# The Norwegian CO2–Infrastructure Initiative: The Economics and Socio-Economics of using CO2 for Enhanced Oil Recovery in the North Sea Basin

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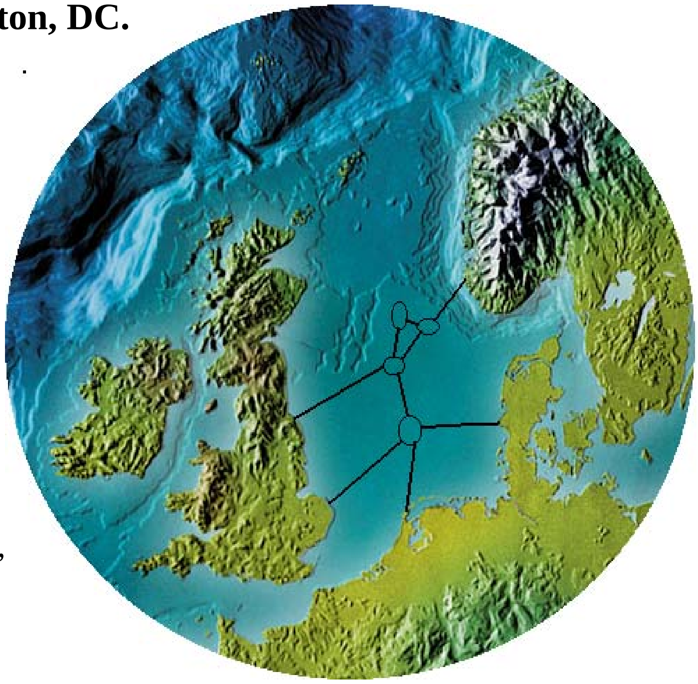


By

Carl-W. Hustad (cwh@co2.no)
CO2 - Norway AS
PO Box 592
N-3605 Kongsberg, Norway.

and

Geir Bjønnes (geir.bjonnes@bi.no)
Norwegian School of Management BI,
PO Box 580,
N-1301 Sandvika, Norway.



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**ABSTRACT**

In 1999 Norway was responsible for exporting 4.0% of oil consumed globally. Furthermore by 2005 it is anticipated that production of natural gas (NG) from the Norwegian sector of the North Sea will be around 140 billion cubic metres (bcm), which is one-third of current European consumption. However, Norwegian annual domestic consumption was in 1999 less than 4 bcm, and there is currently only a limited commitment to develop onshore NG-related industrial activity. Yet studies suggest that these could increase the commercial value of the gas by up to eight-fold, whilst also helping with structural diversification for new industrial activities.

At the same time, Norway is also revealing unease regarding its role as a sizeable exporter of fossil fuels in combination with a growing commitment to limit greenhouse gas (GHG) emissions. However, potentially the Norwegian sector of the North Sea contains oil reservoirs and geologic aquifer structures capable of storing the equivalent of European industrial CO2-emissions for several hundred years. In this light, Norway is re-assessing its long-term industrial, energy, and technology strategy, in order to identify new business opportunities and competitive advantages which the country may have in a "carbon constrained" global economy. This paper is an overview of some of the ideas that are being considered with respect to decarbonisation of fossil fuels and carbon sequestration.

We are currently investigating the feasibility of an integrated system for capture and sequestration of carbon dioxide (CO2) in combination with enhanced oil recovery (EOR) in the North Sea. Initially, an economic model is being developed to minimise overall CO2-sequestration costs. The model considers parameters such as capital investment, technology R&D, oil reservoir characteristics, and "after-use" for existing oil facilities. We also intend to model future industrial activity, energy requirements, and CO2-mitigation from on- and offshore industrial complexes. All of these, together with fluctuating energy prices and eventual cost of using the "Kyoto-like" flexible mechanisms, will influence the commercial feasibility of a future CO2-infrastructure development. Eventually we will also extend the economic model to consider handling CO2-emissions from the industrialised regions bordering on the North Sea Basin in Northern Europe.

However, the paper also describes some of our thoughts around the issue of tackling carbon management in a more holistic manner. We comment on the main drivers: technology costs; market mechanisms (CO2-trading, fiscal incentives, legislation); international consensus; and public perceptions. Within this context we focus on some of the "longer-term" benefits associated with:

i) Potential for technology diversification.
ii) Development of "sustainable" industries.
iii) Competitive benefits attributable to possible industrial clustering.
iv) Benefits of including the <u>total</u> environmental cost in the balance-sheet
v) The implementation of constructive—but coercive—legislation and fiscal measures.
vi) Requirements for developing an *ajour* judicial framework.

All of these are socio-economic considerations which can help Norwegian industry develop a practical and commercial response to the emerging concern regarding GHG-emissions and global climate-change.

## I INTRODUCTION

Norway is a major non-OPEC oil exporting country which was in 1999 responsible for producing 4.3% of global oil consumed, of which 4.0% was exported. At the same time it is also developing natural gas (NG) reserves equivalent to one-quarter of total European reserves (BP-Amoco, 2000). Annual export of NG to the European market was in 1999 around 46 billion cubic metres (bcm)—about 11% of total European gas consumption—but this is expected to reach 80 bcm by 2005. An additional 50 bcm are currently used for enhanced oil recovery (EOR), and it is unlikely that such gas will be economically retrievable towards the end of the oil fields operational life.

By 2005 it is anticipated that total production of NG from the Norwegian sector of the North Sea will be around 140 bcm. However, the annual domestic consumption is presently less than 4 bcm, and there is currently very limited commitment to developing on-shore downstream NG-related industrial activities. There are historically some good explanations for this. First, Norwegian electricity production (around 110 TWh) is based upon hydroelectric energy. With above average rainfall during the passed three years, Norway has been a net exporter of electric power. Second, liberalisation of the North European electricity market has left electricity prices fluctuating at roughly half of that needed to justify investment in new NG-fired power plants. Analysts indicate that it may be several years before electricity prices will be level with the cost of electricity (COE) from new installations. Third, Norway wishes to abide by its commitment to the Kyoto Protocol. For this reason it has been difficult for industry to initiate and obtain permits for NG related projects—which would increase rather than decrease national greenhouse gas (GHG) emissions.

Nevertheless the question remains as to how Norway may develop a "sustainable" approach towards use of its fossil fuel resources, in what appears to be more and more evolving into a "carbon-constrained" regional economy. Within this context, we foresee the possibility of an integrated system in the North Sea for capture and sequestration of CO2—in combination with EOR. Furthermore we believe that this may eventually become cost-competitive, and an integral part of a market for trading CO2-emissions.

In developing a CO2-infrastructure Norway has some distinct competitive advantages: (i) ownership of substantial storage capacity in the form of "saline aquifers" and oil reservoirs; (ii) these are located within comparatively short distance to major European industrial emissions; (iii) considerable engineering experience from oil, gas and on-going CO2 activities; (iv) considerable practical experience with commodity trading in more (or less!) liberalised markets including, shipping, electricity, oil and gas.

This paper is an overview of some of the ideas that are being considered with respect to decarbonisation of fossil fuels and carbon sequestration. The paper is organised as follows. In the next section we present the accepted three main alternatives for carbon mitigation. Section (III) focuses specifically on the proposed CO2-Infrastructure. While in Section (IV) we introduce some socio-economic considerations regarding decarbonisation. Section (V) concludes.

## II THE ECONOMIC ALTERNATIVES FOR CARBON MITIGATION

Globally there are considered to be three viable paths towards reduced carbon emissions (US-DOE, 1999a):

i) Use available fuels more efficiently.

ii) Further promote the transfer to renewable energy sources.

iii) Remove and store the carbon from existing fossil-fuel emissions.

The answer regarding which is the best option, is probably all three. Thereby acknowledging that different countries and regions will have different requirements and means of achieving reduced GHG-emissions, whilst maintaining satisfactory economic growth and a continued raising of living standards—this being particularly important for the non-developed countries.

### The Scope for "Permanent" Storage of CO2

However, for a majority of countries it is the third option (continued use of existing fossil fuels) which may—even in the long run—be the most appropriate path that remains compatible with existing energy systems, as well as future primary energy resources (Bilger, 1999). And this would appear to be particularly true for Norway, which in addition to having considerable fossil fuel reserves also controls CO2-storage facilities equivalent to several hundred years of European CO2-emissions (Holloway, 1997).

These storage capabilities are in conjunction with depleting oil reservoirs and geologic underground structures (called "saline aquifers") located within relatively close proximity to some of the major industrial regions in northern Europe (Herzog *et al*., 2000). Potentially such natural resources and favourable geographic locality could ensure Norwegian industry a competitive advantage in developing new environmental technology for the capture and "permanent" storage of CO2.

### The Cost of CO2-Capture

However for the time being it is apparent that decarbonisation of NG using current technology is not economically viable in the "near-term". Engineering assessments show that for conventional combined-cycle power plants (CCPP) this would reduce overall plant efficiency by between 8 to 10 percentage points. The cost for capture varies from US$ 35 to 55 per tonne of CO2, equivalent to +10 to +18 mills/kWh on COE produced (Hustad, 2000a). However the total sequestration cost must also include an additional US$ 10 to 15 per tonne of CO2 for transportation and final underground injection (Wildenborg, 2000). There is considerable scope for reducing these costs in the future, but this needs to be developed within concerted RD&D efforts such as those proposed within *Vision 21* (US-DOE, 1999b), and for example the "CO2-Capture Project" currently promoted by seven of the major oil companies.

### The Kyoto Flexible Mechanisms

For the "near-term" it is important for industry to also explore the cheaper alternative paths that are emerging in the wake of the Kyoto Protocol (Knöpfel, 1999). These "Kyoto-like" mechanisms comprising *Joint Implementation* (JI), *Clean Development Mechanisms* (CDM) and *International Emissions Trading* (IET), can in combination with practical engineering measures—such as improved efficiency and fuel-switching—yield substantially lower costs for carbon mitigation (Janssen, 1999).

There are also numerous measures (within cogeneration, refineries, chemicals, transportation, power-generation, etc.) which result in GHG-reductions costing well below US$ 10 per equivalent tonne of CO2-avoided (see for example Fang *et al*., 1999). However it is still not resolved whether such projects can eventually be certified as CO2-mitigation measures, nor which GHG they may encompass, nor how one ensures legitimate conversion to saleable emission credits. These questions are still subject to considerable debate regarding international agreements to limit GHG-emissions.

Furthermore, although the role of "new-renewable" energy should not be over-estimated (in context with global energy requirements), neither should it be under-estimated. Wind power for example is certainly approaching commercial levels given favourable locations. Nor should we be forgetting that in developing countries there are still an estimated 2 billion people living without direct access to the electricity grid. Here remoteness and difficult terrain can raise connection costs to between US$ 1000 to 1500 per kW installed, thus providing some commercial incentive for implementation of smaller "new technology" units, and in particular photovoltaics (The Economist, 2000).

**The Role for CO2-Trading**

Industry is anticipating the emergence of a CO2-market and many studies emphasise the advantages of including a broad portfolio of available mechanisms (eg. Holtsmark, 1998; Parry and Toman, 2000). Such prospects are already prompting analysts and traders to develop albeit crude tools to predict the future cost of carbon mitigation (Edmonds *et al*., 1999). And incidentally running very realistic simulations (see www.gets2.org), as well as obtaining practical experience regarding the handling of a CO2-trading market (see www.bpamoco.com).

However it is still uncertain how trading will influence the market price of CO2. With anticipated emission certificates costing from US$ 5 to 15 per tonne of CO2, it is evident that it will be the market mechanisms (including traders and speculators) who will—in combination with eventual regional legislation—initially be forcing down the cost of CO2-sequestration technology.

In order to eventually become competitive with the market, technology projects should realistically in the next 5 to 8 years be focussing on attaining costs below US$ 20 per tonne of CO2-sequestered. The goal of *Vision-21* by year 2015 is considerably lower than this at US$ 10 per tonne of carbon (which is US$ 2.7 per tonne of CO2). However given the hitherto lack of emphasis to actually do anything about CO2-emissions, it may not be wholly unrealistic to have taxing cost targets at this early stage—provided we have complimentary fiscal, legislative and political incentives.

**The Economics for Enhanced Oil Recovery**

In the "near-term" the most viable route for technology cost reductions appears to be in conjunction with enhanced oil recovery (EOR). Typically with oil at US$ 25 per barrel, certain oil reservoirs can be willing to pay between US$ 14 to 18 per tonne of CO2-injected. It is also important to note that about one-third of the overall sequestration cost is associated with handling, transportation, and eventual underground re-injection (Undrum *et al*., 2000). It is for these reasons we are assessing whether "long-term" reductions in CO2-emissions may be commercially achieved by developing a CO2-infrastructure in conjunction with the storage and EOR facilities within the North Sea Basin (Hustad, 2000b).

## III AN INTEGRATED SYSTEM FOR CO2-SEQUESTRATION

Infrastructures for the supply of water, treatment of sewage, electricity distribution, and communication (such as canals, railways, roads, telephony, information technology, etc.) have contributed to the economic foundations of our commercial activities and are considered a prerequisite for economic growth. Furthermore these often typify expenditure which has evolved in a "non-optimal" manner, requiring considerable support from the taxpayer.

Inevitably, a "co-ordinated" infrastructure development requires foresight, planning, and incentives regarding the scope that society would like our industrial activities to embrace. For this reason it is often the responsibility of governments to lead—either through legislation, taxation, or direct capital investments. Such considerations would appear to be underlined by the longer-term challenges posed by climate-change and anthropogenic GHG-emissions.

### The Role of Economic Modelling

The cost benefit of an infrastructure can be assessed using an economic simulation model to optimise the net sequestration costs for CO2. Such a model is currently under development. It is based on an inventory of potential EOR activity and aquifer storage capabilities available in the North Sea region. These, in combination with the potential CO2-emissions from oil-related installations and mainland industrial activity, will form the basis for calculating CO2-sequestration costs. Furthermore we will include an economic assessment of infrastructure capital development cost, as well as CO2-capture, transportation and injection costs, which together with reservoir characteristics and profiles of incremental oil and gas production, will yield a dynamic cost estimating tool for CO2-avoidance.

### Regional Commercial Opportunities

The potential for importing CO2 from neighbouring North European countries is also being considered. Commercially this opens for the possibility of Norway exporting decarbonised "clean" fuel, and at the same time accepting payment to handle residual CO2 from industrial neighbours. Invariably if such a concept is eventually practised on a large scale, then this may have implications regarding the regional cost of CO2-mitigation. It might also influence the question of "Supplementarity" which is intended to stimulate additional measures undertaken at home by the Annex-1 countries under the Kyoto Protocol.

Needless to say, these are "long-term" project ideas and there are numerous other problems which would also need to be identified and resolved even at this early stage. We are currently just starting this process.

### Legal and Environmental Considerations

The consequences of large-scale "permanent" CO2-storage, immediately raises the question of liability, as well as implications regarding licensing, use, and future "after-use" of available blocks in the Norwegian sector of the North Sea. What happens if the CO2 starts leaking, either polluting a neighbouring oil field, or reappearing (Lindeberg, 1997; Chen *et al.*, 1999). Not only adjacent installations, but also neighbouring countries, and international operators with a vested strategic interest in the region may be affected. Here, the legal framework is very much in its infancy and needs to be considered.

### Health, Safety and Public Relations

Perhaps more dramatic are the consequences if one decides to use geological structures closer to shore, or even on land (Liu *et al.*, 1999). This could reduce costs but would also increase risk (Kruse and Tekiela, 1996). Finally we note in passing that public perception and eventual acceptance is also important, as already witnessed by some pilot projects for large-scale $CO_2$-sequestration (Kildow and Harrington, 1999).

## IV THE SOCIO-ECONOMICS OF FOSSIL FUEL DECARBONISATION

Bjønnes *et al.* (2000) considered four different socio-economic aspects from onshore NG-related industrial activities in Norway: (i) corporate level profitability; (ii) environmental effects; (iii) employment and regional effects; (iv) $CO_2$-reinjection as an emerging industrial cluster. The study describes options including power generation, methanol refining (as an alternative to gasoline), and hydrogen production. The results show that Norwegian onshore activities can be profitable on the corporate level, but that the socio-economic benefits are considerably larger.

A project is regarded as profitable in socio-economic terms when the total gains for the society exceeds the investments and costs involved. Externalities (such as health, pollution, long-term effects of climate-change, etc.) often lead to the socio-economic surplus being different from the surplus on a narrower corporate level. Emphasising the fact that the cost of carbon mitigation will be much more complex than conventional "balance-sheet" economics. In relation to GHG's we are beginning to see an acceptance to quantify our commercial activities using the "Total Net Value Added", including social, environmental, and longer-term economic benefits (Packard and Reinhardt, 2000). For these reasons we are also proposing to model a $CO_2$-infrastructure development with respect to social benefits such as alternative industrial activity (employment, export of new technology, regional development, industry clustering, etc.) and environmental improvement.

### Environmental Costs

Tol *et. al*. (1999) applied the "Open Framework" model to estimate the global marginal damages due to $CO_2$-emissions at around US$ 23 per tonne of $CO_2$. Whilst an alternative approach using the "Climate Framework for Uncertainty Negotiation and Distribution" (FUND) model is somewhat higher at US$ 38 per tonne of $CO_2$. Invariably we can at best consider these as indicators of marginal costs. To a certain extent they reflect societies concerns (or perhaps lack of concern) regarding specific issues—definitions of what to include and how to quantify it can be very subjective. However the socio-economic cost of $CO_2$-emissions is estimated to be atleast two to three times the anticipated initial trading price for $CO_2$.

### Employment and Regional Effects

Employment and regional effects will be a direct and natural consequence of the aforementioned activities. From a domestic point of view, the employment potential will depend on: (i) extent to which supplies can be obtained from domestic companies; (ii) potential employment as a result of domestic supply. In addition to the number of persons employed, the implications for improved skills and work-force competency should also be considered.

### CO2-Technology as an Emerging Industrial Cluster

A cluster is a geographically proximate group of interconnected companies and institutions in a particular field, which are inter-linked by commonality and complementarity (see Porter, 1990; Krugman and Venables, 1990). The geographic scope of a cluster can range from a single city or region (e.g. Silicon Valley) to a country or even a network of neighbouring countries. A cluster seems to have a self-enforcing effect, in that introducing one more company is not only profitable for that particular firm, but increases the value of the companies already located in the cluster. In a socio-economic context, clusters increase wages and other factor prices, and thus the real income in the region where the cluster is located. Competition, R&D investment, and pro-active government legislation, are also important for the formation of industrial clusters.

To a certain extent we have already witnessed how a carbon tax in conjunction with North Sea oil installations, of (originally) US$ 55 per tonne of CO2, stimulated Norwegian oil and engineering companies to promote activity regarding CO2-technology (see for example SACS, 2000; Hustad, 2000b). We have also observed how subsequently reducing this tax to US$ 35—primarily due to low oil prices during 1999—limited the incentive to continue with certain types of technology R&D projects.

Power plants based on zero- or low-emissions—in combination with a CO2-infrastructure—could be the foundations for a new cluster promoting Norway (and potentially Northern Europe) as a technology region for “clean” and “sustainable” energy alternatives.

Norway already has a strong technology interest in decarbonisation and sequestration (see for example Holt and Lindeberg, 1993; Holt *et al*., 1995). This in combination with near access to natural resources, government action, constructive legislation, and available investment capital for development work, are all typical ingredients which induce the growth of new clusters.

Furthermore as an important producer of fossil energy, Norway may have special interest in developing “clean” alternatives. With future CO2-trading mechanisms, the producer will inevitably pay some of the costs through lower energy prices. Thus investments in alternative technologies may also be regarded as diversification.

## V CONCLUSIONS

In this paper we have presented some ideas regarding decarbonisation of Norwegian fossil fuel reserves and sequestration of North European industrial CO2-emissions. Norway has a natural advantage for developing a CO2-infrastructure: short distance to the European market, oil reservoirs for EOR, and ownership of “saline aquifers” where substantial quantities of CO2 can be stored.

Hustad (2000b) describes a proposed feasibility study regarding commercial implementation of a CO2-infrastructure in the North Sea Basin. In the present paper we consider some broader aspects regarding socio-economic implications of such an infrastructure. Including related problem areas such as legal, safety and public perception, which will all need to be addressed, yet do not come within the conventional consideration relating to economics and engineering.

Critical factors regarding the economics of a CO2-infrastructure are: the future cost of CO2-capture and –storage; the commercial potential for EOR; the establishment of a CO2-trading market; regional regulations for GHG-mitigation. However currently available cost estimates are crude and for the time being entail considerable uncertainties.

We also present some of the socio-economic aspects regarding fossil fuel decarbonisation. Strong technology skills combined with nearby access to natural resources, and fiscal incentives are already giving rise to an industrial cluster. To maintain this development trend it is important to have constructive government legislation and public investment in a CO2-infrastructure.

Norway in particular may have special interest in developing fossil fuel decarbonisation as a "clean" alternative. With emerging future CO2-trading mechanisms, the producer will ultimately pay much of the costs through lower energy prices. In this respect investments in alternative technologies may be regarded as a sensible diversification.

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## REFERENCES

Bilger, R.W., "The Future for Energy from Combustion of Fossil Fuels", *Fifth Intern. Conf. on Technologies and Combustion for a Clean Environment*, Lisbon, Portugal, 12–15 July, 1999.

Bjønnes, G.H., Ytterhus, B. and Hardhaug, O.J., "Industrial use of Natural Gas in Norway from a Socio-Economic Perspective", *MILJØSOK / BI*, Report (in Norwegian), June, 2000.

BP-Amoco, "Statistical Review of World Energy", (available from web site http://www.bpamoco.com/worldenergy/), June 2000.

Chen, Z., Huang, G.H., Chakma, A. and Tontiwachwuthikul, P., "Environmental Risk Assessment for Aquifer Disposal of Carbon Dioxide", *Greenhouse Gas Control Technologies*, Ed. Riemer, Eliasson and Wokaun, Elsevier Science Ltd., pp.223–228, 1999.

Edmonds, J., Scott, M.J., Roop, J.M. and MacCracken, C.N., "International Emission Trading & Global Climate Change: Impacts on the Cost of Greenhouse Mitigation", *Pew Centre on Global Climate Change*, (available from web site http://www.pew.org/ ), December, 1999.

Fang, J., Zeng, T., Yang, L.I.S., Oye, K.A., Sarofim, A.D. and Beér, J.M., "Coal Utilization in Industrial Boilers in China: A Prospect for Mitigating CO2 Emission", *Greenhouse Gas Control Technologies*, Ed. Riemer, Eliasson and Wokaun, Elsevier Science Ltd., pp.665–670, 1999.

Herzog, H., Eliasson, B. and Kaarstad, O., "Capturing Greenhouse Gases", *Scientific American*, pp.72–79, February, 2000.

Holloway, S., "An Overview of the Joule II Project; The Underground Disposal of Carbon Dioxide", *Energy Conversion Management*, **38**, Suppl., pp.193–198, 1997.

Holt, T. and Lindeberg, E., "CO2 from Industrial Sources as Injection Gas in Oil Reservoirs", *Energy Conversion Management*, **34**, 9-11, pp.1189–1196, 1993.

Holt, T., Jensen J. and Lindeberg, E., "Underground Storage of CO2 in Aquifers and Oil Reservoirs", *Energy Conversion Management*, **36**, 6-9, pp.535–538, 1995.

Holtsmark, B., "From the Kyoto Protocol to the fossil fuel market – A model analysis", CICERO Working Paper No. 9, Oslo University, 1998.

Hustad, C-W., "Review over Recent Norwegian Studies Regarding Cost of Low CO2-Emission Power Plant Technology". *Fifth Intern. Conf. on Greenhouse Gas Control Technologies*, Cairns, Australia, 13–16 August, 2000a.

Hustad, C-W., "The Norwegian CO2-Infrastructure Initiative: A Feasibility Study". *Fifth Intern. Conf. on Greenhouse Gas Control Technologies*, Cairns, Australia, 13–16 August, 2000b.

Janssen, "Joint Implementation and Clean Development Mechanisms in the Natural Gas Sector", *Greenhouse Gas Control Technologies*, Ed. Riemer, Eliasson and Wokaun, Elsevier Science Ltd., pp.483–489, 1999.

Kildow, J.T. and Harrington, S.A., "Policy Protocols for Building a Partnership Between the Public and Marine Scientists: The Ocean Sequestration of CO2 Experiment", *Greenhouse Gas Control Technologies*, Ed. Riemer, Eliasson and Wokaun, Elsevier Science Ltd., pp.243–248, 1999.

Knöpfel, I, "Market-Based Implementation of Kyoto Commitments: How the Financial/Insurance Sector can Support Industry", *Greenhouse Gas Control Technologies*, Ed. Riemer, Eliasson and Wokaun, Elsevier Science Ltd., pp.463–466, 1999.

Krugman, P. and Venables, A. J. "Integration and the Competitiveness of Peripheral Industry", in Bliss, C. and de Macedo, J. (ed.), "Unity with Diversity in the European Community", CEPR/Cambridge University Press, 1990.

Kruse, H. and Tekiela, M., "Calculating the Consequences of a CO2-Pipeline Rupture", *Energy Conversion Management*, **37**, Nos. 6-8, pp.1013–1018, 1996.

Lindeberg, E., "Escape of CO2 from Aquifers", *Energy Conversion Management*, **38**, Suppl., pp.229–234, 1997.

Liu, L., Huang, G.H. and Chakma, A., "Environmental Impacts and Risks of CO2 Injection for Enhanced Oil Recovery in Western Canada", *Greenhouse Gas Control Technologies*, Ed. Riemer, Eliasson and Wokaun, Elsevier Science Ltd., pp.163–168, 1999.

Packhardt, K.O. and Reinhardt, F., "What Every Executive Needs to Know about Global Warming", *Harvard Business Review*, **78**, No.4, pp.129–135, July – August, 2000.

Parry, I.W.H. and Troman, M. "Early Emissions Reductions Programs: An Application to CO2 Policy", *Resources for the Future*, Discussion Paper 00-26, (available from web site http://www.rff.org), June 2000.

Porter, M. "The Competitive Advantage of Nations", MacMillan, 1990.

SACS, "CO2 Storage in Saline Aquifers", Session at *Fifth Intern. Conf. on Greenhouse Gas Control Technologies*, Cairns, Australia, 13–16 August, 2000.

US-DOE, "Carbon Sequestration State of the Science: A Working Paper for Roadmapping Future Carbon Sequestration R&D", *Office of Science*, (available from web site http://www.fe.doe.gov/coal_power/sequestration/), February 1999a.

US-DOE, "Vision 21 Program Plan Clean Energy Plants for the 21st Century", *Federal Energy Technology Center*, (available from web location http://www.fe.doe.gov/coal_ power/vision21/v21plan.pdf ), April 1999b.

The Economist, "The Electric Revolution", 5 – 11 August, 2000.

Tol, R., Downing, T. and Eyre, N., "The Marginal Costs of Radioactively-Active Gases", *Non-Nuclear Energy Programme*, JOULE III, EU-Report, 1999.

Undrum, H., Bolland, O. and Aarebrot, E., "Economical Assessment of Natural Gas Fired Combined Cycle Power Plant with CO2 Capture and Sequestration", *Fifth Intern. Conf. on Greenhouse Gas Control Technologies*, Cairns, Australia, 13–16 August, 2000

Wildenborg, T., "Costs of CO2 Sequestration by Underground Storage", *Greenhouse Issues*, IEA-GHG R&D Programme, No. 47, pp.2 – 4, 2000.