

# Asia/World Energy Outlook 2012

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## Asia/World Energy Outlook 2012

### 1. Introduction

Global energy demand has been expanding rapidly; it expanded 2.3-fold from 5,500 million tons of oil equivalent in 1971 to 12,700 million tons of oil equivalent (Mtoe) in 2010. The Asian region has increased its energy demand remarkably over recent years, accounting for 70% of the growth in global energy consumption since 2000. The rapid energy demand expansion in the region, poor in oil and natural gas resources, has caused major problems in and outside the region. For example, China, with the largest energy demand in the world, has taken all possible measures to secure and diversify its fossil fuel procurements, including constructing international oil pipelines, acquiring overseas oil interests, and expanding Liquefied Natural Gas (LNG) and pipeline-based natural gas imports, while introducing more nuclear and renewable energy. Energy demand, particularly fossil fuel demand, is predicted to continue expanding in the world including Asia. How the unevenly distributed fossil fuel resources will be provided to the points of demand, in a stable manner, is expected to become an increasingly important challenge.

This study used a group of models including an econometric model to analyze energy supply and demand in Asia and other regions of the world through 2035, based on past actual data and latest energy policy trends. The study focused particularly on the relationship between Asia, currently expanding its presence as a large energy consumer. The study provided a quantitative assessment of the fossil fuel supply and demand to project a picture of their future relationship.

## 2 Scenarios

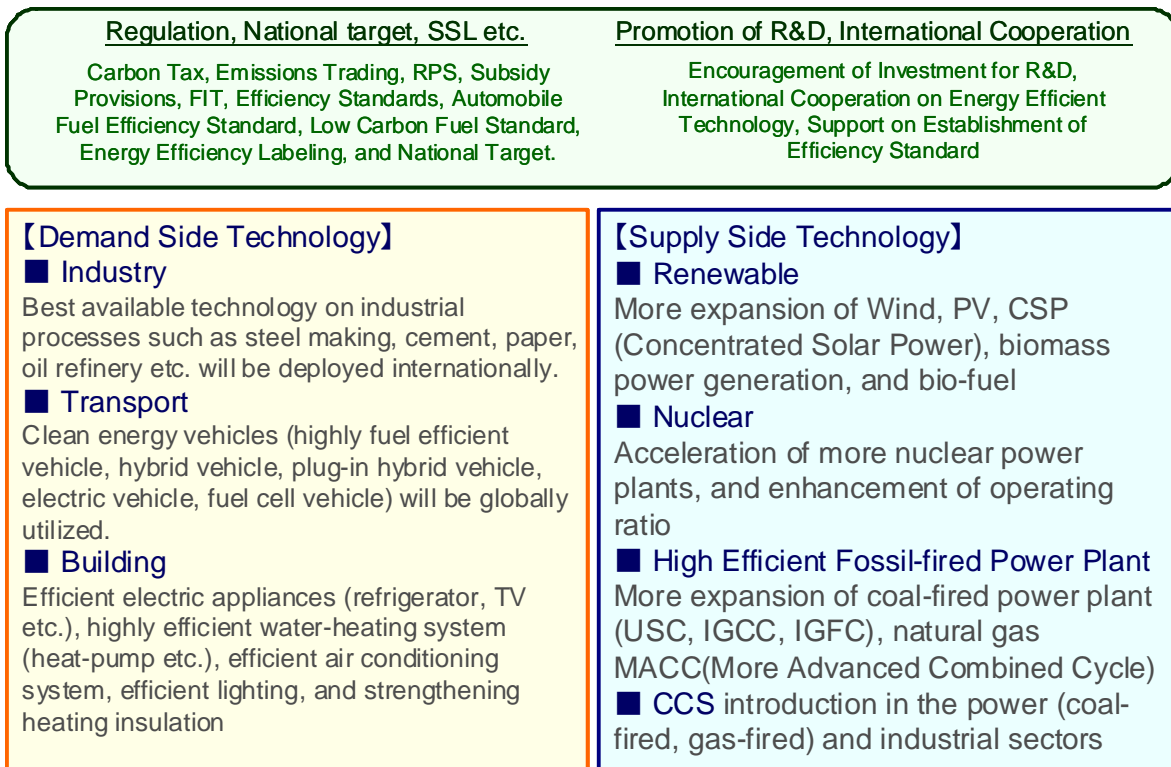
### 2.1 Reference Scenario and Technologically Advanced Scenario

In this study, two scenarios are developed: the Reference Scenario and the Technologically Advanced Scenario. The Reference Scenario assumes highly probable deployment of energy policy and energy technology based on current economic and political situations, which yields normative future evolution of energy demand and supply, whereas in the Technologically Advanced Scenario, (Tech. Adv. Scenario) advanced low-carbon technologies become even more widespread around the world at the back of the promotion of international technology transfers mainly from developed countries to developing countries.

The Technologically Advanced Scenario is prepared to analyze how the global energy demand and supply can be evolved if countries are to adopt all the policies currently considered regarding energy security, CO<sub>2</sub> emissions, and technology transfer. This analysis aims to understand how far those policies and technological development can take us in dealing with energy and environmental challenges. Many of the policies considered in the Technologically Advanced Scenario lead to faster deployment of more efficient and less carbon emitting technologies. As the low-carbon emitting technologies are deployed under the national policies, they will be globally available with the lower cost than in the Reference Scenario, and then, those technologies will be deployed earlier by the larger numbers of countries and areas than in the Reference Scenario. This approach provides insights into the potential energy saving and CO<sub>2</sub> emissions reduction achieved by improving and introducing the technologies that are existing and will be put to the practical use by 2035. In general, the energy efficiency will be developed at higher rate in the developing countries, particularly in Asia, than in the developed countries. The fact reflects that there are larger potential of improving the energy efficiency, and the investments in the capital stocks can be more expected in those regions than in the OECD.

A number of technologies as well as policies are assumed in the Technologically Advanced Scenario as shown in Figure 2-1.

Figure 2-1 Energy-related Technologies Considered in the Technologically Advanced Scenario

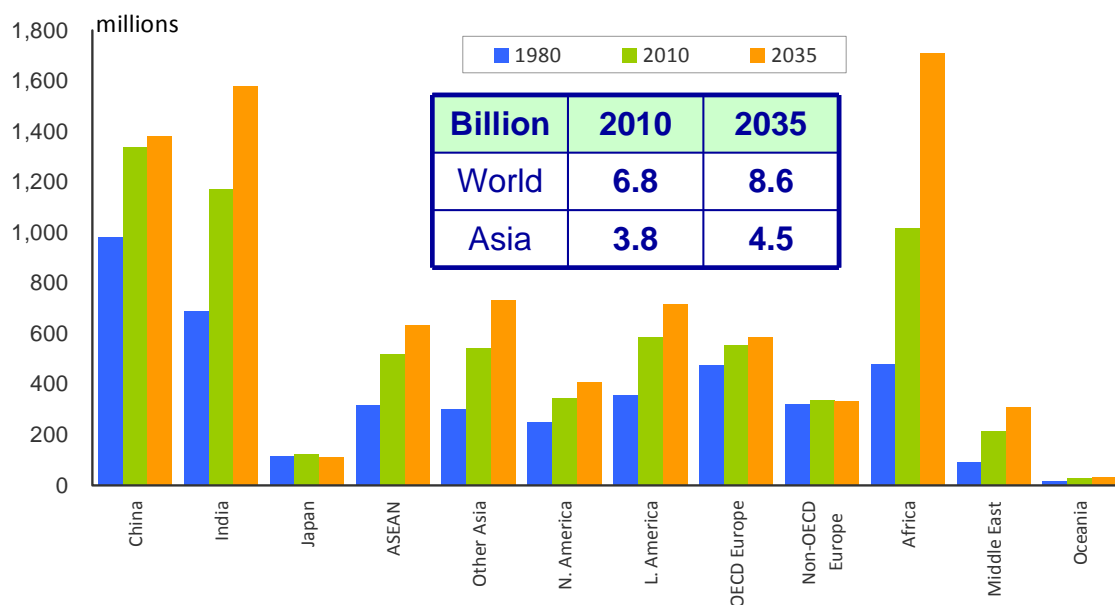


## 2.2 World Economic Growth and Population

### 2.2.1 Population

We referred to the latest United Nations projections for population growth shown in Figure 2-2.

Figure 2-2 Population



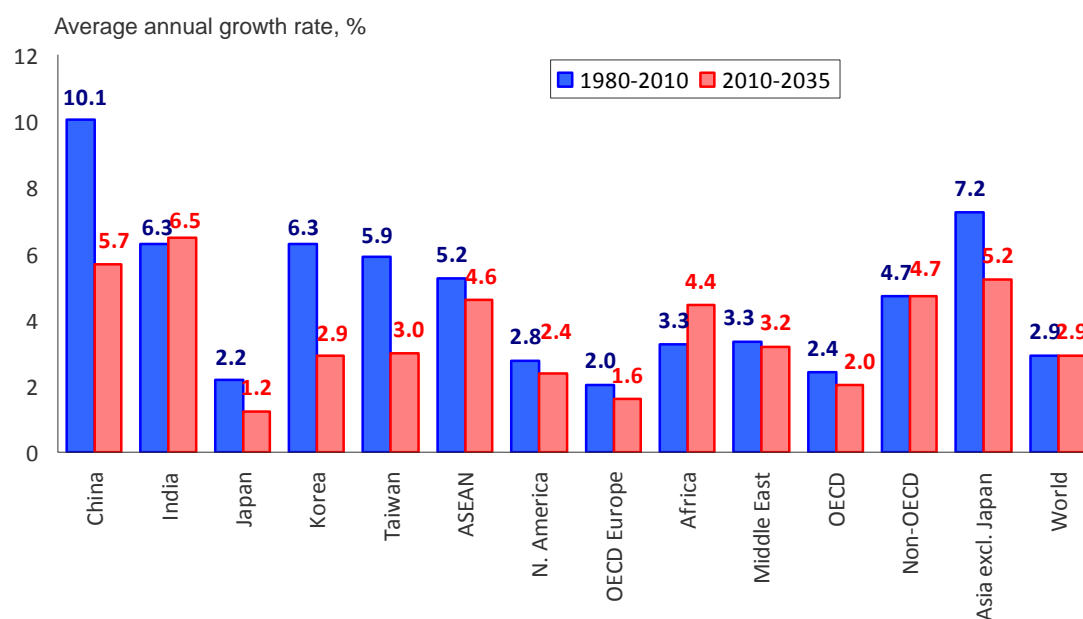
In many OECD (Organisation for Economic Co-operation and Development) countries where the total fertility rate has slipped below 2, downward pressures on population will increase. Even in non-OECD countries, the total fertility rate is following a downward trend in line with income growth. But global population is expected to increase at an average annual rate of some 1% due to developing medical technologies and improving food and sanitation conditions. As a result, global population is projected to increase from 6.8 billion in 2010 to 8.6 billion including 4.5 billion in Asia by 2035.

Non-OECD countries will account for 1.6 billion of the global population growth of 1.8 billion through 2035. Particularly, Africa and the Middle East will experience rapid growth in population. Asian population growth will decelerate as some countries see rapidly aging population. China's population will peak around 2030, while India will retain high population growth and replace China as the world's most populated country by around 2020.

### 2.2.2 Economic Growth

In assuming GDP growth, we referred to economic outlooks by international organizations such as the Asian Development Bank and the International Monetary Fund as well as economic development plans released by national governments. The world economy, which has been flagging since the Lehman Shock, is here assumed to get back on a growth path over a medium to long term. Asian emerging countries, including China that has already realized powerful economic growth, are not expected to see growth as tremendous as in the past. But Asia is assumed to outdo other regions in economic growth and increase its presence in the world economy. Specific assumptions are given in Figure 2-3.

Figure 2-3 Economic Growth Assumptions (annual, %)



The world economy will grow at an annual rate of 2.9% between 2010 and 2035, the same pace as seen in the past 25 years. While OECD countries will see their growth limited to a 1.0-3.0% range, non-OECD countries will achieve growth in a 4.5-5.0% range thanks to sharp increases in population and per capita GDP. As a result, OECD countries' share of the world economy will decline from the current 72% to 58% in 2035.

Asian economies other than Japan will grow at an annual rate of 5.2%. Their GDP in 2035 will increase about 3.5-fold from 2010. Asia will account for 40% of the global GDP growth over the next 25 years and its share of the world economy will expand from 17% in 2010 to 29% in 2035.

China, now the world's second-largest economy, will gradually shift from an investment/export-oriented economy to a consumption-oriented economy over a medium to long term and see a gradual productive population fall amid the aging of its population. Its average annual growth is assumed at 5.7% as growth is expected to moderately decelerate through 2035. Meanwhile, India has a great consumption market growth potential for the future, primarily due to the low per capita income and wide rich-poor gaps at present. As younger generations' share of the total population in India is higher than in aging China, India can expect a population bonus for production over a long term. Its annual average growth rate through 2035 is assumed at 6.5%. Per capita GDP in 2035 will still be limited to one-third of the Chinese level, indicating its further growth potential.

ASEAN (Association of Southeast Asian Nations) is expected to grow as a giant consumption market with its population of 600 million exceeding, the European Union's population. At the same time, rising personnel costs and emerging risks in China will make ASEAN's cheaper and abundant labor more valuable as a production base. Less-developed ASEAN countries are about to launch economic development, invigorating the entire ASEAN economy. ASEAN is assumed to grow at an annual rate of 4.6% through 2035.

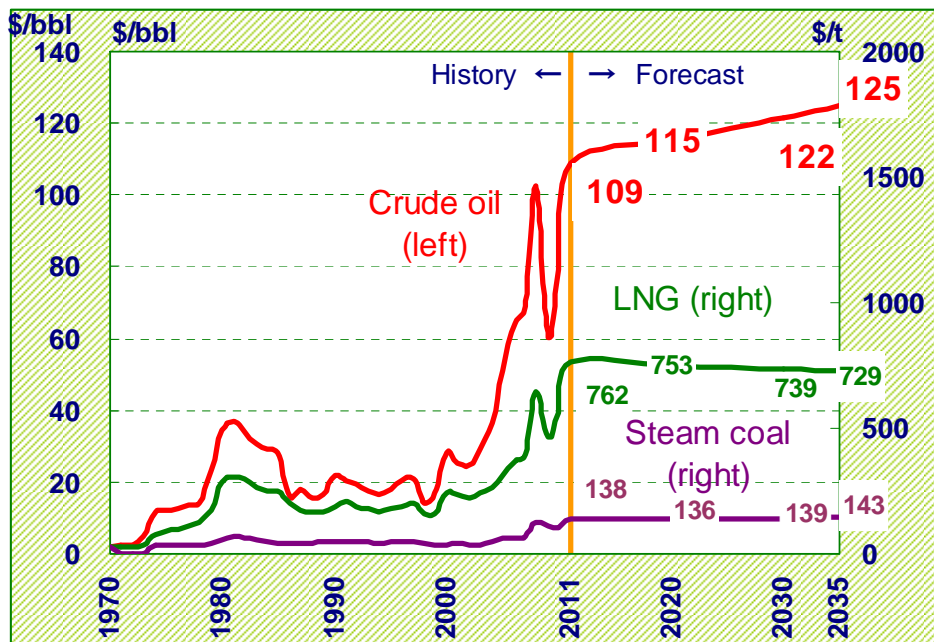
### 2.2.3 Energy Prices

Crude oil prices hit a record high close to \$150 per barrel in the middle of 2008 and plunged close to only \$30/bbl in the next several months, before rising again later. Despite the Europe-based economic crisis casting a dark shadow on the world at present, crude oil prices maintain high levels around \$110/bbl due to by-effects of monetary easing and influences of speculations and investment funds.

While mainly conventional oil is expected to continuously cover the future global oil demand increase, Canadian oil sand, U.S. shale oil, Brazilian pre-salt oil and other oil resources that had been unsuitable for commercial production have begun to play key roles in the market. In the future, oil production is also expected to shift to small and medium-sized oil fields, polar areas, deep-water oil fields and other points where production costs are relatively higher. Given the past history, no powerful regulations are likely to be introduced on excessive fund flows into the oil futures market. Speculations and investment funds can be expected to continue boosting

crude oil prices. Given these factors, crude oil prices are assumed to increase their short-term fluctuations and slowly rise over a medium to long term (Figure 2-4).

Figure 2-4 Energy prices (2011price USD)



The LNG pricing method for Japan is assumed to remain linked to crude oil import prices. But LNG’s relative prices with oil prices are expected to fall over the medium to long term, in line with expanding production of unconventional natural gas and increasing pipeline gas supply for Asia. Meanwhile, U.S. natural gas prices, which have recently sharply fallen due to rising shale gas production, are assumed to rise over the medium to long term, helping narrow the interregional gas price gaps.

Coal prices have so far featured more moderate fluctuations than crude oil and natural gas prices. For the future, coal prices are assumed to slowly increase on a global demand hike. If a carbon tax is imposed on coal prices to help prevent climate change, however, consumer coal prices may rise far more sharply than international prices.

## 3 Energy Outlook in the World/Asia

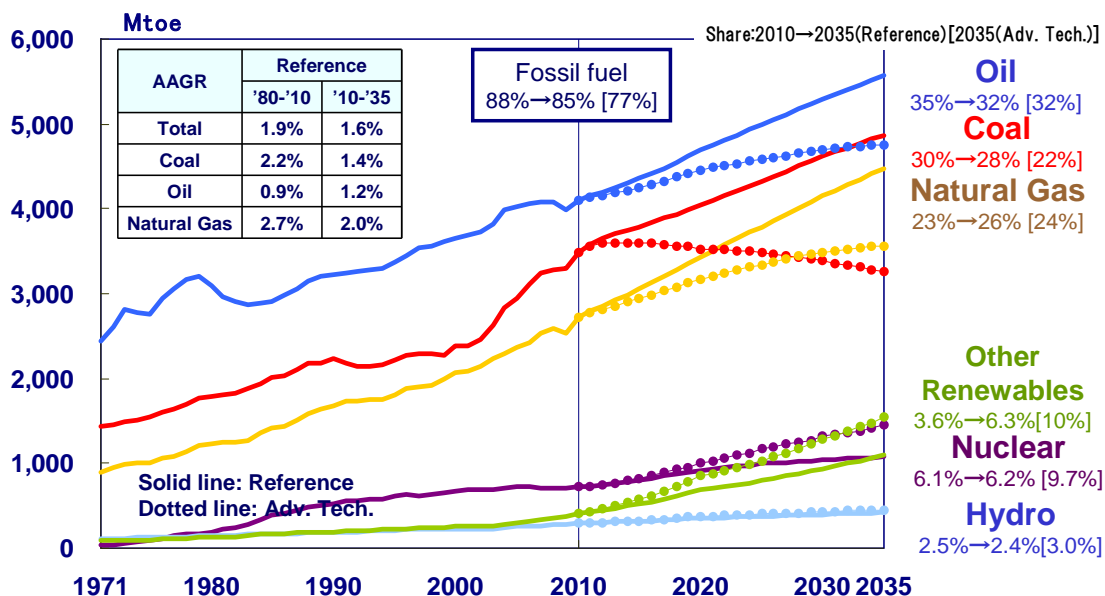
### 3.1 Primary Energy Demand

#### 3.1.1 Primary Energy Demand by Source

Global primary energy consumption will increase about 1.5-fold from 11,743 Mtoe in 2010 to 17,517 Mtoe in 2035 (Figure 3-1). During the coming period, energy efficiency and conservation will accelerate from the pace of the past two decades, allowing energy consumption growth (at an annual rate of 1.6%) to slip below economic growth (at an annual rate of 2.9%). The annual energy demand growth will amount to a half of Japan's present level or one-third of the level for the entire Middle East, indicating that the world will continue to need massive amount of energy in the future. Expected national energy policies and energy conservation technology development and diffusion alone may fall far short of further decoupling energy demand growth from economic growth.

At present, fossil fuels (oil, coal and natural gas) account for about 90% of primary energy consumption. As some 80% of future energy consumption growth will be covered by fossil fuels, the world will remain heavily dependent on fossil fuels even in 2035. Oil will maintain the largest share of primary energy supply, being followed by coal as at present. But the world will gradually reduce its dependence on oil. Natural gas will experience the largest consumption growth over the coming 25 years and will expand substantially in terms of both final consumption and power generation. In 2035, as a result, oil, coal and natural gas will be close to having almost the same shares of total primary energy consumption.

Figure 3-1 Global Primary Energy consumption (by energy source)



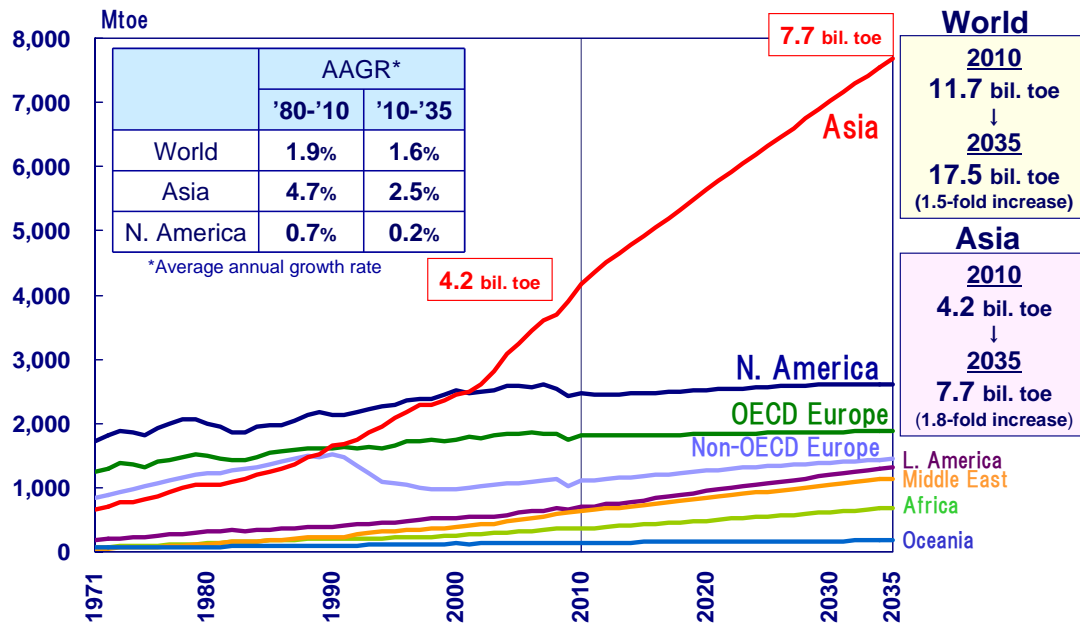
#### 3.1.2 Primary Energy Demand by Region

While global energy consumption will increase through 2035, consumption growth will differ



from region to region (Figure 3-2). While OECD countries will expand energy consumption only slightly, non-OECD countries will continue to substantially boost energy consumption and account for about 90% of the global increase. As a result, non-OECD countries' share of global energy consumption will increase from 53% at present to 66% in 2035.

Figure 3-2 Global Primary Energy Consumption (by region in the Reference Scenario)



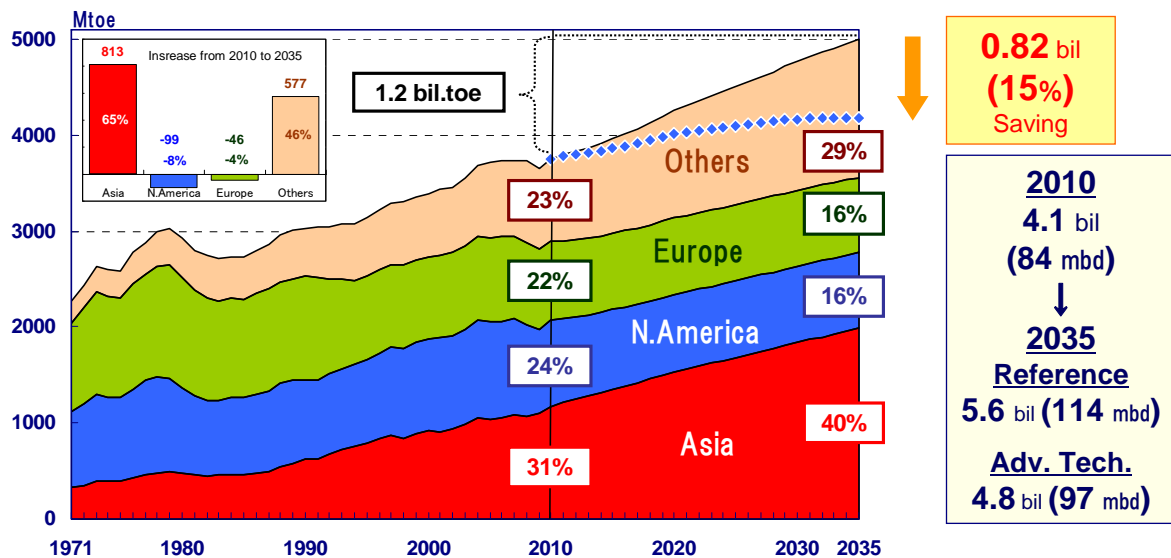
Asian energy consumption will increase 1.8-fold during the next 25 years. China has replaced the United States as the world's largest energy consumer and will consume 1.7-fold more energy than the United States that will be the second largest energy consumer in 2035. India's energy consumption is now almost equal to Japan's consumption and will expand 2.6-fold. India will thus become the third largest energy consumer following China and the United States. While Asia will increase its presence in the world economy more and more, the region, which is less energy efficient and consumes more energy than indicated by its economic size, will exert greater adverse and favorable influences on the international energy market. In Asia, Japan will be the only country reducing its primary energy consumption.

### 3.2 Oil demand

World oil demand will increase from 84 million b/d in 2010 to 114 million b/d in 2035 at an annual rate of 1.2% (Figure 3-3). By region, about 60% of this increase will be derived from Asia. By sector, 60% of this increase will come from the transport sector. The oil demand of OECD has kept decreasing since 2005 and in the future, it will decrease at an annual rate of 0.5% from 2010 to 2035. On the other hand, Non-OECD will increase its oil demand at 2.4% per annum. The share of OECD in world's oil demand will drop from 52% in 2010 to 35% in 2035. That of Non-OECD will rise to 65% in 2035. Asia is projected to expand the share of oil demand from 31% in 2010 to 40% in 2035.

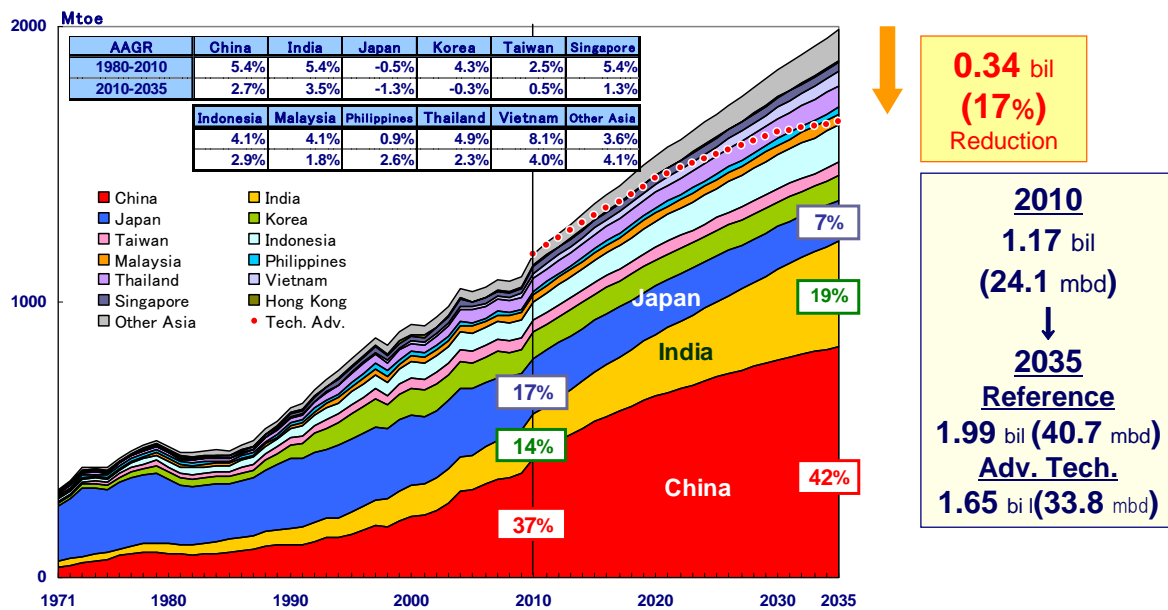
The share of oil in the world's primary energy demand will be on the decreasing trend from 35% in 2010 to 32% in 2035. Despite this, the share of oil represents the largest in the primary energy demand in 2035. In the Tech. Adv. Scenario, by 2035 oil saving (calculated as difference between the Tech. Adv. Scenario and Reference Scenario) will account for 0.82 Btoe (15%).

Figure 3-3 Oil Demand by Region (World)



Asian oil demand will increase from 24.1 million b/d in 2010 to 40.7 million b/d at 2.1% per year (Figure 3-4). By country, China and India will account for 50% and 30% of oil demand growth in Asia, respectively. By sector, the transport sector will account for 70% of this increase, and the building and agriculture sectors combined will account for 20%. The share of oil in primary energy demand will slightly drop from 28% in 2010 to 26% in 2035.

Figure 3-4 Oil Demand by Country (Asia)



In the Reference Scenario, the world oil demand will reach 114 million b/d in 2035, while in the Tech. Adv. Scenario oil demand is expected to account for 97 million b/d in 2035 (15% lower than Reference Scenario). In the Tech. Adv. Scenario, oil demand in Asia will continue to grow, reaching 33.8 million b/d by 2035 (17% lower than in the Reference Scenario). This oil saving in Asia is expected to take place in the transport sector because of fuel efficiency improvement, biofuel diffusion, and rapid deployment of clean energy vehicles.

Oil production from Non-OPEC countries like Latin America and Russia are projected to slow because of resources constraints, while at the back of large-scale reserves and low production cost, OPEC’s oil production will increase to 52.6 million b/d in 2035 expanding OPEC’s share in the world oil production to 46% in 2035 (Table 3-1). With this production growth, OPEC will be responsible for 70% of the world’s incremental oil production growth over the outlook period.

Table 3-1 World Oil Production Outlook

(Mb/d)

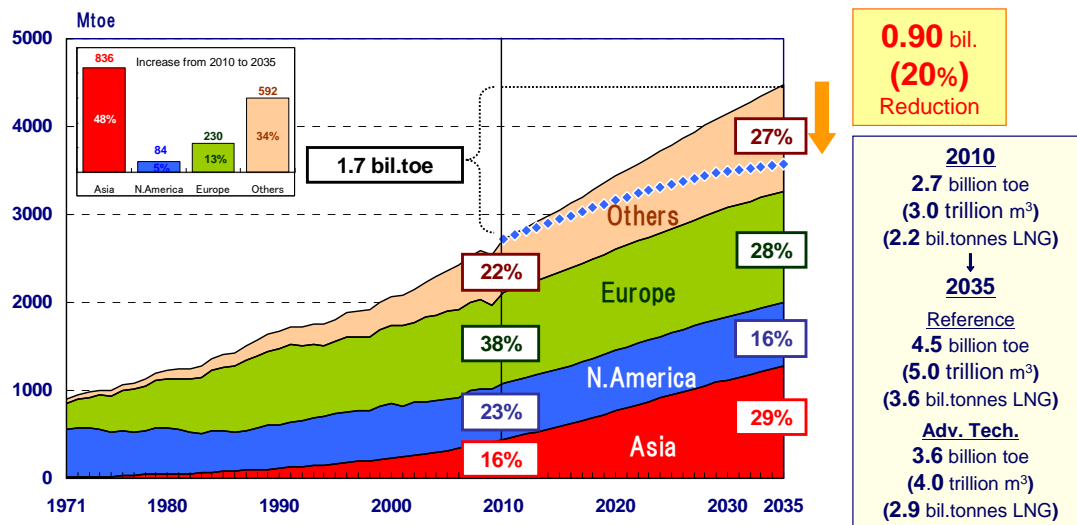
	2011	Reference scenario			Advanced technology scenario		
		2020	2035	2011-2035	2020	2035	2011-2035
<b>World</b>	<b>86.6</b>	<b>96.2</b>	<b>114.2</b>	<b>+27.6</b>	<b>91.3</b>	<b>97.4</b>	<b>+10.8</b>
<b>OPEC</b>	<b>35.7</b>	<b>42.0</b>	<b>52.6</b>	<b>+17.0</b>	<b>39.5</b>	<b>43.6</b>	<b>+8.0</b>
Middle East	27.2	29.9	37.7	+10.5	28.6	32.3	+5.1
Other OPEC	8.5	12.2	15.0	+6.5	11.0	11.4	+2.9
<b>Non-OPEC</b>	<b>48.8</b>	<b>51.9</b>	<b>58.9</b>	<b>+10.1</b>	<b>49.6</b>	<b>51.3</b>	<b>+2.5</b>
N. America	14.6	15.8	17.9	+3.3	15.6	16.9	+2.3
L. America	4.2	5.8	7.1	+2.9	5.1	5.6	+1.4
Europe (inc. Russia)	17.5	17.9	21.3	+3.8	16.9	17.3	-0.2
Middle East	1.7	1.6	1.6	-0.0	1.6	1.5	-0.2
Africa	2.6	2.9	3.4	+0.8	2.8	3.1	+0.5
Asia	8.3	7.9	7.6	-0.7	7.6	6.9	-1.4
China	4.1	4.0	4.0	-0.1	3.9	3.8	-0.3
Indonesia	0.9	0.9	0.9	-0.0	0.8	0.7	-0.2
India	0.9	0.7	0.7	-0.2	0.7	0.6	-0.3

### 3.3 Natural gas demand

The world natural gas demand was 3.0 trillion cubic meters in 2010. The world natural gas demand is expected to grow to 5 trillion cubic meters by 2035 with an annual growth rate of 2.0%, a faster rate than that of coal and oil (Figure 3-5). Of the incremental growth in the world natural gas demand from 2010 to 2035, Asia is expected to account for 48%, while Europe will account for 13%.

In the Tech. Adv. Scenario, the world natural gas demand in 2035 will reach 4.0 trillion cubic meters (or 20% lower than the Reference Scenario), and Asia's natural gas demand in 2035 will reach 1.2 trillion cubic meters (or 19% lower than Reference Scenario). Despite lower projected demand, even in the Tech. Adv. Scenario, natural gas is expected to continue growing, and this suggests the need for resources and infrastructure development to meet demand growth.

Figure 3-5 Natural Gas Demand by Region (World)

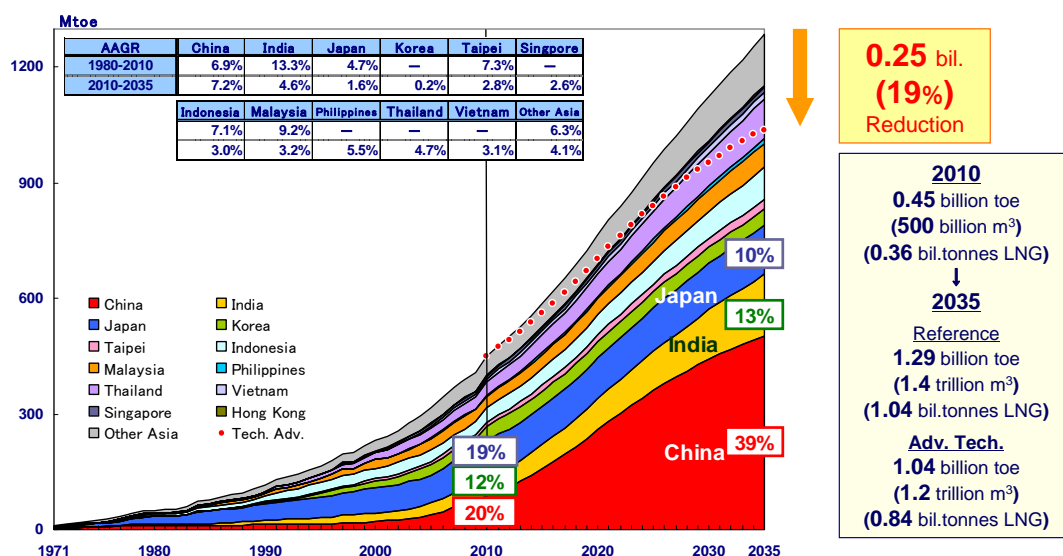


The share of OECD in world natural gas demand is expected to decrease to 35% in 2035 from 48% in 2010. On the other hand, the share of non-OECD will increase from 52% in 2010 to 65% in 2035.

With the expected increase in the use of Combined Cycle Gas Turbine for power generation, the share of natural gas in the world power generation will reach 26% in 2035 from 23% in 2010. And the power sector will account for 50% of the incremental growth in global natural gas demand from 2010 to 2035, while the combined total demand for the residential, commercial and agriculture sector will be responsible for 30%.

In Asia, natural gas demand will increase to 1.4 trillion cubic meters in 2035 from 0.50 trillion cubic meters in 2010 (Figure 3.6). Natural gas is expected to grow at 4.3% – a faster rate than coal and oil. In Asia, the share of natural gas demand in total primary energy demand is expected to increase to 17% in 2035 from 11% in 2010.

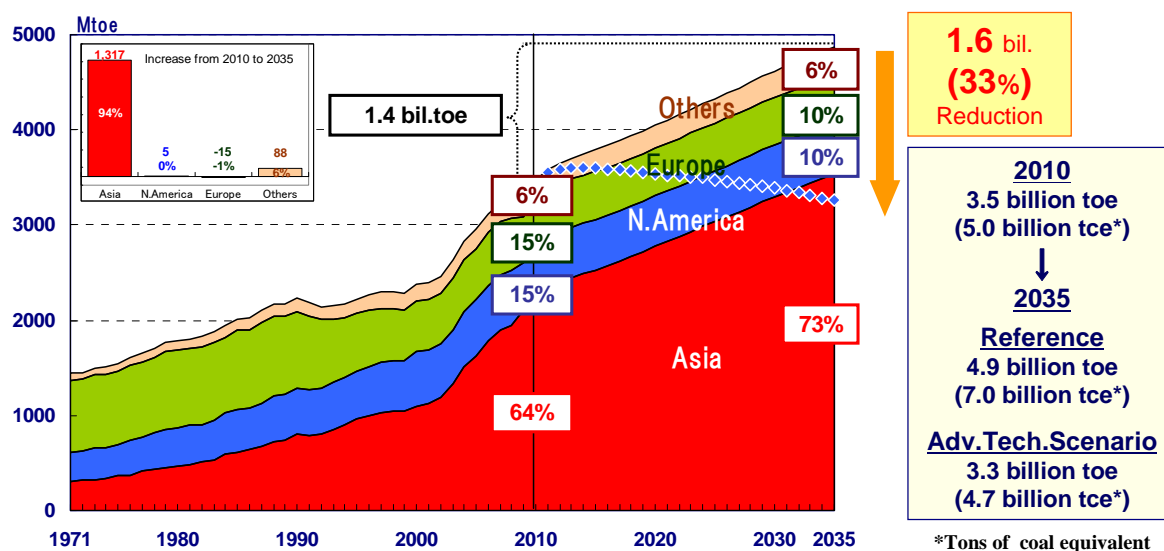
Figure 3-6 Natural Gas Demand by Country (Asia)



### 3.4 Coal demand

The world coal demand is expected to grow to 7.0 billion tons of coal equivalent (tce) by 2035 from 5.0 billion tce in 2010 with average annual growth rate of 1.4% (Figure 3-7). By region, Asia will account for 90% of the world coal demand growth, and China alone will be responsible for 40%. The share of OECD in the world coal demand is expected to decrease to 22% in 2035 from 31% in 2010. By contrast, the share of Non-OECD will increase from 69% in 2010 to 78% in 2035.

Figure 3-7 Coal Demand by Region (World)

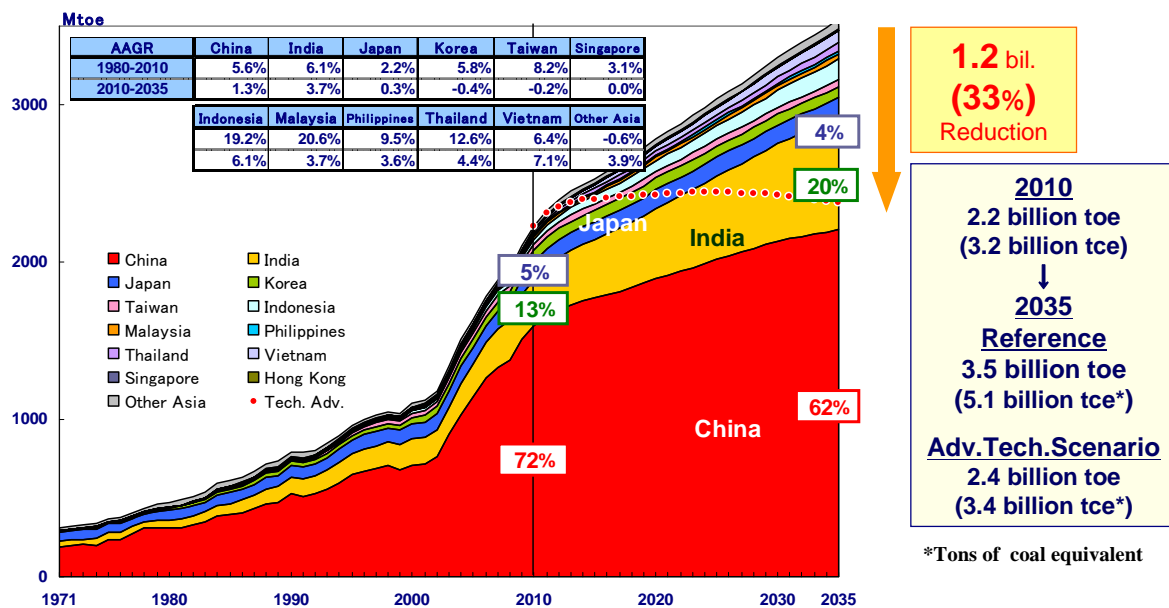


By sector, the power sector will account for nearly the entire increase in coal demand through 2035. The share of coal in the world primary energy demand is expected to maintain 28% through 2035, being an important energy source after oil toward 2035.

In Asia, coal demand will increase to 5.1 billion tce in 2035 from 3.2 billion tce in 2010 with an annual growth rate of 1.9% (Figure 3-8). China will be responsible for about 50% of Asian coal demand growth through 2035, and India 30%, too. By sector, the power sector will account for 90% of incremental growth in Asian in coal demand from 2010 to 2035. The share of coal in primary energy demand will decrease from 54% in 2010 to 46% in 2035, but coal will keep the largest share in primary energy demand.

In the Tech. Adv. Scenario, the world coal demand in 2035 is expected to reach 4.7 billion tce, which is 2.3 billion tce or 33% less than the Reference Scenario. Similarly, coal demand in Asia will be substantially lower in the Tech. Adv. Scenario (by 33%) to reach 3.4 billion tce, with the fuel switching and efficiency improvement in the power sector. In terms of growth rate, Asia's coal demand is projected to increase at 0.3% per year through 2035 (down 1.6% points from the Reference Scenario). Most of the saving in primary coal demand is derived from power generation, with the fuel switching and generation efficiency improvement.

Figure 3-8 Coal Demand by Country (Asia)



### 3.5 Electricity Supply and Demand

#### 3.5.1 Electricity Demand

In line with economic development, income growth and advancing energy consumption, global electricity consumption will increase from 17,860 TWh in 2010 to 32,190 TWh. Electricity's share of final energy consumption will expand by 4% from 20%.

OECD countries account for 52% of global final electricity consumption at present. But non-OECD countries will post rapid growth in electricity consumption, as symbolized by China that is now the second largest electricity consumer in the world and will expand electricity consumption by 1,640 TWh in 10 years to 2020. The projected expansion exceeds a combination of present British, German, French and Italian consumption. In several years, the OECD world's share will slip below that of the non-OECD world. Similarly, China will replace the United States as the world's largest electricity consumer in several years and boost electricity consumption in 2035 to 7,500 TWh, more than 1.5 times as much as U.S. consumption in the year. India will raise electricity consumption at an annual rate of 6.0% to 3,080 TWh. Other non-OECD countries will also increase electricity consumption substantially. Non-OECD countries will account for 80% of a global electricity consumption increase through 2035. In the advanced technology scenario, electricity consumption in 2035 will fall by 14% from the reference scenario to 27,680 TWh thanks to massive energy conservation in industrial and residential/commercial sectors.

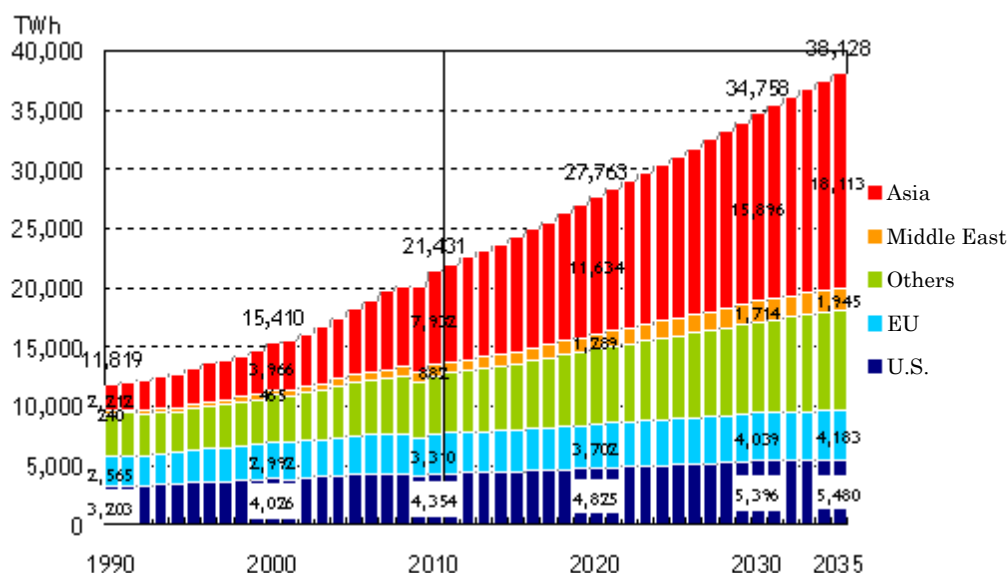
As seen in the past, economic expansion and income growth have backed up an increase in electricity consumption and energy conservation efforts have failed to completely offset the increase or drag down electricity consumption. One reason for this phenomenon is that

electricity is a very convenient energy source and can lead to an increase in machines that use electricity as a power source or an energy source for control. Another reason is that energy conservation technologies include integrated coal gasification combined cycle (IGCC) systems, plug-in hybrid vehicles, heat pumps and many others that additionally consume electricity instead of saving more fuel consumption than represented by an electricity consumption increase.

### 3.5.2 Power generation mix

In response to the electricity demand expansion, global electricity generation will increase from 21,430 TWh in 2010 to 38,130 TWh in 2035 (Figure 3-9). But a decline in the electricity consumption rate for power stations and in the electricity transmission and distribution loss rate will allow the annual electricity generation growth rate at 2.3% to slip below the final electricity consumption growth rate at 2.4%.

Figure 3-9 Global Electricity Generation (by region, reference scenario)



Non-OECD countries will account for more than 80% of the electricity generation growth through 2035. Asian electricity generation will increase at an annual rate of 3.4% from 7,930 TWh in 2010 to 18,110 TWh in 2035. As electric grid enhancement makes progress in response to an expansion in volatile renewable energy (wind power, photovoltaics, etc.) generation, cross-border trade in electricity may increase. Some ASEAN countries have plans to develop rich hydroelectric resources for exporting electricity to earn foreign currencies.

Of the present global electricity generation, coal accounts for the largest share at 41%, followed by 22% for natural gas, 16% for hydro and 13% for nuclear. Through 2035, coal will retain the present level, continuing to serve as a mainstay electricity source (Figures 3-10 and 3-11). Particularly, coal thermal power generation will remain a mainstay electricity source



responding to rapid electricity demand growth in China and India. In 2012, Indonesia began to operate the Cirebon steam power plant as its first supercritical coal power plant, indicating that non-OECD countries will improve coal power generation efficiency.

Figure 3-10 Global Electricity Mix

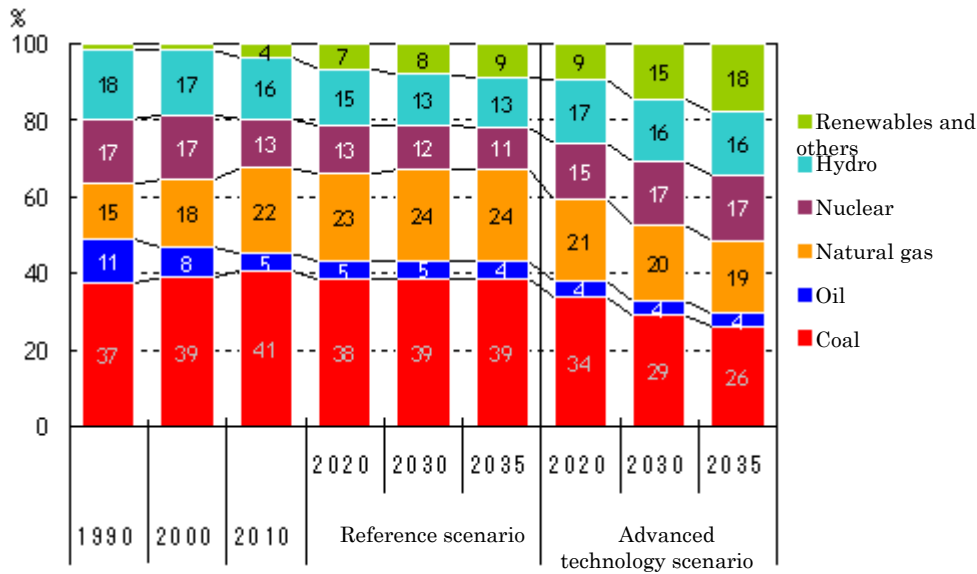
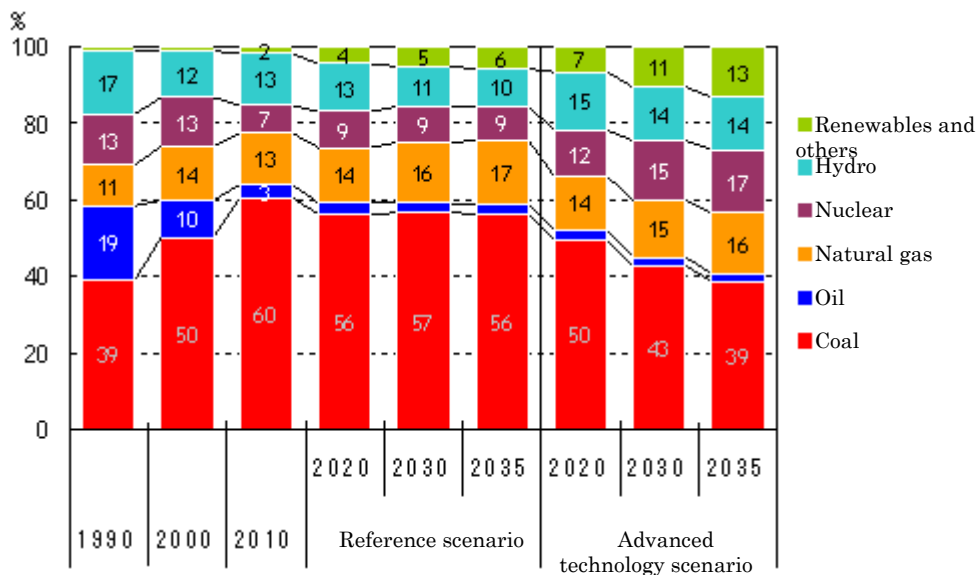


Figure 3-11 Asian Electricity Mix



A shift to natural gas will make progress as combined cycle gas turbines (CCGTs) diffuse thanks to technological development and as gas turbines are used for adjusting volatile

renewable energy generation. The share for natural gas will thus expand from 22% in 2010 to 24% in 2035.

The share for oil will trend down in industrial countries and the oil-rich Middle East. Nuclear plant construction will make progress mainly in Asia as a measure to ensure energy security and prevent climate change. But any increase in nuclear power generation cannot be expected to cover an electricity demand rise through 2035. Nuclear's share of electricity generation will fall slightly from 13% in 2010 to 11% in 2035. Wind power, photovoltaic and other renewable energy generation will expand at an annual rate of 6.1% on the strength of policy support and cost reduction. The growth will be faster than any other electricity generation. Nevertheless, renewable energy's share of electricity generation in 2035 will be limited to 8.3%, slipping below 10%.

ASEAN has made a great shift from oil to natural gas as electricity generation fuel since the 1990s due to natural gas development in the Bay of Thailand and other locations. As natural gas production has hit a peak and gas demand emerged in other sectors than electricity generation, however, natural gas supply capacity for electricity generation has become short. Therefore, the ASEAN electricity generation mix will see a shift from natural gas to coal.

In the advanced technology scenario, electricity generation in 2035 will total 32,400 TWh, a substantial fall of 15% from the reference scenario. As nuclear and renewable energy are promoted, fossil fuels' share of electricity generation will decline. Coal's share will shrink from 39% in the reference scenario to 26%. The share will expand to 17% for nuclear and 34% for renewable energy. Zero-emission electricity sources will thus account for half of the total electricity generation.

### 3.5.3 Nuclear power

The Fukushima Daiichi nuclear power plant accident has directly affected nuclear energy policies not only in Japan but also in foreign countries including some European nations, prompting them to shift away from heavy dependence on nuclear energy. But the United States, France, Russia and South Korea that have proactively promoted nuclear power generation, as well as emerging countries like China and India, have made no change to their respective nuclear promotion policies aimed at securing stable energy supply, preventing global warming, and maintaining and enhancing international competitiveness through their nuclear industry development.

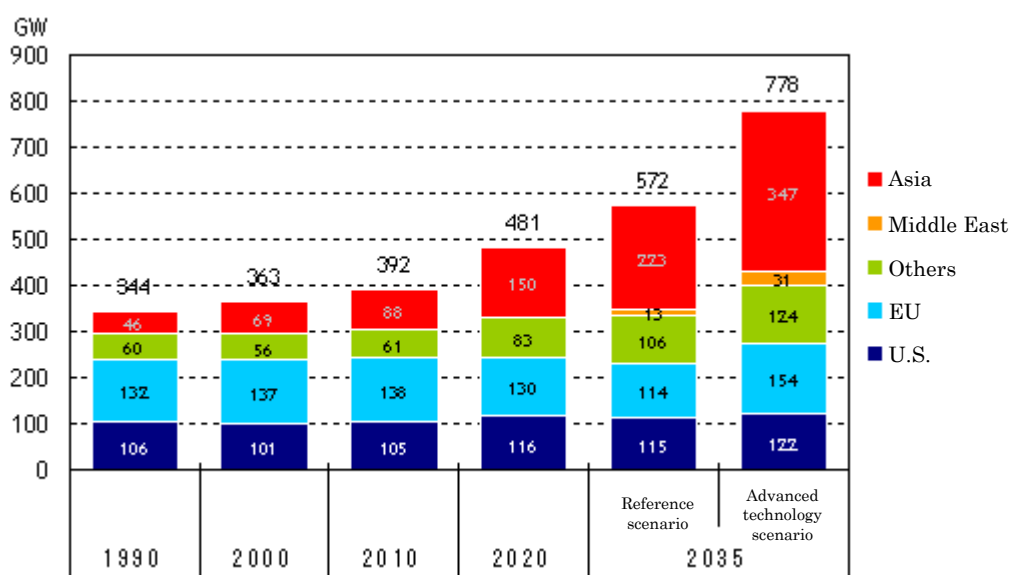
In North America, the United States is constructing five nuclear reactors for electricity generation despite a stall in many other nuclear reactor construction plans that were worked out amid the so-called Nuclear Renaissance. It also plans to improve output at existing reactors and lengthen their service life to more than 60 years. Including Canada with its nuclear technology for unique heavy water reactors, and Brazil and Argentina where new nuclear reactors are under construction, the Americas will gradually increase nuclear power generation capacity.

In Europe, France is expected to continue using nuclear energy despite the results of the 2012 presidential election. But Germany, Switzerland and Belgium plan to phase out nuclear energy. In the former Soviet Union, Russia and Ukraine have retained nuclear promotion policies and are expected to substantially expand nuclear electricity generation capacity.

China was operating 13 nuclear reactors with a total capacity of 10.85 gigawatts and constructing 30 reactors with a capacity of 33 GW before the Fukushima accident. The capacity under construction was three times as much as the existing capacity. China is expected to shortly lift a freeze imposed just after the accident on approval of new nuclear plant construction plans and expand its nuclear generation capacity at the fastest pace in the world. India has promoted a thorium cycle development program using domestic resources and plans to introduce massive light water reactors. Seven such reactors are already under construction.

In Southeast Asia, such countries as Vietnam, Thailand, Malaysia, Indonesia and the Philippines are considering introducing nuclear electricity generation. Vietnam has been proceeding with two nuclear plant construction plans in cooperation with Japan and Russia and made no change to its proactive nuclear promotion policy despite the Fukushima accident. In the other countries, however, nuclear introduction plans have tentatively been stalled. In the Middle East, the United Arab Emirates has launched nuclear plant construction and Saudi Arabia has come up with a plan to build 16 nuclear reactors by 2030. The region has been going ahead with nuclear plant construction plans, though with some delay.

Figure 3-12 Nuclear Electricity Generation Capacity



### 3.5.4 Renewable energy

Great expectations are placed on renewable energy including solar and wind energy. Renewable energy diffusion will accelerate thanks to rich resources and government incentives

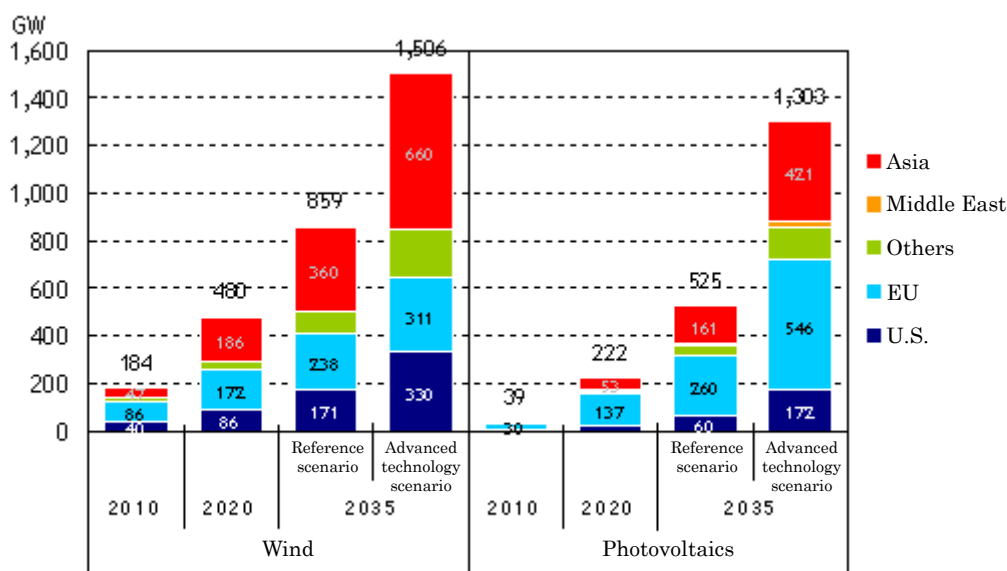
in some regions. But renewable energy-based electricity generation, which costs more and is volatile depending on natural conditions, will fall short of becoming a mainstay energy source rivaling fossil resources on a global scale.

Renewable energy diffusion may contribute to expanding low-carbon electricity sources, reducing dependence on energy imports and potentially holding down fossil fuel prices. Large-scale renewable energy diffusion may depend on reducing costs, improving efficiency and harmonizing renewable energy with energy systems through continuous research and development.

a. Photovoltaics

Photovoltaics have begun to diffuse very rapidly, mainly in Europe. The global photovoltaic market is likely to continue expanding at this pace (Figure 3-13). A major factor behind the rapid diffusion is government incentives. But cost cuts through the market expansion and technological development will help accelerate the diffusion. While photovoltaics still has economic efficiency problems, it is seen as a useful electricity source for non-OECD countries as well as depopulated areas in OECD countries. In the reference scenario, global photovoltaic electricity generation capacity will expand 14-fold from 39 GW in 2010 to 525 GW in 2035. Particularly, Europe and Asia will see rapid growth in photovoltaic electricity generation. In the advanced technology scenario where the diffusion will accelerate further, photovoltaic electricity generation capacity in 2035 will expand 33-fold from 2010 to 1,303 GW.

Figure 3-13 Wind and Photovoltaic Electricity Generation Capacity



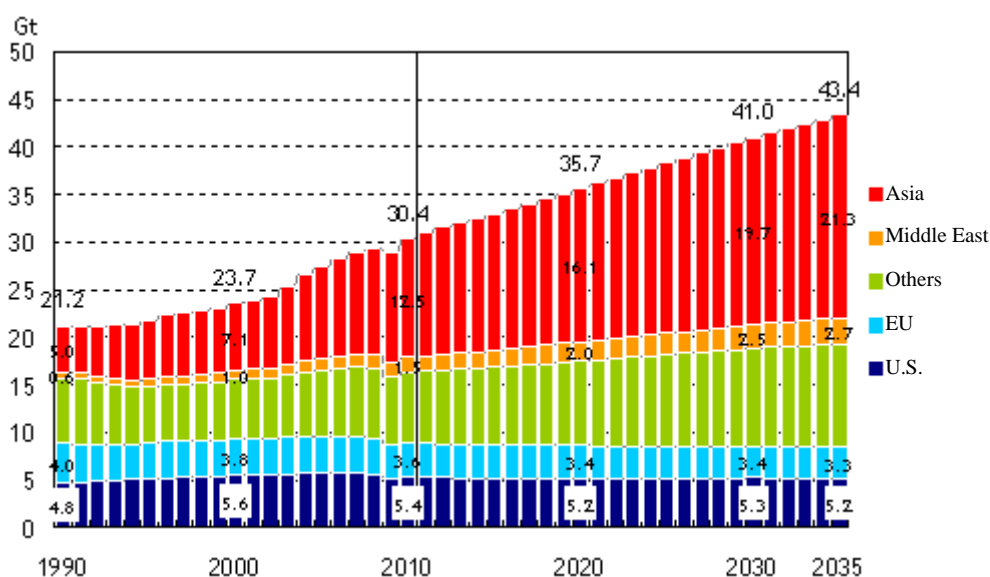
## b. Wind

Through 2035, mainly offshore wind electricity generation will diffuse in Europe including Germany, Spain and Denmark. The diffusion will also take place in China and India among Asian countries. In the reference scenario, wind electricity generation capacity will increase five-fold from 184 GW in 2010 to 859 GW in 2035. The diffusion will accelerate particularly in Europe, Asia and North America. In the advanced technology scenario where the diffusion will accelerate further, wind electricity generation capacity in 2035 will expand eight-fold from 2010 to 1,506 GW.

## 3.6 Outlook for CO<sub>2</sub> Emissions

As fossil fuel consumption accounts for about 80% of global primary energy consumption through 2035, carbon dioxide emissions will increase 1.4-fold from 30.4 Gt in 2010 to 43.4 Gt in 2035 (Figure 3-14). Of the increase, non-OECD countries will account for 96% and Asia for about 70%. Non-OECD countries' share of global CO<sub>2</sub> emissions will rise close to 70% in 2035. China will depend heavily on coal featuring a higher CO<sub>2</sub> emission factor to satisfy growing energy demand, accounting for about 30% of the global CO<sub>2</sub> emission growth.

Figure 3-14 Global CO<sub>2</sub> Emissions (by region, reference scenario)

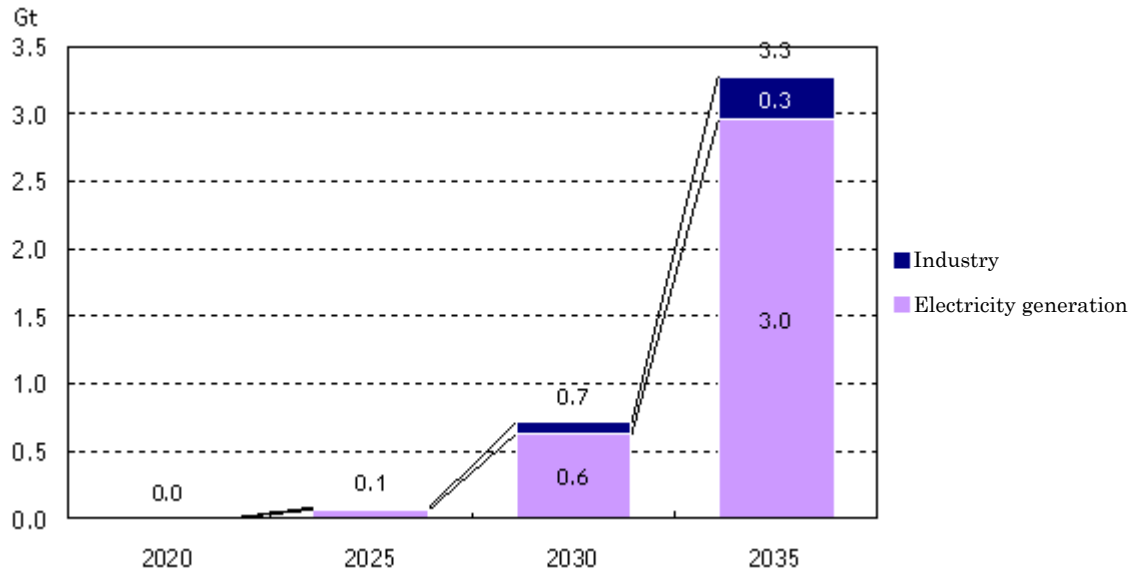


In the advanced technology scenario, global CO<sub>2</sub> emissions will increase to 32.3 Gt in 2020 but peak out by 2030 thanks to developing energy and environmental technologies. Emissions in 2035 will be 29.7 Gt, 13.7 Gt or 31% less than in the reference scenario.

In the advanced technology scenario, carbon capture and storage systems will be introduced from the 2020s (Figure 3-15). CCS systems will be introduced for part of new and existing coal thermal power plants, part of new gas thermal power plants and part of the industrial sector including the steel sector. Accumulated carbon capture and storage between 2020 and 2035 will

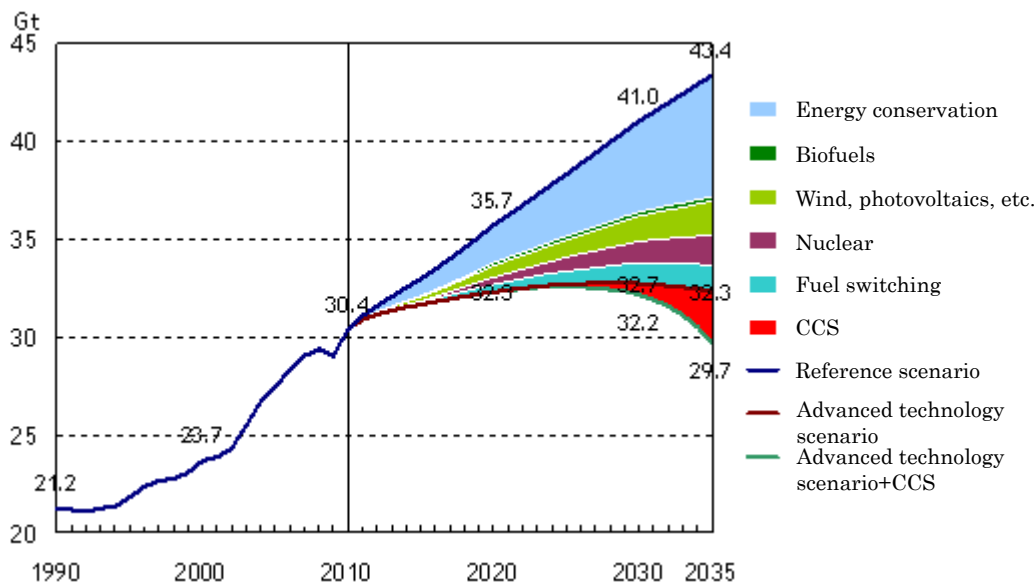
total 12 Gt. The world's geological carbon storage potential theoretically totals 10 Tt and the storage potential for depleted gas, oil and coal fields with test drilling data is estimated at 1 Tt. The world will have sufficient capacity to store the projected captured carbon.

Figure 3-15 CCS Capacity



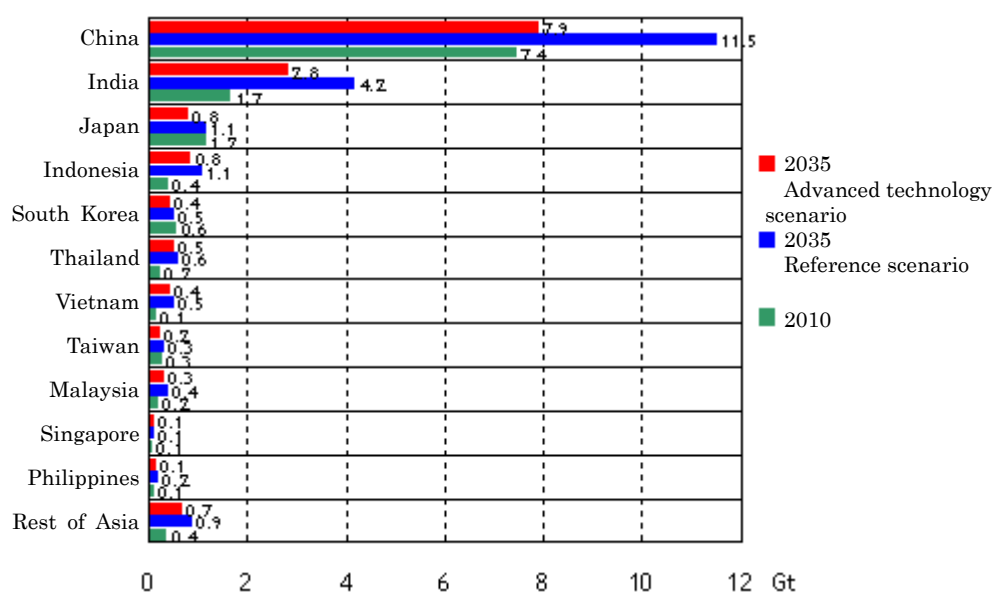
Of global CO<sub>2</sub> emission cuts at 13.7 Gt in 2035 in the advanced technology scenario, energy conservation accounts for 6.2 Gt, renewable energy for 1.7 Gt, nuclear energy for 1.6 Gt, fuel switching for 1.3 Gt and CCS systems for 2.6 Gt (Figure 3-16). Particularly, non-OECD countries will account for about 30% of global CO<sub>2</sub> emission cuts through energy conservation, indicating that technology transfers, institutional development and other energy conservation support measures for non-OECD countries will be very significant.

Figure 3-16 Changes in Global CO<sub>2</sub> Emissions (by technology)



In the advanced technology scenario, Asian CO<sub>2</sub> emissions will peak out in the second half of the 2020s as the low-carbon technology diffusion accelerates (Figure 3-17). Of the 2035 CO<sub>2</sub> emission gap between the advanced technology and reference scenarios, China will account for 3.6 Gt, or about 60% of the gap in Asia.

Figure 3-17 Asian CO<sub>2</sub> Emissions (by region, reference scenario)



There are no simple effective policies for reducing CO<sub>2</sub> emissions. Combining the main energy conservation policy with energy measures such as electricity generation efficiency improvements, non-fossil energy introduction, fuel switching and CCS systems will make great contributions to reducing CO<sub>2</sub> emissions.

## 4 Energy Outlook through 2050

The study projects energy demand and supply in a longer time horizon through 2050 and analyzes further diffusion of clean energy technology and assesses their impacts on global energy demand and supply, as well as CO<sub>2</sub> emissions reduction through developing both the reference scenario and the technologically advanced scenario.

### 4.1 Assumptions

Reflecting the slowing of growth of developing countries, the world GDP is projected to increase slowly from 2035 to 2050 at an annual rate of 2.1%, compared with the annual average growth of 2.6% between 2010 and 2035. The world population is projected to reach 9.3 billion in 2050, from 6.8 billion in 2010. Crude oil price will reach \$130/barrel in 2050, increasing from \$125/barrel in 2035, as a result of rising oil production cost.

Table 4-1 GDP, Population and Energy Price

	<b>2010</b>	<b>2035</b>	<b>2050</b>
<b>GDP</b> (2000 real price)	<b>42</b> tril. \$ (AAGR in 1990-2010:2.7%)	<b>86</b> tril. \$ (AAGR in 2010-2035:3.1%)	<b>118</b> tril. \$ (AAGR in 2035-2050:2.1%) (AAGR in 2010-2050:2.6%)
<b>Population</b>	<b>6.8</b> bil.	<b>8.6</b> bil. (1.8 bil. increase from 2010)	<b>9.3</b> bil. (2.5 bil. increase from 2010)
<b>GDP per Capita</b>	<b>6</b> thousand \$	<b>10</b> thousand \$	<b>13</b> thousand \$
<b>Oil Price</b> (On a Japanese CIF basis, 2011 real price)	(2011) <b>109</b> \$/bbl	<b>125</b> \$/bbl (Nominal price:210 \$/bbl)	<b>130</b> \$/bbl (Nominal price:281 \$/bbl)

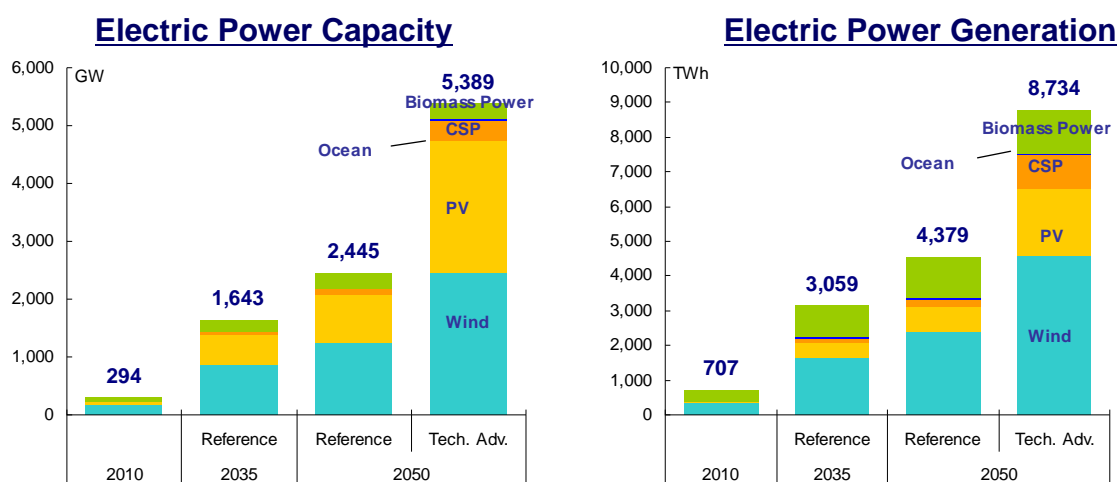
Various energy and environmental technologies are assumed to be introduced beyond 2035. Nuclear power installed capacity will expand from 390 GW in 2010 to 736 GW in 2050 under the Reference Scenario. The Technologically Advanced Scenario assumes further expansion of nuclear power installed capacity, reaching 1,085 GW in 2050. With respect to renewable energy sources, the world PV installed capacity will increase from 39 GW in 2010 to 824 GW in 2050 (the Reference Scenario), and will further be expanded to reach 2,261 GW in 2050 (the Tech. Adv. Scenario). By 2050, wind capacity will reach 1,254 GW (the Reference Scenario), and 2,456 GW (the Tech. Adv. Scenario) from 184GW in 2010.



Table 4-2 Assumed Energy and Environmental Technologies

	2010	2035		2050	
	Actual	Reference	Adv. Tech.	Reference	Adv. Tech.
Nuclear	389 GW	572 GW	778 GW	736 GW	1,085 GW
Conversion Efficiency	Coal:35% Gas:40%	Coal: 39% Gas: 45%	Coal: 41% Gas: 47%	Coal: 40% Gas: 47%	Coal: 43% Gas: 49%
Photovoltaic	39 GW	525 GW	1,303 GW	824 GW	2,261 GW
CSP	0.6 GW	51 GW	94 GW	94 GW	372 GW
Wind	184 GW	859 GW	1,506 GW	1,254 GW	2,456 GW
Biomass Power Gen.	71 GW	203 GW	226 GW	259 GW	279 GW
Biofuel	61 Mtoe	208 Mtoe	264 Mtoe	274 Mtoe	340 Mtoe
CCS	-	0	2.6 bil. Ton	0	10.0 bil. Ton
Adv. Vehicle in Annual Sales PHEV EV/FCV	-	5% 1%	20% 21%	10% 4%	16% 36%
Average Fuel Efficiency of new vehicle sales	(2010) 14 km/L	18 km/L	26 km/L	20 km/L	30 km/L

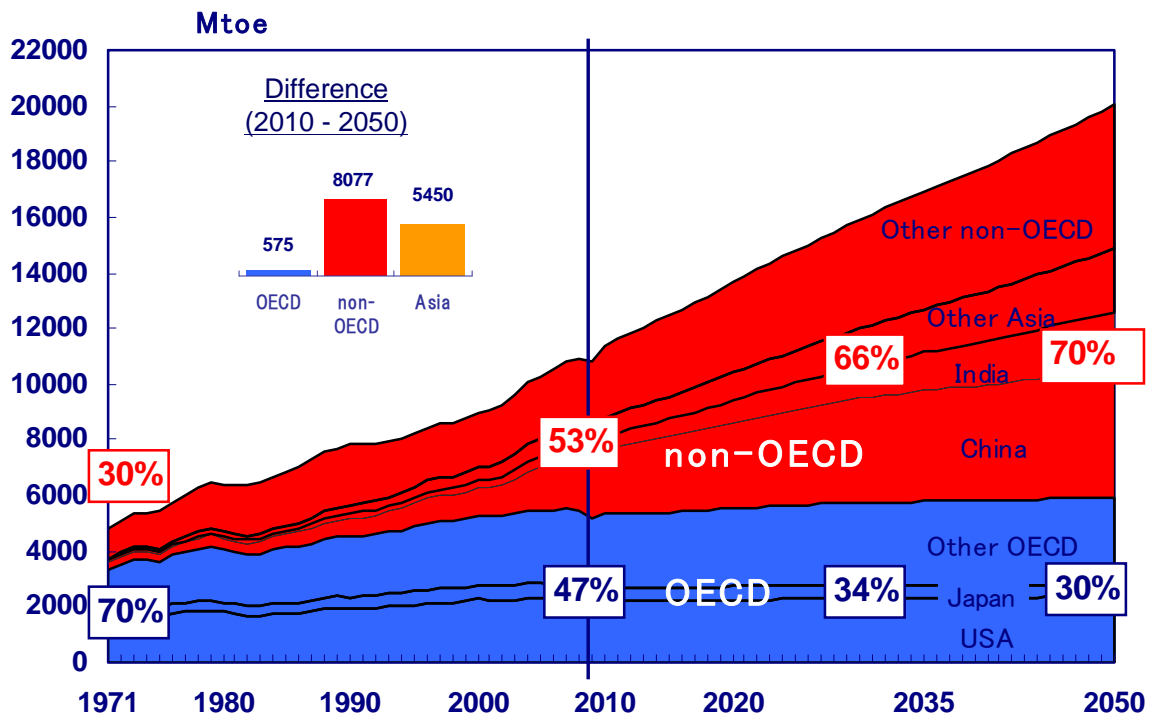
Figure 4-1 Renewable Power Generation Excluding Hydro (World)



## 4.2 Energy demand

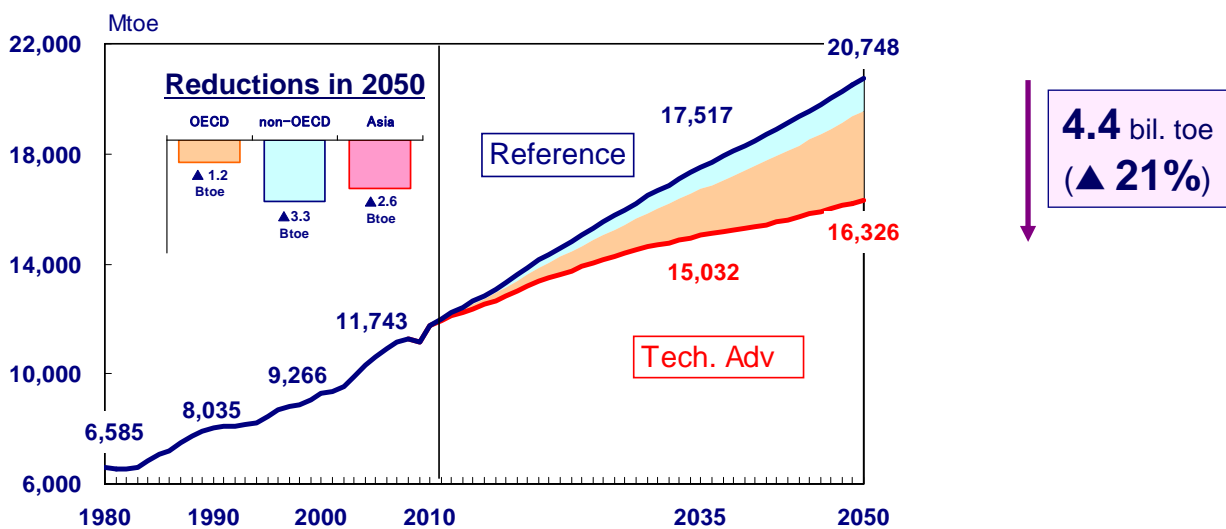
The world primary energy demand will expand from 11.7 Btoe in 2010 to 20.7 Btoe in 2050, showing a 1.8-fold increase from 2010 (Figure 4.2). Non-OECD will lead the world's primary energy demand growth, accounting for nearly 90% from 2010 to 2050.

Figure 4-2 Primary Energy Demand through 2050 by Region (World)



The share of Non-OECD in the world primary energy demand will expand from 53% in 2010 to 70% in 2050. China's share will increase from 19% in 2010 to 22% in 2050, and India's share will increase from 5% in 2010 to 11% in 2050. By contrast, Japan's share to the world primary energy demand will decline from 4% in 2010 to 2% in 2050.

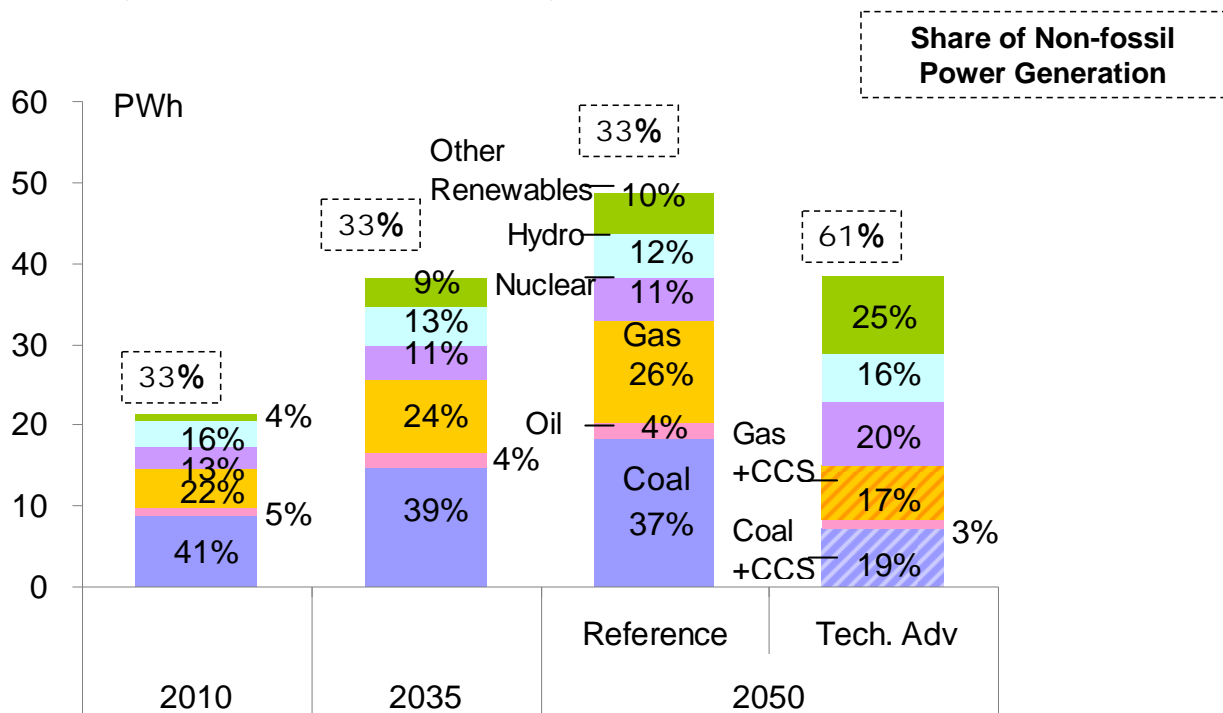
Figure 4-3 Primary Energy Demand through 2050 (World, Reference and Tech. Adv. Scenario)



Compared with the Reference Scenario, primary energy demand under the Tech. Adv. Scenario will be about 4.4 Btoe lower (Figure 4.3). Out of this saving, Non-OECD will account for 3.2 Btoe, which is 2.7 times larger than that of OECD.

In both the Reference and the Tech. Adv. Scenarios, fossil fuels will continue to play a major role in meeting the world energy demand in 2050, accounting for 84%, and 71%, respectively (Figure 4.4). This finding suggests continued need for investment in exploration and development of fossil fuel energy sources to facilitate stable supply. In the Tech. Adv. Scenario, despite a massive reduction from the Reference Scenario, fossil fuel demand will be larger compared with the 2010 level. Coal demand will decrease from 5.0 billion ton of coal equivalent (Btce) in 2010 to 4.3 Btce in 2050 (or 14% decrease), and oil demand will increase from 83.2 million b/d in 2010 to 96.7 million b/d in 2050 (or 16% increase). Even in the Tech. Adv. Scenario, natural gas demand is expected to continue growing from 2010 to 2050 by 40%. The share of natural gas in total primary energy mix will reach 26% in 2050 from 23% in 2010. The share of non-fossil fuels in 2050 will reach 12% in the Reference Scenario, compared with the 29% in the Tech. Adv. Scenario.

Figure 4-4 Power Generation Mix through 2050 (World, Reference and Tech. Adv. Scenario)



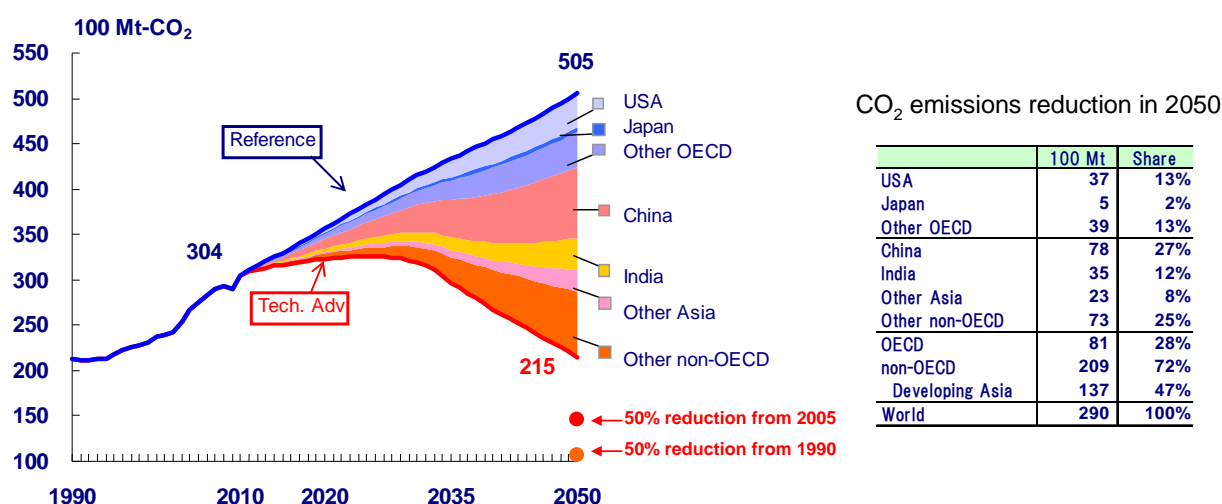
Power generation will expand to 49 Petawatt-hour (PWh) in 2050 from 21 PWh in the Reference Scenario reflecting the Non-OECD's demand increase. By contrast, in the Tech. Adv. Scenario, power generation will reach 38 PWh in 2050 – 11 PWh lower than the Reference Scenario due to energy conservation. The share of non-fossil fuel generation, including nuclear and renewable energy, in the power generation mix will substantially increase in the Tech. Adv. Scenario, reaching 61% in 2050 compared with the 33% in the Reference Scenario.

### 4.3 CO<sub>2</sub> emissions

Under the Reference Scenario, the world CO<sub>2</sub> emissions will increase from 30.3 Gt-CO<sub>2</sub> in 2010 to 50.5 Gt-CO<sub>2</sub> in 2050 (Figure 4.5). While OECD's CO<sub>2</sub> emissions will slightly increase from 12.2 Gt-CO<sub>2</sub> in 2010 to 11.7 Gt-CO<sub>2</sub> in 2050, Non-OECD's CO<sub>2</sub> emissions will more than double from 17.1 Gt-CO<sub>2</sub> in 2010 to 36.6 Gt-CO<sub>2</sub> in 2050 – driven mainly by the increase of Asia (accounting for nearly 70% of world's CO<sub>2</sub> emissions growth through 2050). The share of OECD in the world CO<sub>2</sub> emissions will decline to 23% in 2050 from 40% in 2010. Japan's share will decline 2% in 2050 from 4% in 2010.

In the Tech. Adv. Scenario, compared with the 2010 level, OECD's CO<sub>2</sub> emissions will be 50% lower in 2050, and Non-OECD's CO<sub>2</sub> emissions will be 33% higher in 2050.

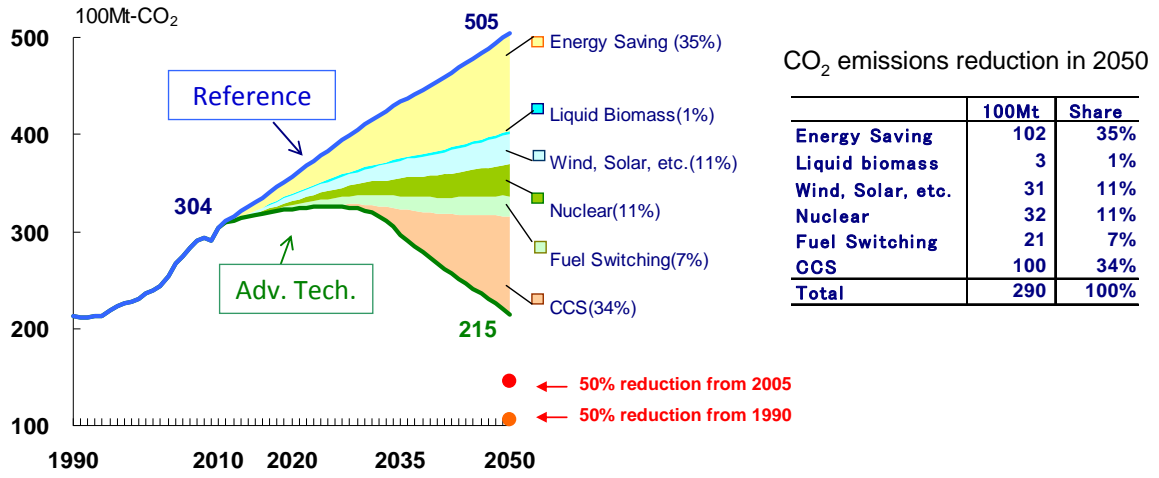
Figure 4-5 CO<sub>2</sub> Emissions Reduction Potential by Region  
(World, Reference and Technologically Advanced Scenario)



Compared with OECD, Non-OECD will have larger CO<sub>2</sub> emissions reduction potential (calculated as difference between the Tech. Adv. Scenario and Reference Scenario) in 2050, accounting for 72% (Figure 4.6). Particularly, Asia will account for the largest share at 47% in the world CO<sub>2</sub> emissions reduction potential.

By technology, energy saving will greatly contribute to the CO<sub>2</sub> emissions reduction, accounting for 35% (or 10.2 Gt-CO<sub>2</sub> reduction) in 2050. This will be followed by CCS (accounting for 34%), nuclear (11%), fuel switching (7%), renewable energy (11%), and biofuel (1%). In order to halve the world CO<sub>2</sub> emissions by 2050, further efforts need to be made to develop innovative technologies and low-carbon-emitting urban energy supply system.

Figure 4-6 CO<sub>2</sub> Emissions Reduction Potential by Technology  
(World, Reference and Technologically Advanced Scenario)



## 5. Conclusion

### (1) Energy demand growth and 3Es+S challenges

Amid economic and population growth, global energy demand will continue expanding, concentrating in non-OECD countries including China and India. While renewable energy diffusion for electricity generation will make great progress over the coming decades, fossil fuels will still account for more than 80% of total energy supply and for most of the supply increase. Therefore, climate change accompanying a sharp increase in fossil fuel-based CO<sub>2</sub> emissions is expected to worsen further. At the same time, stable energy supply will become a major challenge for Asia and some other regions where oil and gas demand will expand substantially along with dependence on energy imports.

In this context, energy problems had focused on the so-called three Es – energy security, environmental conservation and economic growth – with some expectations placed on nuclear power. Since the March 2011 Fukushima nuclear plant accident, however, concerns have grown globally on nuclear power generation safety. As a result, safety has been cited as a major matter in addition to the three Es.

In order to achieve the 3Es+S regarding energy problems, every country must not only promote energy conservation for holding down energy demand growth through energy efficiency improvements and other measures but also enhance efforts to achieve the best energy mix by securing stable energy supply through diversifying supply sources in line with its energy supply and demand structure and economic development stage and by promoting low-carbon energy measures including the cleaner development and utilization of fossil and other energy resources and fuel switching.

In Asia as the center of future global economic and energy demand growth, countries share interests as energy consumers, indicating great potentials and advantages for their cooperation in various areas such as the development and transfer of energy conservation and environmental technologies, and the development, procurement, transportation and storage of energy resources. It will be important for Asian countries to make joint efforts.

### (2) Asia's relationship with the Middle East

Over a medium to long term, global energy demand growth will concentrate in Asia including such non-OECD countries as China, India and ASEAN members. In these countries, fossil fuels will continue to play a central role in energy supply over a long term despite their policies of promoting nuclear and renewable energy. In the world, the Middle East has the greatest capacity to expand supply in response to the Asian energy demand growth. Fossil fuel exports from the Middle East to Asia will increase substantially.

In expanding fossil fuel imports, Asian countries are expected to make maximum efforts to diversify supply sources from the viewpoint of energy security. Particularly, they will expand natural gas imports not only from the Middle East but also from other regions including Australia, the former Soviet Union, Africa and North America. Meanwhile, they have no choice but to increase their dependence on the Middle East for oil supply due to oil resources concentrating in the region. Their oil imports from the Middle East will expand substantially. Therefore, appropriate investment in necessary resources development and smooth fossil fuel

production growth in the Middle East and stable fossil fuel transportation from the region will be indispensable for Asian countries' energy security. The Middle East for its part expects to see no large growth in European demand and Asia's growing presence as its major fossil fuel export destination while North America is going in the direction of energy independence. Therefore, the relationship between Asia and the Middle East will grow more important for both regions. In order to continuously enhance the bilateral relationship over a long term, the two regions should seek to further deepen mutual relations by developing multi-layered relations through bilateral cooperation in fostering industries, developing human resources and promoting technical assistance.

### (3) Japan's desirable direction

The Great East Japan Earthquake and the Fukushima nuclear plant accident have forced Japan to considerably reform its energy policy. While nuclear electricity generation is well expected to decline, safe nuclear generation and dismantling existing nuclear plants are projected to grow more important. As a country that has globally famous nuclear plant makers as promising plant suppliers for emerging countries where nuclear generation demand will increase substantially, Japan is required to learn lessons from the accident and make proactive contributions to securing nuclear plant safety at the global level by working out international safety regulation standards, transferring safety technologies and developing human resources.

For Japan that is poor with fossil energy resources, energy security is a particularly important challenge. Japan must diffuse renewable energy through the feed-in tariff system and other measures and stabilize energy costs to maintain its industrial competitiveness and prevent industrial hollowing-out. Japan must also give priority to procuring fossil fuels amid intensifying global competition for obtaining resources. It is desirable for Japan to ensure energy security through international cooperation including collaboration with other Asian countries.

Japan, which has technological, economic and institutional advantages, can play a great role in allowing the world, including Asia, to simultaneously achieve the 3Es+S. It will grow more important for Japan to further develop and utilize energy conservation and environmental technologies as its strength for enhancing efforts for achieving the 3Es+S and to strengthen its domestic economic base as a technology-oriented country.