Global Environmental Policy
Lecture Plan

- May 11: Overview
  - International aspects
    - Background
    - The Road to Kyoto and Beyond
    - Recent topics
- May 18: Energy and Environmental Policies
  - Japan, US, etc.
- May 25: Challenge towards Deep GHG Reduction

Questions/Comments and Answers

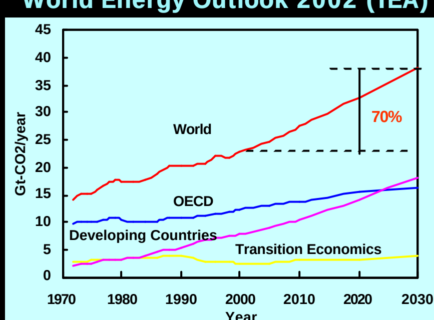
Questions/Comments - 5

- What is the implication on world economics if Russia ratify Kyoto Protocol and USA stay out?
- Some analysis using economic model indicate:
  - With paradigm change (technology, economic structure, etc.)
    - Þ Japan & EU Ý; US ß
  - Without paradigm change
    - Þ Japan ß; EU & US Ý

Questions/Comments - 5'

- What will happen if developing countries become the major CO_2 releasing countries?

Energy-Related CO_2 Emissions by Region
World Energy Outlook 2002 (IEA)



Findings - World Energy Outlook 2002

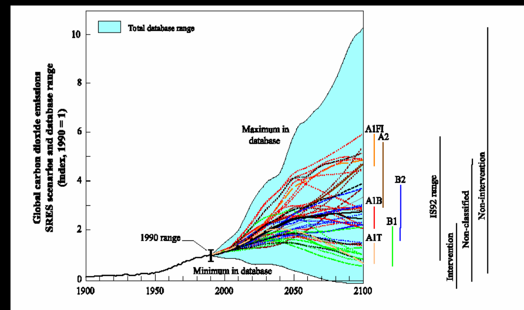
- Fossil fuels will continue to dominate the world's energy mix over the next decades.
  - Hence, even under the international climate policies, emissions of GHGs from the energy sector are expected to continue growing, reaching 38 billion tones-CO_2 by 2030.
- Emissions will shift from the industrialized countries to the developing world.
  - The developing countries' share of global emissions will jump from 34% now to 47% in 2030, while the OECD's share will drop from 55% to 43%.

Indication - World Energy Outlook 2002

Pessimistic with regard to the Kyoto target

- Emissions in those OECD countries that signed the Protocol (including US) will reach 12.5 billion tones in 2010: 2.8 billion tones (29% above the target)
- Russia, like Central and Eastern Europe, is in a very different situation, with projected emissions considerably lower than its commitments.
  - Under the Protocol, "emissions credits" can be sold to countries with emissions over their target. But this will not suffice to compensate for over-target emissions in other countries.
- Net emissions will be about 15% above targets in 2010. If US, which does not intend to ratify the Kyoto Protocol, is excluded, the gap falls to 2%.

IPCC SRES Scenario



Questions/Comments - 6

- Is it possible to achieve the GHG emission reduction;
  - To achieve Kyoto target?
    - Short term target (2008-2012)
    - Legally binding commitment, but ...
  - To a level to prevent "dangerous interference" with the climate system?
    - Longer term target - needs deep reduction

Questions/Comments - 7

- As Japanese government is unable to meet the target of the reduction of CO_2 on a per capita basis, what is the government's step to meet this target?

  → Achievement of Kyoto Target
- When Japan cannot achieve Kyoto target, how will it be punished?

  → Compliance issue common to all parties

Action Program to Arrest Global Warming

In Reality...

- The emissions of CO_2 should be stabilized on a per capita basis in the year 2000 and beyond at about the same level as in 1990

  Þ 00/90 = +7.2%
- Efforts should also be made to stabilize the total amount of CO_2 emission in the year 2000 and beyond at about the same level as in 1990

  Þ 00/90 = +10.2%

Compliance Issue

Kyoto Protocol - Article 18

The Conference of the Parties serving as the meeting of the Parties to this Protocol shall, at its first session, approve appropriate and effective procedures and mechanisms to determine and to address cases of non-compliance with the provisions of this Protocol, including through the development of an indicative list of consequences, taking into account the cause, type, degree and frequency of non-compliance. Any procedures and mechanisms under this Article entailing binding consequences shall be adopted by means of an amendment to this Protocol.

Negotiations on Non-Compliance Issue (1/4)

- At COP 4 (Buenos Aires, November 1998), Parties established a joint working group (JWG) on compliance to develop a compliance system under the Protocol, with a view to adopting a decision on this issue at COP 6 (The Hague, November 2000). The "Buenos Aires Plan of Action" adopted at COP 4 called for work on, among other things, the preparations for COP/MOP 1, including the elements of the Protocol related to compliance.

Negotiations on Non-Compliance Issue (2/4)

- At COP 6 in The Hague, however, Parties were unable to reach agreement on the package of decisions under the Buenos Aires Plan of Action. In the case of compliance, key outstanding issues included what the consequences of non-compliance should be and the membership of the Compliance Committee. As with other issues, the negotiating texts on compliance were forwarded to a resumed session of COP 6 for further consideration.

Negotiations on Non-Compliance Issue (3/4)

- At COP 6 part II, Parties adopted the Bonn Agreements on the Implementation of the Buenos Aires Plan of Action, registering political agreement on key issues, including on compliance. Parties also continued work at COP 6 part II on procedures and mechanisms relating to compliance, based on the Bonn Agreements. Although considerable progress was made, outstanding points remained and the draft decision was forwarded to COP 7 (Marrakesh, October/November 2001) for further elaboration, completion and adoption.

Negotiations on Non-Compliance Issue (4/4)

- At COP 7 (Marrakesh), Parties adopted a decision on the compliance regime for the Kyoto Protocol, which is among the most comprehensive and rigorous in the international arena. It makes up the "teeth" of the Kyoto Protocol, facilitating, promoting and enforcing adherence to the Protocol's commitments.

Marrakesh Accords (1/2)

- In the case of compliance with emission targets, Annex I Parties are granted 100 days after the expert review of their final annual emissions inventory has finished to make up any shortfall in compliance (e.g. by acquiring AAUs, CERs, ERUs or RMUs through emissions trading). If, at the end of this period, a Party's emissions are still greater than its assigned amount, it must make up the difference in the second commitment period, plus a penalty of 30%. It will also be barred from "selling" under emissions trading and, within three months, it must develop a compliance action plan detailing the action it will take to make sure that its target is met in the next commitment period.

Marrakesh Accords (2/2)

- Any Party not complying with reporting requirements must develop a similar plan and Parties that are found not to meet the criteria for participating in the mechanisms will have their eligibility withdrawn. In all cases, the Enforcement Branch will make a public declaration that the Party is in non-compliance and will also make public the consequences to be applied.

Decision in COP 7

Procedures and mechanisms relating to compliance under the Kyoto Protocol

- The Conference of the Parties,
  ....
  - *Noting* that it is the prerogative of the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol to decide on the legal form of the procedures and mechanisms relating to compliance,
- *Decides* to adopt the text containing the procedures and mechanisms relating to compliance under the Kyoto Protocol annexed hereto;
- *Recommends* that the Conference of the Parties serving as meeting of the Parties to the Kyoto Protocol, at its first session, adopt the procedures and mechanisms relating to compliance annexed hereto in terms of Article 18 of the Kyoto Protocol.

Questions/Comments - 8

- Researchers and politicians realize:
  - Kyoto mechanism does not work well after all.
  - Japanese people take a great interest in environmental problems. However, when Japan will not achieve CO_2 emission reduction, this is because many people consider economic activities are more important than environmental issues. This trend will continue in future.

  → YES
- Why they didn't make a strict rule for reduction of CO_2 emission at Kyoto?

  → Always difficult in international negotiations involving various stakeholders

Question/Comment - 8

- There are a lot of programs in Global Warming Research Initiative, but they seem not to be known to people.
- The government should announce their programs more to make people think more about the environment.

  → YES, strategic public outreach is necessary

R&D Policy on Global Warming in Japan (FY2002)

- In September 2001, the Council for Science and Technology Policy established "Promotion Strategy in Prioritized Area based on the Science and Technology Basic Plan"

ß

Global Warming Research Initiative

Above programs will be conducted in an integrated manner with the cooperation of Ministries.

Global Warming Research Initiative

- The Initiative includes the following programs (FY 2002: 219.6 billion yen)
  - Global warming monitoring program
  - Global warming prediction and climate fluctuation research program
  - Global warming effects and risk evaluation program
  - GHG fixation (sequestration) and utilization program
  - Global warming prevention policy research program
  - New & renewable energy and energy conservation technology development programs

Other Prioritized Area Relating to Environmental Problems

- R&D for zero-waste, recycling society
- R&D for restoration of ecosystems of catchment and urban area
- R&D for chemical risk management
- R&D for management of global water resources and cycle

Questions/Comments - 9

- Ongoing projects in Japan?

Energy and Environmental Policies - R&D -

United Kingdom

Key Points in UK Policy (1/2)

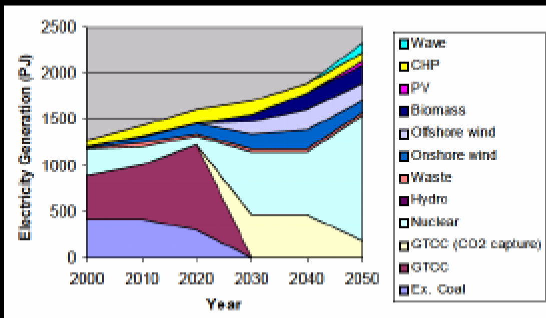
- UK Energy White Paper : environment issues at heart of Energy Policy - desire to put UK on a path to reduce CO_2 levels by 60% in 2050 (compared to 1990 levels)
- No one single winning technology; broad portfolio approach required
- Clean use of fossil fuels world-wide becoming increasingly recognized as a key transitional issue in getting to a sustainable energy future

Key Points in UK Policy (2/2)

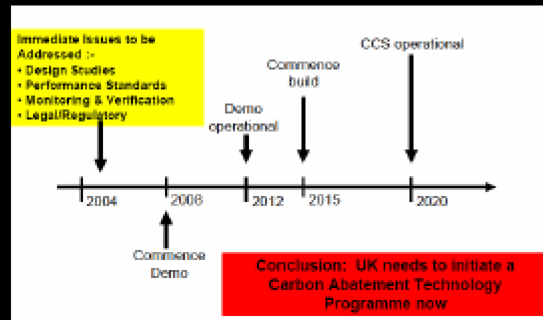
- Desire for a Carbon Abatement Strategy that includes fossil fuels
- CCS considered as one key element in such a strategy; recognized link to "hydrogen economy" needs
- International co-operation recognised as an essential element

UK Fuel Mix in Electricity Generation

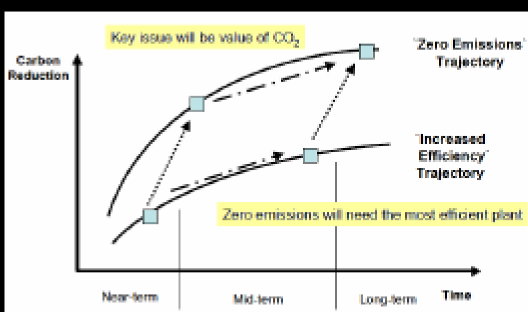
60% CO_2 Reduction in 2050 (limited Energy Efficiency)



UK Roadmap for Carbon Capture and Sequestration



UK Strategy Trajectories

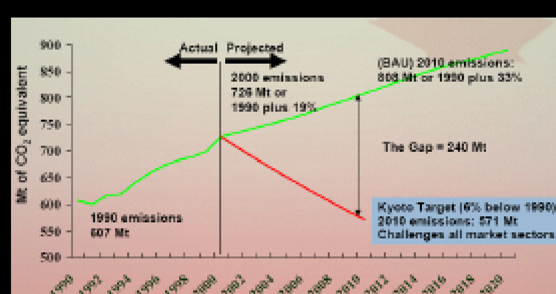


Canada

The Canadian Context

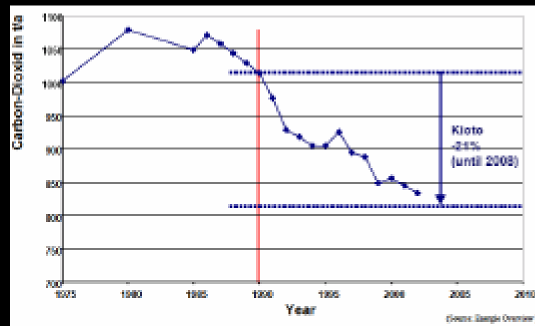
- Canadian energy policy is framed within the context of Sustainable Development
- Sustainable development – pursuit of a balanced portfolio of environmental, economic and social goals
- For energy, sustainable development aims to:
  - Reduce energy use, intensity (and carbon content), emissions
- A major driver is climate change
- CO_2 capture and storage is the natural evolution of leading Canadian initiatives in AGI and EOR in place since the 1980’s

Canada's Kyoto Challenge

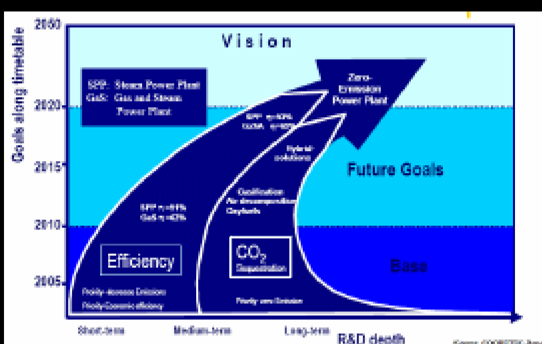


Germany

CO_2 Emissions in Germany



Emission Reduction Roadmap



Italy

GHG Emissions in Italy

- **Italy committed to reduce its total GHG emissions by 6.5% in 2008-2012 compared to 1990 levels**
  - 93 million tonnes by 2010 from the projected level in 2010 without any measures
- **Energy-related CO_2 emissions have been growing gradually and were 6.5% above the 1990 level in 2001 reaching 437 Mt-CO_2**
  - Power sector: 155 Mt-CO_2 (1/3 total)
- **Italian Carbon intensity: 0.35 kg-CO_2/$GDP in 2000 (IEA av. 0.43, EU av. 0.37)**

ß

- **Policy measures (voluntary agreements, carbon tax, regulations, international agreements, …)**
- **R&D initiatives**

Three Horses of the "Troika"

- **Energy efficiency**
- **Renewable energy**

Sometimes operate simultaneously

- **Emission free fossil fuels**

ß

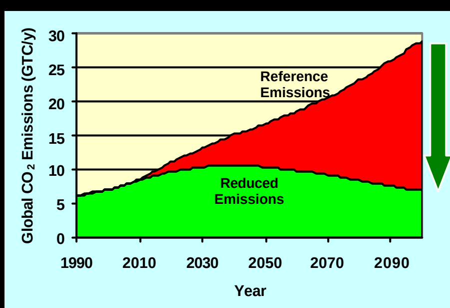
- **Carbon Capture and Storage (CCS), is a crucial issue in energy policy: as the third horse of the troika**

United States

President's Key Policy Addresses:

- June 11, 2001
  - Committed U.S. to Work Within UN Framework
  - Directed U.S.G. to Develop Flexible, Science-Based Response
  - Supported UNFCCC to Stabilize GHG Concentrations
  - Established National Climate Change Technology Initiative
  - Established Climate Change Research Initiative
- February 14, 2002
  - Reaffirmed Long-Term UNFCCC Central Goal
  - Established U.S Goal to Reduce GHG Intensity by 18% by 2012
  - Encouraged Business Challenges and Voluntary Reporting
  - Directed Improvements to the EPACT Emissions Registry
  - Supported Transferable Credits
  - Valued GHG Avoidances by Supporting Financial Incentives

Global Climate Change – The Role for DOE and New Technology



Technology Pathways

#1: Closing the Loop on Carbon
- Introduction of Carbon Sequestration and Hydrogen Technologies Augment the Standard Suite of Energy Technologies

#2: Renewables and Nuclear Succeed
- Major Technological Advances in Renewable and Hydrogen Technologies are Coupled with a New Generation of Nuclear Reactors

#3: Beyond the Standard Suite
- Dramatic Breakthroughs in "New and Advanced Technologies – e.g., Fusion, Bio-X" – Create a Fundamentally Changed Energy System

Current Climate Change Technology R&D Initiatives

- FreedomCAR
- FreedomFuel
  - Hydrogen Technology
  - Nuclear-Based Hydrogen Initiative
  - Large-Scale Hydrogen Production From Fossil Fuels
- Fuel Cell Systems
- Regional Carbon Sequestration Partnerships
- Carbon Sequestration Leadership Forum
- Nuclear Power Generation IV
- Nuclear Power 2010
- International Thermonuclear Experimental Reactor (ITER)
- National Climate Change Technology Initiative Competitive Solicitation Program

Carbon Sequestration Leadership Forum

- CSLF is an international climate change initiative that is focused on development of improved cost-effective technologies for the separation and capture of CO_2
- The purpose is to make these technologies broadly available internationally; and to identify and address wider issues relating to carbon capture and storage.
- This could include promoting the appropriate technical, political, and regulatory environments for the development of such technology.

International Partnership for the Hydrogen Economy (IPHE)

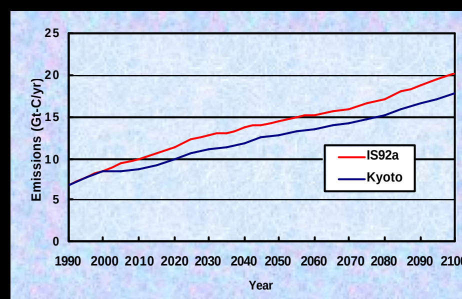
Purposes:

- To serve as a mechanism to organize and implement effective, efficient, and focused international research, development, demonstration and commercial utilization activities related to hydrogen and fuel cell technologies.
- To provide a forum for advancing policies, and common codes and standards that can accelerate the cost-effective transition to a global hydrogen economy to enhance energy security and environmental protection.

Towards a Deep Reduction

Effect of Kyoto Protocol

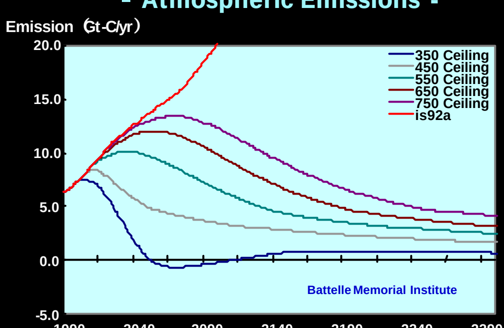
It's just an entrance to a sustainable society



(Pacific Northwest National Laboratory)

CO_2 Stabilization Profiles

- Atmospheric Emissions -



Technological Options for Deep Reduction of GHG Emissions

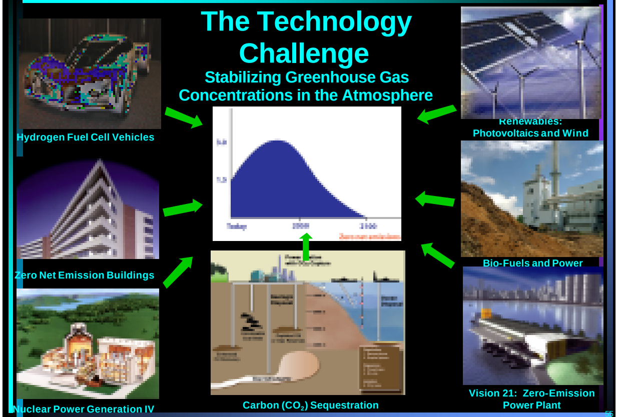
- Improvement of energy efficiency
- Switching to lower carbon fuels, e.g. coal to natural gas
- Use of non carbon fuels, e.g. renewables, nuclear
- Enhancement of natural sinks for CO_2, e.g. forestry
- Capture and sequestration of CO_2.

ß

- Importance of Technology Assessment

The Technology Challenge

Stabilizing Greenhouse Gas Concentrations in the Atmosphere

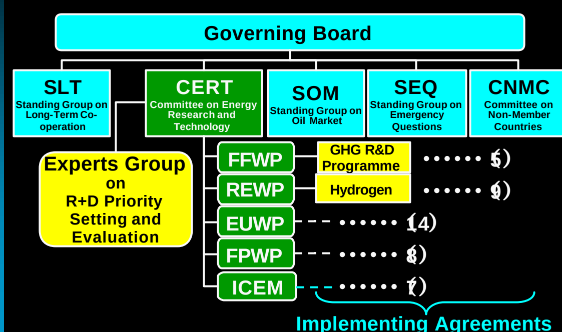


Possible Technology Areas

- Transforming Energy Supply
  - Hydrogen
  - Renewable Energy and Distributed Energy Resources
  - Nuclear Energy
  - Fossil Power Generation (ZEPP)
  - Infrastructure of the Electricity Delivery System (Energy Storage)
- Transforming Energy End-Use
  - Transportation; Buildings; Industry
- Capturing and Sequestering GHGs
  - Geological; Ocean; and Terrestrial Sequestration
- Reducing non-CO_2 Greenhouse Gas Emissions
- Measuring and Monitoring GHG Emissions
  - Measurement, Monitoring and Verification

Discussion in IEA/CERT

Structure of the International Energy Agency



Technology Book

ENERGY TECHNOLOGY: CONFRONTING THE CLIMATE CHALLENGE

SECTION I LONG-TERM VISIONS, NEAR-TERM CHOICES

1. The Challenge
   - Climate Change and Energy
   - Energy Technology: A Weapon in the Arsenal
2. Envisioning a Low-emissions Future: Which Technologies Matter?
   - A Technology Portfolio
   - Different Pathways, Same Destination
   - Robust, Enabling and Bridging Technologies
   - The Question of Timing
3. Energy Technology Policy: An Essential Element
   - Factors Working Against Rapid Technology Development
   - Factors Working Against Rapid Technology Uptake
   - Implications for Policy and Timing

SECTION II TRANSFORMING THE ENERGY SYSTEM: TECHNOLOGIES FOR DRAMATICALLY-REDUCED EMISSIONS

4. Introduction: Transforming the Energy System
5. Transforming Energy Supply
   - Hydrogen
   - Fuel Cells
   - Renewable Energy
   - Nuclear Fission Energy; Fusion Energy
   - Improved Fossil Power Generation
   - Integrated Energy Systems
   - Fossil Energy Resources
   - Electricity System Infrastructure
6. Transforming Energy Use
   - Transport; Buildings and Services; Industry
7. Separating, Capturing and Storing CO_2
8. Reducing Non-CO_2 Greenhouse Gas Emissions

Transition of Hydrogen Technology - Current Technology -

- Production
  - Hydrogen is produced in large centralised facilities, primarily by the reforming of natural gas. High-purity hydrogen is produced for on-site use by water electrolysis.
- Use
  - Hydrogen is used primarily as a chemical to produce industrial commodities, such as reformulated gasoline, ammonia for fertiliser and food products. A limited number of hydrogen fuel cells are also used for grid backup and for premium power applications. Hydrogen is also used in the U.S. Space Program.

Transition of Hydrogen Technology - 2000-2030 -

- Production
  - Hydrogen is produced primarily by steam reforming of natural gas, either at central or distributed facilities. Advanced reforming technologies present an opportunity to decrease the amount of GHG emissions to the atmosphere–the byproduct from the reforming process could be collected and sequestered. Hydrogen from renewables-powered electrolysis will constitute a growing renewable component of the hydrogen production market.
- Use
  - Hydrogen provides the fuel for fuel cell powered vehicle fleets at a central fuelling station. Hydrogen is added to natural gas-powered internal combustion engines to increase performance and decrease pollution. Restructuring of the electric utility industry presents opportunities for distributed power, where hydrogen-powered fuel cells provide on-site CHP.

Transition of Hydrogen Technology - 2030-2050 -

- Production
  - Strong hydrogen markets and a growing hydrogen infrastructure launch opportunities for renewable hydrogen systems. Energy sources such as wind turbines or photovoltaics, for example, provide the necessary power to produce hydrogen from water. This era witnesses the emergence of alternative hydrogen technologies that produce hydrogen directly from water and sunlight.
- Use
  - Hydrogen plays a large role in heating homes and offices, powering appliances and electronics, and fuelling public and private vehicles. Fuel cells use this hydrogen to power our clean transportation system and provide electricity, heating and cooling to our buildings.

Transition of Hydrogen Technology - 2050-2100 -

- Production
  - Water replaces fossil fuels as the primary resource for the energy sector. Petroleum is used only as a chemical feedstock.
- Use
  - Hydrogen offers a universal fuel form to provide the clean mobility and energy services for the world.

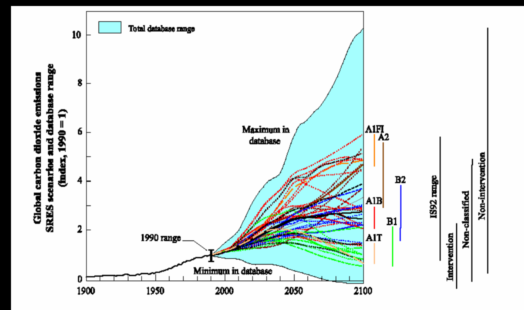
SECTION III SCIENCE: ESSENTIAL TO PROGRESS Linking Basic Research and Applied R&D

SECTION IV FROM THE LABORATORY TO THE REAL WORLD

SECTION V PULLING IT ALL TOGETHER: SUMMING UP AND TAKING ACTION

Scenario Analysis

IPCC SRES Scenario



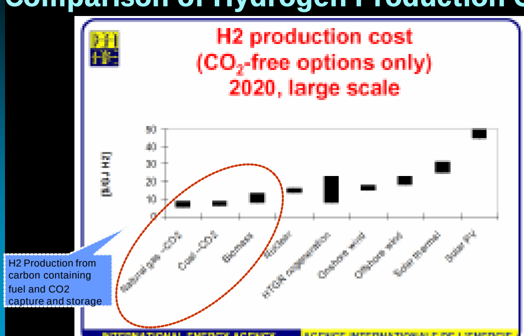
Description on Hydrogen in IPCC SRES & TAR (1/2)

- Innovative transitional strategies of using natural gas as a "bridge" towards a carbon-free hydrogen economy (**including CO_2 sequestration**) are at a premium in a possible future world with low emissions (MESSAGE-MACRO AIM, MARIA, and MiniCAM teams)
- The future electricity sector is not dominated by any single dominant technology, however, **hydrogen fuel cells are assumed to be the most promising technology** among all stabilization cases (MESSAGE-MACRO, IMAGE, and MiniCAM teams)

Description on Hydrogen in IPCC SRES & TAR (2/2)

- Biomass-derived fuels and **hydrogen production from fossil fuels with carbon sequestration** technology, in parallel with improved fuel efficiency conversion, are some of the few more promising alternatives for reducing significantly carbon emissions in the transport sector for the next two decades.
- The fuel economy of hydrogen fuel cell vehicles is projected to be 75% to 250% greater than that of conventional gasoline internal combustion engine (ICE) vehicles, depending on the drive cycle

Comparison of Hydrogen Production Cost



IEA Hydrogen Co-ordination Group (HCG) (2003.6)

Scenario Study

Global Energy Network Model

Appraisal of CO_2 Mitigation Technology

Approach

- Evaluation as a technology
  - Process evaluation for energy penalty and cost
  - Life cycle aspects of the technology
- Comparative evaluation of the technology among a resource and technology mix under CO_2 emission constraint
  - Energy Model
- Decision making
  - Cost-benefit relationship
  - Externality, etc.

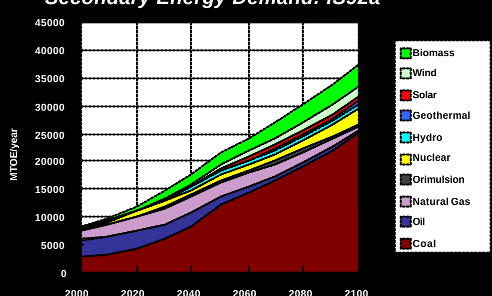
Global Energy Network Model

- Term: 1990 to 2100
- Area: Global
  - 18 world regions considering future energy demand, energy supply potential, geographical condition, etc.
- Energy technologies include:
  - Conventional energy technologies (production, transportation, power generation, etc.)
  - Hydrogen energy system
  - Global renewable energy transportation systems.
  - CO_2 mitigation technologies such as capture and sequestration
- Methodology: Optimization by LP

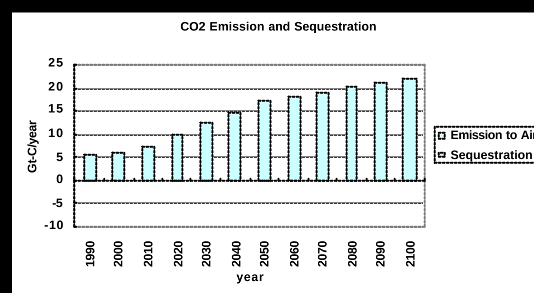
Primary Energy Supply

- 550ppm Stabilization -

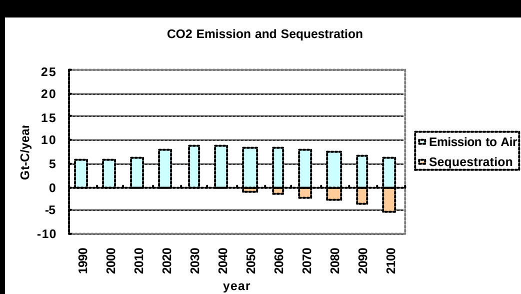
Secondary Energy Demand: IS92a



CO_2 Emission in Base Scenario (IPCC IS92d)



550ppm Stabilization and CO_2 Sequestration



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 -

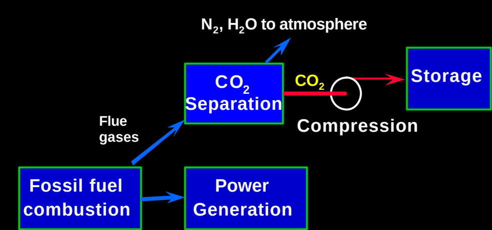
- CO_2 Capture
- CO_2 Transmission
- CO_2 Sequestration
  - Geological
  - Ocean
- CO_2 Utilisation
- Terrestrial sequestration

CO_2 Capture

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

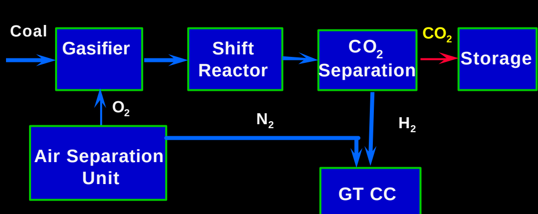
CO_2 Capture

- Post-combustion capture
  - Chemical solvent scrubbing



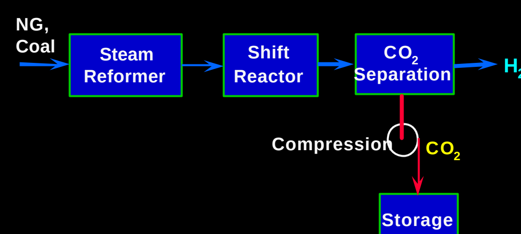
CO_2 Capture

- Pre-combustion decarbonisation
  - Physical solvent scrubbing



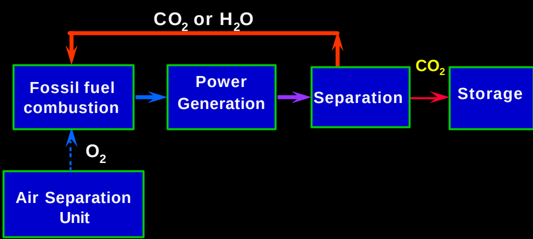
H_2 from Fossil Fuel

- CO_2 capture and sequestration towards hydrogen economy



CO_2 Capture

- Oxyfuel



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

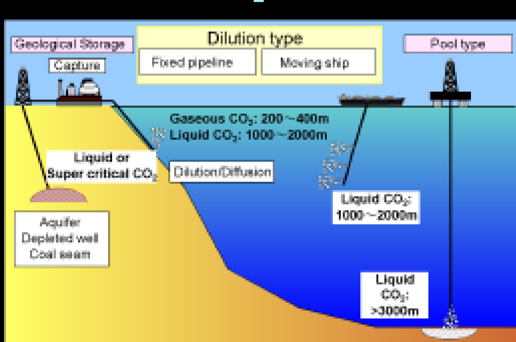
CO_2 Transmission

- 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

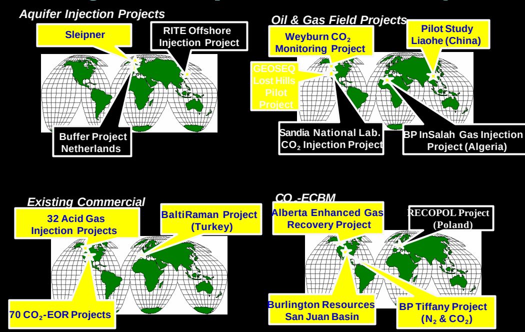
Major Research Programmes

- 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

Geological Sequestration Projects



John Gale, IEA Greenhouse R&D Programme

Sleipner Project

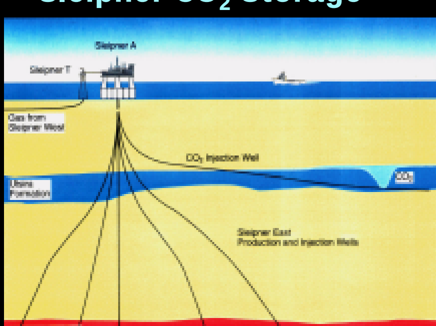
- First commercial scale demonstration of CO_2 capture and storage
- Project commenced in 1996
- 1 million tonnes of CO_2 injected per year
- Deep saline aquifer under the North Sea
- Statoil are the project operators

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

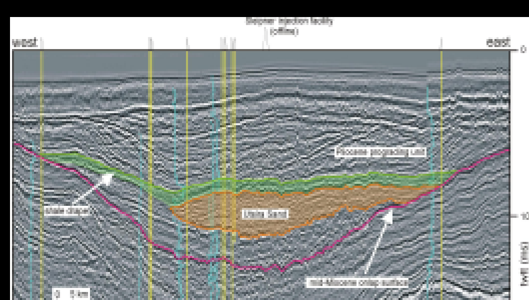
Courtesy of Geological Survey of Denmark and Greenland

Sleipner CO_2 Storage



Courtesy of Statoil

Utsira Cross Section

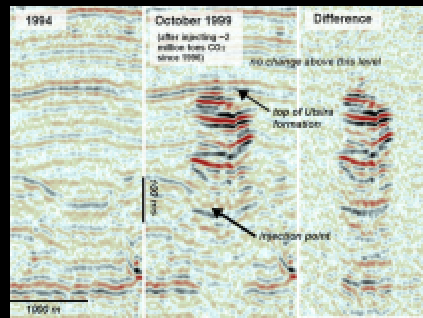


Courtesy of British Geological Survey & Schlumberger Geco-Prakla

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

Seismic Survey of Utsira



Courtesy of Statoil

Weyburn CO_2 Injection Project

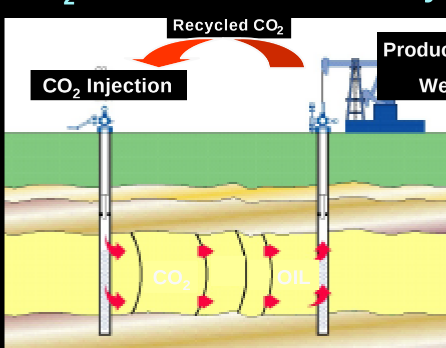
- Site - Southern Saskatchewan, Canada
- Oilfield operated by PanCanadian since 1954
- Conventional and water flood enhanced recovery
- Estimated recovery of oil reserves - 35%
- CO_2 injection commenced in September 2000
- Estimated to recover additional 10-15% of OIP
- Extend field life by 25 years

Weyburn CO_2 Pipeline

- 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

Courtesy of Dakota Gasification.

CO_2 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

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

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…

Recent Topics
Technology into Political Arena

Recognition on Carbon Sequestration in the Political Arena

- Article 2 of the **Kyoto Protocol** acknowledges the importance of R&D on the technologies
- Description in **IPCC TAR (3pages)**
- 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:

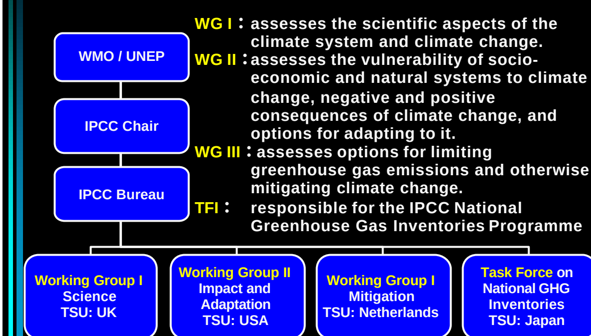
……

(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;

Organizational Structure of IPCC



20th IPCC Plenary Meeting (Feb. 2003, Paris)

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

Proposed Structure of Special Report

1. Introduction
2. Sources
3. Capture
4. Transport
5. Geological storage
6. Ocean storage
7. Re-use and other storage options
8. Total costs and market potential
9. Implications for emission inventories and accounting
10. Critical Gaps in knowledge

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: 2nd LA meeting
- 2003.05?: Release of FOD
- 2004.08: 3rd LA meeting
- 2005.04: 4th LA meeting
- 2005.09?: Release of Special Report

Significance of IPCC Special Report

- The First IPCC assessment report addressing a specific technology
  - To be reflected in Revised 1996 Inventory Guideline
  - To be reflected in AR4
- Potential impacts on negotiation process under UNFCCC

Related Research

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

ARCS

Project Duration: FY02-FY04

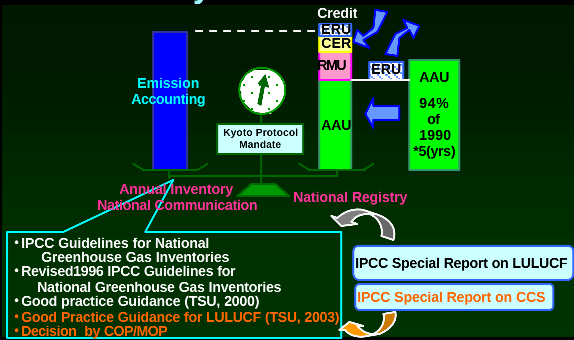
Contact:
Makoto Akai (m.akai@aist.go.jp)
National Institute of Advanced Industrial Science and Technology (AIST)

ARCS Project

Background

- Although there is a growing interest CO_2 capture and sequestration technologies, there is no internationally agreement on the rule for account sequestered amount of CO_2 to be reflected in National Greenhouse Gas Emission Inventories

National GHG Inventories and Kyoto Protocol



Scope of ARCS project

- **To develop models** to assess effectiveness of storage and conduct case studies for various CO_2 injection scenarios
- **To propose guideline and/or protocol** for accounting sequestered CO_2 into GHG emission inventories through "thought experiment" using developed models
- **To assess socio-economic and policy implications** of the technology through energy modeling and evaluation of business opportunities

Cost-Benefit and Externality Study

Examples

- Willingness to pay for human health risk reductions
- Relationship between risk characteristics and preferences on mortality risk reduction (WTP)
- Externality of hydrogen energy system
- Public's perception on CO_2 sequestration technologies

Public's Perception on CO_2 Capture and Storage

Purpose

- To assess potential acceptability of public on CCS.
- To find factors which influence public acceptance on CCS.
- To obtain information to make a effective public outreach plan.

Questions?

Send e-mail to:

m.akai@aist.go.jp