Global Environmental Policy

November 30, 2009:
- Overview
- Challenges and strategies towards Deep GHG Reduction

December 07, 2009:
- Reporting and Discussion

Makoto Akai
National Institute of Advanced Industrial Science and Technology

Recent Findings on Climate Change

IPCC 3rd Assessment Report (TAR) Suggestions
WG1:Scientific Basis-SPM

- An increasing body of observations gives a collective picture of a warming world and other changes in the climate system,
- There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities,
- Human influences will continue to change atmospheric composition throughout the 21st century.

IPCC 3rd Assessment Report (TAR) Suggestions
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.

IPCC 4th Assessment Report (AR4)
Direct Observations of Recent Climate Change

- **Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level.**

IPCC 4th Assessment Report (AR4)
Understanding and Attributing Climate Change

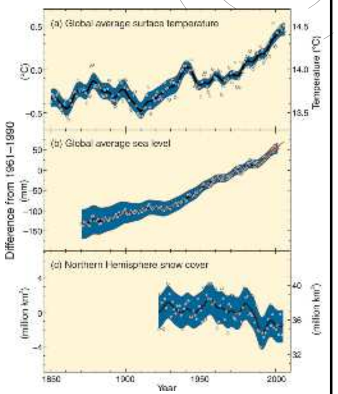
- **Most of the observed increase in global average temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic greenhouse gas concentrations.**
  - **This is an advance since the TAR's conclusion that "most of the observed warming over the last 50 years is *likely* to have been due to the increase in greenhouse gas concentrations".**

NOTE: *Virtually certain* > 99% probability of occurrence, *Extremely likely* > 95%, *Very likely* > 90%, *Likely* > 66%, *More likely than not* > 50%, *Unlikely* < 33%, *Very unlikely* < 10%, *Extremely unlikely* < 5%

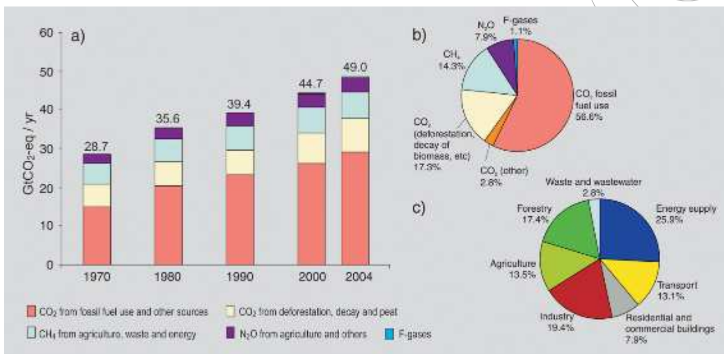
Observations of Climate Change

Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level

- **GRAPH: Observed changes in (a) global average surface temperature; (b) global average sea level from tide gauge (blue) and satellite (red) data; and (c) Northern Hemisphere snow cover for March-April.**
  - **All differences are relative to corresponding averages for the period 1961-1990.**
  - **Smoothed curves represent decadal averaged values while circles show yearly values. The shaded areas are the uncertainty intervals estimated from a comprehensive analysis of known uncertainties (a and b) and from the time series (c).**

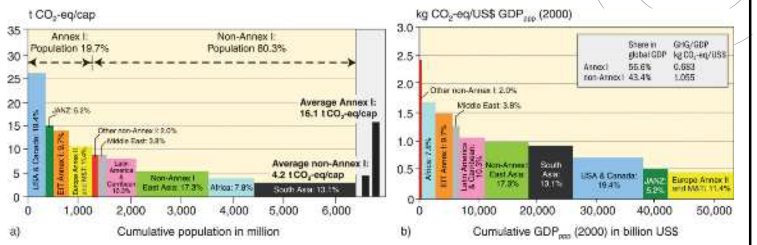


Global Anthropogenic GHG Emissions



- **Global GHG emissions due to human activities have grown since pre-industrial times, with an increase of 70% between 1970 and 2004**

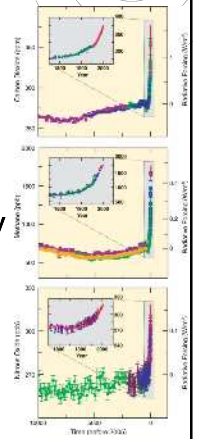
Regional Distribution of GHG Emissions by Population and by GDP



- **Differences in per capita income, per capita emissions and energy intensity among countries remain significant. In 2004, UNFCCC Annex I countries held a 20% share in world population, produced 57% of the world's Gross Domestic Product based on Purchasing Power Parity (GDP_{PPP}) and accounted for 46% of global GHG emissions**

Changes in Atmospheric GHG Concentrations

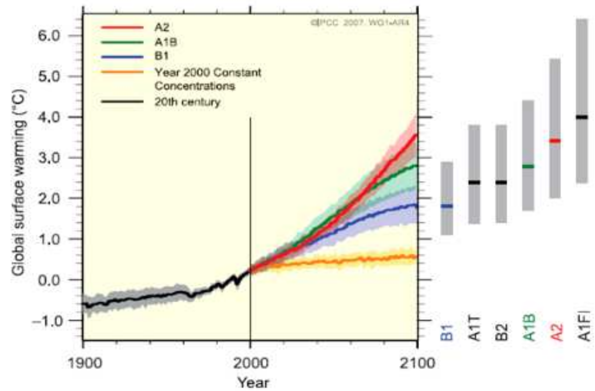
- **Global atmospheric concentrations of CO_2, CH_4 and N_2O have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years.**
- **The atmospheric concentrations of CO_2 and CH_4 in 2005 exceed by far the natural range over the last 650,000 years.**
- **Global increases in CO_2 concentrations are due primarily to fossil fuel use, with land-use change providing another significant but smaller contribution.**
- **It is *very likely* that the observed increase in CH_4 concentration is predominantly due to agriculture and fossil fuel use.**
- **The increase in N_2O concentration is primarily due to agriculture.**



IPCC 4th Assessment Report (AR4)
Projections of Future Changes in Climate

- **For the next two decades, a warming of about 0.2°C per decade is projected for a range of SRES emission scenarios. Even if the concentrations of all greenhouse gases and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected.**
- **Continued greenhouse gas emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would *very likely* be larger than those observed during the 20th century.**

Ranges for Predicted Warming



NOTE: Both past and future anthropogenic carbon dioxide emissions will continue to contribute to warming and sea level rise for more than a millennium, due to the time scales required for removal of this gas from the atmosphere and to the slow response of the oceans.

IPCC 4th Assessment Report (AR4)
Projections of Future Changes in Climate

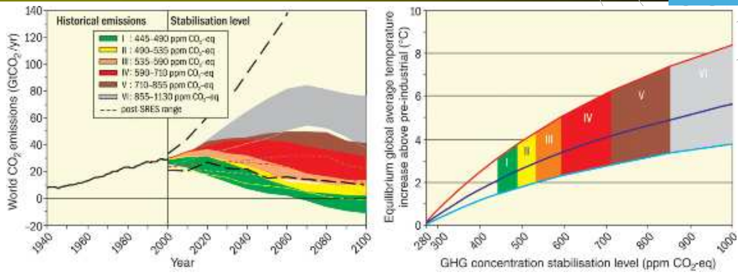
- **Increasing atmospheric carbon dioxide concentrations lead to increasing acidification of the ocean. Projections based on SRES scenarios give reductions in average global surface ocean pH of between 0.14 and 0.35 units over the 21st century, adding to the present decrease of 0.1 units since pre-industrial times.**

IPCC 4th Assessment Report (AR4)
Long Term Mitigation (after 2030)

- **Mitigation efforts over the next two to three decades will have a large impact on opportunities to achieve lower stabilization levels**

Stab level (ppm CO_2-eq)	Global Mean temp. increase at equilibrium (°C)	Year global CO_2 needs to peak	Year global CO_2 emissions back at 2000 level	Reduction in 2050 global CO_2 emissions compared to 2000
445 - 490	2.0 - 2.4	2000 - 2015	2000- 2030	-85 to -50
490 - 535	2.4 - 2.8	2000 - 2020	2000- 2040	-60 to -30
535 - 590	2.8 - 3.2	2010 - 2030	2020- 2060	-30 to +5
590 - 710	3.2 - 4.0	2020 - 2060	2050- 2100	+10 to +60
710 - 855	4.0 - 4.9	2050 - 2080		+25 to +85
855 - 1130	4.9 - 6.1	2060 - 2090		+90 to +140

CO_2 Emissions and Equilibrium Temperature Increases for a Range of Stabilisation Levels



- **In order to stabilise the concentration of GHGs in the atmosphere, emissions would need to peak and decline thereafter.**
- **The lower the stabilisation level, the more quickly this peak and decline would need to occur.**
- **Mitigation efforts over the next two to three decades will have a large impact on opportunities to achieve lower stabilisation levels**

IPCC 4th Assessment Report (AR4)
How can Emissions be Reduced?

Sector	Key mitigation technologies and practices currently commercially available. (Selected)	Key mitigation technologies and practices projected to be commercialized before 2030. (Selected)
Energy Supply	efficiency; fuel switching; nuclear power; renewable (hydropower, solar, wind, geothermal and bioenergy); combined heat and power; early applications of CO2 Capture and Storage (CCS)	CCS for gas, biomass and coal-fired electricity generating facilities; advanced nuclear power; advanced renewables (tidal and waves energy, concentrating solar, solar PV)
Transport	…	…

Costs of Mitigation

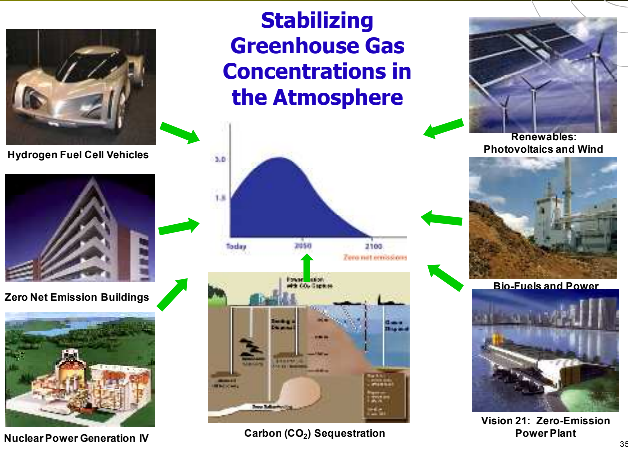
Stabilisation levels (ppm CO_2-eq)	Median GDP reduction[a] (%)		Range of GDP reduction[b] (%)		Reduction of average annual GDP growth rates (percentage points)[c,e]	
	2030	2050	2030	2050	2030	2050
445 – 535[d]	Not available		<3	<5.5	< 0.12	< 0.12
535 – 590	0.6	1.3	0.2 to 2.5	slightly negative to 4	< 0.1	< 0.1
590 – 710	0.2	0.5	-0.6 to 1.2	-1 to 2	< 0.06	< 0.05

Notes: Values given in this table correspond to the full literature across all baselines and mitigation scenarios that provide GDP numbers.
a) Global GDP based on market exchange rates.
b) The 10th and 90th percentile range of the analysed data are given where applicable. Negative values indicate GDP gain. The first row (445-535ppm CO2-eq) gives the upper bound estimate of the literature only.
c) The calculation of the reduction of the annual growth rate is based on the average reduction during the assessed period that would result in the indicated GDP decrease by 2030 and 2050 respectively.
d) The number of studies is relatively small and they generally use low baselines. High emissions baselines generally lead to higher costs.
e) The values correspond to the highest estimate for GDP reduction shown in column three.

- **The macro-economic costs of mitigation generally rise with the stringency of the stabilisation target and are relatively higher when derived from baseline scenarios characterised by high emission levels.**
- **There is *high agreement and medium evidence that in 2050 global* average macro-economic costs for multi-gas mitigation towards stabilisation between 710 and 445ppm CO_2-eq are between a 1% gain to a 5.5% decrease of global GDP**

Towards a Deep Reduction of Greenhouse Gas

The Technology Challenge

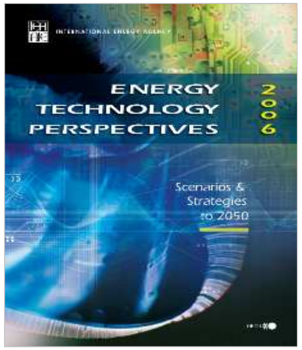


Technological Options for Deep Reduction of GHG Emissions

- **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.**

Energy Technology Perspectives
Scenarios and Strategies to 2050

In support of the G8 Plan of Action



IEA: International Energy Agency

Energy Technology Perspectives Presents

- **Status and perspectives for key energy technologies in:**
  - **Power Generation**
  - **Transport**
  - **Buildings and Appliances**
  - **Industry**
- **Global scenarios to illustrate potentials for different technologies under accelerated policies**
- **Strategies for helping key technologies make a difference**

Key Findings

- **Current policies will not bring us on a path towards a sustainable energy future**
- **A more sustainable energy future is possible with a portfolio of clean and efficient technologies**
- **Using technologies that have an additional cost of less than 25 \$/tonne CO_2 avoided:**
  - **Global CO_2 emissions can be returned to today's level by 2050**
  - **Expected growth in both oil and electricity demand can be halved**
- **Requires urgent action to promote, develop and deploy a full mix of energy technologies**
- **Collaboration between developing and developed nations will be essential**

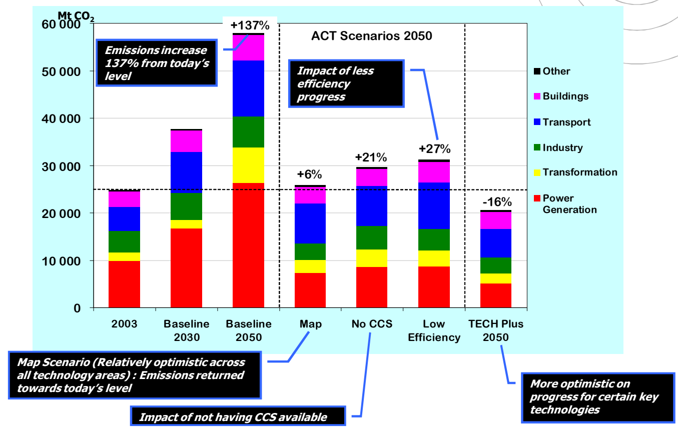
Scenario Analysis

- **Scenarios analysed:**
  - **Baseline Scenario**
  - **Accelerated Technology Scenarios (ACT)**
  - **TECH Plus scenario**
- **ACT and TECH Plus scenarios:**
  - **Analyse the impact from R&D, Demonstration and Deployment measures**
  - **Incentives equivalent to 25 \$/tonne CO_2 for low-carbon technologies implemented world-wide from 2030 and on**
  - **Individual scenarios differ in terms of assumptions for key technology areas**

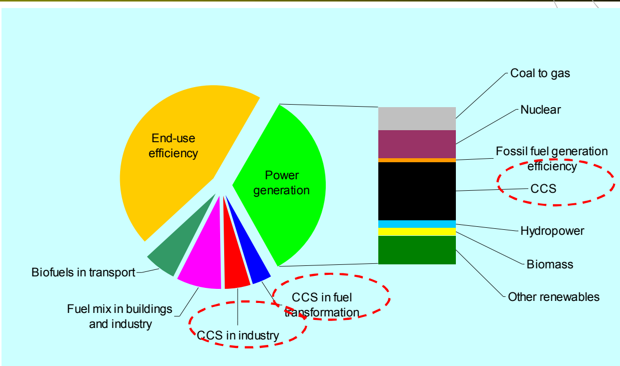
Technology Assumptions

Scenario	Renewables	Nuclear	CCS	H_2 fuel cells	Advanced biofuels	End-use efficiency
ACT Map			Relatively optimistic across all technology areas			2.0 % p.a. global improvement
ACT Low Renewables	Slower cost reductions					
ACT Low Nuclear		Lower public acceptance				
ACT No CCS			No CCS			
ACT Low Efficiency						1.7 % p.a. global improvement
TECH Plus	Stronger cost reductions	Stronger cost reductions & technology improvements		Break-through for FC	Stronger cost reductions & improved feedstock availability	

Global CO_2 Emissions 2003-2050
Baseline, ACT and TECH plus Scenarios



Emission Reduction by Technology Area
ACT Map Scenario

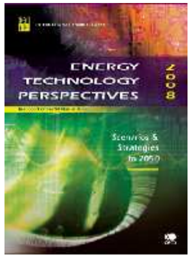


Improved energy efficiency most important contributor to reduced emissions

Electricity Generation
CO_2 Capture and Storage a Key Option

- **CCS is crucial for the role coal can play in a CO_2 constrained world – without CCS coal-fired generation in 2050 drops below today's level**
- **By 2050 more than 5 000 TWh electricity globally can be produced by coal-plants equipped with CCS**
- **There is an urgent need for more R&D and for full-scale CCS demonstration plants**
- **Generation from renewables can quadruple by 2050**
- **Nuclear can gain a much more important role in countries where it is acceptable**

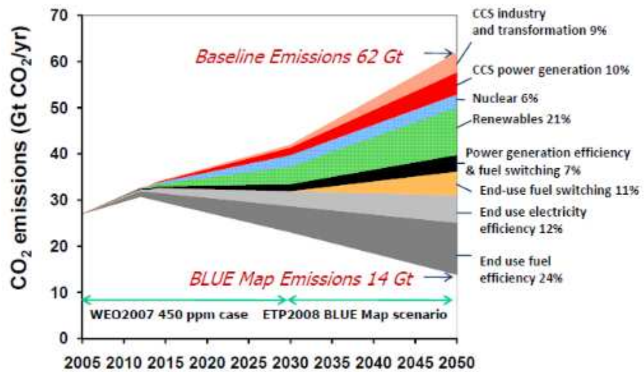
IEA
Energy Technology Perspectives 2008



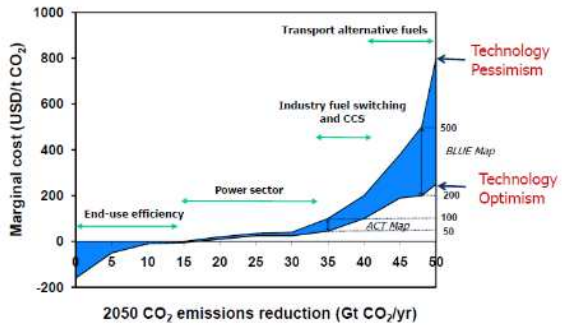
Scenarios in ETP2008

- **ACT Scenarios**
  - **Energy CO_2 emissions in 2050 back to the level of 2005**
  - **Revision of ACT as published in ETP2006**
    - **Options with a marginal cost up to $50/t$CO_2$ – worldwide (+$20/bbl)**
    - **Cost estimate has doubled from ETP2006**
  - **This implies a significantly adjusted energy system**
- **BLUE Scenario**
  - **-50% energy related CO_2 in 2050, compared to 2005**
  - **This could be consistent with 450 ppm (depending on post-2050 emissions)**
  - **Options with a marginal cost of up to $200/t$CO_2$ needed (+$80/bbl)**
    - **Significantly higher cost with less optimistic assumptions**
  - **Blue is uncertain, therefore a number of cases needed**
  - **Blue is only possible if the whole world participates fully**
  - **This implies a completely different energy system**

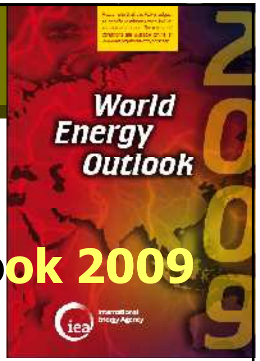
ETP2008
CO_2 Emission Reduction Scenario



ETP2008
Cost of Emissions Reductions



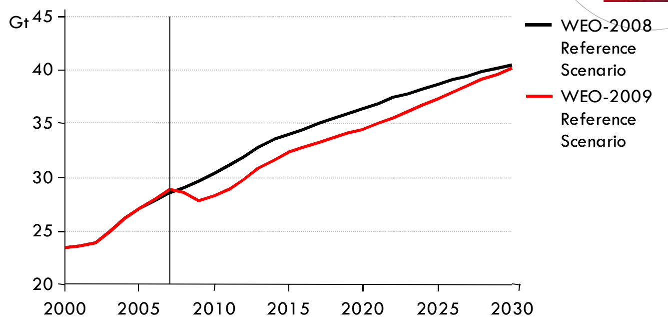
- **To bring emissions back to current levels by 2050 options with a cost up to USD 50/t are needed.**
- **Reducing emissions by 50% would require options with a cost up to USD 200/t (+80 USD/bbl oil) , possibly even up to USD 500/t CO_2**



World Energy Outlook 2009

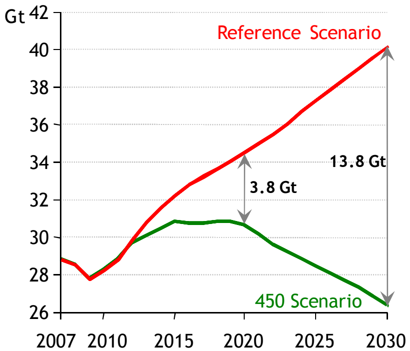
International Energy Agency (IEA)

World's Energy-related CO_2 Emissions in the Reference Scenario in WEO-2009 and WEO-2008



- **In cumulative terms between today and 2030, emissions are 35 Gt lower than in WEO-2008. 75% of this reduction is due to the impact of the financial crisis and 25% to new policies**

The 450 Scenario: Energy-related CO_2 Emissions Compared to the Reference Scenario

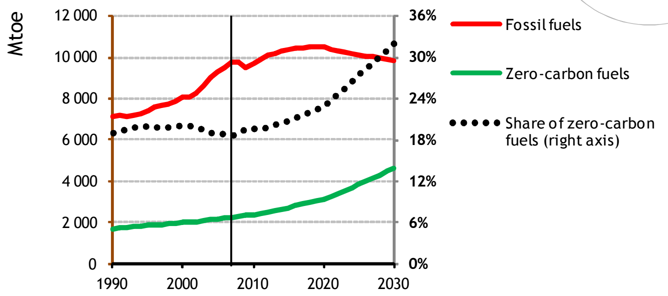


- **In the 450 Scenario, emissions peak before 2020 at 30.9 Gt, falling to 26.4 Gt by 2030**

Policy Mechanisms in the 450 ppm Scenario

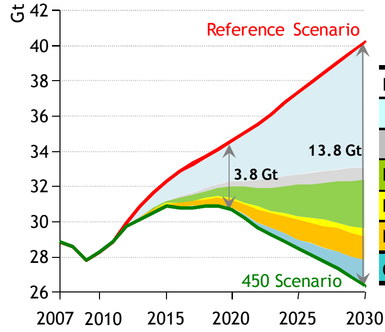
- **A combination of policy mechanisms, which best reflects nations' varied circumstances & negotiating positions**
- **We differentiate on the basis of three country groupings**
  - **OECD+: OECD and other non-OECD EU countries**
  - **Other Major Economies (OME): China, Russia, Brazil, South Africa and Middle East**
  - **Other Countries (OC): all other countries, including India**
- **Three types of policy mechanism**
  - **National policies & measures**
  - **Sectoral agreements for iron & steel, cement, passenger vehicles, aviation & shipping**
  - **Cap-and-trade for some countries in power generation & industry**
- **A graduated approach**
  - **Up to 2020, only OECD+ have national emissions caps**
  - **After 2020, Other Major Economies are also assumed to adopt emissions caps**

World's Primary Energy Demand by Fuel in the 450 Scenario



- **In the 450 Scenario, demand for fossil fuels peaks by 2020, and by 2030 zero-carbon fuels make up a third of the world's primary sources of energy demand**

World's Abatement of Energy-related CO_2 Emissions in the 450 Scenario



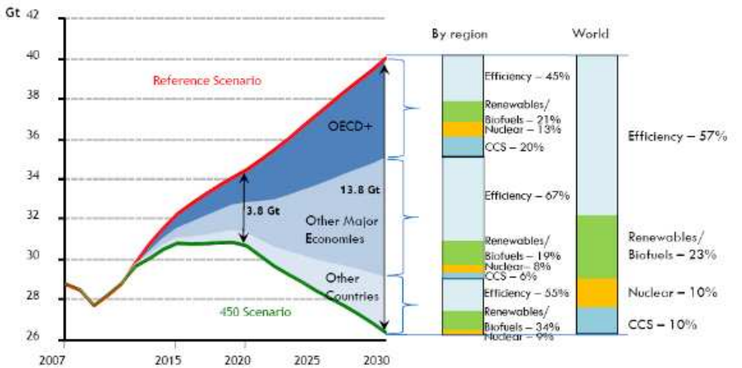
Share of abatement %

	2020	2030
Efficiency	65	57
End-use	59	52
Power plants	6	5
Renewables	18	20
Biofuels	1	3
Nuclear	13	10
CCS	3	10

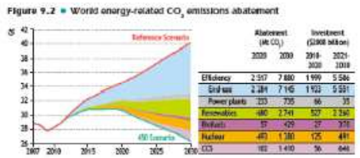
- **Efficiency measures account for two-thirds of the 3.8 Gt of abatement in 2020, with renewables contributing close to one-fifth**

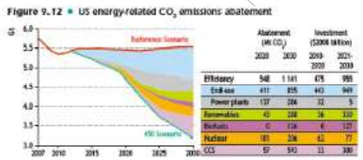
World's Abatement of Energy-related CO_2 by Regions

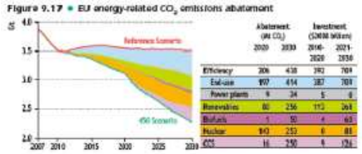
Source: Early excerpt of WEO 2009 for Bangkok UNFCCC meeting

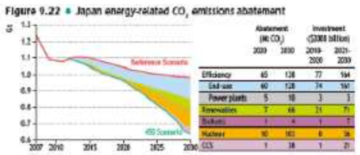


Some Regional Scenarios for Abatement of Energy-related CO_2

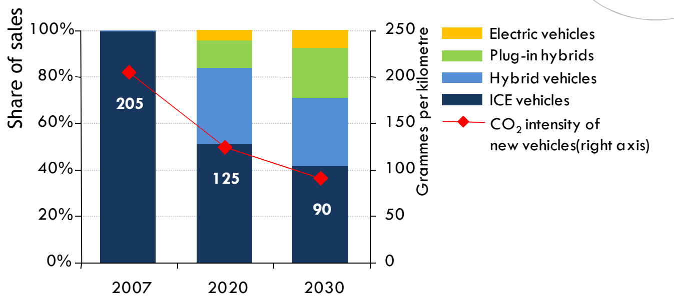

World


USA


EU


Japan

World Passenger Vehicle Sales by Technology & Average New Vehicle CO_2 Intensity in the 450 ppm Scenario



- **Improvements to the internal combustion engine and the uptake of biofuels and next-generation vehicles lead to an 80g/km reduction in new-car emissions by 2020**

Benefits of the 450 Scenario

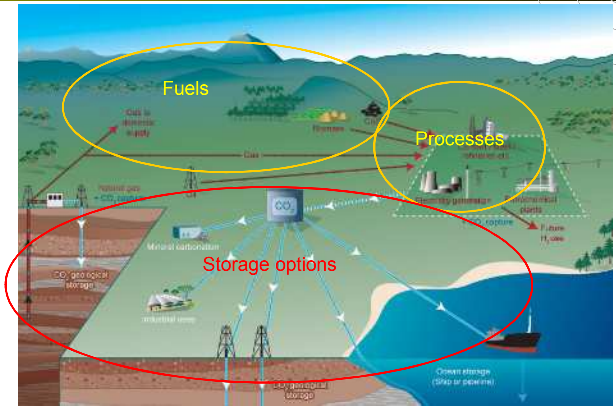
- **Avoiding the worst impacts of climate change**
- **Energy bills in industry, transport & buildings reduced by a total of $8.6 trillion between 2010 and 2030**
  - **Savings in transport alone account for $6.2 trillion**
- **Energy-security benefits and reduced oil & gas imports**
  - **For OECD countries, oil imports are 7 mb/d lower in 2030 than in 2008**
  - **In China & India, oil imports by volume are around 10% lower than in the Reference Scenario; China's gas imports are 23% lower**
- **Sharp reduction in air pollution relative to the Reference Scenario**
  - **In 2030, SO2 emissions are 29% lower than in the Reference Scenario; NOx emissions are 19% lower & emissions of particulate matter 9% lower**
  - **$100 billion of pollution control savings in 2030 & substantial health benefits**

Conclusions – WEO 2009

- **The Reference Scenario puts us on course for 1,000 ppm – a 6°C temperature rise - but the financial crisis has created a unique window of opportunity**
- **Meeting a 450 ppm Scenario is achievable but requires a wholesale transformation of the way we produce & use energy**
- **The investment needs are substantial, but there will be major benefits in terms of fuel savings, enhanced energy security & reduced air pollution**
- **Financial support holds the key, as many of the abatement options are in non-OECD countries**
- **A deal in Copenhagen is crucial – every year of delay adds $500bn to the energy sector's mitigation costs between today & 2030**
- **The energy sector can lead the way and must be at the heart of a Copenhagen agreement**

CO_2 Capture and Storage
or
CO_2 Capture and <u>Sequestration</u>
(CCS)

CO_2 Capture and Storage System



Source: IPCC SRCCS

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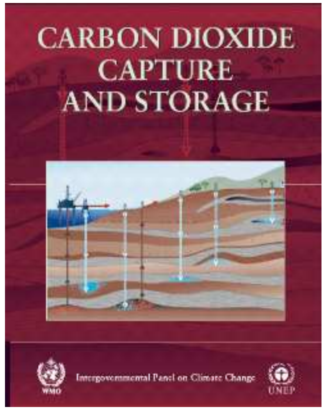
The IPCC Special Report on Carbon Dioxide Capture and Storage



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Structure of the Report

1. **Introduction**
2. **Sources of CO_2**
3. **Capture of CO_2**
4. **Transport of CO_2**
5. **Geological storage**
6. **Ocean storage**
7. **Mineral carbonation and industrial uses**
8. **Costs and economic potential**
9. **Emission inventories and accounting**

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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**

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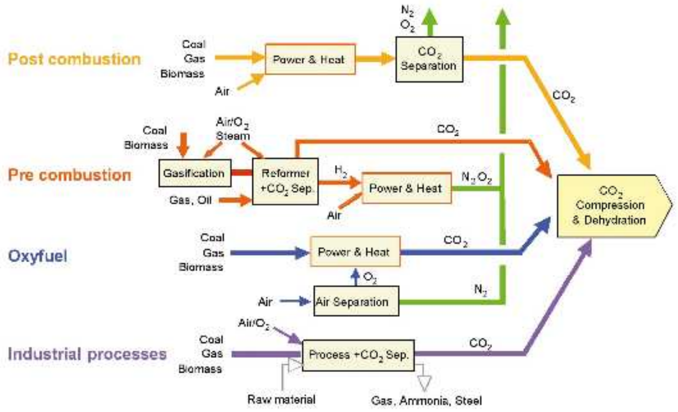
Capture of CO_2

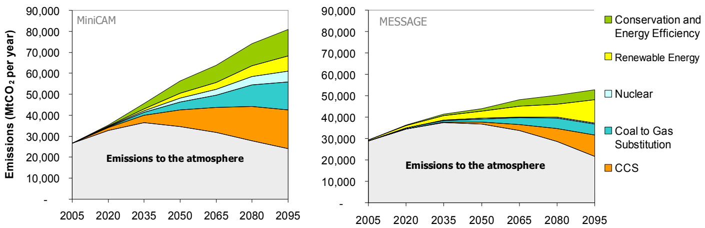


Source: IPCC SRCCS

CO_2 sources

- **Large stationary point sources**
- **High CO_2 concentration in the waste, flue gas or by-product stream (purity)**
- **Pressure of CO_2 stream**
- **Distance from suitable storage sites**

Economic Potential



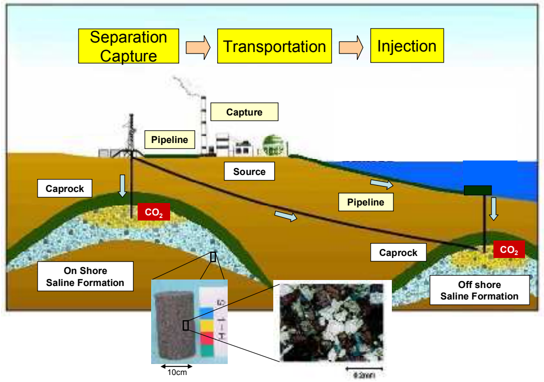
Economic Potential

- **Cost reduction of climate change stabilisation: 30% or more**
- **Most scenario studies: role of CCS increases over the course of the century**
- **Substantial application above CO2 price of 25-30 US$/t$CO_2$**
- **15 to 55% of the cumulative mitigation effort worldwide until 2100, depending on the baseline scenario, stabilisation level (450 - 750 ppmv), cost assumptions**
- **220 - 2,200 GtCO_2 cumulatively up to 2100**

Storage Potential

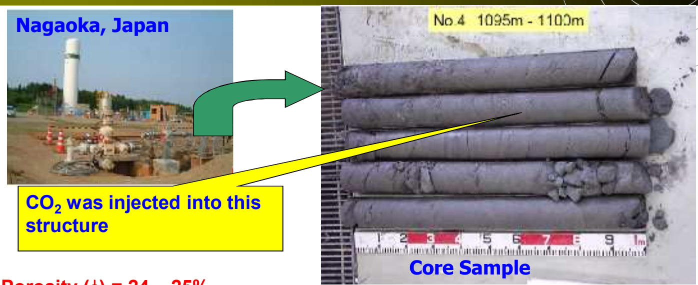
- **Geological storage: likely at least about 2,000 $GtCO_2$ in geological formations**
  - *"Likely" is a probability between 66 and 90%.*
  - **Oil/gas fields: 675 - 900 $GtCO_2$**
  - **Saline formations: 1000 - ~ 10^4 $GtCO_2$**
  - **Coal beds: 3 - 200 $GtCO_2$**
- **Ocean storage: on the order of thousands of $GtCO_2$, depending on environmental constraints**

Schematic of Geological Storage - Saline Formation -



- **CO_2 will not be injected into a cavern!**

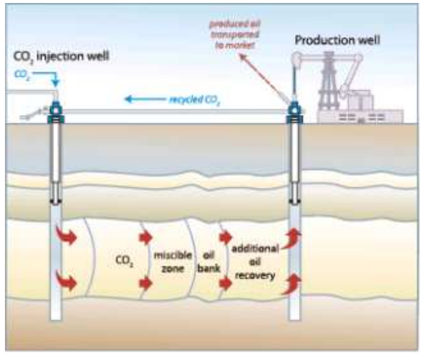
Experimental Site and Core Sample



Porosity (ϕ) = 24 ~ 25%

- Porosity describes how densely the material is packed, and defined by the proportion of the non-solid volume to the total volume
- Examples:
  - ϕ < 1% for solid granite;
  - ϕ > 50% for peat and clay

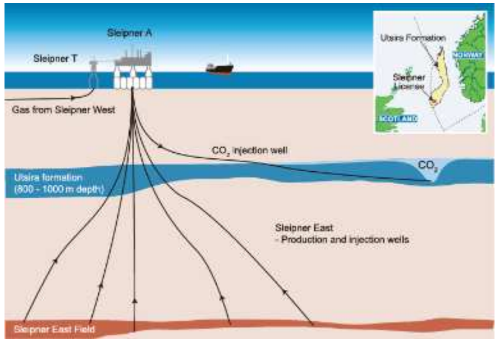
Injection of CO_2 for Enhanced Oil Recovery (EOR)



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.

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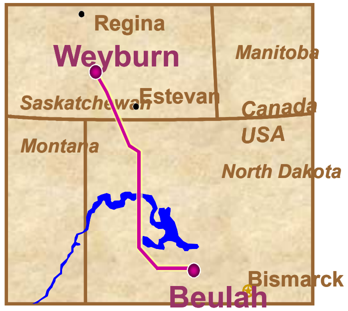
Weyburn CO_2-EOR Project.



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.

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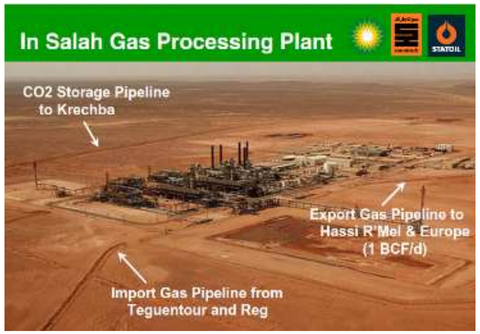
In Salah Gas Project, Algeria.



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.

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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…

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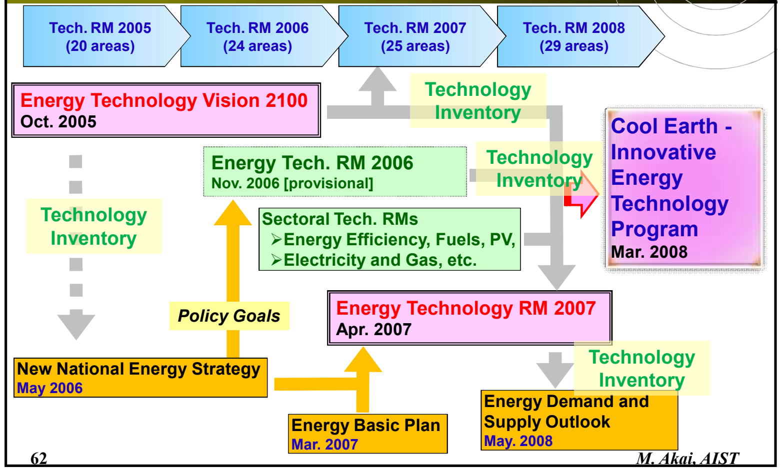
Recent Development of Energy Strategy in Japan (METI)

Recent Development in Energy Policy
Energy Technology Roadmapping



Energy Technology Vision 2100
Agency for Natural Resources and Energy
Ministry of Economy, Trade and Industry

- **An approach to LCS from Energy Policy**
- **Purpose**
  - **To establish strategic energy R&D plan by**
    - **identifying technologies and developing technology portfolio to prepare for resource and environmental constraints**
    - **considering optimum R&D resource allocation in METI**
- **Timeframe:**
  - **Vision and Technology roadmap: - 2100**

⇒http://www.iae.or.jp/2100.html

Why to consider Ultra 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**

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

Methodology - Backcasting

Exploratory (opportunity-oriented):

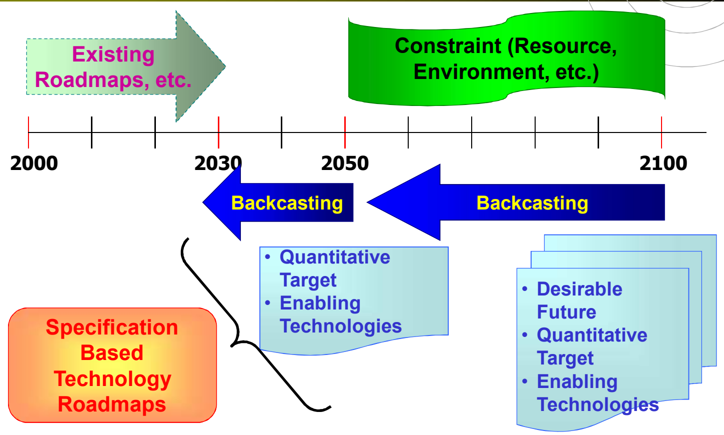
- *what futures are likely to happen? ⇒ Forecasting*
  - starts from today's assured basis of knowledge and is oriented towards the future

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



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.
- Not to set preference to specific technology such as hydrogen, distributed system, biomass, etc.

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.**

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Definition of 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**

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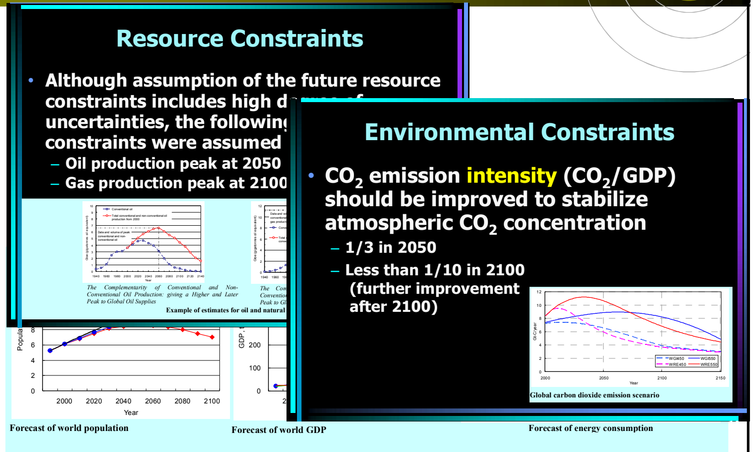
Assumptions towards 2100



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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

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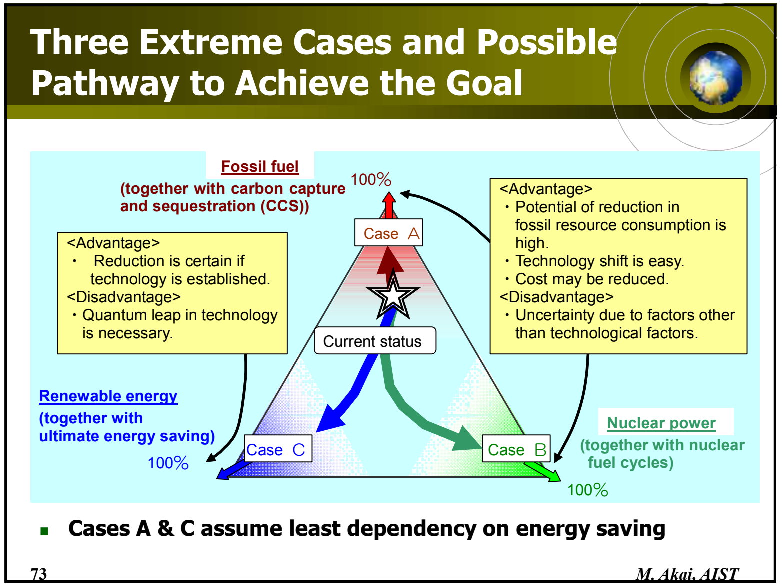

Three Extreme Cases and Possible Pathway to Achieve the Goal
Fossil fuel
(together with carbon capture and sequestration (CCS))
100%
Case A
<Advantage>
・ Reduction is certain if technology is established.
<Disadvantage>
・Quantum leap in technology is necessary.
<Advantage>
・Potential of reduction in fossil resource consumption is high.
・Technology shift is easy.
・Cost may be reduced.
<Disadvantage>
・Uncertainty due to factors other than technological factors.
Current status
Renewable energy
(together with ultimate energy saving)
100%
Case C
Case B
Nuclear power
(together with nuclear fuel cycles)
100%
Cases A & C assume least dependency on energy saving
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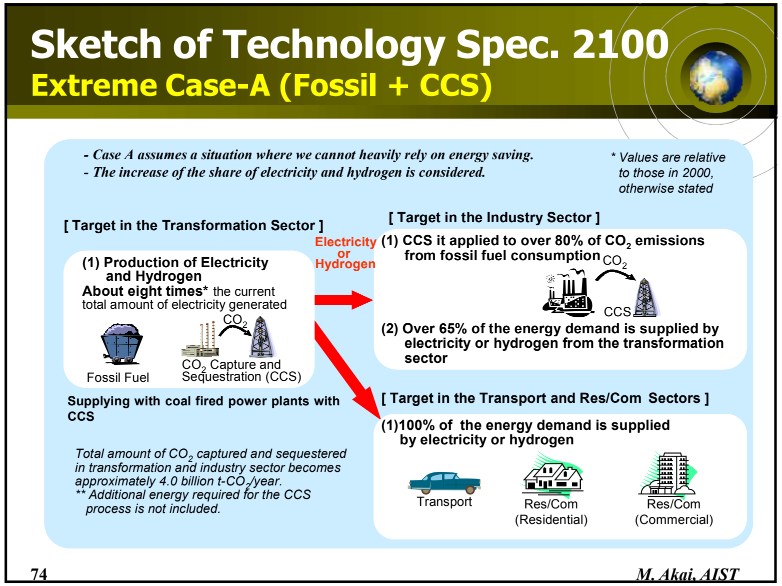

Sketch of Technology Spec. 2100
Extreme Case-A (Fossil + CCS)
- Case A assumes a situation where we cannot heavily rely on energy saving.
- The increase of the share of electricity and hydrogen is considered.
* Values are relative to those in 2000, otherwise stated
[Target in the Transformation Sector]
(1) Production of Electricity and Hydrogen
About eight times* the current total amount of electricity generated
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
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
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.
Transport
Res/Com (Residential)
Res/Com (Commercial)
74
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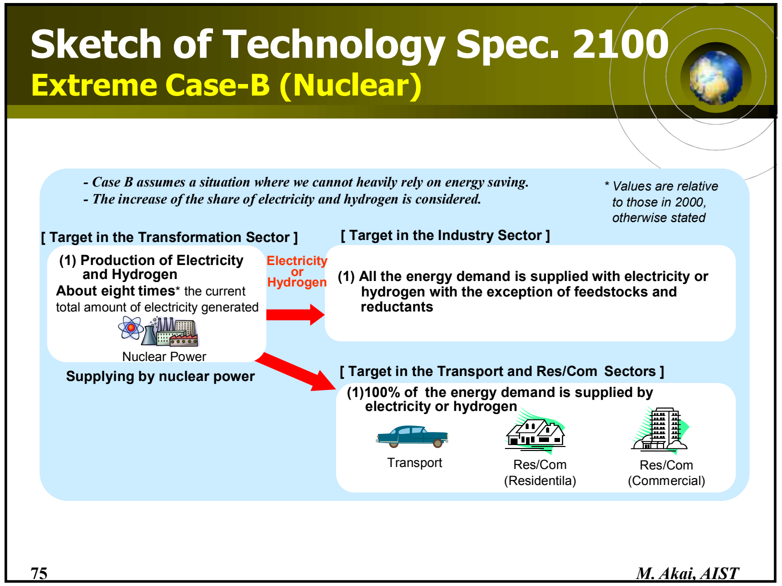

Sketch of Technology Spec. 2100
Extreme Case-B (Nuclear)
- Case B assumes a situation where we cannot heavily rely on energy saving.
- The increase of the share of electricity and hydrogen is considered.
* Values are relative to those in 2000, otherwise stated
[Target in the Transformation Sector]
(1) 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)
75
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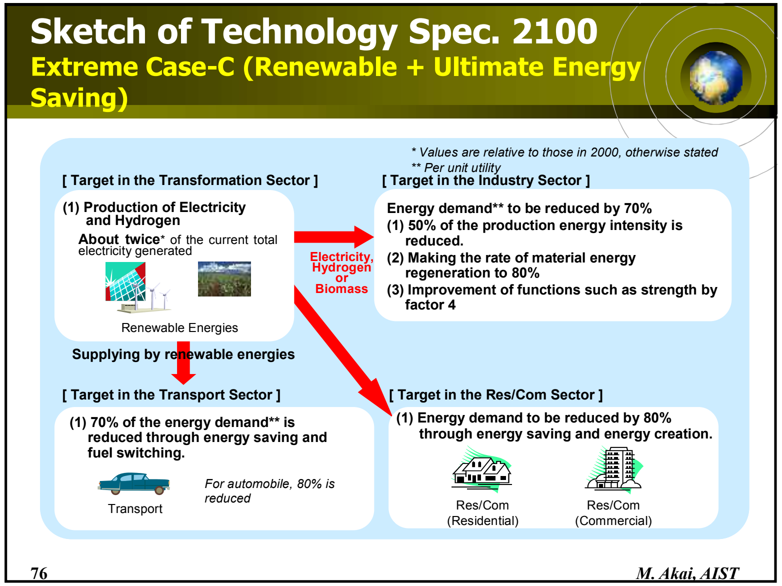

Sketch of Technology Spec. 2100
Extreme Case-C (Renewable + Ultimate Energy Saving)
* Values are relative to those in 2000, otherwise stated
** Per unit utility
[Target in the Transformation Sector]
(1) Production of Electricity and Hydrogen
About twice* of the current total electricity generated
Renewable Energies
Supplying by 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
[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)
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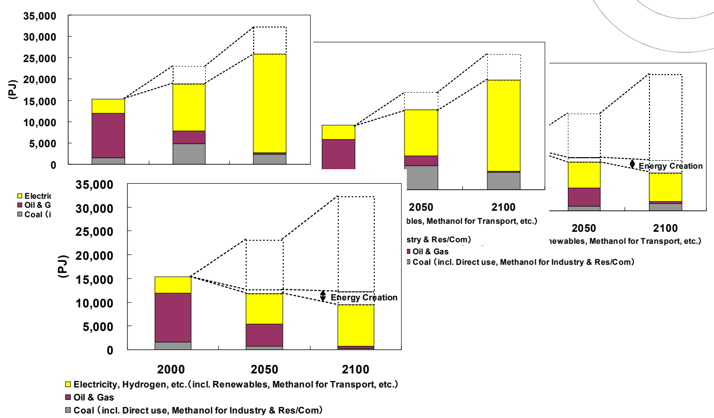
Development of Technology Roadmaps

- Target sectors:
  - Residential and Commercial
  - Transportation
  - Industry
  - Transformation (Energy supply)
- Summary roadmap
  - Target specifications and milestones
  - Typical technologies
- Detailed roadmaps
  - Technology breakdown for sub-sectors

Important Cross-Boundary Technologies

- Once a cross-boundary technology is established, it can work effectively in a wide range of applications. Here, the following technologies are identified:
  - Energy-saving technologies
  - Energy storage technologies
  - Power electronics technologies
  - Gasification technologies
  - Energy management technologies

Verification by Scenario Analysis using Energy Models



Possible Solution with the Combination of Three Cases (2/2)

- ... combination of these cases can vary according to situations in the future. It is **important to prepare technologies** through R&D for social and economic changes at various occasions in the future.
- As a result, we can acquire an optimal and robust energy system structure...
- Also, if we prepare for the three extreme cases ..., their synergy effect enables the reduction of fossil resources consumption and CO_2 emissions...

Implications on Specific Technology Areas

- **Hydrogen**
  - Important as an energy storage medium, especially when energy supply dominated by renewable resources.
- **Biomass**
  - Contribution to transformation sector (power generation and hydrogen production) is relatively small.
  - Mainly used in industrial sector as a carbon free resource containing carbon.
- **CO_2 Capture and Sequestration (CCS)**
  - Important as a short or mid-term option (fossil power plants, industries, hydrogen production) by increasing the flexibility of energy supply and demand structure with moderate cost.

Possible Solution with the Combination of Three Cases (1/2)

- ... capacity for geological sequestration is considered to have limitations. We have to consider ocean sequestration to satisfy the required capacity ...
- Case A (fossil + CCS) cannot be a long-term solution due to the limitation of fossil resources. Therefore, the combination of case C (renewable + energy-saving) and case B (nuclear) is desirable ... on a long-term basis, by avoiding rapid climate change by CCS as required on a mid-term basis.

Possible ETV 2100 Scenario
- Combination of 3 Cases -

- One of the reasonable solutions for sustainable society is a combination of the case A (in short or middle term, reduce atmospheric CO_2 by CCS), C (in long-term, utilize renewables to the maximum beside ultimate energy-saving) and B (stable operation of nuclear power plants).
- However, appropriate combination of each case may change according to the future situation, so it is important to judge R&D priority based on the future social and economical situation or status of technology progress.

Implications on Future Scenario

- Energy efficiency is the key!
- Case-A "Fossil + CCS" would contribute to deep reduction of CO_2 and hydrogen economy but might not be a truly 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 with moderate cost.

Cool Earth - Innovative Energy Technology Program

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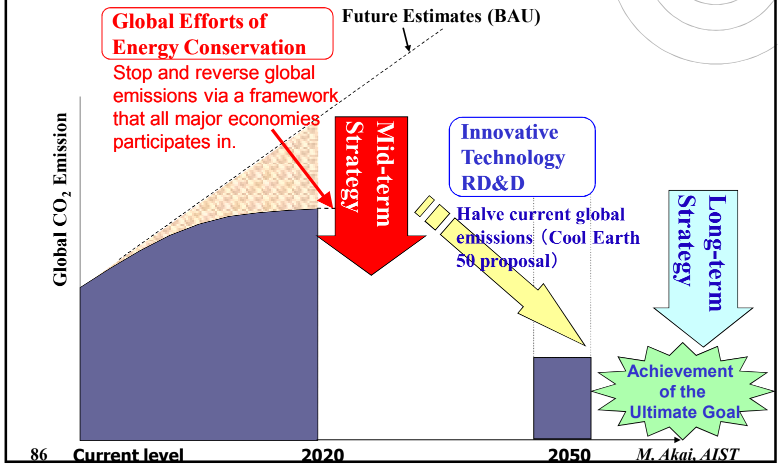
Proposal by Japan's Prime Minister (May 24, 2007)



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Cool Earth- Innovative Energy Technology Program

METI developed "Cool Earth - Innovative Energy Technology Program" to address substantial GHG reduction in the long-term through innovative energy technologies RD&D. (March 5, 2008)

- **Identified 21 key energy technologies to be focused on with high priority.**
- **Formulated technology roadmaps for them, which give RD&D direction and milestones on performance with timelines, and propose further development of global technology roadmaps to monitor global RD&D progress**
- **Strengthen international cooperation to accelerate innovative technology RD&D.**

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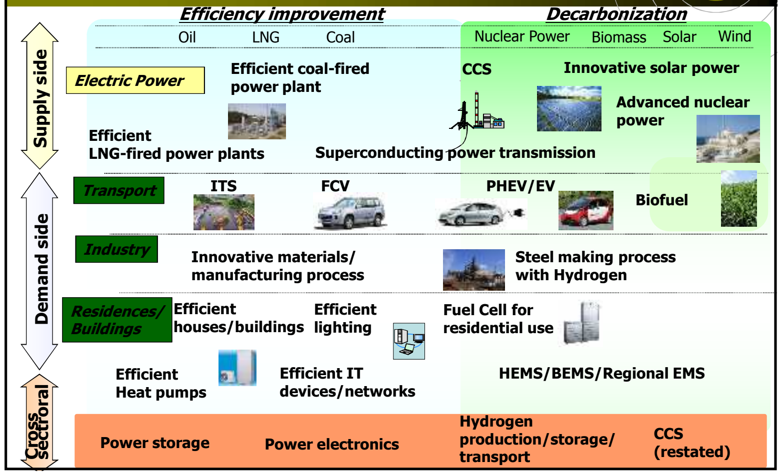
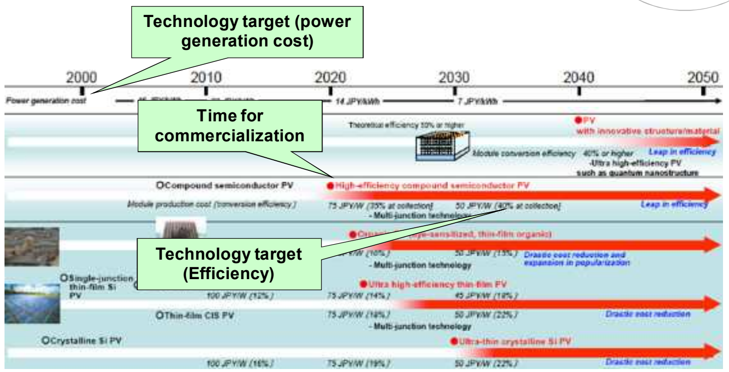
21 Key Innovative Energy Technologies

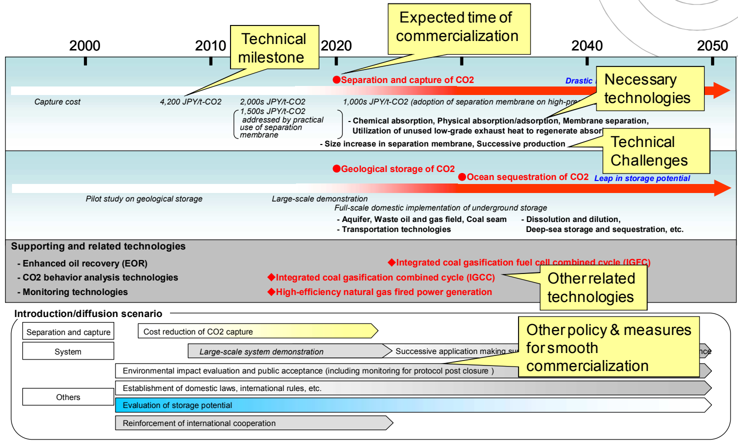


Technology Roadmaps toward 2050
Example on PV

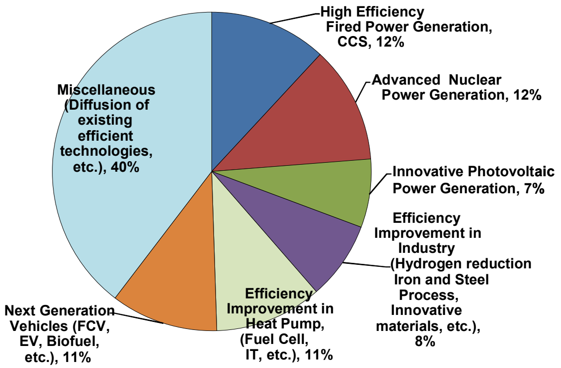
An image of our technology roadmap for innovative PV



Example of Technology Roadmap on CCS



Contribution of Technologies for 50 % Emission Reduction in 2050



Source: Institute of Applied Energy

- 21 innovative technologies contribute to nearly 60% of the necessary reductions for the 50% of emission reduction.
- Technologies for power generation and transportation sectors have relatively large contributions, but it is necessary to address all sectors.

Need for International Action

1. **Expanding RD&D investment by developed countries**
   – Urging developed countries to expand investment for research, development and deployment (RD&D) of innovative technologies
2. **Developing and sharing technology roadmaps**
   – Developing and sharing technology development roadmaps for key innovative energy technologies with the support of the IEA, in order to accelerate their RD&D systematically with making use of strengths of each country
3. **Strengthening international cooperation in each technology**
   – Strengthening existing international RD&D for several technology fields, and exploring new fields, with sharing the progress of each technological development

Outcome of G8 Meetings (2008)
Innovative Energy Technologies

- **Energy Ministers Meeting of G8, The People's Republic of China, India and The Republic of Korea**
  - **We should collectively endeavor to increase energy RD&D according to national circumstances**
  - **Those of us interested will take the initiative to accelerate efficient and lower carbon technology RD&D by using relevant structures within the IEA and the technology development roadmaps for key technologies prepared by the IEA and countries; assessing the current status of existing international partnerships for technology cooperation; and exploring the need for additional ones, along with the IEA non-Member partners and other entities and relevant partnerships, and invite interested major economies to join in these efforts.**
- **G8 Toyako Summit on 7-9 July 2008**
  - **G8 members have so far pledged over the next several years over US$10 billion annually in direct government-funded R&D**
  - **We will establish an international initiative with the support of the IEA to develop roadmaps for innovative technologies and cooperate upon existing and new partnerships**

Accelerating Global RD&D Technology Roadmapping

The EU, U.S. and Japan have already taken substantial steps:

Europe Strategic Energy Technology Plan (2007)
Climate Change Technology Plan (2006)
Energy Technology Strategy (2007)
Cool Earth -Innovative Energy Technology Program (2008)
Energy Technology Perspective 2008"

Sharing of the long-term roadmaps of energy technologies
- To ensure global efforts and promote steady progress through reviewing technology progress based on the common roadmaps
- To identify areas of focus where further global efforts or cooperation is needed, by clarifying the gap between what has been done and what is needed, based on common roadmaps
- To strengthen existing international cooperation and establish new international cooperation, if needed

Developing and Sharing Technology Roadmaps

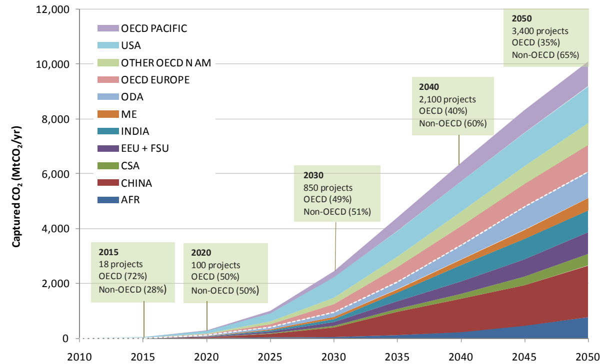
- **Initial action:**

IEA Workshop on
Energy Technology Roadmaps
15 - 16 May 2008
International Energy Agency, Paris

- **Activities will be undertaken through the meeting of CERT(Committee of Energy Research and Technology) and Expert group for R&D priority setting of IEA from to deepen our consideration for common technology roadmaps, and develop roadmaps we can share globally by 2010 as Energy Technology Perspective 2010.**

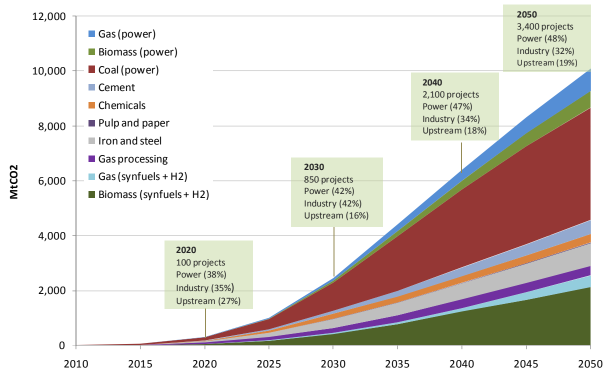
IEA CCS Roadmap
Global Deployment of CCS 2010–50 by Region

BLUE Map Scenario (~450 ppm)



IEA CCS Roadmap
Global Deployment of CCS 2010–50 by Sector

BLUE Map Scenario (~450 ppm)



Political Will and R&D Challenge

- **Political Will as a key driver**
  - To set desirable target for the future
  - To develop roadmaps
  - To promote R&D activities
    - ≈ Implementation of Roadmaps
  - To design and promote socio-economic system to challenge policy goals such as energy security, climate change, etc.
- **Available science and technologies, coupled with proper assessments, to drive Policies**

Statement by Prime Minister Hatoyama
United Nations Summit on Climate Change (Sep. 22, 2009)

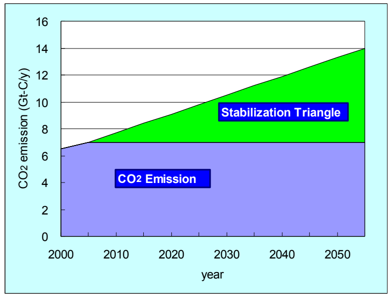
- … For its mid-term goal, Japan will aim to reduce its emissions by 25% by 2020, if compared to the 1990 level, consistent with what the science calls for in order to halt global warming.
- … These will include the introduction of a domestic emission trading mechanism and a feed-in tariff for renewable energy, as well as the consideration of a global warming tax.
- However, … It is imperative to establish a fair and effective international framework in which all major economies participate. The commitment of Japan to the world is premised on agreement on ambitious targets by all the major economies.

Consistency in Policy Measures?

- **Measures which might cause an increase in CO_2 emissions**
  - Abolishment of the extra tax rate on gasoline and other road-related taxes
  - Reduction or elimination of expressway toll
- **Portfolio approach should be necessary based on the scale of mitigation and cost for abatement**
  - Energy efficiency: minus to moderate
  - PV: > ¥100,000/t-CO_2
  - CCS: ~10,000/t-CO_2

Simple Consideration on Deep Reduction Strategy

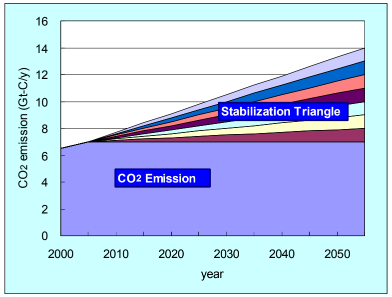
Stabilization Triangle



- **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.**

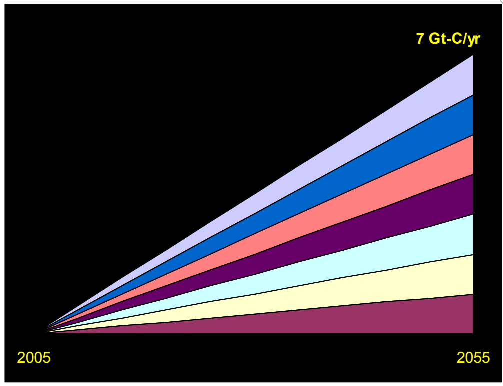
Robert H. Socolow (Princeton Univ.)

Stabilization Wedges



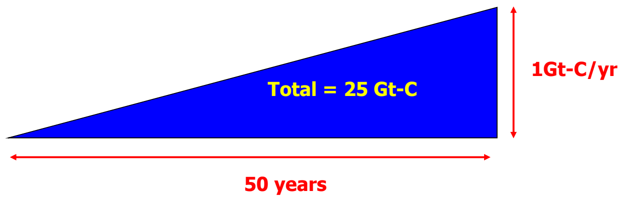
- **To introduce a new physical unit, the wedge, as a unit for describing 50-year strategies.**
- **To explain the strategy is, roughly, a seven-wedge problem.**

Seven Wedges to Fill the Triangle

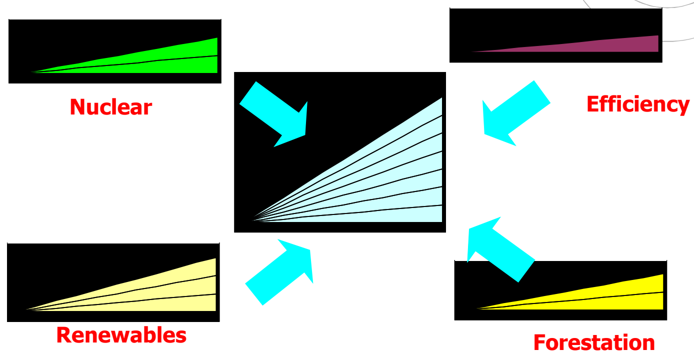


What is a "Wedge"?

- 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)

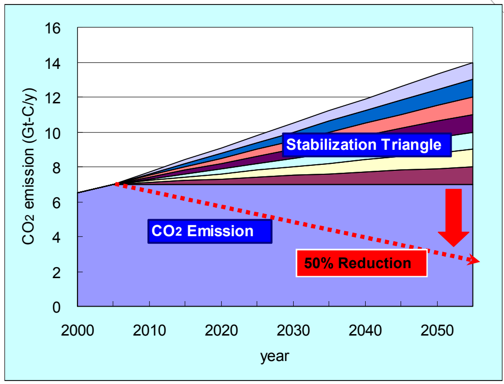
Reporting Subject

- 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),
  - ......

Discussion Subject

- **Consider possible combinations of developed wedges to achieve 50% reduction of CO_2 emission by 2050 both in global scale and in Japan.**
  - **NOT for the "emission stabilization"**
- **Identify barriers to achive the target in relation to the consideration on wedges.**

Reduction Wedges to Stabilize Atmospheric CO_2 Concentration



Thank you!

Documents related to "Cool Earth - Innovative Energy Technology Program" are available from the following URLs:

Japanese: http://www.enecho.meti.go.jp/policy/coolearth_energy/index.htm

English: http://www.meti.go.jp/english/newtopics/data/nBackIssue20080305_04.html