Global Environmental Policy
Lecture Plan

- Overview (April 8)
  - Background
  - The Road to Kyoto and Beyond
- Environmental Policy in Japan (April 15)
  - R&D policy
  - Toward Deep Reduction of GHGs
- Global Challenge towards Climate Change & Recent Topics (April 22)

Towards a Deep Reduction

Technological Options for Deep Reduction of GHG Emissions

- Improvement of energy efficiency
- Switching to lower carbon fuels, e.g. coal to natural gas
- Use of non carbon fuels, e.g. renewables, nuclear
- Enhancement of natural sinks for CO_2, e.g. forestry
- Capture and sequestration of CO_2.

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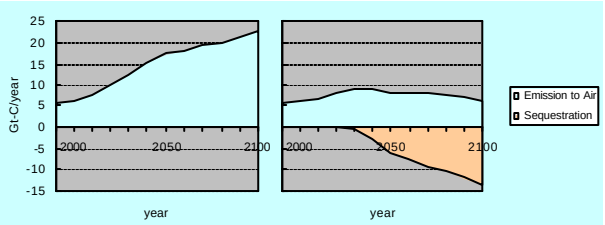
- Importance of Technology Assessment

CO_2 Sequestration May Play an Important Role

- Secondary Energy Demand: IS92a -

Reference 550ppm



CO_2 Capture and Sequestration Technologies

CO_2 Capture and Sequestration (Storage) - Status -

- Fossil fuels can be part of the energy mix
- Capture and storage of CO_2 enables deep reductions in emissions
- Cost ($40-60/t$CO_2$ avoided) is no greater than large-scale application of other deep reduction measures
- It is not expected that all fossil reserves will be exploited
- This is a transition strategy to a different energy system – it is a means of gaining time

CO_2 Capture and Sequestration - Aspects to be considered -

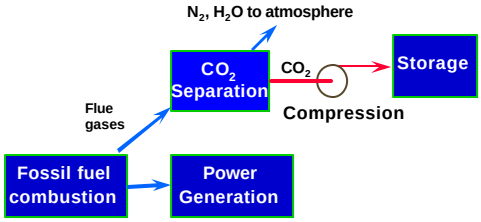
- CO_2 Capture
- CO_2 Transmission
- CO_2 Sequestration
  - Geological, Coal seam
  - Ocean
- CO_2 Utilisation
- Terrestrial sequestration

CO_2 Capture

- 3 options
  - Post-combustion capture
  - Pre-combustion decarbonisation
  - Oxyfuel combustion

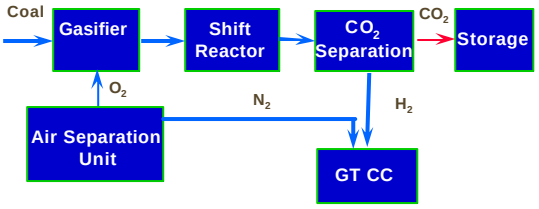
CO_2 Capture

- Post-combustion capture
  - Chemical solvent scrubbing



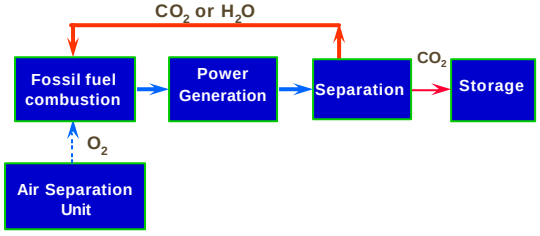
CO_2 Capture

- Pre-combustion decarbonisation
  - Physical solvent scrubbing



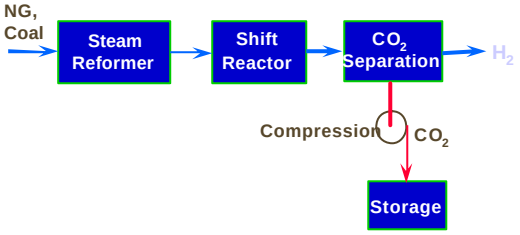
CO_2 Capture

- Oxyfuel



H_2 from Fossil Fuel

- CO_2 capture and sequestration towards hydrogen economy



CO_2 Capture

- Costs comparable with other deep reduction options
  - All 3 approaches would capture CO_2 at costs of \$30-50/t-CO_2 avoided in large scale application
  - To reduce costs further will need radical changes in approach e.g. gas turbine with CO_2 as working fluid
  - **Novel ideas needed to re-optimise the process of generating power without release of CO_2**

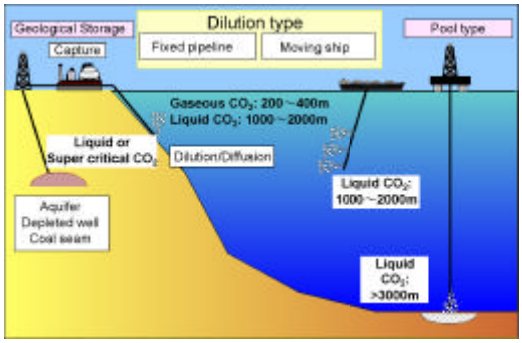
CO_2 Transmission

- Established technology
  - Areas for improvement
    - Limited
  - Action being taken
    - Industry assembling performance data on high pressure behaviour of captured CO_2

CO_2 Sequestration - Options -

- Geological
  - Depleted oil and gas fields
  - Unminable coal measures
  - Deep saline reservoirs
- Deep ocean
- Cost typically \$10/t-CO_2
  - In some cases may generate offsetting income

Concept of CO_2 sequestration



Is there sufficient capacity?

- PNNL Simulation results:
  - Total amount of CO_2 to be captured (1990 – 2095)
    - Coal-based scenario: 1230 Gt CO_2
  - Estimated reservoir capacities:
    - Deep saline reservoirs: 400 - 10000 Gt CO_2
    - Disused oil and gas fields: 920 Gt CO_2
    - Unminable coal measures: >15 Gt CO_2
    - Deep ocean: 4000 Gt CO_2

Battelle Memorial Institute Pacific Northwest National Laboratory

CO_2 Sequestration (Storage)

- All options should be considered
- Areas for improvement
  - Demonstrate CO_2 can be stored safely and securely
  - Verify amount stored (monitoring)
  - Environmental impact – demonstrate minimal leakage and other possible impacts
  - Build confidence with public and NGOs

CO_2 Capture and Sequestration

- CO_2 capture technologies exist
  - Commercial CO_2 capture technology, though expensive, exists today.
- Means must be developed to isolate this CO_2 from the atmosphere
  - The ability to sequester large quantities of CO_2 is uncertain
- Deep ocean is one of a few possible CO_2 sequestration options, so it is important that we understand as much as possible about this option.

Terrestrial sequestration

- Options
  - Afforestation, reforestation and land use changes
  - Popular
  - Allowed in Kyoto protocol
  - Significant potential in near term
  - Issue: security of storage
  - Warning: quoted costs often not on basis comparable with capture/storage

CO_2 Utilisation

- Enhanced recovery of hydrocarbons
  - Established use
  - Result = storage of CO_2
- Chemical fixation
  - More CO_2 released than stored
  - Quantities not material to solving problem
- Biological fixation
  - Vast areas of land required
  - Radical improvements needed in biology

R&D on CO_2 Sequestration

Major Research Programmes

- US DOE Carbon Sequestration Programme
- EC Fifth Framework Programme
- Canada
- Japan
- The Netherlands
- Norway - Klimatek Programme
- Australia - GEODISC Project
- Total Projected Expenditure - $60-70 million
- CO2 Capture Project - $28 million

Goal of the Research Programmes

- Studies to develop detailed scientific understanding of the technology
- Demonstration projects
- Help to build confidence in the technology
- Key ways to gain public acceptance
  - Technology Demonstration
  - Effective communication of results
  - Workshops & Dialogue

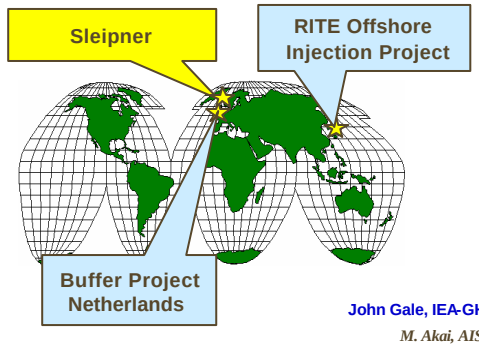
METI's Project
Geological Sequestration of CO_2

- FY2000 - FY2004
- Objectives:
  - Accumulation of the data to assure the safety of underground storage of CO_2 through a small-scale field injection test and laboratory experiments.
  - Study on the social and economic aspects of the technology.
- Small-scale liquid CO_2 injection test will be conducted at an onshore gas/oil field until 2004.

METI's Project
Study on Environmental Assessment of CO_2 Ocean Sequestration

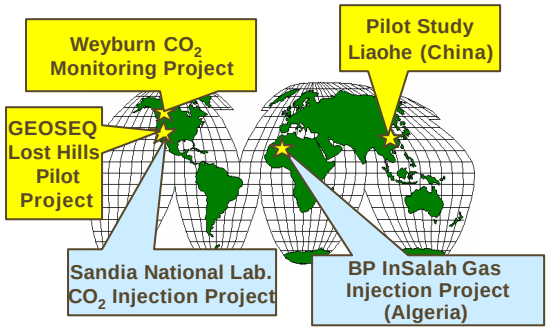
- FY1997 - 2001 (Phase-1)
- FY2002 - 2006 (Phase-2)
- Goal: Development of a generic assessment model for describing and predicting CO_2 behavior from a discharge point to the ambient open sea and the resulting biological impact.
  - to provide necessary information to formulate international understanding/agreement on the technology

Aquifer Injection Projects



John Gale, IEA-GHG

Oil & Gas Field Projects



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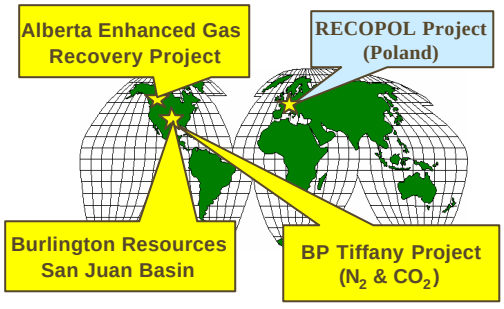
CO2-ECBM Projects



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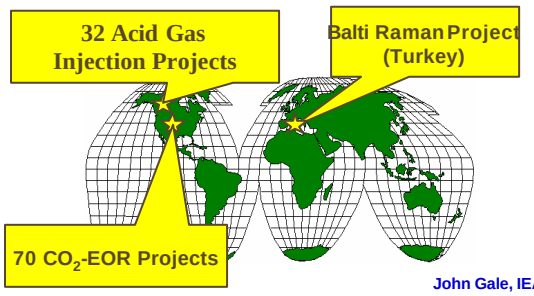
Existing Commercial Projects



John Gale, IEA-GHG

CO_2 Pipelines

Photo courtesy of Dakota Gasification

- Existing CO_2 Pipelines
  - 3100 km of pipelines
  - Transport 114 Mt/y CO_2
  - High purity CO_2 mostly
  - CO_2 transported in dense phase
  - Rated as Low Hazard
  - USDOT statistics
    - Incidents as likely as with gas pipelines
    - Impacts of failure much less significant

John Gale, IEA-GHG

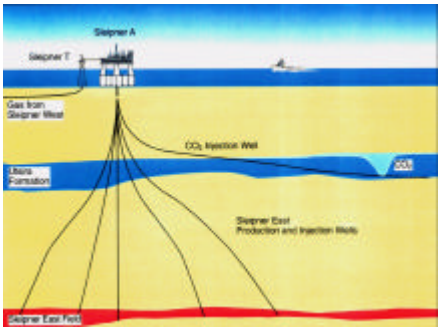
Progress in Demonstration

- Status of Projects Underway
  - Present some initial results on Sleipner & SACS Projects
  - Review status of Weyburn CO2 Monitoring Project

Sleipner Project

- First commercial scale demonstration of CO_2 capture and storage
- Project commenced in 1996
- 1 million tonnes of CO_2 injected per year
- Deep saline aquifer under the North Sea
- Statoil are the project operators

Sleipner CO_2 Storage



Courtesy of Statoil

SACS Project in Sleipner

- Saline Aquifer CO_2 Storage (SACS)
  - EC supported R&D project led by Statoil
  - Project launched after joint IEA GHG/Statoil workshop in November 1997
  - Project is monitoring the injected CO_2 in the Utsira Formation
  - Consortium of energy companies
    - BP, ExxonMobil, Norsk Hydro, TotalFinaElf and Vattenfall
  - Consortium of research groups
    - BGS, BRGM, GEUS, IFP, TNO and Sintef

SACS Project

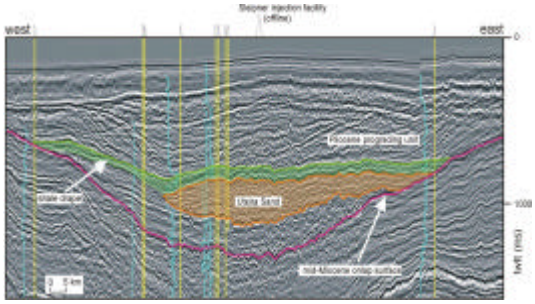
- **Project Structure**
  - Regional geology of Utsira Formation
  - Geochemical reactions with the reservoir
  - Geophysical Monitoring of injected CO2
    - Repeat seismic surveys
  - Reservoir modelling studies
- **Key Deliverable**
  - Best Practise of CO2 storage in a deep saline aquifer

The Utsira Formation

Statistics

- Area - 2.6X10^4 km^2
- Depth - 550 to 1500m
- Two depositional centres
- Slopes south to north
- Uncemented sand
- Shale stringers
- Porosity 30-40%
- Volume - 5.5X10^{11} m^3

Utsira Cross Section

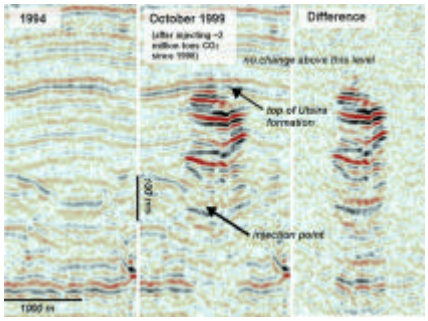


Courtesy of British Geological Survey & Schlumberger Geco-Prakla

Initial Results From SACS

- **Geochemistry Studies**
  - Reaction of CO_2 within the Utsira formation
    - Laboratory scale studies underway
    - Limited potential for CO_2 to react with calciferous minerals within the reservoir
    - CO2 unlikely to be chemically trapped
  - Reaction of CO_2 with cap rock
    - Potential to reduce cap rock integrity
    - Laboratory scale studies underway
    - Results awaited

Seismic Survey of Utsira



Courtesy of Statoil

Initial Results from SACS

- **Conclusions**
  - Geology of Utsira Formation well understood
  - Limited chemical trapping of CO_2 in reservoir
  - Injected CO_2 bubble can be monitored using seismic surveys
  - Injected CO_2 expected to spill out of trap soon
  - Migration paths within reservoir identified
  - Reservoir modelling studies able to simulate injected CO_2

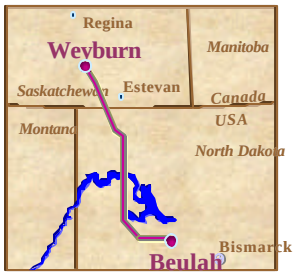
Initial Results from SACS

- Looking Forward
  - New seismic survey in September 2001
    - 5 million tonnes of CO2 injected
    - Data interpretation by early 2002
  - Best Practise Manual in 2002

Weyburn CO_2 Injection Project

- Site - Southern Saskatchewan, Canada
- Oilfield operated by PanCanadian since 1954
- Conventional and water flood enhanced recovery
- Estimated recovery of oil reserves - 35%
- CO_2 injection commenced in September 2000
- Estimated to recover additional 10-15% of OIP
- Extend field life by 25 years

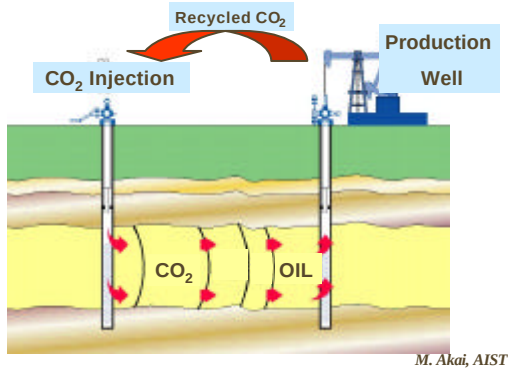
Weyburn CO_2 Pipeline



Courtesy of Dakota Gasification.

- 325 km Pipeline
  - North Dakota Gasification Plant, USA
  - Completed - September 2000
  - 5,000 t/d of CO_2
  - 40% of total capacity
  - Gas Composition
    - 97% CO_2
    - 1% H_2S

CO2 Enhanced Oil Recovery



Weyburn

Weyburn

Weyburn CO_2 Monitoring Project

- Project established in September 1999
- Monitor CO_2 storage in the Weyburn oil field
- Managed by Petroleum Technology Research Centre
- International multi-partner research programme
- Funding:
  - Canadian Federal & Provincial Governments,
  - US DOE & European Commission
  - Industrial sponsors

Weyburn CO_2 Monitoring Project

- Project Structure
  - Field data collection - PanCanadian
  - Geology - Saskatchewan Energy & Mines
  - Geochemistry - Alberta Research Council
  - CO_2 Monitoring - LBNL[1] & CSM[2].
  - Sequestration Performance -PTRC

1- Lawrence Berkeley National Laboratory

2 - Colorado School of Mines

CO_2 Monitoring

- Carboniferous reservoir
- Techniques:
  - 3D 3C Surface Seismic
  - Cross well & VSP Seismic
  - Geochemical Sampling
  - Tracer Surveys
- Contrast with SACS
  - Sandstone reservoir
  - Seismic surveying (towed array)

Progress and Status

- Weyburn Project Progress
  - CO_2 injection underway for 11 months
  - Evidence of incremental oil production
  - Only limited CO_2 response
  - Suggests oil bank forming
- CO_2 Monitoring Project Status
  - Baseline field data sampling completed
  - Pre injection seismic survey completed
  - Post injection seismic survey - autumn 2001
  - Results expected late 2001/early 2002

International Collaboration Project on CO_2 Ocean Sequestration

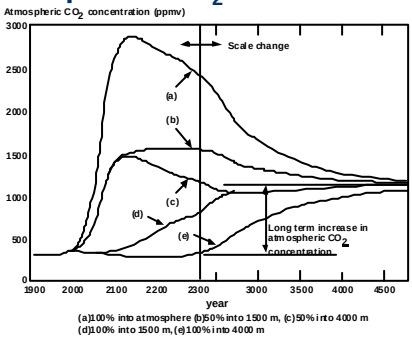
- In December 1997 an agreement was signed by Japan, Norway and the USA under the auspices of the Climate Technology Initiative under the UNFCCC
- Canada and two private sectors - ABB (Switzerland), CRIEPI (Japan) - have subsequently joined as sponsors

Ocean Sequestration - Background

- It is predicted that 80 - 85% of the CO_2 from fossil fuels will eventually be absorbed by the deep ocean, which currently contains ~38 trillion tonnes of carbon.
- CO_2 is accumulating in the air due to the slow rate of transfer between the surface and deep ocean:
  - Of the CO_2 emitted into the air today
    - 6% will be absorbed by the ocean in 1 year
    - 29% will be absorbed in 10 years
    - 59% will be absorbed in 60 years
    - 84% will be absorbed in 360 years

"Atmospheric Chemistry & Physics: from Air Pollution to Climate Change"

Ocean Sequestration and Atmospheric CO_2 Concentration



Hoffert, M.I. et al, Climatic Change, 2, 53 (1977)

Relevance of CO_2 Capture and Sequestration

- CO_2 capture and sequestration might have a important role in deep reduction of GHG emissions allowing **continuous use of fossil fuels** for the time being.
  - Technological "surprise" needed to not to rely on sequestration technologies
- However, there still remains the issues apart from their associated risk and environmental impact…

Technology and Society

- Public Communication -

Assumption

- Science is not a sanctuary
- Any act stands to receive criticism
- Work together to educate and inform the importance of the project
- Reach out in a timely fashion
- Provide clear and accurate information

Information can mitigate risk

Purpose of Public Outreach

- To obtain public trust for scientists and experiments
- To make sure environmental groups and other local stakeholders are well informed and that their concerns are heard
- To minimize the possibility of unanticipated opposition that could impede the progress of the research

Typical Lessons Learned

International Collaboration Project on CO_2 Ocean Sequestration

- Proposed Experiment in Hawaii -

Efforts

- The project committed significant project resources to a PO program which consistently reaches out to inform and involve the public.
- The effort was carefully coordinated through regular international teleconferences, usually on a bi-weekly basis, with Consultants and responsible members.
- The team responded in a timely manner to letters sent to the web-site or to the project team, and letters to the media.
- The team provided straightforward and substantive responses to concerned public, despite being scorned in letters from some opponents.
- The team adapted the experimental design as much as possible to address public concerns.

Lessons Learned
- Apotheosis of Marine Environment -

- Even the concerned researchers had been making light of the public's view that marine environmental protection is a top priority in Hawaii, especially for Native Hawaiians.

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- PO should focus locally first, being aware and responsive to local cultural and social issues.

Target Audience

- There are those individuals who, for their own personal reasons, choose to oppose the experiment.
  - These personal reasons may have nothing to do with the merits of the project, but relate to career or political aspirations.
  - For these people, no matter how much logical justification for such a project is presented to them, they will oppose it.

Inside Story
Opponents based on Personal Reasons

- On 18 May 2000, an email is received from Dr. W with his CV asking for a consulting role with the project for himself and Mr. H.
- On May 25, the Project team responds to Dr. W by asking for Mr. H's CV. Dr. W responds by saying he does not need compensation, but suggests that Mr. H be hired as a consultant to the project. Mr. H sends his CV to the project team.
- After the rejection, their activities became violent.

Lessons Learned
- Audience -

- PO can not guarantee 100% approval by the public.
  - The team should dialog with everyone, including opponents, but focus on cultivating supporters, rather than trying to convince opponents to change their mind.
- Do not waste resources to respond to those who oppose the project for their own personal reasons.
  - Some just want to manipulate our regulatory and governmental system in the hopes of receiving a payout from us.

CO_2 Sequestration Technologies
- Political Aspects -

Recognition on Carbon Sequestration in the Political Arena

- **Article 2 of the Kyoto Protocol acknowledges the importance of R&D on the technologies**
- **Received attention by IPCC TAR**
- **Recommendation by Marrakesh Accord in COP-7 for IPCC to prepare a technical report on (geological) sequestration technology**

Article 2 of the Kyoto Protocol

1. Each Party included in Annex I, in achieving its quantified emission limitation and reduction commitments under Article 3, in order to promote sustainable development, shall:

(a) Implement and/or further elaborate policies and measures in accordance with its national circumstances, such as:

……

(iv) Research on, and promotion, development and increased use of, new and renewable forms of energy, of carbon dioxide sequestration technologies and of advanced and innovative environmentally sound technologies.

Marrakesh Accord

- Invites the Intergovernmental Panel on Climate Change, in cooperation with other relevant organizations, **to prepare a technical paper on geological carbon storage technologies**, covering current information, and report on it for the consideration of the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol at its second session;

Status of IPCC Special Report on Carbon Capture and Storage

- **Decision at the 19th IPCC plenary meeting:**
  - **To hold a workshop to consider the issues associated with geological and oceanic carbon separation, capture and storage**
  - **To develop expert advice to the Panel whether to develop a Special Report or to incorporate the issue in the Fourth Assessment Report**
  - **To deliver a scoping paper, timetable and detailed outline for a Special Report, and a proposed list of authors in case the experts would recommend a Special Report**
- **Workshop (Nov. 18-22, 2002; Regina)**
- **20th IPCC Plenary Meeting (Feb. 19-21, Paris)**

IPCC Workshop on Carbon Capture and Storage

November 18-22, 2002; Regina

- **Mandate**
  - **To support a decision by the IPCC Plenary on a SR on Carbon Capture and Storage by 2005 or inclusion of this subject in the AR4 by 2007**
- **Program**
  - **Introductory Lecture**
  - **Discussion**
    - **Issues to be addressed in a Special Report**
    - **Availability of published papers by 2004**
  - **Consensus on Special Report**
  - **Preparation of documents**
    - **Draft table of contents**
    - **Scoping paper for the IPCC Plenary**

Recommendation for a Special Report - Scoping Paper -

- **CO_2 capture and storage (CCS) is an emerging technological option with a very high mitigation potential. It has been suggested that about half the world cumulative emission to 2050 may be stored at costs comparable to other mitigation options.**
- **Policymakers have a growing need for a reliable synthesis of the available scientific literature in order to facilitate the decision making process on the plans for CCS as a climate change mitigation option.**

20th IPCC Plenary Meeting

- Decision
  - IPCC Plenary has decided to prepare a Special Report on Carbon Dioxide Capture and Storage as proposed by the Scoping Paper.
- Issues to be addressed:
  - Participation of developing countries
    - To invite authors
    - To include a section on technology transfer
  - Permanence, environmental impacts and safety of both geological and ocean storage

Related Decision

REVISION OF THE "REVISED 1996 IPCC INVENTORY GUIDELINES"

COVERAGE AND METHODOLOGY DEVELOPMENT include:

- Following completion of the SR on Carbon capture and storage this issue will need to be considered in the Revised 2006 Guidelines.

Schedule

- 2003.2: Decision by IPCC Plenary
- 2003.3: Selection of authors (CLA, LA RE, etc.)
- 2003.7.2-4: 1st LA meeting (Oslo)
- 2003.12 or 2004.1: 2nd LA meeting
- 2004.6: 3rd LA meeting
- 2004.12: 4th LA meeting
- 2005: Release of Special Report

Still...

- There is no (International) Rule on how to count captured and sequestered CO_2 in national GHG inventories
- Factors to be considered:
  - Permanency (long term leak),
  - Monitoring,
  - Verification, etc.
- Also important when used as a tool for Kyoto Mechanism

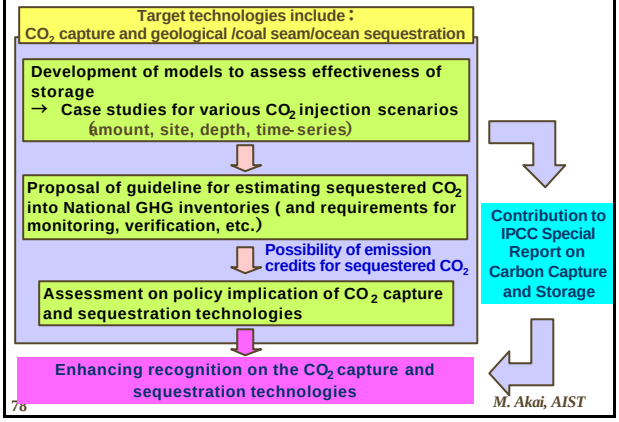
International Research Project on Global Environment

A Research Project on Accounting Rules on CO_2 Sequestration for National GHG Inventories (ARCS)

Project Duration: FY02-FY04

Contact:
Makoto Akai (m.akai@aist.go.jp)
National Institute of Advanced Industrial Science and Technology(AIST)

R&D Steps and Goals



Towards the Future

- Social acceptance for the technology
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- Conformity with regulations
  - London Convention, OSPAR, Domestic Laws, etc.
  - Action for amendment, if necessary
  Ý
- Definite recognition by IPCC and UNFCCC
  Ý
- Better communication
  - Audience: general public, scientists, industries, policy makers, NGOs, etc.
  Ý
- Accumulation of scientific knowledge

Questions?

Send e-mail to:

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