Imperial College London

東京大学 THE UNIVERSITY OF TOKYO

Energy and Green House Gas Mitigation Technologies

Japan Society for the Promotion of Science-Imperial College London-University of Tokyo Symposium on Climate Change

Thursday 28th and Friday 29th September 2006

energy futures lab

Imperial College London, South Kensington Campus, London SW7 2AZ

JAPAN SOCIETY FOR THE PROMOTION OF SCIENCE • FOUNDED 1932 •

Long Term Strategies for Mitigating Climate Change: Barriers and Responses

Yoichi Kaya
Director General
Research Institute of Innovative Technology for the Earth (RITE) ,Japan

Contents

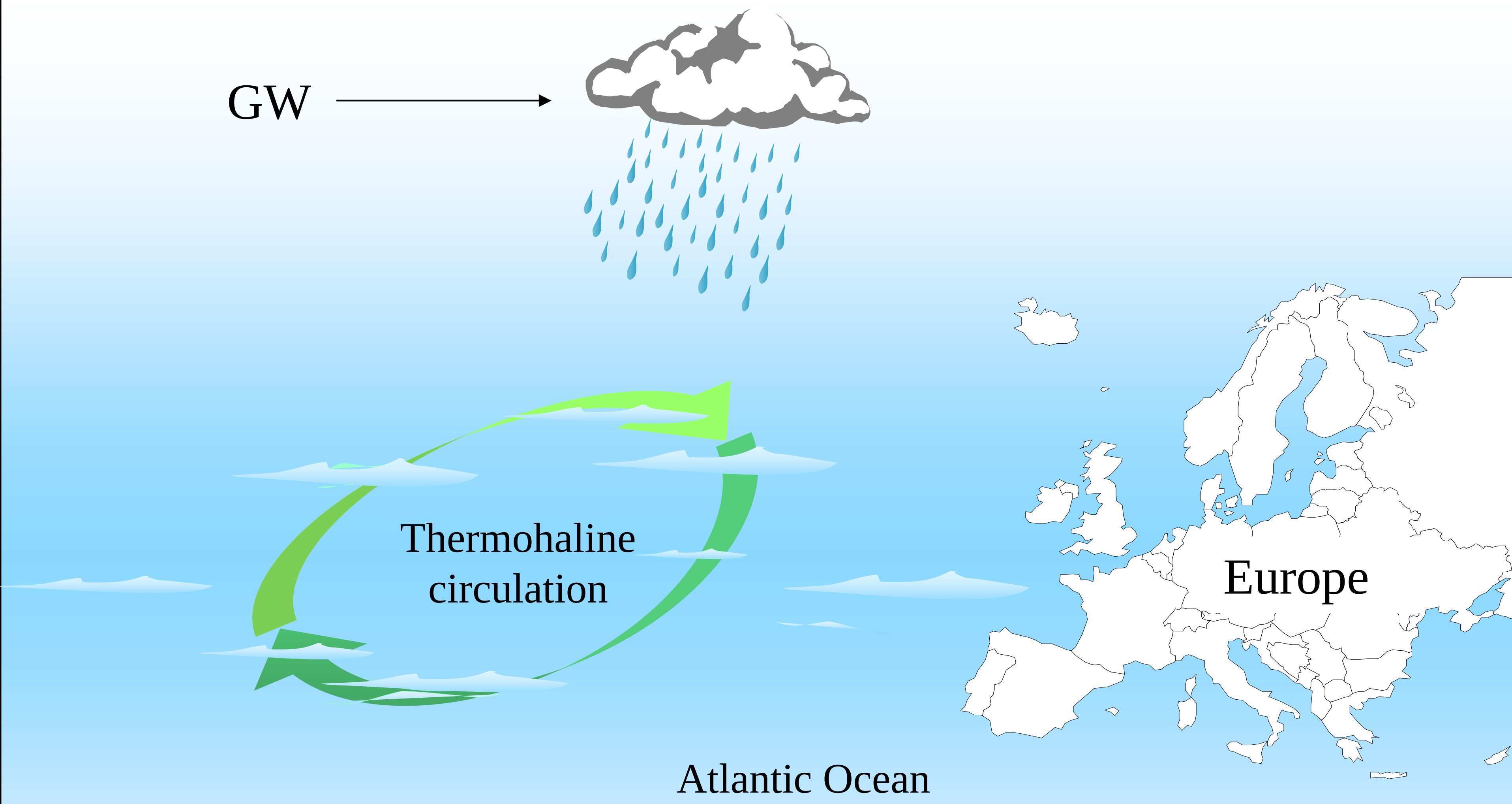


Fig. Thermohaline circulation and European Climate

Source:Bryden,H.L. et al, Nature, Dec.2005

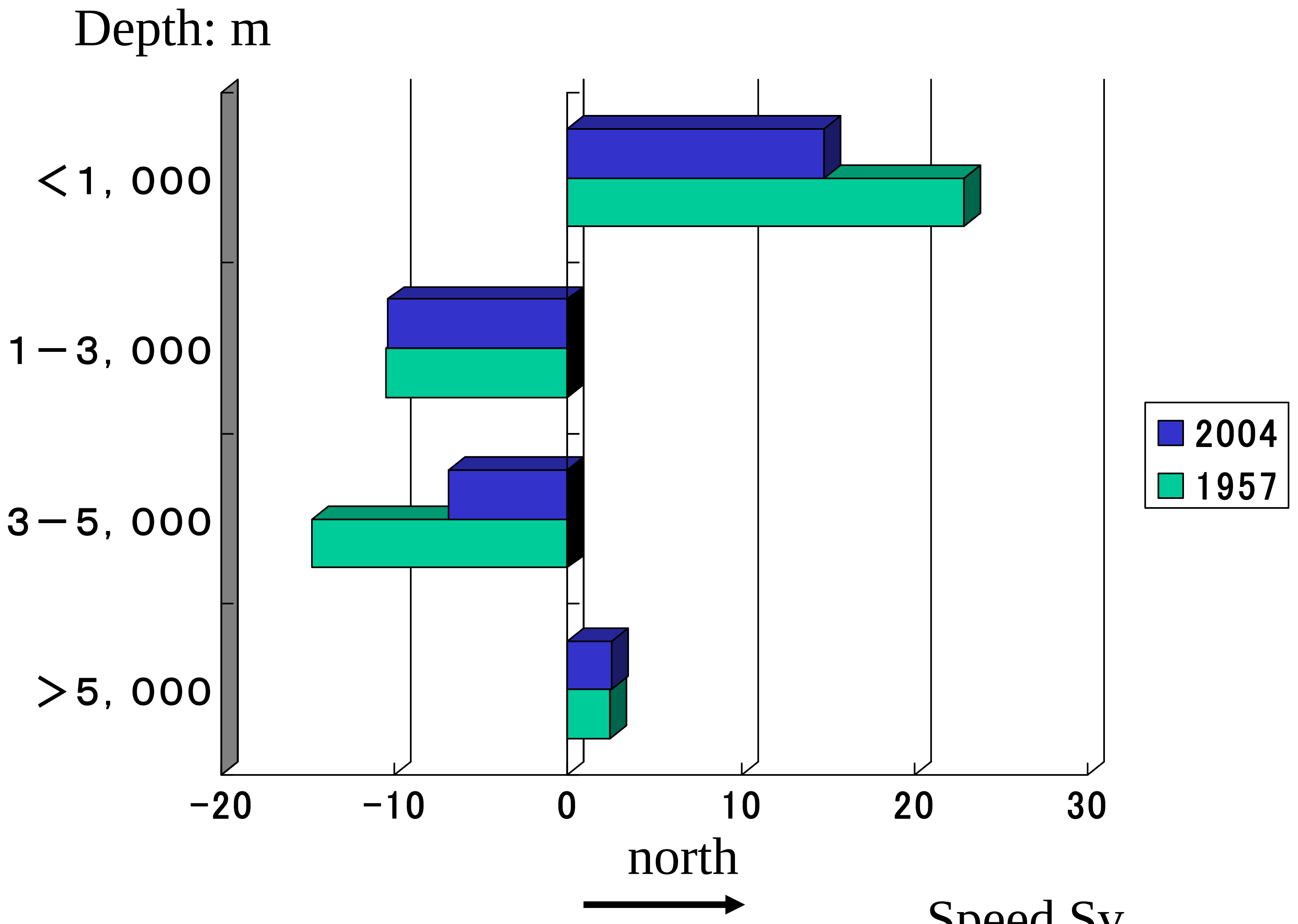


Fig. Slow down of thermohaline circulation in the Atlantic

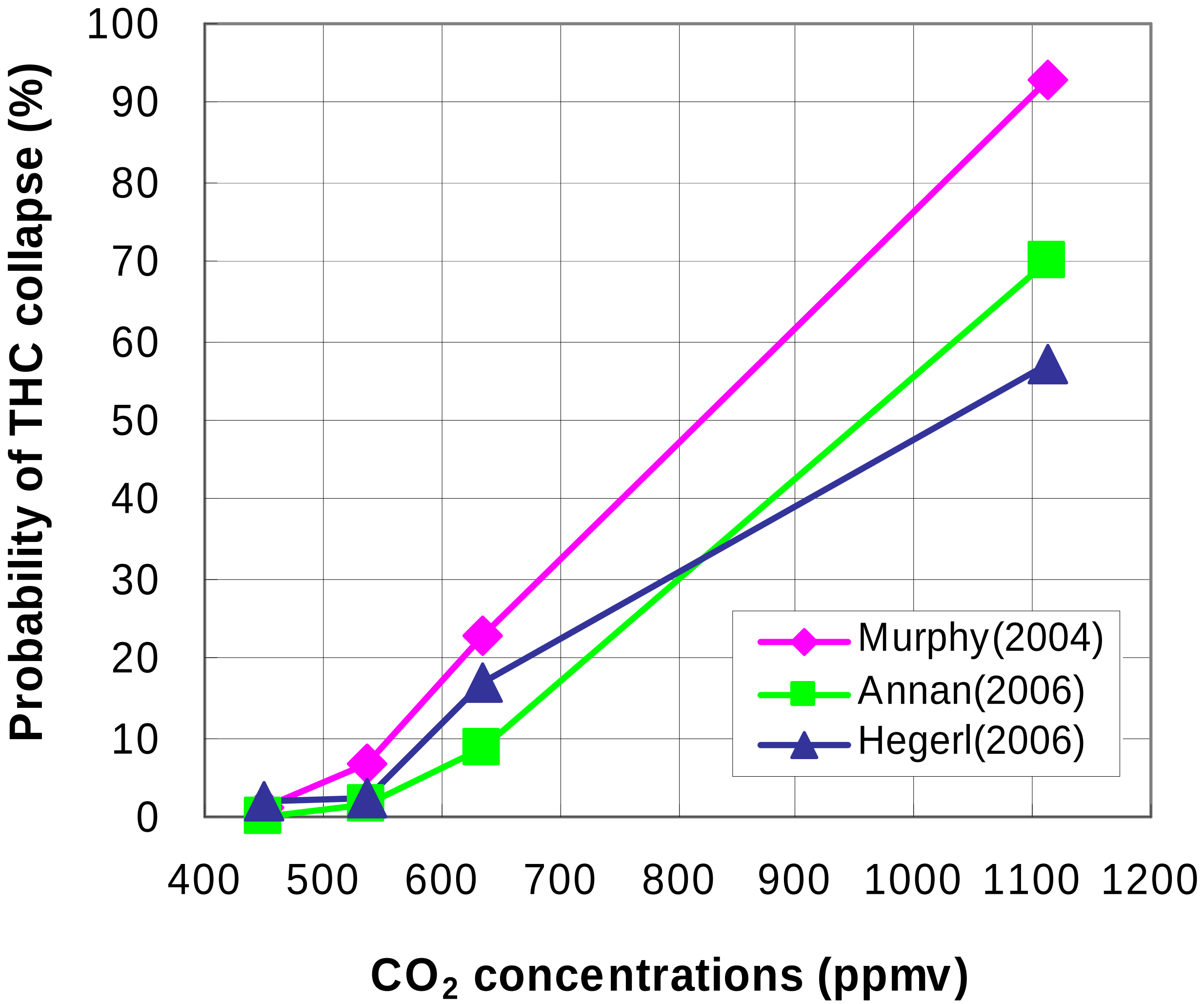


Fig. Possibility of the Collapse of Thermohaline Circulation (THC)

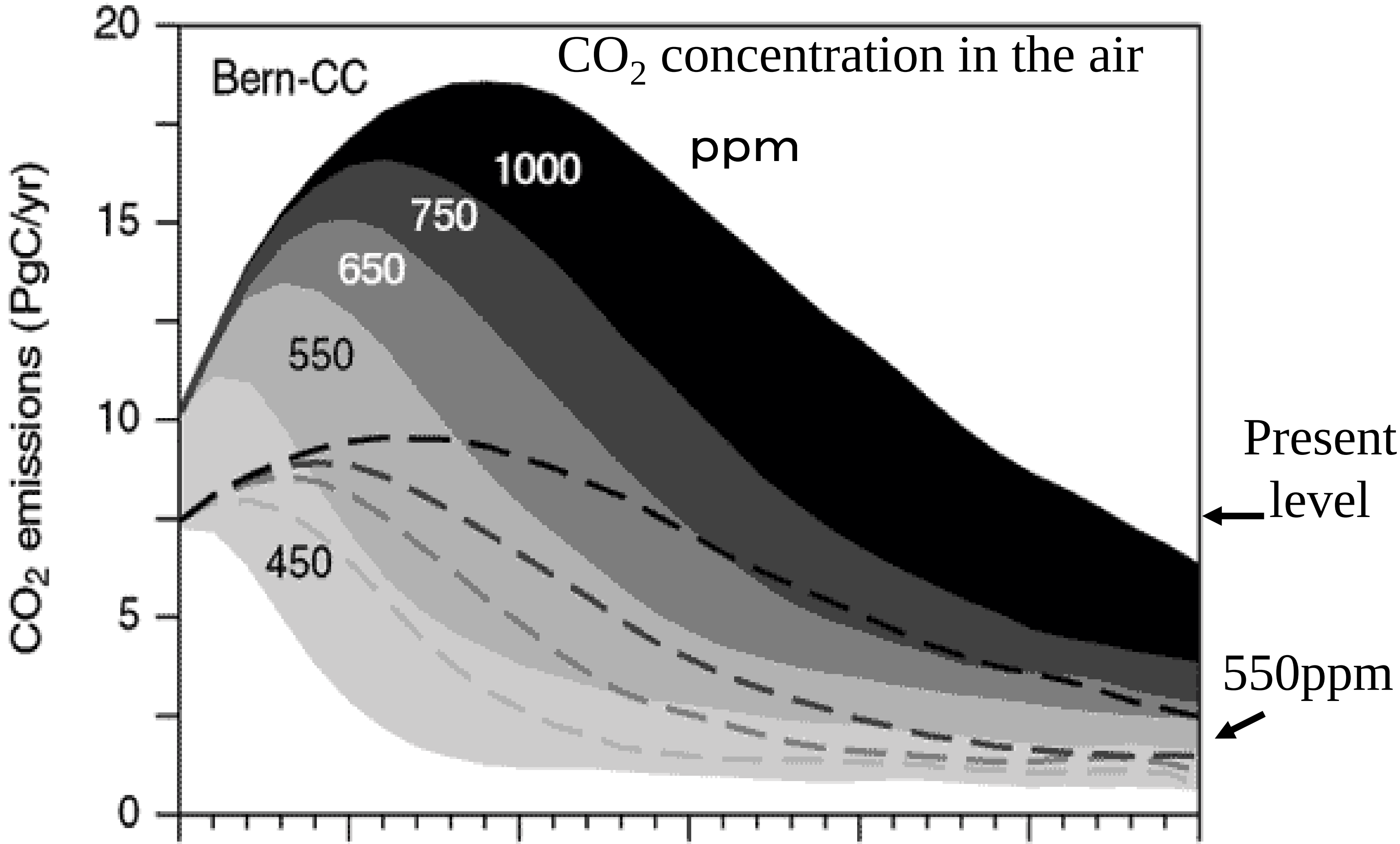


Fig. CO_2 emission for stabilizing its concentration in the air
Source: IPCC TAR technical summary

Decarbonization of primary energy

1. Nuclear power △
2. Renewables (‘new’)
 1) photovoltaics / wind power ○
 2) active / passive solar energy for houses ○
 3) biomass
 4) geoheat and other ambient energy ○
 5) space solar power ○
3. Fossil fuels with CCS ○

Table:Impacts of nuclear moratorium on carbon intensity of energy - %, average rates of change, 1980 - 2000

	Energy Intensity + $\Delta E/G$	Carbon intensity + $\Delta C/E$	Economic growth = ΔGDP	CO2 emission $\Delta CO2$
OECD total	- 1.4	- 0.6	+ 2.7	+ 0.7
moratorium case		↓ 0.0		↓ + 1.3
Japan	- 1.0	- 0.5	+ 2.7	+ 1.2
moratorium case		↓ +0.3		↓ + 2.0

Note: $\Delta E/G + \Delta C/E + \Delta G = \Delta C$, Δ is the rate of change

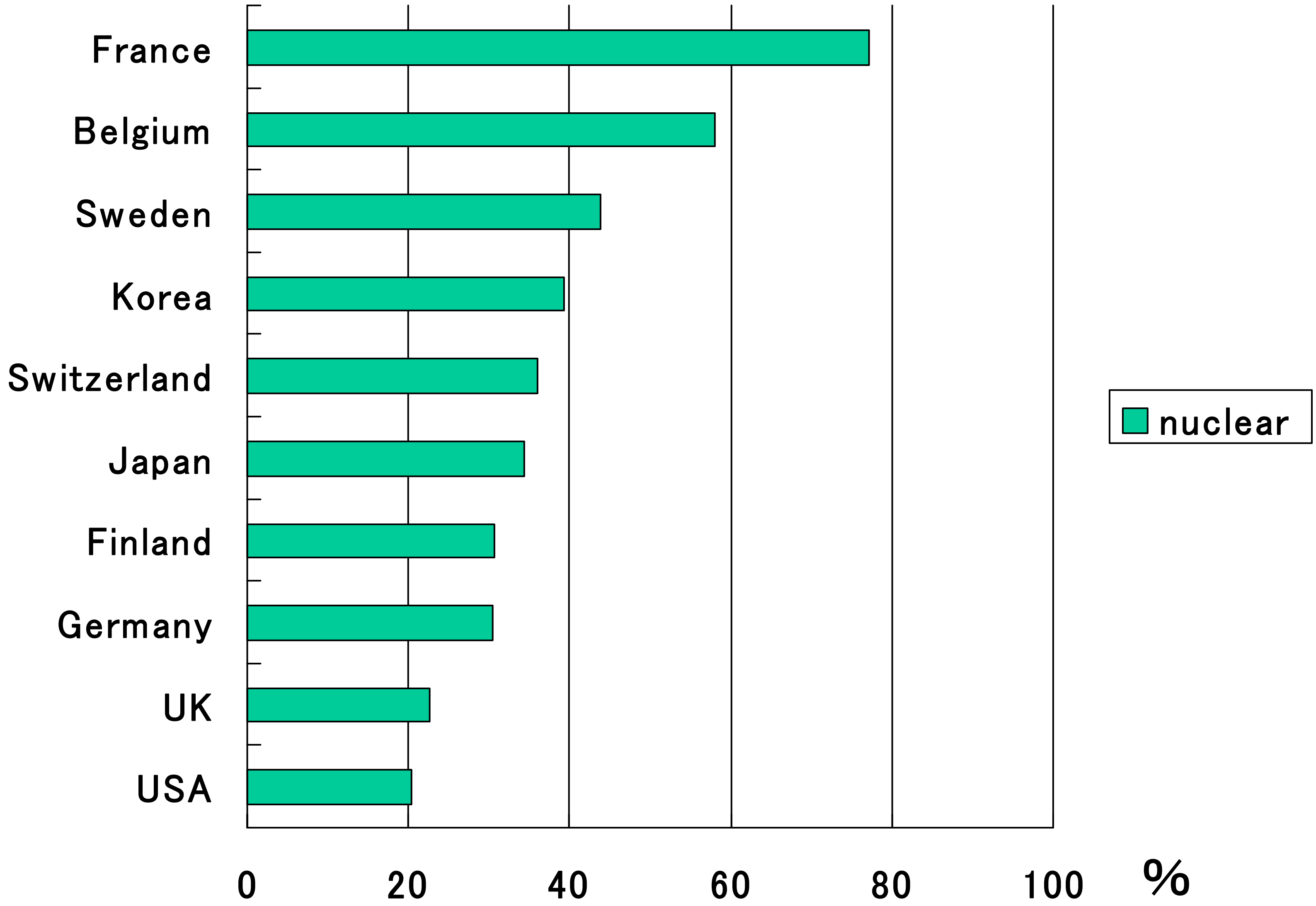


Fig. Share of nuclear in power supply (kwh、2001)

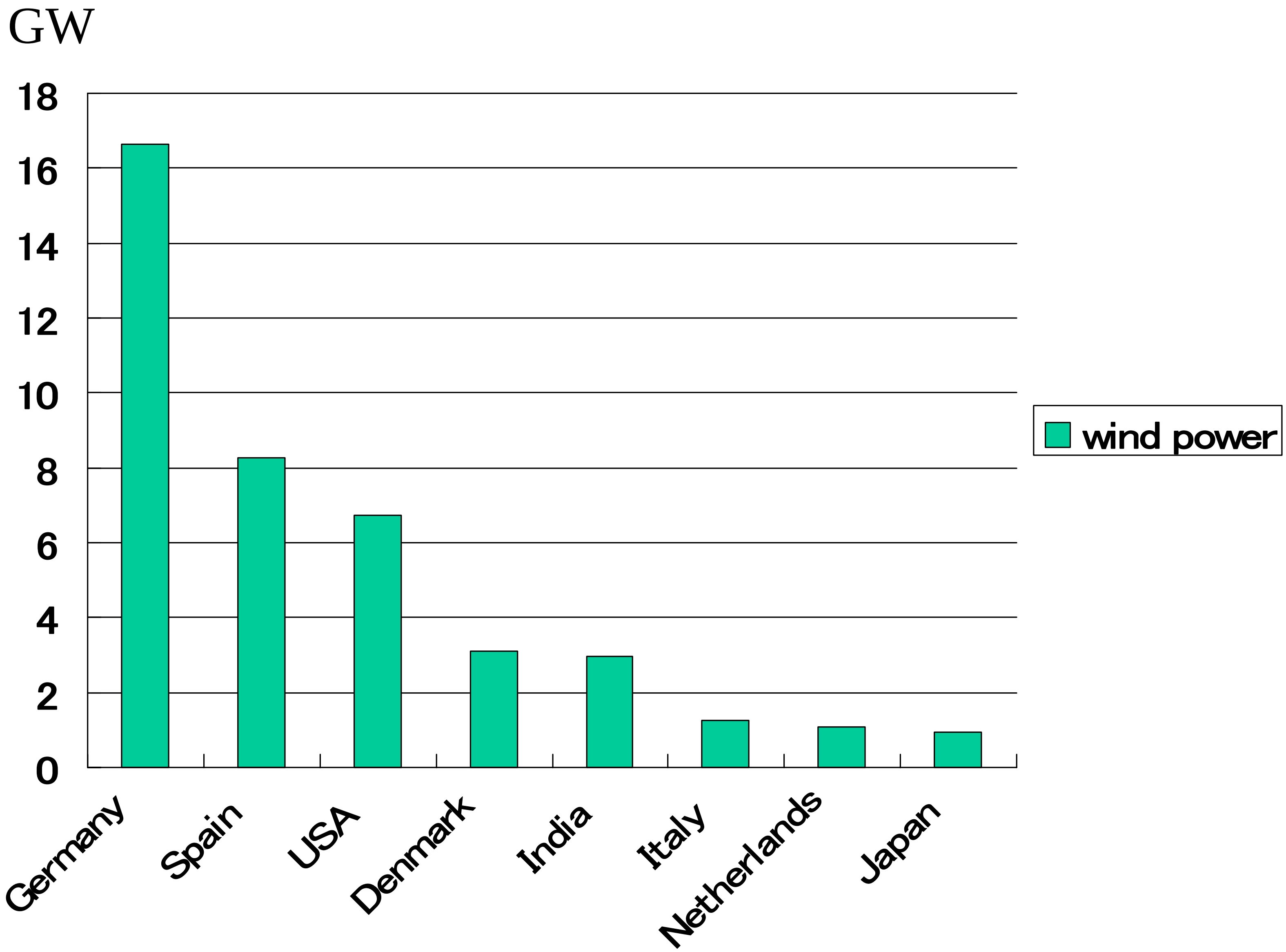


Fig. Capacity of wind power（2004）

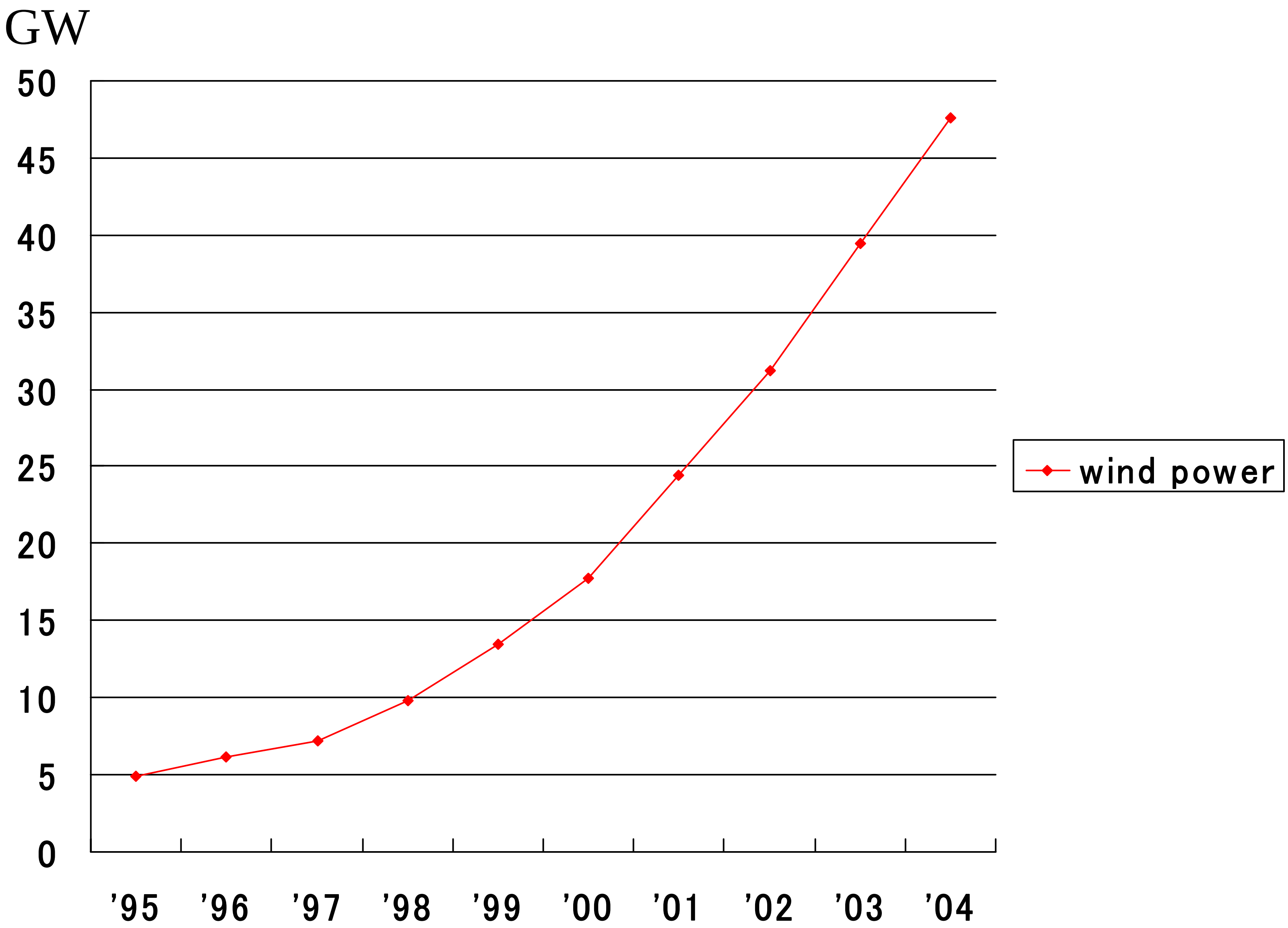


Fig. Total capacity of wind power (World)

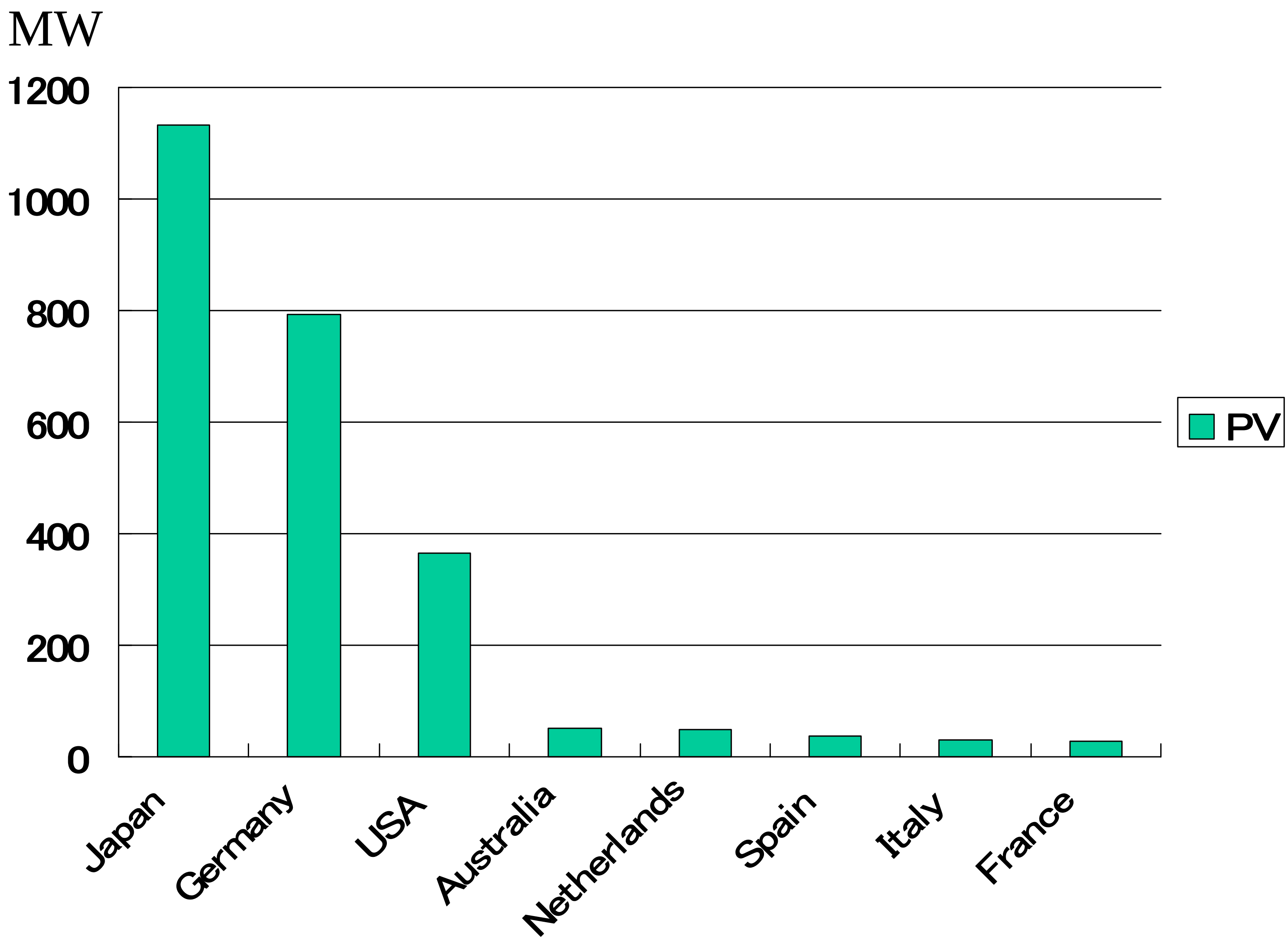


Fig. Capacity of Photovoltaics（2004）

	Capacity (2004)	Future target (% of elec.power)
Germany	16.6 GW	25% (2025)
Spain	8.3 GW	---------
USA	6.8 GW	6 % (2020)
Denmark	3.1 GW	20% (2030)
Japan	0.9 GW	3.4 % (2030)

Table. Present and future target of wind power

Present and future of photovoltaics of Japan

1. Present 1.13 GW (2005)
2. Future government plan

   4.8 GW (2010)

   82.8 GW (2025)

Note: its capacity utilization ratio is around 12% while the average capacity utilization ratio of the grid power plants is about 55%.

Fig. time variability of outputs of wind power(Germany)

1 plant

1,500 plants

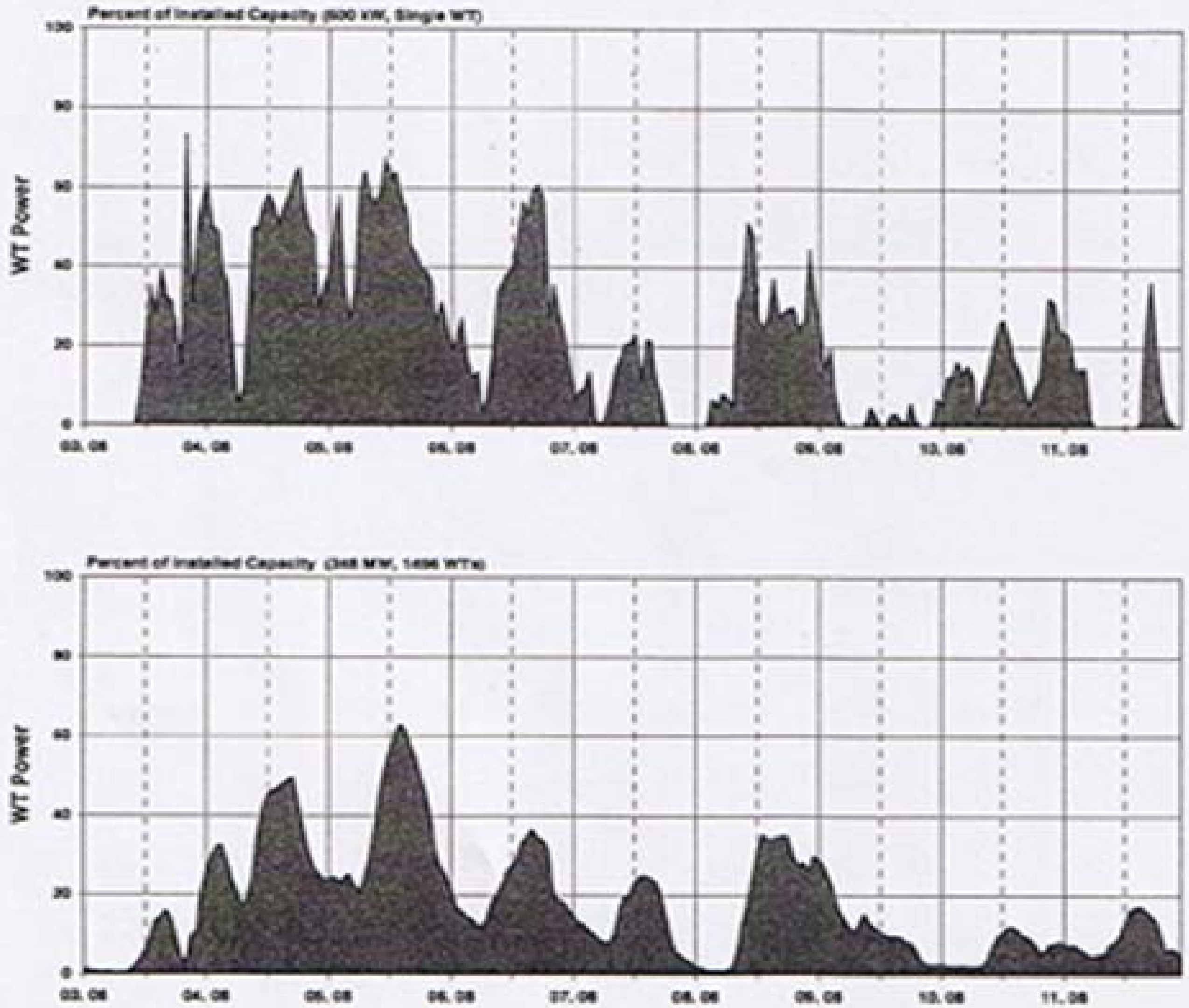
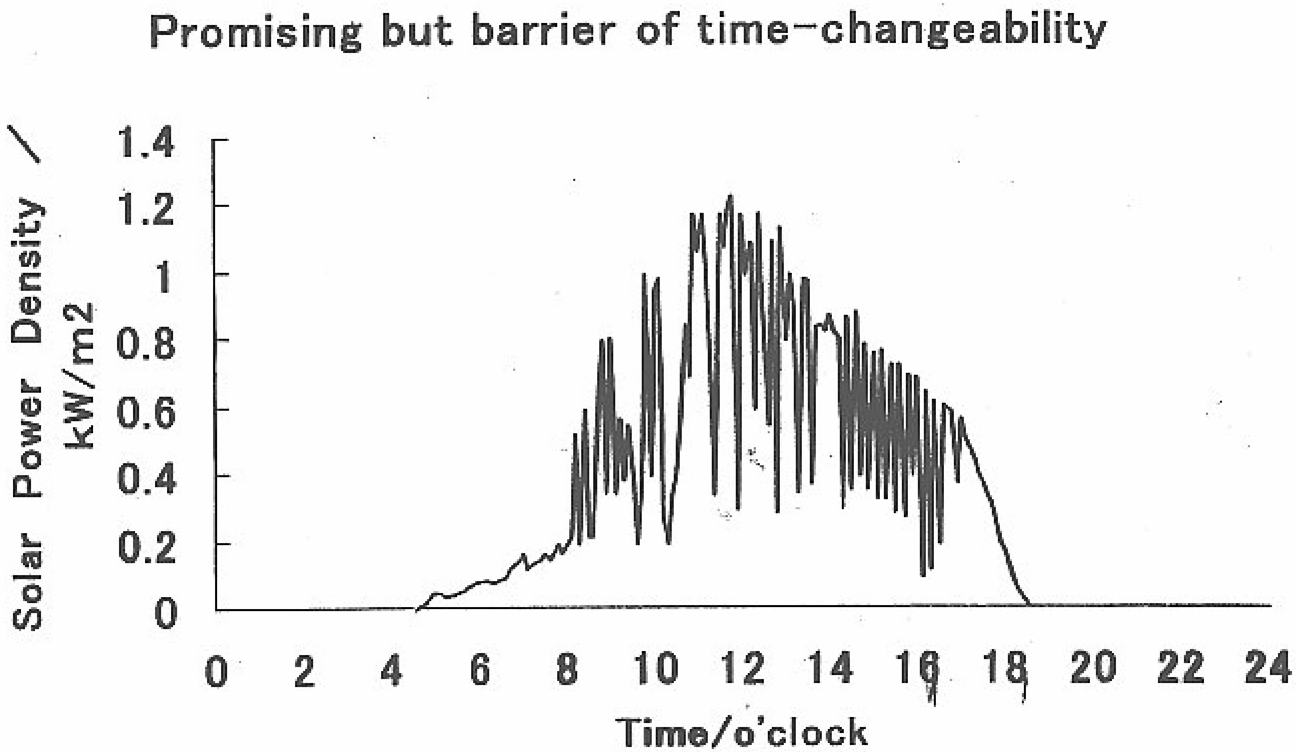


Fig. 9: Comparison of WT Individual and Cumulative Power [3]

Fig. Time changeability of photovoltaics



Output variability of wind power / photovoltaics

1. Outputs of wind power and photovoltaics (WP/PV) change randomly with time.
2. Some of grid power plants are used for satisfying the relation

   total supply = total demand

3. Then

   the facility cost of these grid power plants

   ↓

external cost of WP/PV due to output variability

External cost of WP / PV
- Japanese case -

1. Corresponding power plants :
   oil fired power plants
2. Their capacity utilization ratio: low
   20 -30 %
3. Costs
   10 -14 Yen per kwh (8 – 11 US cents)

Limits of WP / PV due to output changeability

1. Their output changeability innevitably requires installation of those power plants which adjust their outputs so as to satisfy the condition

   total supply = total demand

2. Facility costs of these power plants are additional costs of the grid solely due to introduction of WP/PV.

   → **capacity of WP/PV << grid capacity**

Two candidates for future renewable energy supply

1. Use of ambient energy resources for low temperature heat supply (residential)

2. Space solar power system (SSPS) for large scale stable power supply

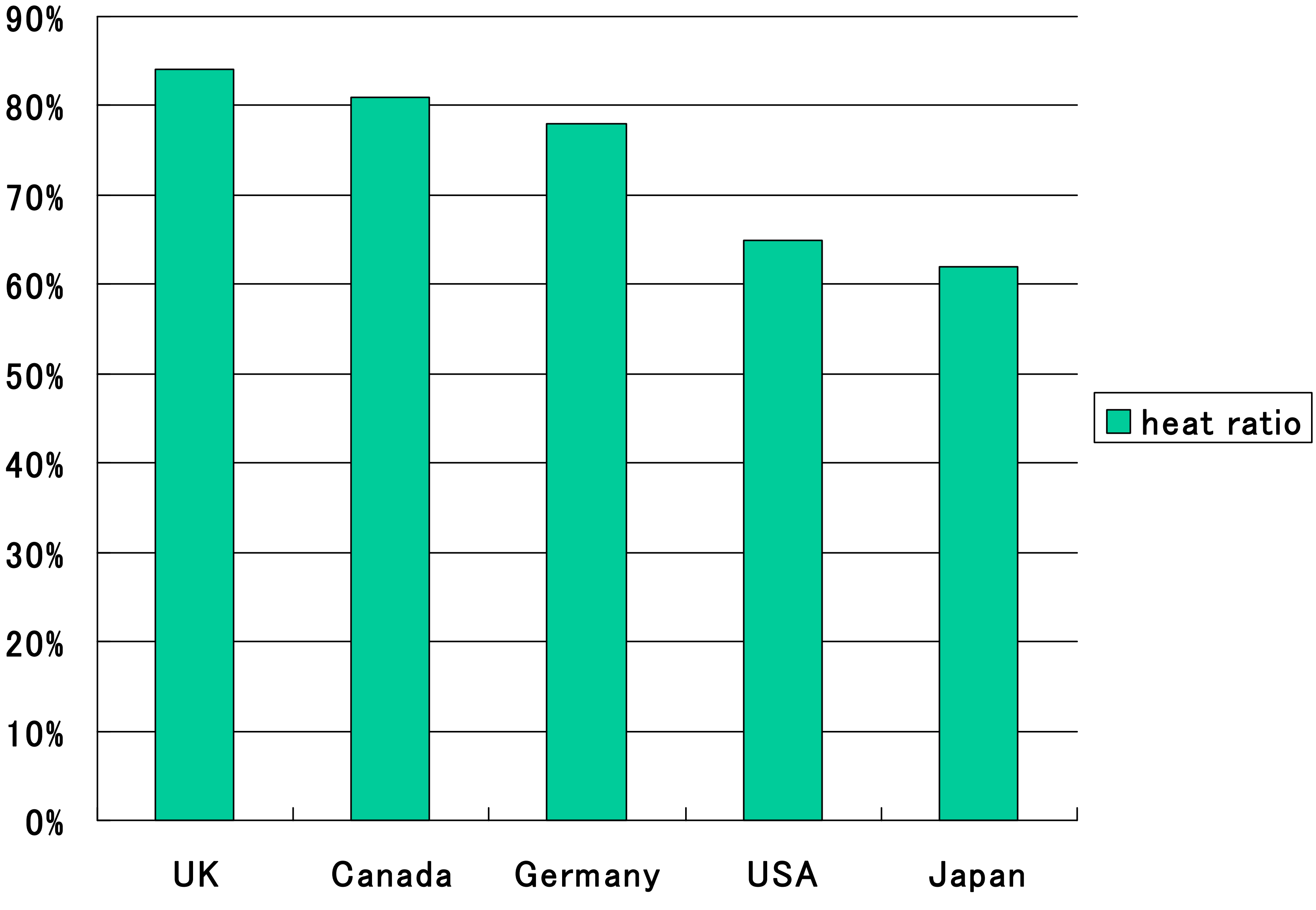


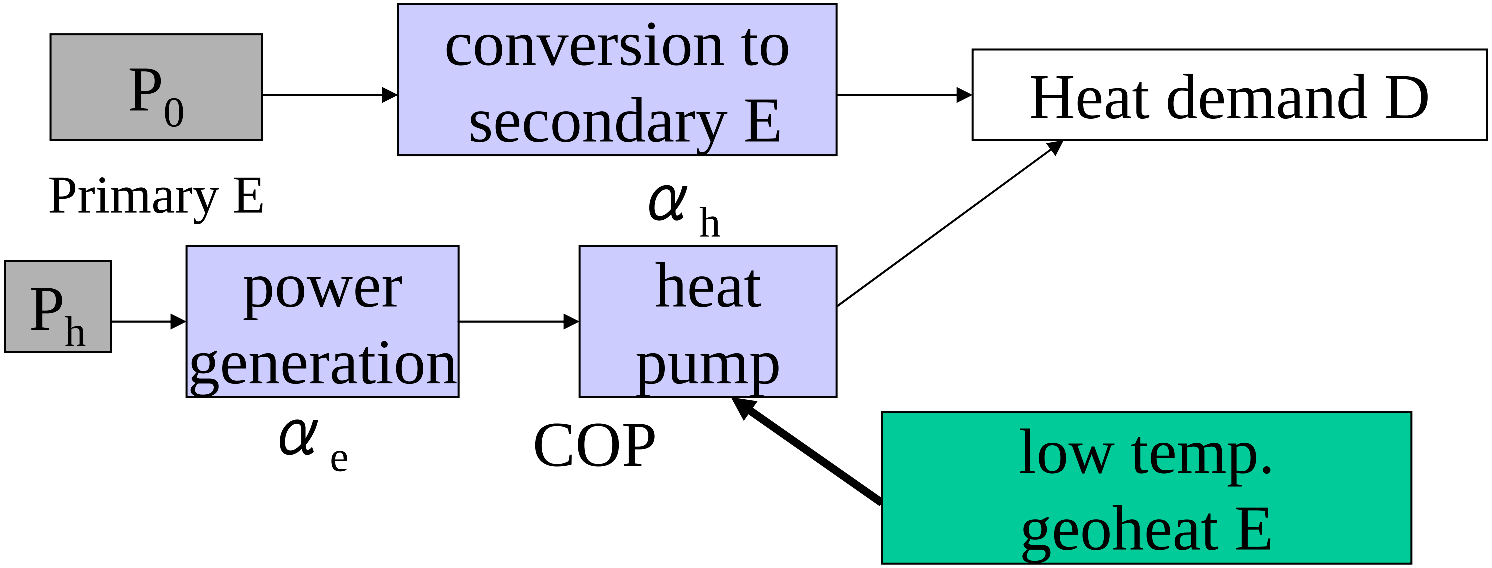
Fig. Share of heat in residential energy demand

How to satisfy residential heat demand

1. Passive use of solar power
   ex. Passive house in Germany
2. Active use of solar power
   introduction of solar heater,etc.
3. Utilization of ambient energy resources
   as low temp. heat source of heat pump
   ex. rivers, ponds, ocean, etc.
   → utilization of geoheat

Fig. Passive House (Wiesbaden, Germany):
No heating devices installed

Utilization of low temp. geoheat in residential sector

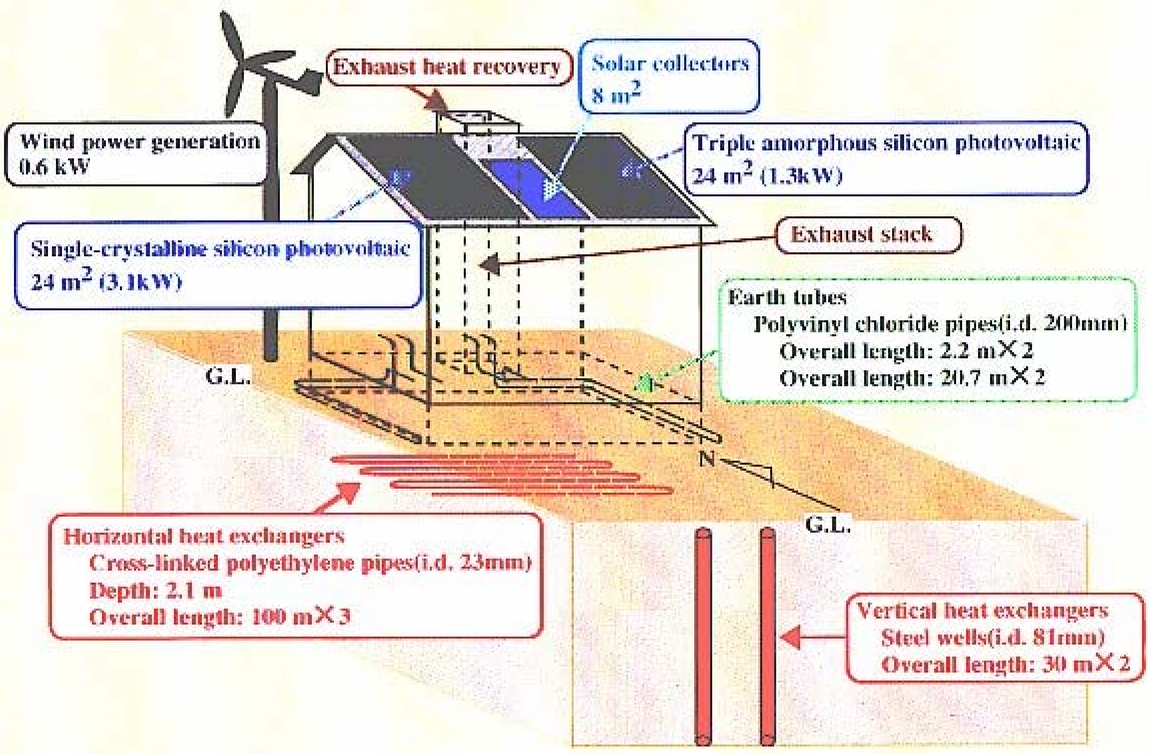


$$D = \alpha \cdot COP \cdot P \qquad (1)$$

Energy gain from geoheat F

$$F = P_O - P_h = (1/\alpha_h - 1/\alpha e \cdot COP) \qquad (2)$$

Low energy house in Hokkaido



Equipment design for "Low Energy House"

	地中熱利用家屋数
米国	500, 000
ドイツ	50, 000
スイス	42. 000
フランス	9. 000
日本	200

表：主要国における地中熱の利用家屋数

Potential of low temp. geothermal E
- share in residential E, Japan -

1. COP of heat pump
   geothermal: 10 degrees in Celsium (Sapporo, 10m deep)

supply temp.	Theoretical	real
30 deg. (room?)	15	8 ?
50 deg. (water?)	8	6 ?

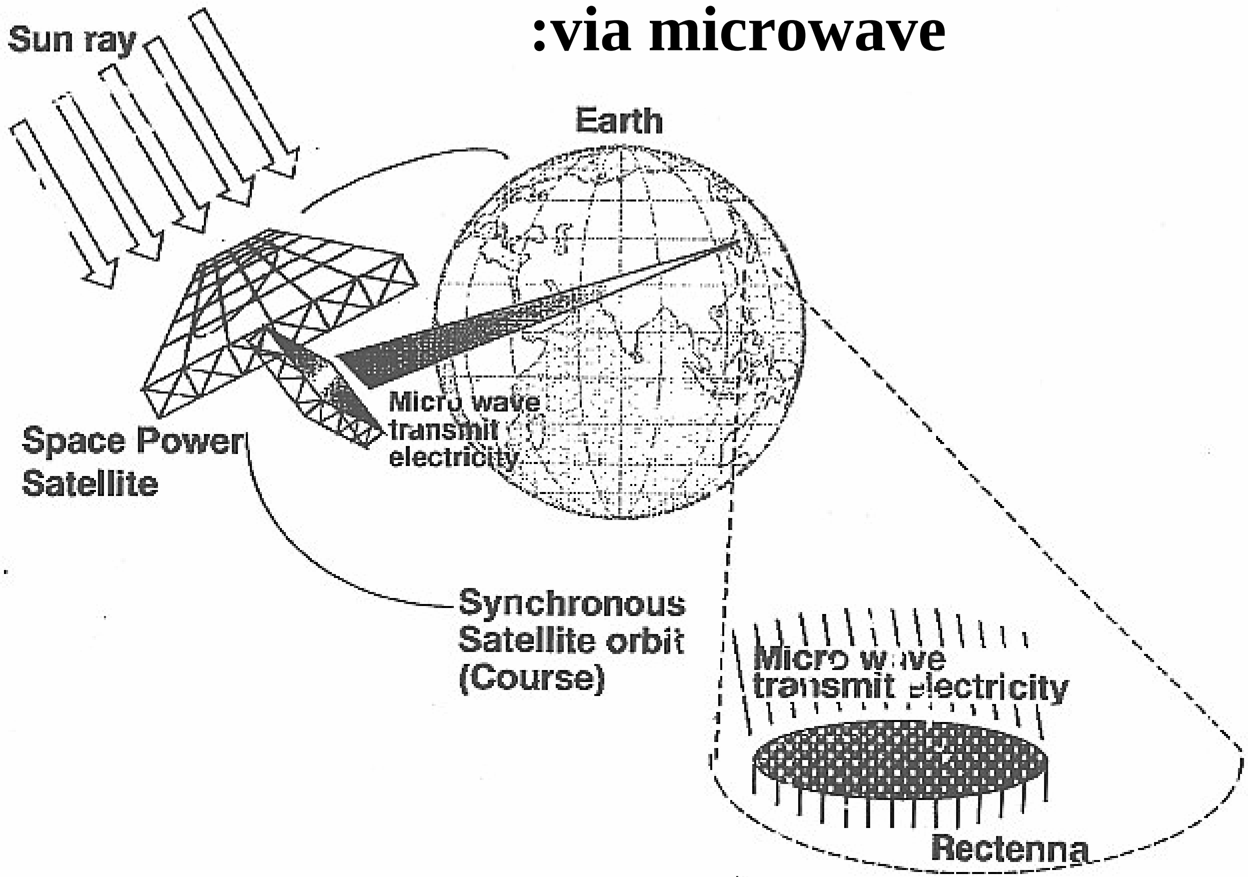
2. Availability of low temp. geothermal (potential)

Share in primary energy in Japan

	residential	commercial	total
COP=5	3.7 %	2.5 %	**6.2 %**
COP=10(heating)	4.3	3.0	**7.3**

Space Power Generation System

:via microwave



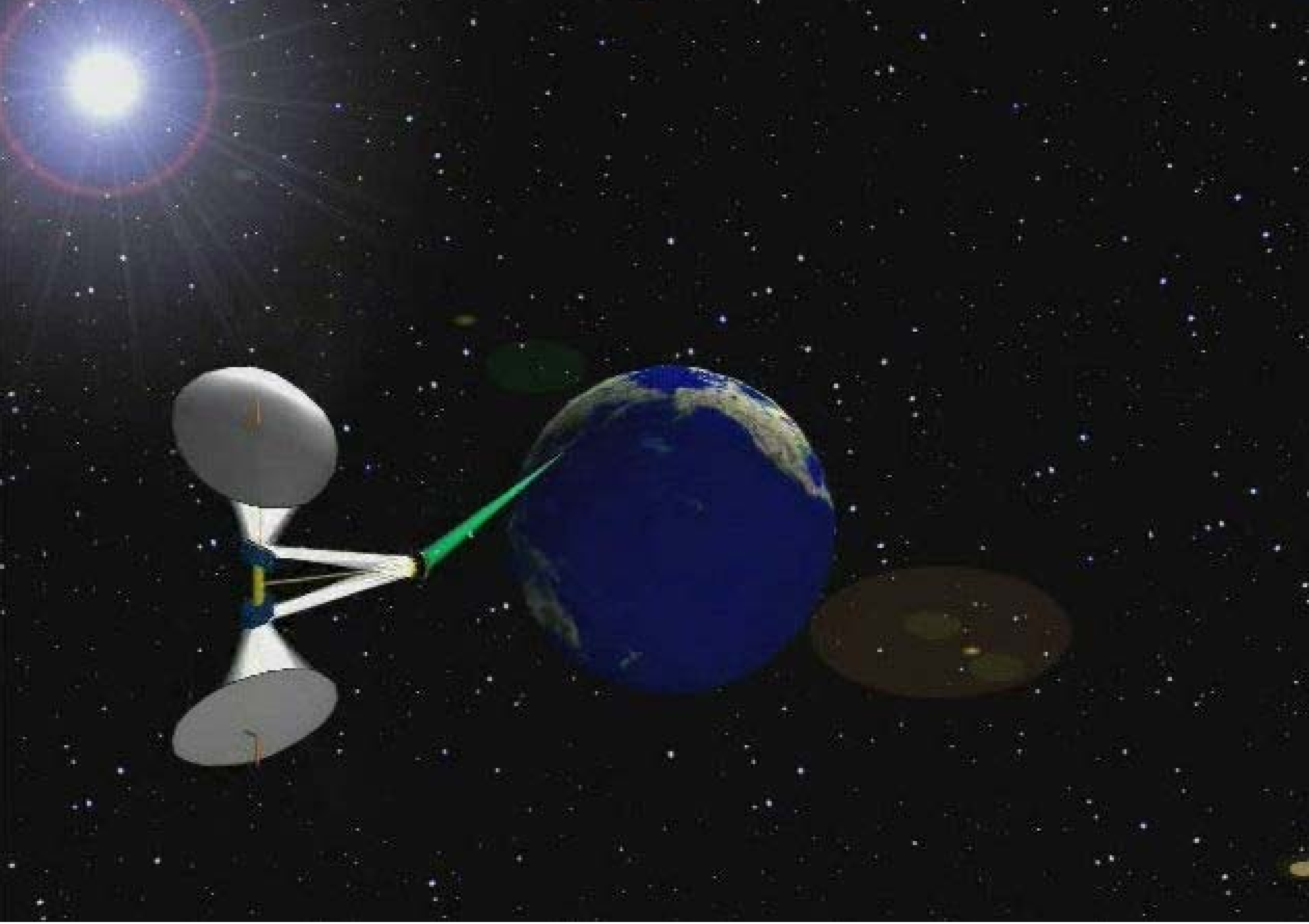


Fig. Space Solar Power System (Laser based) :source JAXA

Merits and demerits of SSPS

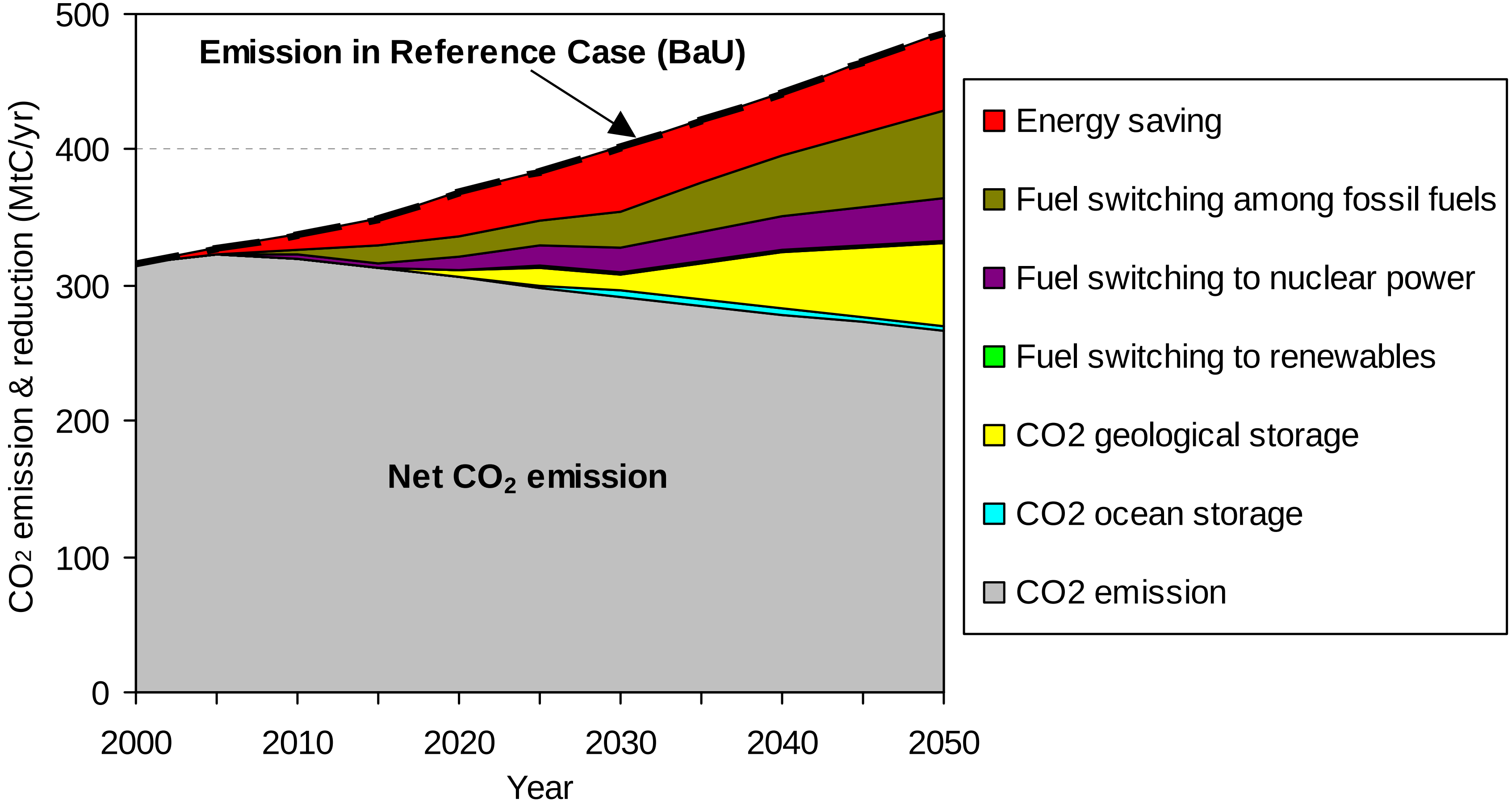
<u>Merits</u>

1. Stable power supply (little output changeability)
2. Large scale power generation being possible

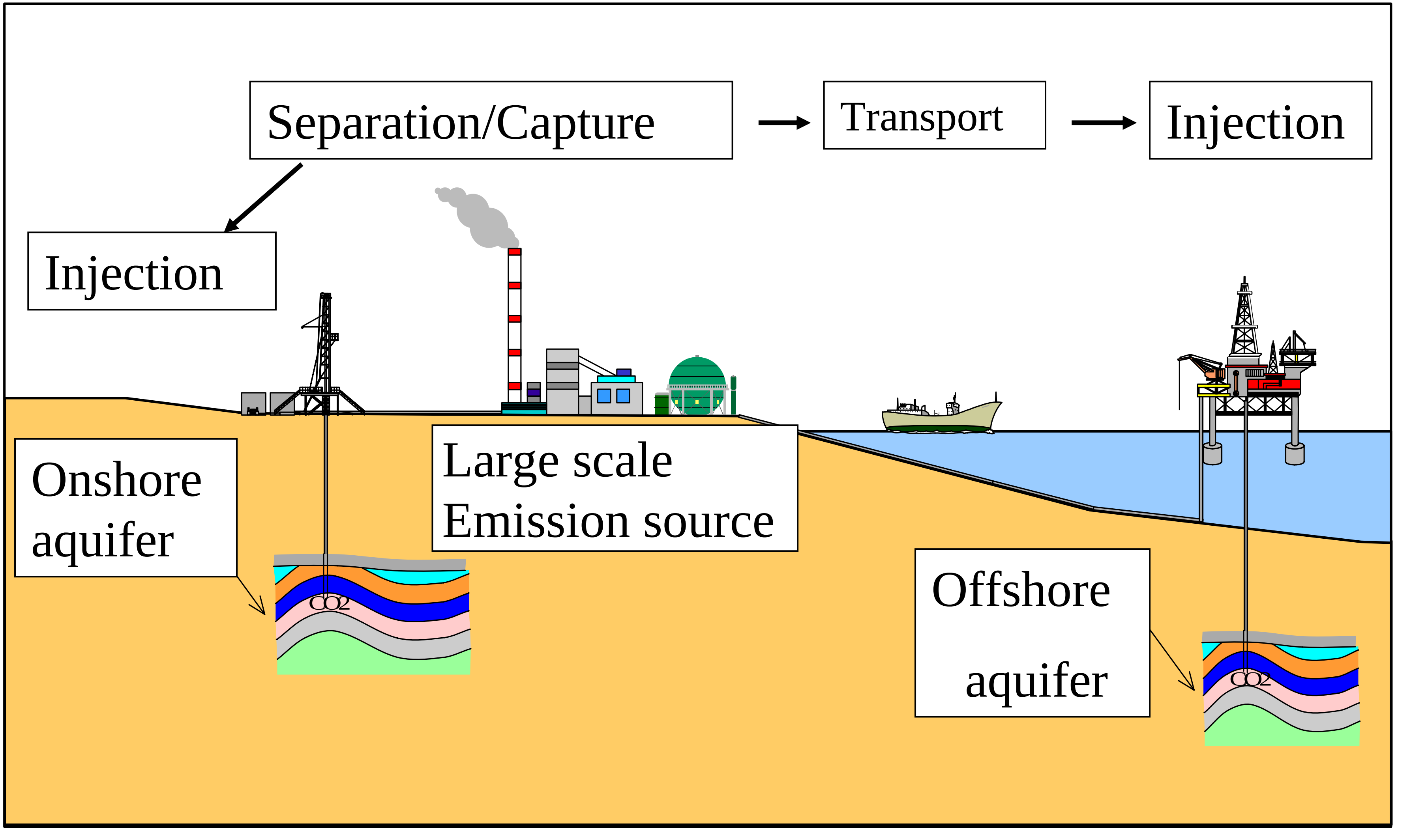
<u>Demerits</u>

1. High costs (transportation of materials, etc.)
2. Related construction technologies being premature

Future CO2 Reduction Scenario of Japan
- target: halving CO2/GDP in 2050 -



CO2 Capture and Storage (CCS)



Basic Character of Carbon Capture and Storage (CCS)

1. Process

   Recover CO_2 from flue gas of large scale CO_2 emitters such as power plants

   Store CO_2 recovered into aquifer or other underground storage sites

2. Basic character

   technology bridging between fossil fuel age and post fossil fuel age

   complementary to mitigation technology

Character of CCS

1. CCS is an end of pipe technology which disposes pollutants after their emission. **Use of non carbon fuels** which do not emit CO_2 is **preferable** if it is available.
2. CCS is not new but **comprised of known technologies, therefore easily put into practice**.

   CO_2 capture: separation of CO_2 from natural gas

   CO_2 storage: CO_2 for enhanced oil recovery (EOR)
3. CCS has a considerably **large potential** in reduction of CO_2 emission.
4. Fossil fuels now occupy about 87% of the world primary energy.

   We **need time for transition from present to decarbonized society**.

→ **CCS is a technology bridging the present and the future decarbonized society**

Concluding remarks

1. **Decarbonization** of primary energy is a "must" in the long run.
2. **Wind power and photovoltaics** which outputs are changeable with time have high external costs when connected to the grid. Therefore **their capacity should be limited, compared with the demand size of the grid**.
3. Utilization of various types of **ambient energy sources including geoheat** should be promoted.
4. **Space solar power system** should be developed as a solution in the long term.
5. Carbon capture and storage (**CCS**) should be promoted but with the recognition of its character as "bridging technology".