Global Environmental Policy
Lecture Plan

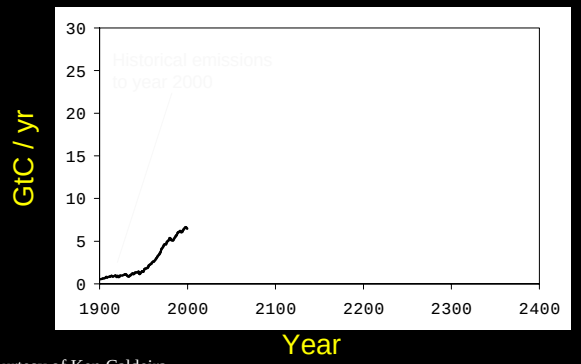
- May 24: Overview
  - International aspects
    - Background
    - The Road to Kyoto and Beyond
    - Recent topics
- May 31: Challenge towards Deep GHG Reduction
- June : ???

Background
Recent Findings on Climate Change

IPCC TAR Recommendations
WG3:Mitigation-SPM

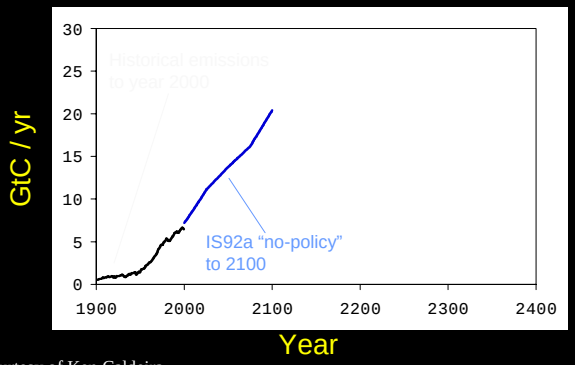
- **Earlier actions**, including a portfolio of emissions mitigation, technology development and reduction of scientific uncertainty, **increase flexibility** in moving towards stabilization of atmospheric concentrations of greenhouse gases,
- **Rapid near-term action** would decrease environmental and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

What happens if we do nothing?



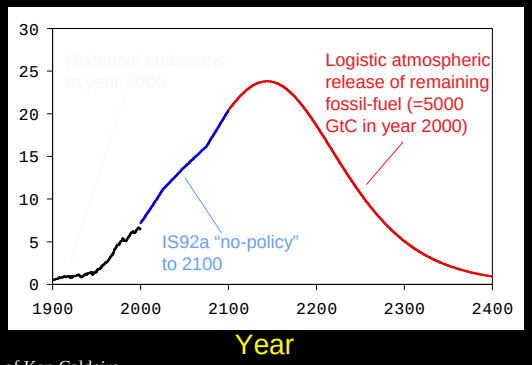
Courtesy of Ken Caldeira

What happens if we do nothing?



Courtesy of Ken Caldeira

What happens if we do nothing?

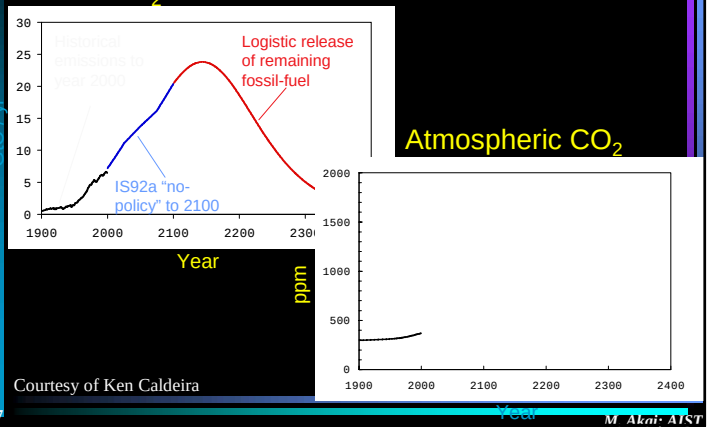


Courtesy of Ken Caldeira

What happens if we do nothing?

CO_2 emissions

Atmospheric CO_2

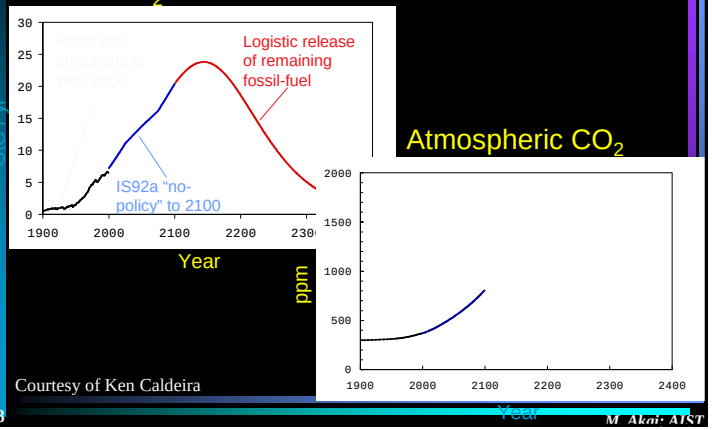


Courtesy of Ken Caldeira

What happens if we do nothing?

CO_2 emissions

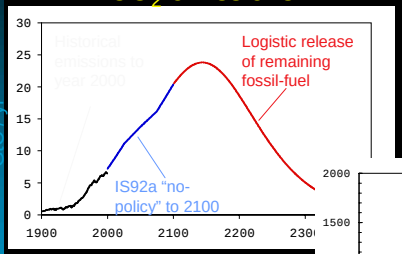
Atmospheric CO_2



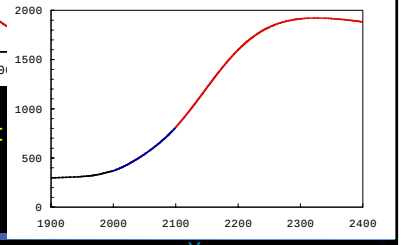
Courtesy of Ken Caldeira

What happens if we do nothing?

CO_2 emissions



Atmospheric CO_2



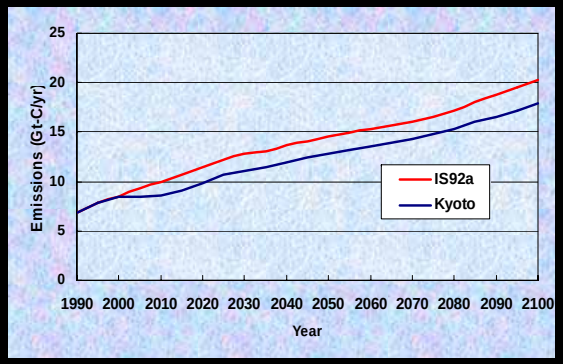
Courtesy of Ken Caldeira

Kyoto Protocol to the UNFCCC

- **38 developed countries agreed to reduce their emissions of six GHGs by a total of 5.2% between 2008 and 2012 from 1990 levels**
  - **CO_2, CH_4, N_2O, HFCs, PFCs, SF_6**
- **Party quantified emission limitation or reduction commitment include (% reduction):**
  - **Austria (8); Canada (6); Japan (6); Romania (8); Russian Federation (0); Switzerland (8); USA (7); UK (8);**

Effect of Kyoto Protocol

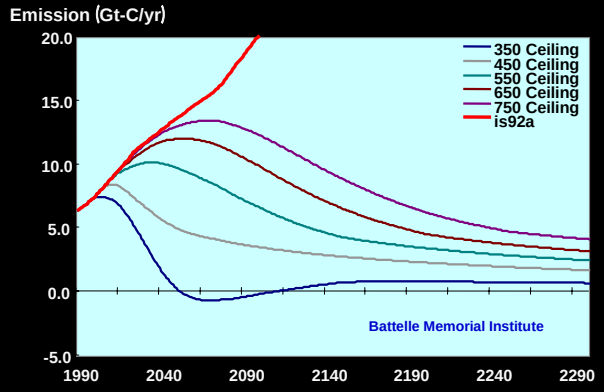
It's just an entrance to a sustainable society



(Pacific Northwest National Laboratory)

Towards a Deep Reduction

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.

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

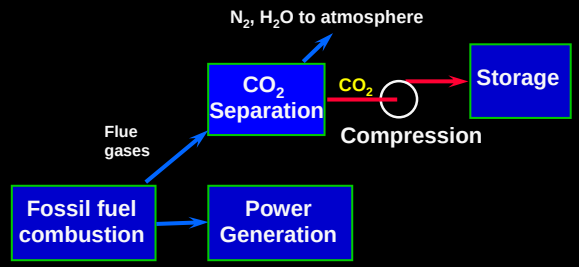

Renewables: Photovoltaics and Wind


Bio-Fuels and Power


Vision 21: Zero-Emission Power Plant

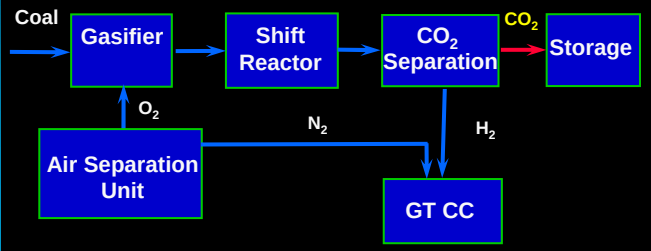
CO_2 Capture

- Post-combustion capture
  - Chemical solvent scrubbing



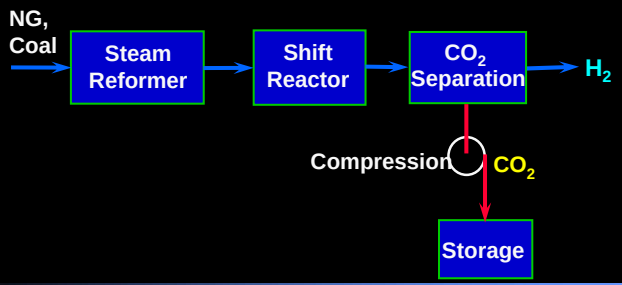
CO_2 Capture

- Pre-combustion decarbonisation
  - Physical solvent scrubbing



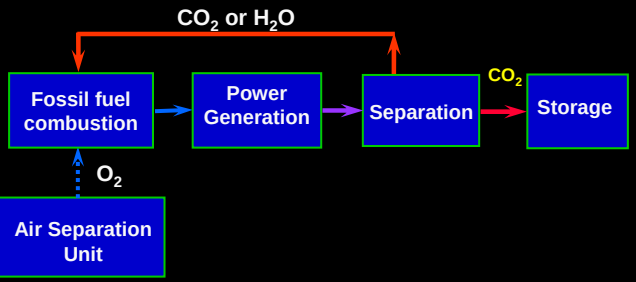
H_2 from Fossil Fuel

- CO_2 capture and sequestration towards hydrogen economy

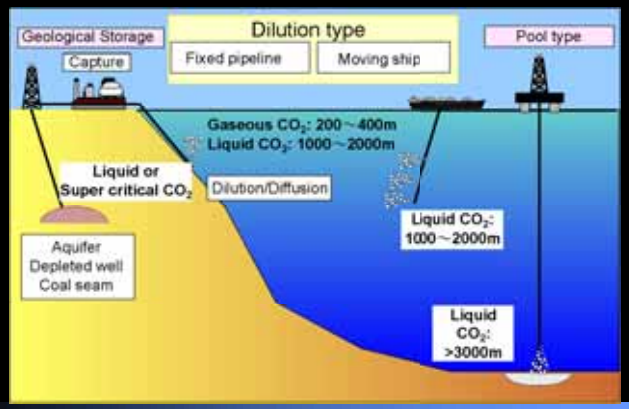


CO_2 Capture

- Oxyfuel



Concept of CO_2 sequestration

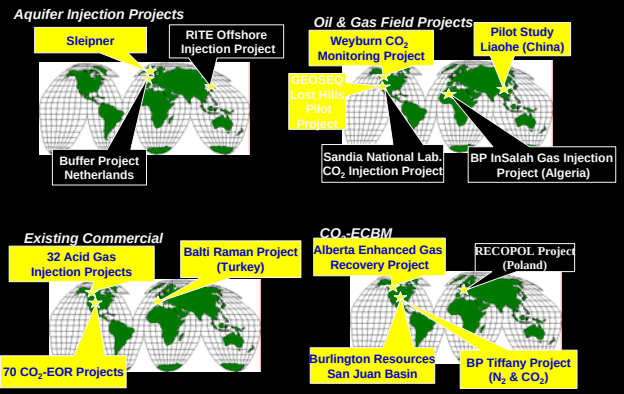


Is there sufficient capacity?

- 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

Geological Sequestration Projects



John Gale, IEA Greenhouse R&D Programme

Sleipner Project

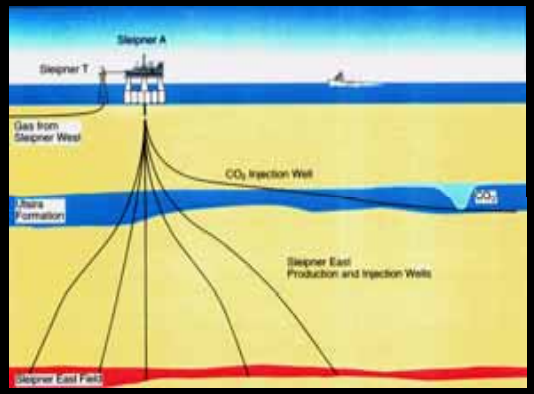
- First commercial scale demonstration of CO_2 capture and storage
- Project commenced in 1996
- 1 million tonnes of CO_2 injected per year
- Deep saline aquifer under the North Sea
- Statoil are the project operators

The Utsira Formation

Statistics
- Area - 2.6X10⁴ km²
- Depth - 550 to 1500m
- Two depositional centres
- Slopes south to north
- Uncemented sand
- Shale stringers
- Porosity 30-40 %
- Volume - 5.5X10¹¹ m³

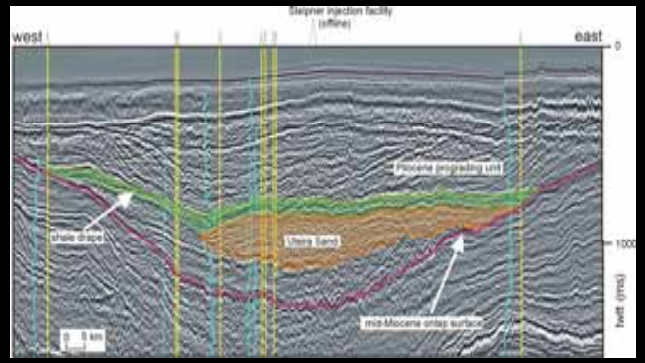
Courtesy of Geological Survey of Denmark and Greenland

Sleipner CO_2 Storage



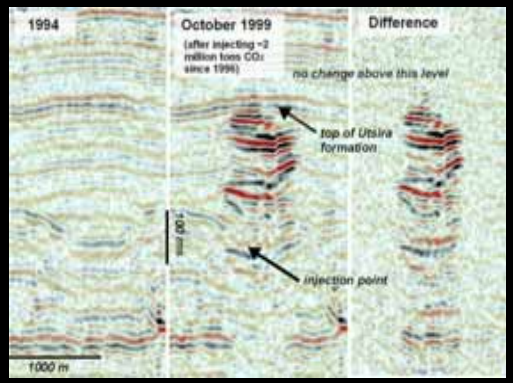
Courtesy of Statoil

Utsira Cross Section



Courtesy of British Geological Survey & Schlumberger Geco-Prakla

Seismic Survey of Utsira



Courtesy of Statoil

Weyburn CO_2 Injection Project

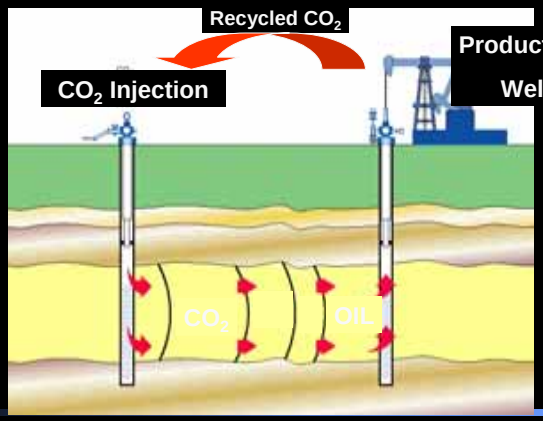
- Site - Southern Saskatchewan, Canada
- Oilfield operated by PanCanadian since 1954
- Conventional and water flood enhanced recovery
- Estimated recovery of oil reserves - 35%
- CO_2 injection commenced in September 2000
- Estimated to recover additional 10-15% of OIP
- Extend field life by 25 years

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

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…

Summary of Costs

Capture

- Comparable with or less than other deep reduction options
  - All approaches would capture CO_2 at costs of \$30-50/t-CO_2 avoided.
  - Significant cost reduction should be necessary.

Sequestration

- Typically less than \$10/t-CO_2

H_2 production with CCS

- Less than other carbon free production, typically less than \$10/GJ-H_2

Scenario Study

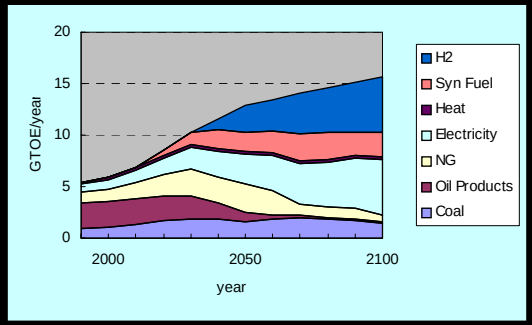
Global Energy Network Model

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

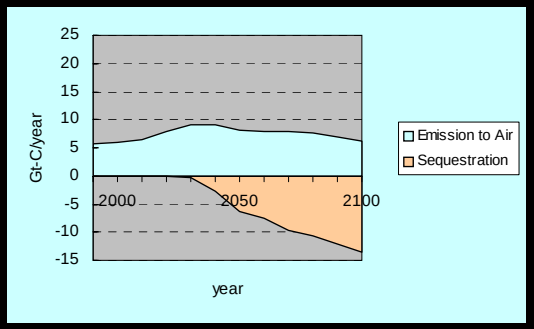
Secondary Energy Demand

- 550ppm Stabilization -



CO_2 Sequestration

- 550ppm Stabilization -



CO_2 Sequestration Technologies

from Laboratory to Policy Agenda

IPCC Special Report on CCS

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

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

Schedule

- 2002.4: Recommendation to hold workshop at the 19th IPCC plenary
- 2002.11: Workshop (Regina)
- 2003.2: Decision by 20th IPCC plenary
- 2003.3: Selection of authors
- 2003.7: 1st LA meeting (Oslo)
- 2005.4: 4th LA meeting (Oviedo)
- 2005.9: Adoption by IPCC plenary
- 2005.E: Publish

Structure of Special Report on CCS

1. Introduction
2. Sources
3. Capture
4. Transport
5. Underground geological storage
6. Ocean storage
7. Mineral carbonation and industrial uses
8. Costs and market potential
9. Implications of carbon dioxide capture and storage for greenhouse gas inventories and accounting

Summary for Policymakers
Second Order Draft - IPCC SRCCS

- CCS technology could be applied to large point sources of CO_2, such as large fuel burning electric power generation facilities or hydrogen plants.
- In the longer term, CCS enables low-carbon production of electricity or hydrogen for transport fuel and distributed energy supply systems.

Significance of IPCC Special Report

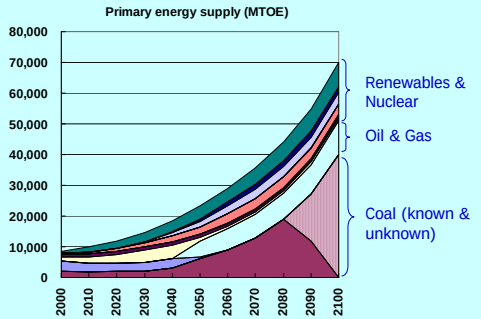
- The First IPCC assessment report addressing a specific technology
  - To be reflected in Revised 1996 Inventory Guideline
  - To be reflected in AR4
- Potential impacts on negotiation process under UNFCCC

Relevance of CCS

SPM – IPCC SRCCS

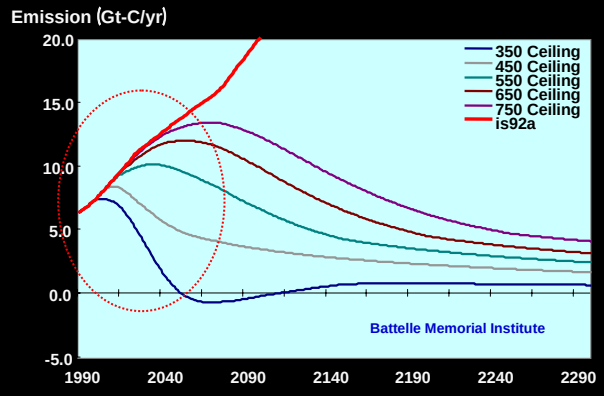
- CCS would allow the continued use of coal in a carbon-constrained world.
- It would also allow more time to introduce and commercialize non-fossil fuel energy sources while contributing to the stabilization of greenhouse gas concentrations in the atmosphere.
- HOWEVER...

Hydrogen Society with CCS is NOT a Sustainable Option



Simple Consideration on Deep Reduction Strategy

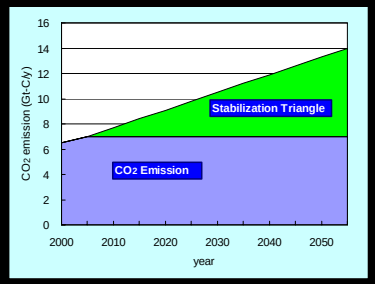
CO_2 Stabilization Profiles
- Atmospheric Emissions -



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.

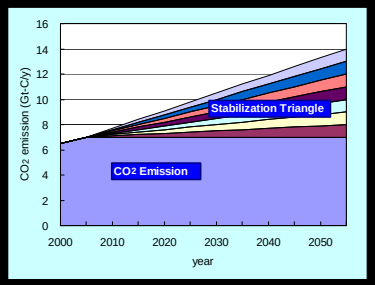
Stabilization Triangle



- Restrict attention to 50 years
- Use only straight lines! Take the goal to be flat emissions and the baseline to be doubling linearly in 50 years.

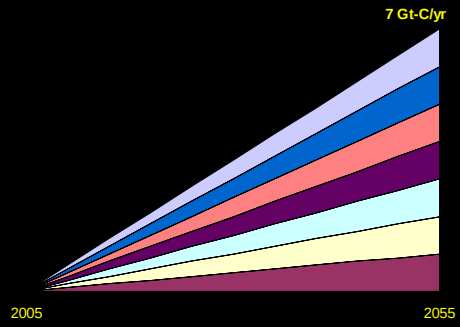
Robert H. Socolow (Princeton Univ.)

Stabilization Wedges



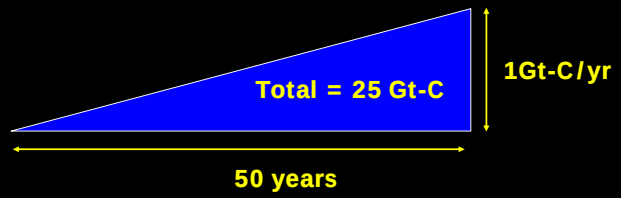
- To introduce a new physical unit, the wedge, as a unit for describing 50-year strategies.
- To explain the strategy is, roughly, a seven-wedge problem.

Seven Wedges to Fill the Triangle

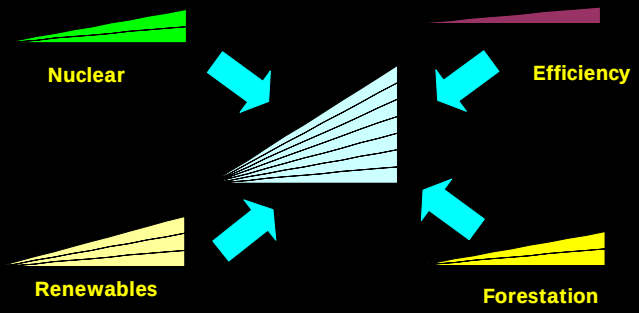


What is a “Wedge”?

- A “wedge” is an activity reducing the rate of carbon build-up in the atmosphere that grows in 50 years from zero to 1.0 Gt-C/yr.



Filling the Stabilization Triangle



- Many candidate wedges are available

Example of a Wedge - Nuclear -

- Displacement of coal fired power plant
  - CO_2 emission from 1GW coal fired plant:
    - Specific emission: 0.887 kg/kWh
    - Availability: 80 %

      $1\times10^6\times24\times365\times0.8\times0.887=6.22\times10^6$ (t-CO_2/yr)

      $=6.22\times10^6\times12/44 = 1.70\times10^6$ (t-C/yr)
  - To reduce 1Gt-C:
    - 1×10^9 (t-C/yr) / 1.70×10^6 (t-C/yr) = 590
- Effort needed to 1 wedge:
  - Add 590 GW that displaces coal (~1.7×current capacity)

Report Subject

- Develop a wedge with explanation of
  - Estimation procedures
  - Comparison of current market scale, etc.
- Candidate technologies include:
  - CO_2 capture and sequestration,
  - Renewables (Solar, Wind, etc.),
  - Efficiency improvement (Vehicles, etc.),
  - Shifting to low carbon fuel (Natural gas),

Send to:

m.akai@aist.go.jp

By June 10