2007 Global Focus on Knowledge Lecture Series

Energy and the Earth

Shigefumi Nishio

Natural Environment and Artificial Environment

Global Environment Change

Energy Consumption

Sustainability

Toward the Sustainable Society

Natural Environment and Artificial Environment

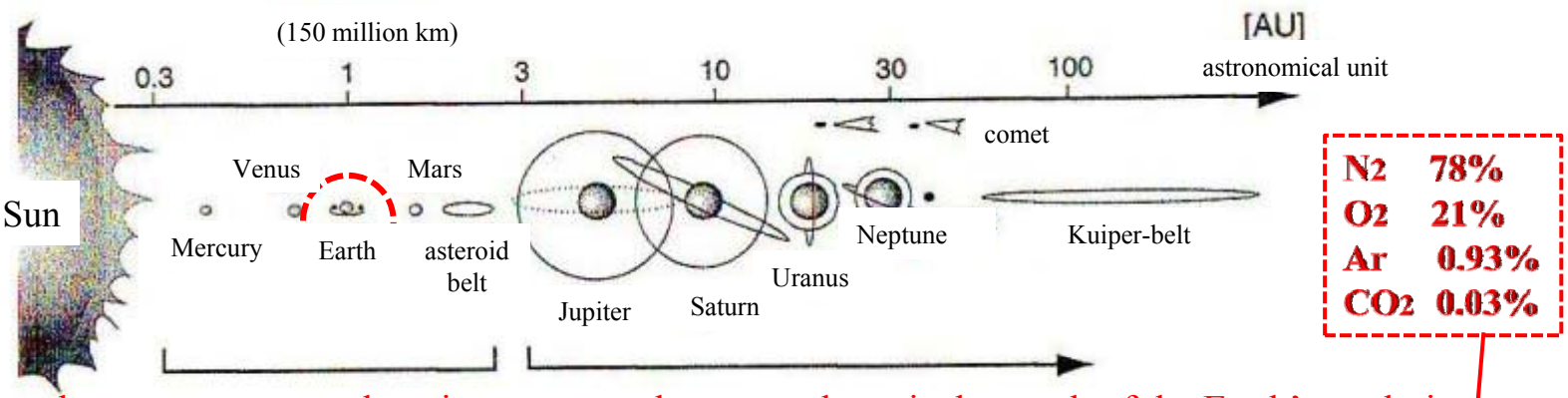
Now, while very convenient societies (an artificial environment) based on

transportation networks, energy networks, and information networks have appeared and are flourishing.

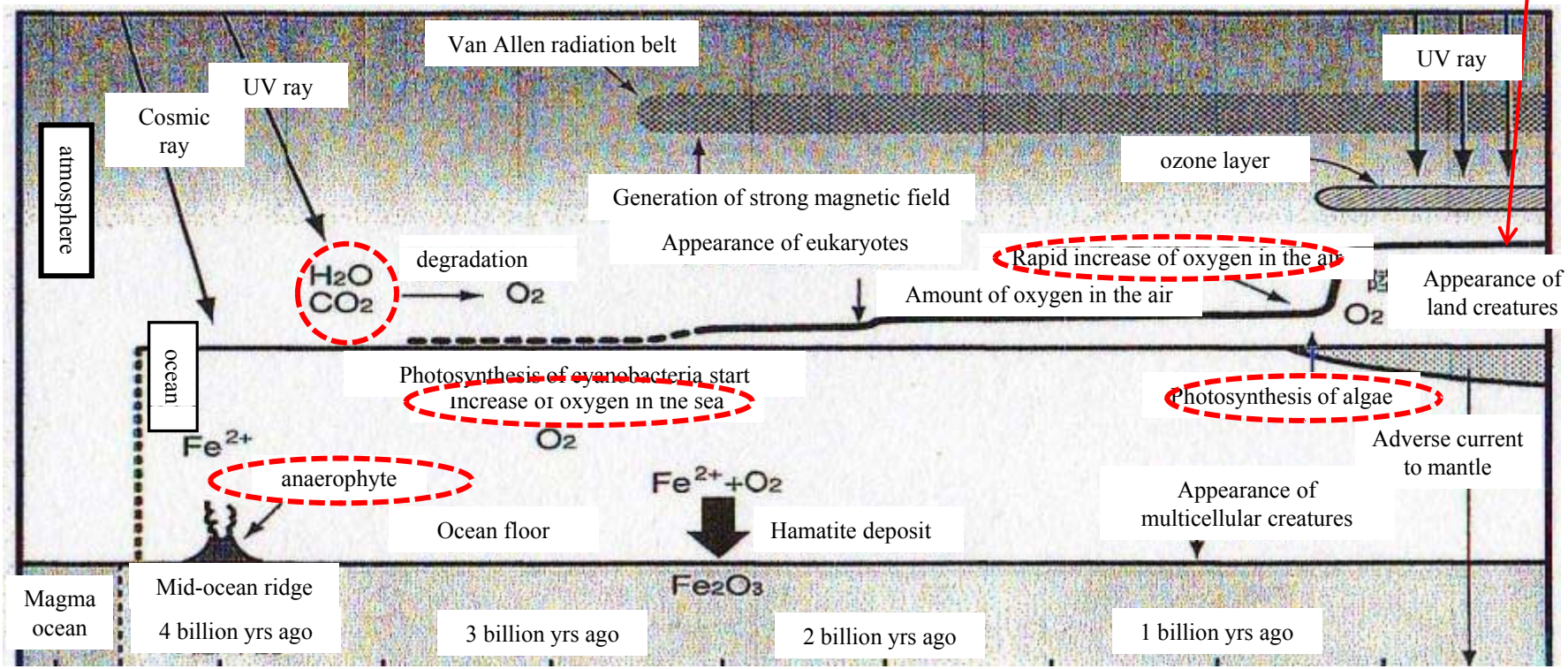
What is happening to the Earth?

Nishio Lab. IIS UT

Natural Environment and Artificial Environment



The 3rd planet in the solar system = natural environment on the water planet is the result of the Earth's evolution



[Shigetoku Maruyama・Yukio Isozaki:"The History of Life and the Earth", (1998), (Iwanami Shinsho), fig1.4 and 6.2 revised]

Natural Environment and Artificial Environment

The 20th Century

"Artificial Environment " such as transportation networks, energy networks and information networks appeared.

Running power = Transportation Revolution

Airplane, car, railway

Force = Energy Revolution

Nuclear reactor, rocket

Computation, memory, audiovisual = Information Revolution

Life force = Biological Revolution

Genetic engineering

Physical science and technology are as compelling as religions.

"Importance of landing man to the moon is almost equal to importance of the instance in the evolutionary processes when the first creature from the sea dragged itself on to the land. We are, extending our brain, arms and legs to the maximum. This is the new step in human evolution." Wernher von Braun

"If there were no God, it would be necessary to invent him. " Voltaire

"The future is of cars. It releases humans."Zola

Physical science and technology = segmentation, separation to disciplines

Enhancement of human physical abilities, and liberty from physical constraints are motive

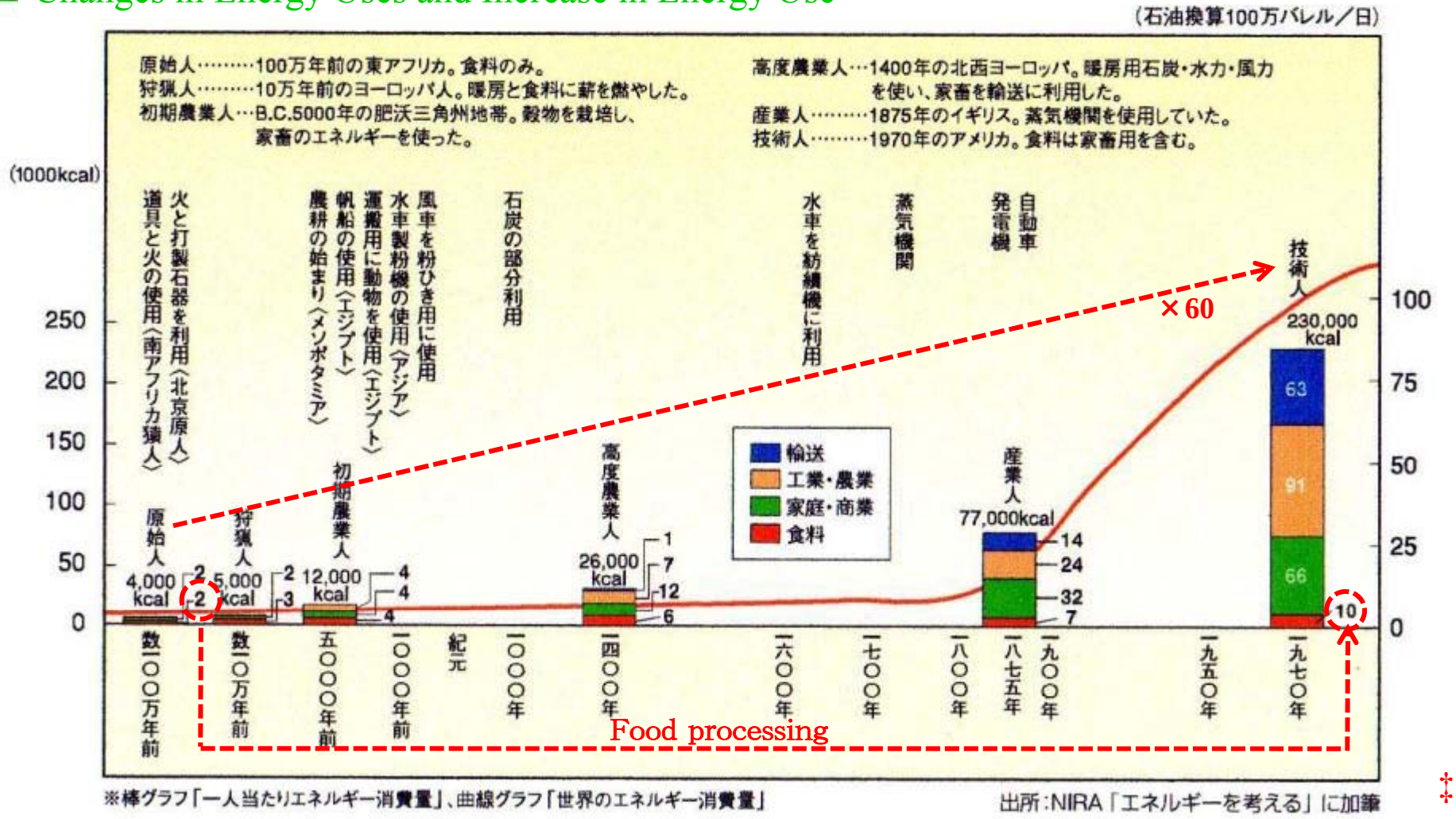
Segmentation of human function → single-function machine as a substitute → layered structure of elements

Nishioka Lab. IIS UT

Natural Environment and Artificial Environment

Energy Supply for Artificial Environment Increased Rapidly

Changes in Energy Uses and Increase in Energy Use

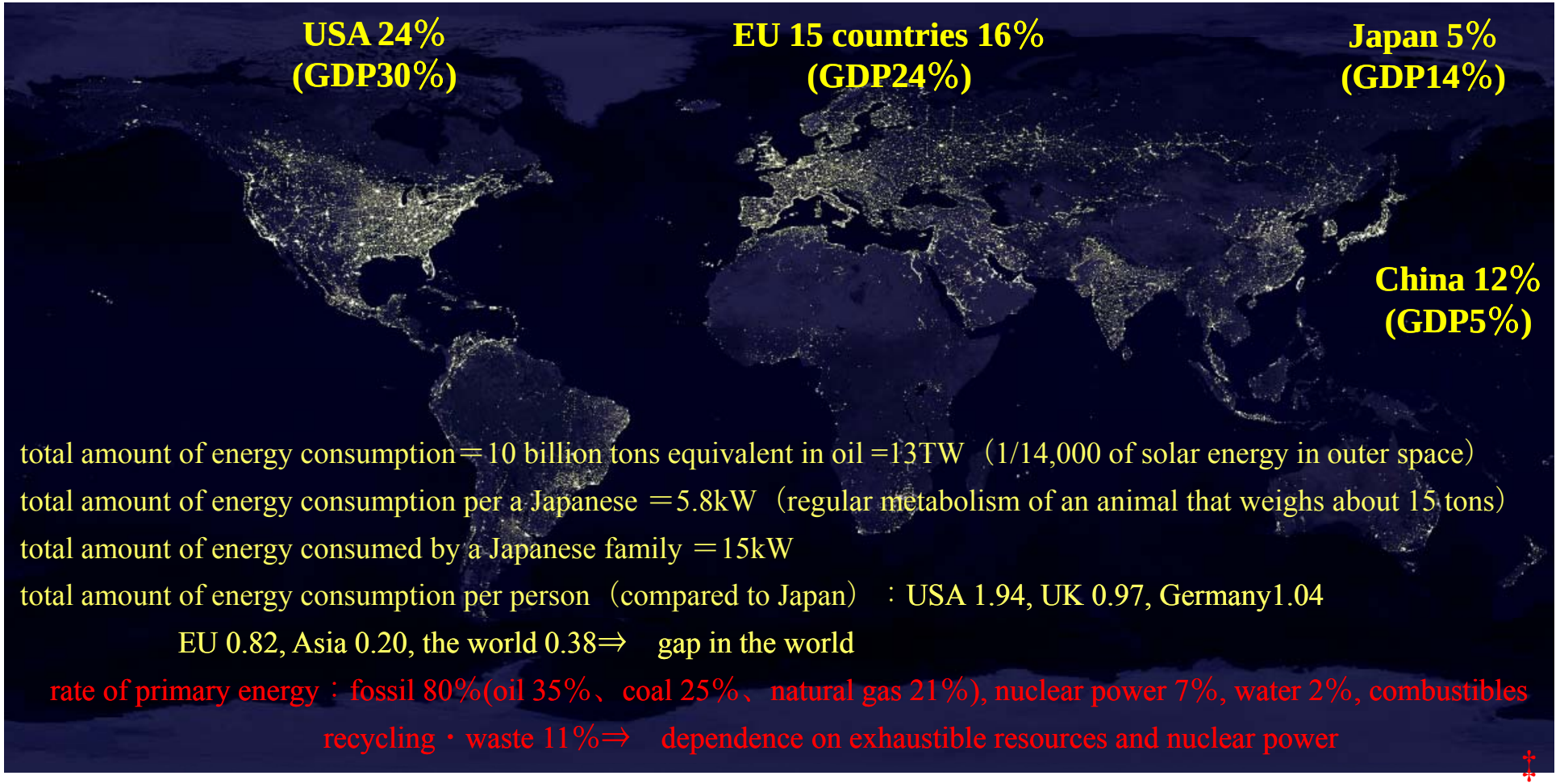


[Agency for Natural Resources and Energy, "4 Keywords to Think About Energy and Environment", (2007), p.10]

Nishio Lab. IIS UT

Natural Environment and Artificial Environment

Conditions in 2003



total amount of energy consumption＝10 billion tons equivalent in oil =13TW （1/14,000 of solar energy in outer space）

total amount of energy consumption per a Japanese ＝5.8kW （regular metabolism of an animal that weighs about 15 tons）

total amount of energy consumed by a Japanese family ＝15kW

total amount of energy consumption per person（compared to Japan） ：USA 1.94, UK 0.97, Germany1.04

EU 0.82, Asia 0.20, the world 0.38⇒ gap in the world

rate of primary energy：fossil 80%(oil 35%、coal 25%、natural gas 21%), nuclear power 7%, water 2%, combustibles recycling・waste 11%⇒ dependence on exhaustible resources and nuclear power

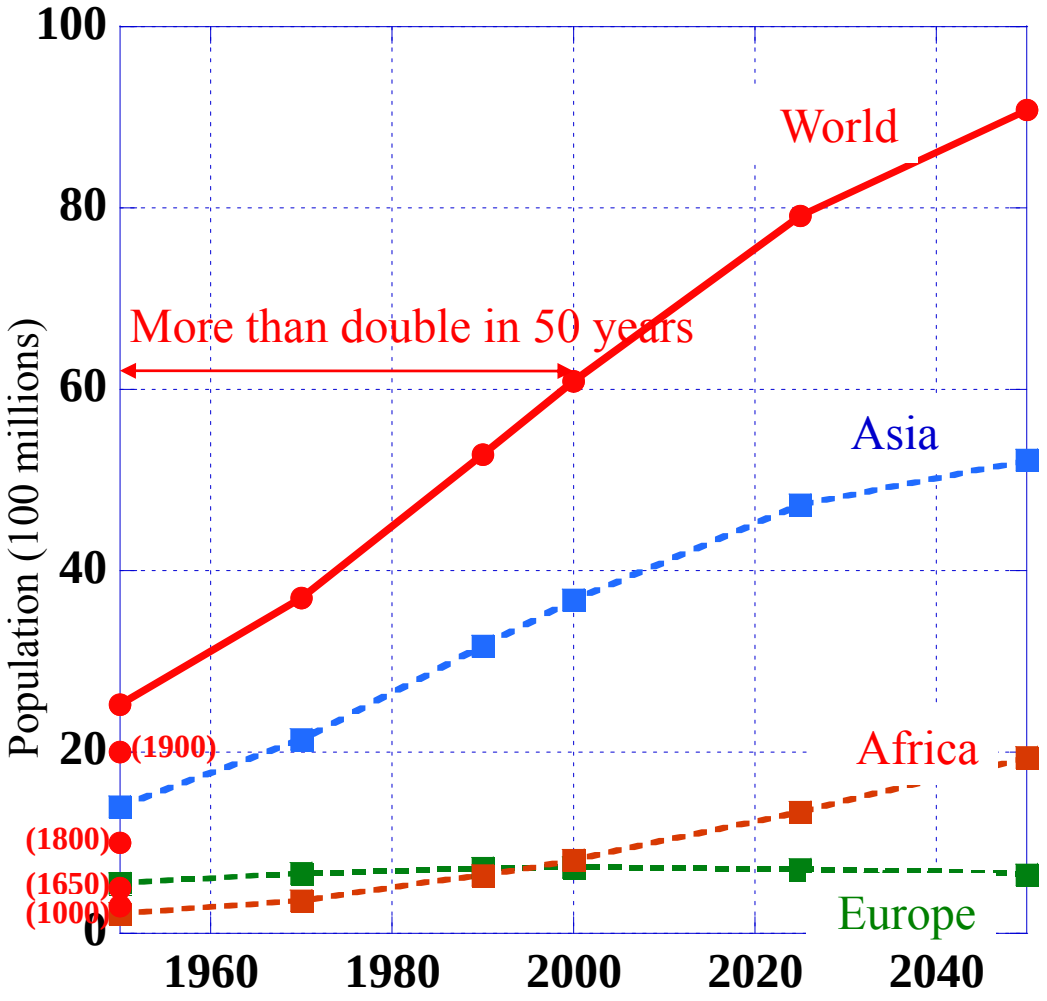
["Earth at Night" http://apod.nasa.gov/apod/ap001127.html]

Nishio Lab. IIS UT

Natural Environment and Artificial Environment

Rapid increase of population and energy consumption in developing countries →

rapid increase of oil needs (1.6-1.8-fold increase from 2000 to 2030)



‡

[The Energy Data and Modeling Center, The Institute of Energy Economics, "Energy and Economics Statistics Data", Energy Conservation Center, Japan (2006)]

Natural Environment and Artificial Environment

As needs for oil and other fossil resources rapidly increase and resource nationalism rises, obtaining fossil resources which are convenient but unevenly distributed has become a political and economic issue.

About 2/3 of remaining oil reserves are distributed in Middle-Eastern countries.
About 2/3 of remaining natural gas is distributed in Russia and Middle-Eastern countries.

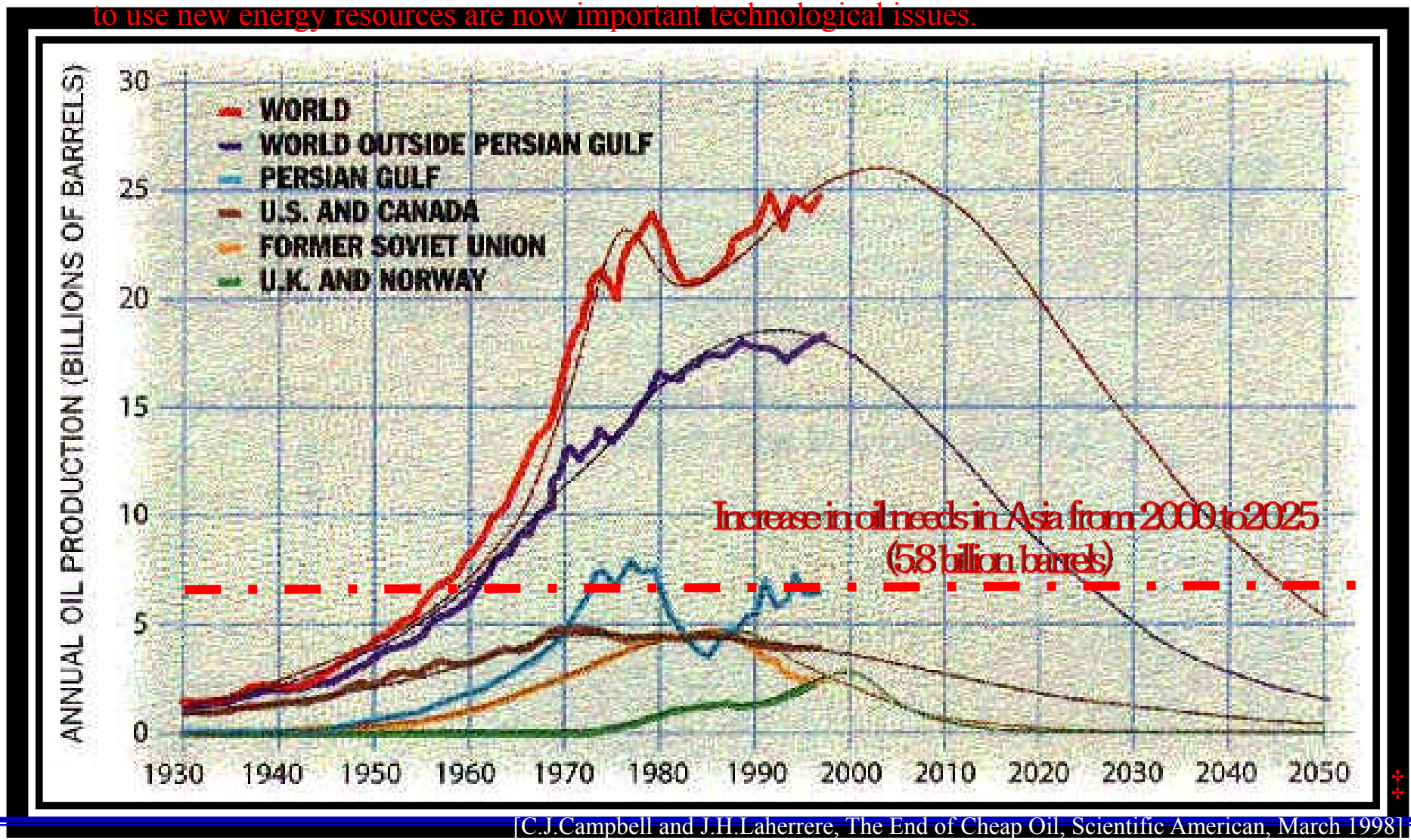
Saudi Arabia	National Saudi Aramco Co. has rights for all oil
UAE	National ADNOC Co. has 60% of rights for oil
Iran	National NIOC has right for mining, development and production.
Kuwait	National KOC has right for mining, development and production
Russia	Enhanced national control of rights for natural gas, and foreign currency restrictions
Kazakhstan	Enhanced national control of rights for natural gas, and foreign currency restrictions

2004.11 On the background of rapid increase in energy needs in China, Exxon Mobil Co. which was a development body of large-scale pipeline building project between Sakhalin, Russia and Japan called off the project.
2006.12 Russia notified Republic of Belarus ("White Russia") of raising natural gas prices 4 –fold. Belarus suggested the possibility of disconnecting gas pipeline to Europe.

Natural Environment and Artificial Environment

Increase in oil needs in Asia is equivalent to oil production in Persian Gulf.

Oil production is said to achieve a peak shortly, and on the edge of depletion of fossil resources, development of methods to restrain energy resource consumption by increasing energy efficiency or to use new energy resources are now important technological issues.



[C.J.Campbell and J.H.Laherrere, The End of Cheap Oil, Scientific American, March 1998]

Natural Environment and Artificial Environment

Global warming?
Development of methods to understand and predict changes in natural environment and restrain artificial changes to natural environment are now major challenges for science and technology.

Figure removed due to copyright restrictions

[Climate Change 2001 (Synthesis Report), (2001), Cambridge Univ. Press, Fig.2-3より]

Natural Environment and Artificial Environment

Atmospheric CO2 measurements
at Mauna Loa Observatory

Changes in average temperature
of the Earth's surface (land and sea)

Figure removed due to
copyright restrictions

["C.D.Keeling et al., Nature, 375(1995), pp.666-670", Fig.1]

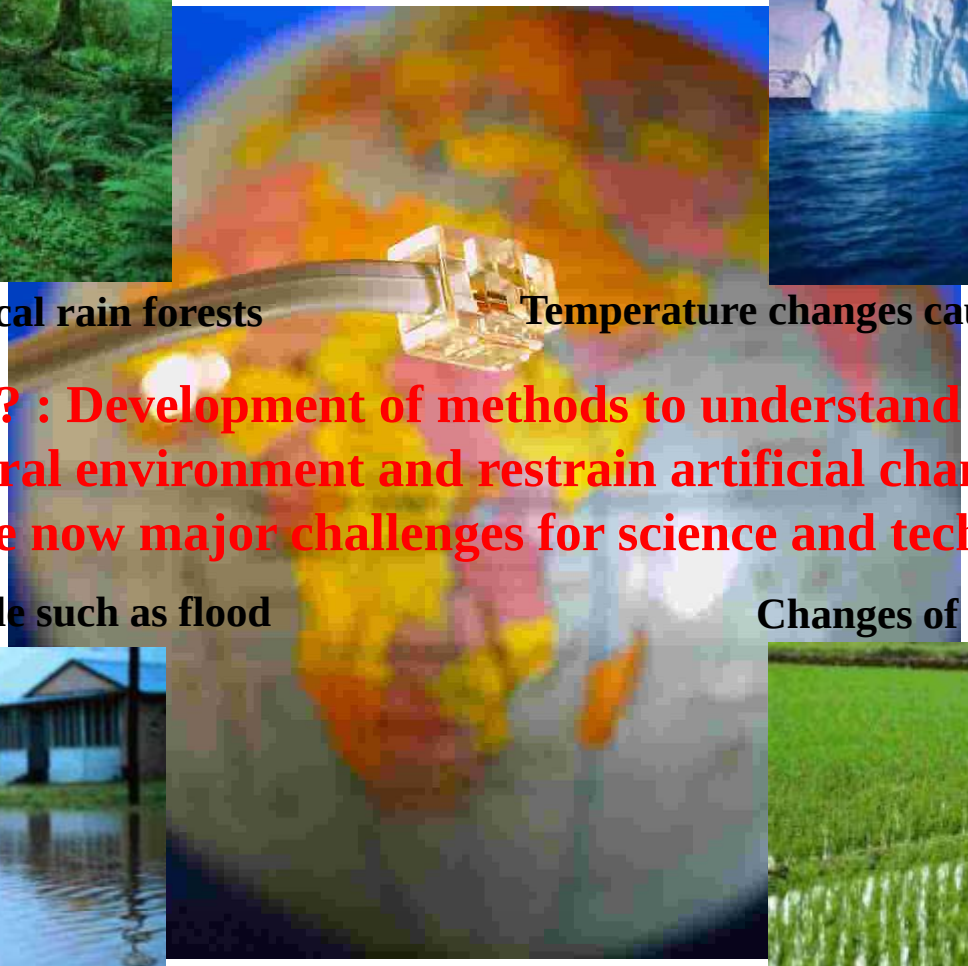
[Climate Change 2001 (Synthesis Report), (2001), Cambridge Univ. Press, Fig.2-3]

Nishio Lab. IIS UT

Natural Environment and Artificial Environment

Plant changes in tropical rain forests

Temperature changes causing ice sheets melting

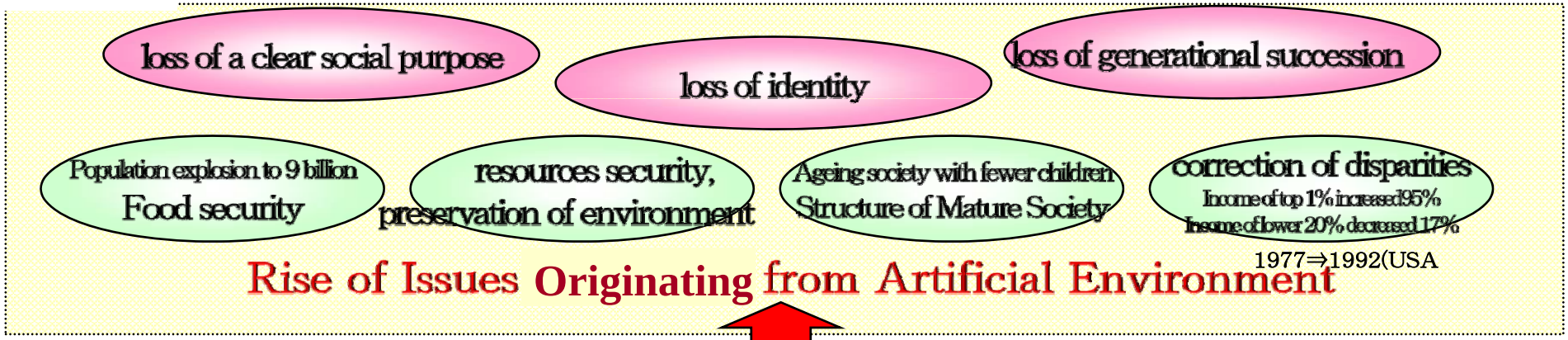


Climate change? : Development of methods to understand and predict changes in natural environment and restrain artificial changes to natural environment are now major challenges for science and technology.

Changes in water cycle such as flood

Changes of crops in agriculture

Natural Environment and Artificial Environment



Running power = Transportation Revolution

Airplane, car, railway

Force = Energy Revolution

Nuclear reactor, rocket

Computation, memory, audiovisual = Information Revolution

Life force = Biological Revolution

Gene engineering

Physical science and technology are as compelling as religions.

"Importance of landing man on the moon is almost equal to importance of the instance in the evolutionary processes when the first creature from sea dragged itself on to the land. We are, extending our brain, arms and legs to the maximum. This is the new step in human evolution." Wernher von Braun

"If there were no God, it would be necessary to invent him. " Voltaire

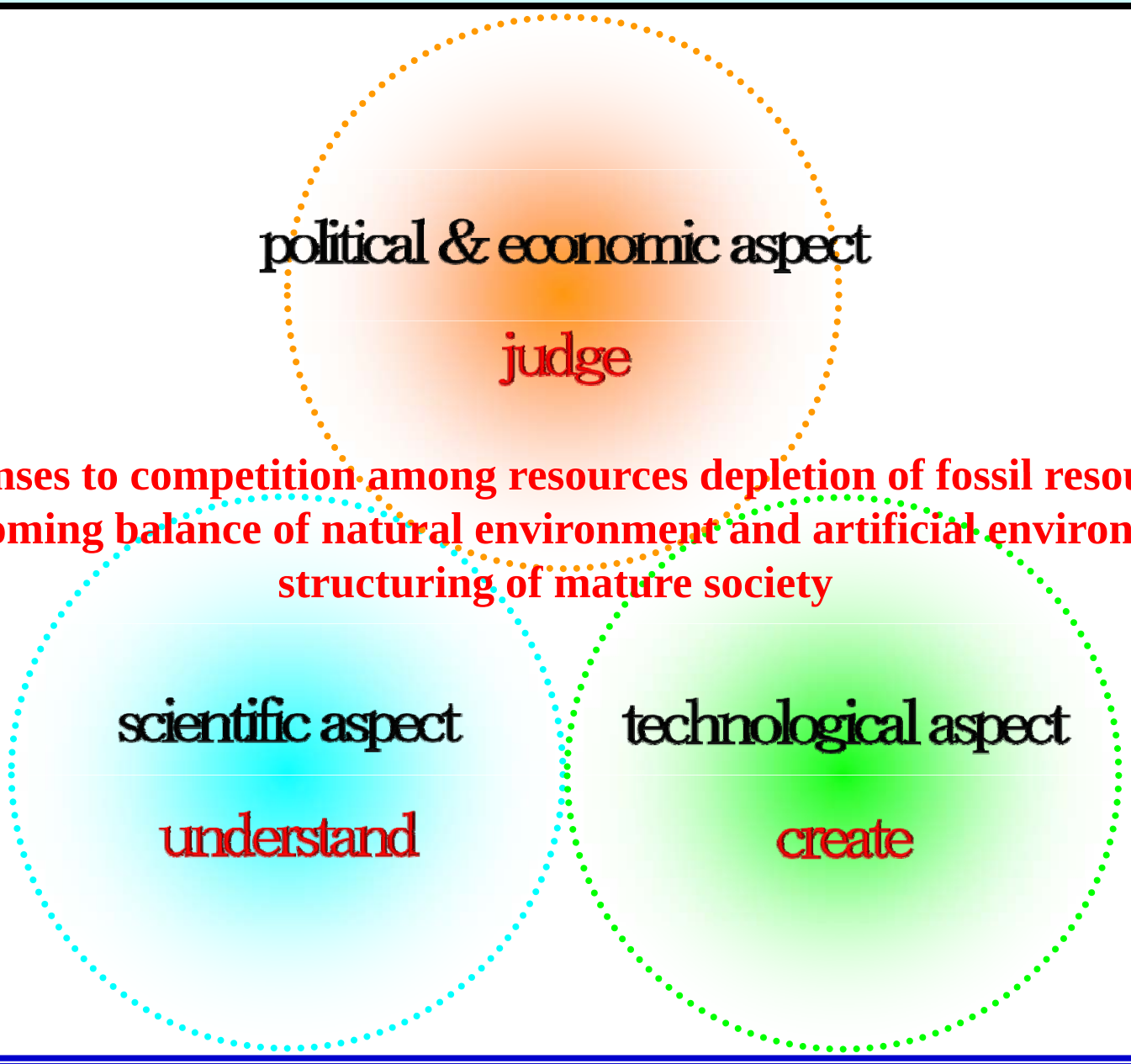
"The future is of cars. It releases humans."Zola

Physical science and technology = segmentation, separation to disciplines

Enhancement of human physical abilities, and liberty from physical constraints are motive

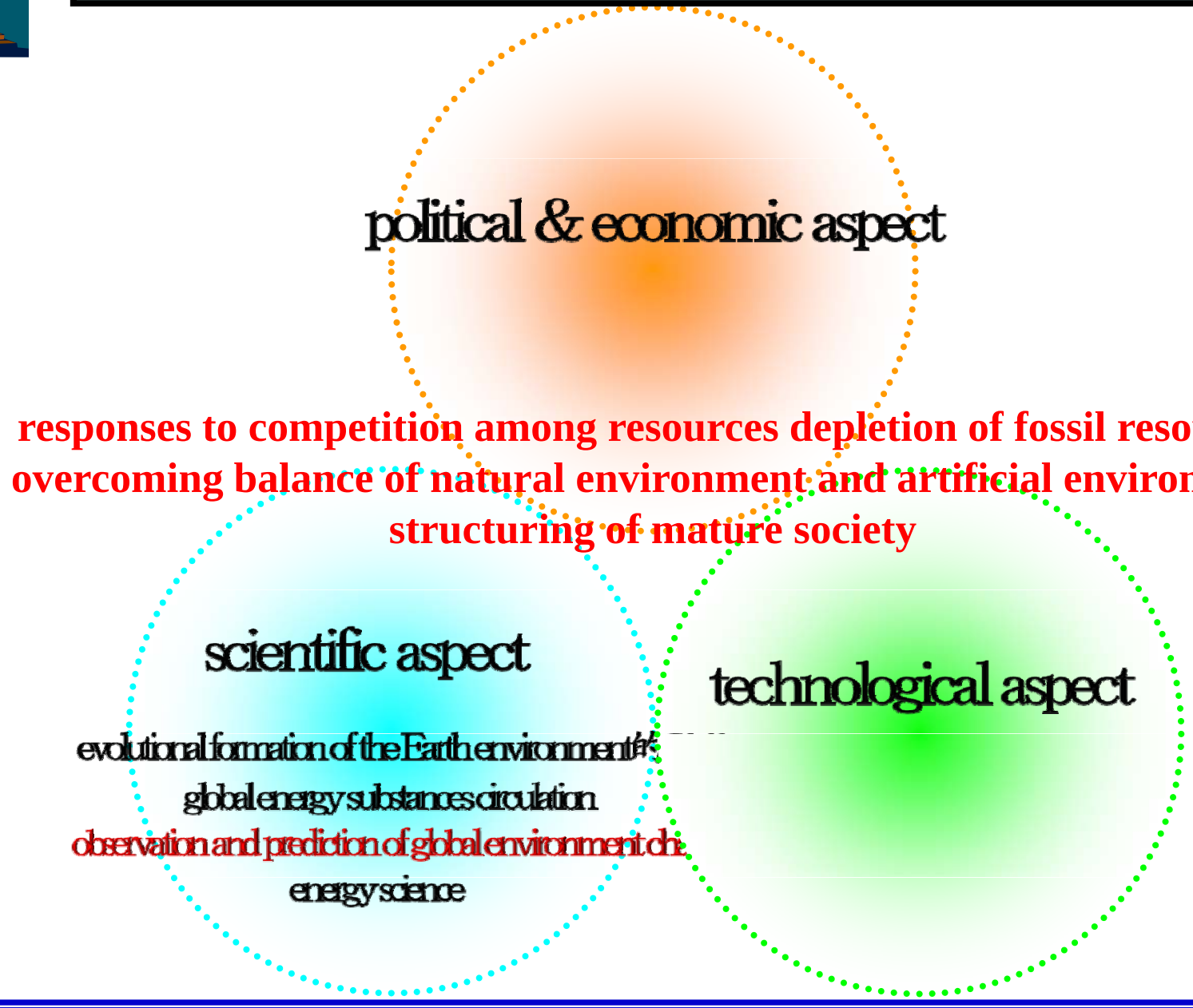
Segmentation of human function → single-function machine as a substitute → layered structure of elements

Natural Environment and Artificial Environment



responses to competition among resources depletion of fossil resources
overcoming balance of natural environment and artificial environment
structuring of mature society

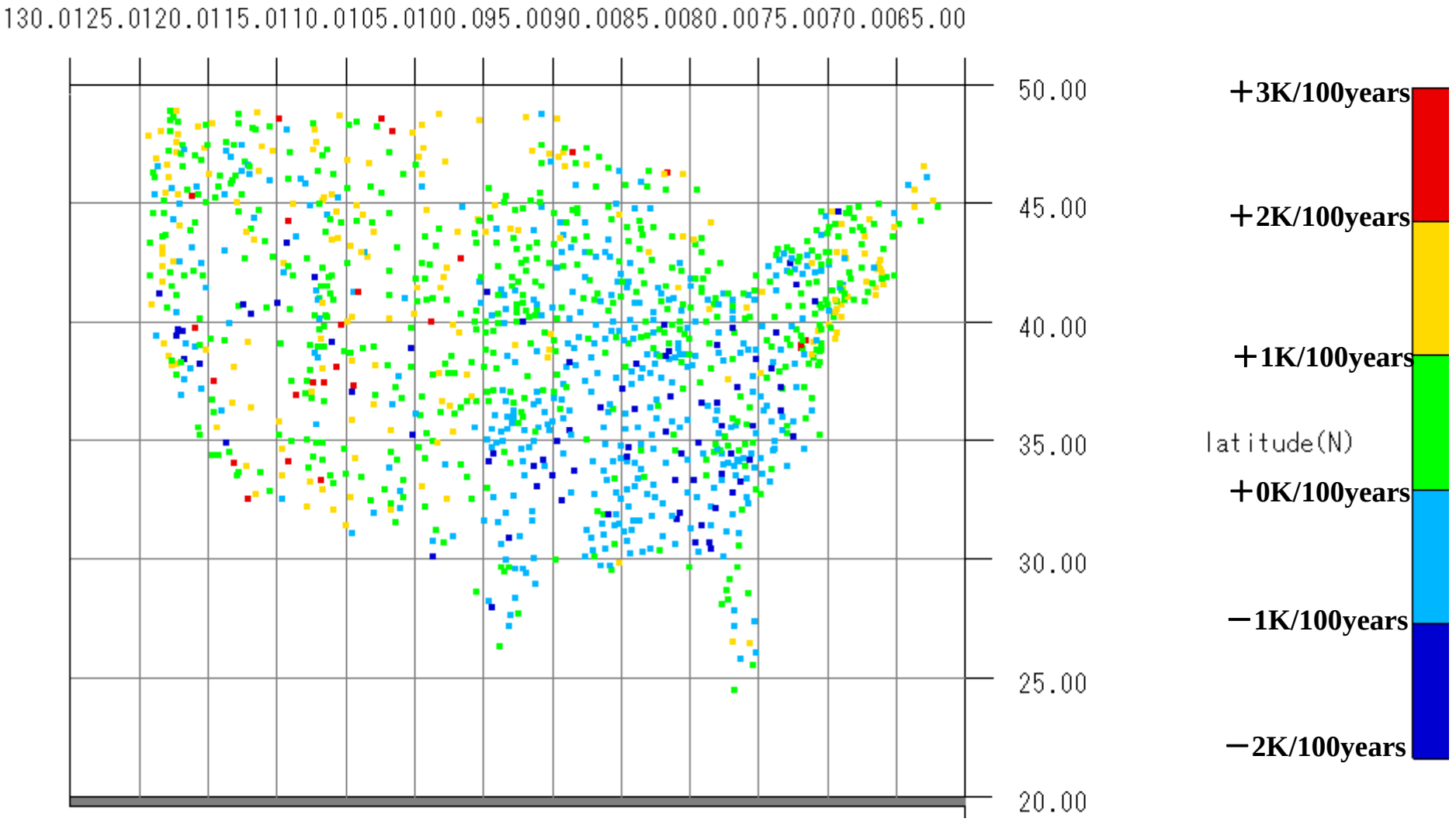
Natural Environment and Artificial Environment



Nishio Lab. IIS UT

Global Environmental Change

Temperature in the USA does not seem to have risen significantly in the past 100 years.
Is global warming really happening? Isn't it a problem only in urban environment?



Global Environmental Change

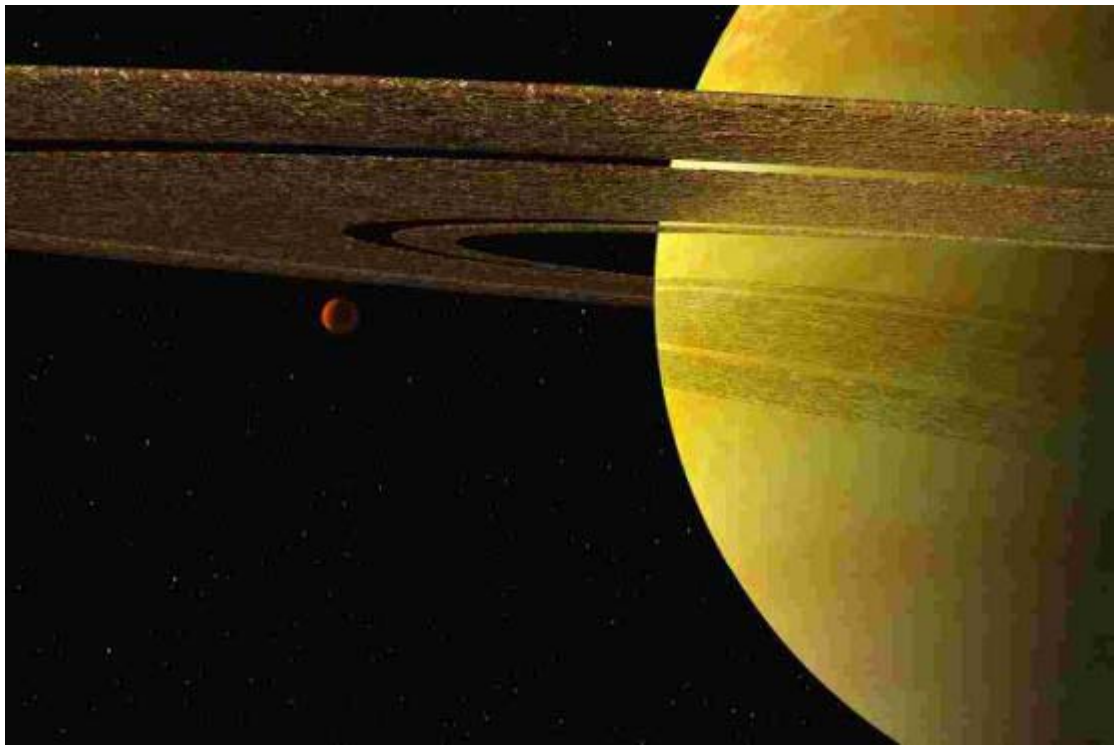
Wien's displacement law $T\lambda_{\max} = 2898\,[\mathrm{K}\cdot\mu\mathrm{m}]$

Stefan-Boltzmann law $E = \sigma T^4$

Figure removed due to copyright restrictions

[Masayuki Tanaka, "Warming Earth" (Yomiuri Kagaku Sensho23), (1989), Yomiuri Shimbun, p.21]

Global Environmental Change



$$\pi R^2 C_S (1 - F_A) = 4\pi R^2 \sigma_{SB} T_E^4$$

$R \equiv radius\ \ of\ \ the\ earth$

$C_S \equiv 1370 W/m^2$

$F_A \equiv 0.3$

$\sigma_{SB} \equiv 5.67 \times 10^{-8} W/m^2 K^4$

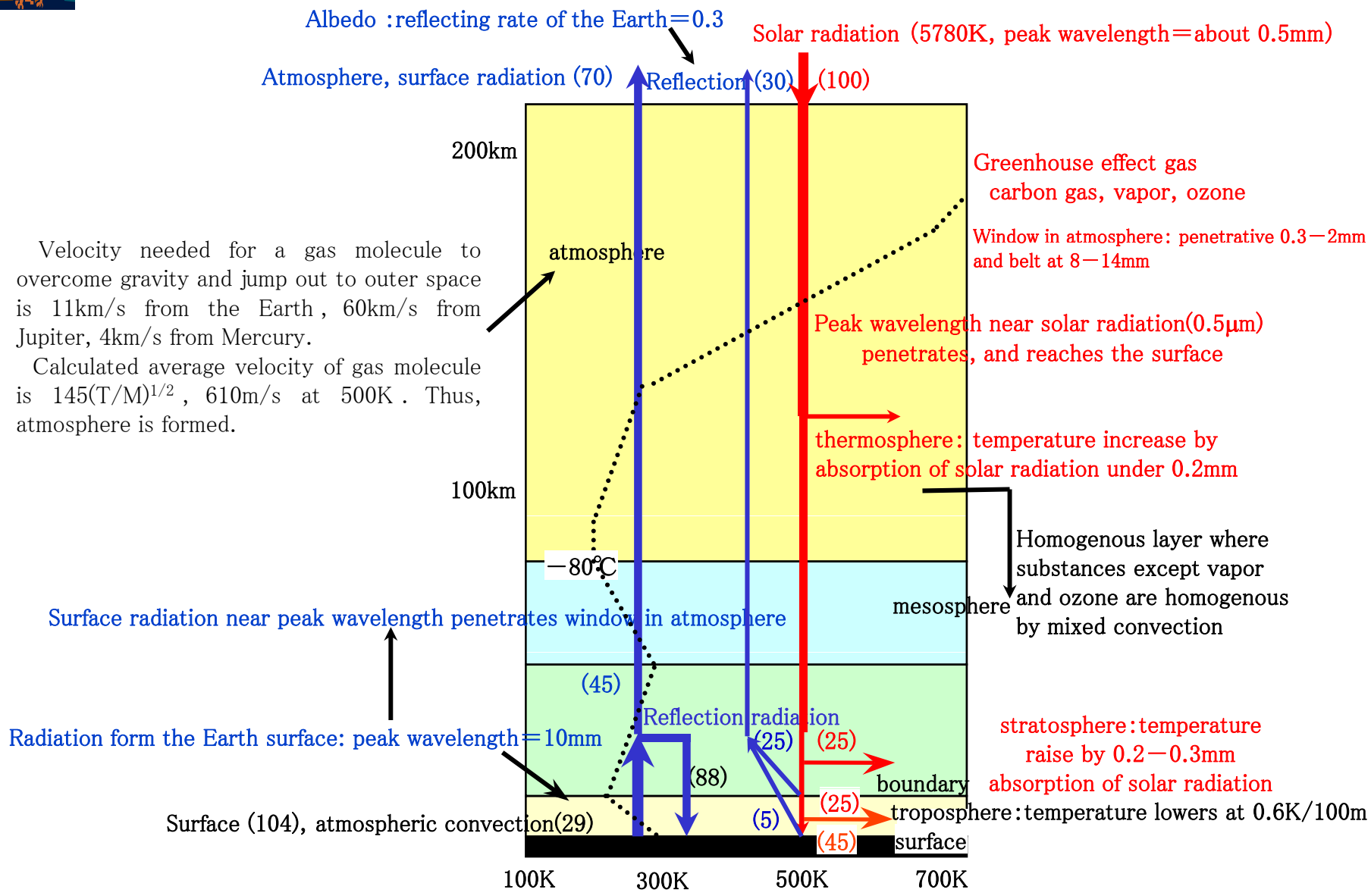
$T_E = 255K = -18^{\circ}\mathrm{C}$

$T_A - T_E = 288 - 255 = 33K$

Radiated spectrum from the Earth's surface has its peak at 10 μ m. This surface radiation is absorbed in the atmosphere (75% is absorbed by vapor, especially radiations with long wavelength more than 15μ m are completely absorbed by vapor). As a result, atmospheric radiation warms the surface, and surface temperature T_A gets warmer than effective Earth radiation temperature T_E.

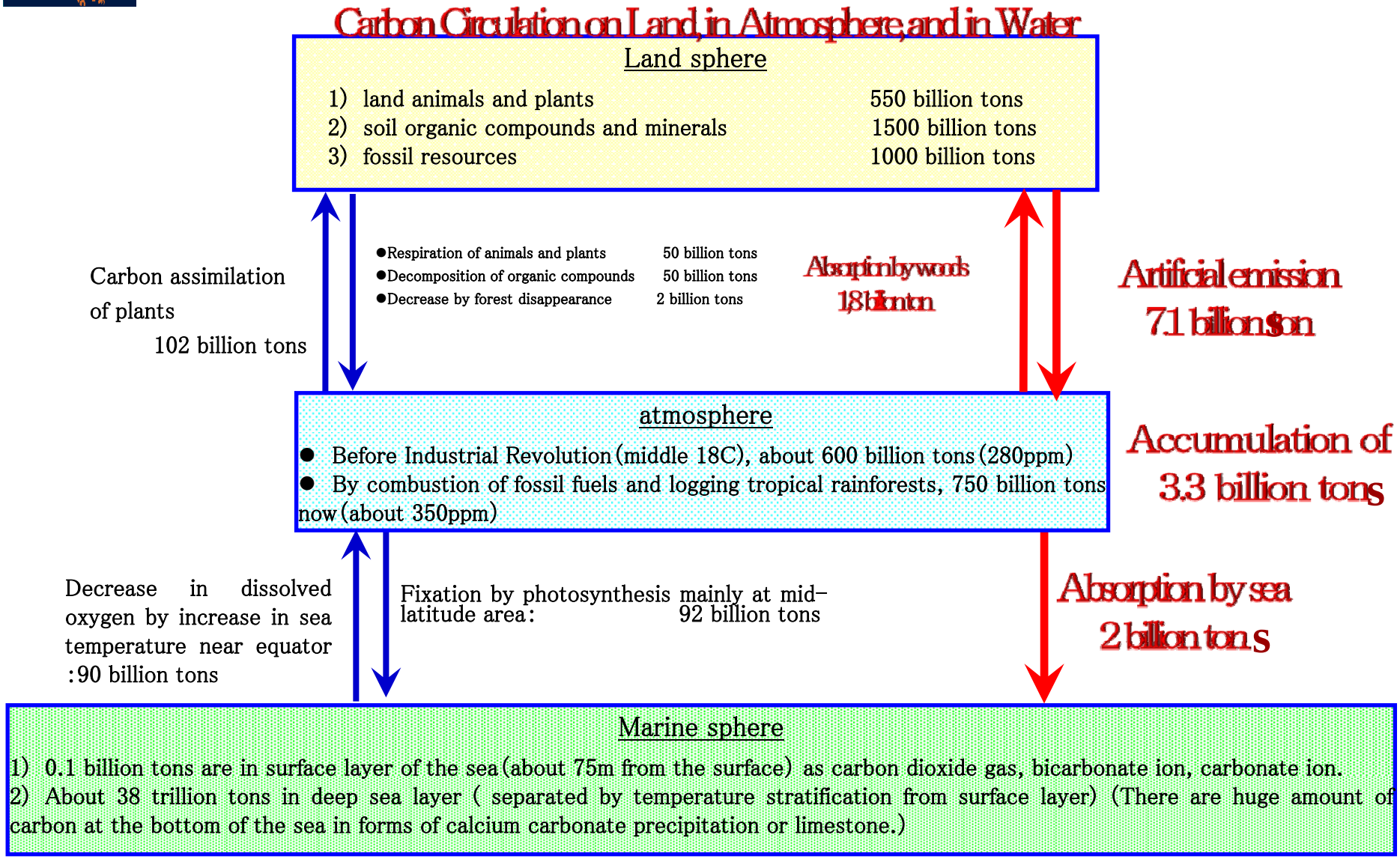
Nishio Lab. IIS UT

Global Environmental Change



Nishio Lab. IIS UT

Global Environmental Change



[drawn from J.T.Houghton et al., Climate Change –The IPCC Scientific Assessment, Cambridge Univ. Press, (1990), p.8]

Global Environment Change

・ CO2 concentration in the atmosphere was found to be around 280 ppm in the 1800s by a joint French-Russian project to analyze excavated ice at Vostok Station in Antarctica(1980.) CO2 concentration measurement at the top of Mauna Loa in Hawaii and in the Antarctica by Prof. Kiring at the California Institute of Technology indicated that it would be as high as 370 ppm in 2000.

・ By fixed-point observation and oxygen-isotope ratio analysis, (If temperature is high when sea water evaporates, O18/O16 ratio in the water is high. Vapor changes into oxygen by plant photosynthesis and is released into the air) , it is understood that the temperature of sea water increased twice from 1900.

・If 58% of carbon dioxide emitted from fossil fuel combustion and cement industries accumulated in the atmosphere are considered, the upward trend of carbon dioxide in the atmosphere after 1960 can be explained.

・ However, since carbon dioxide in the sea is released into the air when temperatures rise, there is a need to find out which is the cause for rises in temperature and carbon dioxide concentration. In another words, there is a need to verify that rise in carbon dioxide concentration causes temperature increase that is happening now.

Global Environmental Change

IPCC

Intergovernmental Panel on Climate Change

- Members of the panel are scientists from each country chosen by public subscription
- WG I ：Assess scientific reasonings for climate system and climate changes
  WG II ：Assess vulnerability of ecosystem, effects from climate changes and countermeasures
  WG III ：Assess easing measures for climate changes
- The 1st Assessment Report (1990)、The 2nd Assessment Report (1995), The 3rd Assessment Report (2001)
- The 4th Assessment Report (approved in May, 2007, the 26th IPCC Congress)
- Summary for governments and summary for experts
  - virtually certain (99% certainty)
  - very likely (90～99%)
  - likely (66～90%)
  - medium likelihood (33～66%)
  - unlikely (10～33%)
  - very unlikely (1～10%)
  - exceptionally unlikely (less than 1%)

Global Environmental Change

Can temperature change be predicted?

Figure removed due to
copyright restrictions

[Climate Change 2001 (Synthesis Report), (2001), Cambridge Univ. PressFig.SPM-2より]

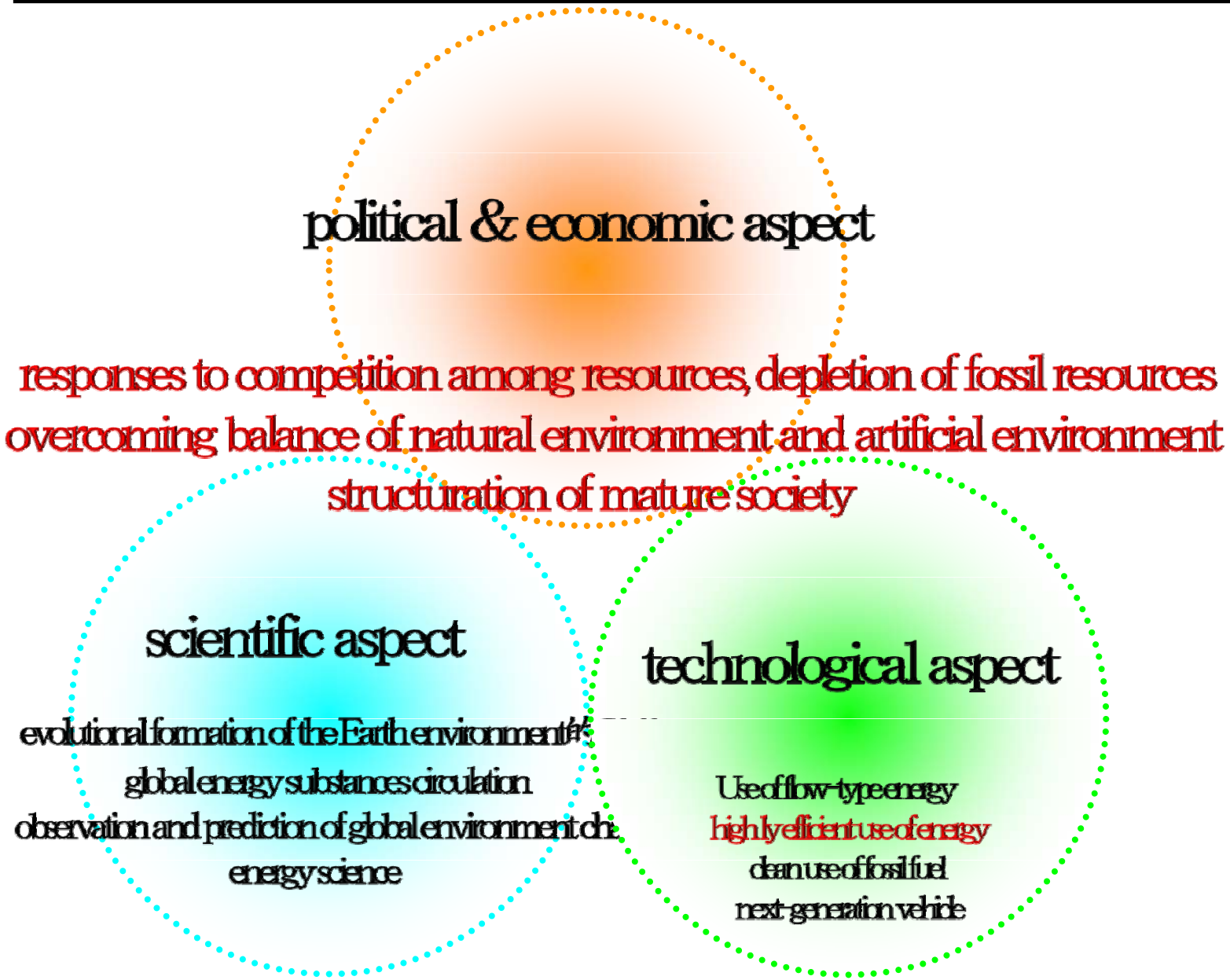
Global Environmental Change

Can temperature change be predicted?

Figure removed due to
copyright restrictions

["Climate Change 2001 (Synthesis Report), (2001), Cambridge Univ. Press, Fig.2-3"]

Natural Environment and Artificial Environment



Energy Consumption

Energy consumption

chemical energy of gasoline
↓
combustion
↓
heat energy
↓
motion of piston
↓
rotation of a wheel
↓
motion energy of car
+heat energy of exhaust gas

Energy conservation

Energy Consumption

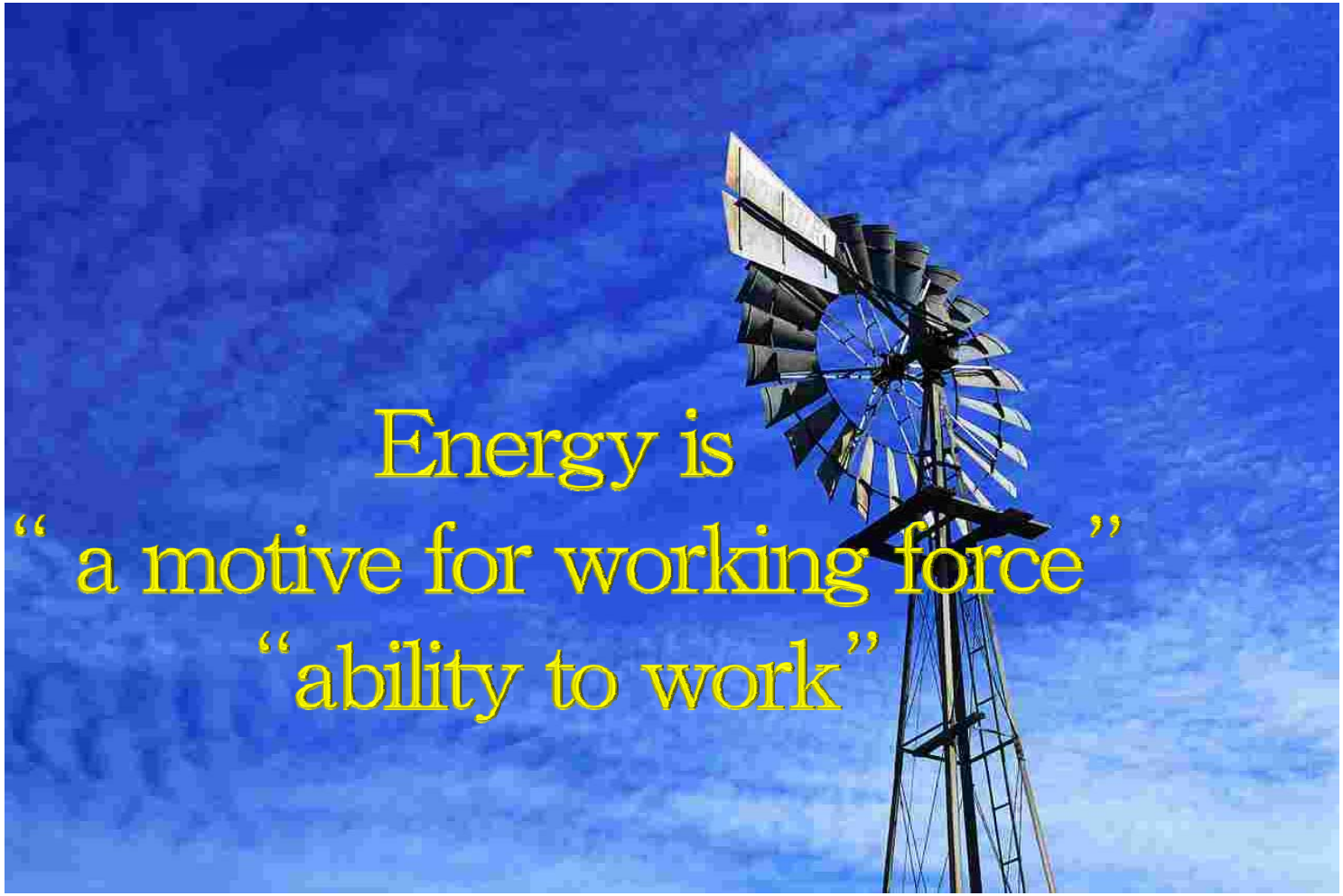
Fossil energy

Solar energy

Energy ?

Renewable energy

Energy Consumption



Energy Consumption

Potential energy

Nuclear energy

Chemical energy

Motion energy

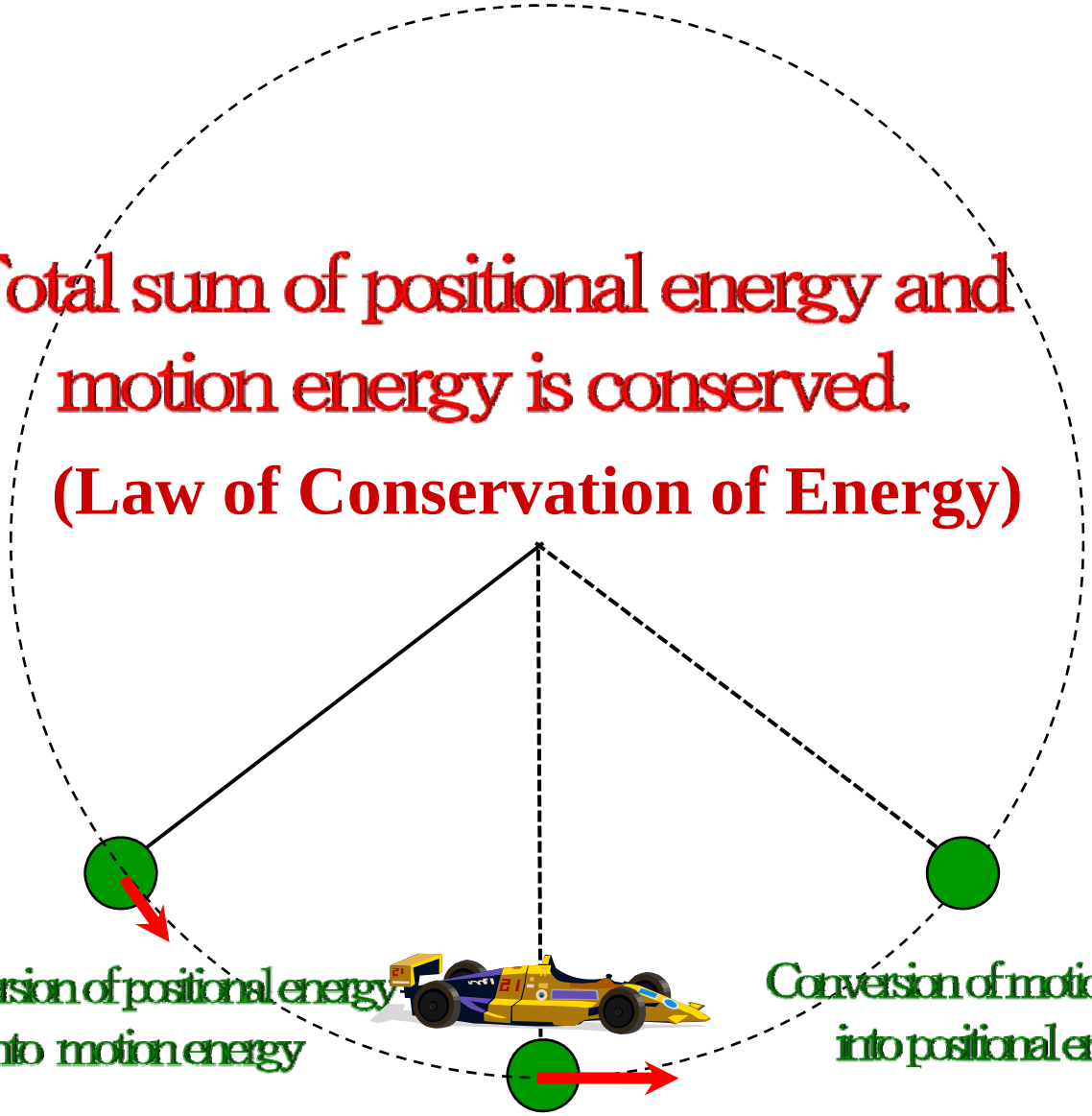
Electromagnetic energy

Energy can be converted and the total amount remains constant.
(Law of Conservation of Energy)

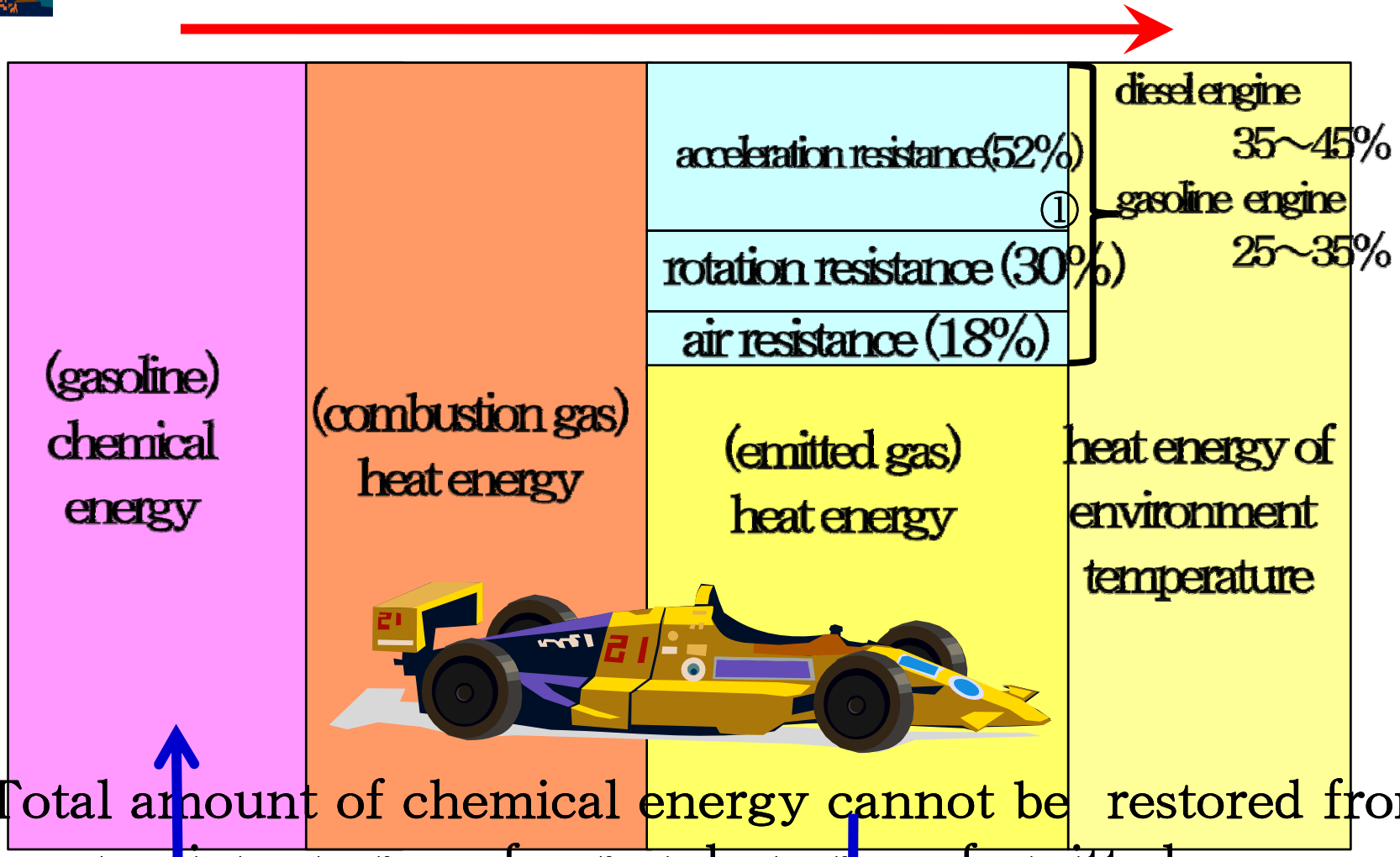
Internal energy

Heat energy

Energy Consumption



Energy Consumption



②Total amount of chemical energy cannot be restored from motion energy of car and energy of emitted gas

Total amount of energy is conserved, but some is consumed during conversions.

Energy Consumption

Quality of energy was consumed at the same time with energy resource.
It is important to discover techniques to use energy efficiently.
For example, heat cascading which is to convert to work at high temperature and investigate using heat at low temperature.

$$\eta = 1 - \frac{T_E}{T}$$

$$T_E = 300K$$

$$T = 3000K \Rightarrow \eta = 90\%$$

$$T = 1500K \Rightarrow \eta = 80\%$$

$$T = 1000K \Rightarrow \eta = 70\%$$

$$T = 600K \Rightarrow \eta = 50\%$$

$$T = 400K \Rightarrow \eta = 25\%$$

Energy and the Earth's Environment

Political, economic aspect

energy security
international strategies for obtaining resources
international cooperation for preserving environment
(compliant economic efficiency and fairness of responsibilities)

national strategies for technology development

responses to competition among resources, depletion of fossil resources
overcoming balance of natural environment and artificial environment
structuration of mature society

Scientific aspect

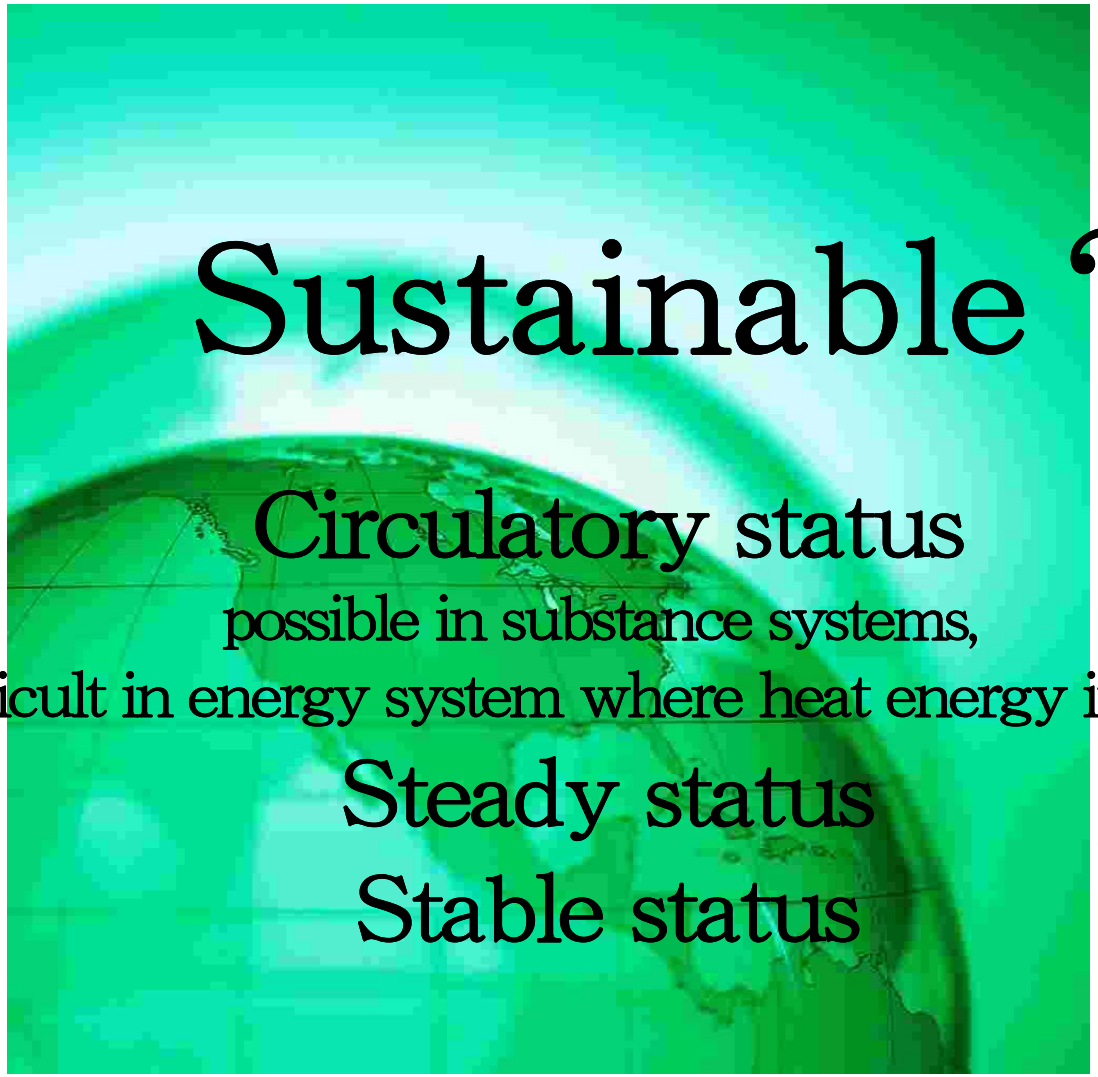
evolutionary formation of the Earth environme
global cycle of energy substances
observation, prediction of
the global environment changes
energy science

Technological aspect

utilization of flow-type energy
energy high-efficiency use
clean use of fossil fuel

the next generation vehicle

Sustainability



Sustainable ?

Circulatory status

possible in substance systems,

but difficult in energy system where heat energy intervenes

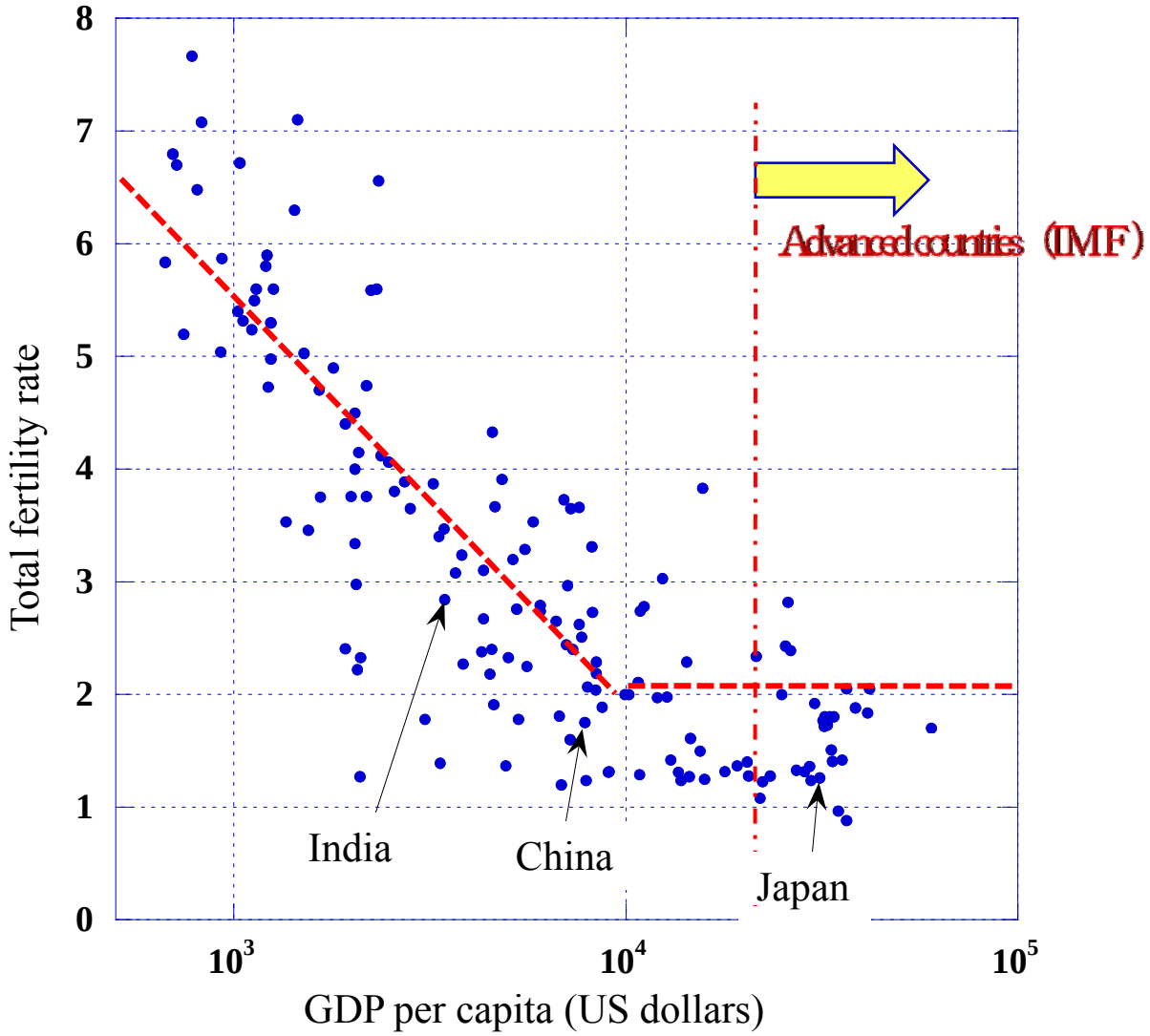
Steady status

Stable status

Nishioka Lab. IIS UT

Sustainability

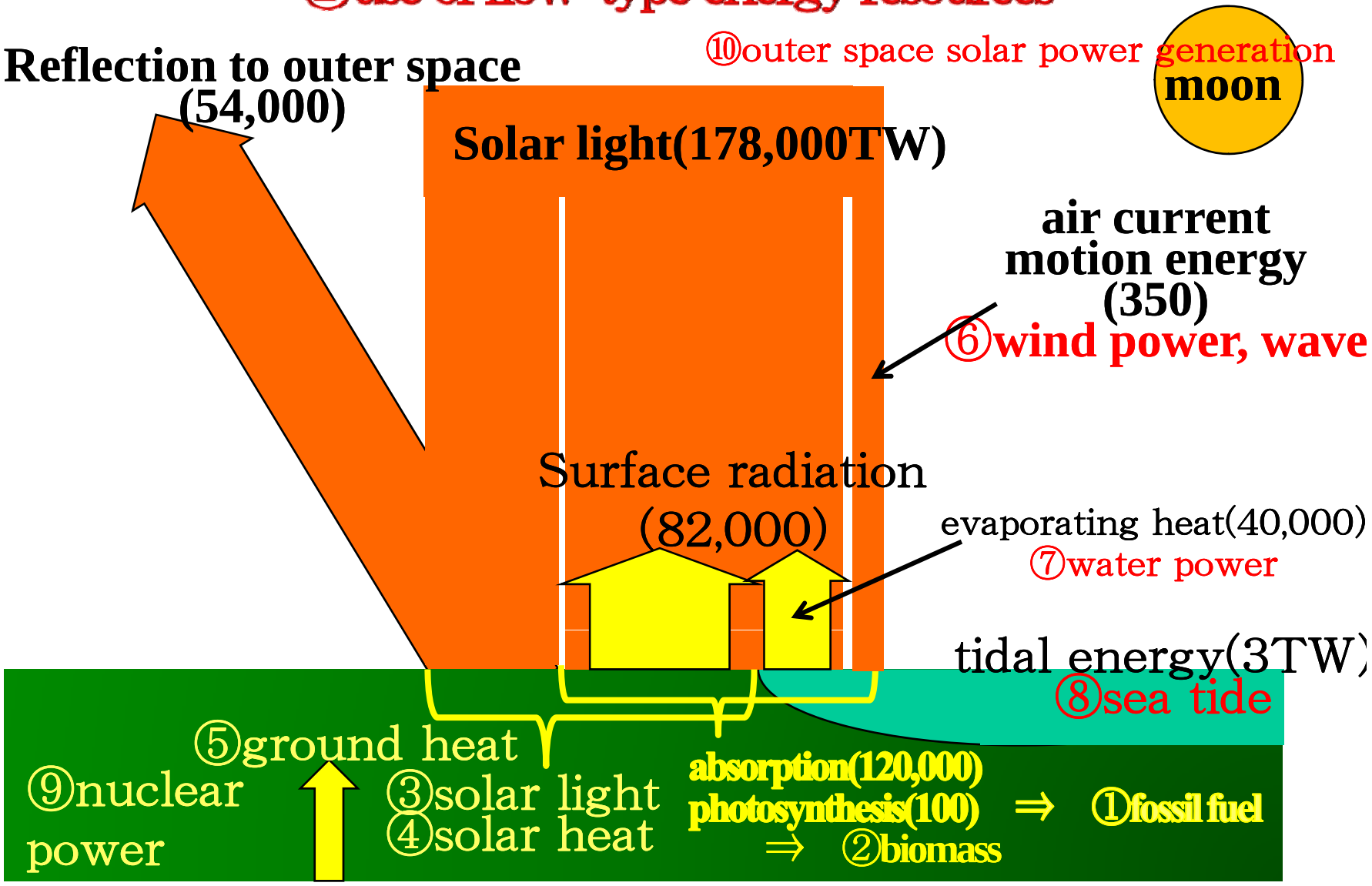
①stabilization of population : Improvement of economy would dedicate to this



Nishio Lab. IIS UT

Sustainability

②use of flow-type energy resources



Sustainability

②Use of Flow-type Energy Resources

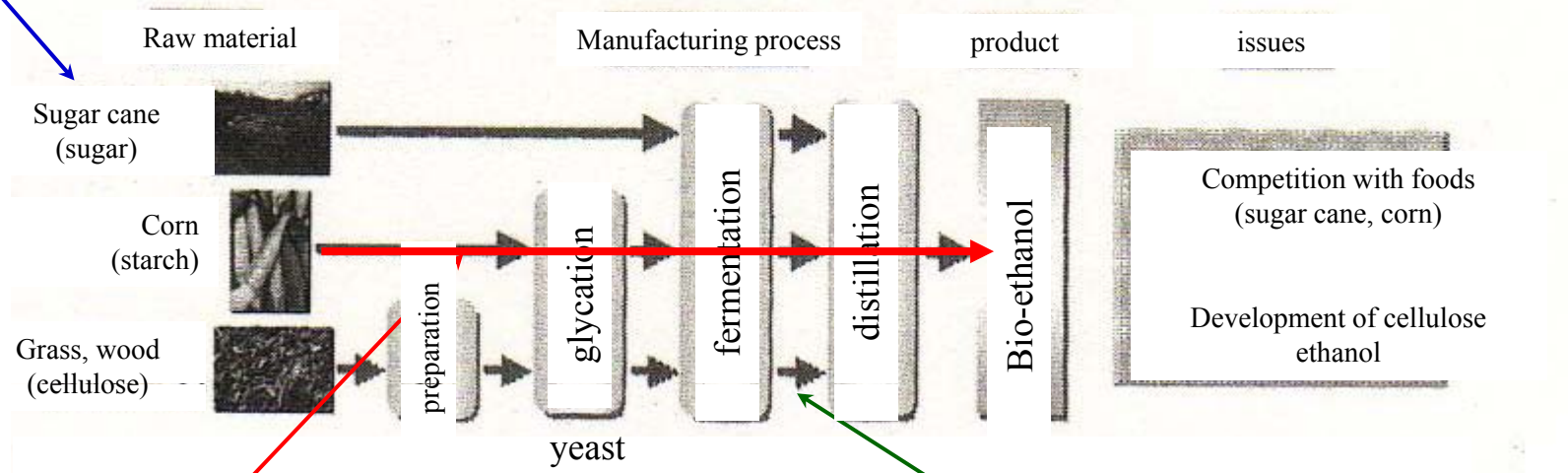
	Setting cost (yen/kW)	Driving cost (yen/kWh)	Generating cost (yen/kWh)	Energy budget(－)
	Kazunari Kainou, "Calculation Model for Power Supply Structure and Comparison of Costs for Electricity Generation", RIETI,2003.7			IEEJ, Vol.126,(2006), pp.222-224
Combined thermal power［LNG, operating rate50%］	20.8	4.9	9.3	6 Large amount of energy is needed in liquidizing processes
Fire power［coal, operating rate 60%］	30.8	3.3	8.7	21
Nuclear power［light-water reactor, operating rate80%］	33.8	3.6	7.1	26 pluthermal
Water power			（13.6）	50
Wind power [operating rate20%]	20.8	15.5	23.4	22
Solar power [operating rate12%]	94.0	0.1	65.8	5～9 Energy density is low.

Energy budget： ratio of electric power produced by generating technologies in durable years and energy input to construction of generator sets needed for electric supplies or maintenance of operation (excluding energy input for power generation)

Sustainability

②Use of Flow-type Energy Resources

- If sugar cane is used as a raw material, process of glycation is not needed, and net energy production is possible (3.7-fold of needed energy)
- However, sugar cane is produced in limited geographical area .



- If corn is used as a raw material, to make 1 ℓ ethanol, heat energy as much as 45% of calorific value (about 5000kcal) is needed only in manufacturing process.
- Considering energy needed to collect raw materials, transport manufactured ethanol (transport by pipeline is difficult for water mixes into ethanol) , it is important to check net energy gain.

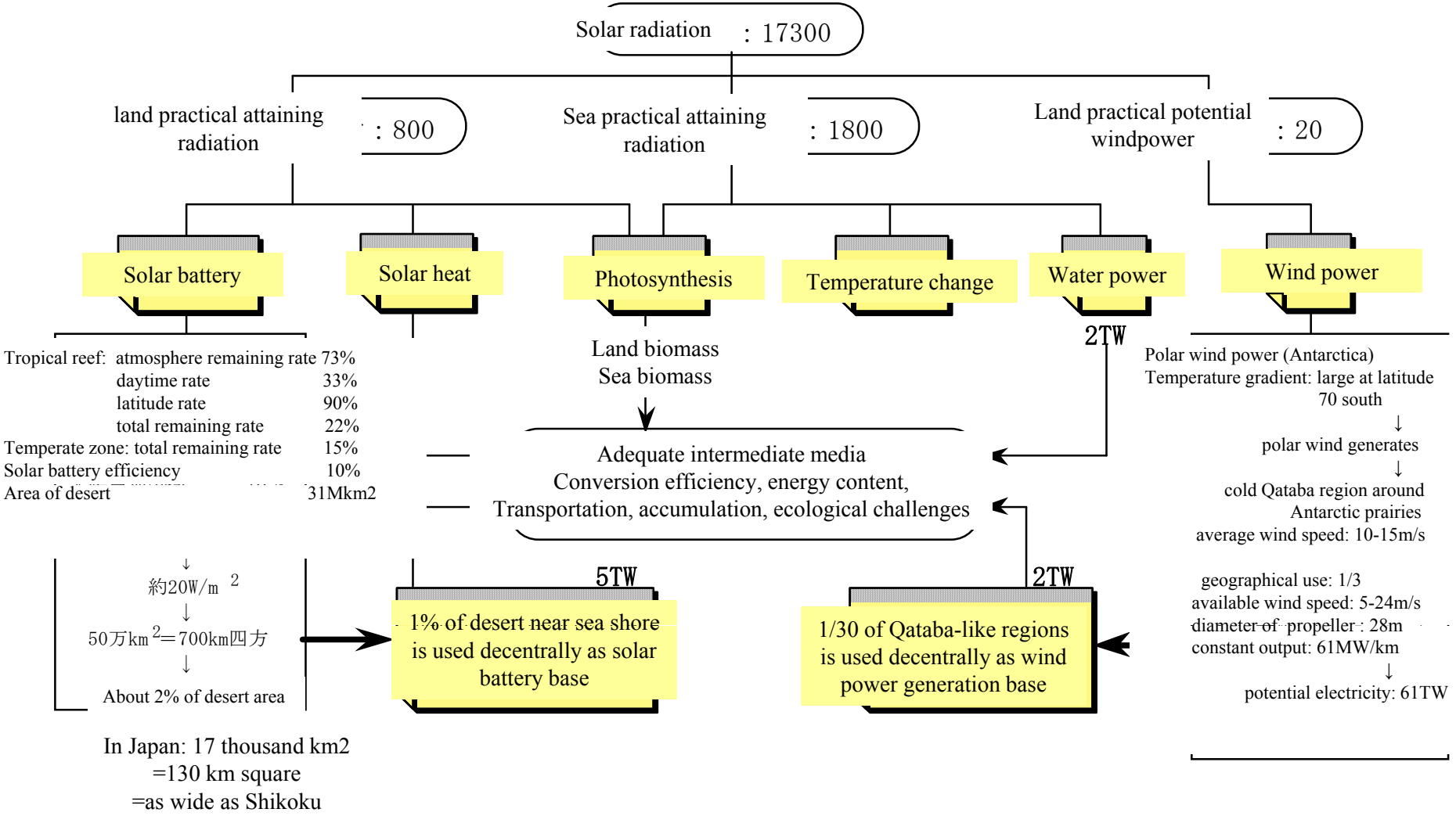
- In the case of corn as a raw material, if glucose fixed to cellulose that cannot be eaten and lignin are separated, ethanol from glucose and combustible substance (lignin) can be produced at the same time, and the effect on food is small. Cellulose ethanol can use whole biomass as a resource, and is the favorite target of bioethanol.
- Enzyme to separate glucose and lignin is needed.

[Kenjin Ueda, "Total Engineering of Energy", 29-4(2007]

Nishio Lab. IIS UT

Sustainability

②Use of Flow-type Energy Resources

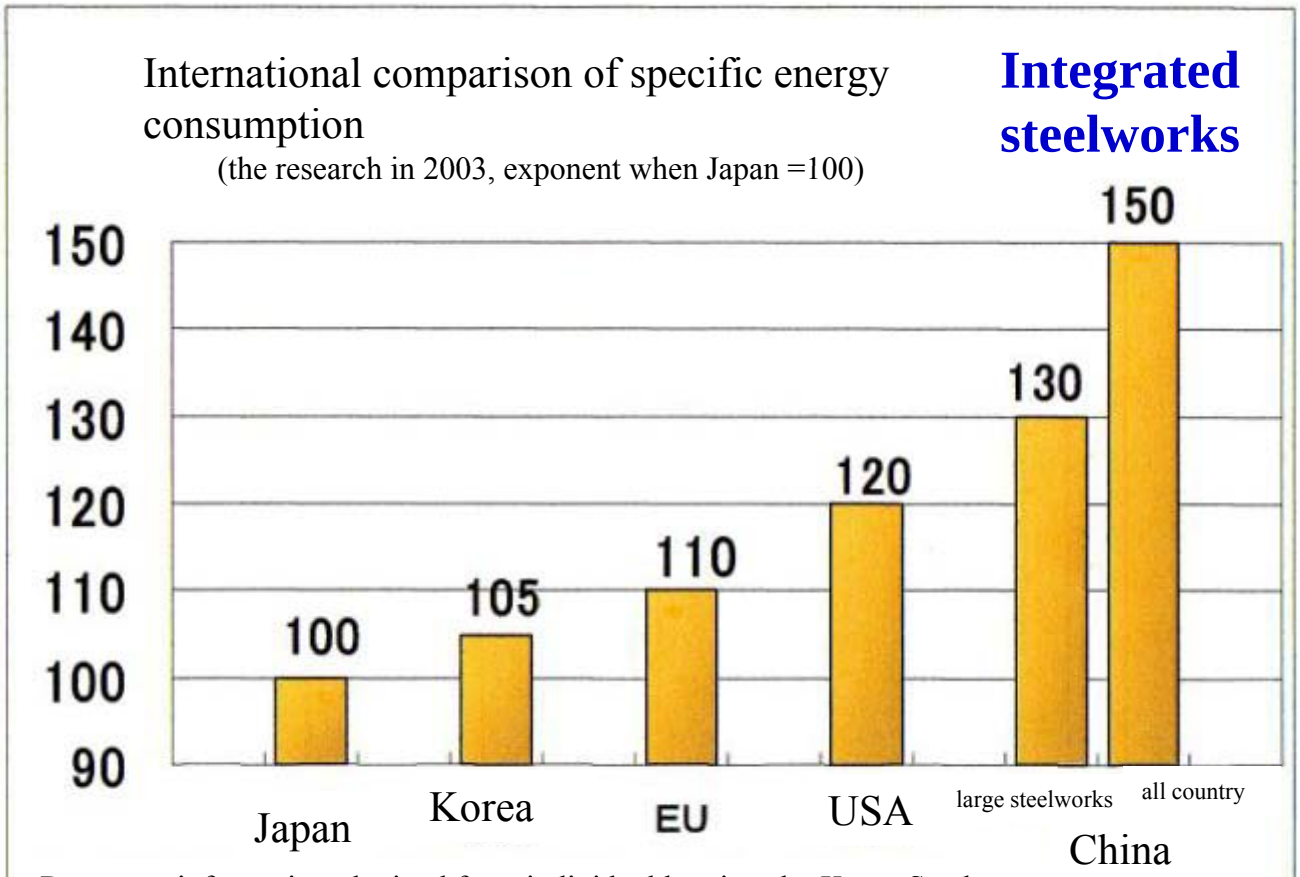


Utility of solar radiation: Distributed use of various renewable natural energy sources

Nishio Lab. IIS UT

Sustainability

③Improvement of Energy Efficiency



International comparison of specific energy consumption (energy consumption/GDP)

Japan	**1.00**
UK	**1.43**
Germany	**1.74**
France	**1.87**
USA	**2.08**
World	**2.65**

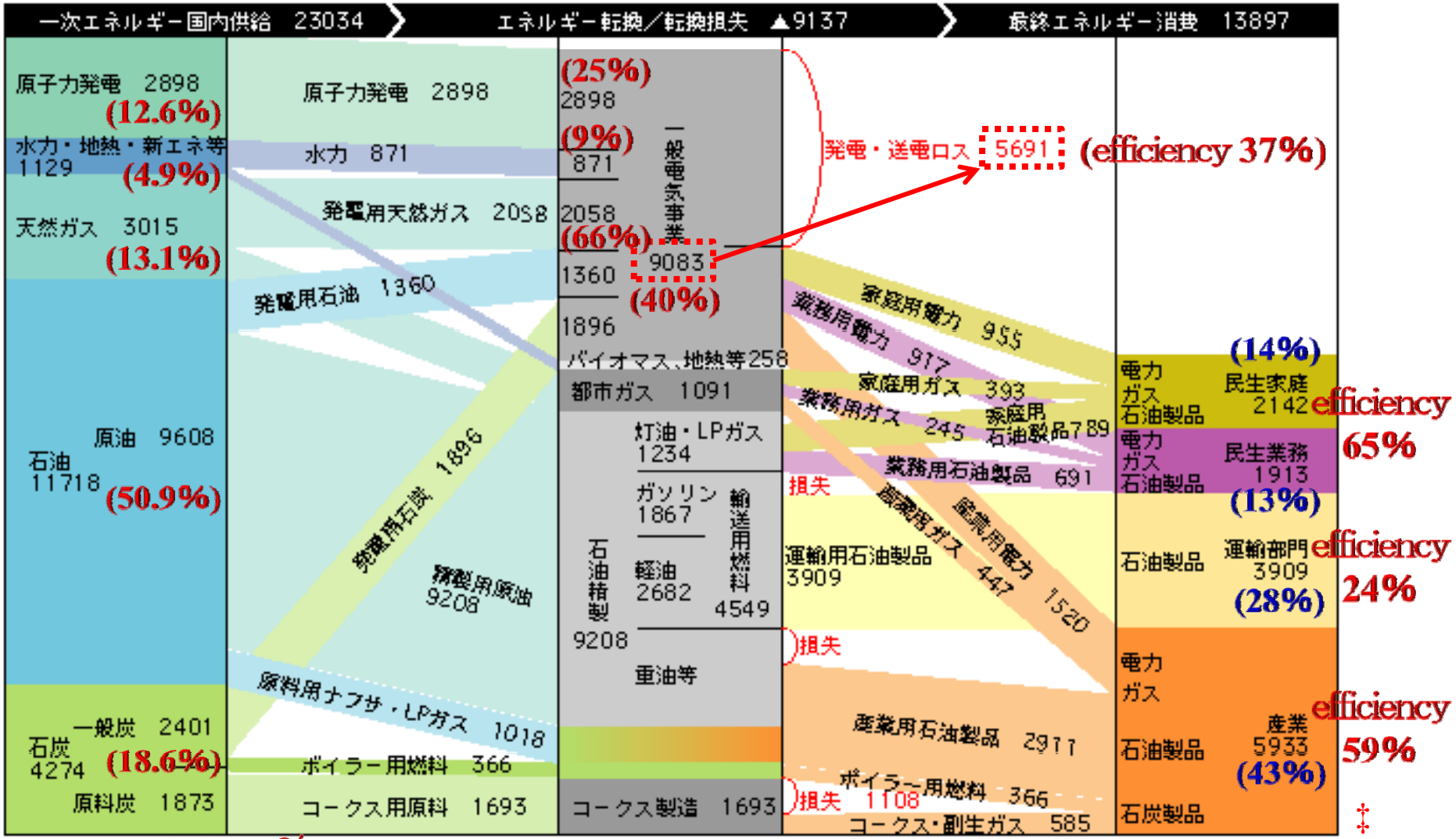
[METI Department of Environment, "Challenges to Achieve Goals of the Kyoto Protocol" (2005.1)]

Nishio Lab. IIS UT

Sustainability

③Improvement of Energy Efficiency

日本

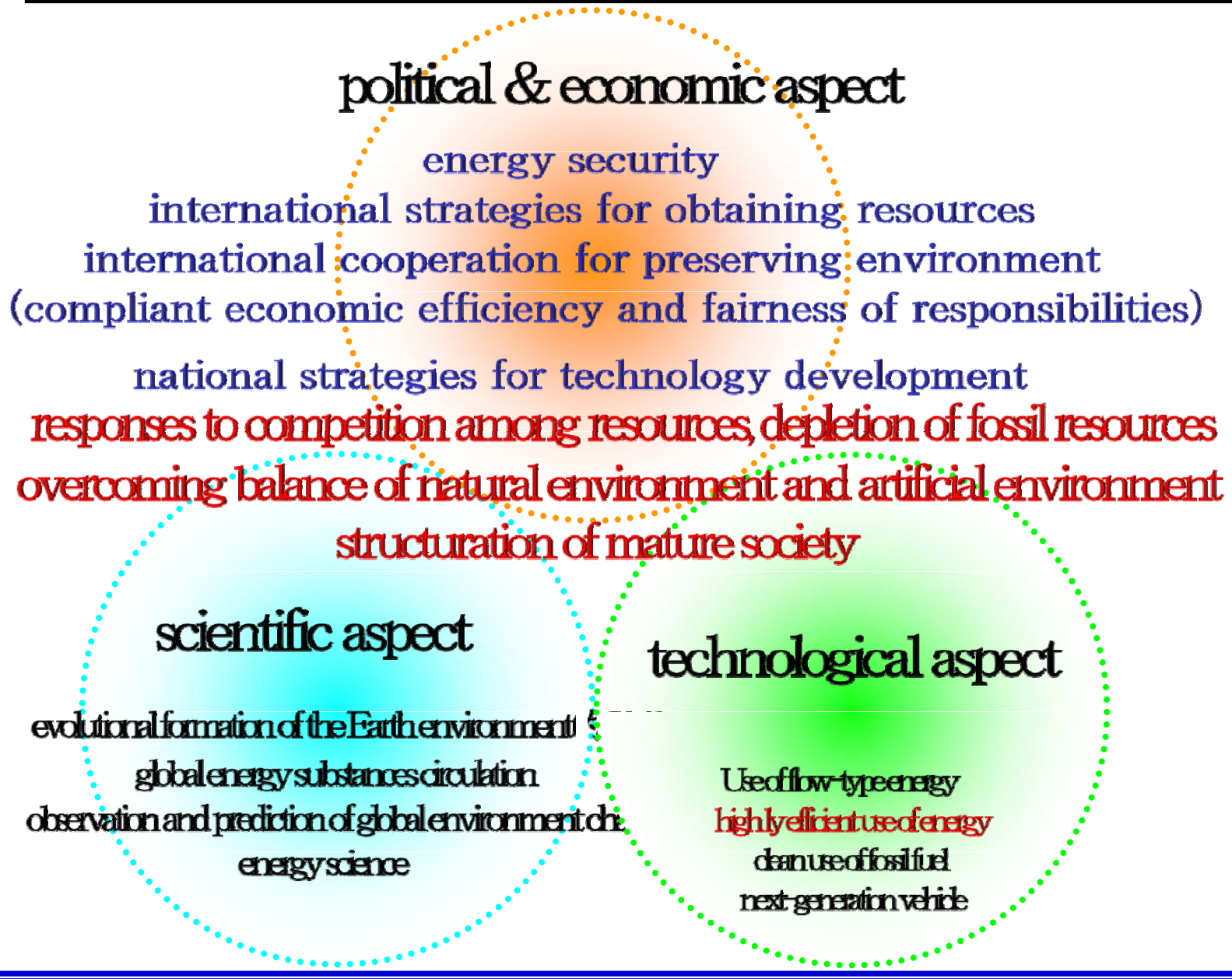


Dependence on fossil 82.5%

[METI Agency for Natural Resources and Energy, "FY 2004 Annual Energy Report"(2004)]

Nishio Lab. IIS UT

Natural Environments and Artificial Environments



Toward the Sustainable Society

8 Major Issues

- How to improve accuracy of predictions or observations of global environment changes (not only temperature, but includes water, plants and ecosystems)
- When extreme energy systems such as nuclear fusion, outer space solar power generation or superconducting can be realized
- How can flow-type (renewable) energy resources be utilized (not only solar power or wind power, but includes biomass plantations)
- How energy efficiency can be improved (Energy saving, superinsulation, vehicle, eco community, life style are included)
- How to secure fossil resources and realize coexistence of natural environment and artificial environment in a period premised on large-scale usage of fossil fuel (securement of energy security, correspondence with climate changes, carbon dioxide separation, collection and accumulation, disparity adjustment)
- How to consider nuclear power generation in Japan which generate 25% of electricity with 53 generators (not only light water fuels but light water pulthermal, FBR and nuclear fuel cycle, and prevention of nuclear proliferation are to be discussed.)
- How to consider hydrogen and electricity as intermediate media (second energy) (This is related to the future of transportation)
- How to deal with urban environment problems such as heat island

Toward the Sustainable Society

COP(Conference of the Parties)

COP-FCCC(Framework Convention on Climate Change)
Bio diversity COP-CBD
Convention for desertification COP-CCD

Framework Convention on Climate Change(1992)

COP1(1995)：The treaty is not enough.
COP2(1996)：Approved to have legal binding force as a protocol
COP3(1997)：the Kyoto Protocol

the Kyoto Protocol(1997)

Regulating emissions of greenhouse effect gas in 2008-2012 on basis of 1990
Greenhouse effect gases were reduced 6% on average in the 1st commitment period .
Carbon dioxide(92%), methane, nitrogen monoxide (5%) ⇒ −6.4%
(Detail of 6.4% is 3.9% by woods absorption, 2.5% by emission reduction)
ＨＦＣ・ＰＦＣ・ＳＦ６(3%) ⇒ 2.0%

Toward the Sustainable Society

Under the Kyoto Protocol, Japan is to reduce emission of greenhouse effect gas 6% from 1990, but it i was d 7.8% in 2005.

The government considers that even if 5.4% absorption by forestation is expected, 1.5- gases re is needed for the goal. About 9% reduction can be expected in industries, but there would be 15% increase in transportation and 10% increase by citizens.

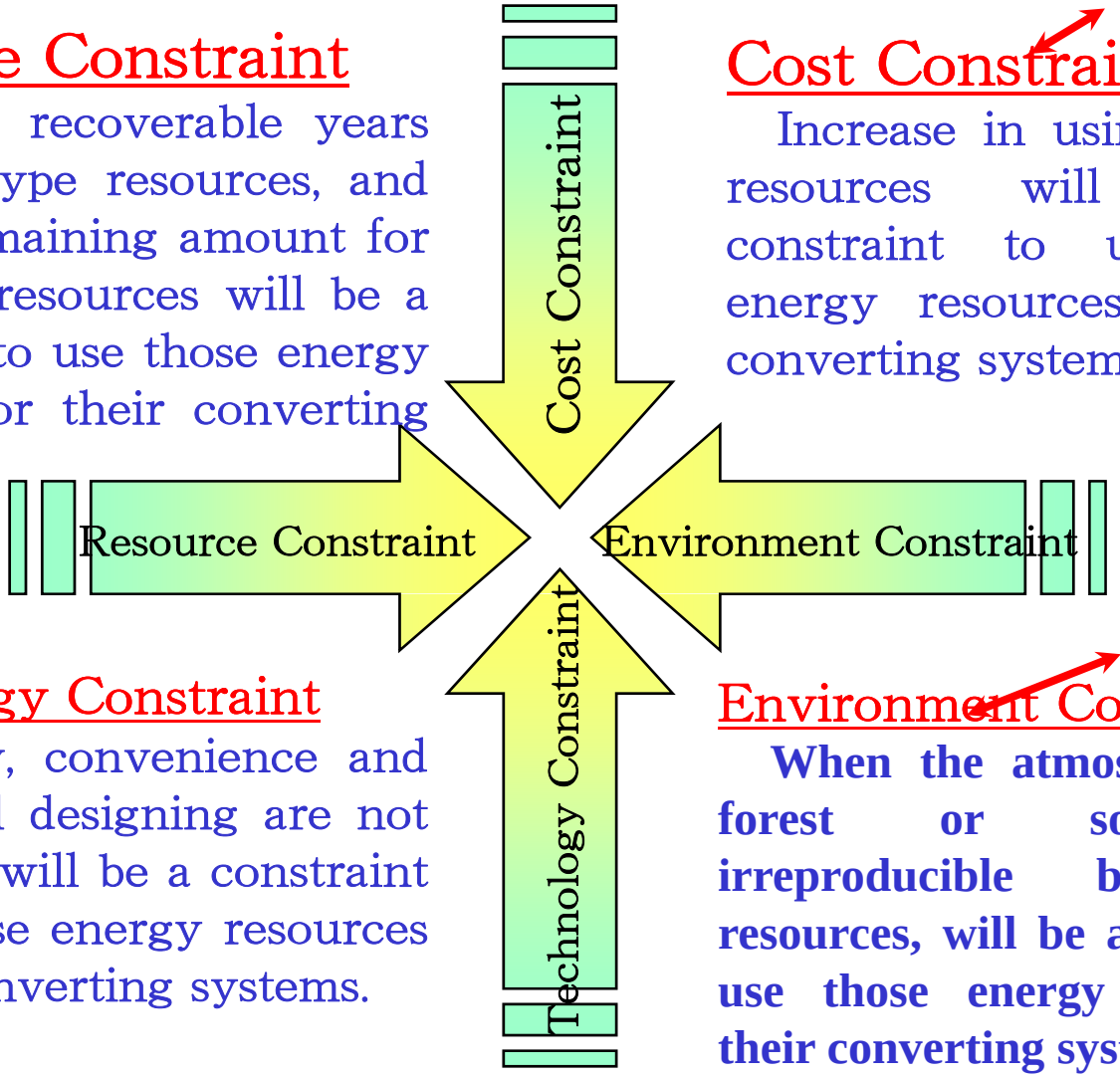
Figure removed due to copyright restrictions

[The New York Times, February 16, 2005]

Nishio Lab. IIS UT

Toward the Sustainable Society

Energy Strategy



Resource Constraint

Limit of recoverable years for stock-type resources, and limit of remaining amount for flow-type resources will be a constraint to use those energy resources or their converting systems.

Cost Constraint

Economic Efficiency

Increase in using cost of resources will be a constraint to use those energy resources or their converting systems.

Technology Constraint

If safety, convenience and such social designing are not enough, it will be a constraint to use those energy resources or their converting systems.

Environment Constraint

Load evenness

When the atmosphere, ocean, forest or soil become irreproducible by use of resources, will be a constraint to use those energy resources or their converting systems.

Nishio Lab. IIS UT

Toward the Sustainable Society

An Energy Strategy: Triple 50

Rise in Industrial Competitiveness

Back Cast from 2030

efficient use increases
３５％⇒５０％

Ultra high efficient energy converting, accumulating and using technology

Renewable Energy Using Technology

Efficient use increases
⇒Energy supply decreases
⇒dependence on fossil fuel decreases.

Strategic Policy

self-sufficiency rises
２０％⇒５０％

use of non-fossil fuel increases
１９％⇒５０％

dependence on fossil fuel lowers
⇒self-sufficiency rises

Upgrade of Energy Security

International Cooperation

Energy carrier utilizing technology
CO2 separation, resumption, isolation technologies

Nishio Lab. IIS UT

Energy and the Earth Environment

Political, economic aspect

energy security
international strategies for obtaining resources
international cooperation for preserving environment
(compliant economic efficiency and fairness of responsibilities)

national strategies for technology development

Starting Global Focus on Knowledge Lecture Series “Energy and the Earth”

Academia accepts the challenge of Solving These Issues

Global and General Structure of Academic Disciplines

Scientific aspect

evolutionary formation of the Earth environme
global cycle of energy substances
observation, prediction of
the global environment changes
energy science

Technological aspect

utilization of flow-type energy
energy high-efficient use
clean use of fossil fuel

the next generation vehicle

Nishio Lab. IIS UT

Energy and the Earth Environment

Political, economic aspect

⑤Prof. Toru Iwami
"Energy and Environment Issues : From a Viewpoint of Economics"

in relation to economical development
in relation to the world economics
as global environment issues

④Prof. Hideaki Shiroyama
Governance of Energy and Environment Issues

science, technology and decision making
social induction processes of energy related technologies
international political processes
among energy security and global warming

Global Focus on Knowledge Lecture Series "Energy and the Earth"

Scientific aspect

③Prof. Akimasa Sumi
The Climate System as a Basis for Energy and Environment Issues

the Earth as a water planet
Can we predict the future?
What are environment problems?

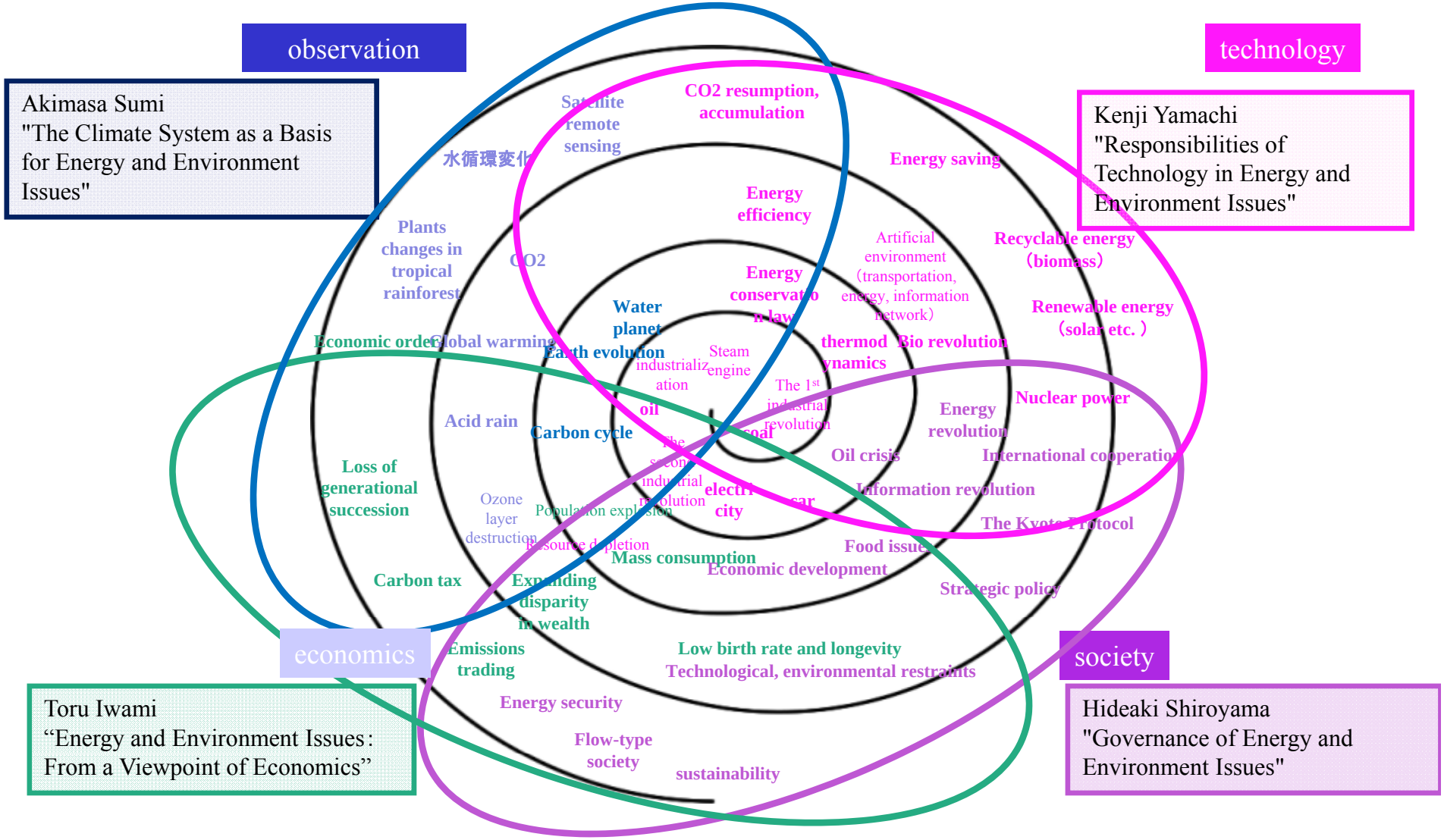
Technological aspect

②Prof. Kenji Yamachi
Responsibilities of Technology in Energy and Environment Issues

viewpoint of energy
energy resources and technologies
long-term technology scenario
for global warming

Nishio Lab. IIS UT

Energy and the Earth Environment



Akimasa Sumi
"The Climate System as a Basis for Energy and Environment Issues"

Kenji Yamachi
"Responsibilities of Technology in Energy and Environment Issues"

Toru Iwami
“Energy and Environment Issues: From a Viewpoint of Economics”

Hideaki Shiroyama
"Governance of Energy and Environment Issues"