Global Environmental Policy

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Lecture Plan

- **May 23: Overview**
- **May 30: Challenges and strategies towards Deep GHG Reduction**
  - **Discussion on Stabilization Wedge**
- **June 06: Energy and Global Environmental Policies**

Towards a Deep Reduction

IPCC TAR Recommendations

WG3:Mitigation-SPM

- **Earlier actions, including a portfolio of emissions mitigation, technology development and reduction of scientific uncertainty, increase flexibility in moving towards stabilization of atmospheric concentrations of greenhouse gases,**
- **Rapid near-term action would decrease environmental and human risks associated with rapid climatic changes.**

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.**

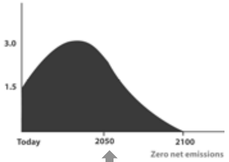
The Technology Challenge

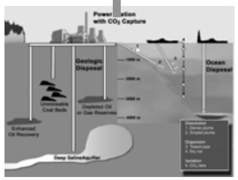
Stabilizing Greenhouse Gas Concentrations in the Atmosphere

Hydrogen Fuel Cell Vehicles

Zero Net Emission Buildings

Nuclear Power Generation IV





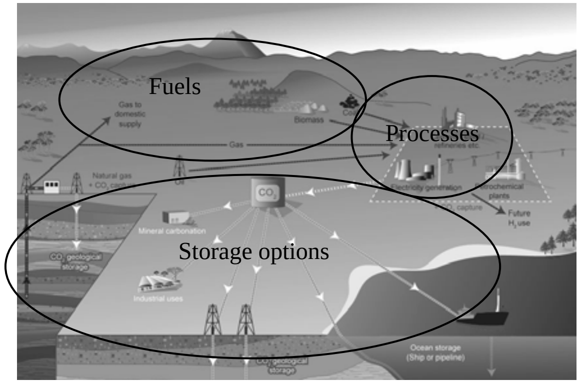
Carbon (CO_2) Sequestration

Renewables: Photovoltaics and Wind

Bio-Fuels and Power

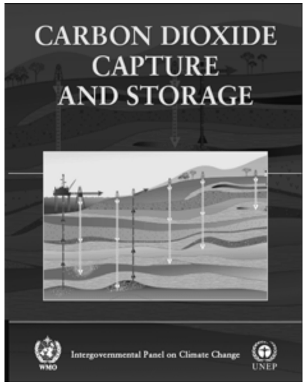
Vision 21: Zero-Emission Power Plant

CO_2 Capture and Storage System



Source: IPCC SRCCS

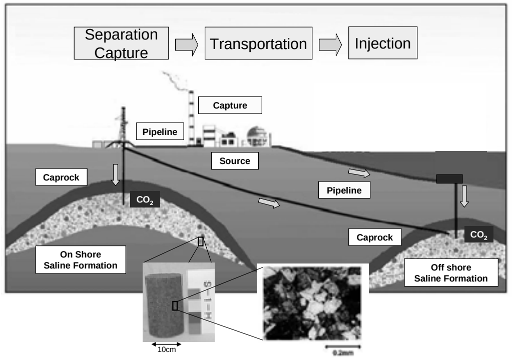
The IPCC Special Report on Carbon Dioxide Capture and Storage



How Could CCS Play a Role in Mitigating Climate Change?

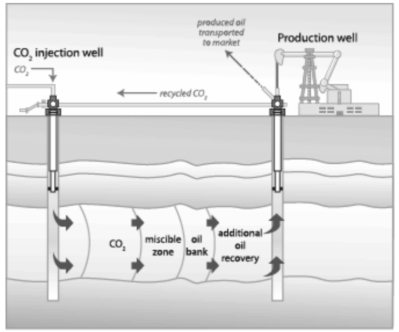
- Part of a portfolio of mitigation options
- Reduce overall mitigation costs
- Increase flexibility in achieving greenhouse gas emission reductions
- Application in developing countries important
- Energy requirements point of attention

Schematic of Geological Storage
- Saline Formation -



- CO_2 will not be injected into a cavern!

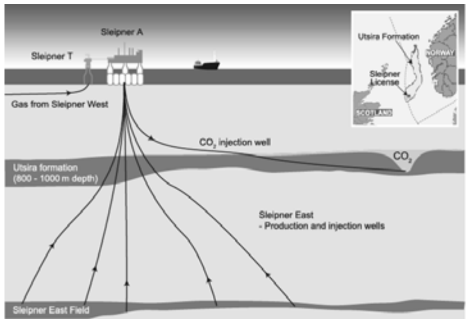
Injection of CO_2 for Enhanced Oil Recovery (EOR)



From IPCC SRCCS

- CO_2 produced with the fossil fuel combustion is captured and re-injected back into the formation.
- Recycling of produced CO_2 decreases the amount of CO_2 that must be purchased and avoids emissions to the atmosphere.

Sleipner CO_2 Storage Project.



CO_2 (about 9%) from Sleipner West Gas Field is separated, then injected into a large, deep, saline formation 800 m below the seabed.

Approximately 1 $MtCO_2$ is injected annually started in October 1996 and, by early 2005, more than 7 $MtCO_2$ had been injected at a rate of approximately 2700 t/day.

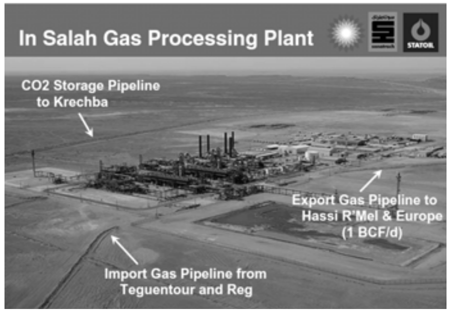
Weyburn CO_2-EOR Project.

Dakota Gasification.

The source of the CO_2 for the Weyburn CO_2-EOR Project is the Dakota Gasification Company facility, located approximately 325 km south of Weyburn, in Beulah, North Dakota, USA. At the plant, coal is gasified to make synthetic gas (methane), with a relatively pure stream of CO_2 as a by-product. This CO_2 stream is compressed and piped to Weyburn in Saskatchewan, Canada, for use in the field.

The Weyburn CO_2-EOR Project is designed to take CO_2 from the pipeline for about 15 years, with delivered volumes dropping from 5000 to about 3000 t/day over the life of the project.

In Salah Gas Project, Algeria.



The Krechba Field at In Salah produces natural gas containing up to 10% CO_2 from several geological reservoirs and delivers it to markets in Europe, after processing and stripping the CO_2 to meet commercial specifications.

The project involves re-injecting the CO_2 up to 1.2 $MtCO_2$/yr into a sandstone reservoir at a depth of 1800 m. Injection started in April 2004 and it is estimated that 17 $MtCO_2$ will be stored over the life of the project.

CCS R&D Projects under METI

- Ocean Sequestration
  (Environmental Assessment for CO_2 Ocean Sequestration)
  - 1997 - 2001 (Phase-1)
  - 2002 - 2006 (Phase-2)
- Geological Sequestration
  - 2000 - 2004 (Phase-1)
  - 2005 - (Phase-2)
- ECBM
  - 2002 - 2006 (Phase-1)

Other CCS Research under METI

- Accounting Rules on CO_2 Sequestration for National GHG Inventories [ARCS] (2002 -)
  - Development of accounting methodology
  - Contribution to NGGIP
  - Policy studies including CCS-CDM
- Environmental Impact and Safety Management based on Natural Analogue (2005 -)
- Methodology of Applicability of CCS to Kyoto Mechanism including CDM (2004 -)
- Public Perception on CCS (2002 -)
  - Cooperation with AGS Project

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…

Energy and Global Environmental Policies in Several Nations

United Kingdom

Key Points in UK Policy (1/2)

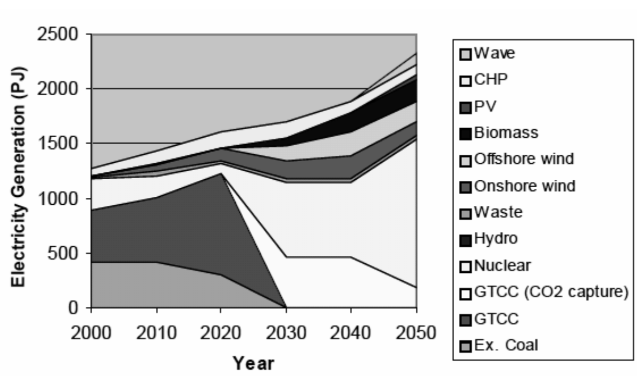
- UK Energy White Paper : environment issues at heart of Energy Policy - desire to put UK on a path to reduce CO_2 levels by 60% in 2050 (compared to 1990 levels)
- No one single winning technology; broad portfolio approach required
- Clean use of fossil fuels world-wide becoming increasingly recognized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

Key Points in UK Policy (2/2)

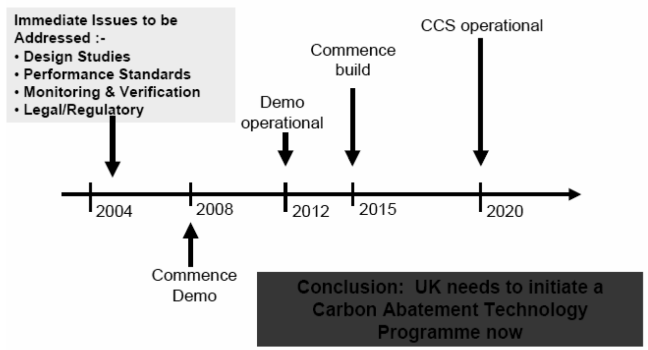
- Desire for a Carbon Abatement Strategy that includes fossil fuels
- CCS considered as one key element in such a strategy; recognized link to "hydrogen economy" needs
- International co-operation recognised as an essential element

UK Fuel Mix in Electricity Generation

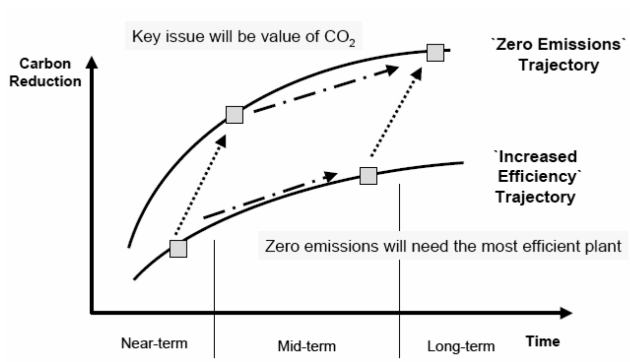
60% CO_2 Reduction in 2050 (limited Energy Efficiency)



UK Roadmap for Carbon Capture and Sequestration



UK Strategy Trajectories

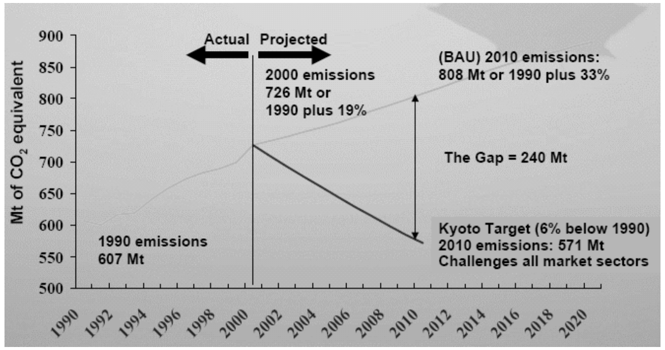


Canada

The Canadian Context

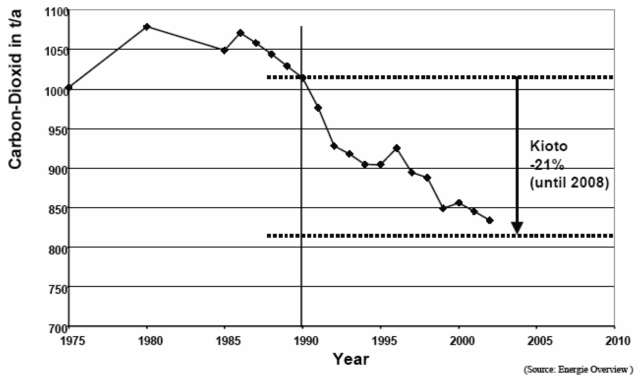
- Canadian energy policy is framed within the context of Sustainable Development
- Sustainable development – pursuit of a balanced portfolio of environmental, economic and social goals
- For energy, sustainable development aims to:
  - Reduce energy use, intensity (and carbon content), emissions
- A 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

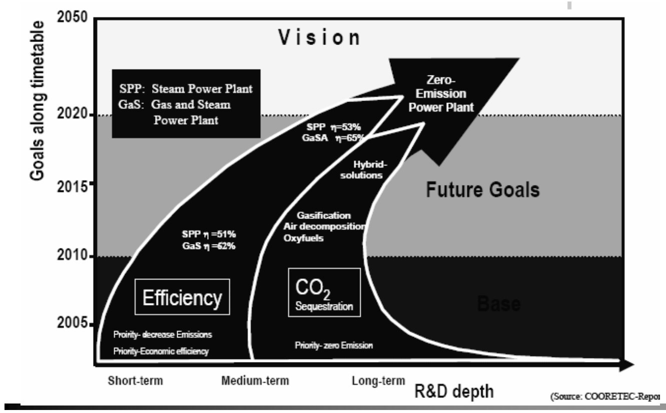


Germany

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)**

⇓

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

Three Horses of the "Troika"

- **Energy efficiency**
- **Renewable energy**
- **Emission free fossil fuels**

Sometimes operate simultaneously

⇓

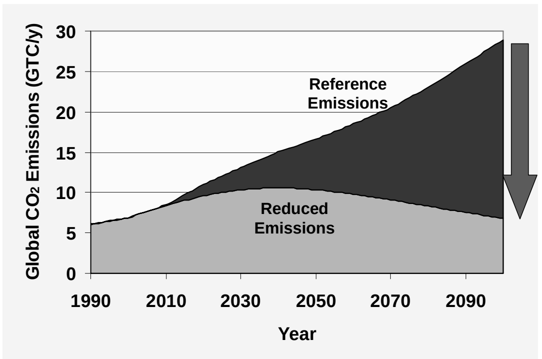
- **Carbon Capture and Storage (CCS), is a crucial issue in energy policy: as the third horse of the troika**

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

U.S. Initiatives for International Activities

– Carbon Sequestration Leadership Forum (CSLF)

– International Partnership for the Hydrogen Economy (IPHE)

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.

The First Ministerial-level Meeting

June 23-25, 2003

- Attended by delegations from 16 countries and the European Commission.
- The CSLF charter was signed by representatives of 13 countries and EC.
  - Stay in effect for 10 years
  - Additionally, Germany, South Africa, France, Norway, The Netherlands have joined

CSLF Activities

- Framework for international cooperation in research and development for the separation, capture, transportation and storage of CO_2.
- The activities will be conducted by:
  - Policy Group
    - Governing the overall framework and policies of the CSLF
  - Technical Group
    - Reviewing the progress of collaborative projects and makes recommendations to the Policy Group on any needed actions.

CSLF Collaborative Projects

Review by Technical Group

- Information exchange and networking,
- Planning and road-mapping,
- Facilitation of collaboration,
- Research and development,
- Demonstrations,
- Public perception and outreach,
- Economic and market studies,
- Institutional, regulatory, and legal constraints and issues,
- Support to policy formulation, or
- Other issues as authorized by the Policy Group.

Global Environmental Policy 2005

Global Environmental Policy 2005

FutureGen – Goals (1/2)

A Sequestration and Hydrogen Research Initiative

- Design, construct, and operate a nominal 275MW (net equivalent output) prototype plant that produces electricity and H_2 with near-zero emissions. The size of the plant is driven by the need for producing commercially-relevant data, including the requirement for producing one million metric tons per year of CO_2 to adequately validate the integrated operation of the gasification plant and the receiving geologic formation.
- Sequester at least 90 % of CO_2 emissions from the plant with the future potential to capture and sequester nearly 100 %.

Global Environmental Policy 2005

FutureGen – Goals (2/2)

A Sequestration and Hydrogen Research Initiative

- Prove the effectiveness, safety, and permanence of CO_2 sequestration.
- Establish standardized technologies and protocols for CO_2 measuring, monitoring, and verification.
- Validate the engineering, economic, and environmental viability of advanced coal-based, near-zero emission technologies that by 2020 will: (1) produce electricity with less than a 10% increase in cost compared to nonsequestered systems; (2) produce hydrogen at $4.00 per million Btus (wholesale), equivalent to $0.48/gallon of gasoline, or $0.22/gallon less than today's wholesale price of gasoline.

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.

Japan

Energy Technology Vision 2100 (METI)

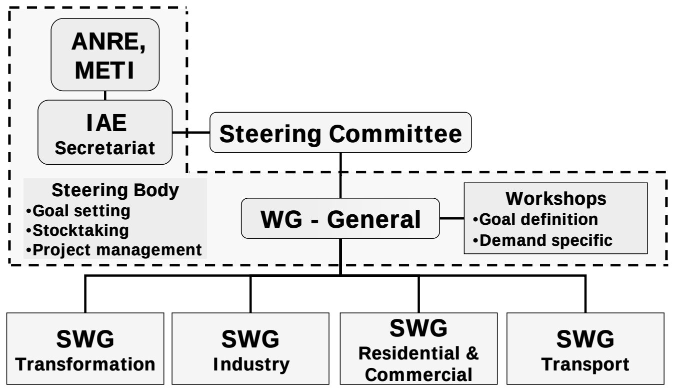
Purpose

Development of "Technology Vision"

- To establish strategic energy R&D plan
  - To consider optimum R&D resource allocation.
  - To prioritize energy and environmental R&D programs and specific project of METI.
- To prepare strategy for post-Kyoto and further deep reduction of GHG
- To develop technology roadmap to be reflected in METI's energy, environmental and industrial policy

Work Structure

Development of Draft "Technology Vision"



Scope of Work

- Timeframe
  - Vision: - 2100
  - Technology roadmap: -2100
    - Benchmarking years: 2030 and 2050
- Approach
  - To introduce backcasting methodology
  - To compile experts' view
  - To confirm long-term goal using both top-down and bottom-up scenario analysis

Why to consider Long-term?

- Timeframe for future risk or constraint
  - Resource (10s ~ 100yrs?)
  - Environment (100 ~ 1000 yrs)
- Long lead time for energy sector in general
  - Research and development to commercialization
  - Market diffusion
  - Stock turnover time (10s yrs)
  - Infrastructure development

Methodology - Backcasting

Exploratory (opportunity-oriented):

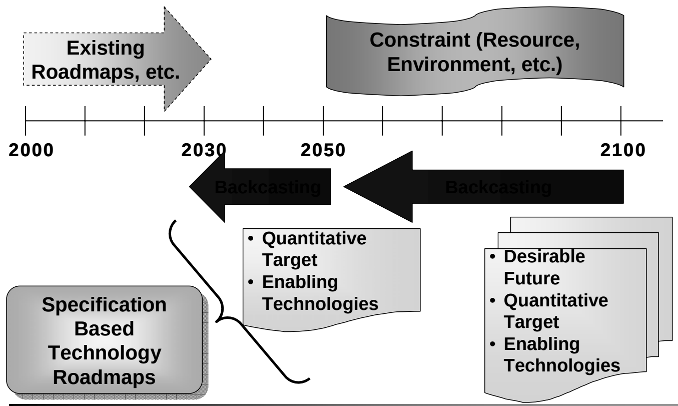
- *what futures are likely to happen? ⇒ Forecasting*
  - starts from today's assured basis of knowledge and is oriented towards the future

Normative (goal-oriented):

- *how desirable futures might be attained? ⇒ Backcasting*
  - first assesses future goals, needs, desires, missions, etc. and works backward to the present

Clement K. Wang &Paul D. Guild

Framework of Backcasting



Basic Recognition on the Energy Sector

- Constraints on energy connect directly to the level of human utility (quantity of economic activity, quality of life).
- Consideration of future energy structure should take into account both resource and environmental constraints.
- The key to achieve a truly sustainable future is technology.
- However, there is great uncertainty because various kinds of options are selected in the actual society.

Premises

- Resource and environmental constraints do not degrade utility but enrich the human race (improve utility)
- To develop the technology portfolio for the future in order to realize it through development and use of the technologies.
- <u>Not to set preference to specific technology such as hydrogen, distributed system, biomass, etc.</u>

Assumptions

Developing a Challenging Technology Portfolio

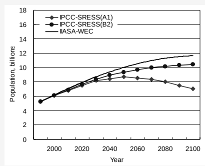
- The effect of modal shift or changing of lifestyle were not expected.
- Although the assumption of the future resource and environmental constraints includes high uncertainties, rigorous constraints were assumed as "preparations".
- To set excessive conditions about energy structure to identify the most severe technological specifications.
  - As a result, if all of them are achieved, the constraints are excessively achieved.

Desirable Futures

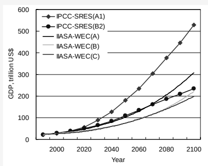
- Society where the economy grows and the quality of life improves
- Society where necessary energy can be quantitatively and stably secured
- Society where the global environment is maintained
- Society where technological innovation and utilization of advanced technology are promoted through international cooperation
- Society with flexible choices depend on national and regional characteristics

Assumptions towards 2100

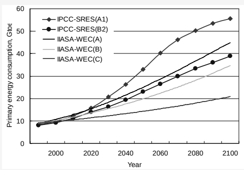
- Population and economy
  - To increase continuously
- Energy consumption
  - To increase following the increase in population and GDP



Forecast of world population



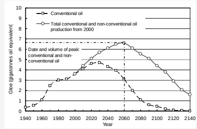
Forecast of world GDP



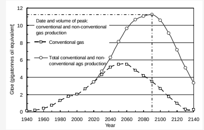
Forecast of energy consumption

Resource Constraints

- Although assumption of the future resource constraints includes high degree of uncertainties, the following rigorous constraints were assumed as "preparations".
  - Oil production peak at 2050
  - Gas production peak at 2100



The Complementarity of Conventional and Non-Conventional Oil Production: giving a Higher and Later Peak to Global Oil Supplies

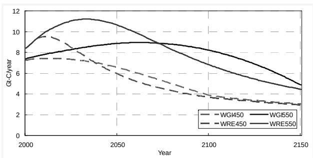


The Complementarity of Conventional and Non-Conventional Gas Production: giving a Higher and Later Peak to Global Gas Supplies

Example of estimates for oil and natural gas production

Environmental Constraints

- CO_2 emission intensity (CO_2/GDP) should be improved to stabilize atmospheric CO_2 concentration
  - 1/3 in 2050
  - Less than 1/10 in 2100 (further improvement after 2100)



Global carbon dioxide emission scenario

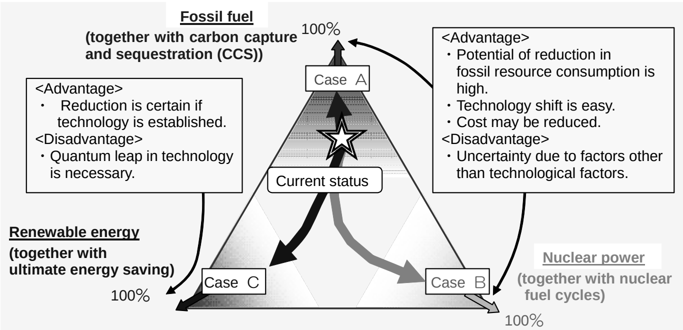
To Overcome Constraints ---

- Sector specific consideration
  - Residential/Commercial
  - Transport
  - Industry
  - Transformation (Elec. & H_2 production)
- Definition of goal in terms of sector or sub-sector specific CO_2 emission intensity.
- Identification of necessary technologies and their targets

Demand sectors and their typical CO_2 emission intensity

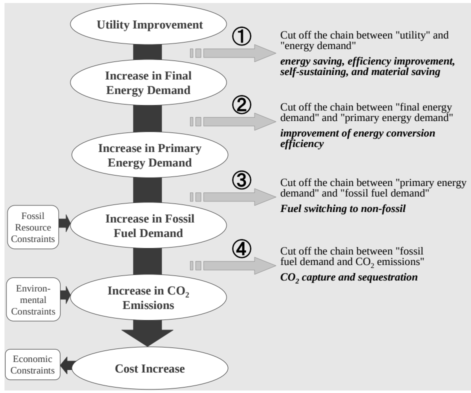
Industry	:	t-C/production volume	=	t-C/MJ	×	MJ/production volume
Commercial	:	t-C/floor space	=	t-C/MJ	×	MJ/floor space
Residential	:	t-C/household	=	t-C/MJ	×	MJ/household
Transport	:	t-C/distance	=	t-C/MJ	×	MJ/distance
(*Transformation sector*: t-C/MJ)				Conversion efficiency		Single unit and equipment efficiency

Three Extreme Cases and Possible Pathway to Achieve the Goal



- **Cases A & C assume least dependency on energy saving**

Basic Approach to Achieve the Desirable Future



Sketch of Technology Spec. 2100
Extreme Case-A (Fossil + CCS)

- Case A assumes a situation where we cannot heavily rely on energy saving.
- The increase of the share of electricity and hydrogen is considered.

** Values are relative to those in 2000, otherwise stated*

[Target in the Transformation Sector]

(1) Production of Electricity and Hydrogen
About eight times* the current total amount of electricity generated

CO_2
Fossil Fuel
CO_2 Capture and Sequestration (CCS)

Supplying with coal fired power plants with CCS

Electricity or Hydrogen

[Target in the Industry Sector]

(1) CCS it applied to over 80% of CO_2 emissions from fossil fuel consumption

CO_2
CCS

(2) Over 65% of the energy demand is supplied by electricity or hydrogen from the transformation sector

[Target in the Transport and Res/Com Sectors]

(1)100% of the energy demand is supplied by electricity or hydrogen

Transport | Res/Com (Residential) | Res/Com (Commercial)

Total amount of CO_2 captured and sequestered in transformation and industry sector becomes approximately 4.0 billion t-CO_2/year.
*** Additional energy required for the CCS process is not included.*

Sketch of Technology Spec. 2100
Extreme Case-B (Nuclear)

- Case B assumes a situation where we cannot heavily rely on energy saving.
- The increase of the share of electricity and hydrogen is considered.

** Values are relative to those in 2000, otherwise stated*

[Target in the Transformation Sector]

(1) Production of Electricity and Hydrogen
About eight times* the current total amount of electricity generated

Nuclear Power

Supplying by nuclear power

Electricity or Hydrogen

[Target in the Industry Sector]

(1) All the energy demand is supplied with electricity or hydrogen with the exception of feedstocks and reductants

[Target in the Transport and Res/Com Sectors]

(1)100% of the energy demand is supplied by electricity or hydrogen

Transport | Res/Com (Residentila) | Res/Com (Commercial)

Sketch of Technology Spec. 2100

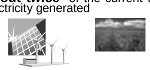
Extreme Case-C (Renewable + Ultimate Energy Saving)

** Values are relative to those in 2000, otherwise stated*
*** Per unit utility*

[Target in the Transformation Sector]

(1) Production of Electricity and Hydrogen

About twice* of the current total electricity generated



Renewable Energies

Electricity, Hydrogen or Biomass

[Target in the Industry Sector]

Energy demand to be reduced by 70%**
(1) 50% of the production energy intensity is reduced.
(2) Making the rate of material energy regeneration to 80%
(3) Improvement of functions such as strength by factor 4

Supplying by renewable energies

[Target in the Transport Sector]

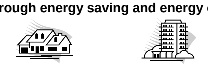
(1) 70% of the energy demand is reduced through energy saving and fuel switching.**

Transport

For automobile, 80% is reduced

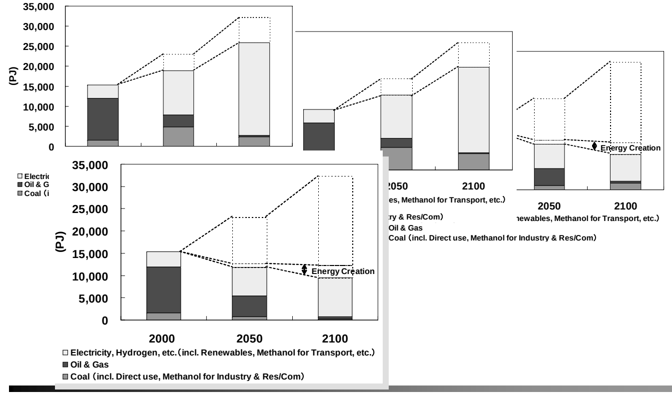
[Target in the Res/Com Sector]

(1) Energy demand to be reduced by 80% through energy saving and energy creation.



Res/Com (Residential) Res/Com (Commercial)

Scenario Analysis on Extreme Cases and Mix Case



Energy Scenario of Japan

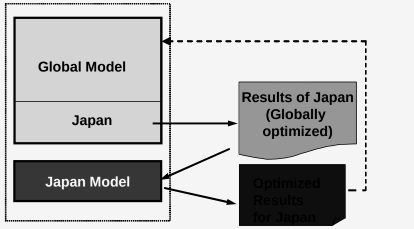
based on Energy Technology Vision 2100

- **Case Study by an Energy Model "ATOM-J" developed by Akai.**

ATOM-J Model

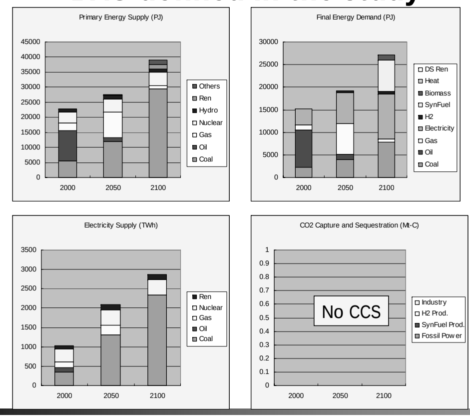
- **Optimized LP**
- **Term：1990-2100**
- **18 world regions**
- **Demand Sectors**
  - ➢ **Industry**
  - ➢ **Household**
  - ➢ **Service**
  - ➢ **Transport**

Structure of ATOM-J Model

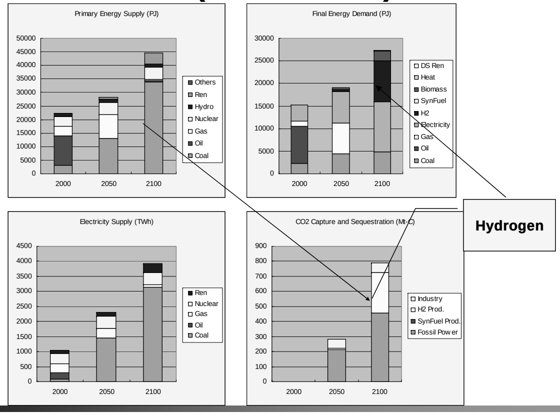


Energy Scenario of Japan

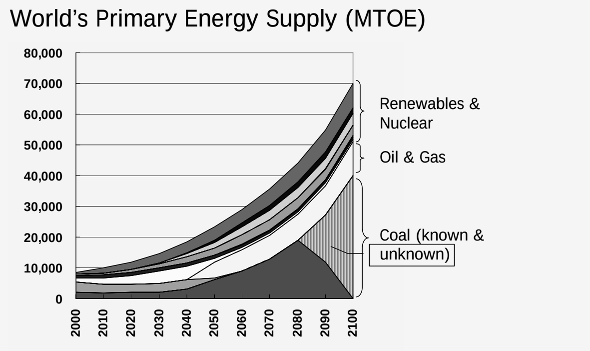
BAU defined in the study



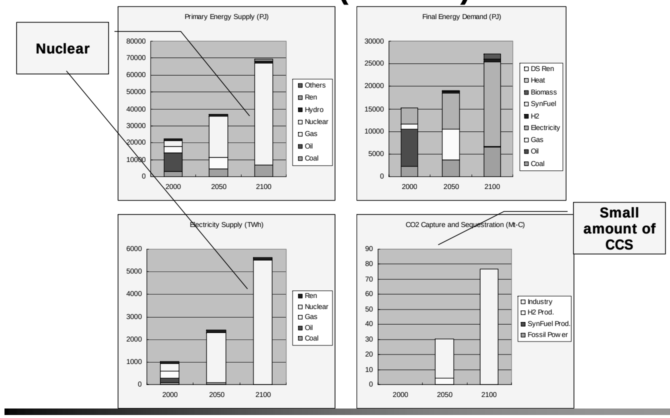
Energy Scenario of Japan
≈ Case-A (Fossil + CCS)



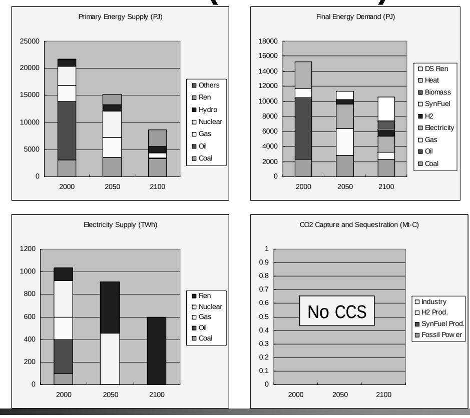
Hydrogen Society with CCS is NOT a Sustainable Option



Energy Scenario of Japan
≈ Case-B (Nuclear)

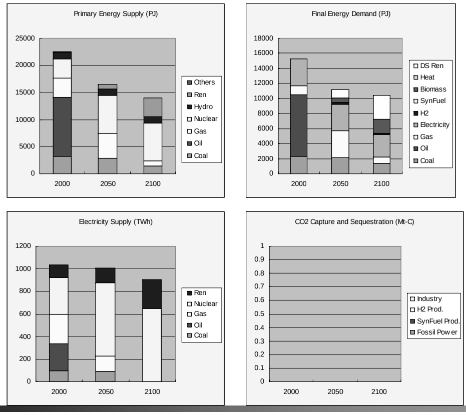


Energy Scenario of Japan
≈ Case-C (Renewable)



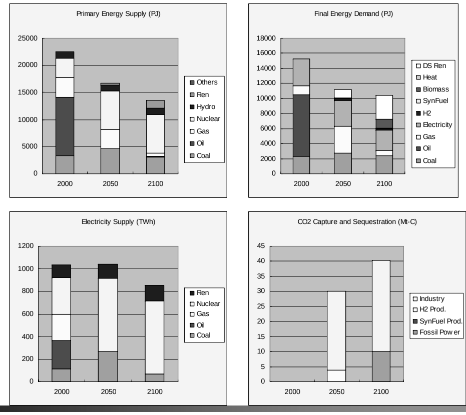
Energy Scenario of Japan

≈ Mix (Moderate limit for Nuc. + Case-C; w/o. CCS)



Energy Scenario of Japan

≈ Mix (w. CCS, Cumulative CCS potential: 10Gt-CO_2)



Implications from Scenario Study

- **Case-A “Fossil + CCS” would contribute to hydrogen economy but not be a sustainable option from the viewpoint of resource depletion.**
- **Nuclear and CCS, especially as a mid-term option, would increase the flexibility of energy supply and demand structure.**
- **Energy efficiency is the key!**

Questions?

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