Lecture of Global Focus on Knowledge:
Energy and Global Environment
THE ROLE OF TECHNOLOGY
IN ENERGY & GLOBAL ENVIRONMENTAL ISSUES

By
Kenji Yamaji

(October 22, 29 and November 5)

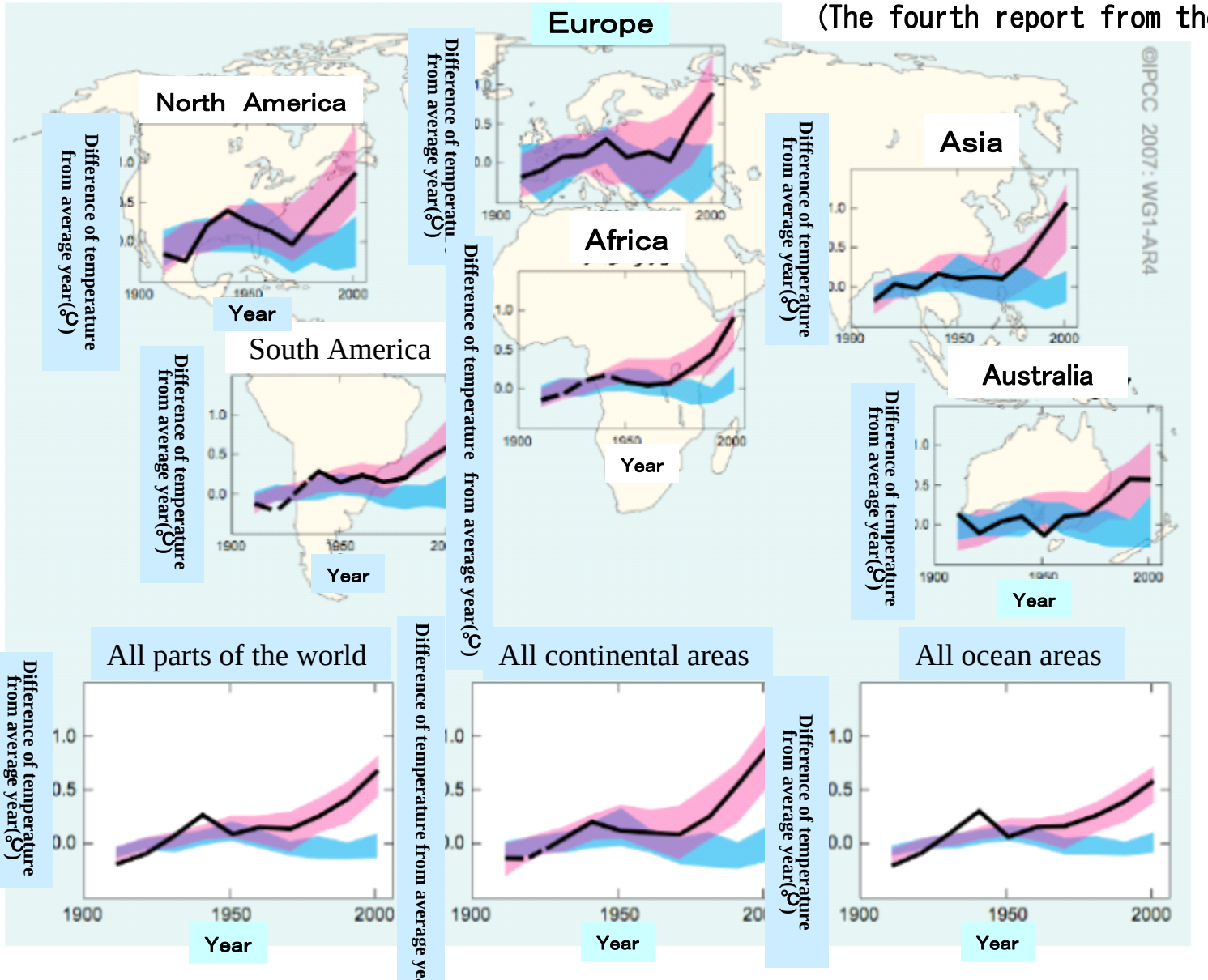
- **Perspectives on Energy Systems**
- **Energy Resources and Technology**
- **Long-Range Technological Scenario against Grand Strategy for Global Warming**

Long-Range Technical Scenario for Grand Strategy for Global Warming

- **Mechanism , Current conditions , and Effects of Global Warming**
  - With a focus on the knowledge from the fourth report of the IPCC
- **Ultimate Goal for Grand Strategy for Global Warming**
  - Countermeasures under the uncertainty of science
  - Stabilization level for the concentration of GHG
  - Information on the countermeasures from the fourth report of the IPCC
- **Study of Long-Range Technical Scenario of Grand Strategy for Global Warming**
  - Fundamental structures of countermeasures against global warming
  - Composition of world energy model DNE21
  - Scenario of optimum strategy to stabilize atmospheric CO2 concentration at 550ppm
- **Evaluation of Grand Strategy for Global Warming with Kaya Identity**
- **Basic Understanding about Grand Strategy for Global Warming**

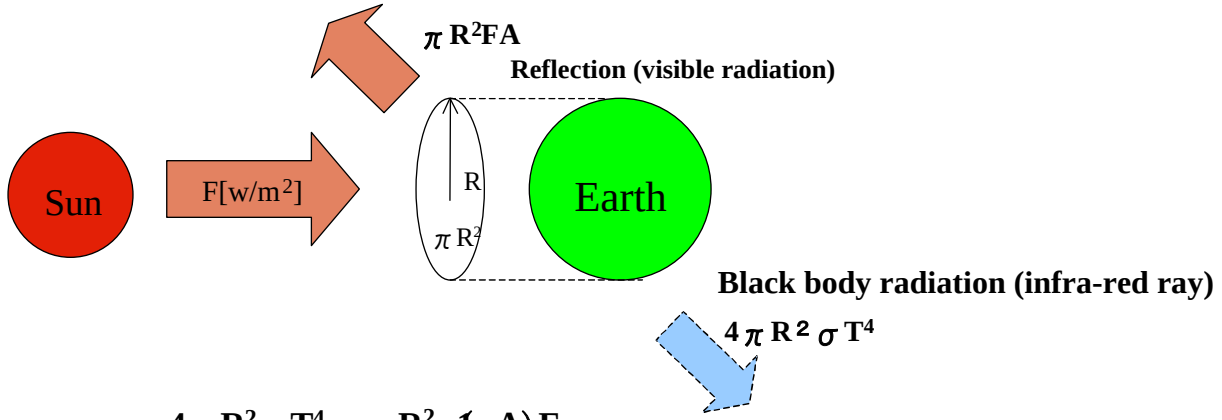
Change of Temperature on a Global and a Continental Scale

(The fourth report from the IPCC)



‡Source: IPCC,2007 WG1-AR4 translated text, p.13 (15th sheet), FigureSPM-4
http://www.data.kishou.go.jp/climate/cpdinfo/ipcc/ar4/ipcc_ar4_wg1_spm_Jpn_rev2.pdf

How is the Earth's temperature determined?



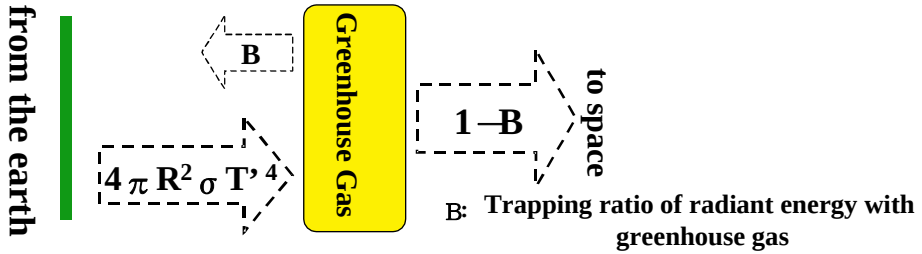
$$4\pi R^2 \sigma T^4 = \pi R^2 (1-A) F$$

$$T = \left[\frac{(1-A)F}{4\sigma}\right]^{1/4}$$

A (albedo) = 0.3, F(Solar constant)=1368W/m²

σ (Stefan-Bozemann law of radiation)= 5.67×10^{-8} $Wm^{-2}K^{-4}$

T=255K (-18℃)



B: Trapping ratio of radiant energy with greenhouse gas

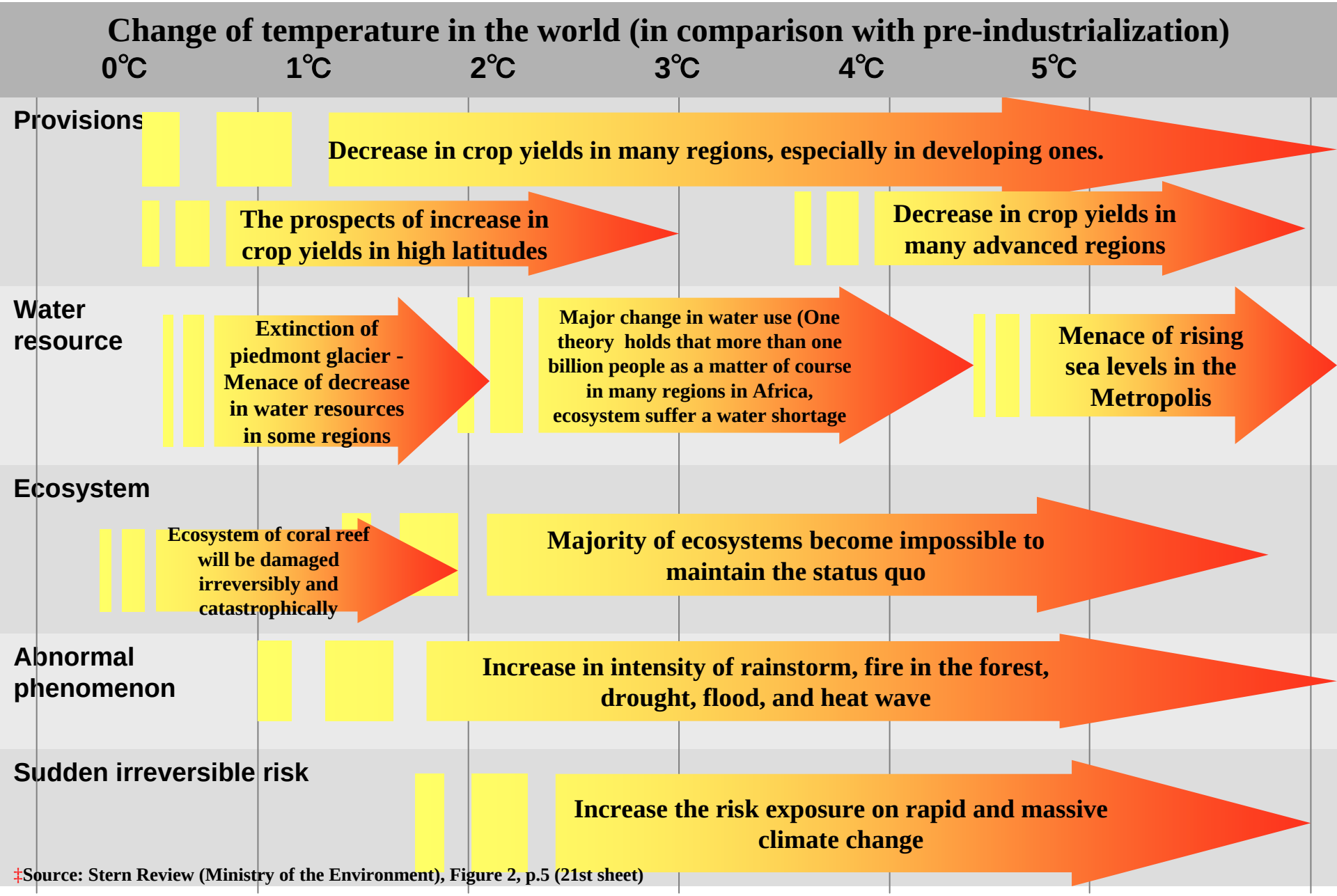
$$T' = \left[\frac{(1-A)F}{4(1-B)\sigma}\right]^{1/4}$$

B=0.4

T'=288K (15℃)

‡Source: Kenji Yamaji, *System methodology of Energy, Environment, and Economics*. Iwanami-shoten, 2006 Figure 3-9 (p.87)

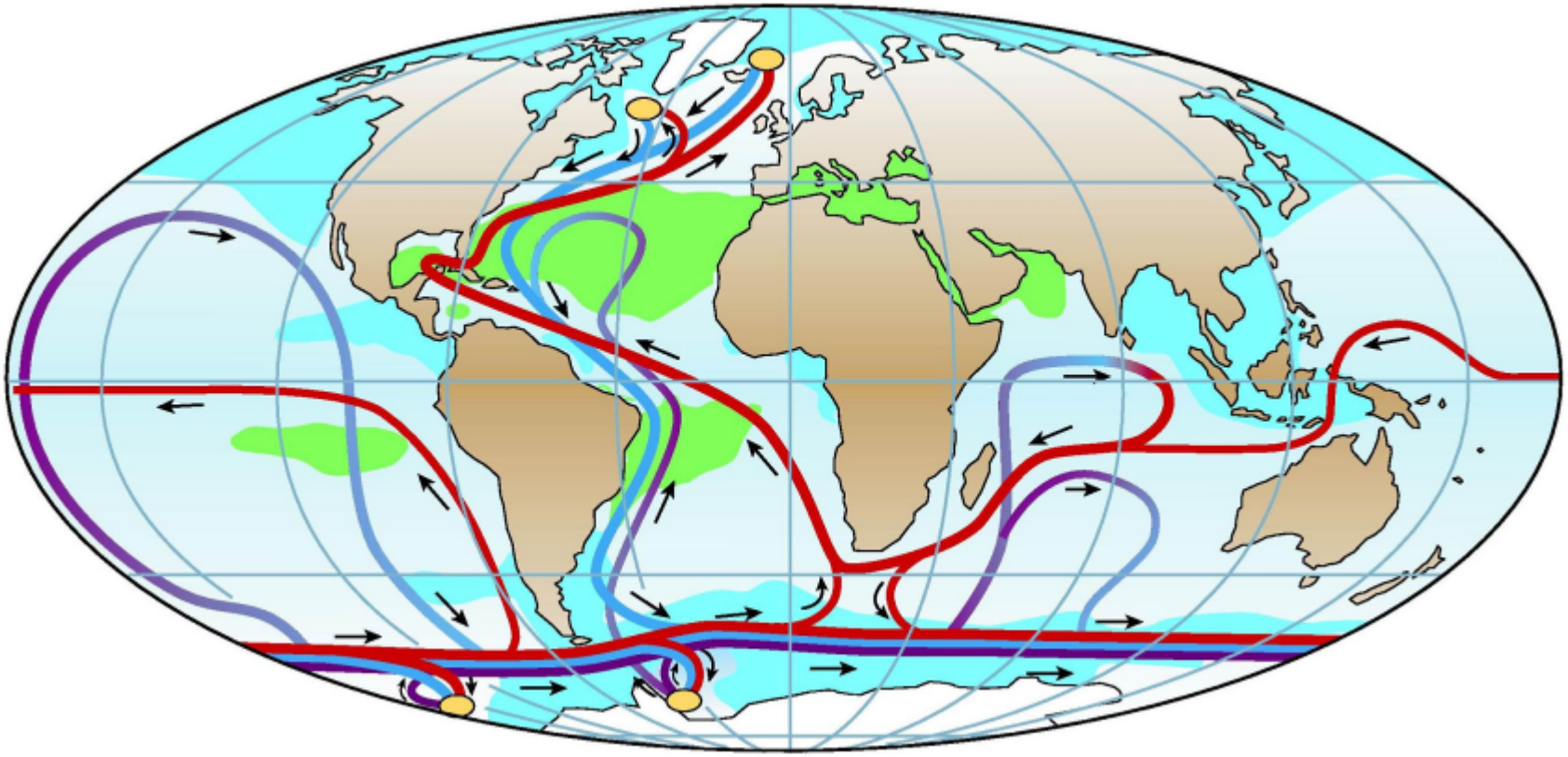
The effects of foreseen climate change



‡Source: Stern Review (Ministry of the Environment), Figure 2, p.5 (21st sheet)

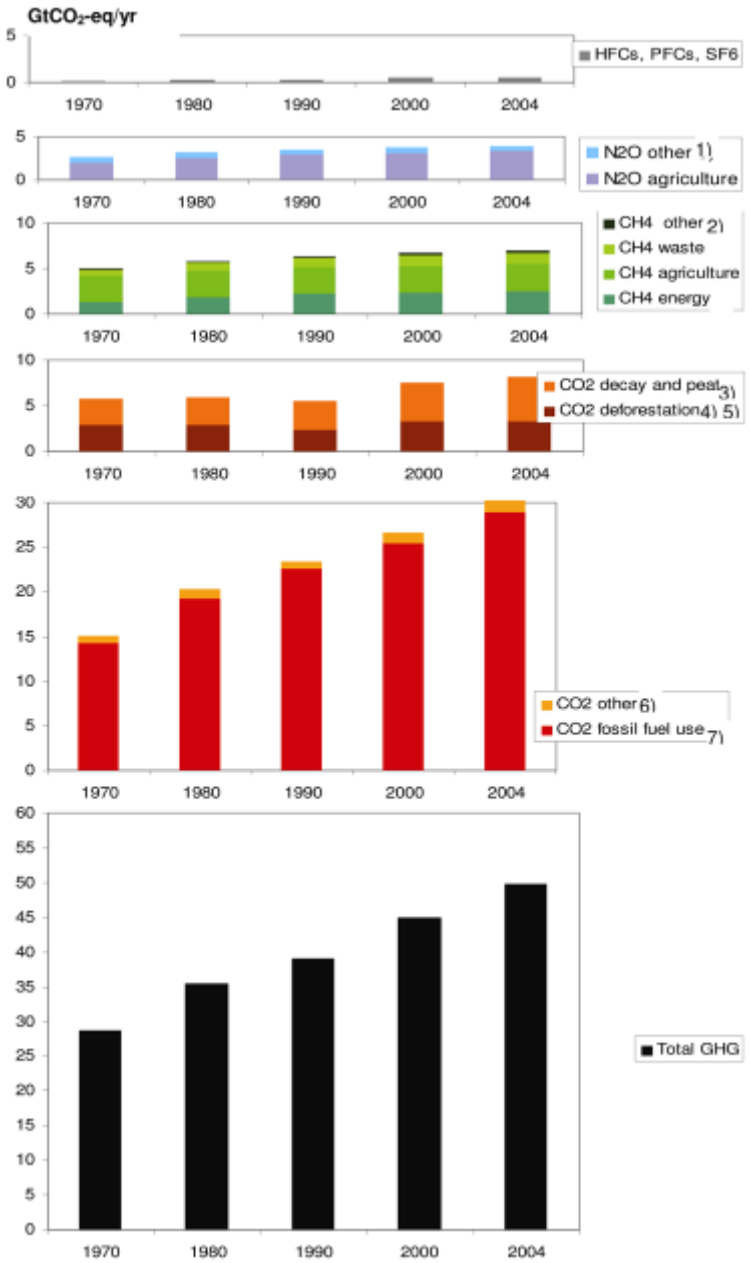
Thermohaline circulation arrest (Example of irreversible risk)

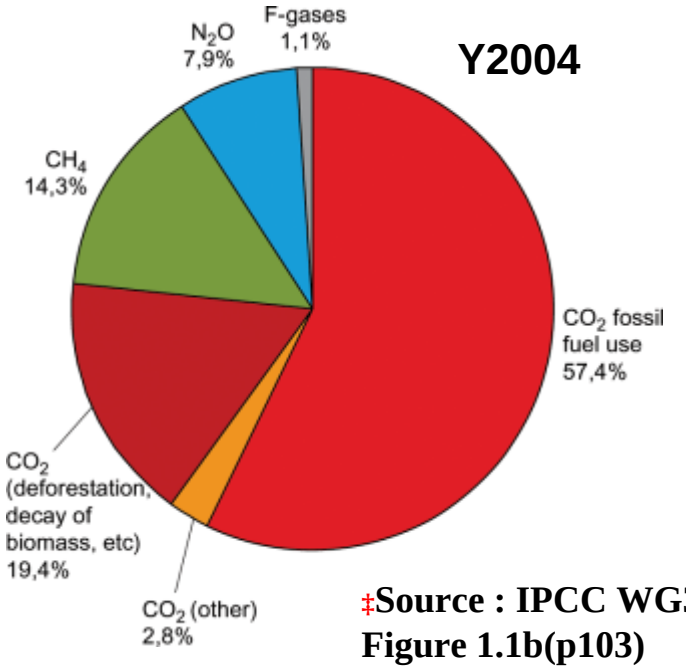
- Because Thermohaline circulation (THC) arrest is likely to affect the weather systems, in the North Atlantic in particular, as well as to disturb the global ocean ecosystems, it is one of the standard countermeasures against global warming to avoid it from a preventive point of view.



‡**Source :S. Rahmstorf, *Nature*, 2002**

Greenhouse Gas Emissions (1970-2004)



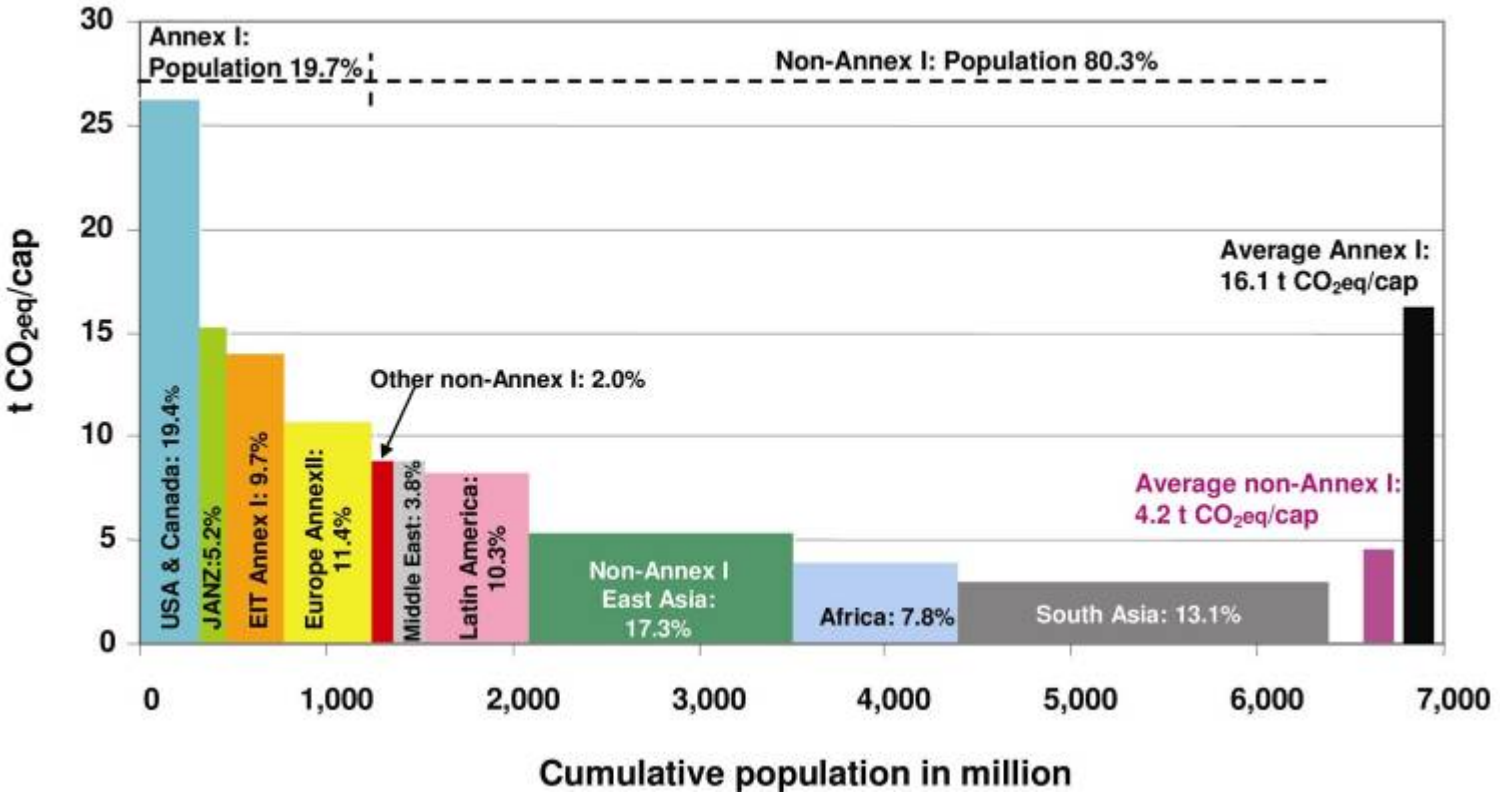


‡**Source : IPCC WG3 AR4, Ch.1 Figure 1.1b(p103)**

- GHG increased by about 70% between 1970 and 2004.
- Increase in CO2 is particularly prominent among others.
- CO2 from burning fossil fuel constitutes about 57%.
- CO2 concentration in the atmosphere in 2005 was 379ppm.
- Equivalent CO2 concentration by GHG was 455 ppm-CO2eq.
- Equivalent CO2 concentration including aerosol was 375 ppm-CO2eq.

‡**Source : IPCC WG3 AR4, SPM**

Per capita GHG emissions by region（2004）



	Annex I	Non-Annex I
Population	19.7%	80.3%
GHG emissions	48%	52%
Per capita emissions	16.1 tCO2eq./cap	4.2 tCO2eq./cap

‡**Source : IPCC WG3 AR4, SPM**

Ultimate Goal for Grand Strategy for Global Warming (Framework Convention on Climate Change, the Second Clause)

- **Target Level: Stabilize the concentration of greenhouse gases in the atmosphere with the level outside the reach of artificial interference, which is dangerous to climate system.**
- **Time boundary of Telesis: Achieve the target within a time frame when Ecosystems adapt climate change naturally without menace to food production and economic development that can be promoted on sustain ably.**

Signification of the goal to stabilize temperature at 2℃ (Uncertainty of Climate Science)

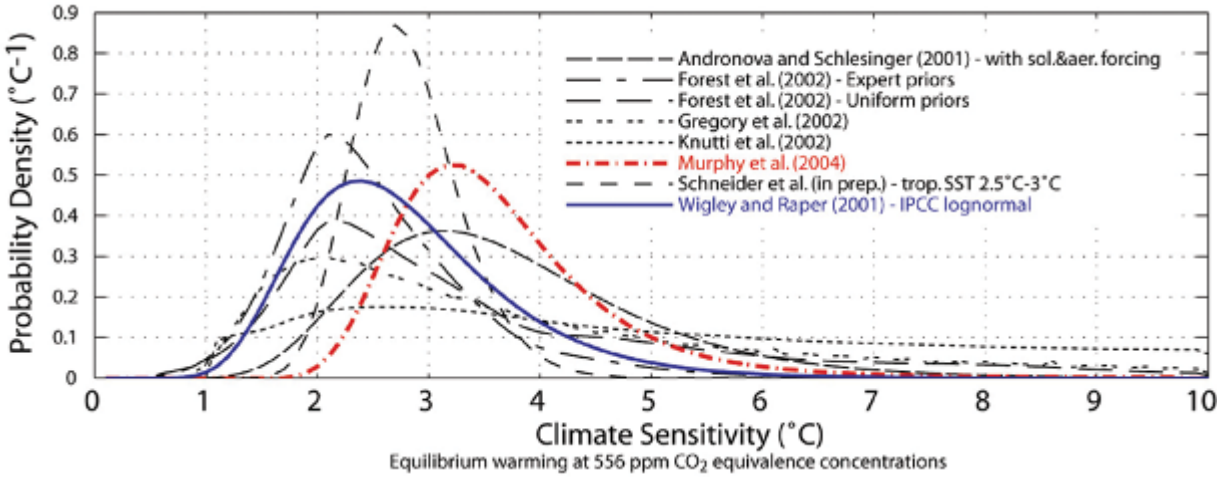
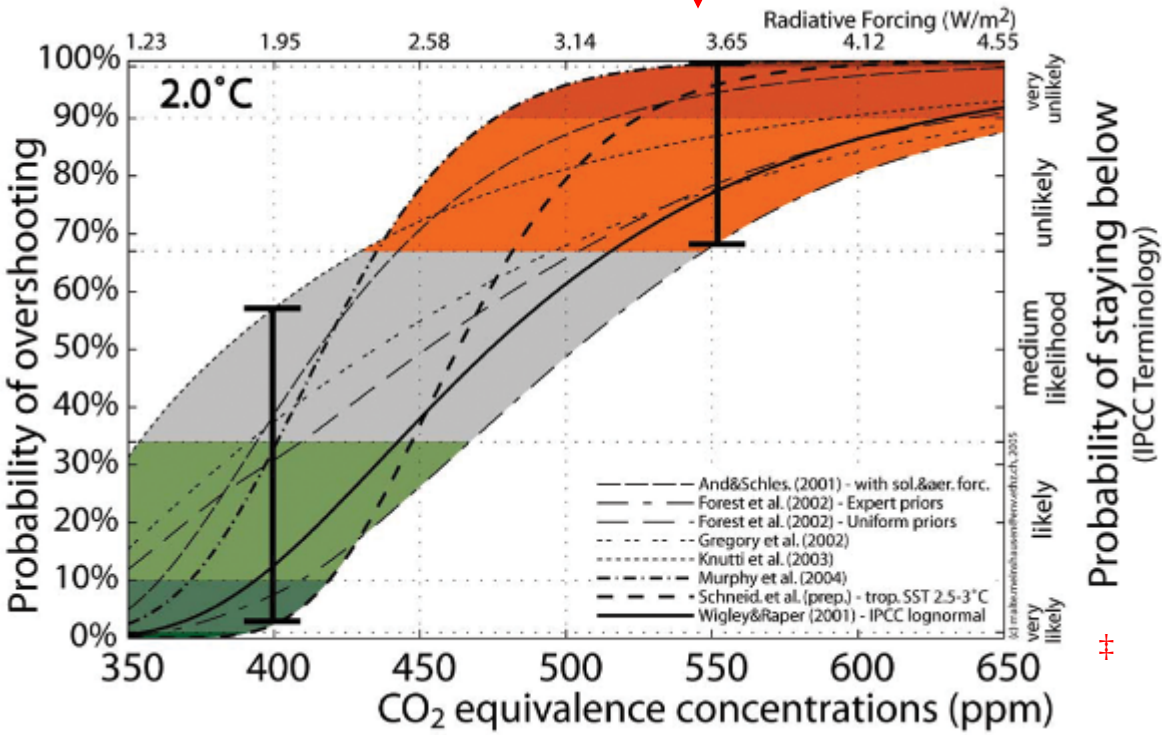


Figure out the probability of overshooting 2℃ from the distribution of Probability Density of Eight Climate Sensitivities

The Probability of overshooting 2℃ is estimated to be less than 10 to 60 percent in Stabilized 400ppmvCO2eq



Source: B. Hare & M. Meinshausen, “How much warming are we committed to and how much can be avoided?” *PIK Report No.93*, 2004

http://www.pik-potsdam.de/research/publications/pikreports/.files/pr93.pdf、figure2, p12、figure8,p26

Damage caused by Global Warning and costs for measures

EU proposal

Stern Review

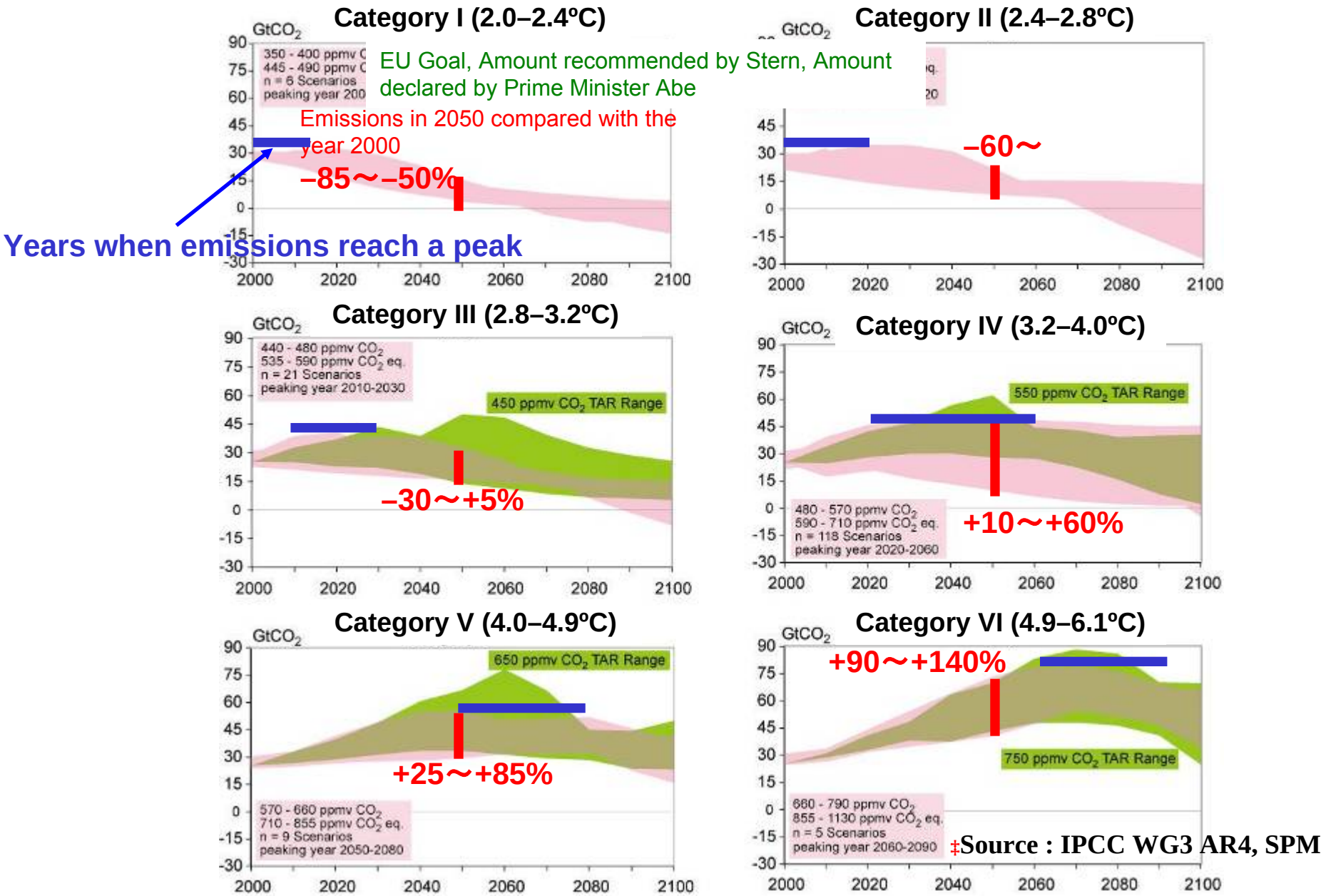
Government Proposal

CO2 concentration (ppm)	CO2 equivalence concentrations	Range of temperature increasing before Industrial Revolution(℃)	Percentage of reducing CO2 in 2050 (year %)	Cost of reducing CO2 (against GDP %)	Losses caused By global Warning (against GDP %)
350-400	445-490	2.0-2.4	-85~-50	＋5.5未満	Loss(＋)/benefit(-) Mixed in regions
400-440	490-535	2.4-2.8	-60~-30		
440-485	535-590	2.8-3.2	-30~＋5	1.3 (-0~4)	All regions ＋
485-570	590-710	3.2-4.0	+10~+60	0.5 (-1~2)	
570-660	710-855	4.0-4.9	+25~+85	—	1~5
660-790	855-1130	4.9-6.1	+25~+140	—	—

‡Source: Organized from the IPCC WG2 & WG3 AR4, SPM

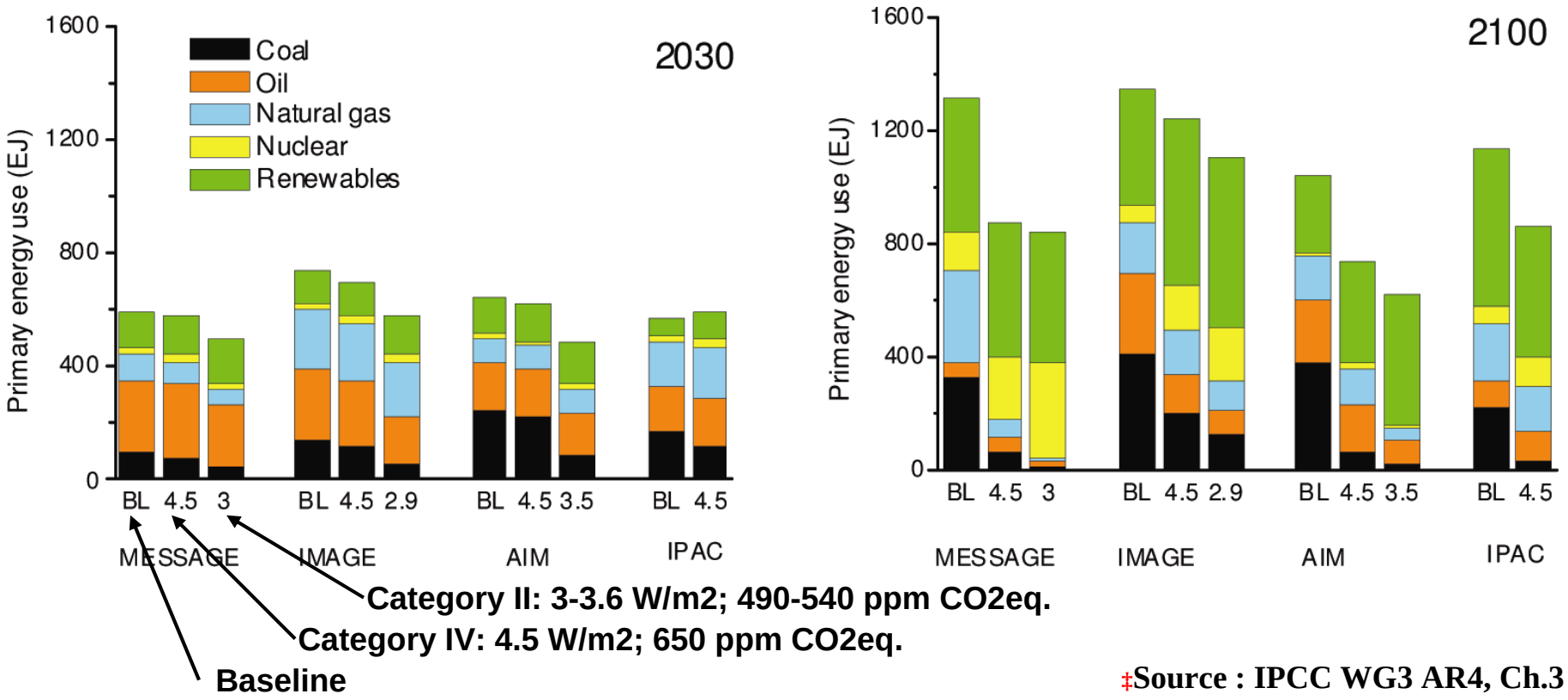
Note) In cost benefit, it is recommended that the sum of reduction costs and effected losses are the minimum.

Emissions Process Required to Stabilize at Each Level



‡Source : IPCC WG3 AR4, SPM

Reduction Technology Required by Stabilized Levels

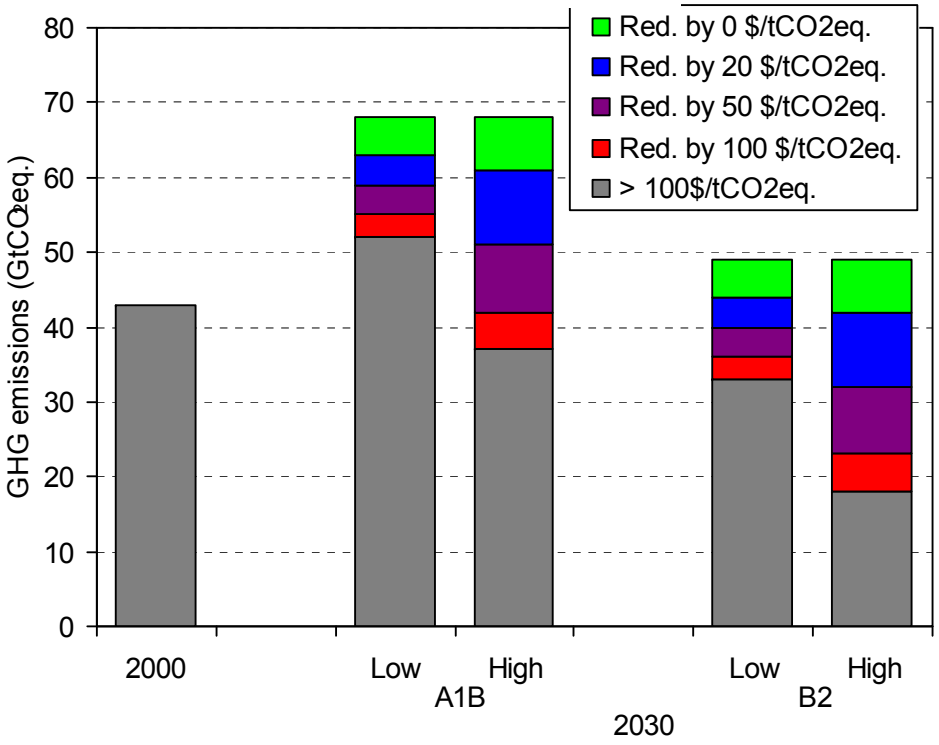


‡Source : IPCC WG3 AR4, Ch.3

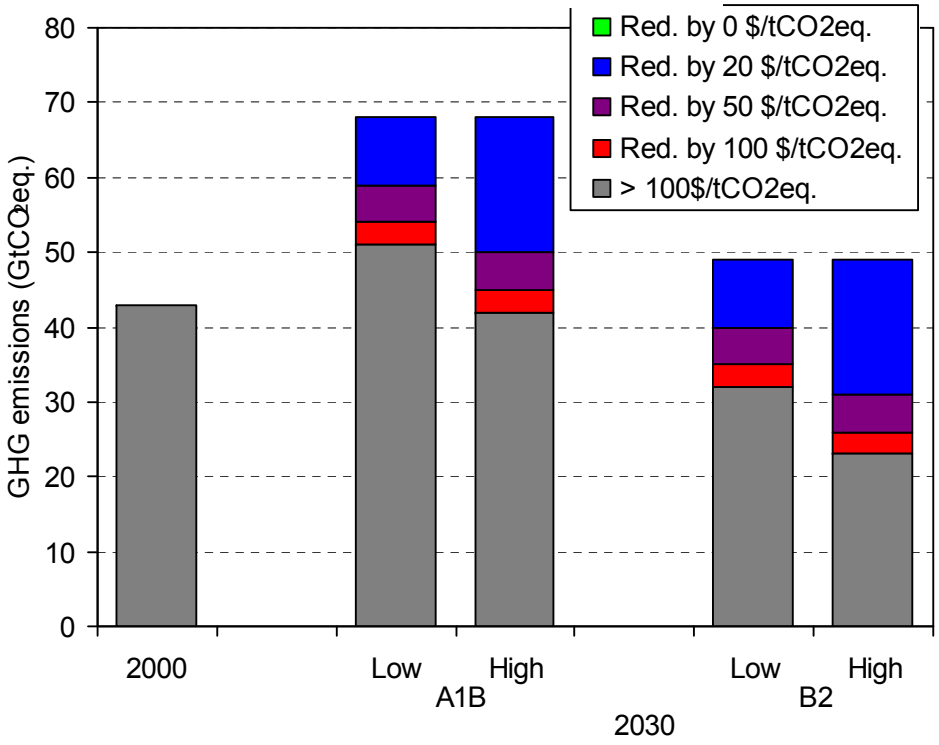
- The results of each model all suggest that more than half of the primary energy supply comes from the renewables in 2100. (A little too optimistic?)
- Message: Also a large scale of biomass CCS application.

Potential of the economy in 2030

Bottom-up Evaluations



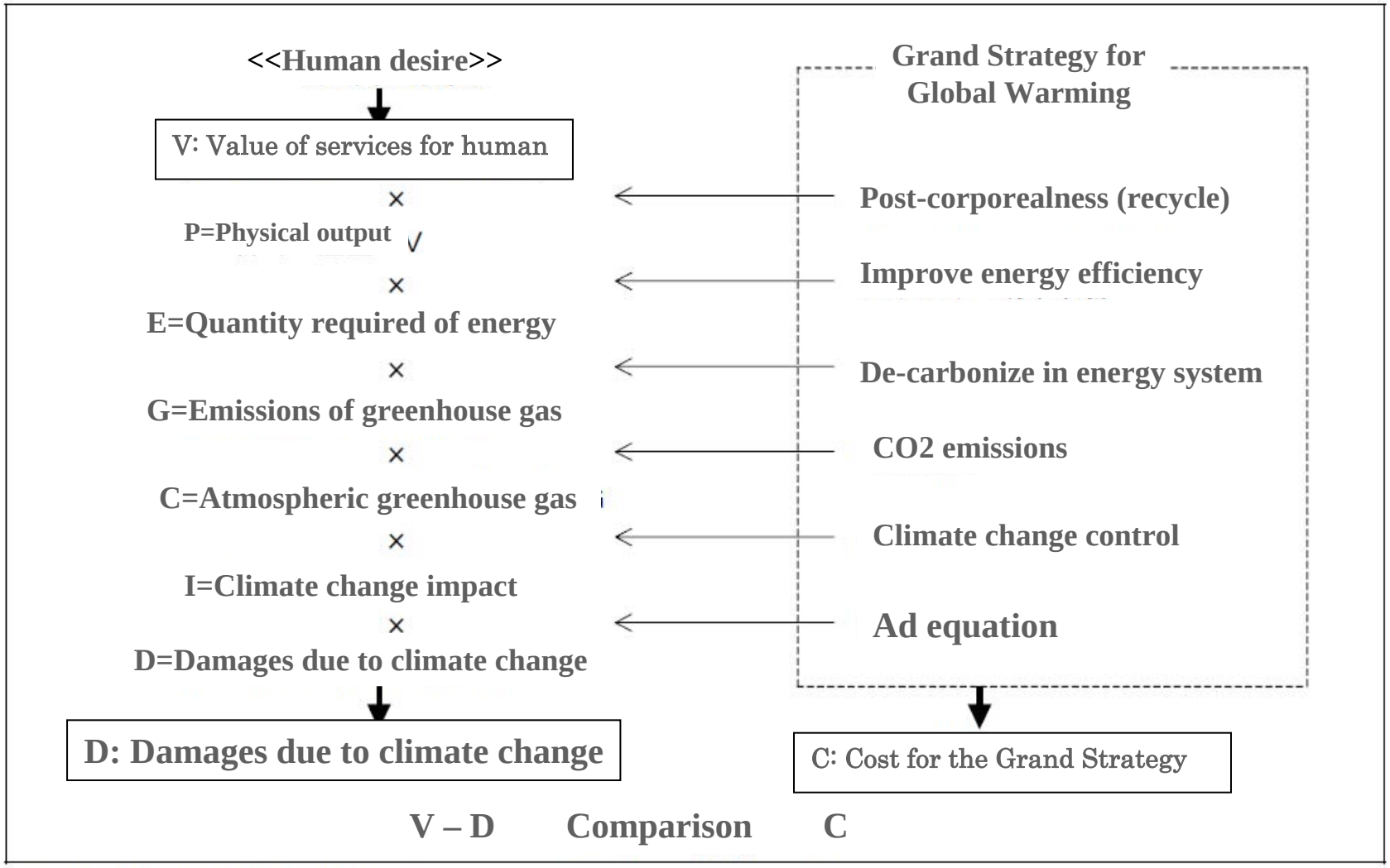
Top-down Evaluations



Source: Created based on the IPCC WG3 AR4, SPM with RITE. ‡

- **There exists a potential to offset the world emissions increases or to reduce to less than current level.**
- **The numerical value which was able to reduce ideally from the lowest price region in the world.**
- **Most commonly, negative costs are supposed to be included in SRES scenario itself.**

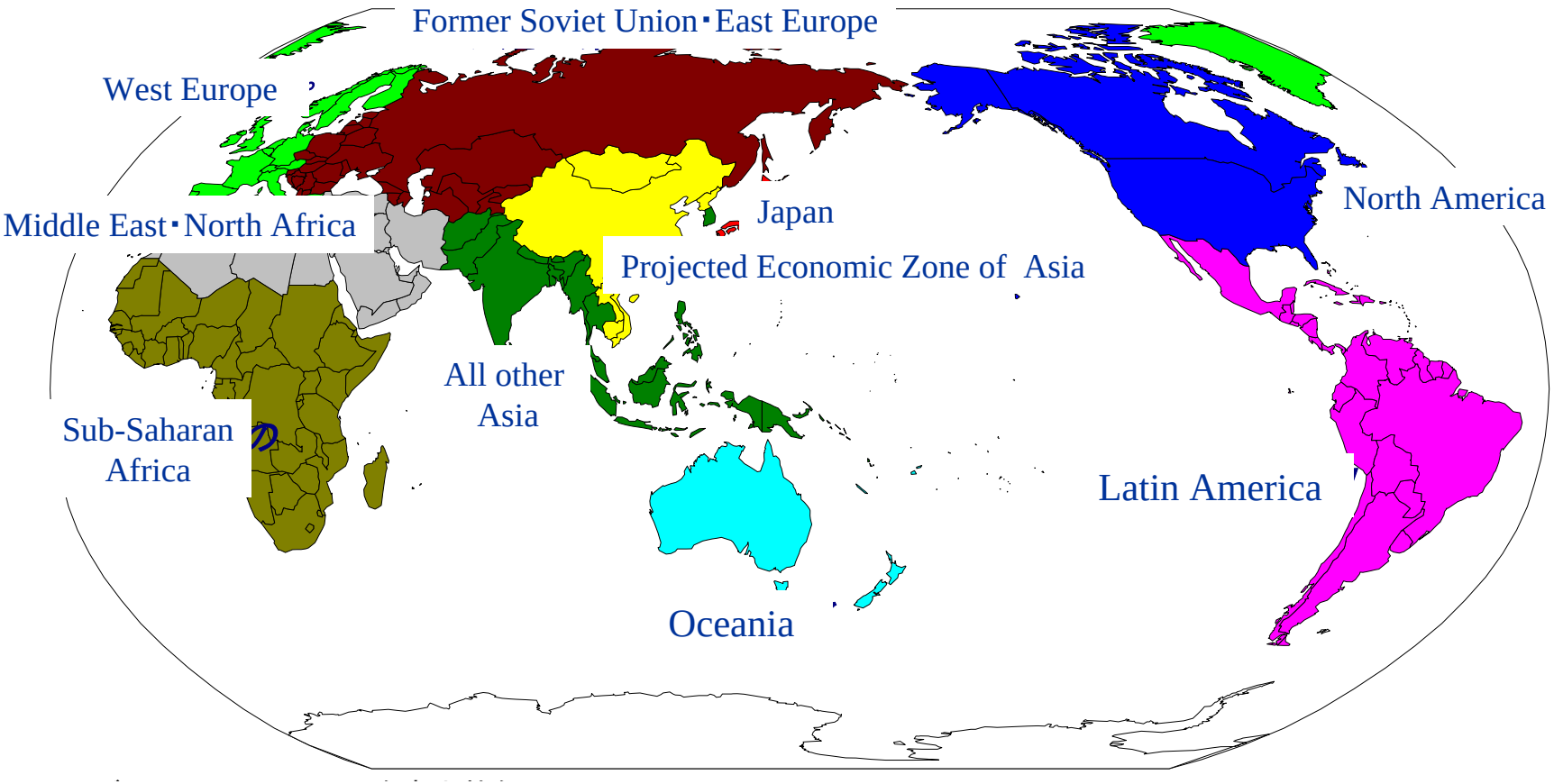
Fundamental Structures of Grand Strategy for Global Warming



※Including final demand energy use

Source: Kenji Yamaji, *System Methodology of Energy, Environment, and Economics* Iwanami-shoten, 2006 Figure3.11 (p93)

World Regional Dismemberment of DNE 21 Model



‡ See also the following with reference to DNE21 Model

Kenji Yamaji, Yasumasa Fujii: *Global Energy Strategy*, Denryoku-Shinposha (1995)

Fujii, Y., K. Yamaji: Assessment of technological options in the global energy system for limiting the atmospheric CO2 concentration, Environmental Economics and Policy Studies, vol.1, pp.113-139 (1998)

New Energy・Industrial Science and Technology Development Institution /(Foundation) Industrial Science and Technology Research Institution : Business Report for Investigation of Enforcement Planning, “New Earth 21”, (1994 – 2002)

http://www.rite.or.jp/English/lab/syslab/research/new-earth/download-page/downloadable-data/dne21-manual.pdf, 図2-2、p6

Technology for Reduction of CO2 Emissions

Promotion of Energy Saving

- Saving on ultimate demand (Vehicle fuel efficiency)
- Improvement in conversion efficiency

Fuel conversion

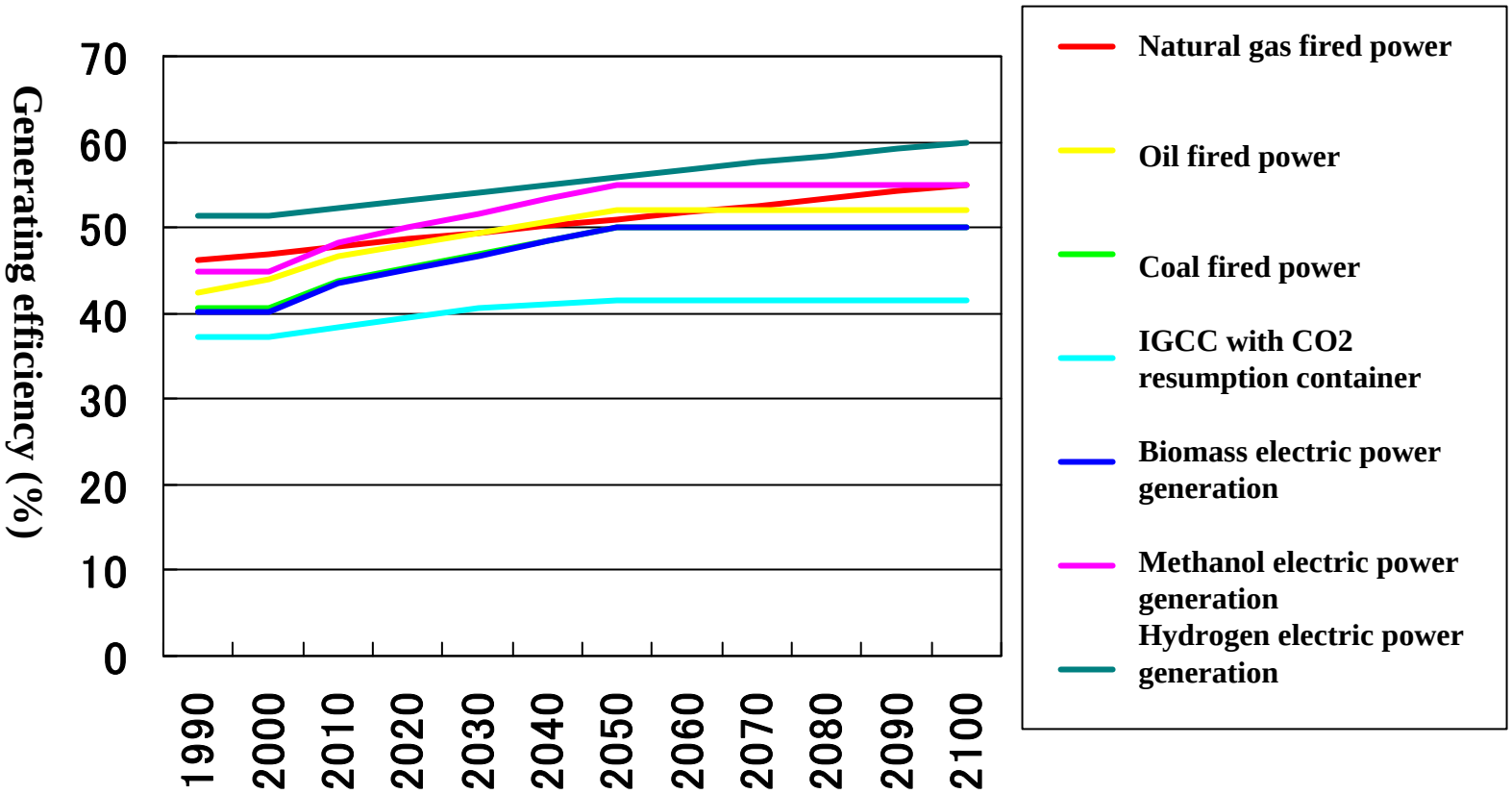
- Fuel conversion (Switch from coal to natural gas)
- Recyclable Energy, Nuclear Power

Sequestration, Resumption, Disposal of CO2

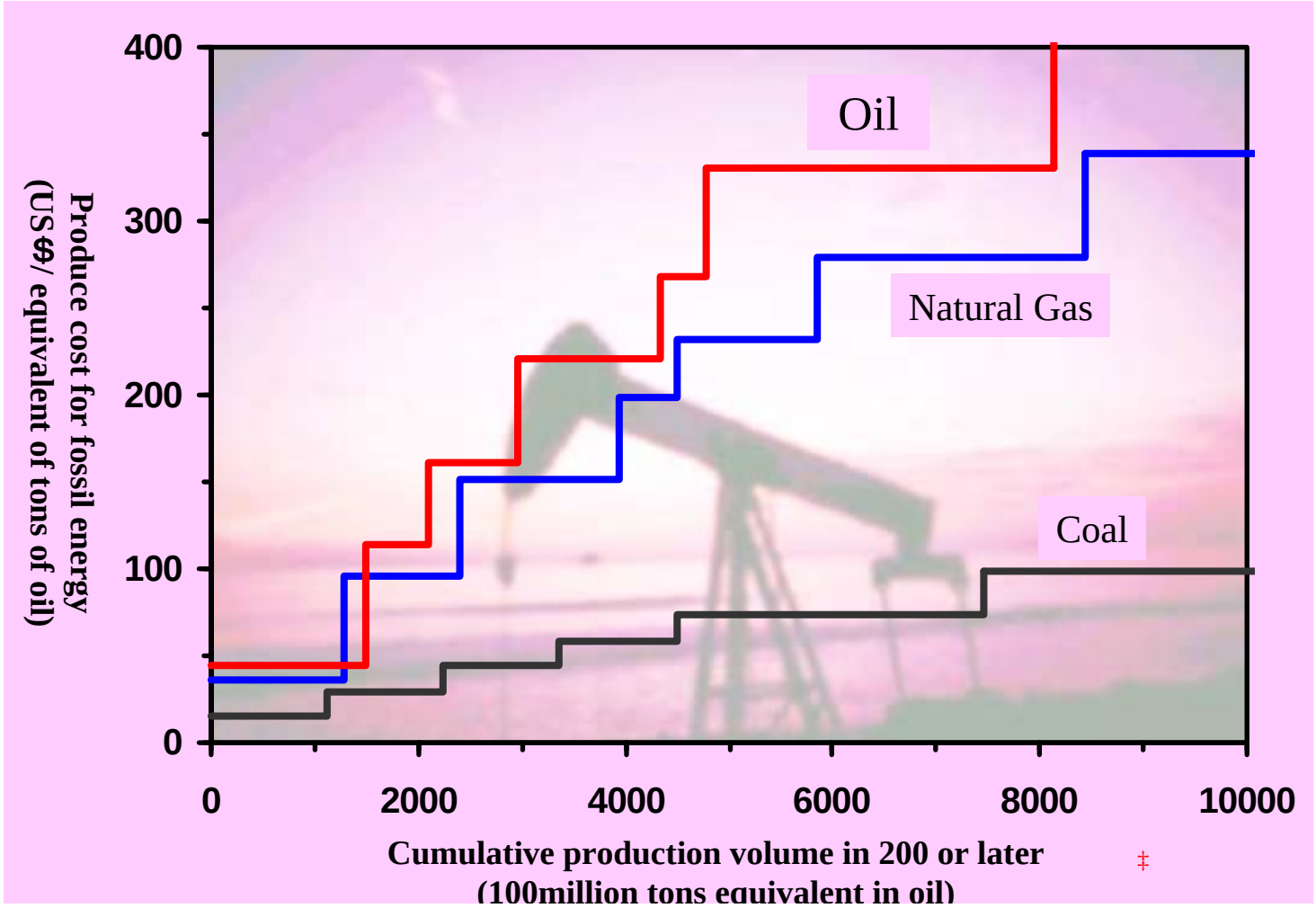
- CO2 resumption from Power Plant Emissions
- Underground disposal, Ocean disposal of CO2

Promotion of Energy Saving

Improvement in Conversion Efficiency

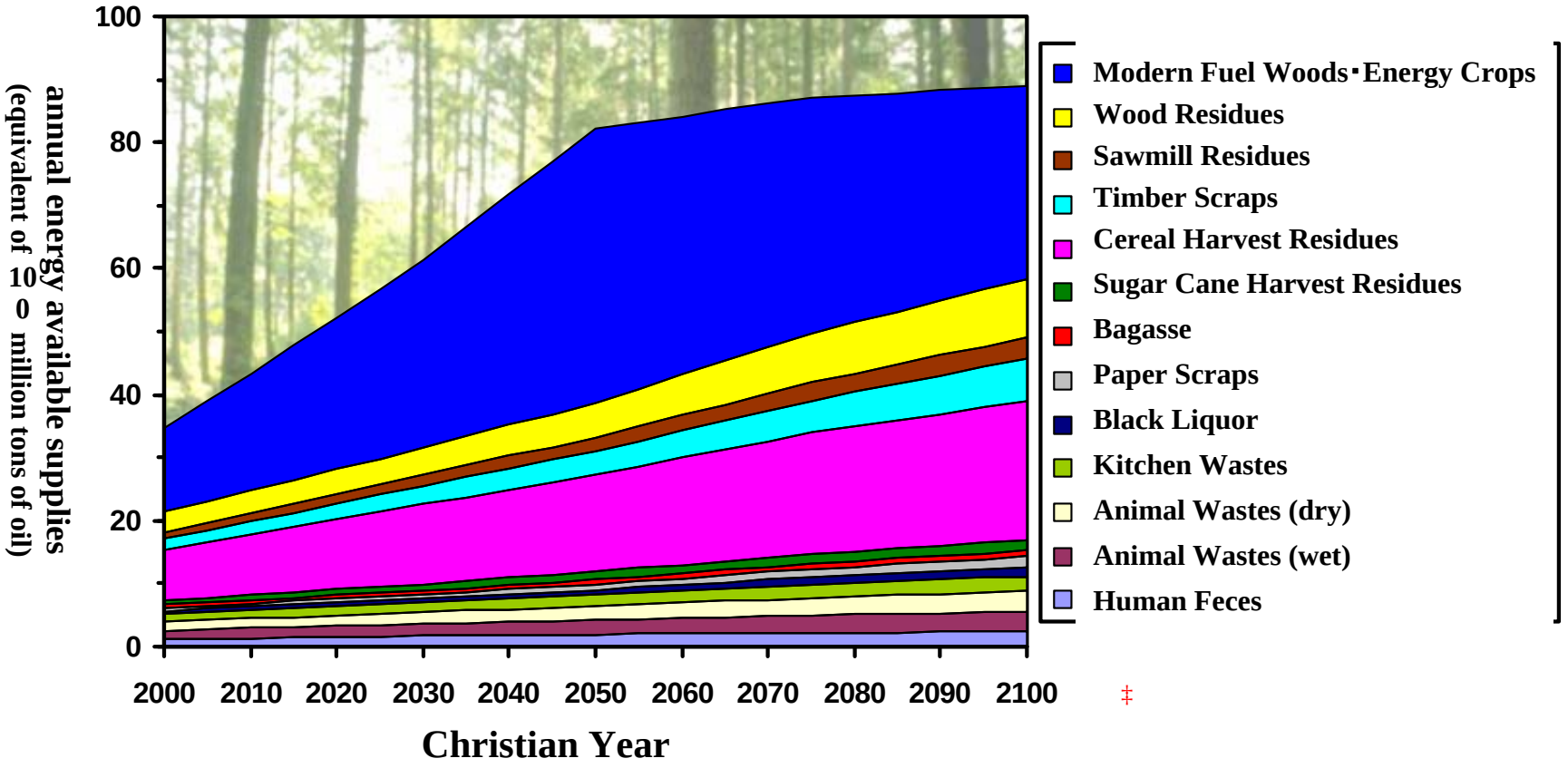


Fossil Fuel Resources



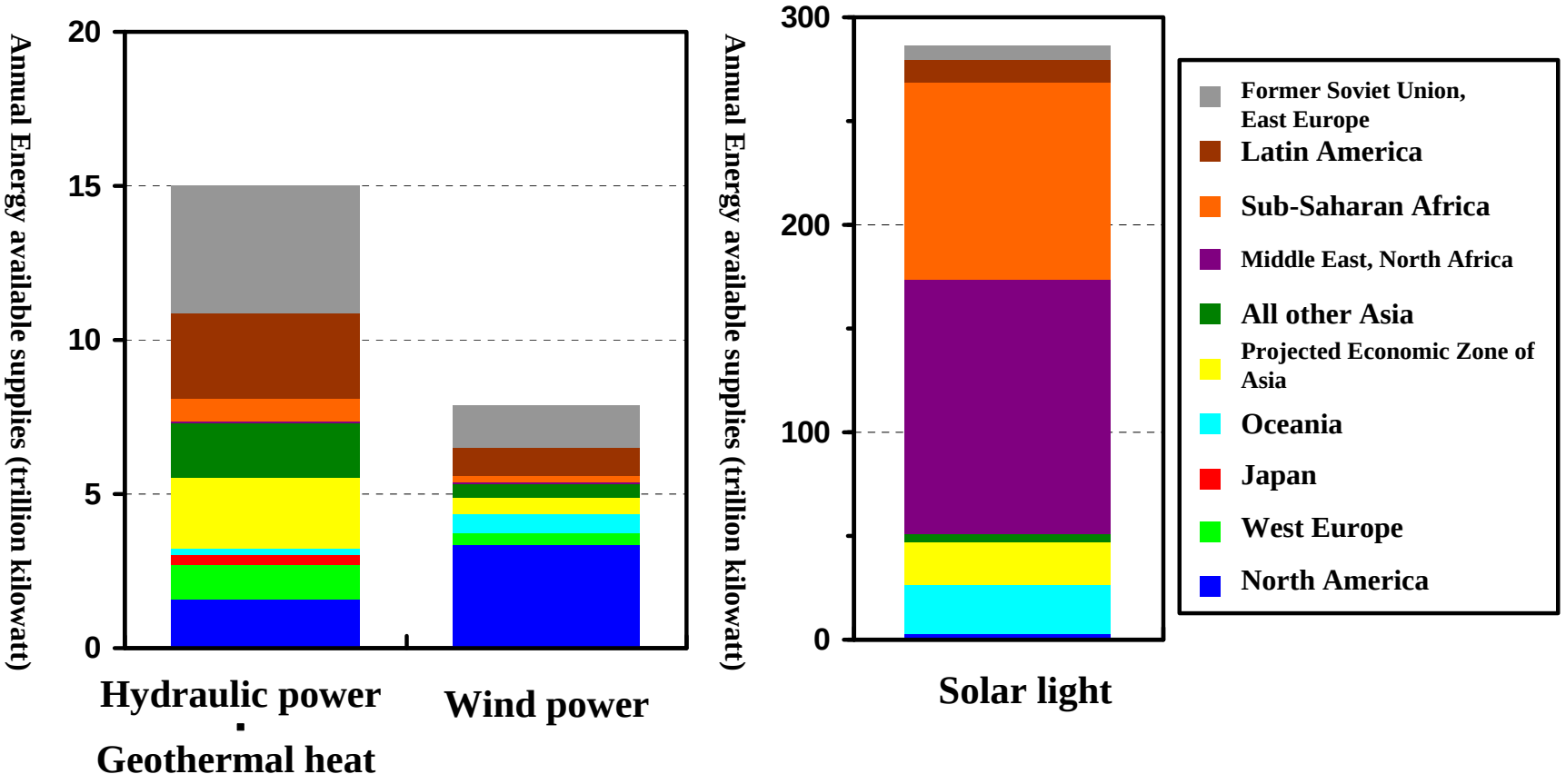
Source: http//www.rite.or.jp/English/lab/syslab/research/new-earth/download-page/downloadable-data/dne21-manual.pdf,figure2-4, p.10

Biomass Energy Resource

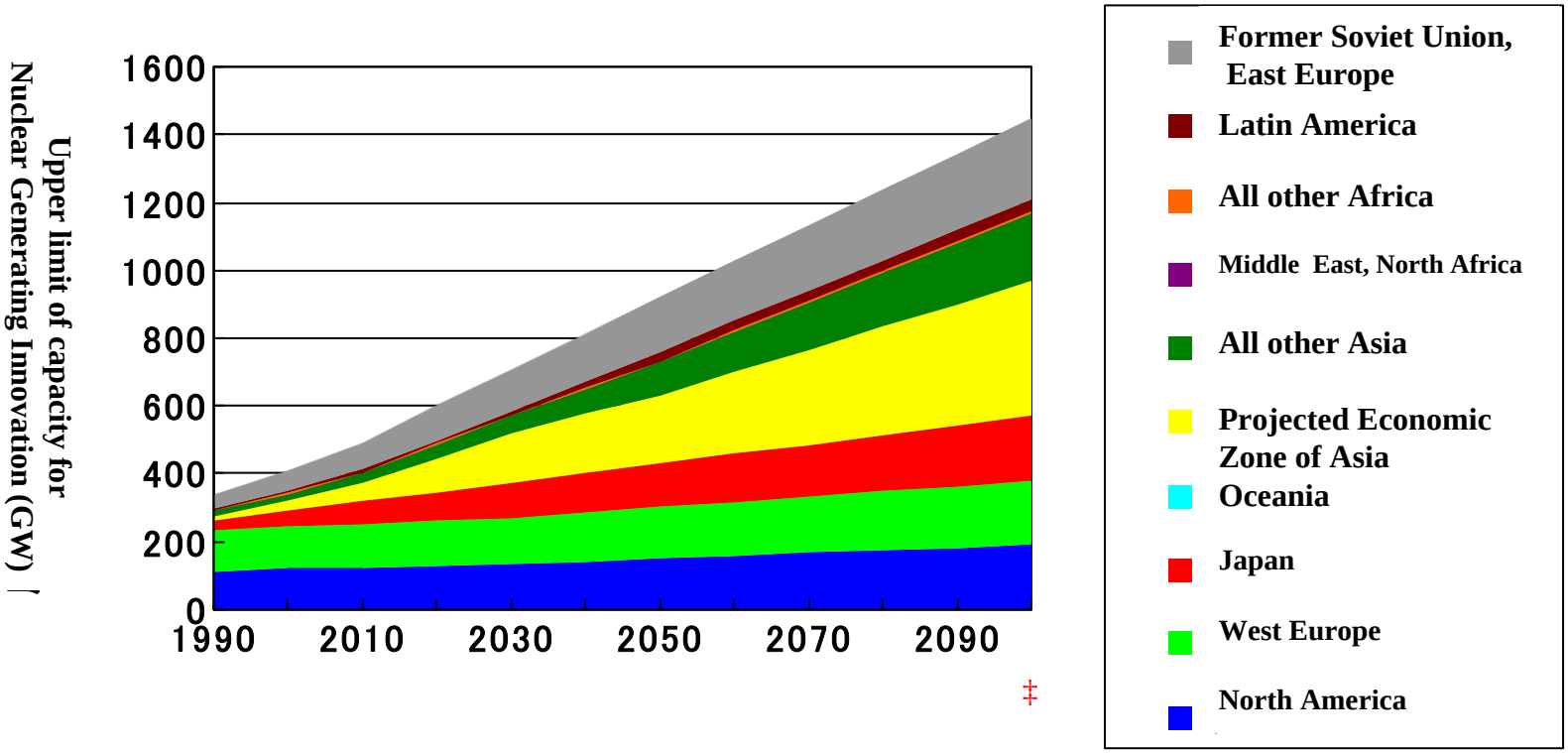


Source: http//www.rite.or.jp/English/lab/syslab/research/new-earth/download-page/downloadable-data/dne21-manual.pdf, figure2-5,p.11

Recyclable Energy Resource



Nuclear Power Generation



Source: http//www.rite.or.jp/English/lab/syslab/research/new-earth/download-page/downloadable-data/dne21-manual.pdf, figure2-8,p.14

Sequestration Resumption of CO2

CO_2 resumption from exhaust gas

- *Chemical Absorption*

  A kind of Alkanolamine

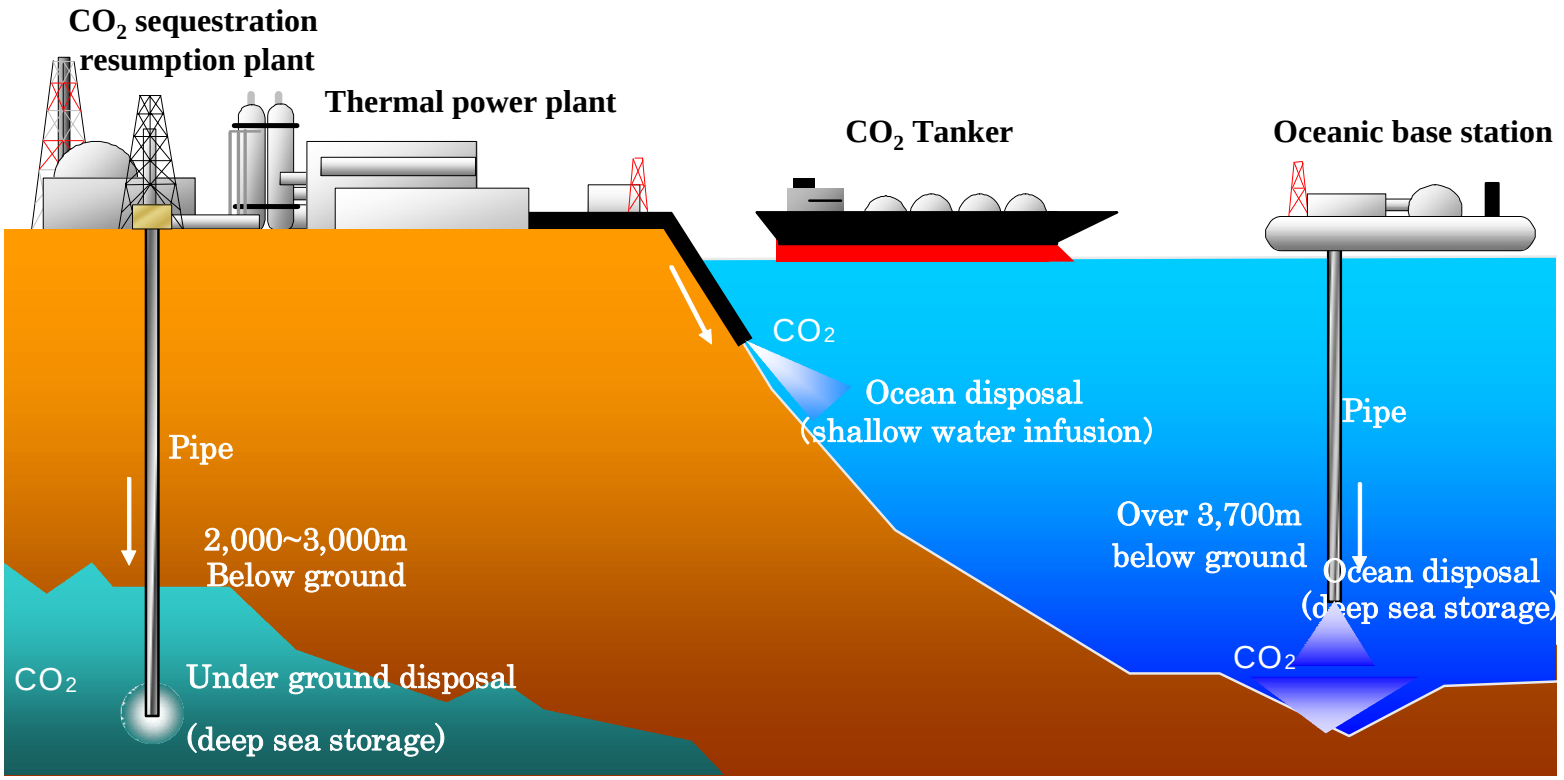
$$R\text{-}NH_2 + H_2O + CO_2 \underset{\leftarrow 150℃}{\overset{40℃\rightarrow}{\Leftrightarrow}} R\text{-}NH_3HCO_3$$

- *Physical Absorption*

  Selexol process

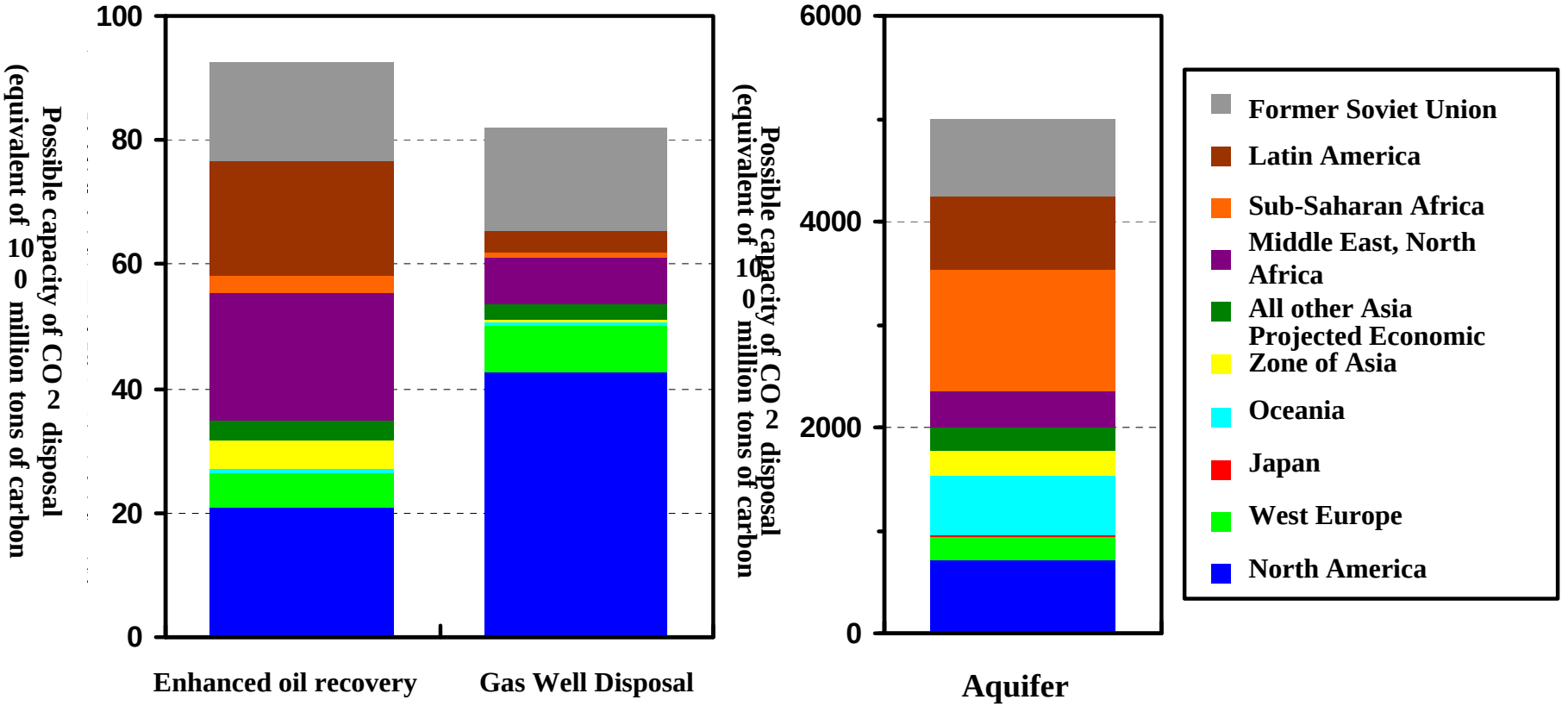
  Dissolve CO_2 Polyethylene glycol

CO_2の処理　地中処理、海洋処理

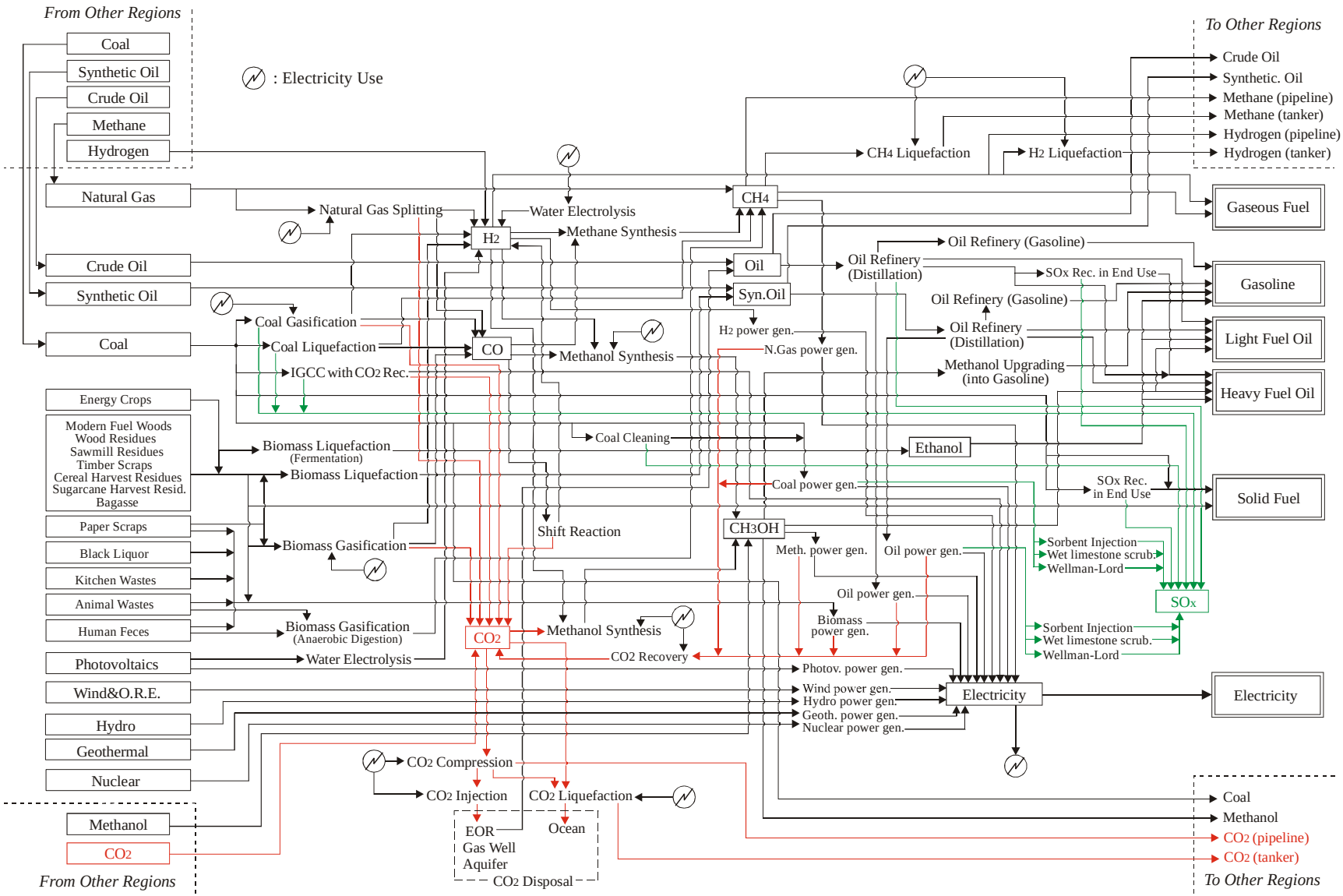


Dispose of CO2

Underground disposal, Ocean disposal

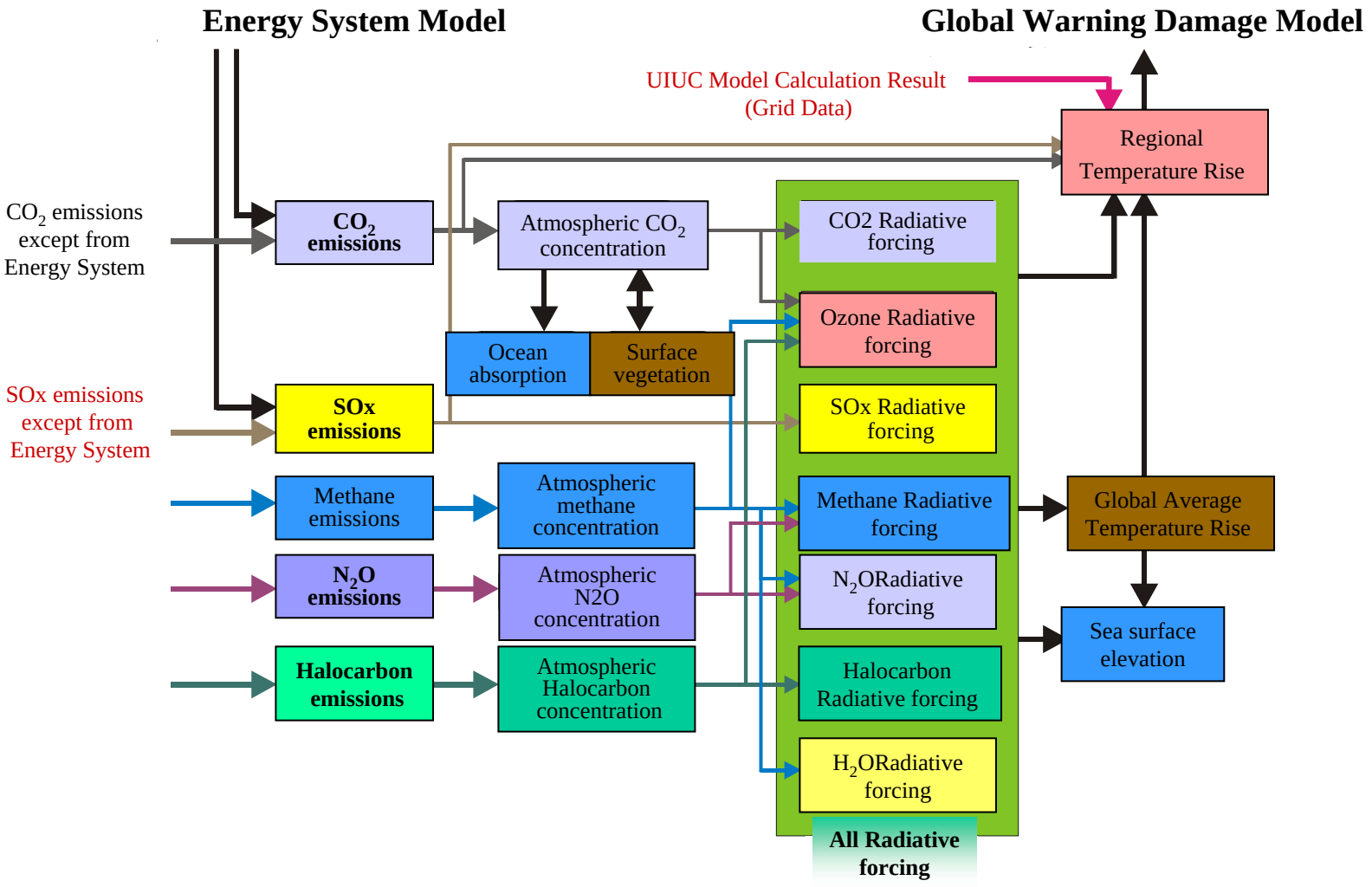


Energy System Constitution



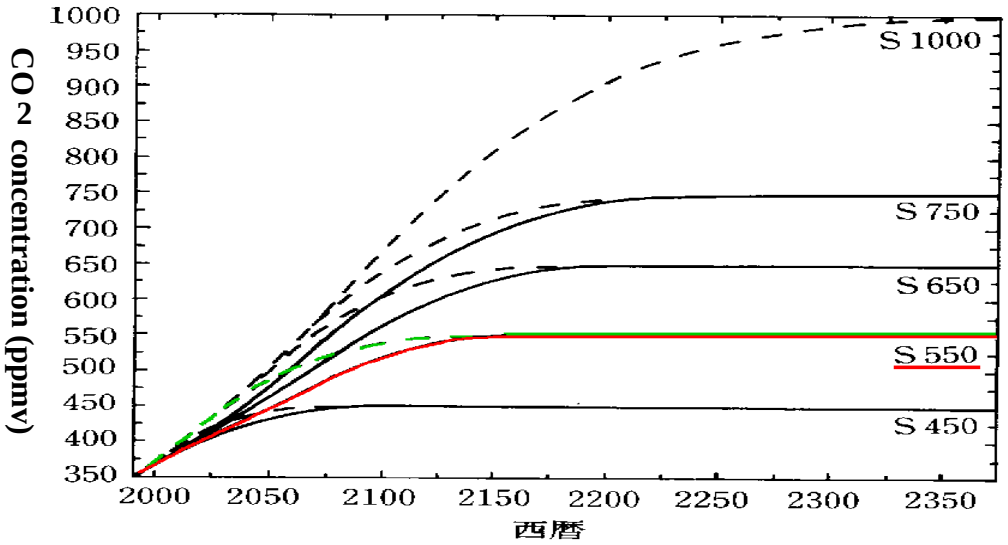
Source : http://www.rite.or.jp/English/lab/syslab/research/new-earth/download-page/downloadable-data/dne21-manual.pdf, Figure 2-3、p7

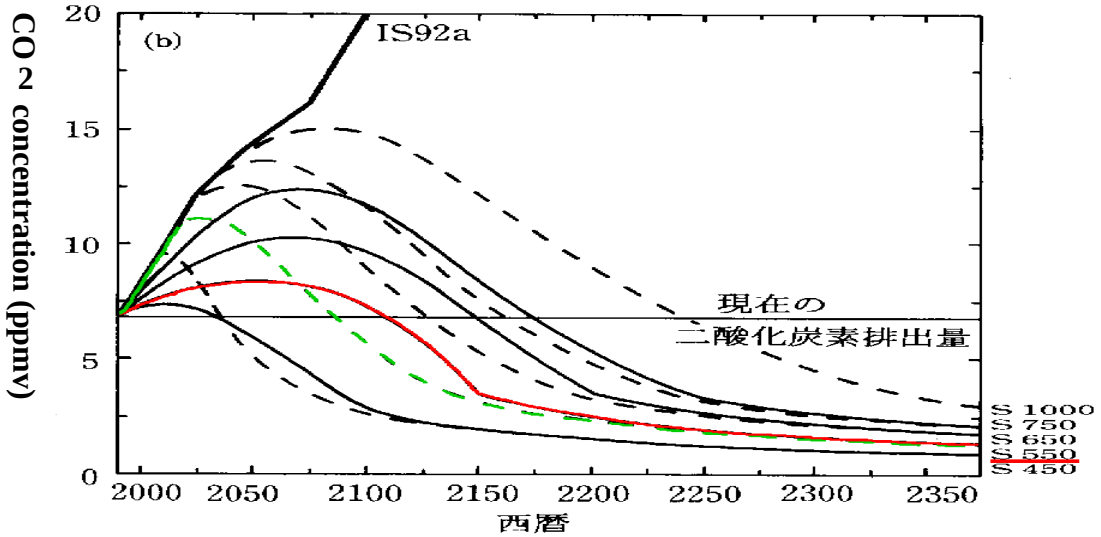
Climate Change Module Outline



The following is the calculation of Atmospheric CO2 concentration

Path of Stabilization for Atmospheric Co2 Concentration





There are so many routes of elimination to meet the concentration targets: they're able to be determined.
Routes of elimination to meet the concentration targets, Regional reduction amount, Choice of technology to realize the reduction is able to be determined by minimization of aggregate total cost in DNE21 model.

http://www.aec.go.jp/jicst/NC/tyoki/chokei2004/chokei01/siryo2.pdf、p3

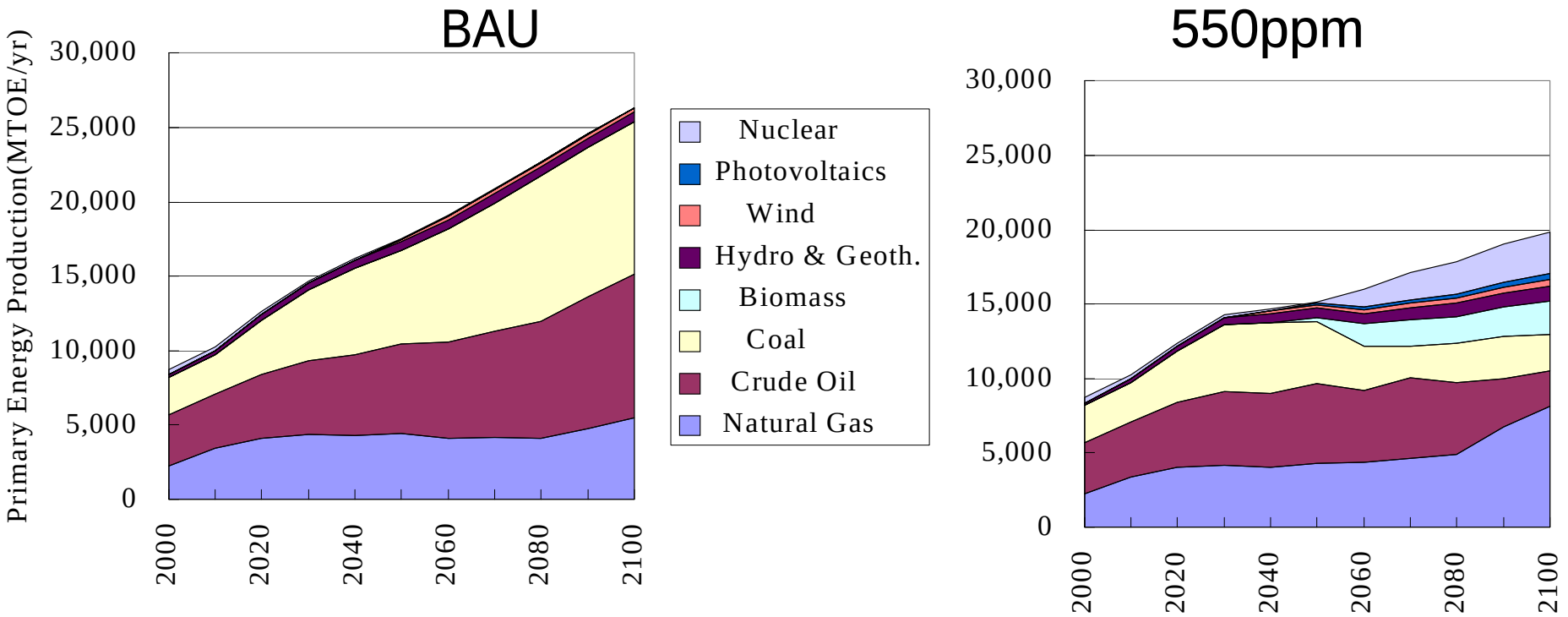
Source: IPCC The 2nd report

Simulation cases

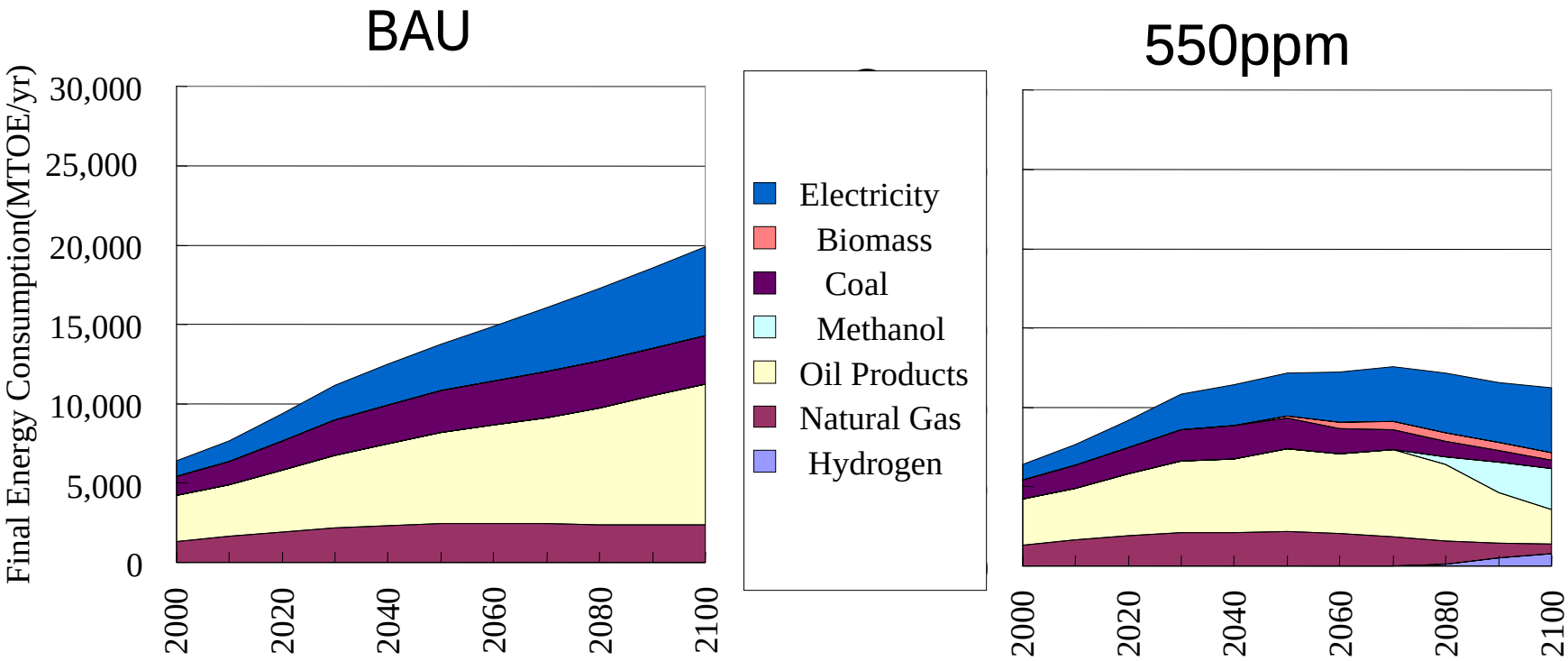
Reference of the following model analysis**:** : K. Yamaji, Long-Range Strategy for the New Earth 21 Plan, Japan Review of International Affairs,**1999**, Vol.12, No.4, pp.267-282 (1999)

	Case	CO2 constraints
1	BAU	free
2	550ppm	Global atmospheric CO2 concentration at 550ppm in 2100
3	COP3 forever	COP3 forever in Annex1 after 2010
4	300%	after 2020: Annex1:80% CO2 emissions at 1990 non-Annex1: 300% CO2 emissions at 1990

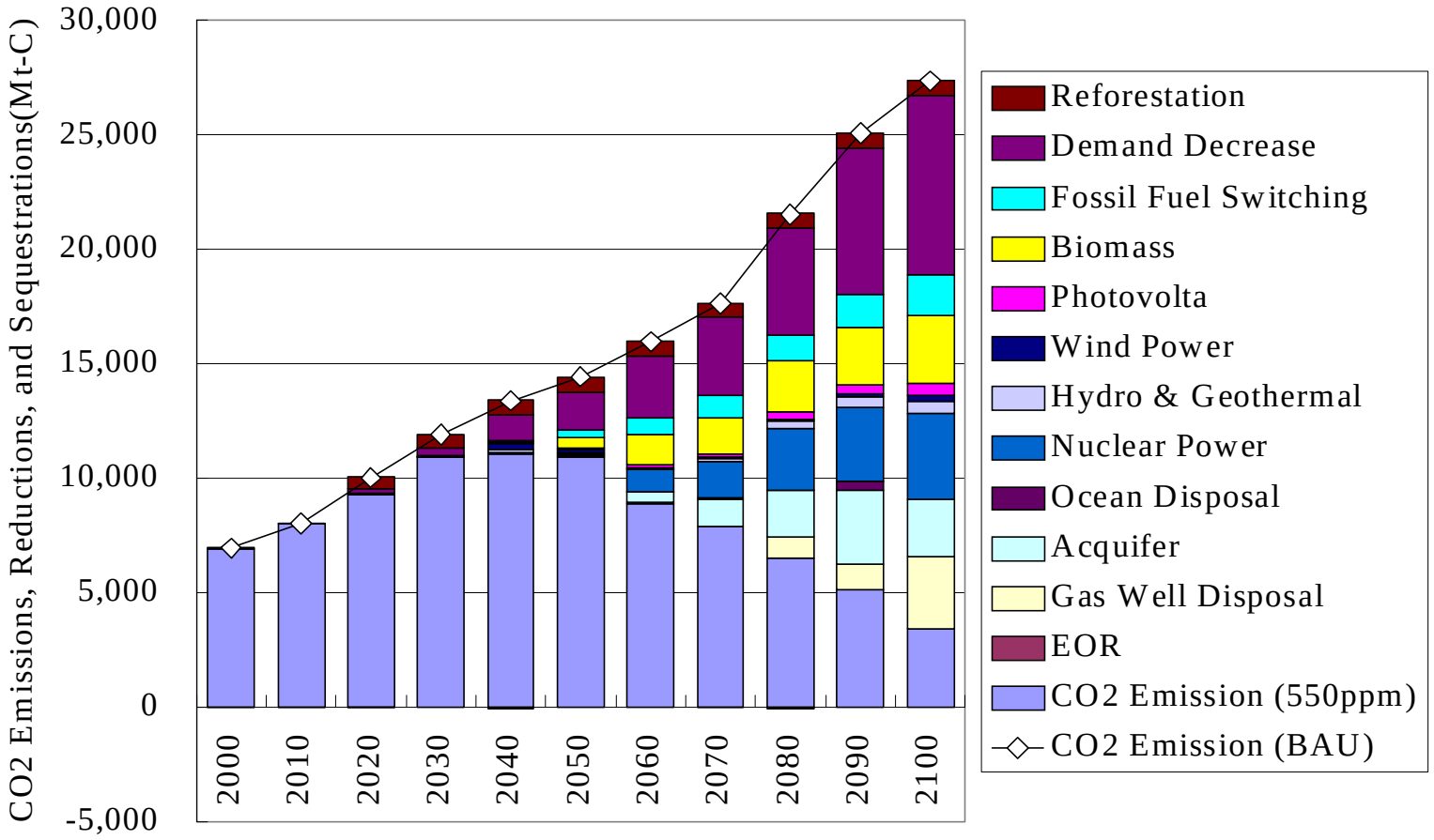
Primary energy production



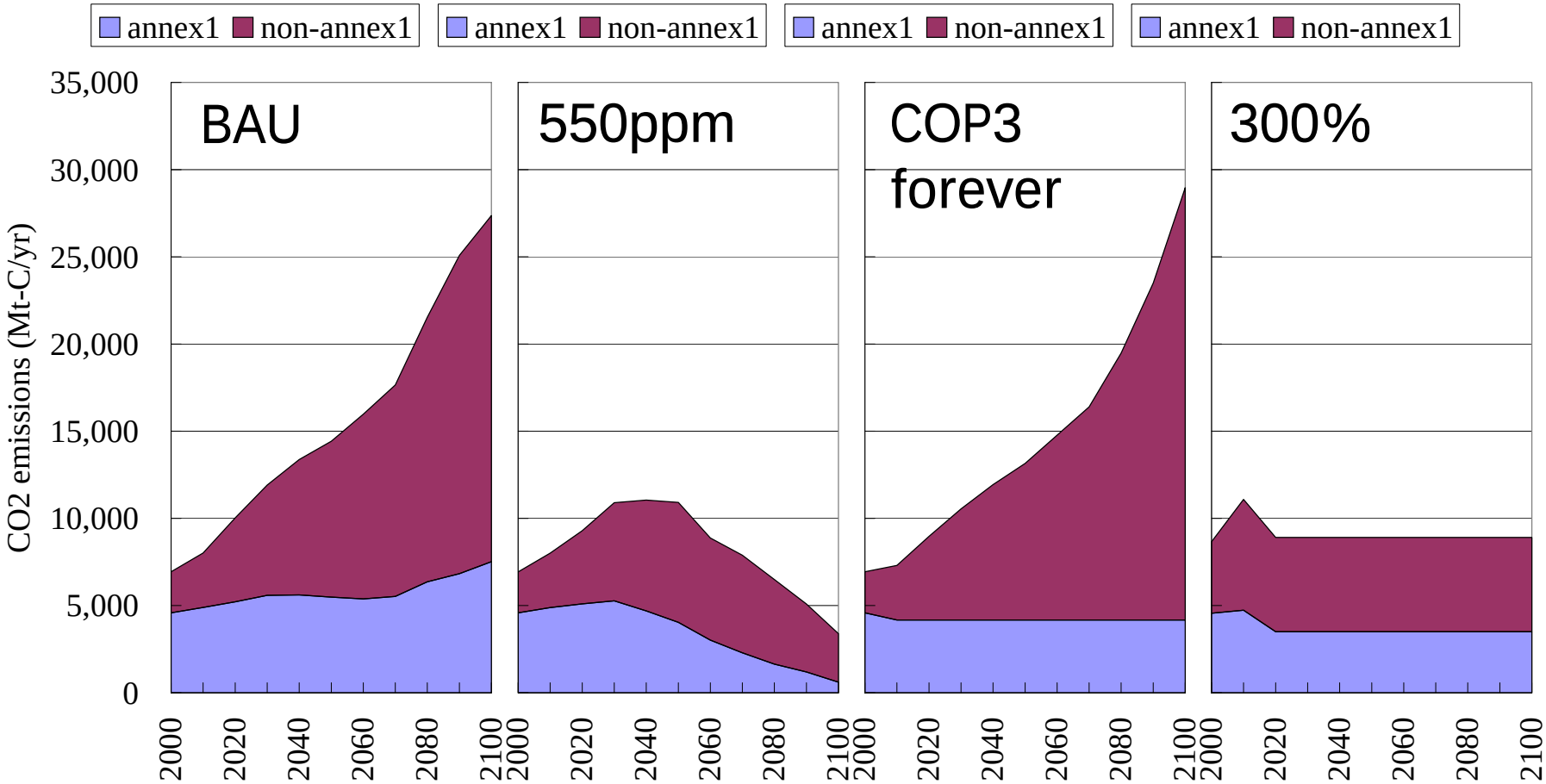
Final energy consumption



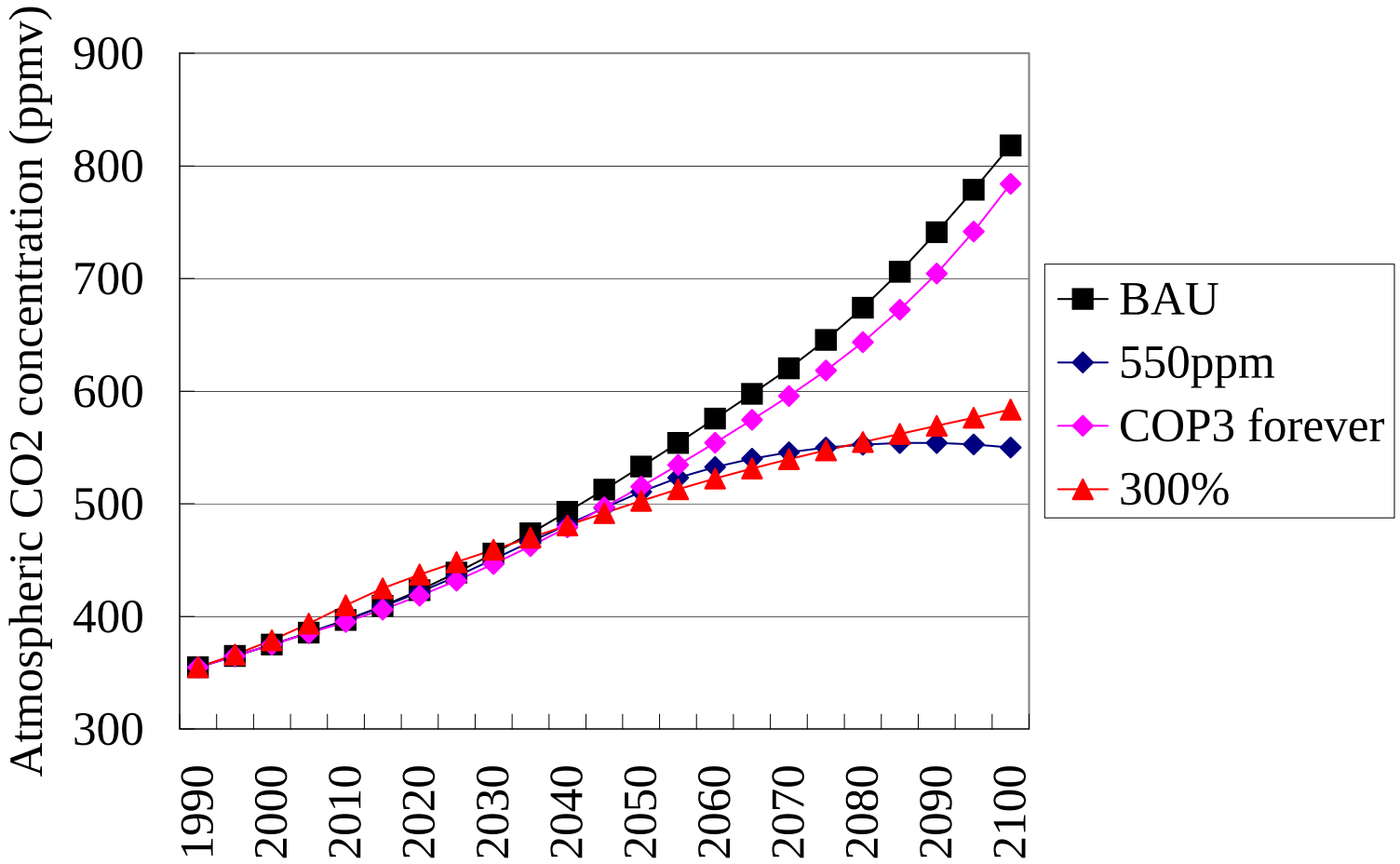
Contributions of each technological option



CO2 emissions



Atmospheric CO2 concentration



Principal Conclusions from The Analysis of DNE21 Model

- **Stabilization of Global atmospheric CO2 concentration at 550ppm is possible**
- **Fossil Fuel combined with CCS will fulfill the crucial role for Grand Strategy for Global Warming**
- **Flexibility about the timing of reduction is important.**
- **Kyoto Protocol is an important starting point.**
- **Greenhouse Gas Emissions Reduction program will be incomplete without conducting in developing countries.**

Kaya Identity

CO_2＝（CO_2 /Energy）×（Energy/GDP）×GDP

When X = (CO2/Energy), X shows carbon intensity of energy; Effect of CO2 Reduction taken by the choice of energy source. Also when Y = (Energy/GDP), Y shows energy source unit of GDP; Macro characteristic of Energy-saving system. The following formula is derived by time from the formula above.

$$\frac{1}{CO_2}\frac{dCO_2}{dt} = \frac{1}{X}\frac{dX}{dt} + \frac{1}{Y}\frac{dY}{dt} + \frac{1}{GDP}\frac{dGDP}{dt}$$

To sum up, increasing rate of CO2 emission will be shown by the sum of X (Carbon intensity of energy), Y (energy source unit of GDP), and increasing rate of GDP.

Source of Kaya Identity：Kaya, Y., K.Yamaji, R.Matsuhashi: Grand Strategy for Global Warming, Proceedings of the Government Symposium on Global Environment, Tokyo, September 1989

figure 5: Improvement speed during the period from 2000 through 2050 needs to put into practice for low-carbon society

Y X

		Improvement rate of energy-intensive (% per year)	Improvement rate of carbon-intensive (for CCS) (%per year)	Envisaged GDP growth rate [GDP growth rate per person] (%per year)	Reduction target in 2050 [Reduction rate of the standards in 2000 (%per year)
Range for the rate of change in the past	**World**	1.0～1.5	0.3～0.4		
Trial calculation for the scenario of low-carbon society in Japan for 2050 (Standards in 1990)	**Scenario A**	2.4	1.3 [0.5]	1.4 [2.0]	70 [68]
	Scenario B	1.7	1.4 [0]	0.5 [1.0]	70 [73]
European countries	England	2.6～2.9	1.2～1.8 [0.3～0.9]	2.2～3.0 [2.1～2.8]	60 [60]
	Germany	1.8～2.8	1.3～2.3 [0～1.4]	1.4 [1.7]	80 [75]
	France	1.3～2.3	1.7～2.6 [0～2.0]	1.7 [1.7]	75 [70]

Base year for the reduction target is 1997 (current status) in England, 1990 in Germany and France.

$$(1-0.025)^{50}=0.975^{50}=0.282$$

Basic understanding on Grand Strategy for Global Warming

- **Global Warming is actually on the move. And that the cause of it is Greenhouse Gas Emissions with human activities is identified by the IPCC. ⇒ Not only figuring out the phenomenon but also beginning to take full effect of the strategy for Global Warming on a global scale from the present moment. We should have a system of Environmental cost for Greenhouse Gas Emissions (conversely worth of reduction) to report clearly to society.**
- **However, science of anathermal (especially impact forecast) is still uncertainty. ⇒ Strategy should be moved into action promptly under the principle of preventive maintenance. But it is important to give much thought to uncertainty in the choice of strategy. It requires the implementation of energy saving, forestation and recycling which are also beneficial on a priority base besides strategy for Global Warming. In addition to that, taking measures to adapt land improvement in developing countries is also important with a certain level of global warming is seemingly inevitable.**
- **In the choice of strategy, the important thing is effectiveness and equitability among regions and generations. ⇒ Do all kinds of things to create mechanism, just like Kyoto Mechanism (emissions permit transaction, joint implementation, and CDM) instituted measures in a coordinated manner in the world. Global dissemination of the latest technology, International agreements about long-term root of elimination.**
- **It is a necessity for major countries with CO2 emission to participate in the strategy. ⇒ It'll be incomplete without developing countries like China, India and the U.S. as a matter of course.**
- **Measures of the Kyoto Protocol which includes goal setting of CO2 emission by countries makes difficult to expand the number of countries participating in the strategy as an effective international system. ⇒ Not country-based but sectoral-based approach of primary emissions, energy saving would carry weight.**
- **Condition ordering is required for society to gain the acceptance of atomic energy and CCS (CO2 resumption・ reservoir) as well as energy saving and promotion of renewable renewal energy resources which easily gain public acceptance.**
- **Although technology holds the great possibility of reduction of global warming, to bring it reality, we should give greater importance to social dimensions (economical efficiency, international prevalence and social acceptance.**