# 2. Management of Primary Energy Sources

## 2.1 Promotion of international Coordination in the Development of Energy Resources

**【Points】**

- Although sufficient amounts of fossil fuel reserves are ensured on a global basis at least for the present, reserve locations are distributed unevenly. Anxiety about future supply is increasing among countries without such the resources (Table 2.1-1 and Figure 2.1-1). Proponents of the peak oil theory predict the future depletion of fossil fuel resources (Figure 1.4-3).
- Some of the non-conventional fuels have almost reached the stage of commercial production. Canadian oil sand has been included in recoverable reserves (Figure 2.1-2). Venezuelan extra heavy oil is also a promising non-conventional fuel. However, IEA predicts that non-conventional fuels would account for not more than 7% of total oil supply in 2030, failing to contribute to the stabilization of the energy supply-demand balance over a medium term.
- In consideration of these circumstances, the main priority of energy policy in major countries is placed on securing stable supplies of primary energy through the extended cooperation with oil-producing countries. Unfortunately, the cooperation tends to be aimed at pursuing their own interests rather than establishing the global stabilization of energy demand and supply balances.

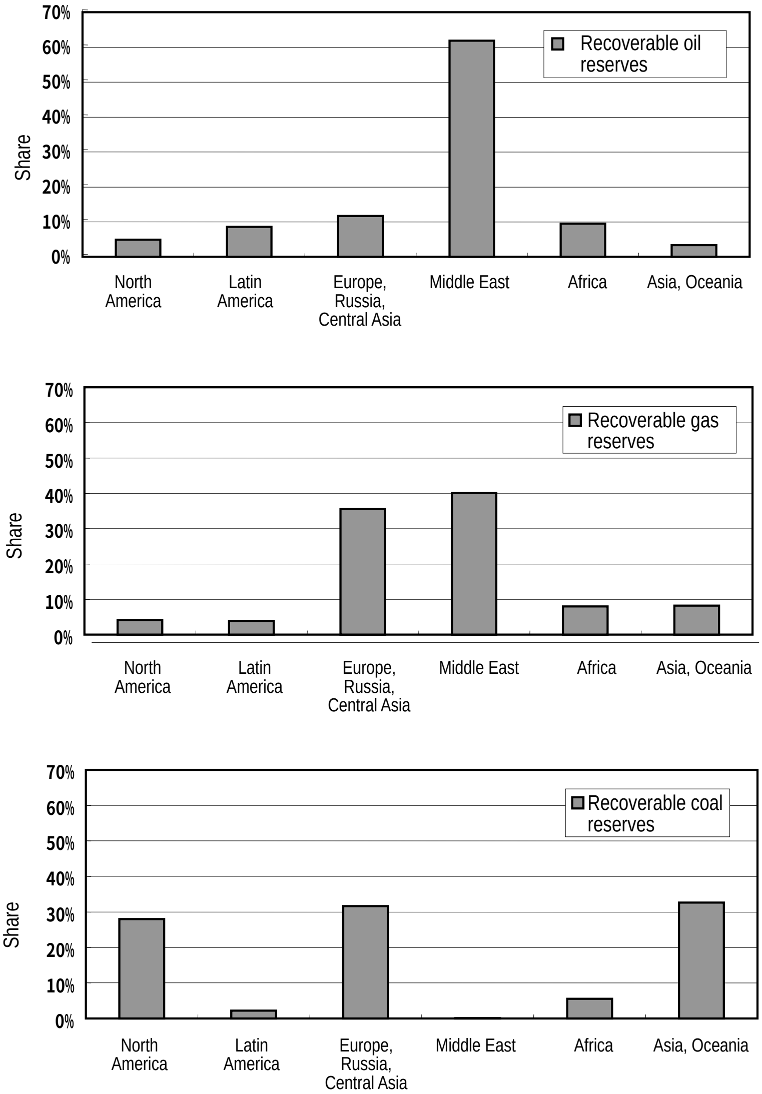
  [Case] China's involvement in Africa (Figure 2.1-3)
  Development of LNG terminals by European countries (Figure 2.1-4)
  Japan's energy policy (Table 2.1-2)
- To maintain the long-term global stability of the energy supply and demand, international coordination is encouraged in the development of energy resources and trading, instead of pursing their respective interest alone.

*［Related Data and Facts］*

***Table 2.1-1 Recoverable reserves of fossil fuels and reserve-production ratio (as of December 2005)***

| | Recoverable reserves | Reserve-production ratio |
|---|---|---|
| Petroleum | 1,200.7 billion barrels | 40.6 years |
| Gas | 179, 83 trillion $m^3$ | 65.1 years |
| Coal | 90,90.64 billion tons | 155 years |

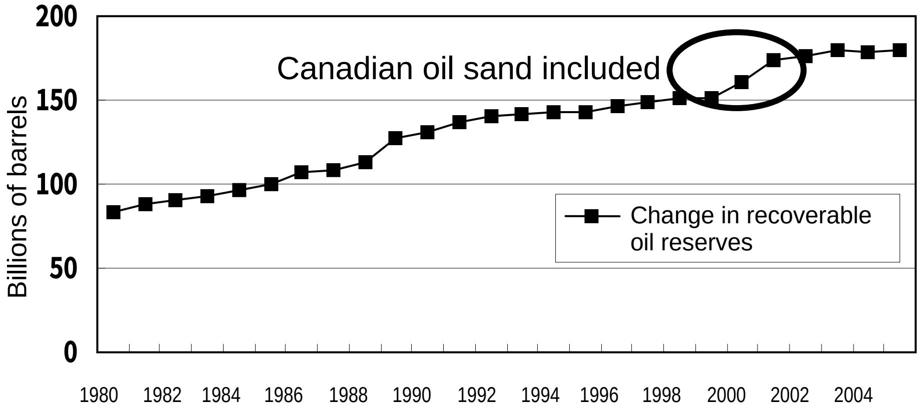
Source: BP Statistical Review of World Energy 2006




Note:
North America: United States, Canada, Mexico
Latin America: All regions to the south of Mexico
Europe and Russia: Europe and former Soviet regions
Africa: All African regions
Asia, Oceania: includes India and Australia

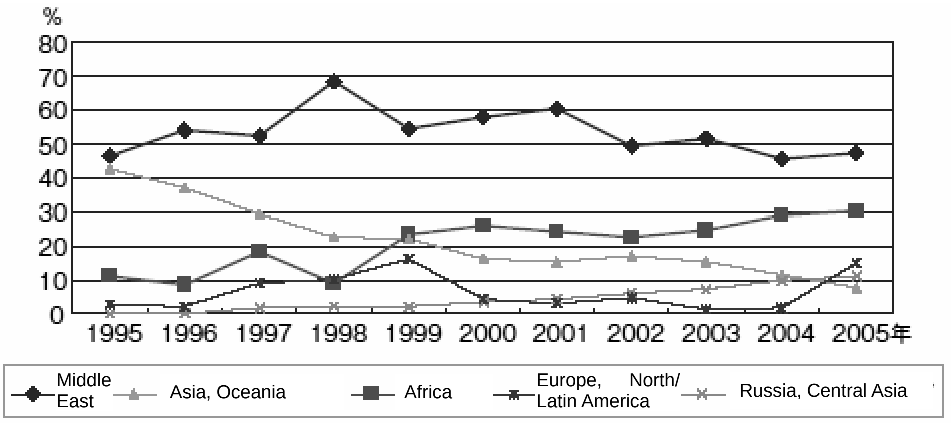
Source: BP Statistical Review of World Energy 2006

***Figure 2.1-1 Uneven distribution of fossil fuels reserves (recoverable deposits)***



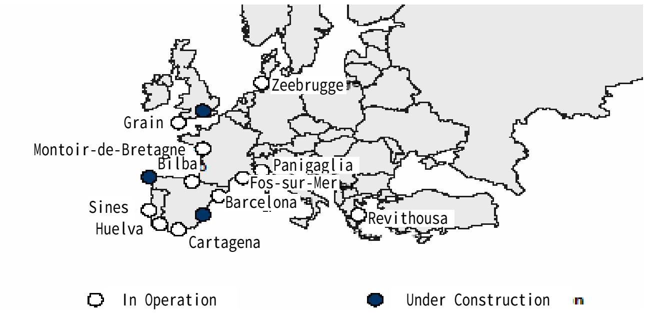

Source: BP Statistical Review of World Energy 2006

***Figure 2.1-2 Changes in recoverable oil reserves***




Source: Oil and Natural Gas Review (JOGMEC), November 2006

***Figure 2.1-3 China's imports of crude oil (Increasing imports from Africa)***




| No | Country | Terminal | Owner | Start Date | Existing Capacity (bcm p.a.) | Existing+Potential Capacity (bcm p.a.) |
|---|---|---|---|---|---|---|
| Exisiting Terminal | | | | | | |
| 1 | Spain | Huelva | Enagas | 1988 | 4 | 12 |
| 2 | Spain | Cartagena | Enagas | 1989 | 4 | 12 |
| 3 | Spain | Barcelona | Enagas | 1969 | 11 | 12 |
| 4 | Italy | La Spezia | Snam Rete Gas | 1969 | 5 | 5 |
| 5 | France | Fos sur Mer | GDF | 1972 | 5 | 5 |
| 6 | France | Montoir de Bretagne | GDF | 1980 | 10 | 10 |
| 7 | Greece | Revithousa | DEPA | 2000 | 3 | 3 |
| 8 | Belgium | Zeebrugge | Fluxys | 1987 | 5 | 9 |
| 9 | Spain | Bilbao | Repsol, et al. | 2003 | 4 | 7 |
| 10 | Portugal | Sines | GALP | 2003 | 5 | 16 |
| 11 | UK | Isle of Grain | National Grid | 2005 | 5 | 17 |
| | | | | Subtotal | 61 | 108 |
| Expected Future Terminal | | | | | | |
| 12 | Spain | El Ferrol | Sonatrach et al. | 2006 | | 4 |
| 13 | Spain | Sagunto | Union Fenosa | 2006 | | 5 |
| 14 | Italy | Rovigo | QP/EM/Edison | 2007 | | 8 |
| 15 | Italy | Brindisi | BG | 2006 | | 12 |
| 16 | France | Fos II | GDF | 2006 | | 8 |
| 17 | France | Le Verdon | TFE | | | ? |
| 18 | UK | Milford Haven | Petroplus | 2006 | | 9 |
| 19 | UK | Milford Haven | EM/QP | 2007 | | 21 |
| | | | | Subtotal | | 67 |
| Other Future Potential Terminal | | | | | | |
| 20 | Italy | Livorno | BP/Edision | | | 3 |
| 21 | Italy | Calabria 1 | | | | 10 |
| 22 | Italy | Calabria 2 | | | | 8 |
| 23 | Greece | New Terminal | | | | ? |
| 24 | Netherlands | Emshaven | | | | ? |
| 25 | Cyprus | Vasilikos | | | | 1 |
| 26 | UK | Coryton | BP | | | ? |
| 27 | Poland | Gdansk | | | | ? |
| | | | | Subtotal | | 22 |
| Total (Exisiting + Planned + Potential) | | | | | | 197 |

Source: Compiled based on OFGEM materials

***Figure 2.1-4 LNG terminal construction projects in EU countries (to obtain access to gas reserves in Middle East and Latin America)***

***Table 2.1-2 Japan's energy policy (for securing energy resources)***

| | |
|---|---|
| ODA White Paper (released in 2006) | In the new international environment with the emergence of BRICs, Japan's ODA is required to perform new missions. In particular, in the environment where countries are being connected more closely with each other in line with the development of Asian markets, we should promote private economic activities, deepen coordination, and utilize ODA for securing resources and energy. |
| New National Energy Strategy (released in 2005) | In order to fulfill the primary objective of ensuring stable energy supplies, Japan will make the maximum efforts with the relevant domestic and international policies. In devoting such efforts, it is important that we should endeavor not to stimulate global competition for resources. For this purpose, under the basic philosophy that Japan will coexist with Asian and global economies, we must put into practice our energy technology and experiences in addressing international energy issues. |

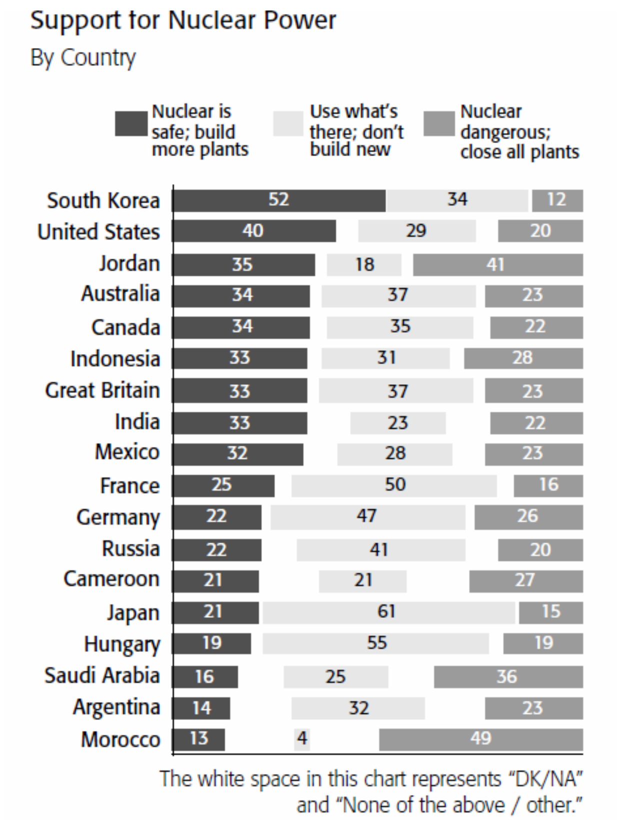
Source: Compiled based on various materials

## 2.2 Deepening of Discussion on Nuclear Power Development

*【Points】*

- Countries are divided in their views concerning the use of nuclear power, reflecting different energy demand and supply situations, including energy self-sufficiency ratios, and people's receptivity to nuclear power (Figure 2.2-1). In developed countries such as Germany and Sweden, people have negative views to the development of nuclear power, while some other countries are reevaluating their nuclear policies with respect to energy security and global warming. On the other hand, developing countries including Asian countries, such as China and India, are planning to introduce more nuclear power systems to secure energy to sustain economic growth (Table 2.2-1, Figure 2.2-2, Figure 2.2-3).
- The use of nuclear power is a beneficial policy in that it may not only ensure economic growth and energy security but also help combat global warming more effectively. At the same time, however, nuclear power creates a variety of problems involving the back-end measures and nuclear proliferation. Discussion in this respect must be deepened among countries worldwide.
- Developing countries are strongly advised to introduce relevant technologies from developed countries in order to ensure nuclear safety, while strictly complying with the nonproliferation policy.
- In addition to back-end measures, issues concerning nuclear fuel cycles require intensive discussion. It is essential to make efficient use of the limited supply of nuclear energy sources and reduce radioactive waste. At the same time, to ensure nuclear safety and prevent nuclear proliferation, we need to carefully watch movements in technological development and international consensus building.

*［Related Data and Facts］*




Source: IAEA "Global Public Opinion on Nuclear Power Issues and the IAEA", 2005

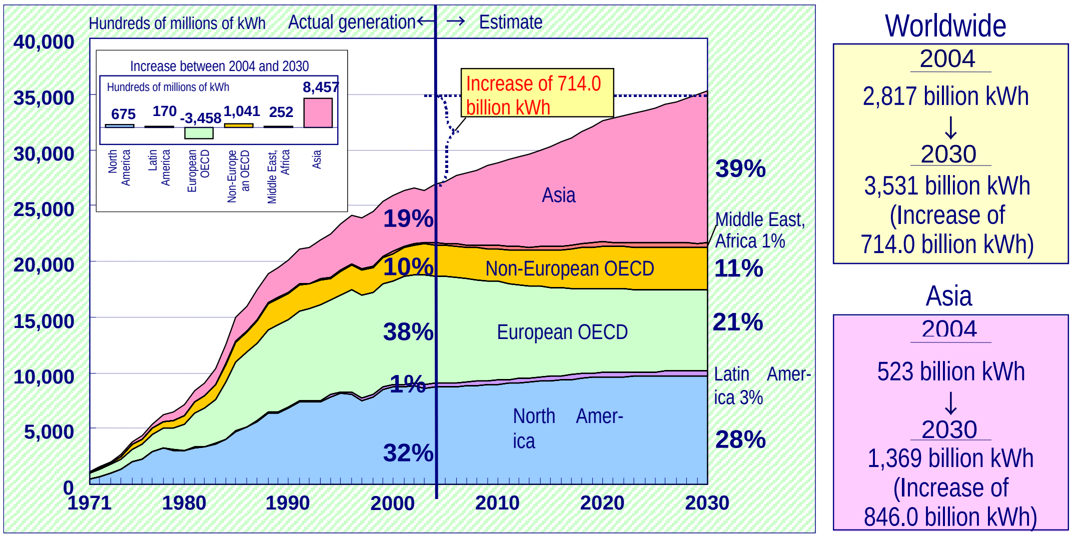
***Figure 2.2-1 Receptivity to nuclear power generation***

### *Table 2.2-1 Total energy production and nuclear energy production by region*

| Country Group | 2002 | | | 2010 | | | 2020 | | | 2030 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total Elect. | Nuclear | | Total Elect. | Nuclear | | Total Elect. | Nuclear | | Total Elect. | Nuclear | |
| | TW-h | TW-h | % | TW-h | TW-h | % | TW-h | TW-h | % | TW-h | TW-h | % |
| **North America** | 4,779 | 851.1 | 17.8 | 5,034 | 874 | 17 | 5,784 | 870 | 15 | 6,451 | 844 | 13 |
| | | | | 5,444 | 894 | 16 | 6,709 | 939 | 14 | 8,146 | 944 | 12 |
| **Latin America** | 1,078 | 28.6 | 2.7 | 1,178 | 29 | 2.5 | 1,628 | 47 | 2.9 | 2,227 | 30 | 1.3 |
| | | | | 1,427 | 38 | 2.7 | 2,291 | 50 | 2.2 | 3,758 | 92 | 2.4 |
| **Western Europe** | 3,084 | 880.2 | 28.5 | 3,352 | 858 | 26 | 3,634 | 823 | 23 | 3,942 | 564 | 14 |
| | | | | 3,609 | 893 | 25 | 4,687 | 961 | 20 | 6,061 | 1,090 | 18 |
| **Eastern Europe** | 1,758 | 298.5 | 17 | 1,884 | 319 | 17 | 2,174 | 423 | 19 | 2,463 | 378 | 15 |
| | | | | 2,074 | 399 | 19 | 2,867 | 552 | 19 | 4,133 | 611 | 15 |
| **Africa** | 459 | 12 | 2.6 | 538 | 13 | 2.5 | 699 | 14 | 2 | 876 | 14 | 1.6 |
| | | | | 612 | 14 | 2.3 | 973 | 24 | 2.4 | 1,530 | 60 | 3.9 |
| **Middle East and South Asia** | 1,176 | 19.6 | 1.7 | 1,342 | 41 | 3.1 | 1,805 | 53 | 3 | 2,327 | 70 | 3 |
| | | | | 1,626 | 47 | 2.9 | 2,596 | 100 | 3.9 | 3,946 | 194 | 4.9 |
| **South East Asia and the Pacific** | 600 | | | 736 | | | 934 | | | 1,162 | | |
| | | | | 786 | | | 1,119 | 5.5 | 0.5 | 1,584 | 18 | 1.2 |
| **Far East** | 3,157 | 484.3 | 15.3 | 3,399 | 695 | 20 | 4,199 | 855 | 20 | 5,073 | 981 | 19 |
| | | | | 4,296 | 702 | 16 | 6,605 | 1,125 | 17 | 9,830 | 1,361 | 14 |
| **World Total** Low Estimate | 16,090 | 2,574.2 | 16 | 17,463 | 2,830 | 16 | 20,857 | 3,085 | 15 | 24,520 | 2,881 | 12 |
| High Estimate | | | | 19,873 | 2,987 | 15 | 27,848 | 3,756 | 13 | 38,989 | 4,369 | 11 |

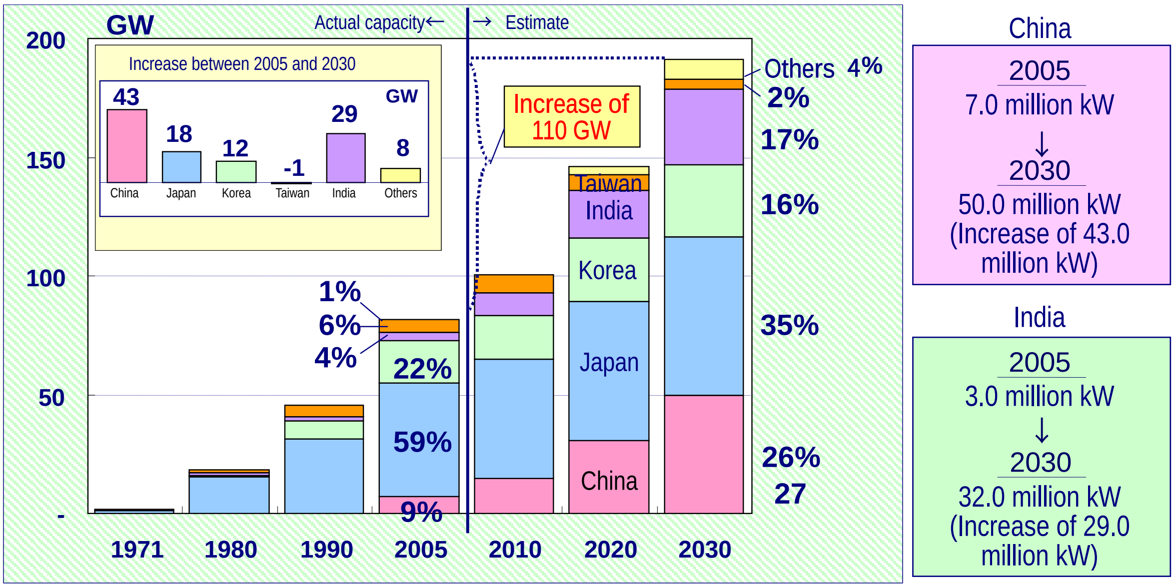
Source: Nuclear Technology Review 2004 (IAEA)

Note: “Low Estimate”: Low demand case
“High Estimate”: High demand case




Source: Asia/World Energy Outlook 2006 (The Institute of Energy Economics, Japan)

***Figure 2.2-2 Outlook for global nuclear energy (Electricity generation)***




Source: Asia/World Energy Outlook 2006 (The Institute of Energy Economics, Japan)

***Figure 2.2-3 Outlook for Asian nuclear energy (Plant capacity)***

*Table 2.2-2 Years of resource availability for various nuclear technologies*

| Reactor/Fuel cycle | Years of 2002 world nuclear electricity generation with known conventional resources (1) | Years of 2002 world nuclear electricity generation with toral conventional resources (2) | Years of 2002 world nuclear electricity generation with toral resources (3) |
|---|---|---|---|
| Current fuel sysle (LWR, once-through) | 85 | 270 | 8,200 |
| Recycling fuel cycle (plutonium only, one recycle) | 100 | 300 | 9,200 |
| Light water and fast reactors (mixed with recycling) | 130 | 410 | 12,000 |
| Pure fast reactor fuel cycle with recycling | 2,500 | 8,500 | 240,000 |

(1) Known conventional resources include all cost categories of reasonably assured resources (RAR) and estimated additional resources - category I (EAR-I) for a total of 4,588,700 tU.[6]
(2) Total conventional resources include all cost categories of reasonably assured resources, estimated additional resources, and speculative resources for a total of 14,382,500 tU.
(3) Total resources assume conventional resources of 14,382,500 tU, plus 90% of phosphate resources of 22,000,000 tU (=19,800,000 tU), plus 10% of the estimated seawater uranium resources of 4,000,000,000 tU (=400,000,000 tU) for a total of 434,182,500 tU.

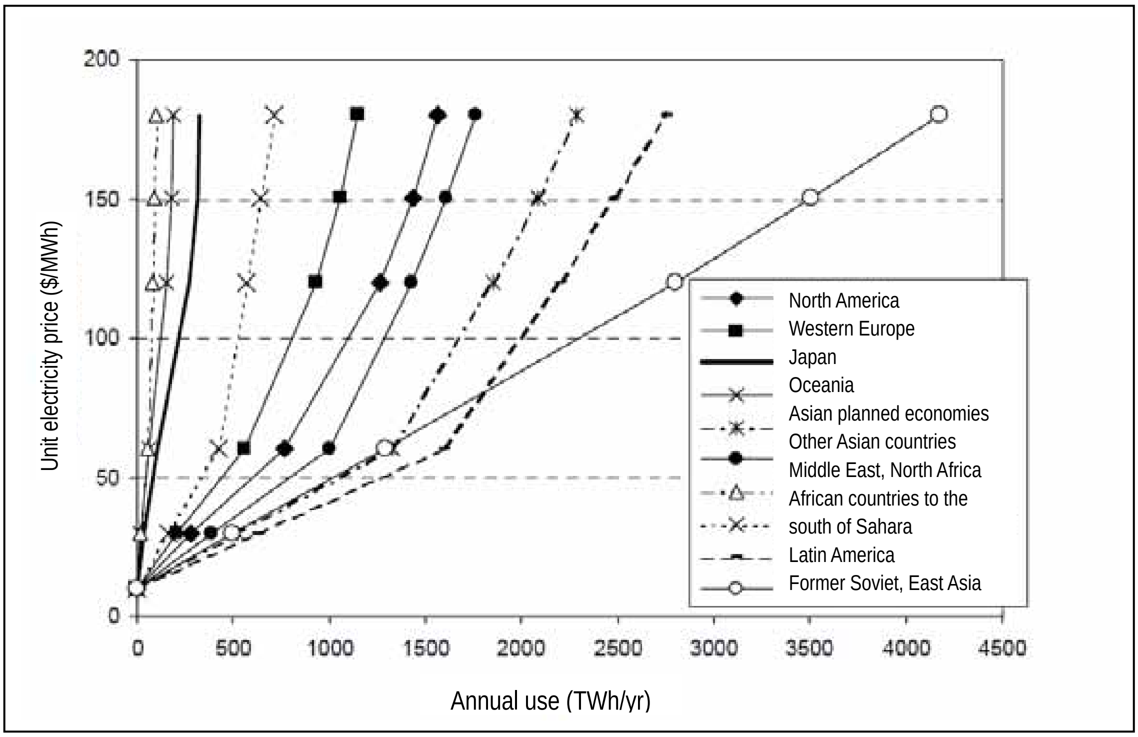
Source: Nuclear Technology Review 2004 (IAEA)

## 2.3 Promotion of Renewable Energy

***[Points]***

- Electricity generation systems using photovoltaic power or wind power have been introduced in many countries in recent years at staggering rates (Figure 2.3-4, Figure 2.3-5). However, the use of these energy sources is almost negligible when compared with the use of other conventional renewable energy sources, such as hydro power and geothermal (Figure 2.3-2).
- IEA suggests that, in order to reduce climate change impacts and ensure energy security, we need several times more amount of renewable energy than currently introduced, including hydro power and geothermal, by 2050 (Figure 2.3-6). Photovoltaic power generation and wind power generation still have the large potential for wider introduction (Figure 2.3-1).
- For accelerated introduction of photovoltaic power and wind power generation, it is essential to solve technological problems, including fluctuations in power generation output (Figure 2.3-8) and high costs (Figure 2.3-9). The government's policy initiatives will also play an important role in accelerating the introduction of these renewable power systems.
- Technological challenges common to countries include the development of materials for solar panels, electric systems for reducing fluctuations in power generation output, and technologies for predicting wind conditions. International coordination will be effective in establishing a product and quality code and an environmental standard. It is also important to develop locally needed technologies reflecting the situations and characteristics of each country, such as low-speed windmills and offshore wind farms. (Table 2.3-1, Table 2.3-2)
- Experts are studying innovative technologies for renewable energy utilization intended for such applications as floating ocean windmills, large-scale solar energy generation systems, and space photovoltaics systems.
- As part of their efforts to encourage the use of renewable energy, developed countries have adopted an energy quota, an energy certificate trading system and other deployment policies (Figure 2.3-10).
- In developing countries, a renewable energy system has another advantage in improving access to energy in areas where power transmission systems are underdeveloped. It is desirable to develop low-cost power generation systems and local power transmission networks.

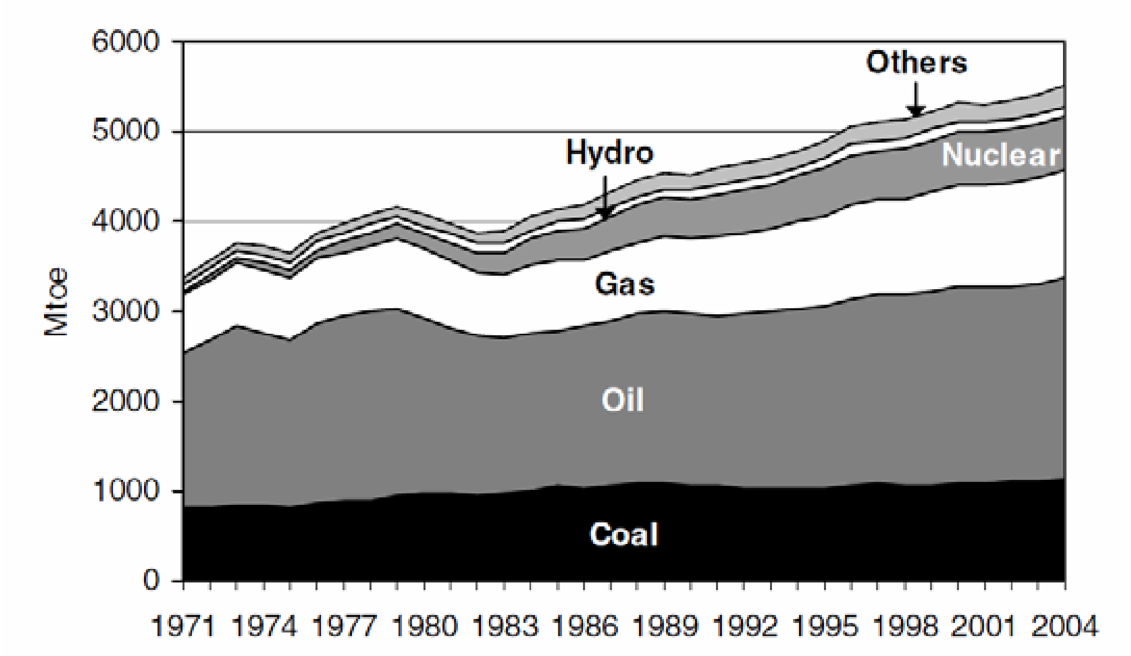
*[Related Data and Facts]*




Source: RITE, Outline of Integrated Assessment Model DNE21, 2002

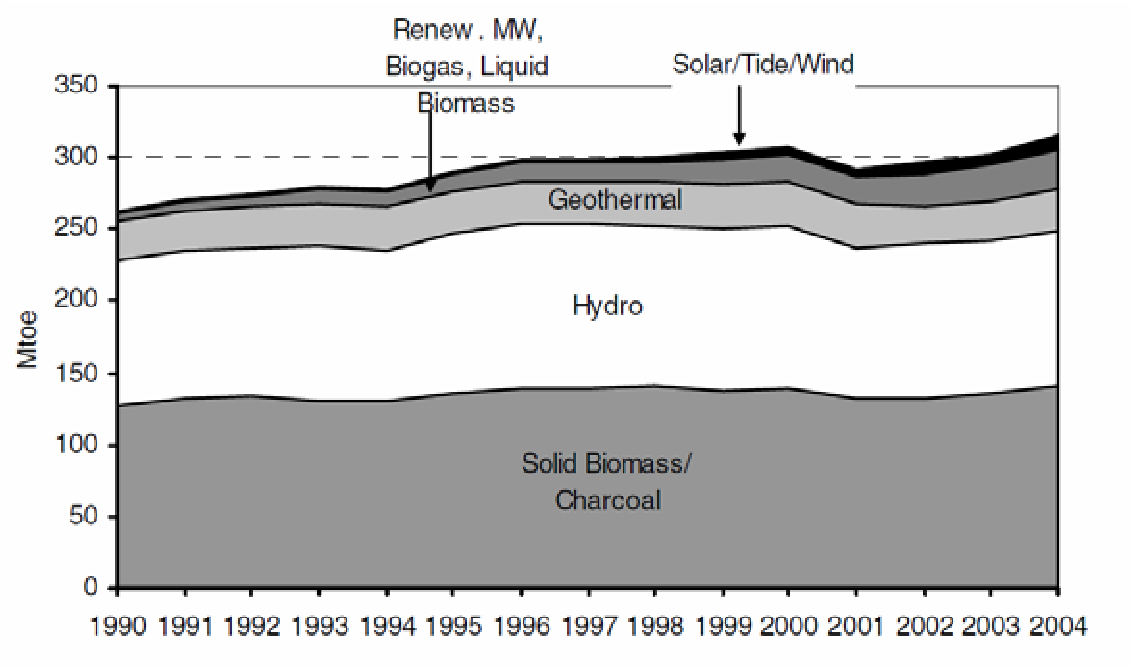
Note: 1TWh to 0.215MTOE (in primary energy equivalent)

***Figure 2.3-1 Estimated supply curve for wind power generation***



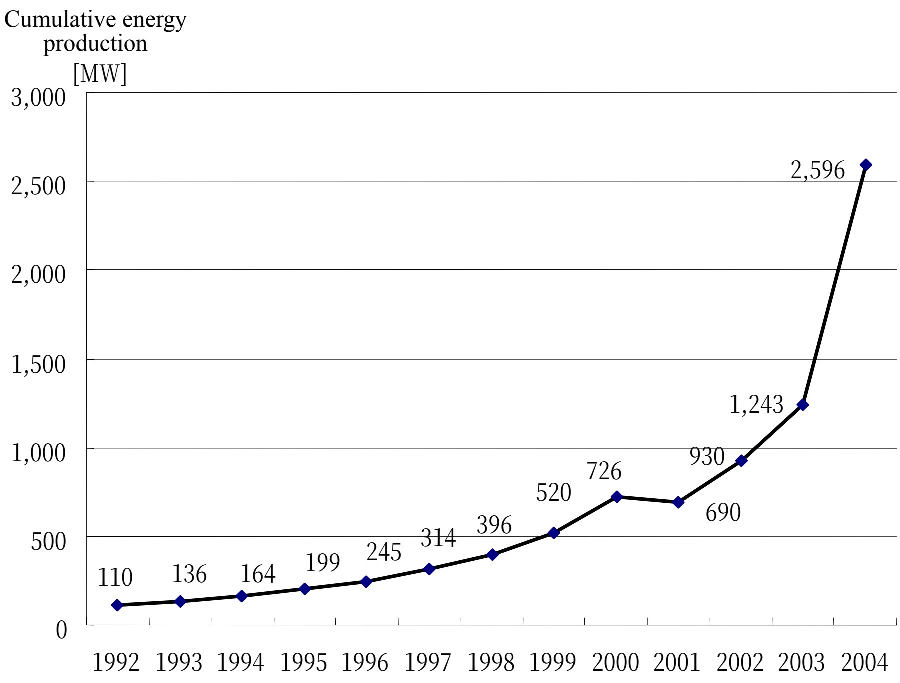

Source: IEA "Energy Balances of OECD Countries: 2003/2004", 2006

***Figure 2.3-2 Primary energy supply in OECD countries***



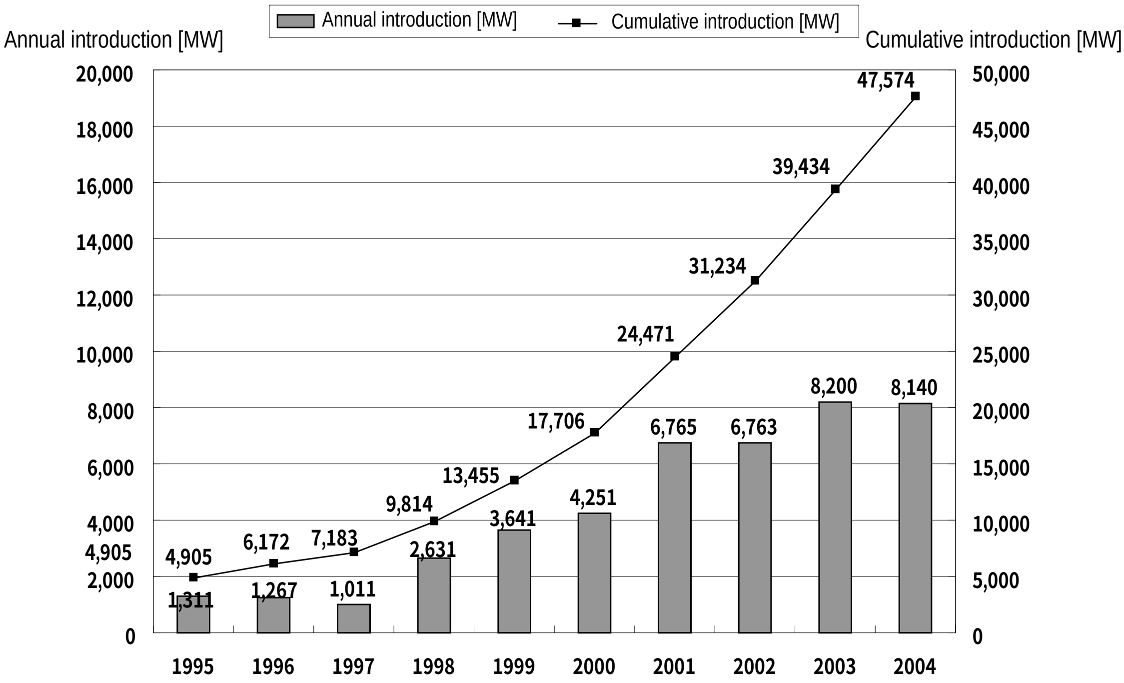

Source: IEA, Renewable Information: 2006 Edition, 2006

***Figure 2.3-3 Introduction of renewable energy in OECD countries***



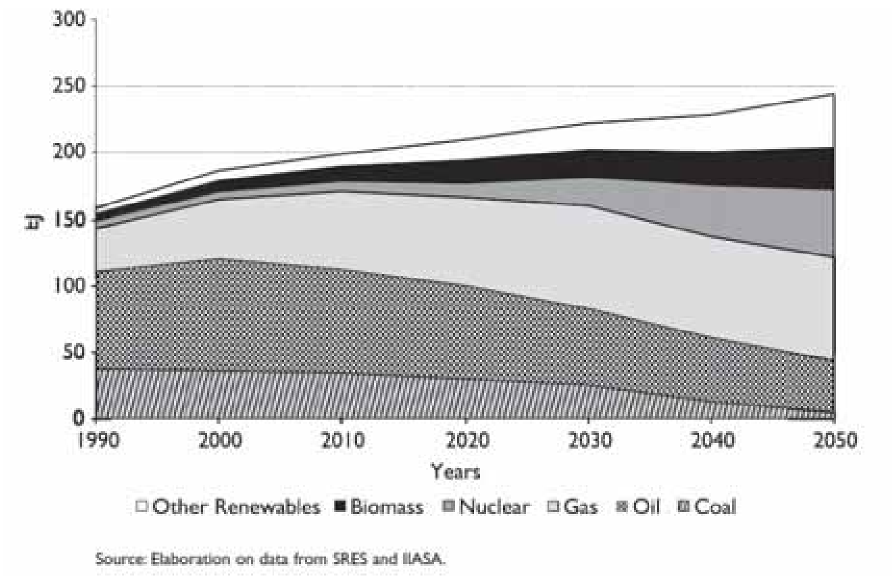

Source: Compiled based on NEDO materials
Original source: Trends in Photovoltaic Applications, IEA-PVPS

***Figure 2.3-4 World introduction of photovoltaic power generation***




Source: NEDO "Guidebook on the Introduction of Wind Power Generation 8th Edition" 2005
Original source: IEA 1994-1996, WINDPOWER MONTHLY April 1997-2005

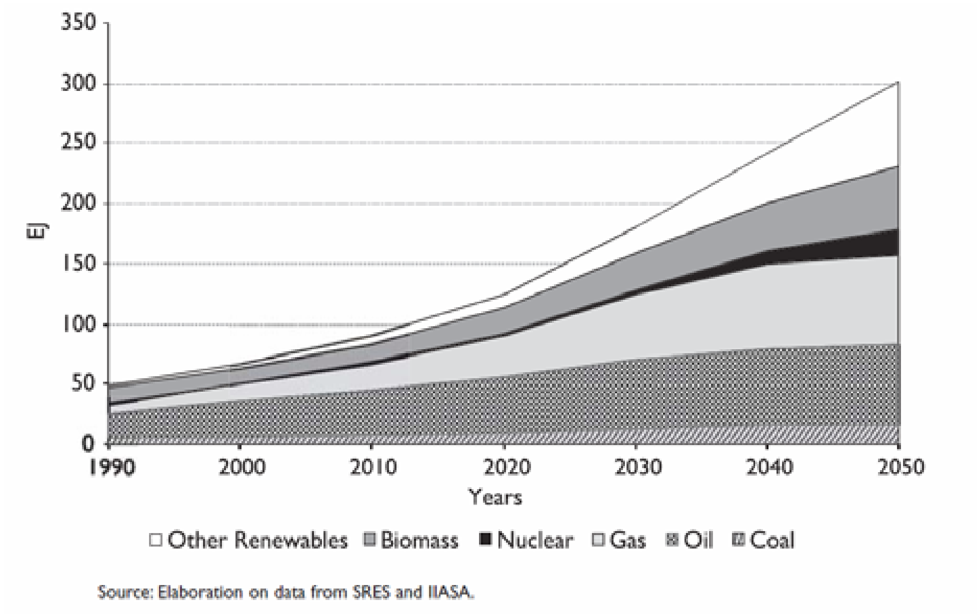
***Figure 2.3-5 World introduction of wind power generation***




Source: IEA "Energy to 2050: Scenarios for a Sustainable Future", 2003

Note: This outlook is based on a "standard scenario" developed in a back-casting method for the purpose of sustainable development, including reducing climate change, ensuring energy security, and improving access to energy. "Other Renewables" include conventional renewable types of energy, such as hydro power and geothermal.

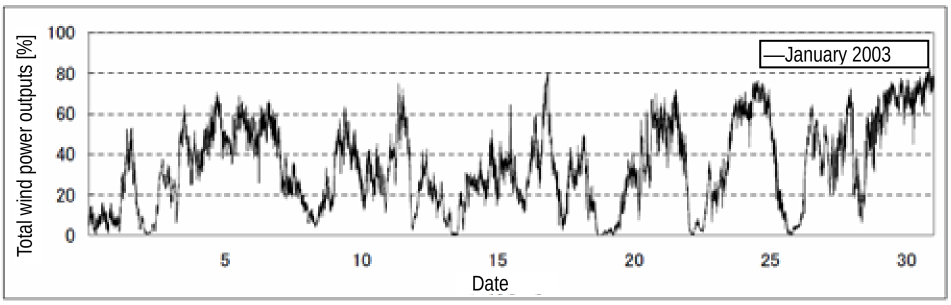
***Figure 2.3-6 Outlook for primary energy supply in OECD countries***




Source: IEA "Energy to 2050: Scenarios for a Sustainable Future", 2003

Note: See Figure 2.3-6 (Note).

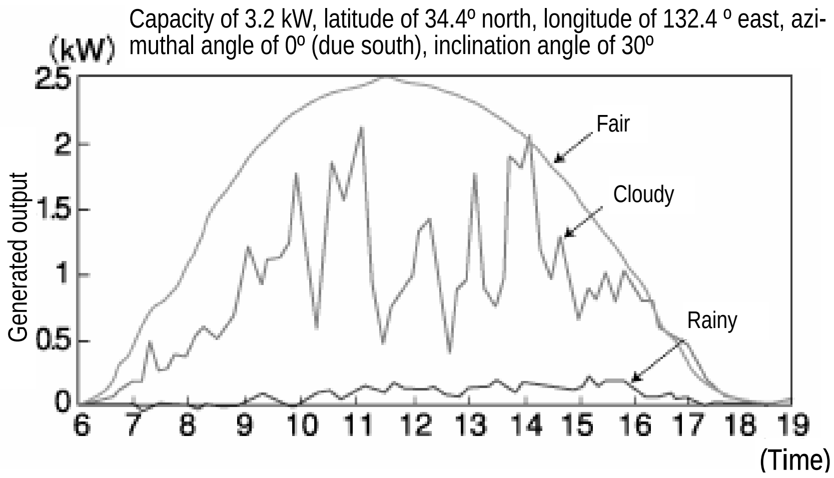
***Figure 2.3-7 Outlook for world primary energy supply***




Source: Materials from Tokyo Electric Power Co.

***Figure 2.3-8 Output fluctuations in wind power generation***

***(Fluctuations in total wind power output in northeast areas in Japan )***




Source: Federation of Electric Companies of Japan

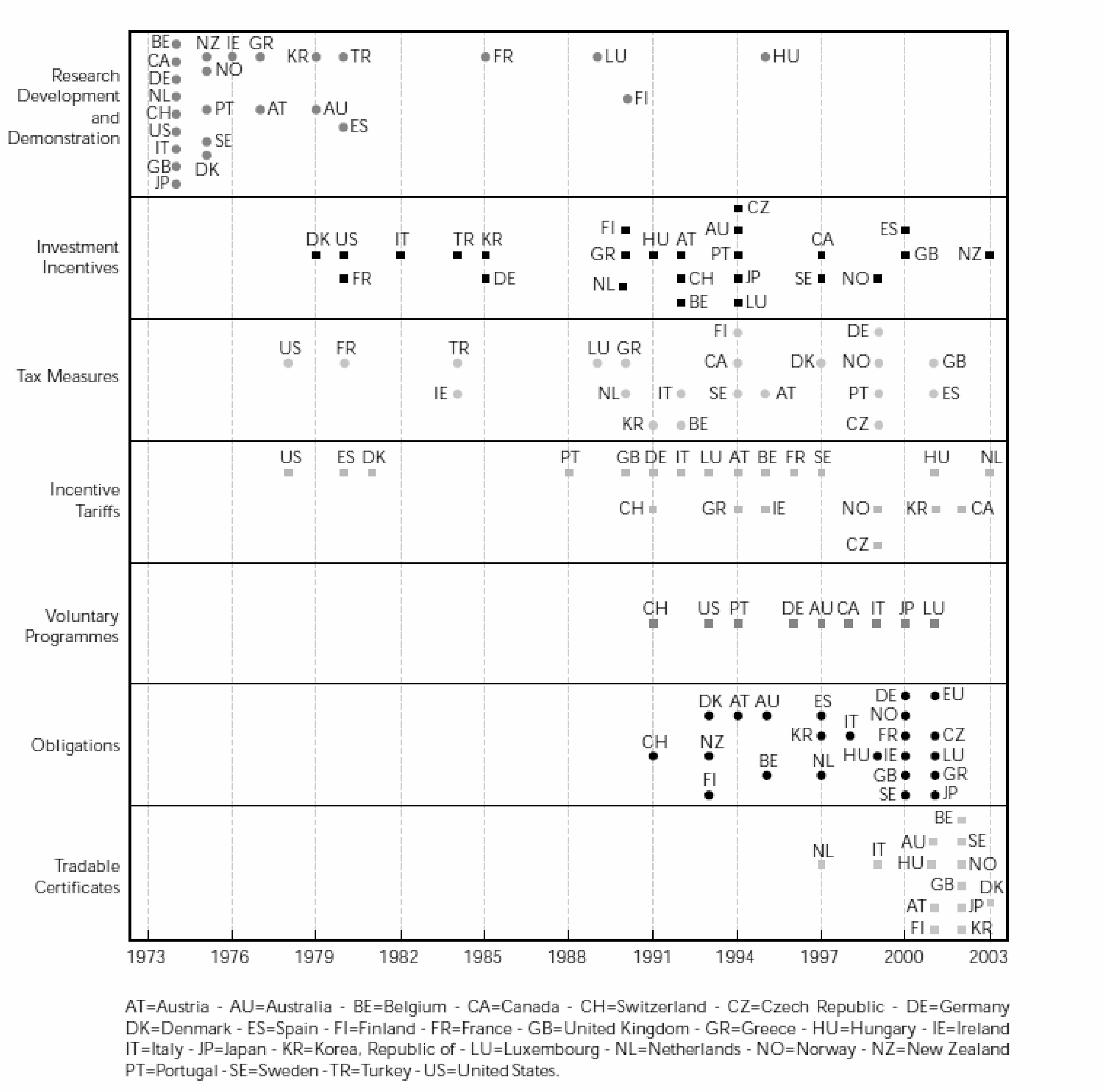
***Figure 2.3-9 Output fluctuations in photovoltaic power generation (Springtime)***

*Table 2.3-1 Renewable energy technological development strategy of main countries*

| | Japan | United States | Europe |
|---|---|---|---|
| Photovoltaic power | ・Solar panel technology (new materials, such as thin-film silicon compound and pigments)<br>・System technology (independent system, active network control ) | ・Fundamental Research (Measurements and Characterization, Basic Research, High-performance Advanced Research)<br>・Advanced Materials & Devices (Crystalline silicon technology, Thin films, PV modules)<br>・Systems Technology Development (Systems Modeling and Analysis, Systems engineering, Concentrator PV Systems) | ・Devises Wafer technologies, thin film silicon and compound semiconductors, novel devices<br>・Module technology<br>・Grid connection, storage, mounting<br>・Standardization, harmonization |
| Wind power | ・Japanese-stile wind turbines<br>・Electricity stabilization (system stabilization , power output prediction, new electricity network)<br>・Faster wind simulation system<br>・Offshore wind power generation (wind turbine development, verification testing)<br>・Energy conversion (conversion to hydrogen, ethanol, etc.) | ・Low-cost power (Low wind speed technology, Distributed wind technology)<br>・Acceptance in marketplace (Systems integration) | ・Wind turbine & component design<br>・Testing, standardization, certification<br>・Grid integration, energy systems & resource prediction<br>・Operation & maintenance<br>・Offshore wind technology<br>・Mega watt wind turbine |

Source: Compiled based on the materials listed below.

- NEDO Overseas Report: Development and Introduction Renewable Energy Technology in Japan, September 7, 2005.
- DOE Energy Efficiency and Renewable Energy Website (http: //www.eere.energy.gov/)
- PVNET “European Roadmap for PV R&D”
- The European Wind Energy Association “The European Wind Industry Strategic Plan for Research & Development”




Source: IEA "Renewable Energy: Market & Policy Trends in IEA Countries"

***Figure 2.3-10 Time of introduction of renewable energy policy in OECD countries***

*Table 2.3-2 RD&D Priorities*

| | |
|---|---|
| Bioenergy | Primary objectives of additional RD&D are to:<br>-Promote market deployment of technologies and systems for sustainable energy production from biomass.<br>-Actively encourage the maintenance and development of networks of participants involved in RD&D and education, and to provide for the effective dissemination of information on bioenergy.<br><br>Short-term technology needs include:<br>-Increasing the relative availability of cheap feedstock in large quantities; the development of fuel quality standards.<br>-Improving the efficiency of some basic processes while reducing their costs; innovative approaches in materials.<br><br>Medium-term needs include:<br>-Further development of the biorefinery concept for biomass feedstocks.<br>-Production of ethanol from lignocelluloses.<br>-Development of dedicated crops tailored to the requirements of biorefineries.<br><br>Long-term needs include:<br>-Development of pathways for bioenergy to start playing an important role in the evolving hydrogen economy through gaseous and liquid biofuels. |
| Wind energy | Increase value and reduce uncertainties in fields such as:<br>-**Forecasting power performance** (target of uncertainty of power output 5% to 10%).<br>-Reduce uncertainties related to engineering integrity, development and validation of **standards** in terms of providing better understanding of extreme environmental conditions, safety, power performance and noise.<br>-Storage techniques.<br><br>Continue cost reductions through:<br>-Improved models for **aerodynamics/aeroelasticity**.<br>-Improved site assessment including **off-shore**.<br>-New intelligent **structures/materials and recycling**.<br>-More efficient **generators and converters**.<br>-New concepts including devices such as highly **flexible downwind machines** and **diffuser-augmented turbines**.<br>-Improved stand-alone and hybrid systems that **integrate PV or diesel generating systems** for remote locations where grid connection is not feasible.<br><br>Enable large-scale use through:<br>-Electric **load flow control and adaptive loads**.<br>-Improved **power quality** (especially in weak grids).<br><br>Minimise environmental impacts by addressing issues related to:<br>-Compatible use of land and aesthetic integration (e.g., visual impact).<br>-Noise studies.<br>-Flora and fauna. |
| Photovoltaics | Additional RD&D priorities can be categorised as follows:<br>-**New feedstock** production to meet the demand of world market c-Si.<br>-Early assessment for **immature solar cell technologies**, including thin-film manufacturing processes.<br>-Better **balance-of-system** (BOS) components in terms of the efficiency, lifetime and operation of some components, especially inverters and batteries.<br>-Performance development and further cost reduction of **thin-film technologies**.<br>-Exploration into scientific fields, including nanotechnology, organic thin films and molecular chemistry for novel concepts regarding PV.<br>-Develop devices with **high conversion efficiencies and long-term stability** in order to match the expected lifetime of 25 years and more.<br>-Building integration, manufacturing issues, quality assurance and standardisation. |

Source: IEA "Renewable Energy: RD&D Priorities"

## 2.4 **Sustainable Promotion of Biomass Energy**

***[Points]***

- Biomass energy, a relatively cost-effective type of renewable energy, is being introduced by many countries (Table 2.4-1). Developed countries are promoting biomass resources for transport fuels (e.g. bio-ethanol, bio-diesel-fuel), in addition to power generation (e.g. direct combustion generation and gasification power generation) (Figure 2.4-2). In developing countries, biomass, which accounts for most part of their energy consumption, has been traditionally used for cooking and other inefficient applications, unable to ensure its sustainable utilization (Figure 2.4-1).
- Under these circumstances, we expect not only to develop high-efficiency biomass utilization technologies but also to accelerate the transfer of existing technologies from developed to developing countries, so that biomass resources can be used more efficiently. Further, in order to minimize negative impacts of biomass utilization on food prices and food balances of supply and demand, it is particularly important to develop the cellulosic ethanol production technologies using non-food biomass resources and to improve resource productivity by the genetic engineering (Table 2.4-2, Table 2.4-3).
- Some environment protection organizations doubt the sustainability of biomass resources (Table 2.4-4). In this respect, we should accumulate accurate facts and evidence to find a biomass utilization policy and scheme (e.g. an authentication system) in order to prevent biomass utilization from leading to destruction of tropical rain forests and other natural environments.

〔Related Data and Facts〕

***Table 2.4-1 Introduction and cost of major renewable energy (Present situation/outlook)***

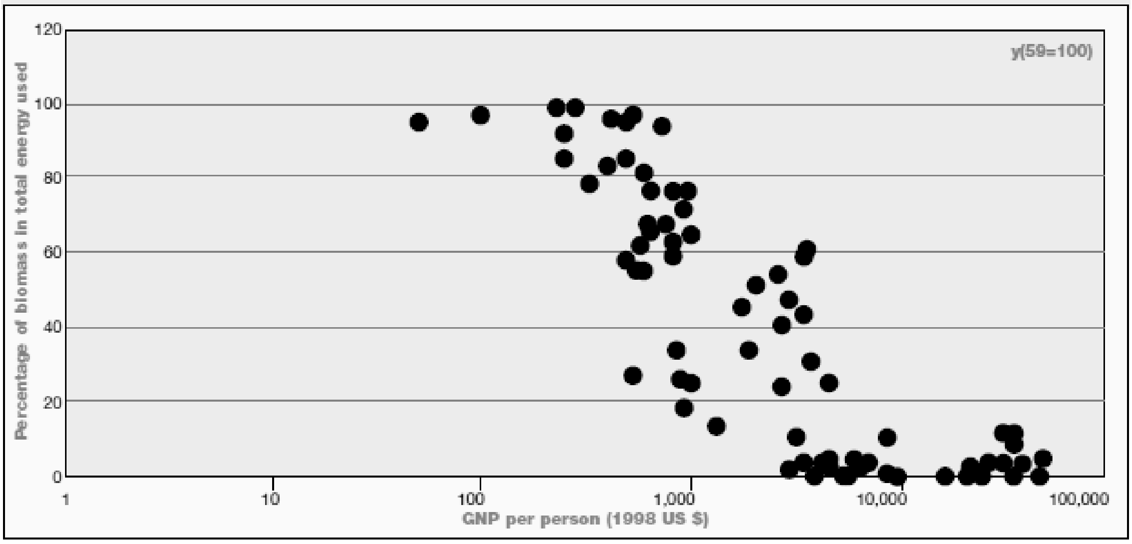
**CURRENT STATUS AND POTENTIAL FUTURE COSTS OF RENEWABLE ENERGY TECHNOLOGIES**

| Technology | Increase in installed capacity in past five years (percent a year) | Operating cpacity, end 1998 | Capacity factor (percent) | Energy production, 1998 | Turnkey investment costs (U.S. dollars per kilowatt) | Current energy cost | Potential future energy cost |
|---|---|---|---|---|---|---|---|
| **Biomass energy** | | | | | | | |
| Electricity | -3 | 40 GWe | 25-80 | 160 TWh (e) | 900-3000 | 5-15 ¢/kWh | 4-10 ¢/kWh |
| Heat[a] | -3 | >200 GWth | 25-80 | >700 TWh (th) | 250-750 | 1-5 ¢/kWh | 1-5 ¢/kWh |
| Ethanol | -3 | 18 billion litres | | 420 PJ | | 8-25 $/GJ | 6-10 $/GJ |
| **Wind electricity** | -30 | 10 GWe | 20-30 | 18 TWh (e) | 1100-1700 | 5-13 ¢/kWh | 3-10 ¢/kWh |
| **Solar photovoltaic electricity** | -30 | 500 MWe | 8-20 | 0.5 TWh (e) | 5000-10000 | 25-125 ¢/kWh | 5 or 6-25 ¢/kWh |
| **Solar thermal electricity** | -5 | 400 MWe | 20-35 | 1 TWh (e) | 3000-4000 | 12-18 ¢/kWh | 4-10 ¢/kWh |
| **Low-temperature solar heat** | -8 | 18 GWth (30 million $m^2$) | 8-20 | 14 TWh (th) | 500-1700 | 3-20 ¢/kWh | 2 or 3-10 ¢/kWh |
| **Hydroelectricity** | | | | | | | |
| Large | -2 | 640 GWe | 35-60 | 2510 TWh (e) | 1000-3500 | 2-8 ¢/kWh | 2-8 ¢/kWh |
| Small | -3 | 23 GWe | 20-70 | 90 TWh (e) | 1200-3000 | 4-10 ¢/kWh | 3-10 ¢/kWh |
| **Geothermal energy** | | | | | | | |
| Electricity | -4 | 8 GWe | 45-90 | 46 TWh (e) | 800-3000 | 2-10 ¢/kWh | 1 or 2-6 ¢/kWh |
| Heat | -6 | 11 GWth | 20-70 | 40 TWh (th) | 200-2000 | 0.5-5 ¢/kWh | 0.5-5 ¢/kWh |
| **Marine energy** | | | | | | | |
| Tidal | 0 | 300 MWe | 20-30 | 0.6 TWh (e) | 1700-2500 | 8-15 ¢/kWh | 8-15 ¢/kWh |
| Wave | - | exp. Phase | 20-35 | Unclear | 1500-3000 | 8-20 ¢/kWh | Unclear |
| Current | - | exp. Phase | 25-35 | Unclear | 2000-3000 | 8-15 ¢/kWh | 5-7 ¢/kWh |
| OTEC | - | exp. Phase | 70-80 | Unclear | Unclear | Unclear | Unclear |

Note: The cost of grid-supplied electricity in urban areas ranges from 2-3 ( ¢/kWh (off-peak) to 15-25 ¢/kWh)(peak).
a. Heat embodied in steam (or hot water in district heating), often produced by combined heat and power systems using forest residues, black liquor, of bagasse.

Source: World Energy Assessment / overview 2004 Update (United Countries Development Program / United Countries Department of Economic and Social Affairs / World Energy Council)

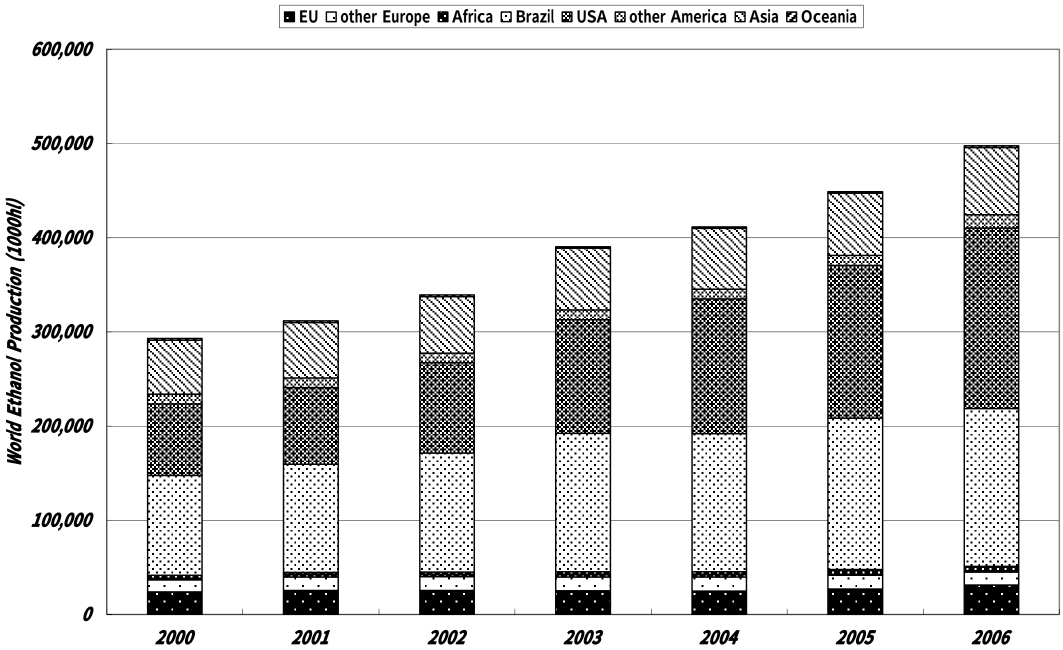
FIGURE 11.1. USE OF BIOMASS AS A COOKING FUEL RELATIVE TO GNP PER CAPITA IN 80 COUNTRIES




Source: World Bank, 1996.

Source: World Energy Assessment / energy and the challenge of sustainability (United Countries Development Program / United Countries Department of Economic and Social Affairs/ World Energy Council)

***Figure 2.4-1 Levels of economic growth and utilization ratio for biomass energy***




Source: Materials from F.O.Licht

Note: The above figures include those other applications than fuels (Global ratio of fuel to total production ＝about 76%)

***Figure 2.4-2 Development in the world's bio-ethanol production (development of biofuels for transport)***

***Table 2.4-2 Availabilities of biomass resources for conversion technology***

| | | | Biomass Type | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Wood biomass | | | Paper biomass | Plant biomass | | | Manure and sludge biomass | | Food waste biomass | Other biomass | |
| | | | | | | | Pasture grass, water-weed, seaweed | | Agricul-tural residue | | | | Sugar and starch | Plant oil |
| Dry/Wet | | | D | D | D | D | D | W | D | W | W | W | | |
| Case | | | Waste wood from timber mills and forests | Waste wood from construc-tion | Energy crops | Use paper | Pasture-grass, napier grass | Water hyacinth | Maize, rice straw, rice husk, barley straw | Animal manure | Sewage, sludge manure purifica-tion tank residue | Food waste, kitchen garbage, seafood residue | Sweet potato | Used cooking oil, canola oil, palm oil |
| Conversion technology | Combustion | Direct- combustion power generation | ■ | □ | ■ | □ | □ | | □ | | | | | |
| | | Co-combustion power generation | ■ | □ | ■ | □ | □ | | □ | | | | | |
| | Thermochemical conversion | Gasification | ■ | ■ | ■ | | ■ | | ■ | | | | | |
| | | Heat decomposition | ■ | | ■ | | | | □ | | | | | |
| | | Supercritical methanol processing | ■ | | ■ | ■ | | | | | | | | |
| | | Supercritical water gasification | | | | | | ■ | | ■ | ■ | ■ | | |
| | | Carbonization | ■ | | ■ | | | | | | | | | |
| | | Esterification | | | | | | | | | | | | ■ |
| | Biochemical con-version | Methane fermentation | | | | | | ■ | | ■ | ■ | ■ | | |
| | | Ethanol fermentation | ■ | □ | ■ | ■ | □ | | □ | | | | ■ | |
| | | Acetone and butane fermentation | | | | | | | | □ | □ | ■ | ■ | |
| | | Hydrogen fermenta-tion | | | | □ | | | ■ | □ | □ | ■ | ■ | |

Source: Compiled based on materials from NEDO

Note: The colors indicate the following:
■ Biomass fit for conversion technology
□ Biomass not best fit for conversion technology but applicable

***Table 2.4-3 Major conversion technologies provided in the Biomass Energy Road Map***

| Technology Fields | Individual Technologies | |
|---|---|---|
| Production | Genetically modified crops, new countryside project, mechanized logging, genetically modified ocean biomass | |
| Collection and transport | Mechanized wood processing, moving plant, information platform | |
| Pre-treatment | Wood saccharization (hydrothermal, enzyme, biochemistry), drying process (VCR, hydrothermal, supersonic, microwave, component separation, grinding, partial carbonization) | |
| Energy conversion | Gasification-related | Heat decomposition, microwave thermolysis, partially oxidized supercritical water, carbonization, oil reforming, co-combustion, DME, GTL, compact gasification power generation |
| | Ethanol-related | Direct cellulose fermentation, solid fermentation |
| | Hydrothermal technology | Slurry-making technology, liquid fuel, new biodiesel |
| | Direct stirring engine | |
| | Neoplastic | Bio-battery, electric hydrogen production, optical methane fermentation, high-density microorganism fermentation, complex microorganism control, improved productivity, dry wood methane fermentation, halotolerant bacteria |
| | New esterification | Supercritical methanol, supersonic, solid catalyst, microwave, optical |
| | Cost-efficiency | |
| Post-treatment | Ethanol | Supersonic condensation, membrane dehydration |
| | Digestive fluid | Nanobubble, bio-discoloring, supersonic decomposition, optical bleaching |
| | Membrane utilization | Hydrogen separation, gas condensation, ethanol dehydration, butanol condensation |
| | Tar removal and reforming, methane chemistry | |
| | Energy saving | |
| Peripheral | GTL catalyst, carbon nanotube, advanced carbon utilization, utilization of useful components of waste fluid, salt- and corrosion-resistant alloy | |
| Fuel utilization | Carbon-related | Powdered carbon combustion, catalysis carbonation, carbon fuel cell |
| | Hydrothermal slurry combustion, greenhouse pellet boiler | |
| Byproduct and residue utilization | Wood gas –related | Gasified residue, tar |
| | Fertilizer component collection | Fertilizer component collection |

Source: Compiled based on NEDO materials.

***Table 2.4-4 NPO views of biomass resource utilization***

| Target resource | Organization | Views on biofuels |
|---|---|---|
| Biofuels | World Wildlife Fund (WWF) International | • Biofuel production should be carried out with materials and methods best fit for the location and supported by effective management and monitoring systems.<br>• We should not relocate forests and other environmentally valuable ecosystems for bioenergy production, which could increase environmental burden on the ecosystem and biodiversity of the site. |
| | The World Conservation Union (IUCN) | • The development of biofuel resources would change land utilization patterns, which could lead to loss and decomposition of animal and plant habitats, degeneration of the ecosystem, structural changes within the population, while creating problems with biodiversity and genetic resources as a result of development of single crop farming. In addition, biofuel resource development will have such impacts as intensified competition with food and price increases in agricultural products. |
| Bioethanol | Worldwatch Institute | • Some production methods can cause energy inputs to exceed outputs or result in an increase in greenhouse gas emissions.<br>• Biofuels may lead to reduction in air pollution but it can also cause environmental problems when used without care.<br>• In line with greater biofuel demand, more low-productivity land may be used for cultivation of fuel crops, leading to such environment problems as destruction of tropical forests, soil erosion, and pollution of underground water sources.<br>• Without an effective established policy, we can face social problems, as well as environmental problems (e.g. income disparities among farmers). |
| Palm oil | WWF Indonesia | • Palm oil makes an important resource of income for Indonesia. Tropical rainforests are being destroyed with oil palm plantation, imposing greater burden on wildlife and aboriginal people. Further, increasing forests fires and land reclamation by burning are causing more health damage.<br>• At the same time, the development of plantations is causing such social problems as the infringement of the rights and interests of aboriginal people. |
| | FoE UK (Friends of the Earth UK) | • Failure in sustainable use of biofuels will lead to increases in greenhouse gas emissions, degeneration in stable food supplies, destruction of ecosystems and biodiversity, and aggravation of social problems.<br>• Palm oil has contributed a great deal to the economic development of Malaysia and Indonesia. At the same time, however, responses to growing palm oil demand can result in destruction of tropical rain forests in line with increasing farmland, aggravating life threat to orangutans, increasing environmental costs due to more frequent forest fires, and increasing social costs due to such factors as the deprivation by plantation businesses of forest resources and people's land.<br>• In light of growing demand for palm oil as an energy source, the political unrest, and the government's plantation initiatives, palm oil should not be used for power generation. |

| Target resource | Organization | Views on biofuels |
|---|---|---|
| Wood | Greenpeace Japan | • Japan should immediately stop importing wood chips produced in Tasmania, Australia, because such imports accelerate the destruction of primary forests there.<br>• Japan may purchase wood chips produced from artificial forests grown in a sustainable and systematic manner. |

Source: Compiled from relevant materials