Global Environmental Policy

December 13, 2010:

- Overview
- Challenges and strategies towards Deep GHG Reduction

December 20, 2010:

- Reporting and Discussion

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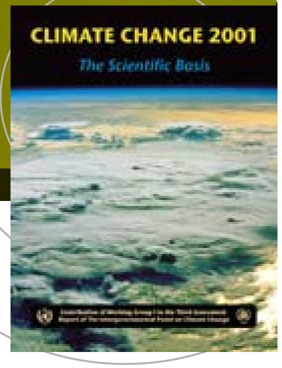
Recent Findings on Climate Change

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.**

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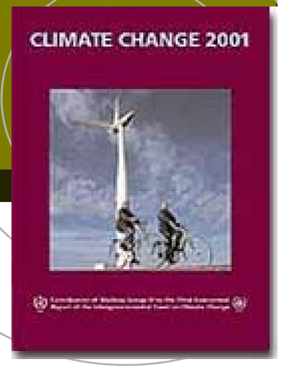
IPCC 3rd Assessment Report (TAR) Suggestions
WG3:Mitigation-SPM



- **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.**

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

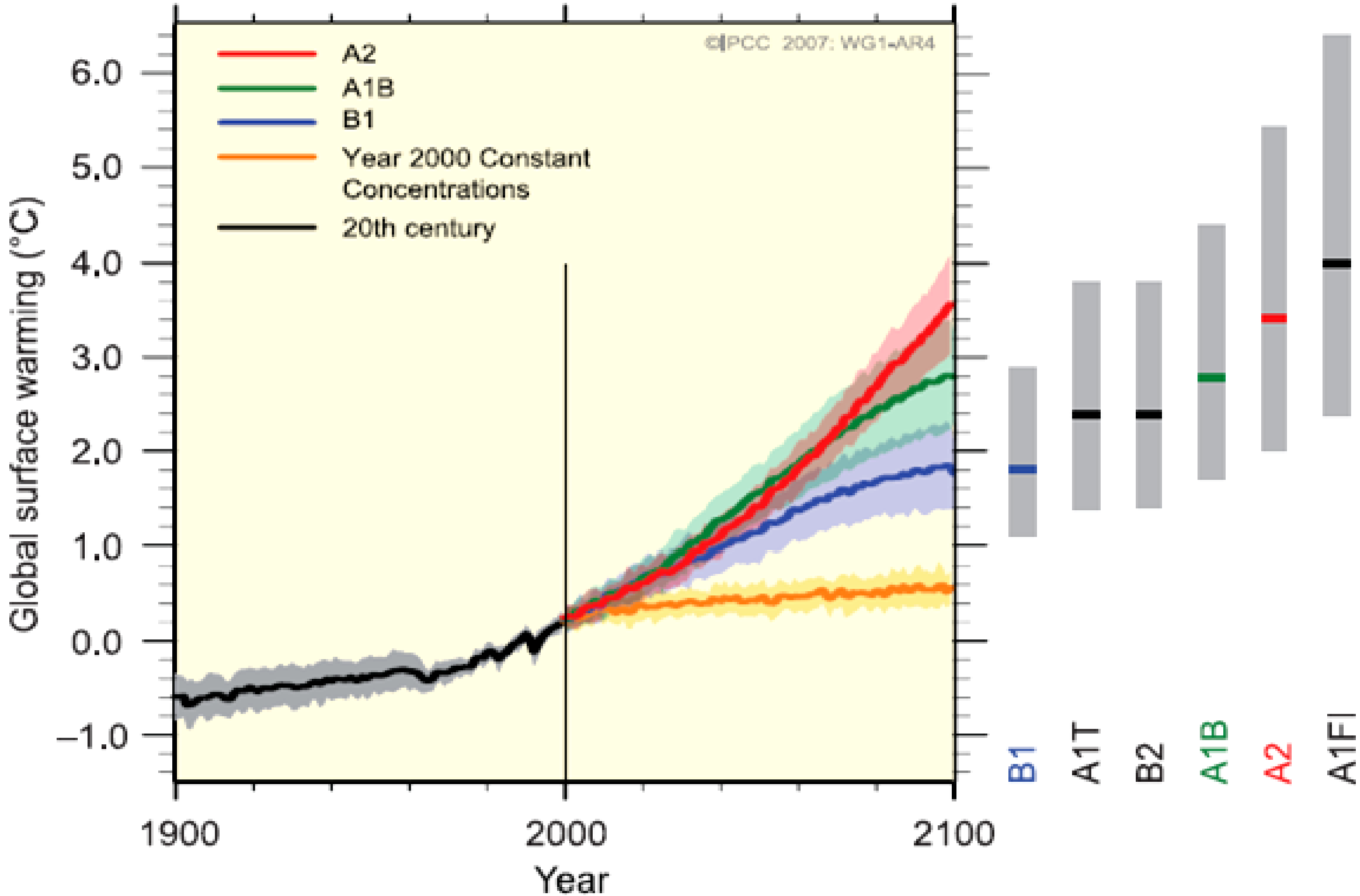
- **Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level.**

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%**

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

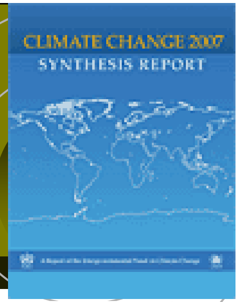
- **Increasing atmospheric carbon dioxide concentrations lead to increasing acidification of the ocean. Projections based on SRES scenarios give reductions in average global surface ocean pH of between 0.14 and 0.35 units over the 21st century, adding to the present decrease of 0.1 units since pre-industrial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

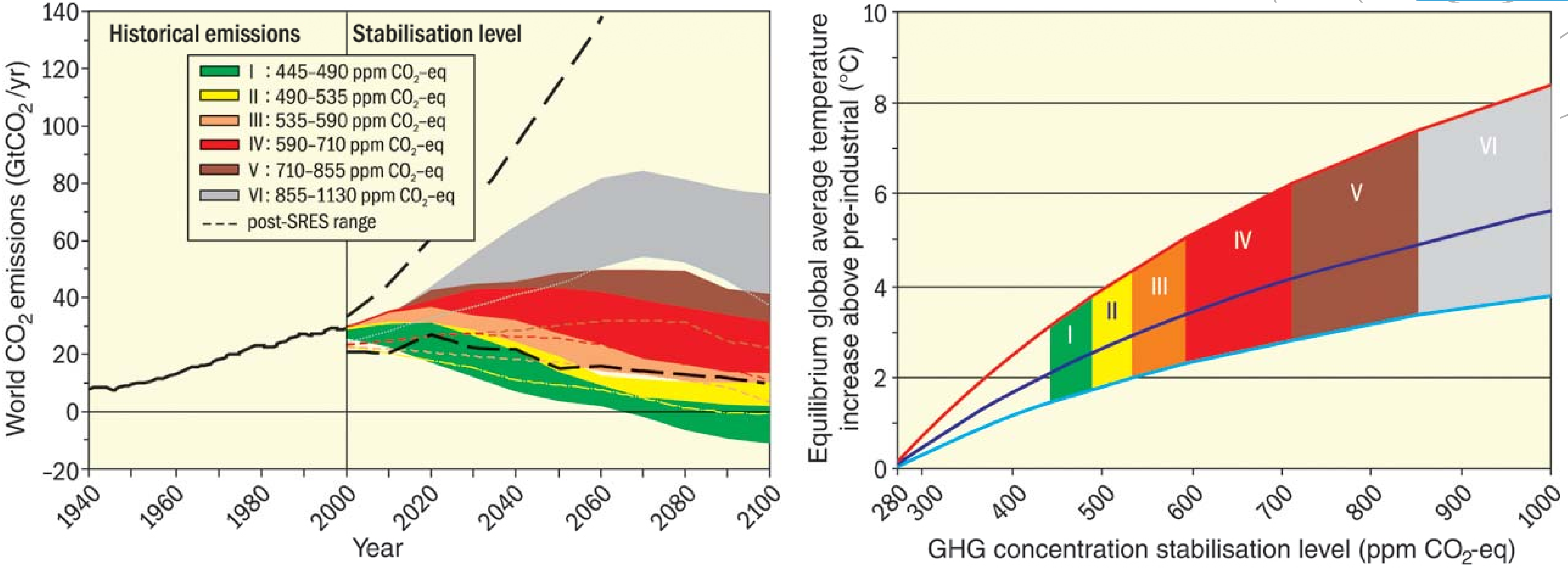
IPCC 4th Assessment Report (AR4)
Long Term Mitigation (after 2030)

- **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 (^oC)	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

Towards a Deep Reduction of Greenhouse Gas

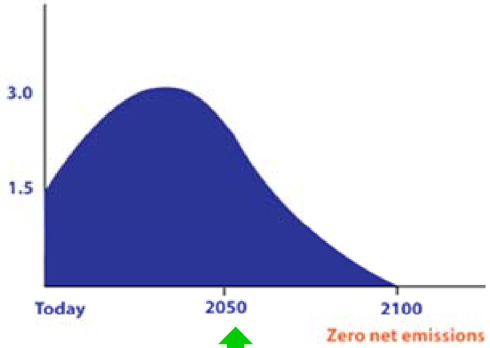
The Technology Challenge

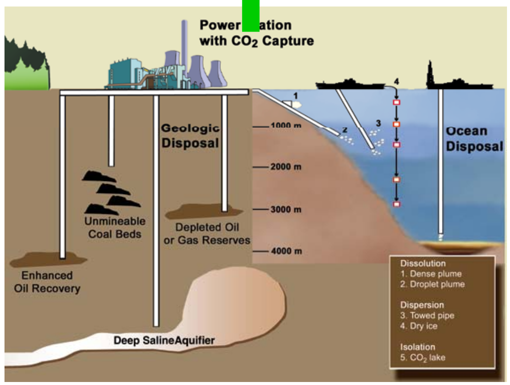
Hydrogen Fuel Cell Vehicles

Zero Net Emission Buildings

Nuclear Power Generation IV

Stabilizing Greenhouse Gas Concentrations in the Atmosphere





Carbon (CO_2) Sequestration

Renewables: Photovoltaics and Wind

Bio-Fuels and Power

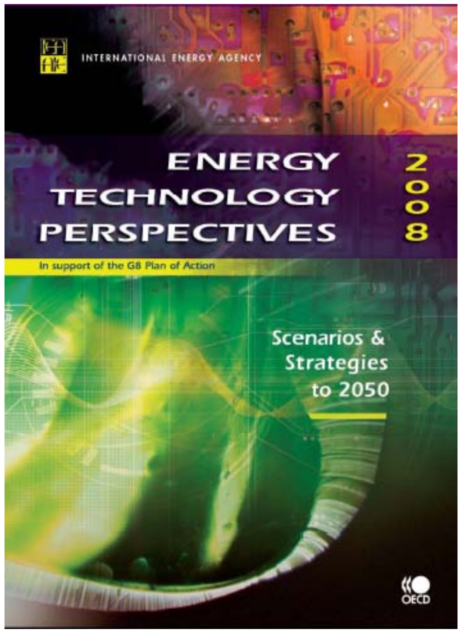
Vision 21: Zero-Emission Power Plant

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.

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

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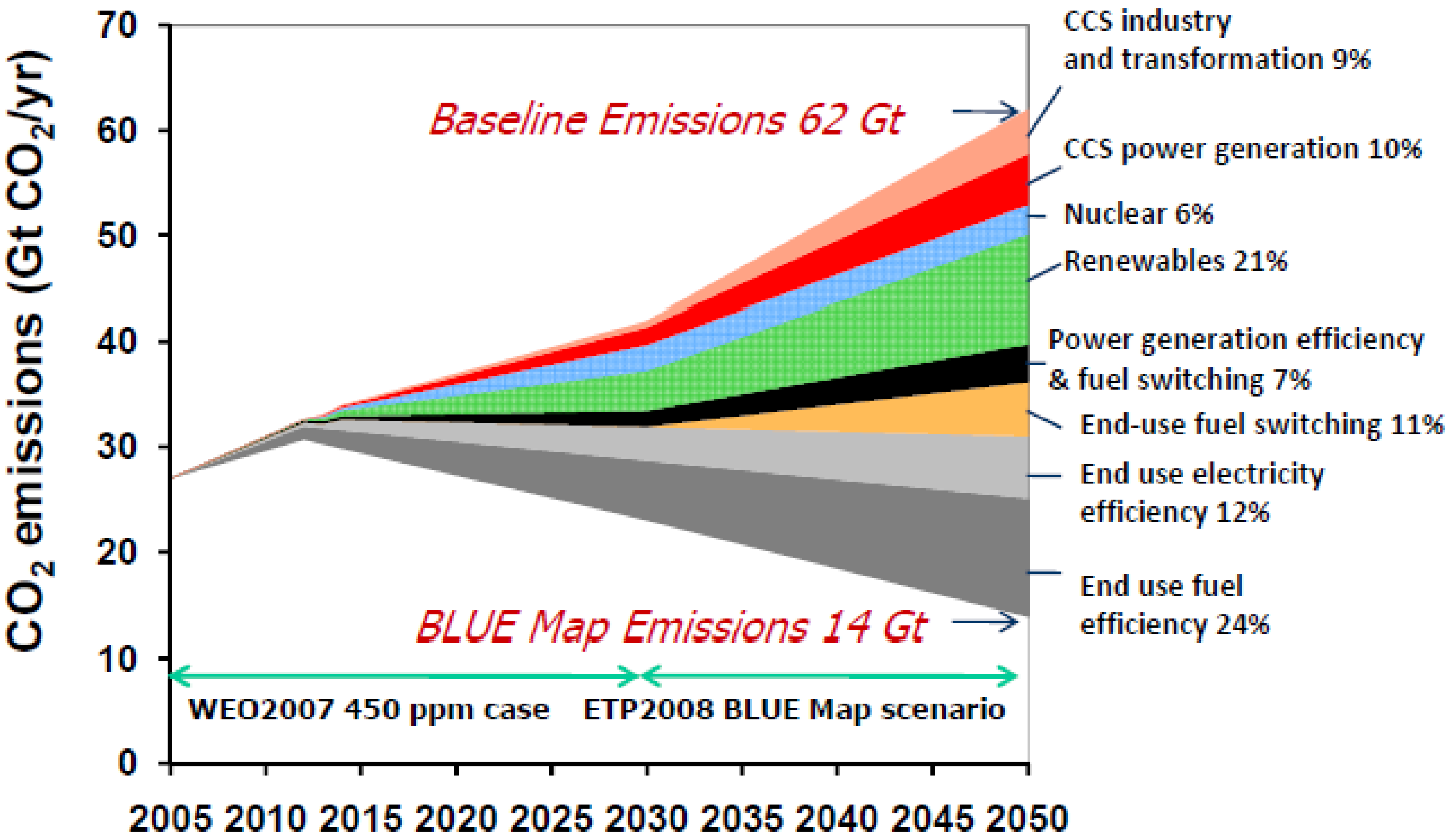
ETP2008
CO_2 Emission Reduction Scenario



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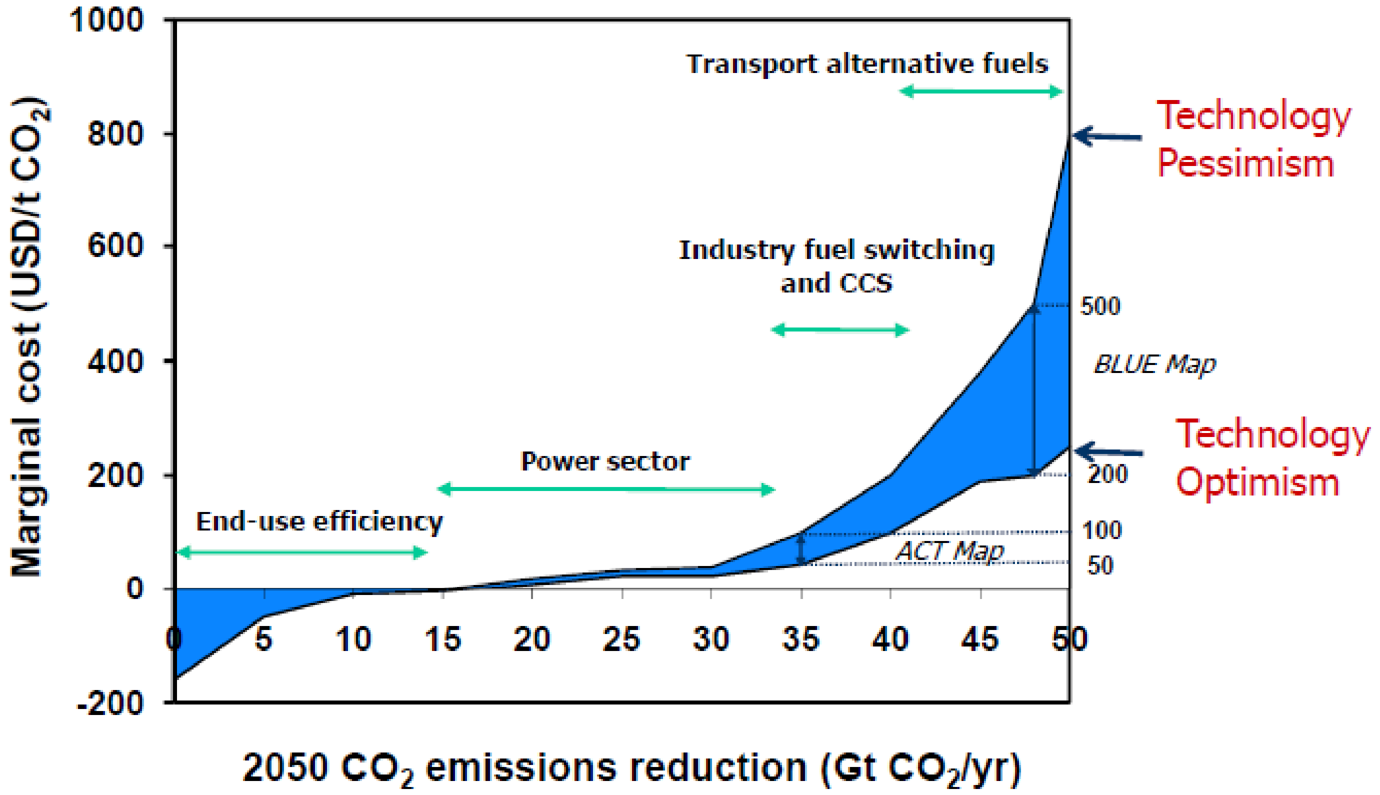
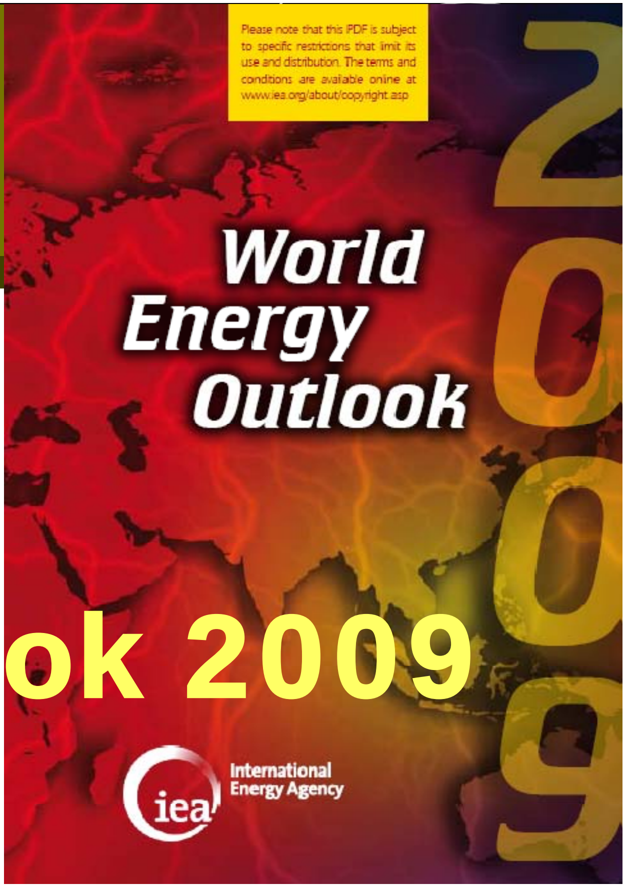
ETP2008
Cost of Emissions Reductions



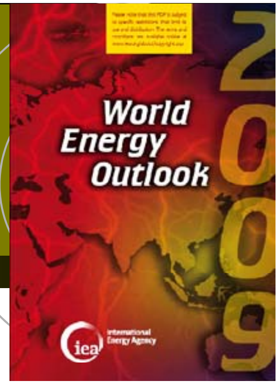
- **To bring emissions back to current levels by 2050 options with a cost up to USD 50/t are needed.**
- **Reducing emissions by 50% would require options with a cost up to USD 200/t (+80 USD/bbl oil), possibly even up to USD 500/t CO_2**

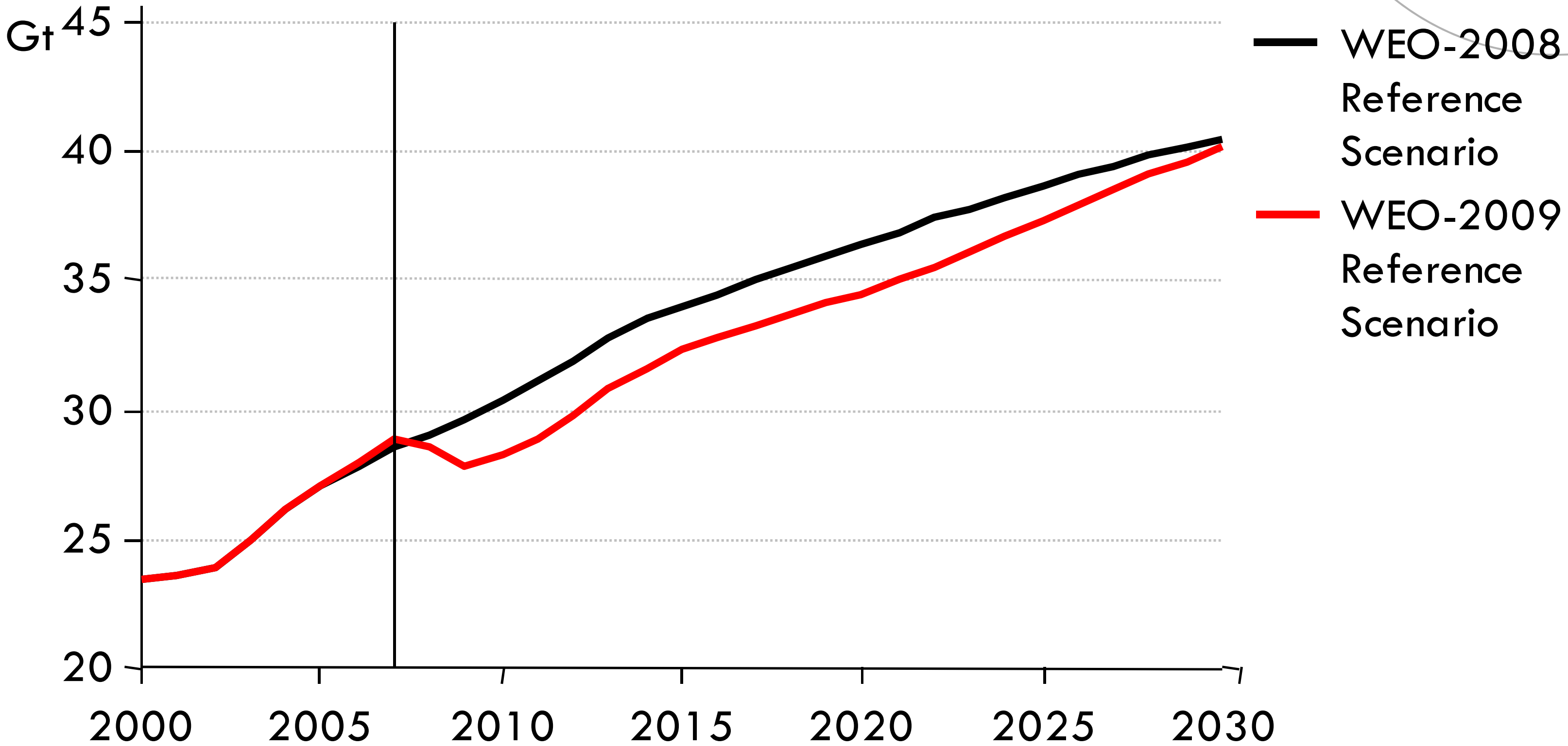


World Energy Outlook 2009

International Energy Agency (IEA)

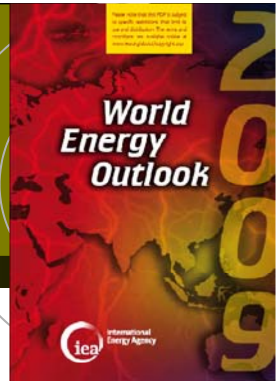
World's Energy-related CO_2 Emissions in the Reference Scenario in WEO-2009 and WEO-2008

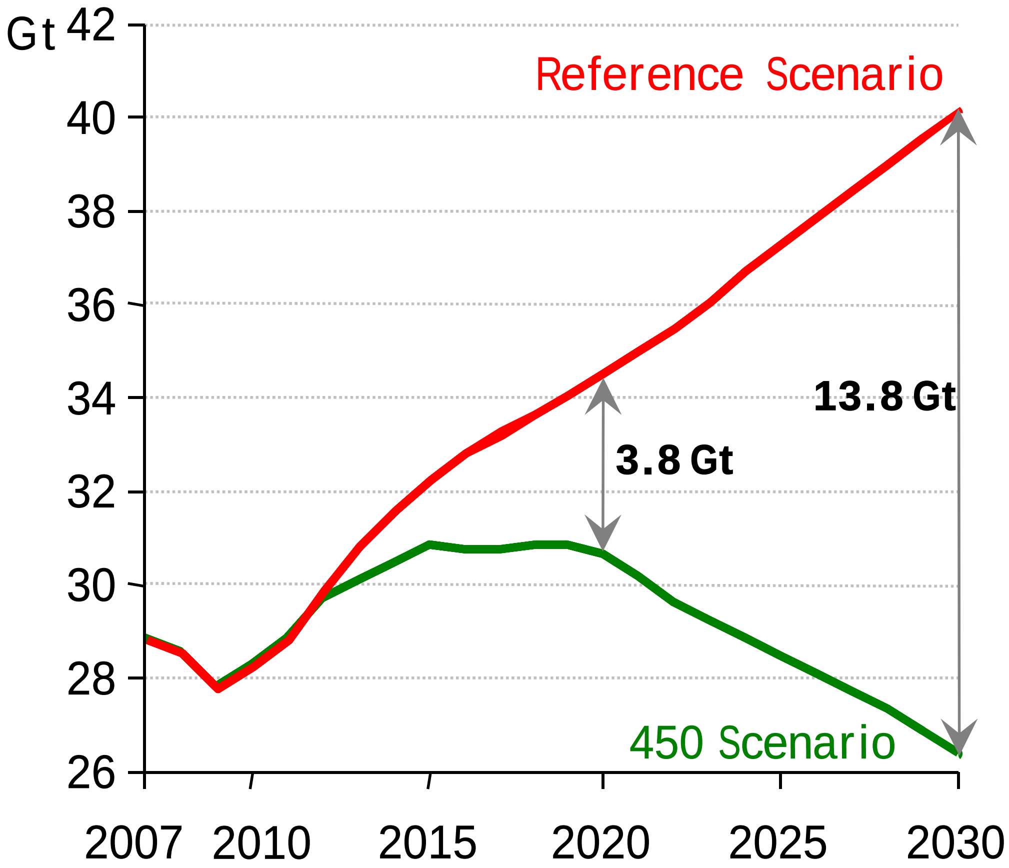




- In cumulative terms between today and 2030, emissions are 35 Gt lower than in WEO-2008. 75% of this reduction is due to the impact of the financial crisis and 25% to new policies

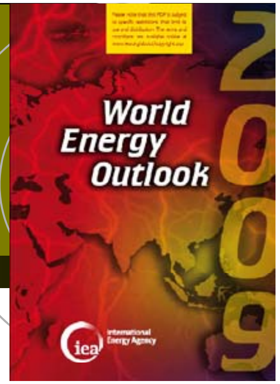
The 450 Scenario: Energy-related CO_2 Emissions Compared to the Reference Scenario





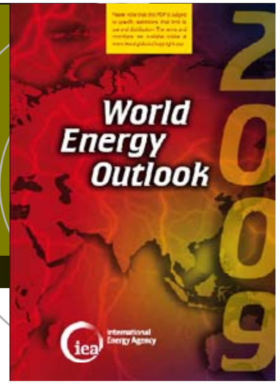
- **In the 450 Scenario, emissions peak before 2020 at 30.9 Gt, falling to 26.4 Gt by 2030**

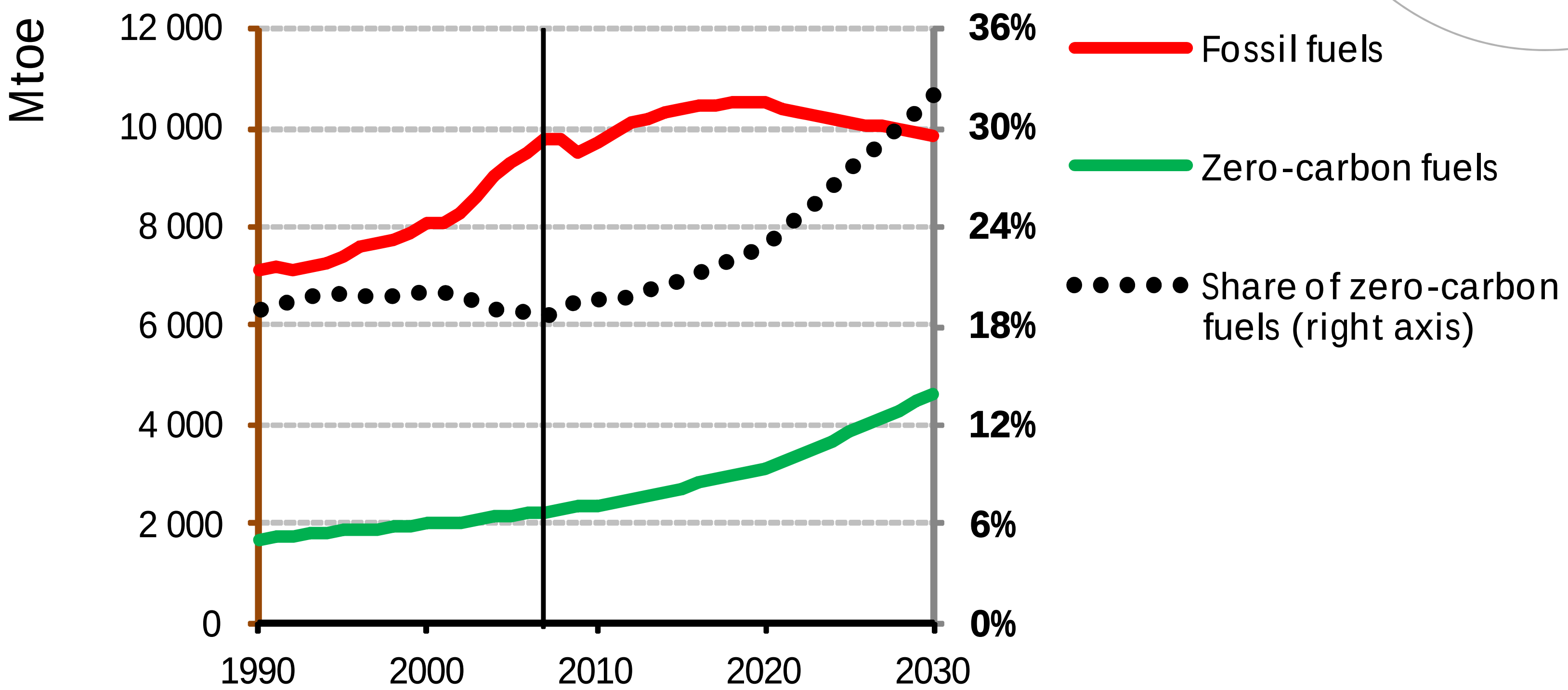
Policy Mechanisms in the 450 ppm Scenario



- 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

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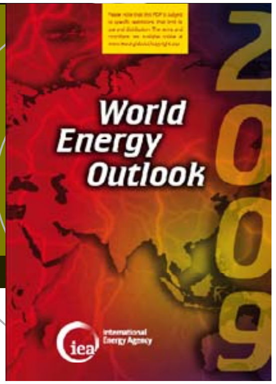
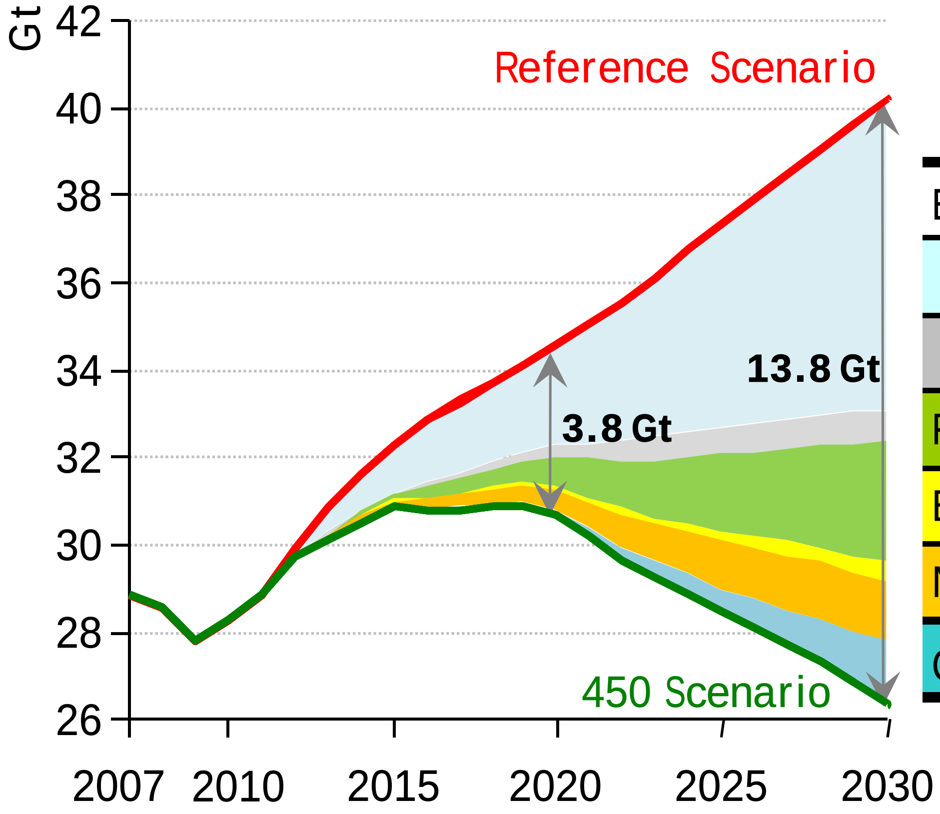
World's Abatement of Energy-related CO_2 Emissions in the 450 Scenario



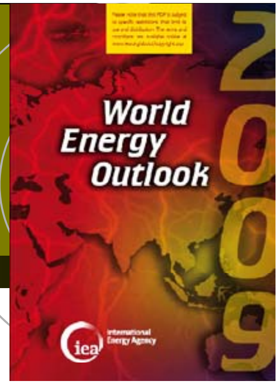


Share of abatement %

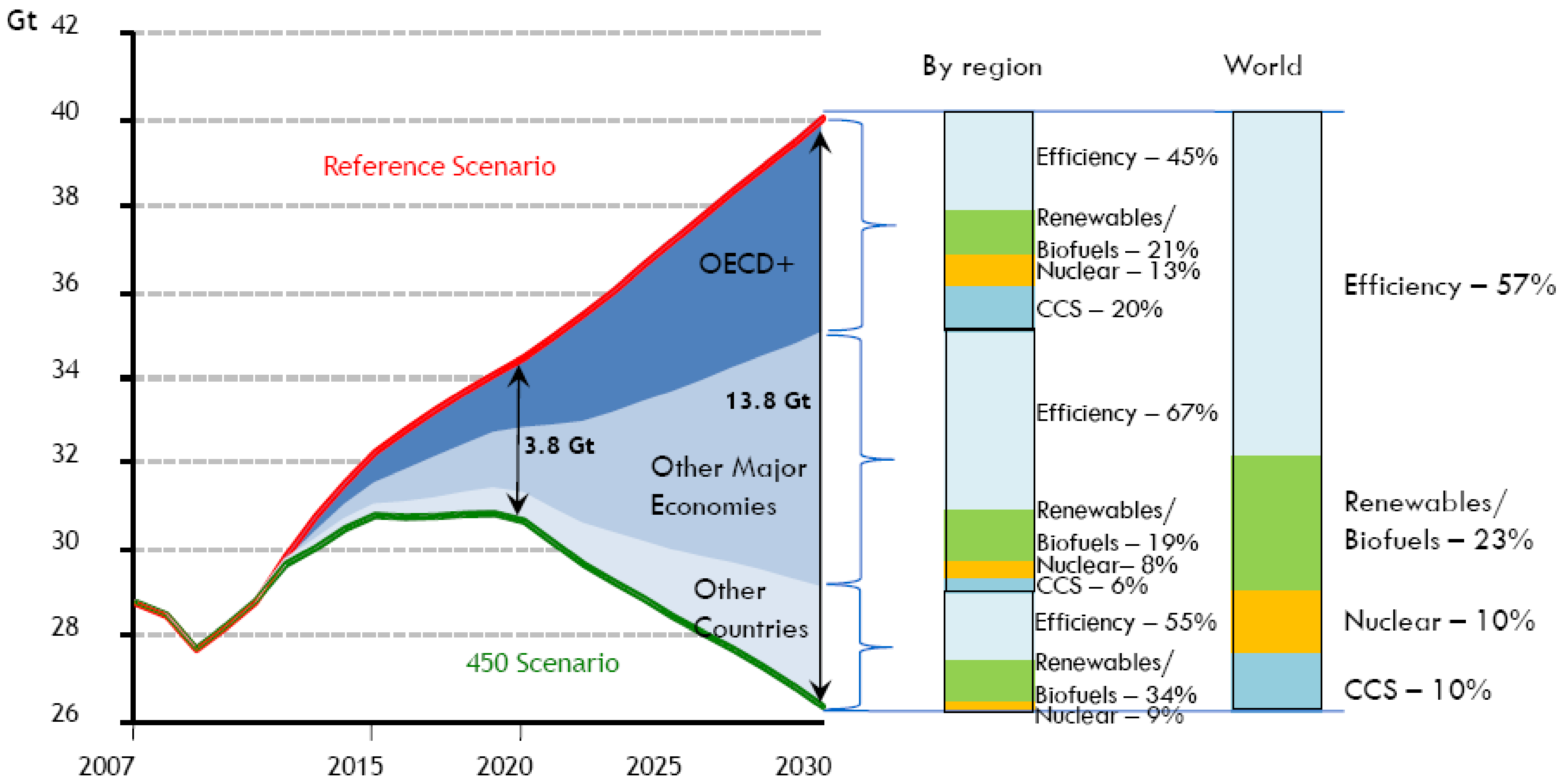
	2020	2030
Efficiency	65	57
End-use	*59*	*52*
Power plants	*6*	*5*
Renewables	18	20
Biofuels	1	3
Nuclear	13	10
CCS	3	10

- **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



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Some Regional Scenarios for Abatement of Energy-related CO_2

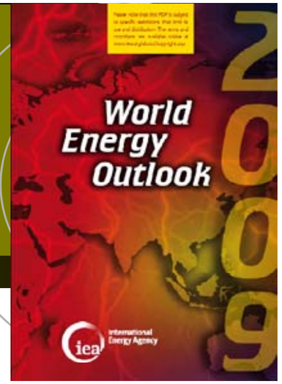
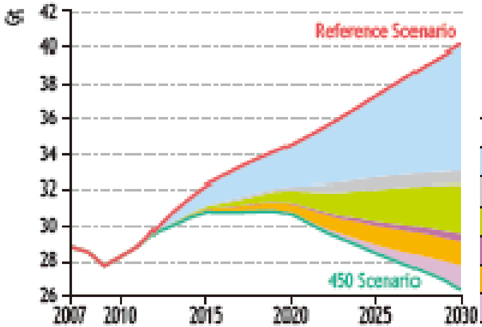


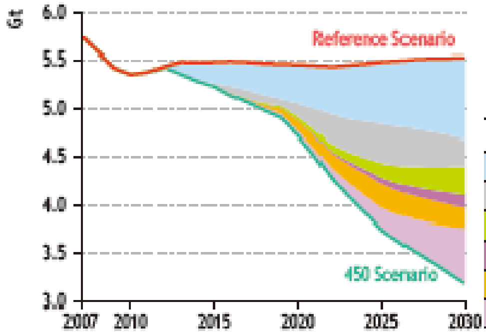
Figure 9.2 • World energy-related CO_2 emissions abatement



	Abatement (Mt CO_2)		Investment ($2008 billion)	
	2020	2030	2010-2020	2021-2030
Efficiency	2 517	7 880	1 999	5 586
End-use	2 284	7 145	1 933	5 551
Power plants	233	735	66	35
Renewables	680	2 741	527	2 260
Biofuels	57	429	27	378
Nuclear	493	1 380	125	491
CCS	102	1 410	56	646

World

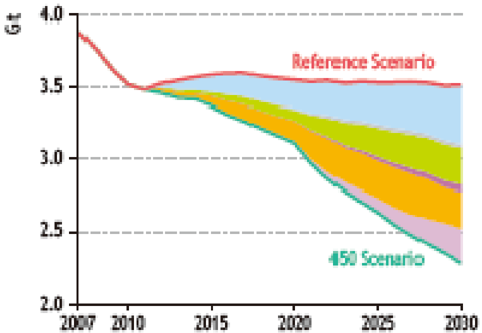
Figure 9.12 • US energy-related CO_2 emissions abatement



	Abatement (Mt CO_2)		Investment ($2008 billion)	
	2020	2030	2010-2020	2021-2030
Efficiency	548	1 141	475	955
End-use	411	855	443	949
Power plants	137	286	32	5
Renewables	43	288	36	330
Biofuels	0	136	0	127
Nuclear	101	206	62	77
CCS	57	593	33	300

USA

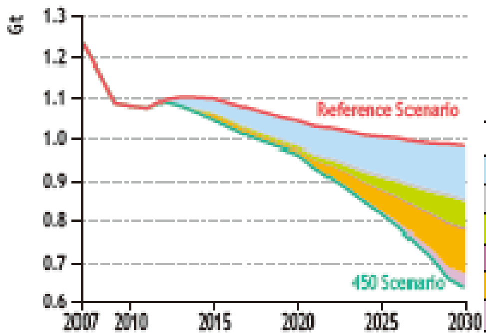
Figure 9.17 • EU energy-related CO_2 emissions abatement



	Abatement (Mt CO_2)		Investment ($2008 billion)	
	2020	2030	2010-2020	2021-2030
Efficiency	206	438	392	709
End-use	197	414	387	709
Power plants	9	24	5	0
Renewables	80	256	113	268
Biofuels	1	50	4	60
Nuclear	143	253	0	88
CCS	16	250	9	126

EU

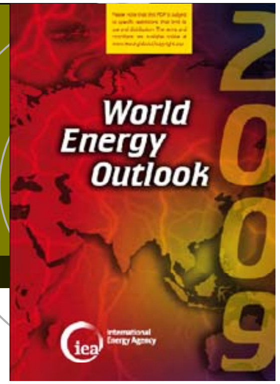
Figure 9.22 • Japan energy-related CO_2 emissions abatement



	Abatement (Mt CO_2)		Investment ($2008 billion)	
	2020	2030	2010-2020	2021-2030
Efficiency	65	138	77	164
End-use	60	128	74	161
Power plants	5	10	3	3
Renewables	7	66	21	71
Biofuels	1	4	1	7
Nuclear	10	103	0	36
CCS	1	38	1	21

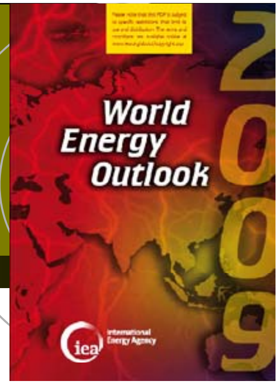
Japan

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

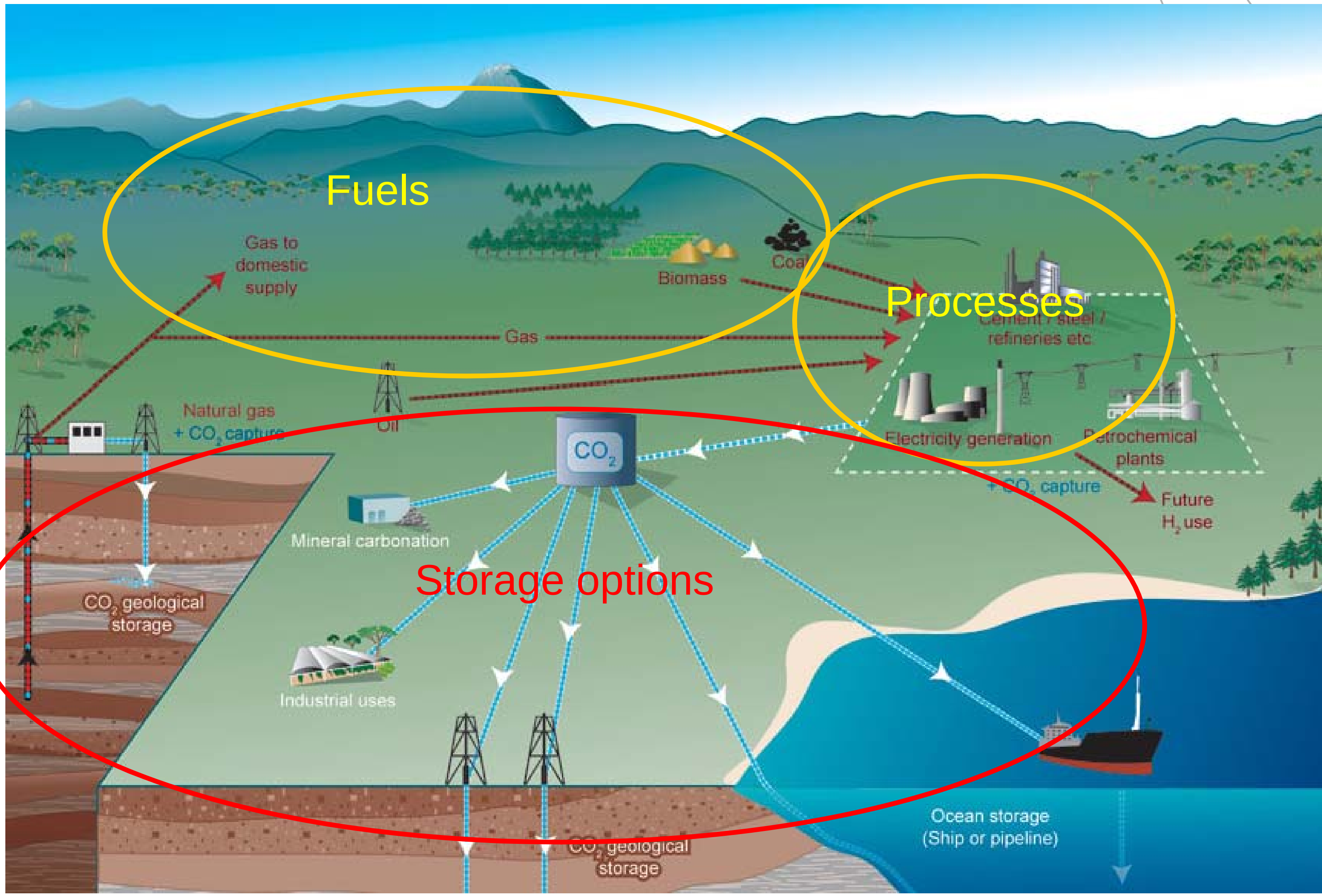
CO_2 Capture and Storage

or

CO_2 Capture and Sequestration

(CCS)

CO_2 Capture and Storage System



Source: IPCC SRCCS

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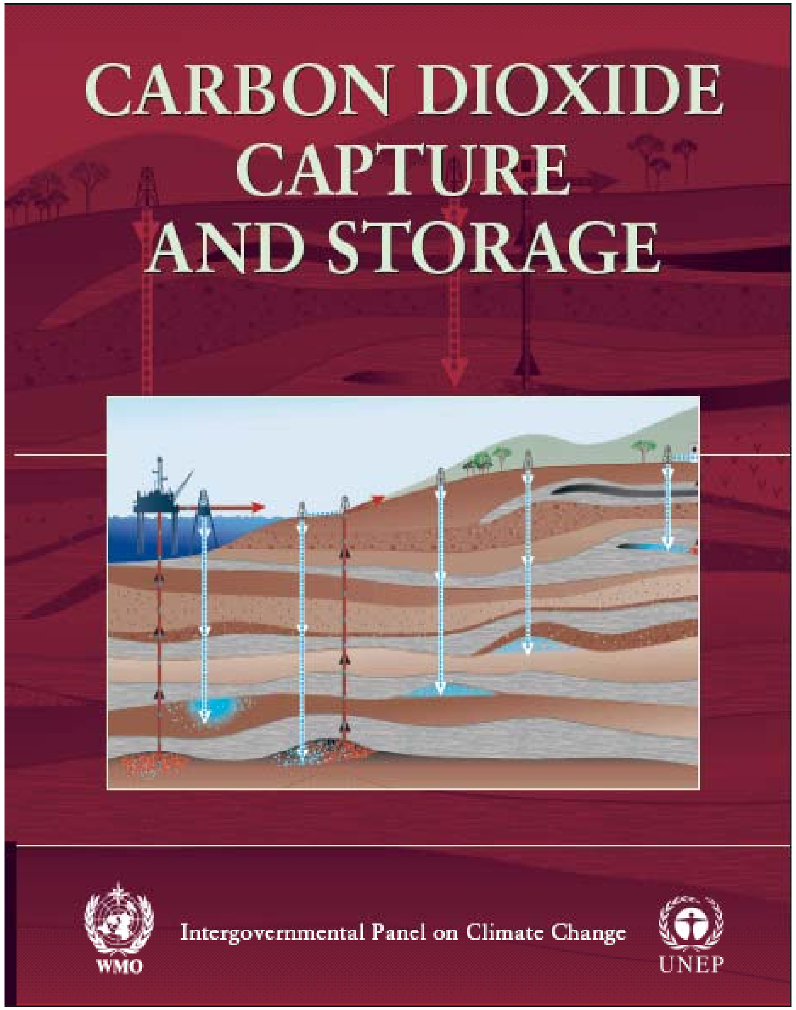
The IPCC Special Report on Carbon Dioxide Capture and Storage



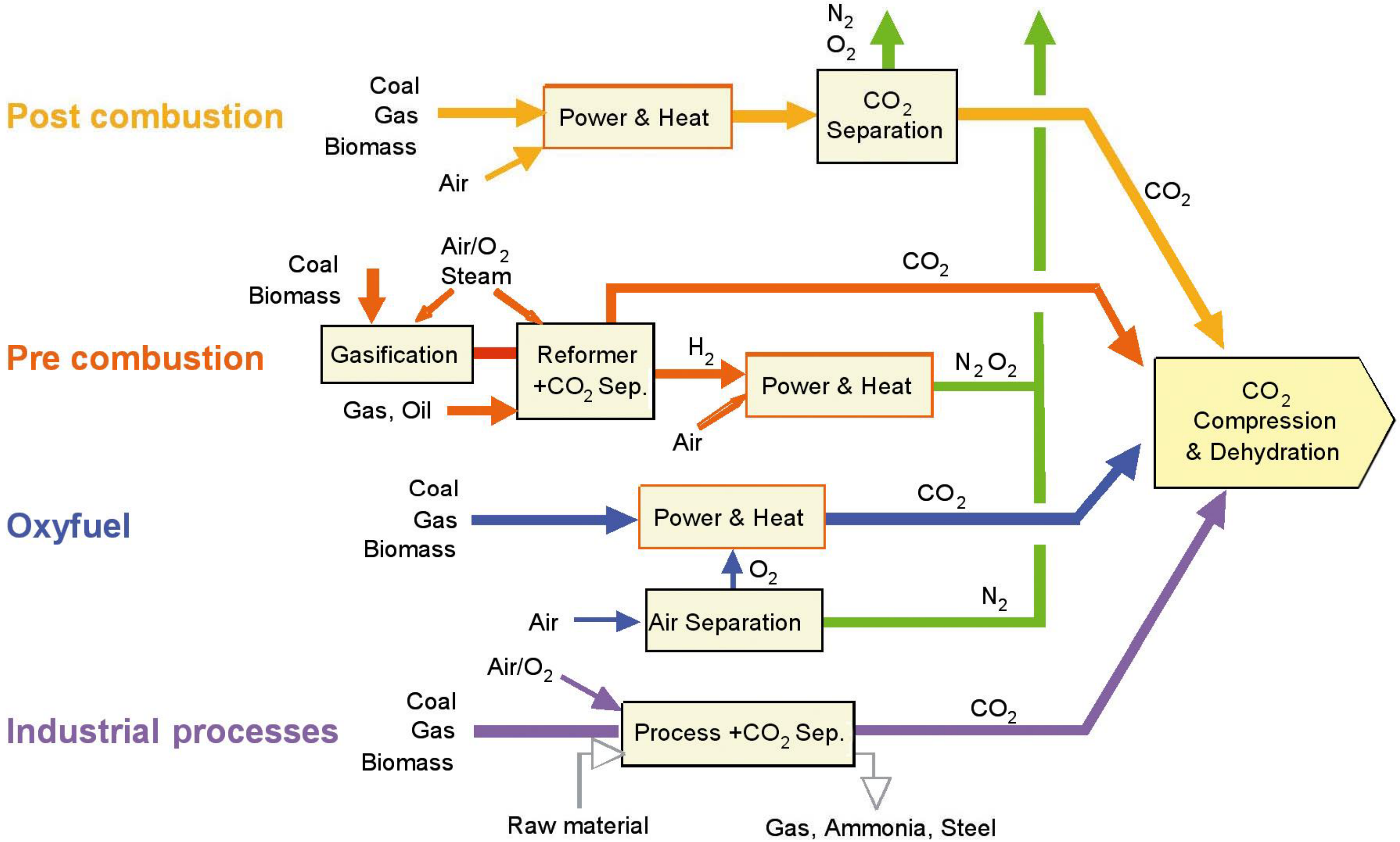
Structure of the Report

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

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

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

- 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

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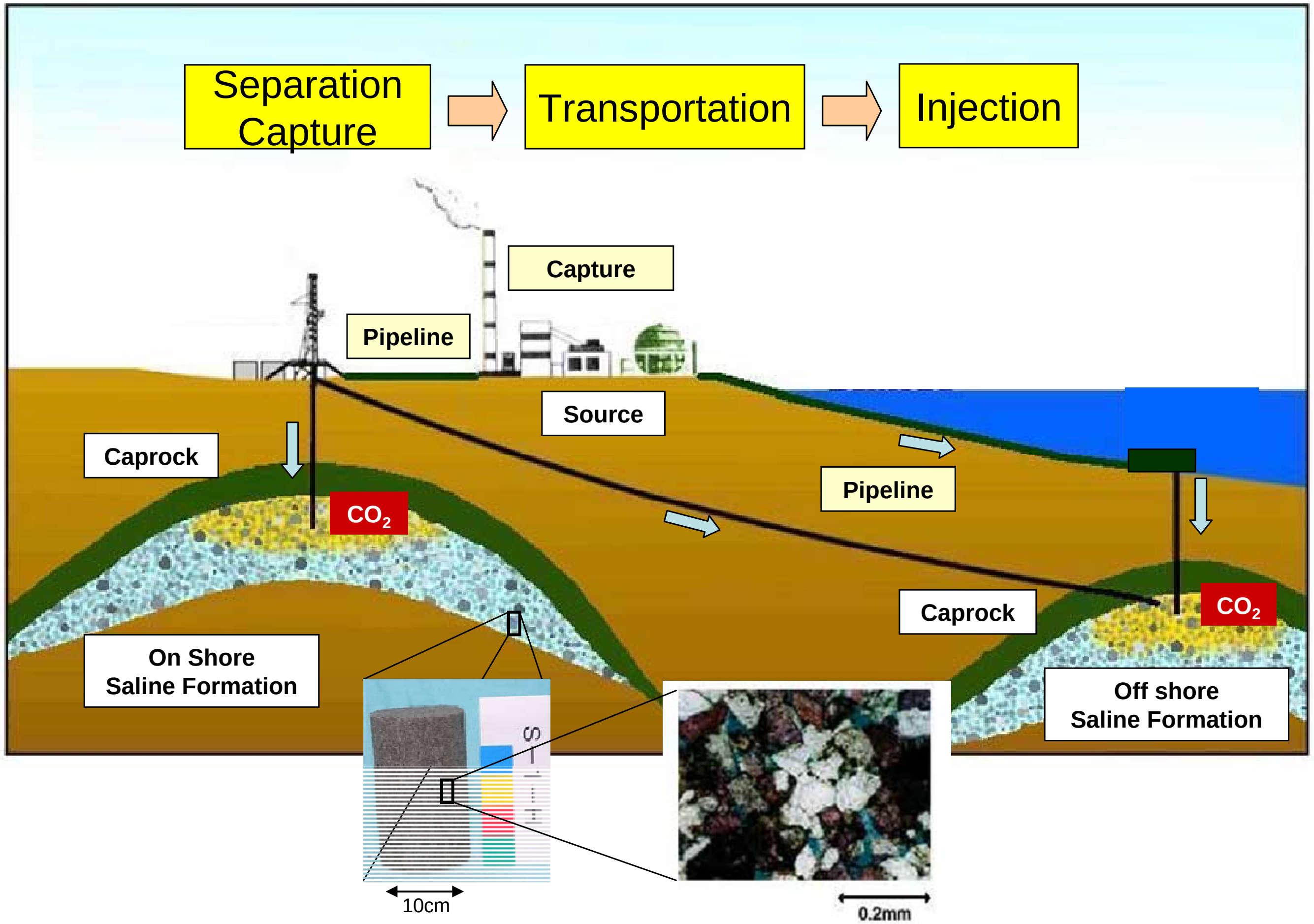
Storage Potential

- 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 - ~ 104 $GtCO_2$
  - 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!**

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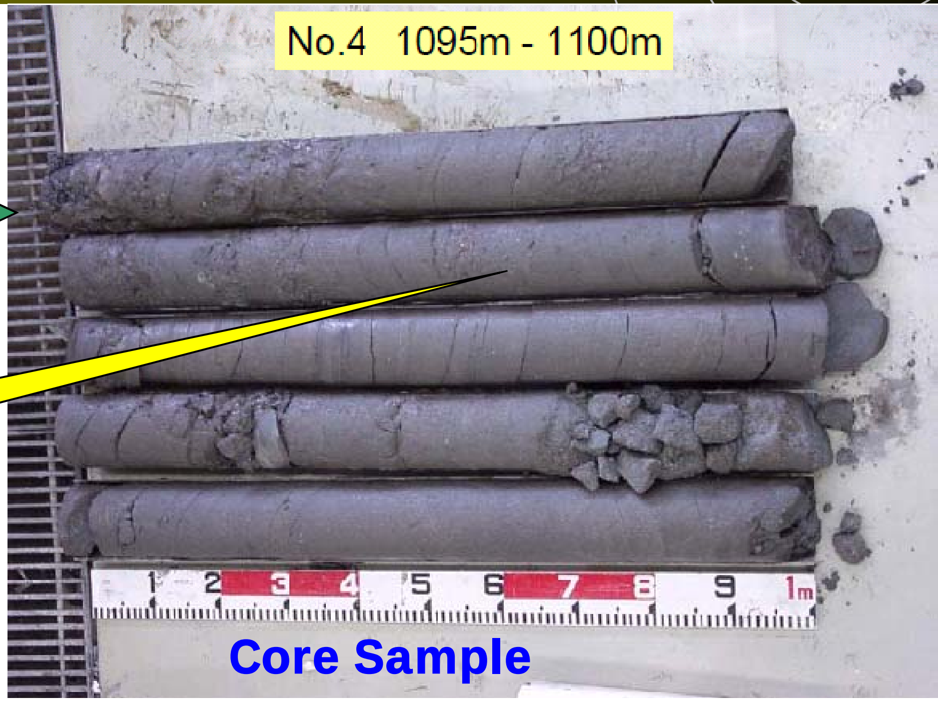
Experimental Site and Core Sample

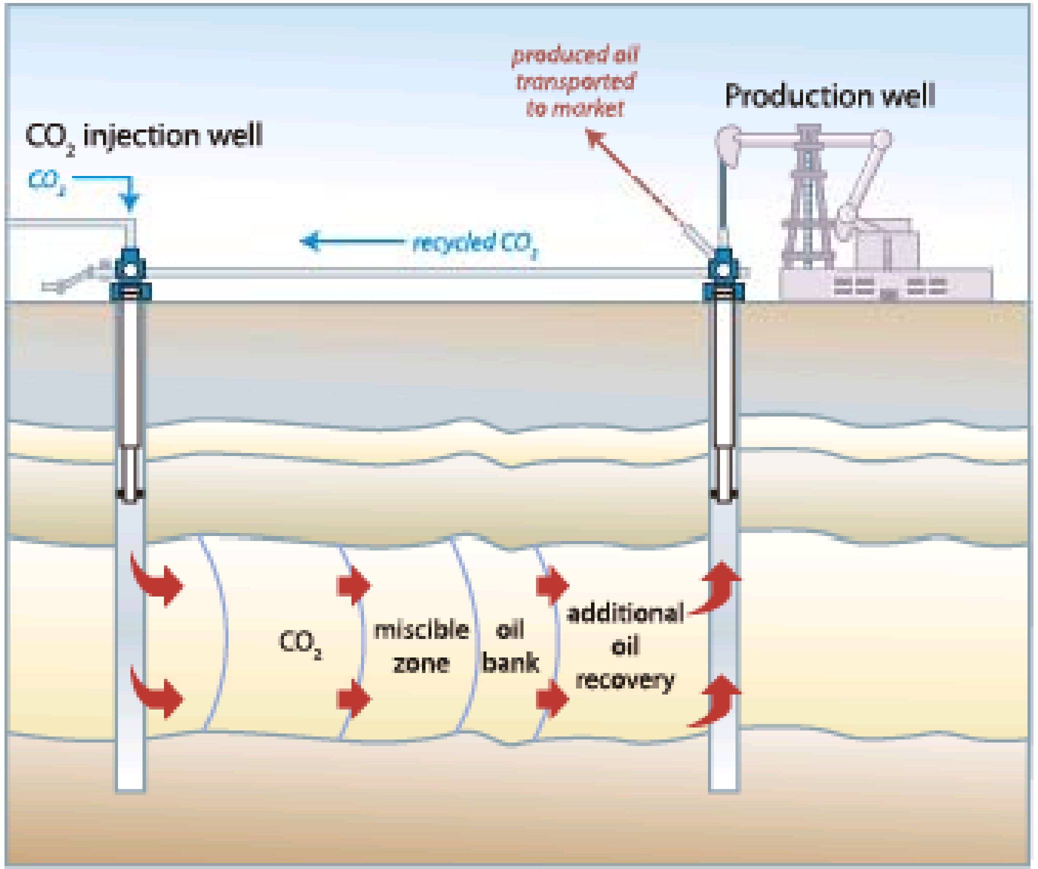
CO_2 was injected into this structure



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

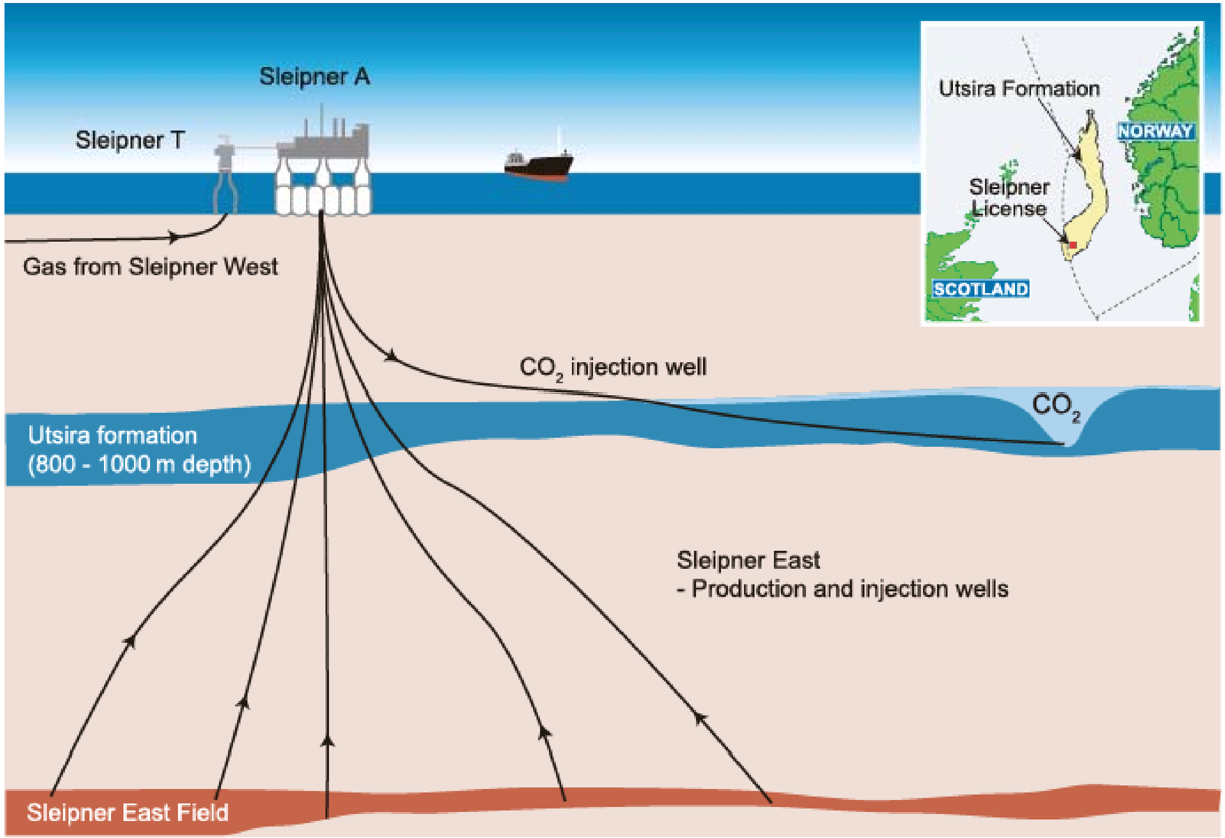
Injection of CO_2 for Enhanced Oil Recovery (EOR)



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.

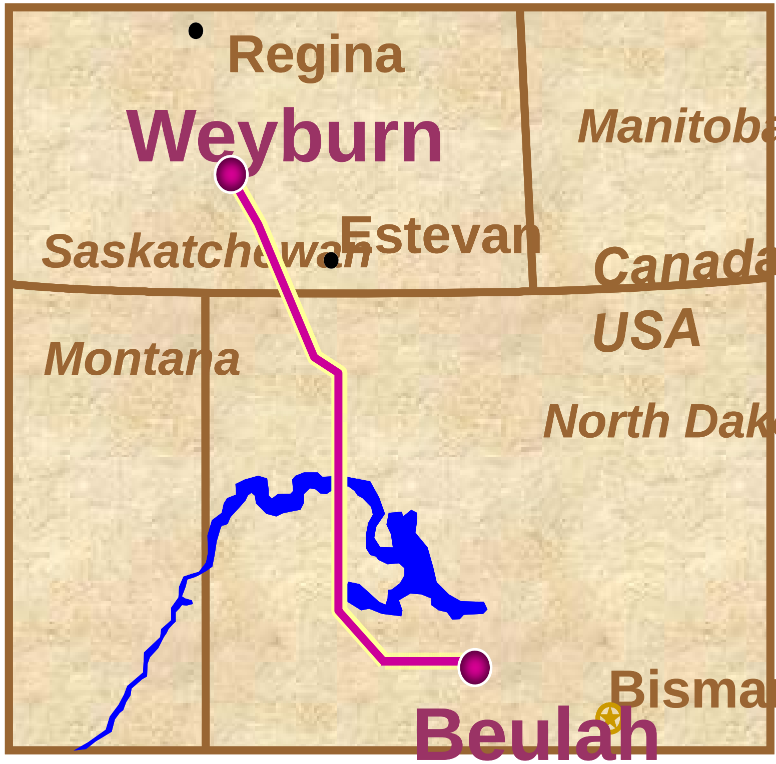
Sleipner CO_2 Storage Project.



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.

Weyburn CO_2-EOR Project.

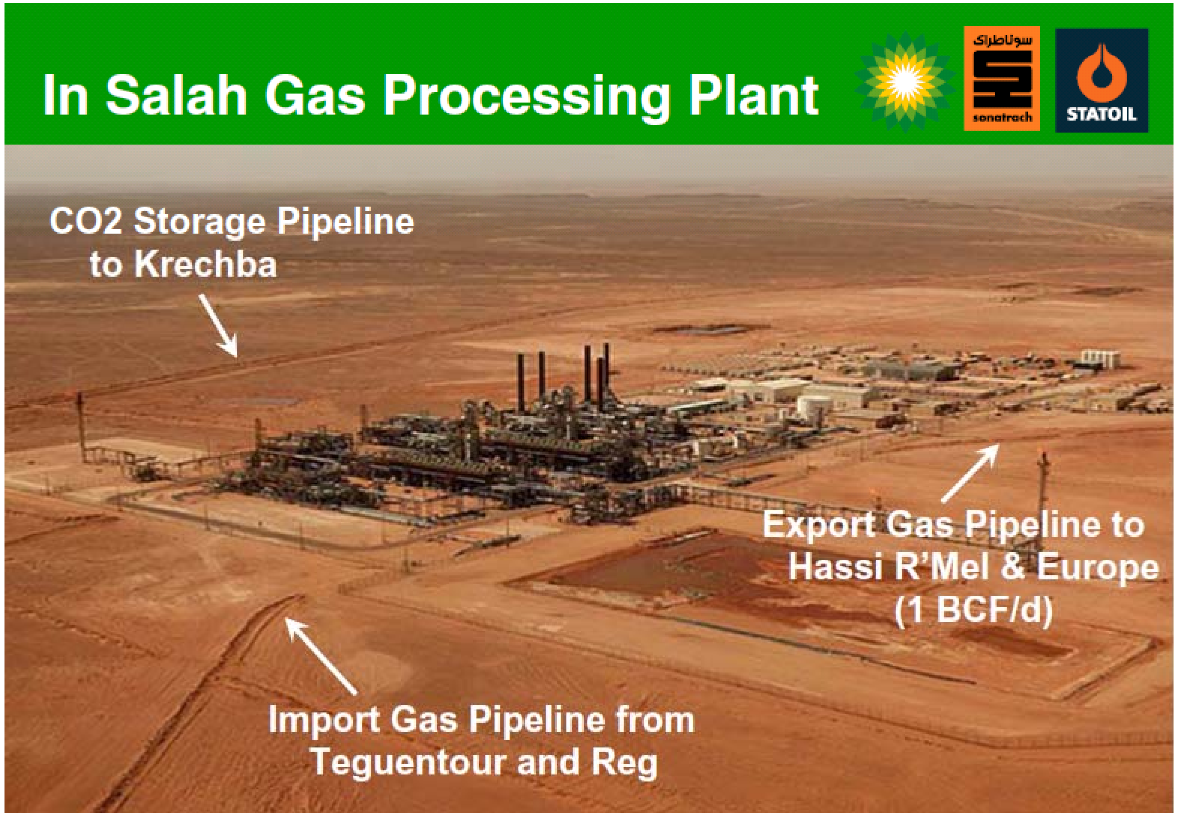


Dakota Gasification.

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.

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…

CCS in G8 Summit
Gleneagles Plan of Action on Climate Change and Sustainable Development (8 July 2005)

We will work to accelerate the deployment and commercialization of Carbon Capture and Storage technology by:

a. endorsing the objectives and activities of the Carbon Sequestration Leadership Forum (CSLF), and encouraging the Forum to work with broader civil society and to address the barriers to the public acceptability of CCS technology;

b. inviting the IEA to work with the CSLF to hold a workshop on short-term opportunities for CCS in the fossil fuel sector, including from Enhanced Oil Recovery and CO2 removal from natural gas production;

c. inviting the IEA to work with the CSLF to study definitions, costs, and scope for 'capture ready' plant and consider economic incentives;

d. collaborating with key developing countries to research options for geological CO2 storage; and

e. working with industry and with national and international research programmes and partnerships to explore the potential of CCS technologies, including with developing countries.

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CCS in G8 Summit

G8 Hokkaido Toyako Summit Leaders Declaration (8 July 200)

31. 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, including carbon capture and storage (CCS) and advanced energy technologies. Reaffirming our Heiligendamm commitment to urgently develop, deploy and foster clean energy technologies, we recognize and encourage a wide range of policy instruments such as transparent regulatory frameworks, economic and fiscal incentives, and public/private partnerships to foster private sector investments in new technologies. We strongly support the launching of 20 large-scale CCS demonstration projects globally by 2010, taking into account various national circumstances, with a view to beginning broad deployment of CCS by 2020.

Global Carbon Capture and Storage Institute

- **Announced by the Australian Government in September 2008, the Global CCS Institute was formally launched in July 2009, with the Australian Government initially committing AU$100M annual funding to the organisation for a four year period.**

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Global CCS Institute Strategic Framework

OVERARCHING OBJECTIVE

“To accelerate the broad deployment of commercial CCS”

Regional Profiles and Global Services

ENABLING STRATEGIES

- Policy/Regulatory
- Financial/Commercial
- Public Awareness
- Technical
- Capacity Building

PROJECTS STRATEGY

- Strategic Analysis of Projects
- Project Support Program
- Thematic Focus Groups

Knowledge Sharing

MEMBERS

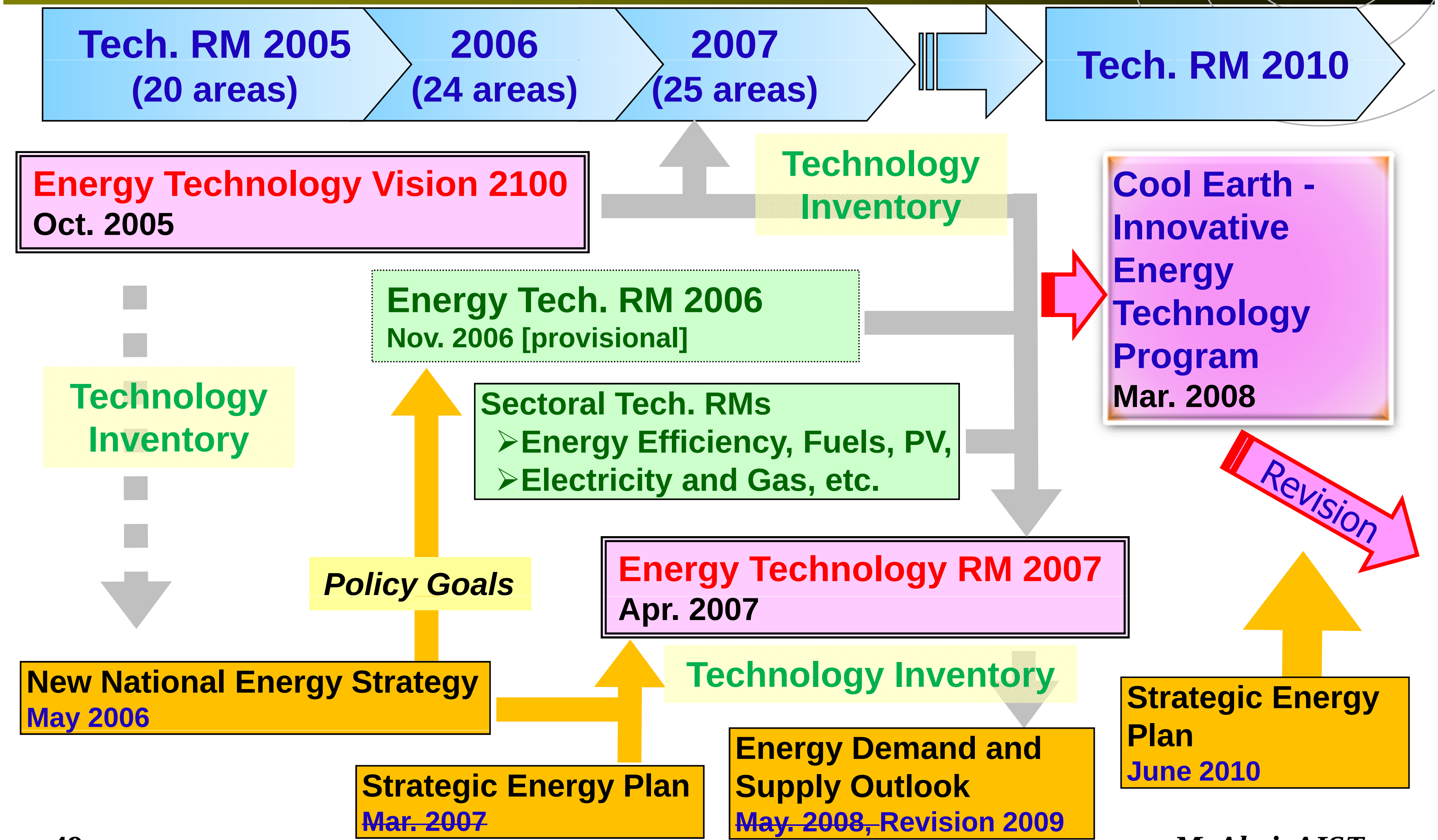
Services Model

Member Charter

Recent Development of Energy Strategy in Japan (METI)

Recent Development in Energy Policy

Energy Technology Roadmapping



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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

Scope of Work

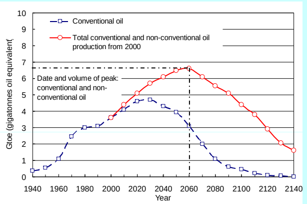
- **Timeframe**
  - Vision: - 2100
  - Technology roadmap: -2100
    - Benchmarking years: 2030 and 2050

- **Approach**
  - To introduce backcasting methodology
  - To compile experts' view
  - To confirm long-term goal using both top-down and bottom-up scenario analysis

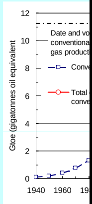
Assumptions towards 2100

Resource Constraints

- Although assumption of the future resource constraints includes high d... uncertainties, the following constraints were assumed
  - 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

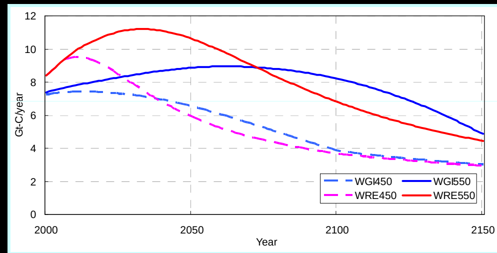


The Com... Conventio... Peak to Gl...

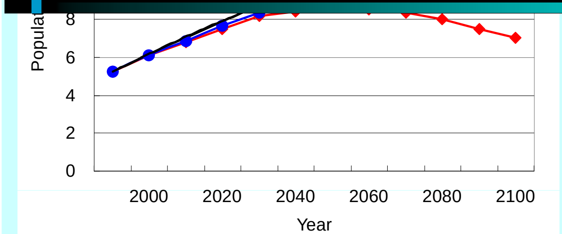
Example of estimates for oil and natural ...

Environmental Constraints

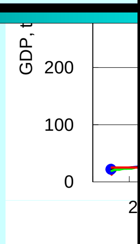
- CO_2 emission **intensity** (CO_2 / GDP) should be improved to stabilize atmospheric CO_2 concentration
  - 1/3 in 2050
  - Less than 1/10 in 2100 (further improvement after 2100)



Global carbon dioxide emission scenario



Forecast of world population



Forecast of world GDP

Forecast of energy consumption

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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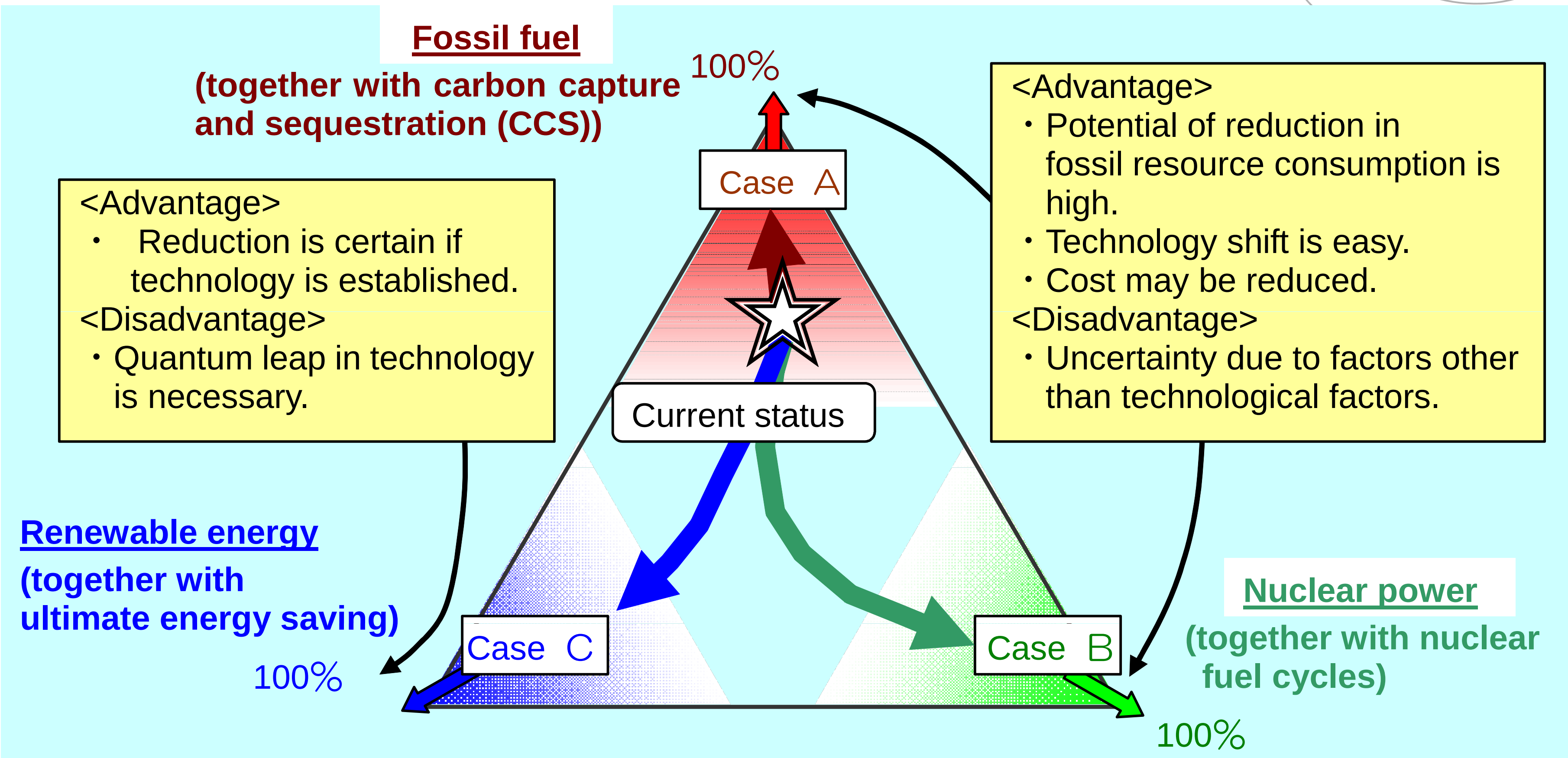
Three Extreme Cases and Possible Pathway to Achieve the Goal



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

Sketch of Technology Spec. 2100

Extreme Case-A (Fossil + CCS)

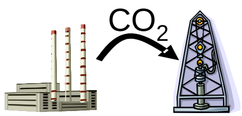
- Case A assumes a situation where we cannot heavily rely on energy saving.
- The increase of the share of electricity and hydrogen is considered.

** 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)

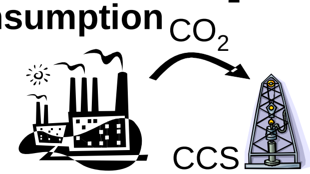
Supplying with coal fired power plants with CCS

Electricity or Hydrogen

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.*

[Target in the Industry Sector]

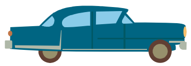
(1) CCS it applied to over 80% of CO_2 emissions from fossil fuel consumption



(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)

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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

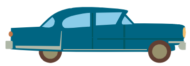
Electricity or Hydrogen

[Target in the Industry Sector]

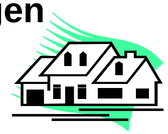
(1) All the energy demand is supplied with electricity or hydrogen with the exception of feedstocks and reductants

[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)

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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

Electricity, Hydrogen or Biomass

Supplying by renewable energies

[Target in the Industry Sector]

Energy demand to be reduced by 70%**

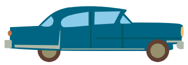
(1) 50% of the production energy intensity is reduced.

(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

ETV 2100 [Residential / Commercial]
Net-Zero Energy Supply

Res/Com		2000	2030	2050	2100
Total energy demand		1 time		1.5 times	2.1 times
Energy supplied from transformation sector*	Residential / Commercial		45% / 35% reduction	60% / 55% reduction	80% / 80% reduction
CO_2 intensity	Residential	3.5 t-CO_2/household (1 time)	1.9 t-CO_2/household (1/2 times)	1.1 t-CO_2/household (1/3 times)	0 t-CO_2/household
	Commercial	118 kg-CO_2/m^2 (1 time)	77 kg-CO_2/m^2 (2/3 times)	40 kg-CO_2/m^2 (1/3 times)	0 kg-CO_2/m^2

*The percentage of reduction of energy per unit should be supplied from the transformation sector, compared with total energy demand increases in proportion to GDP.

Energy saving

Efficiency improvement of equipment

- *Lighting with less heat loss* — *Equipment with less heat loss*
- *Improving thermal performance of housing and building* → *Active control of sun shading and thermal insulation*
- *Efficient heating* → *Efficient heat transfer, preheating by unused energy*
- *Improving electric power conversion efficiency* → *Electric power conversion with least loss*
- *Food storage at room temperature*

Use of ubiquitous energy
(minute pressure, temperature difference, vibration, radiowaves, etc.)

- *Energy saving enables equipment using little energy*
- *Energy creation from ubiquitous energy*

Photovoltaic generation

- *Installation in all places such as PV paint*
- *Installation in windows*
- *Installation in curved surfaces*
- *Installation facilitation*

Energy creation

- *Efficiency improvement and increase of durability*

Self-sustaining

0 t-CO_2/household

0 kg-CO_2/m^2

Energy management

BEMS•HEMS

Self-sustainable housing and building

- *Demand management* → *Management of demand and energy creation* → *Energy accommodation in community*
- *(Energy supply in community)* → *Supply and storage management in community* → *Supply and demand management in community*

TEMS **Self-sustainable community**

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ETV 2100 [Industry]

Integration of Material & Energy Production

Industry	2000	2030	2050	2100
(Production) X (Value of product)	1 time		1.5 times	2.1 times
Energy supplied from transformation sector*		25% reduction	40% reduction	70% reduction
1) Production energy intensity		20% reduction	30% reduction	50% reduction
2) Material/energy regeneration ratio		50%	60%	80%
3) Improvement of functionality such high-strength etc. (functionality / amount of material)	1 time	2 times	3 times	4 times

*The percentage of reduction of energy per utility (production x value of product) should be supplied from transformation sector, compared with the case where total energy demand increases in proportion to GDP.

High level of energy use at production process ***"create skillfully"***

(Energy saving in process)

Development of innovative production process
Use of bio/nano catalyst etc

Zero-emission process

Cogeneration & cascade use of heat

Integration and cooperation of material and energy

Co-production (simultaneous production of material and energy)

(Fossil resource use) → *Biomass/hydrogen use*

Regeneration of material/energy ***"use skillfully"***

Efficiency improvement of material regeneration process

Regeneration and utilization of material/energy in products

Regeneration & utilization of material/energy beyond sectors

Cross-boundary measures beyond sectors

Design technique for easy separation & sorting
Durability improvement

Improvement of functionality of material and parts

Material saving of products

Energy reduction for production with few resources ***"create good things"***

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ETV 2100 [Transport]

Near-zero Emission

Transport		2000	2030	2050	2100	
Utility (person-km, ton-km)		1 time		1.5 times	2.1 times	
Energy supplied from transformation sector* (overall)			20% reduction	50% reduction	70% reduction	
Automobiles	Energy demand		30% reduction	60% reduction	80% reduction	
	Share of electricity and/or hydrogen	0%	1% or more	40%	100%	
	CO_2 intensity	160 g-CO_2/km (1 time)	100 g-CO_2/km (2/3 times)	50 g-CO_2/km (1/3 times)	0 g-CO_2/km	→ Consequentially, 1/10 or less is achieved.
Aircraft, ships, and trains	Energy demand		10-20% reduction	20-35% reduction	30-50% reduction	

*The percentage of reduction of energy per unit should be supplied from the transformation sector, compared with utility increases in proportion to GDP.

Energy Conservation

Automobiles

(Engine) → *Engine/Electric motor (hybrid system)* → *Electric motor Fuel cell/Battery*

Energy saving by vehicle weight reduction *Super-light compact cars for regional use*

0 g-CO_2/km (Automobiles)

Liquid fuel (Oil) → *Synthetic fuel (mixture)*

Biomass fuel (mixture)

Hydrogen storage: *Compressed hydrogen → liquid hydrogen, hydrogen storage material*

Hydrogen supply: *Batch transportation → Effective on-site production → pipeline transportation (limited region)*

Electric energy storage: *Battery and capacitor, etc.*

Electricity supply: *Cable-connected charge → Cable-less non-contact charge*

Aircraft

Ships

Trains

Transport systems

Engine efficiency improvement

Energy saving by body weight reduction

Hydrogen drive, Superconducting motor drive

Ship enlargement, Low-speed operation

Hybrid drive

Energy saving by transport system cooperation

Fuel switch

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ETV 2100 [Energy Supply]
Near-zero Emission

Transformation	2000	2030	2050	2100
Total energy demand on the demand side (maximum case)	1 time		1.5 times	2.1 times
Share of electricity and/or hydrogen in final energy	1 time		2 times (Case A and C) 3 times (Case B)	4 times (Case A and B) 3 times (Case C)
CO_2 Intensity	370 g-CO_2/kWh (1 time)	270 g-CO_2/kWh (2/3 times)	120 g-CO_2/kWh (1/3 times)	0 g-CO_2/kWh *110 g-CO_2/kWh (1/3 times)* *In the case of fossil fuel use with CCS*

Reduction in fossil use

Efficiency improvement of fossil fuel use

Fuel switching and efficiency improvement

(oil) → *Natural gas*

(coal) → *Coal (clean coal technology + CO_2 capture and sequestration (CCS))*

Nuclear energy use

Nuclear fuel cycle

Load following operation

Efficiency improvement

0 t-CO_2/kWh

Renewable energy use

Solar — *Technology that can be set up in all places such as roads and dams*

Geothermal

Wind power — *Onshore* → *Offshore*

Biomass — *Wood and biomass (waste and unused biomass)* → *Fuel crops production*

Efficiency improvement

Installation simplification

Energy storage

Introduction of non-fossil energy

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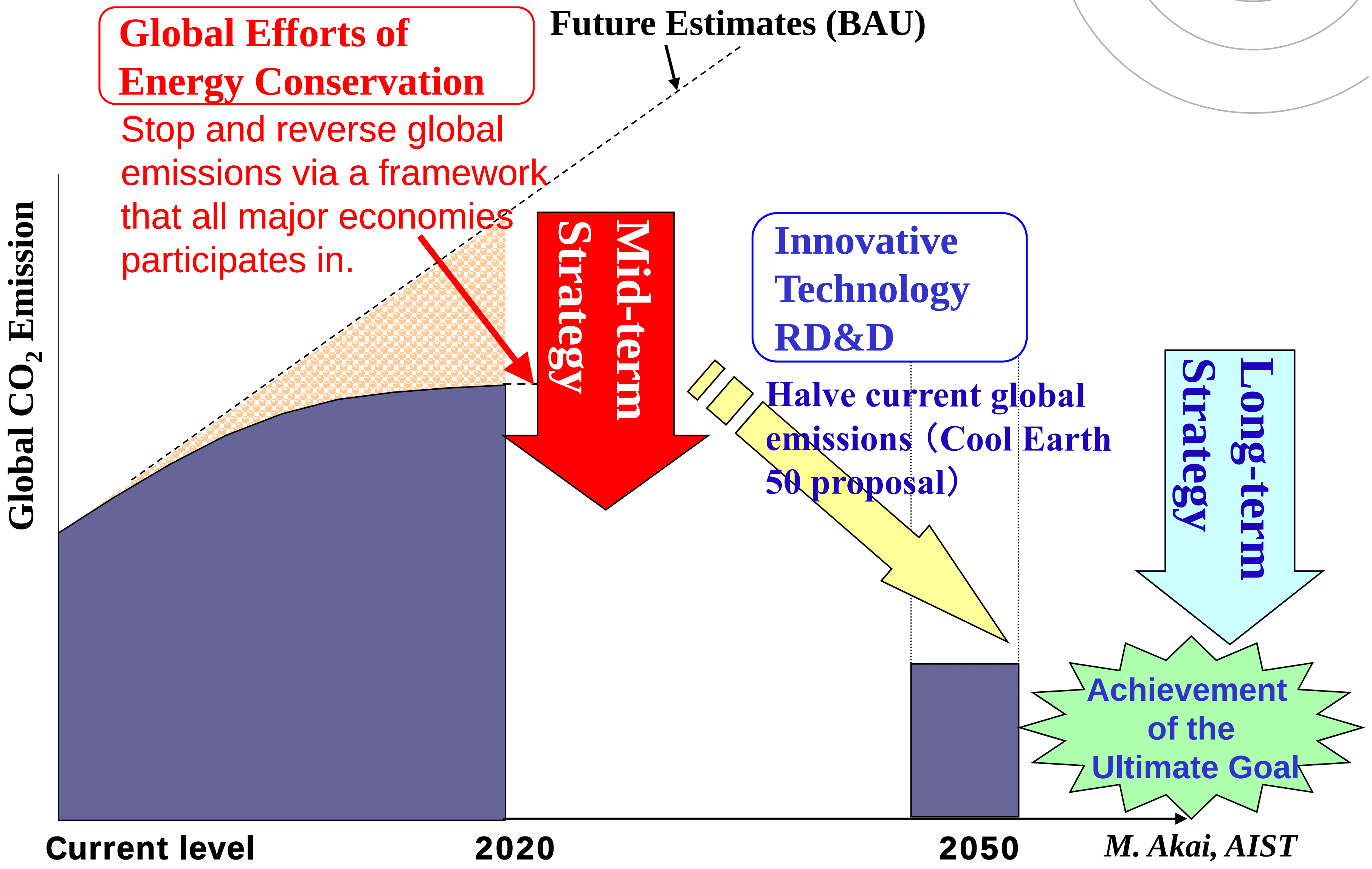
Proposal by Japan's Prime Minister
(May 24, 2007)



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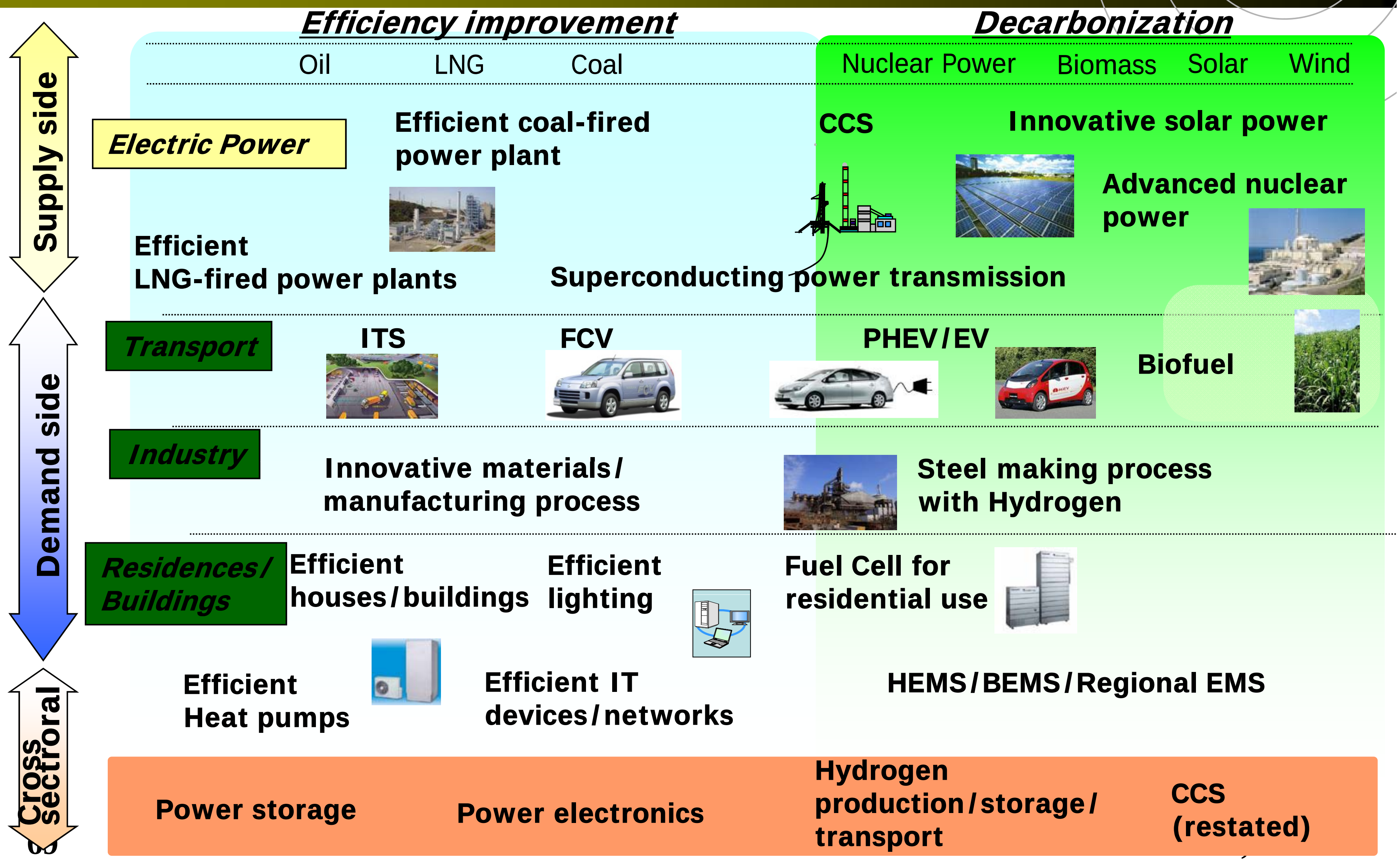
Cool Earth-
Innovative Energy Technology Program

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)

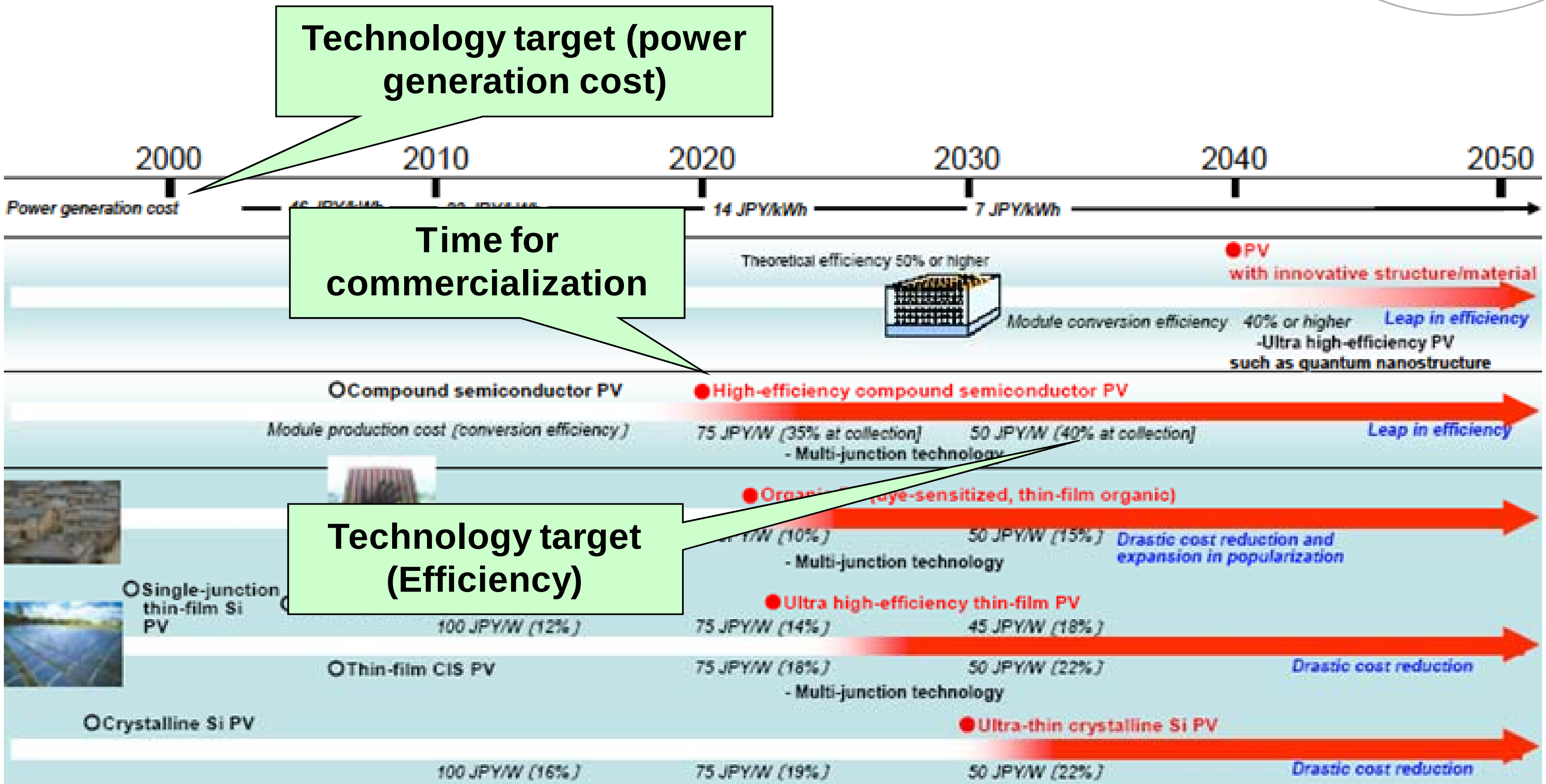
- **Identified 21 key energy technologies to be focused on with high priority.**
- **Formulated technology roadmaps for them, which give RD&D direction and milestones on performance with timelines, and propose further development of global technology roadmaps to monitor global RD&D progress**
- **Strengthen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

21 Key Innovative Energy Technologies



Technology Roadmaps toward 2050
Example on PV

An image of our technology roadmap for innovative PV



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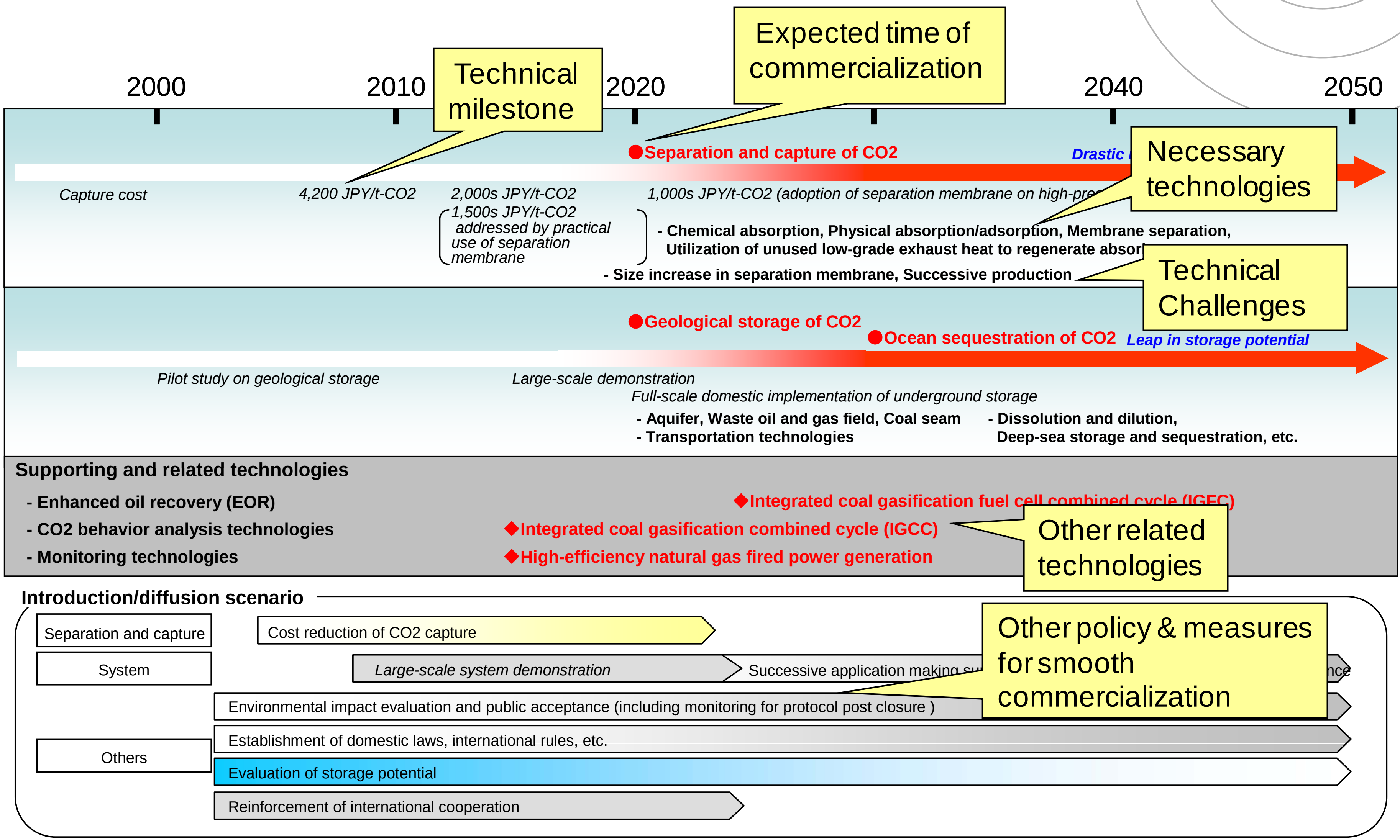
Example of Technology Roadmap on CCS



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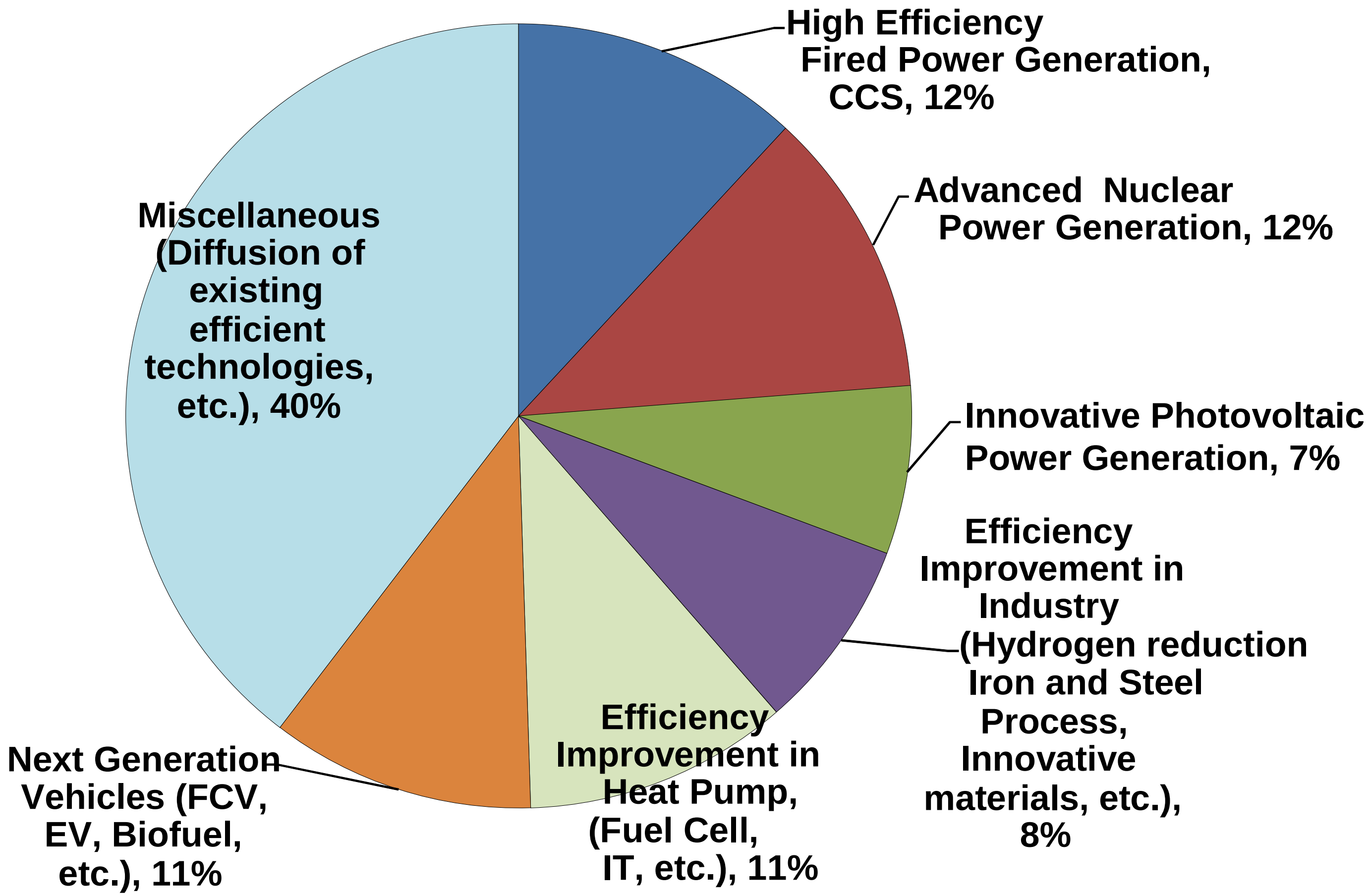
Contribution of Technologies for 50 % Emission Reduction in 2050



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.**

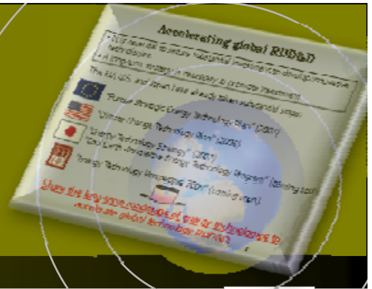
Need for International Action

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

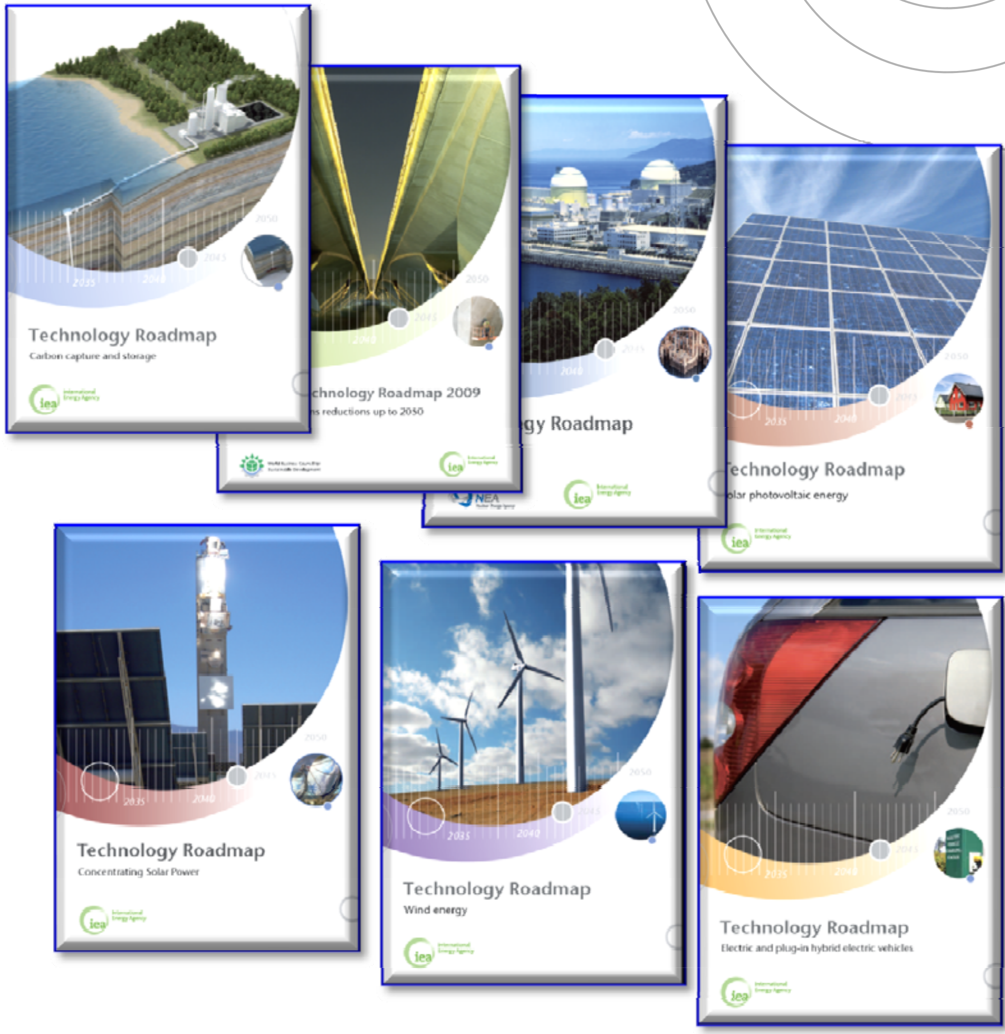
International Energy Agency, Paris

- **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.**

Development of Technology Roadmaps in IEA

- **Carbon Capture and Storage**
- **Cement industry**
- **Nuclear Power**
- **Solar photovoltaic energy**
- **Concentrating Solar Power**
- **Wind Energy**
- **Electric and Plug-in Hybrid Vehicles**

- **Smart Grids**
- **Bioenergy**
- **Biofuels**
- **Energy Efficient/Low-Carbon Buildings**
- **Geothermal**
- **Efficient Industry Processes**



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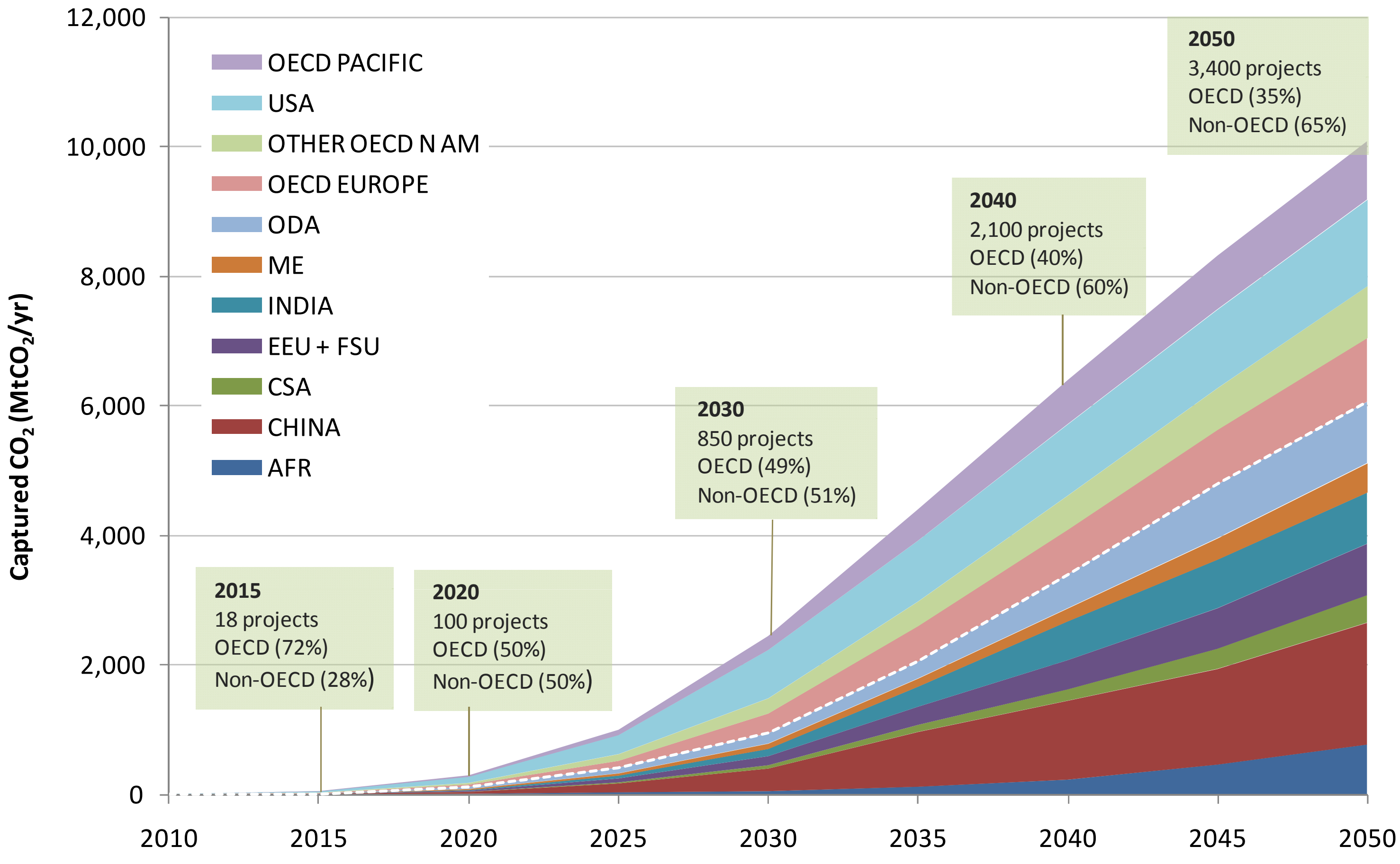
IEA CCS Roadmap

Global Deployment of CCS 2010–50 by Region

BLUE Map Scenario (~450 ppm)



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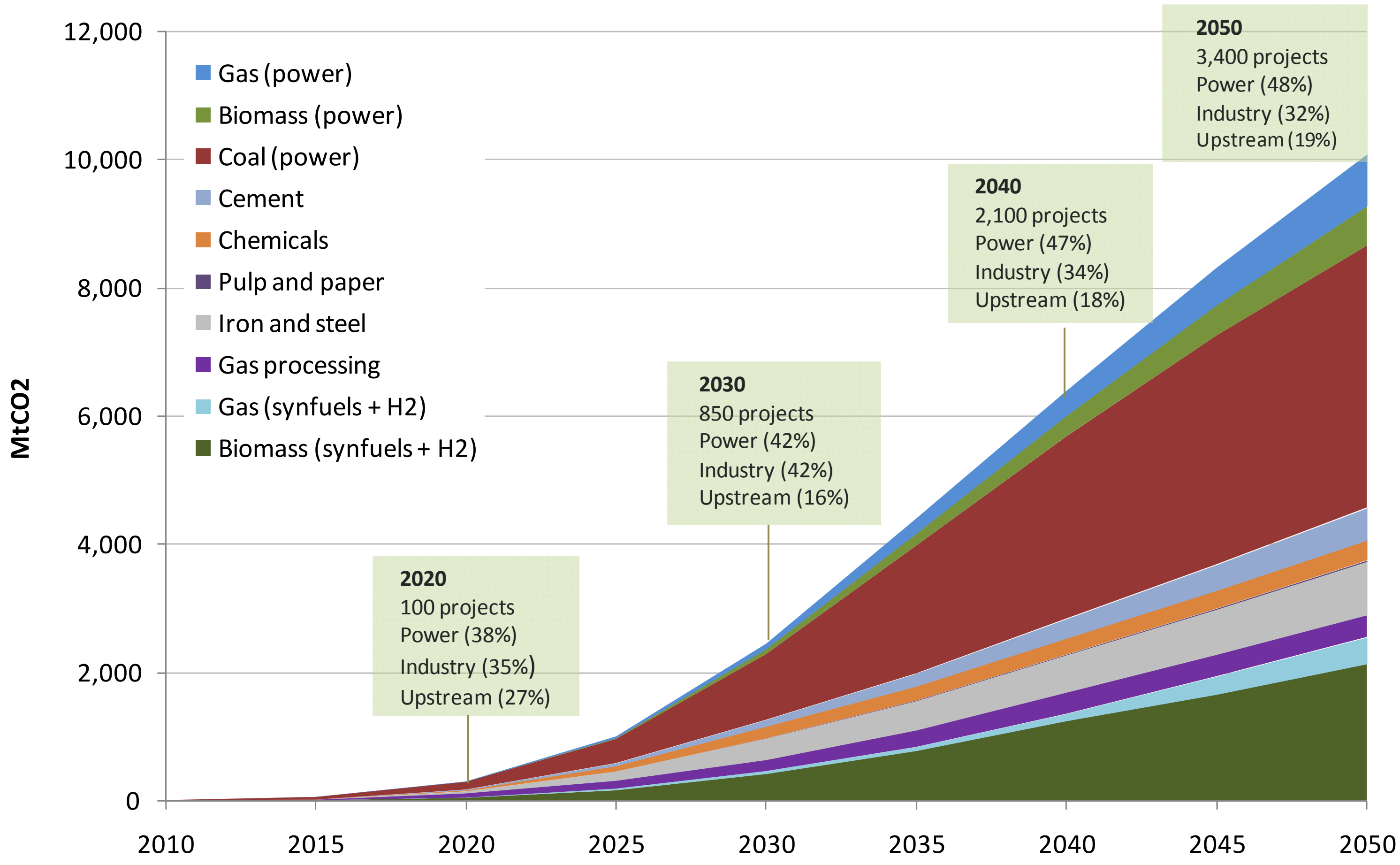
IEA CCS Roadmap

Global Deployment of CCS 2010–50 by Sector

BLUE Map Scenario (~450 ppm)



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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

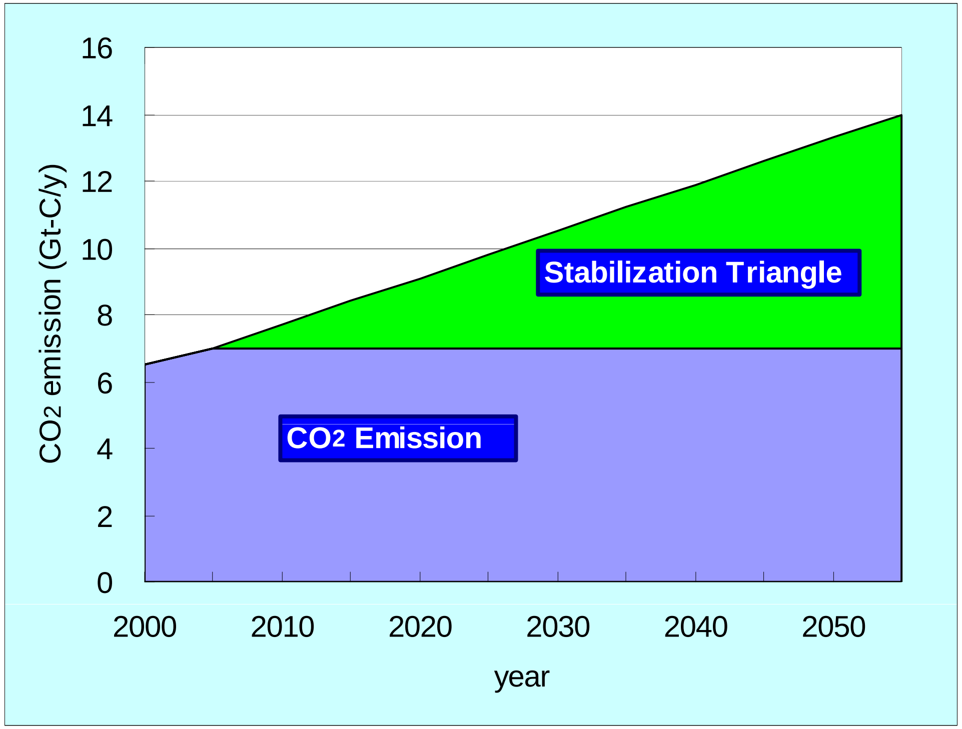
    ≈ **Implementation of Roadmaps**
  - To design and promote socio-economic system to challenge policy goals such as energy security, climate change, etc.
- **Available science and technologies, coupled with proper assessments, to drive Policies**

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: > ¥50,000/t-CO_2
  - CCS: ~10,000/t-CO_2

Simple Consideration on Deep Reduction Strategy

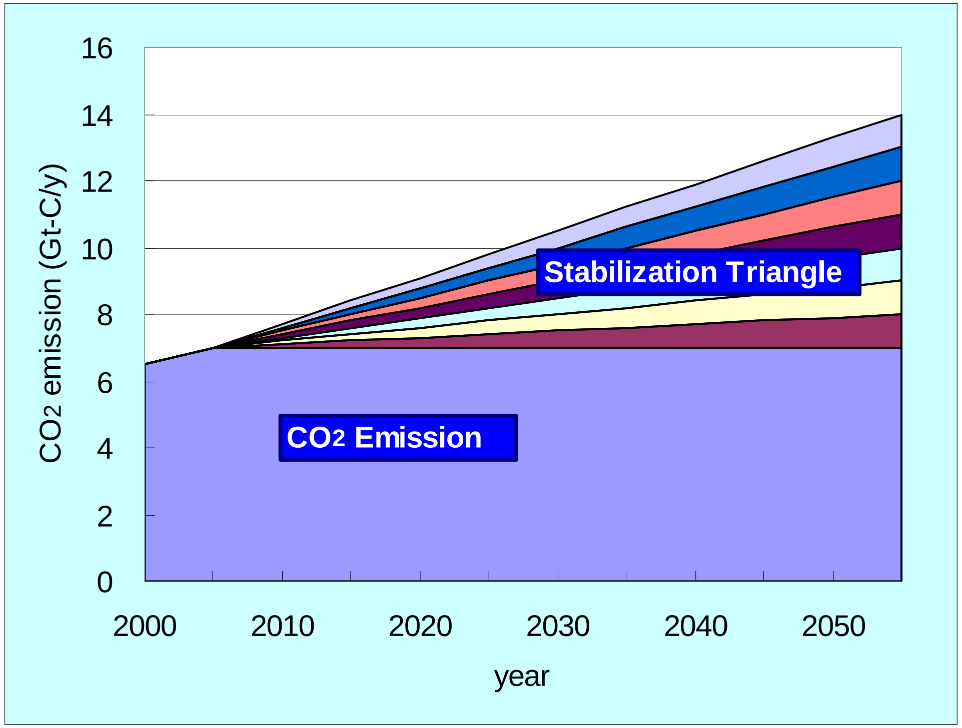
Stabilization Triangle



- **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.**

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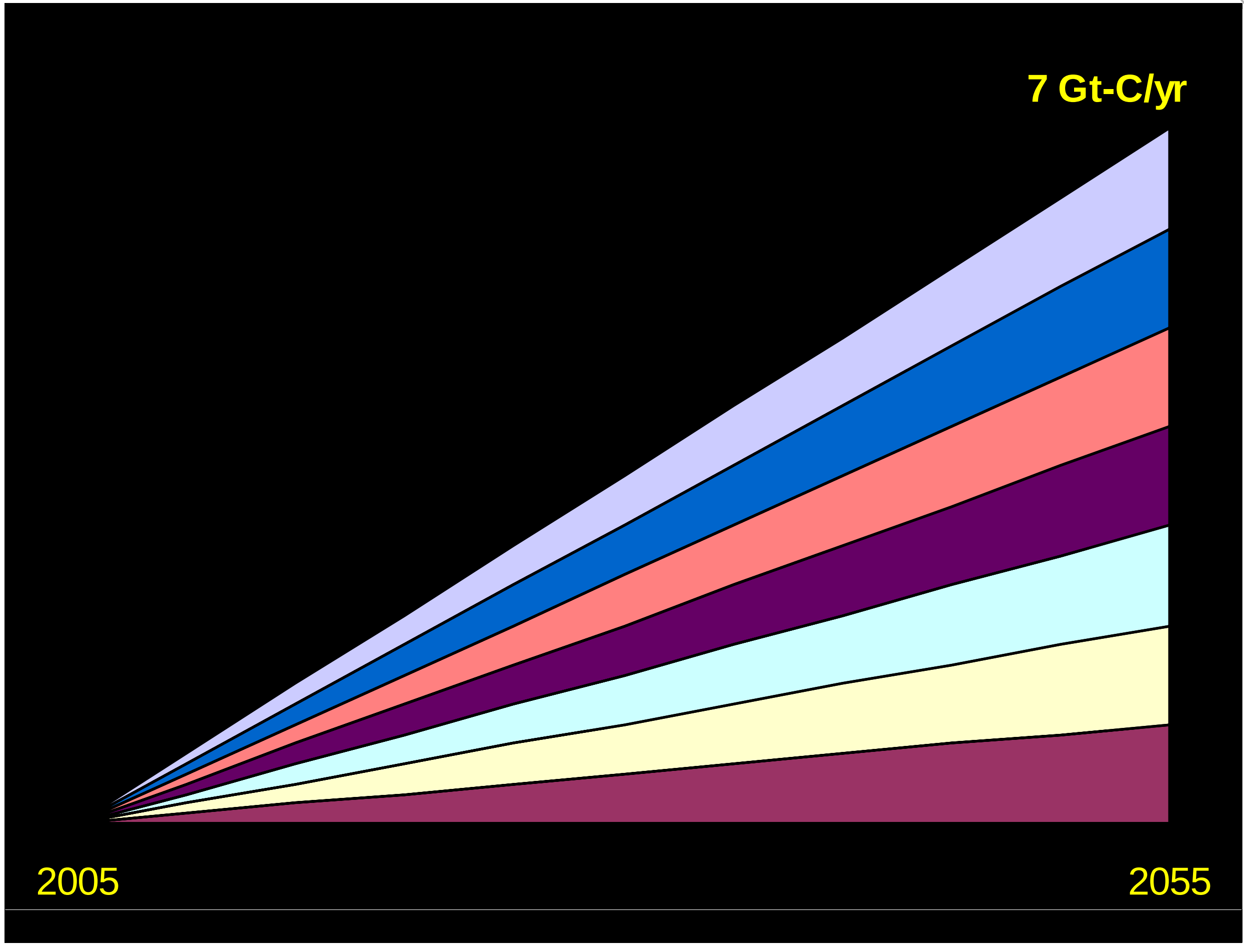
Seven Wedges to Fill the Triangle



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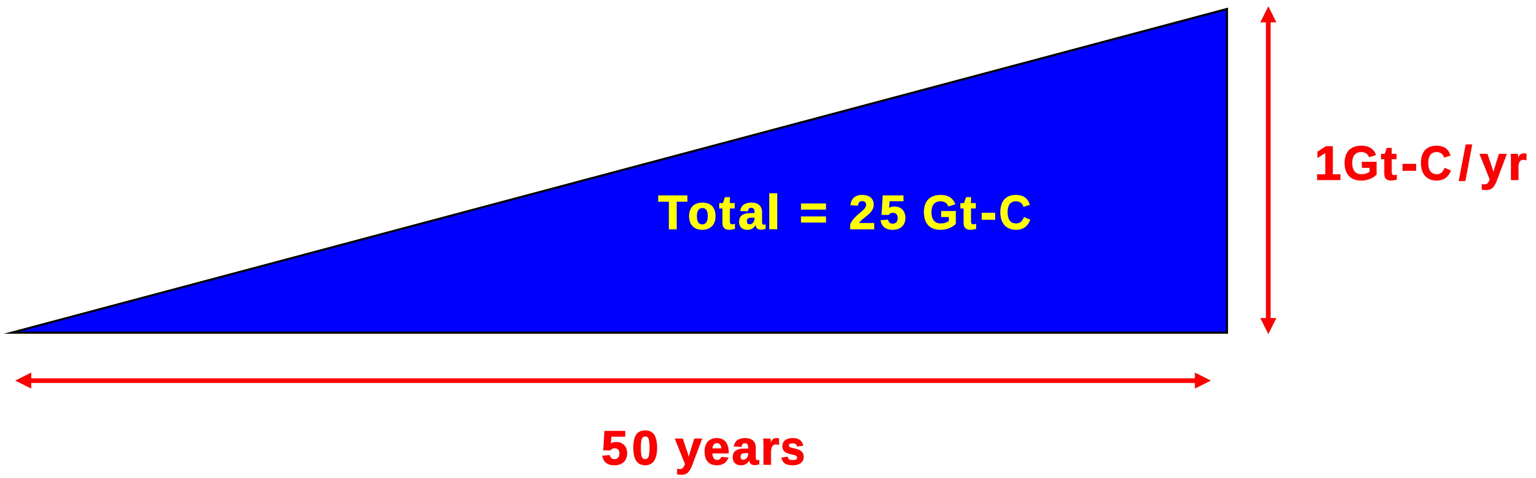
What is a “Wedge”?

- 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.



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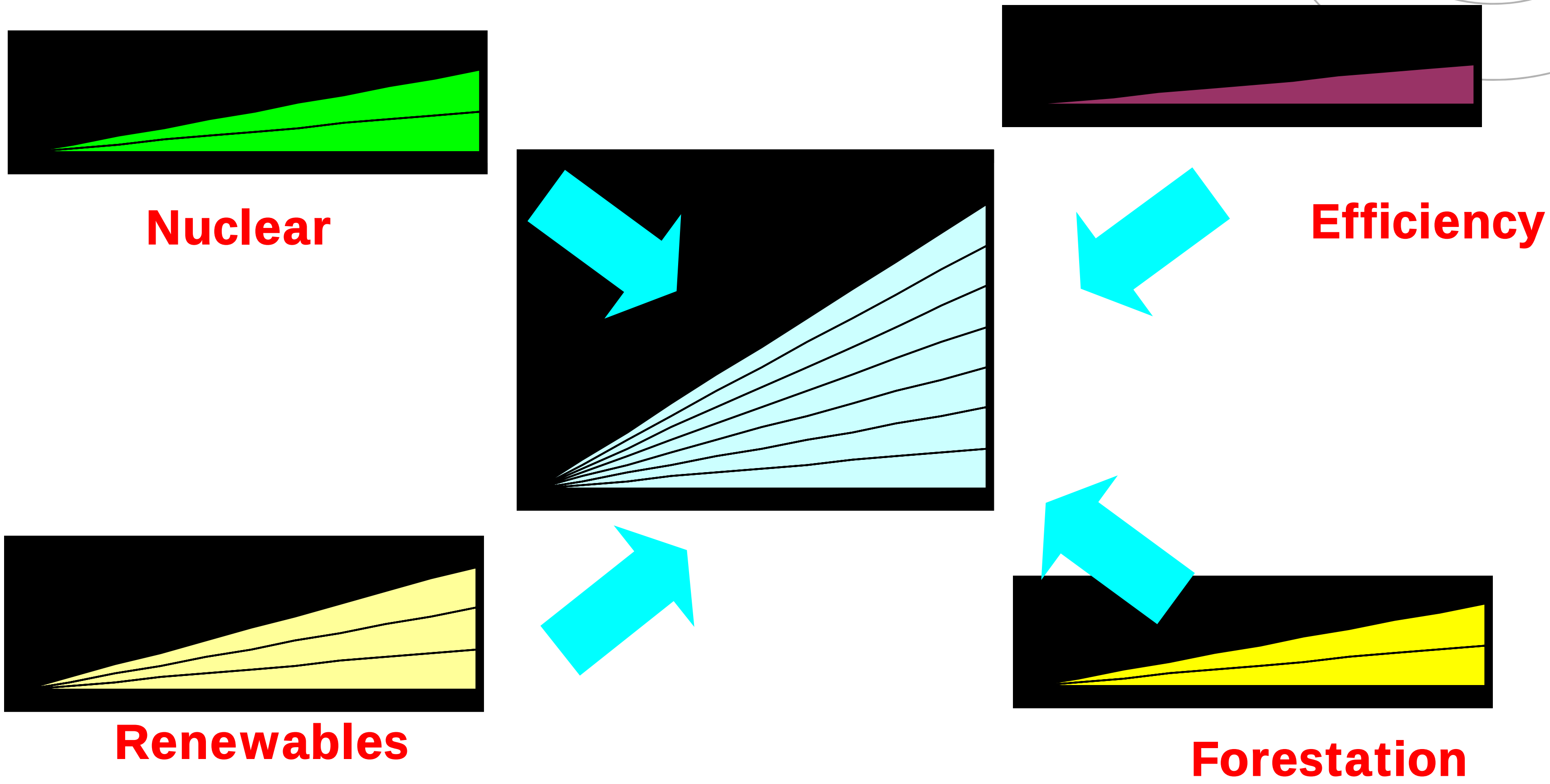
Filling the Stabilization Triangle



- **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 (~$1.7\times$current capacity)

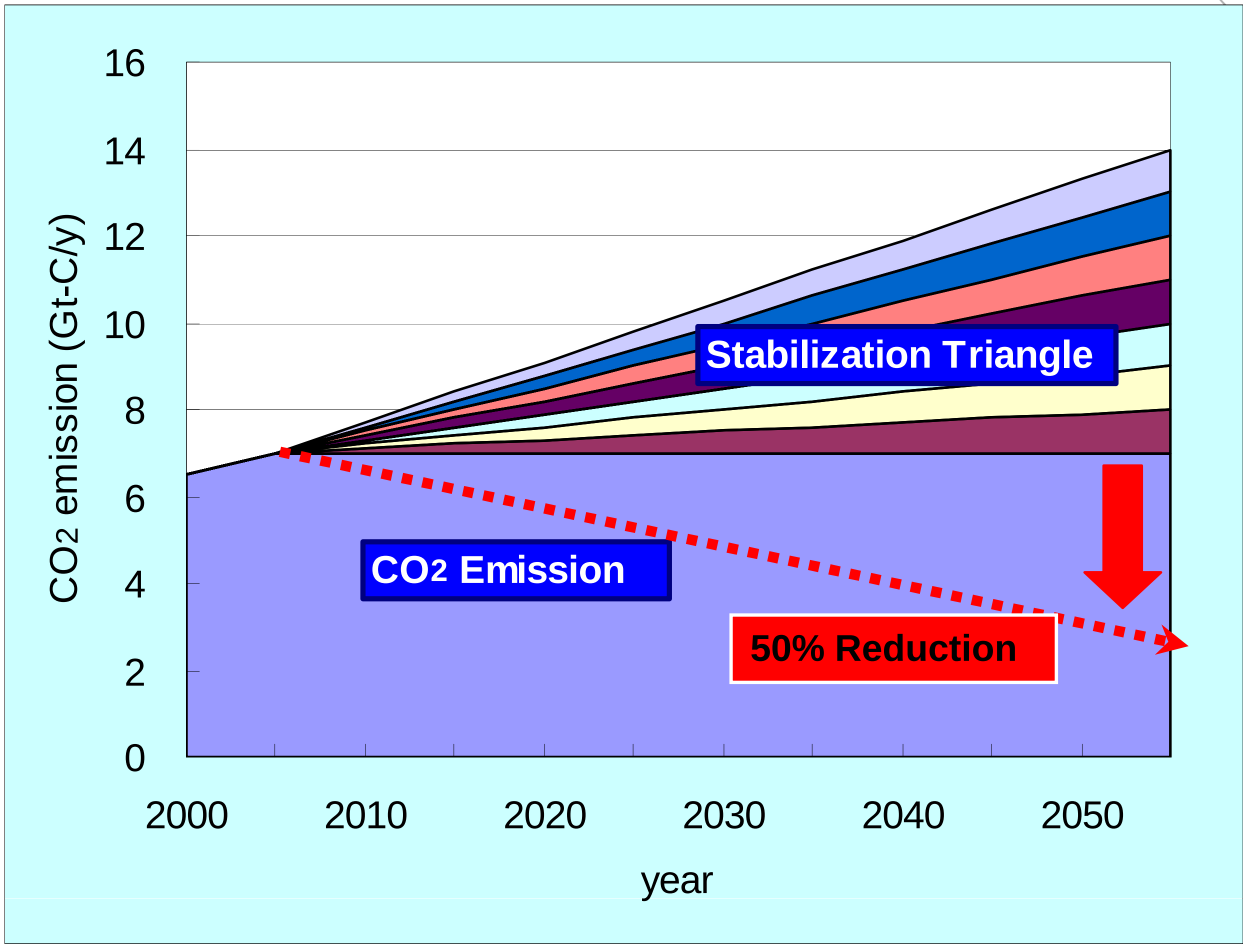
Reporting Subject

- 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



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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