technology is Becoming Recognized and Credited in some Regulatory Regimes, Though it is not Yet Widely Recognized Nor Credited. A Monitoring and Verification Framework is Needed to Achieve Wide Recognition and Crediting
The assessment of the CO_2 Capture Project's P&I Team is that emission reduction from geological storage of CO_2 will likely be creditable in monitoring and reporting systems related to the European Union's Emission Trading System. This assessment is based on preliminary national guidelines, while more

permanent guidelines will likely follow the publication of the IPCC special report on the topic, which should have significant influence on how the EU and the UNFCCC processes develop. At this time, CO_2 capture and storage technology is not yet generally recognized nor credited in a regulatory framework except in Norway, where CO_2 produced from the Sleipner field and injected into the Utsira formation in the North Sea is not included as a part of the reported emissions from Norway. Such a volume of CO_2 is also excluded from the Norwegian CO_2 tax. Further, such emission reductions have been accepted as part of the national inventory reported to the United Nations Framework Convention on Climate Change by Norway. This CO_2 would otherwise have been vented.

At the same time, most European officials interviewed by ERM abstained from giving a formal opinion on the issue of whether CO_2 capture and geological storage will be included and creditable in the EU implementation of the Kyoto mechanisms. In the Netherlands, the Ministry believes that CO_2 capture and storage should be eligible for trading at the EU level and internationally, and that without this the technology will not become fully viable. In all the countries reviewed, the international treatment of CO_2 capture in relation to the Kyoto mechanisms is recognized as a key issue. In the United Kingdom, no decision has yet been made on how CO_2 capture and storage technology will be treated under the Climate Change Levy and the broader Emission Trading Scheme, though the UK government is generally quite favorable to CO_2 capture and storage technology.

The European Commission's Directorate General of Environment (EC DG Environment) is currently developing implementation guidelines for monitoring and reporting requirements under the EU Emissions Trading Directive. These guidelines will include a paragraph specific to CO_2 capture and geological storage. It is expected that the use of CO_2 capture and geological storage will be accepted by the guidelines to the EU ETS. This conclusion has been made following a number of informal discussions with members of the UK Department of Trade and Industry and Department of Environment Food and Rural Affairs. The P&I Team has come to a similar conclusion based on information received from the Government of Norway.[17]

It is interesting to note that European officials interviewed by ERM did not stress monitoring and verification issues, even though reliable monitoring and reporting of carbon captured, transported and stored is likely to be very important to the technical operation, crediting and public acceptance of the practice. The inference is, therefore, that monitoring and reporting issues are not seen to pose significant barriers, even though details remain to be decided.

Workshop of Policy Issues Outlined a Vision of Success, the Factors, and the Broad Steps Necessary to Advance Policy and Incentives Development for CO_2 Capture and Storage Technology deployment

On 17th October 2002, the P&I Team organized a one-day workshop to discuss policy issues with 29 policy experts from governments, companies, academia, and consulting firms. Experts came from the Netherlands, United Kingdom, Denmark, Sweden, Germany, Australia, the US, Norway, and the European Commission. The types of participating companies were primarily oil and gas companies, one electric power company, and one representative from the electricity services association of Australia. The workshop was held under

[17] This information was communicated to Frede Cappelen from the Government of Norway. The relevant wording from the EU emissions trading system draft monitoring regulation is quoted as follows:

> 4.2.2.1.3 *CO_2 capture and storage*. The Commission is stimulating research into the capture and storage of CO_2. This research will be important for the development and adoption of guidelines on the monitoring and reporting of CO_2 capture and storage, where covered under the Directive, in accordance with the procedure referred to in Article 23(2) of the Directive. Such guidelines will take into account the methodologies developed under the UNFCCC. Member States interested in the development of such guidelines are invited to submit their research findings to the Commission in order to promote the timely adoption of such guidelines. Before such guidelines are adopted, Member States may submit to the Commission interim guidelines for the monitoring and reporting of the capture and storage of CO_2 where covered under the Directive. Subject to the approval of the Commission, in accordance with the procedures referred to in Article 23(2) of the Directive, the capture and storage of CO_2 may be subtracted from the calculated level of emissions from installations covered under the Directive in accordance with those interim guidelines.

Chatham House rules, which means no quotes would be made unless permitted. All results from the discussion are deemed to result collectively from the range of discussion reflecting the range of views of the participants. "We" refers to the collective sense of the participants.

Although it was not intended to be a detailed planning session on how to get from "where we are" to "where we want to be" in terms of technology and policy development for CO_2 capture and storage, the participants did come to a consistent view towards the following in terms of a "gap" analysis, that is, the factors that would bridge the gap from the current state to the desired state.

Vision of Success. We will be successful if we gain public and regulatory acceptance of CO_2 capture and storage technology and that the technology can be economically applied.

Factors to Success. We will be successful if the following happen:

- Carbon markets (including Clean Development Mechanism/Joint Implementation) recognize and accept credits from CO_2 capture and storage projects.
- We are able to describe the pros and cons of monitoring, and the risk factors of developing technologies.
- CO_2 capture and storage technology is demonstrated through two demonstration sites within different time frames, with cost/risk curves being validated by the projects' experience.

CONCLUSIONS

Members of the CO_2 Capture Project realized from the beginning of the project the reality of interdependency between technology and policy developments. The P&I Team was formed to provide information and advice to the CO_2 Capture Project's Executive Board on national and global policies, regulations and legislation, incentives and any other external developments that may impact or benefit the technology program being developed by the CO_2 Capture Project. The team completed a survey of existing policies and incentives and their potential future development and initiated a preliminary "gap analysis" to understand what the current state is and what would be desirable in terms of policy development that would favorably impact the development and deployment of CO_2 capture and storage.

The key vision of success continues to be gaining public and regulatory acceptance of CO_2 capture and storage technology and that the technology can be applied safely and cost effectively. Interpretation of international treaties such as the London Convention and the OSPAR Convention already raise significant issues that need to be clarified in order to understand their applicability to the deployment of CO_2 storage in offshore geologic structures. The key issue of whether to treat CO_2 as a waste needs to be resolved, which would affect the applicability of the London, the OSPAR, and the EU Water Framework Directive. Currently, public awareness is low to non-existent, posing a significant challenge for eventual public acceptance if the technology is to be widely deployed. More work in these policy and public outreach efforts will have to be done by future collaborations and commercial projects aiming to develop and deploy CO_2 capture and technology. Further, future projects should develop and adopt monitoring and verification frameworks appropriate for public and regulatory acceptance.