Asia/World Energy Outlook 2011

Growing Uncertainty over International Energy Trends and the Future of Asia

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Summary

This report analyzes the long-term perspective of energy supply and demand for Asia and the world, up to 2035. It provides a consistent, quantitative and detailed analysis of changes in the international energy situation, in light of current world economic trends, the anticipated development of emerging countries, mainly in Asia, the energy and environmental policy trends and other matters. This outlook also provides a detailed analysis of the long-term implications of the incident at the Fukushima Daiichi Nuclear Power Station that followed the Great East Japan Earthquake.

In the Reference Scenario which is based on past trends and current energy and environment policies, various low carbon technologies to improve energy efficiency and reduce fossil fuel consumption are expected to play a greater role in supporting our goals on global warming and for securing a more stable energy supply in the future. A much faster dissemination of low carbon technologies through the promotion of international technology transfers has been developed in the Advanced Technologies Scenario. The “Advanced technologies" scenario has been further developed with a substantial slow down in nuclear power generation developments, to account for worldwide nuclear policy changes since the Fukushima incident. This “Low Nuclear Case” (along with a “Zero Nuclear Case” when necessary) is compared with the two scenarios to analyze the impact of the incident.

Finally, assuming the expansion and dissemination of innovative technologies to be introduced until 2050, the report reviews the growing worldwide interest of setting long-term reduction targets for greenhouse gases. It presents a view of the reduced greenhouse gas emissions over the long-term and its implications for the international energy situation.

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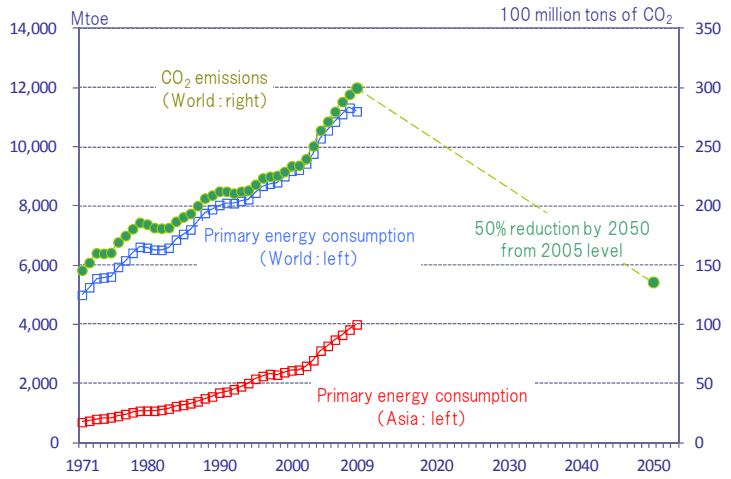
1. Introduction

Global energy demand continued to expand relatively fast over the past several decades. As shown in Figure 1-1, world primary energy demand increased from 5 gigatons of oil equivalent (Gtoe) in 1971 to 11.2 Gtoe in 2009, more than doubling in 38 years. Due to the rapid industrialization and economic growth of China, India and other ASEAN countries, the region which also features large populations, has rapidly increased its share of the world's energy consumption from 14% in 1971 to more than one-third at present. Asia accounts for more than 70% of the increase since 2000 in world primary energy consumption.

Figure 1-1 Trends of Global Primary Energy Demand and Energy-based CO_2 Emissions



Source: IEA "Energy Balances of non-OECD Countries"

Large economic stimulus packages helped escape the worst of the financial crisis that the world has been experiencing since 2008. In the aftermath of large-scale fiscal policies, Europe and the United States still remain vulnerable. Meanwhile, China and other emerging Asian countries are experiencing strong growth leading in the global economic recovery and increasing their economic share of the world economy. While Asia is expected to play an ever increasing important role in world economic growth, it will also rapidly expand its energy requirements which could possibly lead to some destabilization of the international energy markets.

Meanwhile, the current trends in international negotiations on environmental issues are becoming increasingly complex to reflect. As the First Commitment Period (2008-2012) under the Kyoto Protocol enters its final stage, countries are negotiating an international system for greenhouse gas emission reductions post 2012. The negotiations are difficult because they require consensus not only from developing countries but from the entire world, if effective GHG reductions are to be achieved. China, India and other emerging countries, as well as the United States, that has not ratified the Kyoto Protocol, should positively engage in the next global GHG emission reduction framework and strongly promote global warming measures. The widely shared goal to half the current level of GHG emissions by 2050 is not an easily achievable task. As energy consumption (and CO_2 emissions) is expected to continue to grow in China, India and other Asian countries, it is becoming increasingly important to include those countries in such framework.

The March 2011 incident at the Fukushima Daiichi Nuclear Power Station significantly influenced the development of new nuclear energy policies, not only in Japan, but also in the world (for example, Germany decided to decommission the seven nuclear reactors that were in commercial operation before 1980 and will sequentially phase out the remaining reactors by 2021). Prior to March 2011, large deployments of nuclear power were anticipated in developing countries to meet expanding

electricity demand and many industrialized countries viewed nuclear power generation as key to energy security and global warming prevention. Various countries' nuclear policy trends are attracting attention.

Based on the abovementioned conditions, this study assesses world economic trends including Asian and other emerging countries' economic development, international energy situation changes, nuclear policy reforms, trends of low-carbon technologies accompanying the enhancement of global warming prevention measures, and other matters. It also analyzes Asian and global energy supply and demand from the long-term perspective. The detailed country-by-country analysis takes advantage of a complex network of related organizations around the world that perform detailed analysis of Asian countries.

A consistent detailed quantitative analysis that takes into account the trends in economic developments, the social structure as well as energy trends and policies of each country is presented. The analysis which focuses on the long-term (2035) for Asia, provides for a more consistent view of worldwide energy demand. Furthermore, given the worldwide interest for setting ultra-long-term reduction targets for GHG emissions (2050), the current outlook estimates the impact of deployment and diffusion of advanced technologies until 2050 on energy demand and greenhouse gas emissions worldwide.

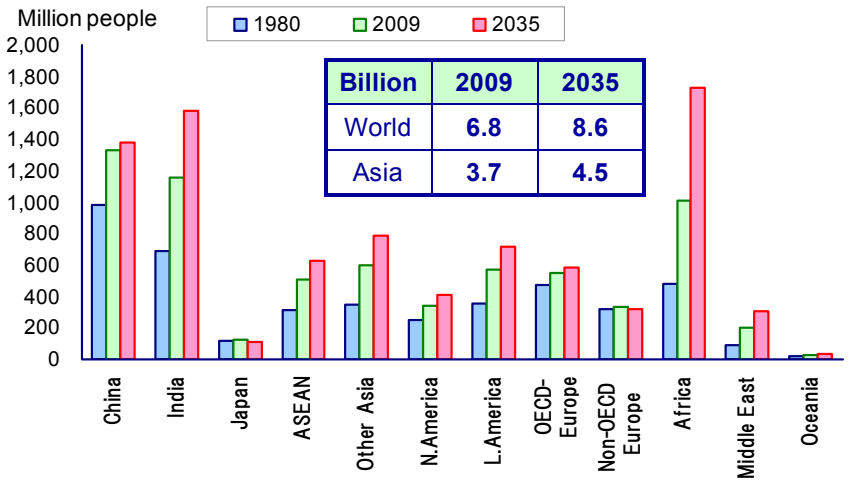
2. Assumptions

Population and economic growths as well as energy prices are critical elements that affect the pace of growth for energy demand.

2-1 Population outlook

The analysis incorporates the latest world's population forecast from the UN which suggests that the world population will continue to grow at about 1 percent per year, from 6.8 billion in 2009 to 8.6 billion by 2035. Among industrial countries, the United States is projected to sustain a moderate population increase, but its share in the global population is decreasing. Japan's population already peaked and is projected to continue its rapid decline. Russia's population has also begun to shrink and will continue its downward trend. Overall, Western European countries are projected to peak by 2020.

Figure 2-1 Population Outlook



On the other hand, population in developing countries is projected to increase steadily. The population increase in non-OECD countries, by 2035, will account for 1.7 billion of the worldwide growth of 1.8 billion. Population is expected to increase in the Middle East at an annual average rate of 1.6% and in Africa at 2.1%. Asia`s population is expected to increase at a lower

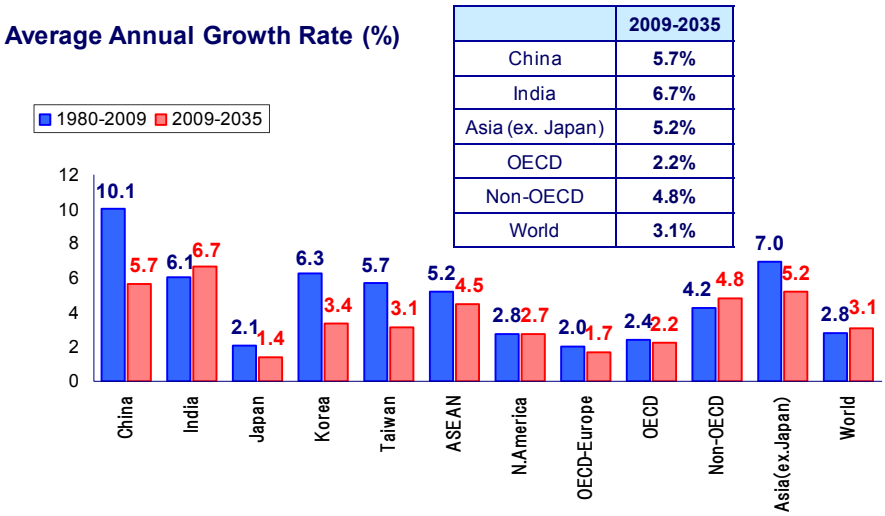
annual average growth rate of 0.8%, primarily because China, currently the world's largest populated economy, is projected to increase at an annual average rate of only 0.1%, reaching 1.38 billion in 2035. The population of India is projected to experience a much faster annual average increase at 1.2% and will surpass China by 2020, reaching an estimated 1.58 billion by 2035.

2-2 Economic growth outlook

The GDP growth assumptions for this study are based on forecasts provided by such international organizations as the Asian Development Bank and the International Monetary Fund, and on economic development plans released by governments.

The world economy experienced a crisis triggered by the so-called Lehman Shock in the autumn of 2008. But it has passed the worst phase thanks to large-scale economic stimulus packages and unusual monetary policy measures introduced in various countries. Strong growth in emerging Asian countries, such as China, also contributed to the overall economic recovery. The world economy is gradually shifting from the overconcentration of Western countries (such as Europe and the United States) towards the influence of emerging economies which are increasing their economic presence in terms of growth and size. The world economy is shifting towards a multipolarization reflecting Asian economic growth potential expected to grow as a consumer market. Meanwhile, there remain many risks to a full-fledged economic recovery. Issues such as budget deficits, debt problems in Greece, high unemployment rates and concerns about possible bubble economy in emerging countries could negatively influence future growth.

Figure 2-2 Economic Growth Outlook



	2009-2035
China	5.7%
India	6.7%
Asia (ex. Japan)	5.2%
OECD	2.2%
Non-OECD	4.8%
World	3.1%

Despite those issues, the long-term perspective for the world economic growth is likely to remain strong and steady. Driven by the Asian economy, as in the recent past, the global economy is expected to grow at a moderate annual rate of some 3.1% through to 2035. GDP in OECD countries will grow at 2.2% annually and non-OECD, mainly developing countries, will grow twice as fast at 4.8% annually on the strength of population and income growth. Non-OECD countries' share of global GDP is expected to rise from 26% in 2009 to 40% in 2035.

The North American economy is expected grow at 2.7 % per year over the forecast period. Its population growth, due to immigration from developing and other countries and its higher birth rate relative to other industrial countries, provides for a greater economic potential than in other developed countries. In contrast, Japan's economic growth potential is expected to be moderate at an annual rate of 1.4%. Increasing exports to emerging countries will offset the modest potential growth from its reduced active population. The relative position of Japan' economy in the world is expected to fall over a long term. As Central and Eastern European countries joined the EU, Europe's economy is invigorated and assumed to grow at a modest

pace of 1.7%.

In non-OECD countries, Asian economies (excluding Japan) will by far experience the highest growth at 5.2% per year, quadrupling their 2009 GDP by 2035. Those economies currently depend on the economic growth of North America and Europe for their exports, but as China, India and other economies grow, it will strengthen the market interdependence in the region and with future technological advances, the region is expected to evolve from the "world factory" into a "world market". Meanwhile, the Middle East and African countries are facing a decline in primary production and should be growing at 3.7% and 4.3%, respectively.

China maintained high growth in exports and construction investments during the economic crisis. In 2010, its economy (GDP) surpassed Japan and became the world's second largest economy. Overtime, China will gradually change its economic structure and growth will come less from investments and more from domestic consumption. Annual growth which is expected at 5.7% on average over the forecast period will gradually decrease towards 2035, reflecting changes in its labor force caused by an aging population. GDP per capita in 2035 will reach an average of U.S. $ 9,000, widening the income gap between the rural and urban areas and potentially creating socio-economic problems.

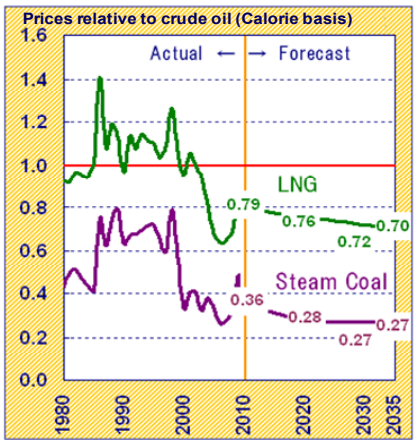
India’s population will increase from 1.16 billion to surpass China and become the most populous country by 2035. Its current high percentage of young people, compared to China's aging population, is India’s long term advantage as it provides for a major consumer market potential in the future. With underdeveloped socio-economic infrastructure, the current per capita GDP is about one-third of China's national income, but the potential for growth is considered large. As domestic problems such as power shortages are resolved, the economic structure will shift from an agriculture-based economy towards industry and related services, likely to sustain high growth in the long-term. The Indian economy is projected to grow at an annual rate of 6.7% from 2009 to 2035.

Southeast Asian countries including Indonesia, Malaysia, Thailand and Vietnam are also expected to take advantage of their large population to grow as giant consumer markets. Supported by diligent, cheap and abundant labor, they may play a major role as a production base to provide industrial products not only to their domestic markets but also to the rest of the world including their neighboring giant markets, China and India. Backed by Asian economic invigoration, Southeast Asia is expected to become another major driver in the world economy.

2-3 Energy price outlook

Prices for West Texas Intermediate crude oil hit a record high of $ 147/barrel in July, 2008, before plummeting toward the end of that year at 30 dollars/barrel as the impact on the world economy triggered by the U.S. Lehman Shock caused a short term decline in oil demand. Oil prices have risen since, soaring to over the $100 mark again and, since 2010, oil prices have settled to a standard of around $ 80. As oil exploration and development are dependent on future oil prices, there are concerns for the balance between demand and supply in the future. Due to sluggish past investments, an increasing rate of decline of existing fields will gradually create supply constraints. As production is anticipated to shift from large oil fields to smaller ones or deep water oil fields with relatively much high production costs, oil prices are expected to increase further. Increased oil production from unconventional oil sands and oil shale will not be enough to meet the anticipated strong demand; conventional oil will continue to set the pace on prices.

Figure 2-3 Energy Price Outlook (CIF import prices for Japan)



		2000	2010	2020	2030	2035
Crude Oil	Real	35	79	110	117	120
USD/bbl	Nominal	28	79	134	173	197
LNG	Real	297	564	746	753	754
USD/t	Nominal	244	564	910	1,118	1,237
Steam Coal	Real	43	107	114	117	120
USD/t	Nominal	35	107	139	173	197

* Real prices are set in 2010. ** Inflation rates are assumed at 2% annually.

As conventional oil resources are concentrated in the Middle East, changes in production from OPEC and Russia will cover most of the demand increase during the outlook period. As oil importing countries grow more dependent on a limited number of oil producing countries, OPEC countries including Middle East members will expand their oil market control. These countries' policy of keeping crude oil prices at high levels and their political moves to take advantage of oil resources for international negotiations will exert upward pressures on crude oil prices over a long term.

Japan's CIF crude oil import price (real 2010$) will gradually rise in line with oil production cost over the long term, reaching $110/barrel in 2020, $117/barrel in 2030 and $120/barrel in 2035. (The nominal prices are $134/barrel in 2020, $170/barrel in 2030 and $197/barrel in 2035.) The LNG pricing system for Japan will continue to be primarily linked to oil prices. However, LNG prices may fall over the medium to long term relative to crude oil prices reflecting increases in global unconventional gas production and gas pipeline projects for Asia. Changes in coal prices are expected to be much lower than for oil or LNG. Coal for power generation and steel production is far less resource constraint than oil or natural gas. Coal mining production costs in major producing countries such as Australia, are anticipated to decrease over time due to cost rationalization. On the other hand, rising oil prices affect production and transportation costs for coal and new environmental regulations are likely to also increase its utilization cost.

3. Scenarios for estimation

In this study, a Reference Scenario and an Advanced Technologies Scenario are set for estimation. The Reference Scenario reflects past trends and the energy and environmental policies adopted so far. In this scenario, countries are assumed to implement no additional energy conservation or low-carbon measures. Ambitious targets vowed by various countries for the introduction of energy conservation and low-carbon technologies are assumed to fail due to financial or other difficulties. In the scenario, global energy demand will increase according to past trends, with a limited introduction of renewable and nuclear energies replacing fossil fuels.

The Advanced Technologies Scenario assumes that countries implement a series of energy and environmental policies and measures aimed at securing stable energy supply and reducing global warming, and accelerate the development and introduction of innovative technologies. Basically, various assumptions are set to reflect energy policies for each region of the world. Asian countries are assumed to improve energy efficiency faster than in the Reference Scenario and expand the introduction of nuclear, solar power generation and other non-fossil energies through the promotion of technology transfer from industrial countries.
The Fukushima Daiichi nuclear power plant incident greatly affected the world's perception of nuclear power. Some countries have vowed to eliminate nuclear power generation or revised construction plans for new ones. To reflect as much as possible such policy changes, nuclear power generation development is assumed to stagnate in a Low Nuclear Case.

Technological and other assumptions in the Advanced Technologies Scenario can be summarized as follow.

【Non-fossil energy】

In the Advanced Technologies Scenario, nuclear and renewable energy power generation will be promoted substantially in response to firm growth in global electricity demand and the enhancement of global warming measures. The next-generation of biofuels (cellulose-based) that do not conflict with food and land utilization needs will be developed smoothly and introduced rapidly. As such, the introduction of non-fossil energy will increase globally. By 2035, non-fossil fuel demand will reach 3.4 Gtoe accounting for 23% of primary energy demand. (Chapter 4 provides more details.)

Table 3-1 Assumptions for the Advanced Technologies Scenario

Introduction and enhancement of environmental regulations and national etc.	Enhancement of R&D, promotion of international technological cooperation
Carbon tax, emissions trading, RPS, subsidy provisions, FIT, energy efficiency standards, automobile fuel efficiency standards, low-carbon fuel standards, energy conservation/environmental labeling, national strategies/targets, etc.	Expansion of R&D investment, international cooperation in energy efficient technology (steel, cement and other areas), support for establishment of energy efficiency standards

【Demand-side technology】

■ Industry sector

Best-practice industrial process technologies (for steelmaking, cement, paper-pulp and oil refining) will be deployed globally under the sectoral approach, etc.

■ Transportation sector

Clean energy vehicles (highly fuel efficient vehicles, hybrid vehicles, plug-in hybrid vehicles, electric vehicles, fuel cell vehicles) will be globally diffused.

■ Residential/commercial sector

Efficient electric appliances (refrigerators, TVs, etc.), highly efficient water-heating systems (heat-pump, etc.), efficient air conditioning systems, diffusion of efficient lighting, and enhanced heating insulation

【Supply-side technology】

■ Renewable energy

Diffusion of wind, PV, CSP (Concentrated Solar Power) and biomass power generation, and biofuels

■ Nuclear

Acceleration of nuclear power plant construction and enhancement of operating ratios

■ Highly efficient fossil-fired power generation technology

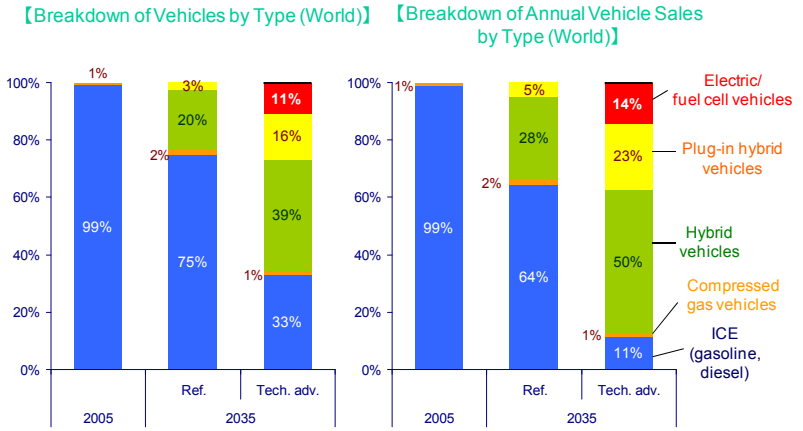
Diffusion of ultra-supercritical coal power generation, coal IGCC, coal IGFC and natural gas MACC (more advanced combined cycle) plants

■ CCS

The power generation sector (existing and new coal and gas-fired power plants) and the industry sector (including steelmakers, cement producers and other major sources of CO2 emissions) will expand CCS deployment

In the Reference Scenario, hybrid vehicles will account for about 20% and plug-in hybrids for 3% of the total stock by 2035. In the Advanced Technologies Scenario, clean energy vehicles will account for about two-thirds of the total stock in 2035, with plug-in & other hybrids accounting for 55% and electric & fuel cell vehicles for 10%. In this scenario, the expanded diffusion of plug-in hybrid, electric and other next-generation cars, increases the fuel efficiency assumed in the Reference Scenario by 24%.

Figure 3-1 Vehicle Outlook (World)



【Clean coal technology (CCT)】

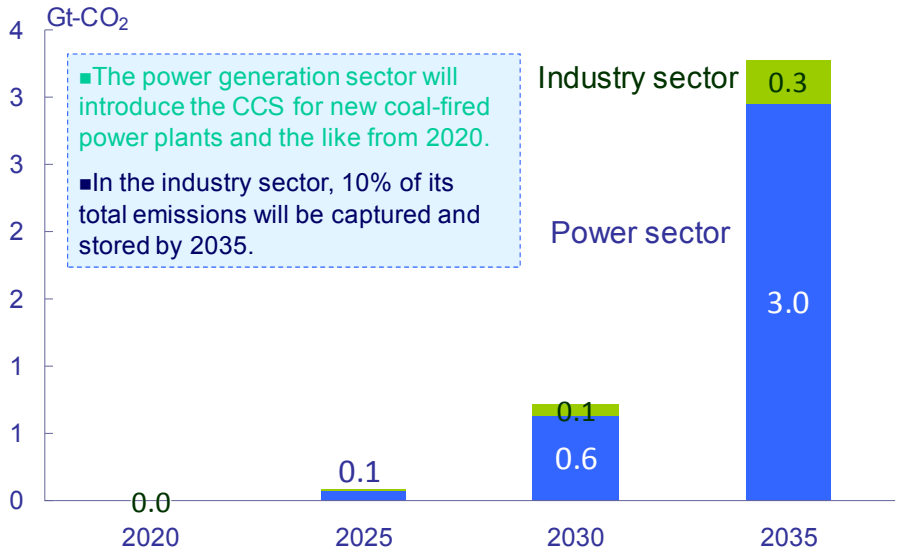
As coal deposits are abundant and exist widely in the world, it is positioned as an indispensable energy source providing stability for future energy supply and features better economic efficiency than other fossil energy resources. On the other hand, given the growing environmental concerns regarding global warming, coal is increasingly required to be used with considerations as it emits more CO_2 per unit of energy. As such, cleaner and highly efficient utilization of coal have become urgent challenges. Efforts are underway in Japan and other countries to develop highly efficient coal power generation and

CO_2 capture and storage technologies. Japan's Cool Earth Energy Technology Innovation Plan specifies a technology development roadmap for "highly efficient coal power generation" and "CCS," and steady implementations are expected. Coal power generation is expected to substantially improve its efficiency through technological innovation.

In the Reference Scenario, the coal-fired thermal power generation efficiency will rise from 34% to 39%, as ultra-supercritical pressure steam power plants are gradually introduced with supercritical and subcritical pressure steam power plants remaining dominant. In the Advanced Technologies Scenario, the efficiency will rise to 42% by 2035, due to an increase in advanced supercritical pressure steam and integrated coal gasification combined cycle (IGCC) plants and the partial introduction of integrated coal gasification fuel cell combined cycle (IGFC) plants.

In the Advanced Technologies Scenario, CCS systems will be introduced from 2020 for new coal-fired power plants, part of old coal-fired plants, part of new gas-fired plants and the industry sector including steelmakers. About 0.6 Gt-CO_2 will be captured in 2030 and about 3.3 Gt-CO_2 by 2035, for a cumulative total of about 12 Gt-CO_2 captured and stored. The world's theoretical geological CO_2 storage potential is estimated at about 10 teratons (Tt). Depleted gasfields, oilfields and coalbeds with drilling data are estimated to have a storage potential of about 1 Tt, indicating that the captured CO_2 could be stored easily.

Figure 3-2 Assumed CCS Introduction (World)



【Energy conservation, etc.】

With the introduction of energy conservation technologies in the Advanced Technologies Scenario in the industry, residential/commercial and transportation sectors, the world's final energy demand in 2035 will be 1.47 Gtoe less than in the Reference Scenario. Energy savings will total 0.55 Gtoe in industrial countries and almost twice as much (0.92 Gtoe) in developing countries. Developing countries offer great energy conservation potential in the industry sector with energy savings reaching 0.32 Gtoe out of a world's total of 0.41 Gtoe. The diffusion of clean energy vehicles will achieve energy savings of 0.42 Gtoe in the transportation sector (0.19 Gtoe in industrial countries and 0.23 Gtoe in developing countries). Through the enhancement of energy conservation standards and energy efficiency for electric home appliances, the world's residential/commercial sector will achieve 0.59 Gtoe in total energy savings, (0.27 Gtoe in industrial countries and 0.32 Gtoe in developing countries). The world's electricity consumption as part of final consumption in the Advanced Technologies Scenario will be 6,020 TWh less than in the Reference Scenario (1,670 TWh in industrial countries and 4,350 TWh in developing countries).

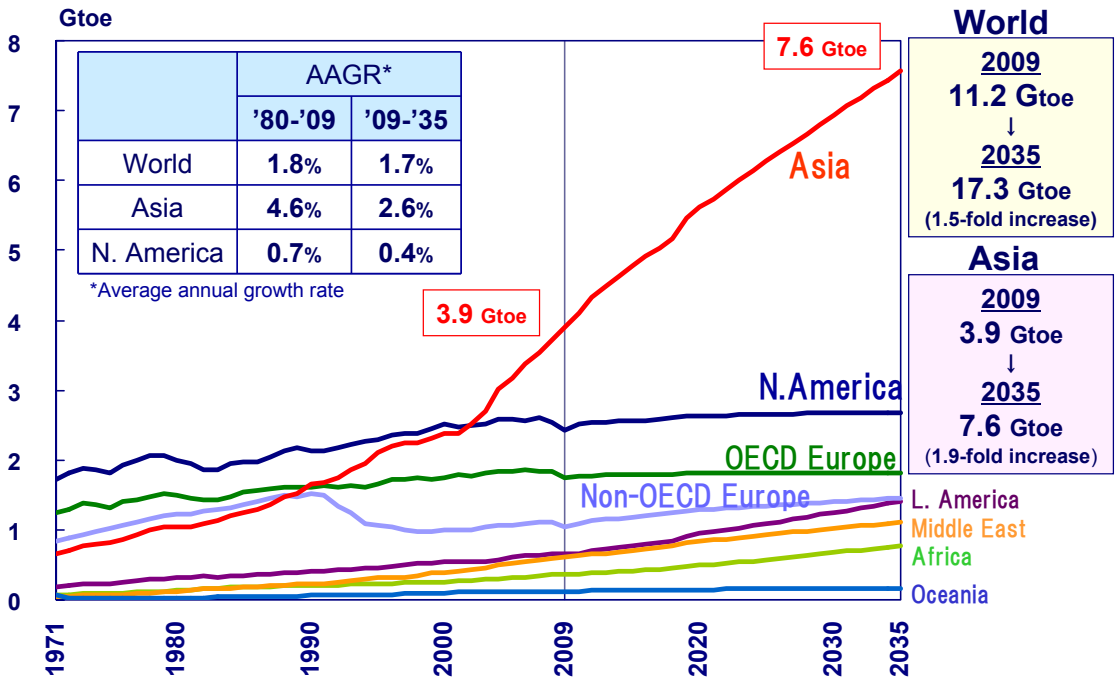
The power generation sector will reduce its CO_2 emissions intensity due to progress in nuclear and renewable energy power generation and increased efficiency in fossil power generation (through the introduction of clean coal and MACC (More Advanced Combined Cycle) technologies). In the Reference Scenario, the intensity in 2035 will fall by 13% from 2009 in the world and 18% in Asia. In the Advanced Technologies Scenario, the emissions intensity in 2035 will plunge 40% from 2009 in the world and 45% in Asia, thanks to the expansion of low-carbon electricity sources.

4. Energy supply/demand outlook for Asia and the World

4-1 Region-by-region primary energy demand outlook

The world's primary energy demand will increase at an annual rate of 1.6% from 2009 to 2035 from 11.2 Gt in 2009 to 17.3 Gt. Non-OECD countries, including developing nations, will account for about 90% of the increase in the world's energy demand. Asia, for instances, will account for about 60% of the increase with China alone responsible for about 30%. Non-OECD countries' share of the world's primary energy demand will expand from 52% in 2009 to 66% in 2035, due to their population and economic growth. Asia's share will rise from 36% in 2009 to 45% in 2035. China's share will increase from 19% (world's second largest energy consumer after the United States) to 23% in 2035 surpassing the United States in energy demand. Supported by steady economic growth, China and India will account for about 30% of the world's primary energy demand by 2035.

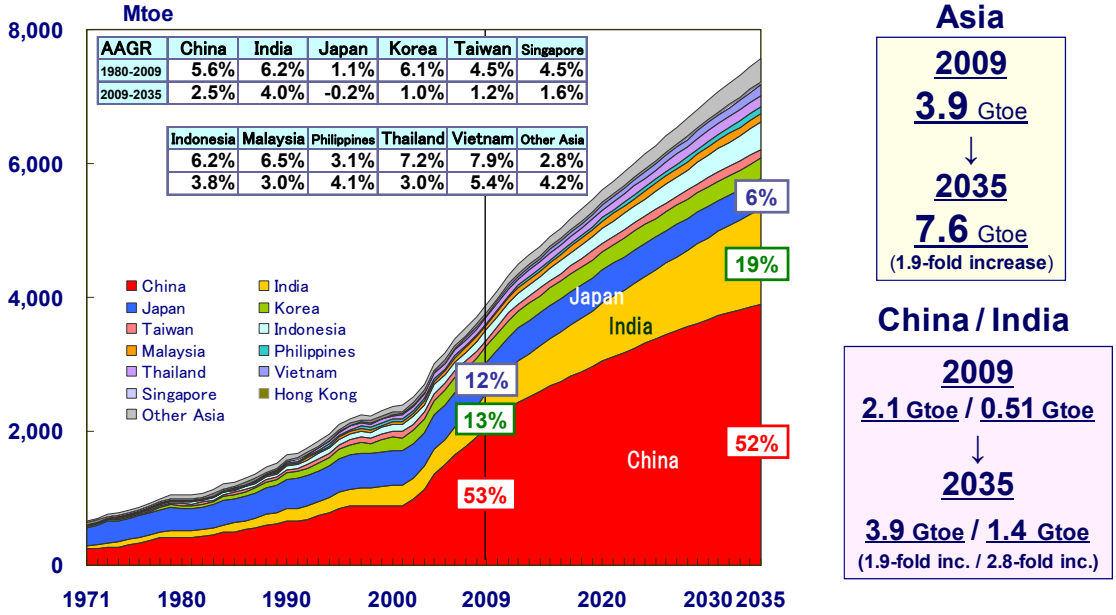
Figure 4-1 World Primary Energy Demand by Region



Asia's primary energy demand will increase at an annual rate of 2.6% from 3.9 Gtoe in 2009 to 7.6 Gtoe in 2035. Energy demand will expand rapidly on robust economic growth particularly in such countries as China, India, Vietnam, Thailand, Malaysia and Indonesia. China will account for about half of the energy demand growth between 2009 and 2035 and India for about a quarter. Japan's primary energy demand will decrease instead of increasing. China's share of Asia's primary energy demand will level off from 53% in 2009 to 51% in 2035, while India's share will expand from 13% to 19%. Meanwhile, Japan's share of Asia's primary energy demand will decline from 12% in 2009 to 6% in 2035 as the economy

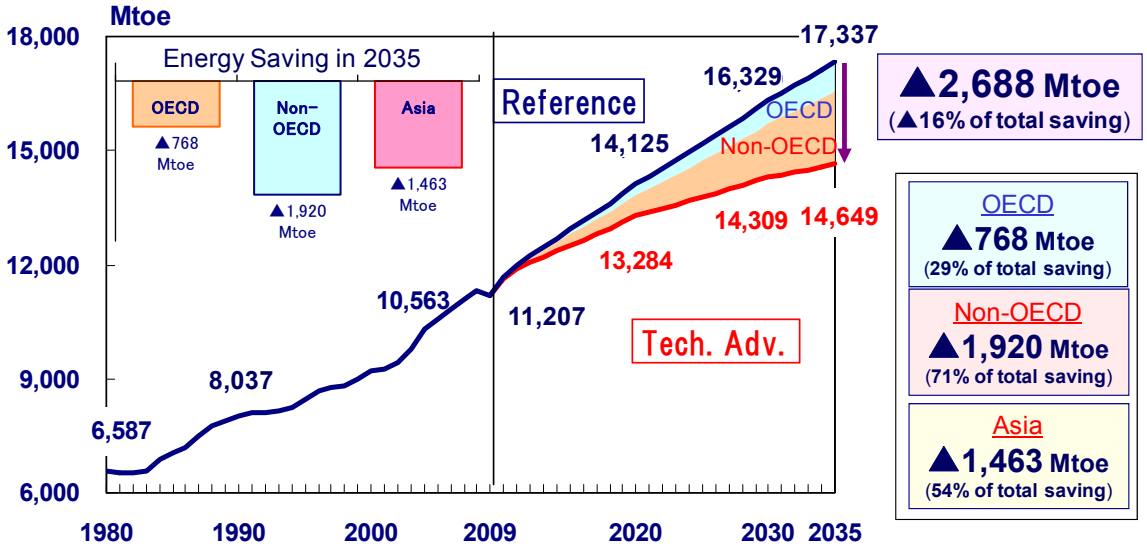
matures with the population falling. The Japanese share then will be the third largest after China and India. The per capita energy demand in developing countries such as China and India will still be much lower than in industrial countries. In and after 2035, therefore, their per capita energy demand and their overall energy demand will still have great growth potentials.

Figure 4-2 Asian Energy Demand by Region



In the Advanced Technologies Scenario, the world's primary energy demand in 2035 will be 14.7 Gtoe, 16% less than in the Reference Scenario. Developing countries will account for 71% and Asia for 54% of the global 2.7 Gtoe energy savings. China will account for 56% and India for 23% of the Asian energy savings.

Figure 4-3 Primary Energy Demand (Advanced Technologies Scenario)



4-2 Primary energy supply/demand outlook by energy source

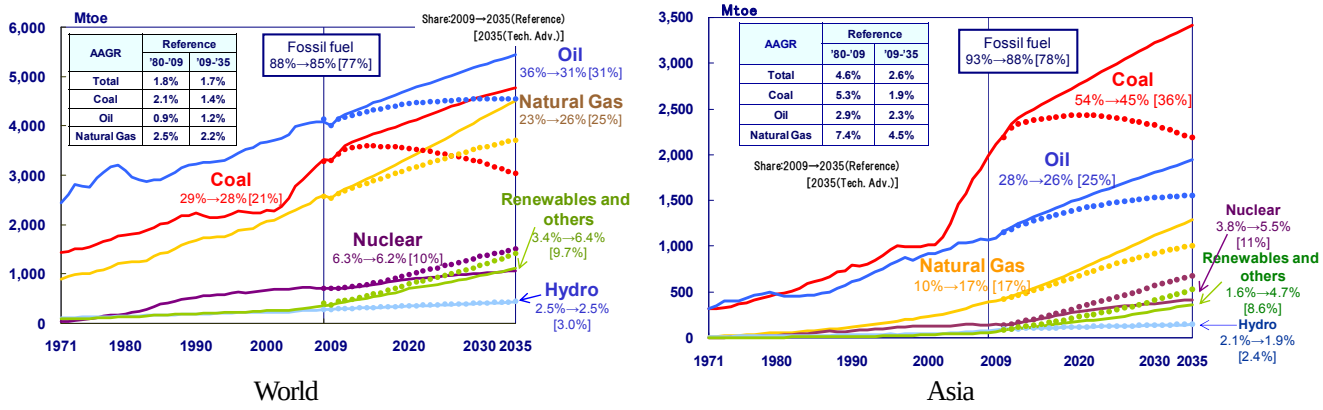
A breakdown of primary energy demand by source indicates that oil will continue to account for the largest share until 2035 in both the Reference and Advanced Technologies Scenarios. In the Reference Scenario, coal and natural gas demand will expand and by 2030, oil, coal and natural gas will have almost similar shares. Fossil fuels (coal, oil and natural gas) will remain the major energy source, accounting for about 80% of a primary energy demand increase between 2009 and 2035.

Among fossil fuels, natural gas will increase the most, accounting for 32% of the primary energy demand increase, followed by coal at 24% and then oil at 23%. Nuclear energy will account for 6% of the increase, hydro energy for 2% and renewable energy for 12%.

In the Advanced Technologies Scenario, oil demand will peak out in 2030. Fossil fuels will remain as major energy sources, although their share of primary energy demand will fall from 85% in the Reference Scenario to 77%. Through fossil fuel switching, natural gas demand will expand its share of the total energy demand and continue increasing instead of leveling off.

A comparison of the world energy demand breakdown by source between the two scenarios indicates no major gap in shares for oil and natural gas. But the share in the Technologies Advanced Scenario will be 4 percentage points larger than in the Reference Scenario for nuclear energy and 3 points higher for renewable energy. In contrast, the share for coal will be 7 points lower. In Asia alone, a similar trend will be seen, with the share for coal being 9 points lower.

Figure 4-4 Primary Energy Demand for Asia and the World



World Asia

(1) Oil supply/demand outlook

World oil demand will increase at an annual rate of 1.2% from 81 million barrels per day (mbd) in 2009 to 110 mbd in 2035. While oil's share of world primary energy demand will fall from 36% in 2009 to 31% in 2035, oil will remain as the largest primary energy source. Among regions, Asia accounts for some 60% of the increase and among sectors, transportation also accounts for about 60% of the increase. Industrial countries' oil demand which began falling in 2005, will continue its decline at an annual rate of 0.3% from 2009 to 2035. In developing countries, however, oil demand will increase at an annual rate of 2.2 percent. Industrial countries' share of world oil demand will fall from 49% in 2009 to 33% in 2035, while developing countries' share will expand to 67% in 2035. (Asia's share will increase from 30% to 38%.)

In the Advanced Technologies Scenario, world oil demand will peak out in 2030, in line with improvements in vehicle fuel efficiency. In 2035, oil demand will be 0.9 Gtoe, or 18% less than in the Reference Scenario. Asia's oil demand will increase at an annual rate of 2.3% from 22.7 mbd in 2009 to 40.5 mbd in 2035. Of the increase, China will account for about 50% and India for about 30%. Among sectors, the transportation sector will account for about 80% of the increase and the residential/commercial sector (including agriculture) for the rest. Oil's share of primary energy demand will decrease slightly from 28% in 2009 to 26% in 2035.

In the Advanced Technologies Scenario, oil demand in 2035 will be 18 percent lower at 92 mbd, compared to 110 mbd in the Reference Scenario. In Asia, oil demand will be 20% lower at 32.4 mbd and will not peak out but continue rising. The transportation sector will account for most of oil consumption savings due to vehicle fuel efficiency improvements, the rapid

diffusion of alternative-energy vehicles and the growing introduction of biofuels. The sector has a great energy saving potential in developing countries.

The outlook for future world oil production indicates that non-OPEC oil producing countries including Latin American nations and Russia will slow down their production growth under resources constraints. As a result, OPEC countries with richer resources and lower production costs will need to expand their output to 49 mbd and their share of global output will rise to 45% in 2035. OPEC output growth will cover about 70% of the future global oil demand increase. As Middle Eastern OPEC countries will experience remarkable growth in their domestic oil demand, the international oil supply/demand balance is expected to tighten unless sufficient investments in their output expansions are made to meet the growth both in domestic and foreign demand. As easy oil resources are becoming constraints, interests in oil shale, oil sand and other unconventional oil resources are expected to grow further.

Figure 4-5 World Oil Demand

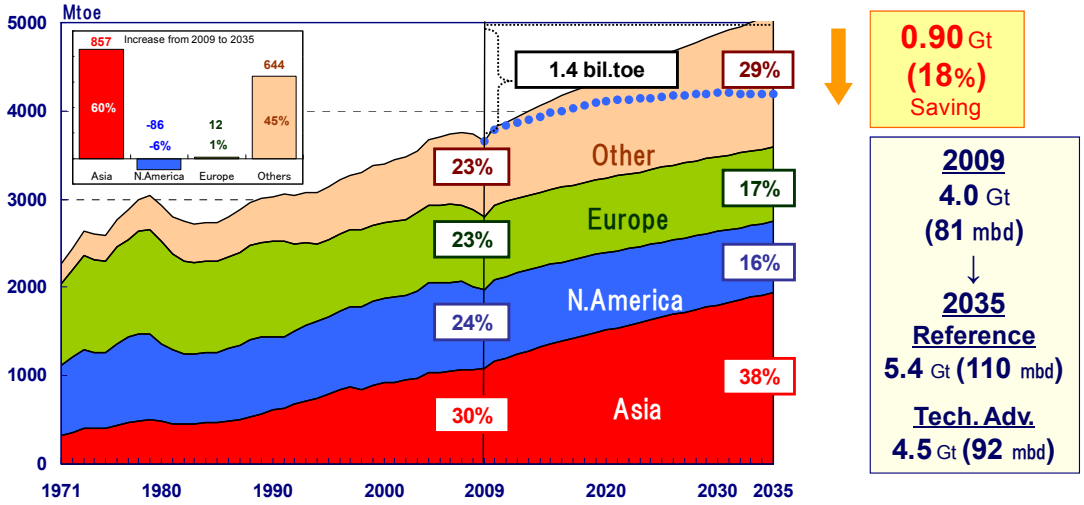


Table 4-1 World Oil Production Outlook

Million B/D	2009	2020	2030	2035	2009-2035
OPEC	34	44	47	49	15
Middle East	23	33	34	35	12
Other OPEC	11	11	13	14	3.5
non-OPEC	52	51	58	60	8.5
N.America	14	16	20	20	6.4
L.America	3.9	6.0	8.0	9.0	5.1
Europe, Former USSR	18	17	18	19	1.1
Middle East	1.7	1.3	1.2	1.2	▲ 0.5
Africa	2.6	2.8	3.0	3.2	0.6
Asia	8.1	8.5	8.0	7.8	▲ 0.3
China	3.9	4.2	4.1	4.0	0.1
India	0.8	1.0	1.0	1.0	0.2
Indonesia	1.0	1.0	0.8	0.8	▲ 0.2
Malaysia	0.7	0.7	0.6	0.6	▲ 0.1
Vietnam	0.3	0.3	0.3	0.3	0.0
World (Ref.)	85	95	105	109	24
World (Tech. Adv.)				91	

(2) Natural gas supply/demand outlook

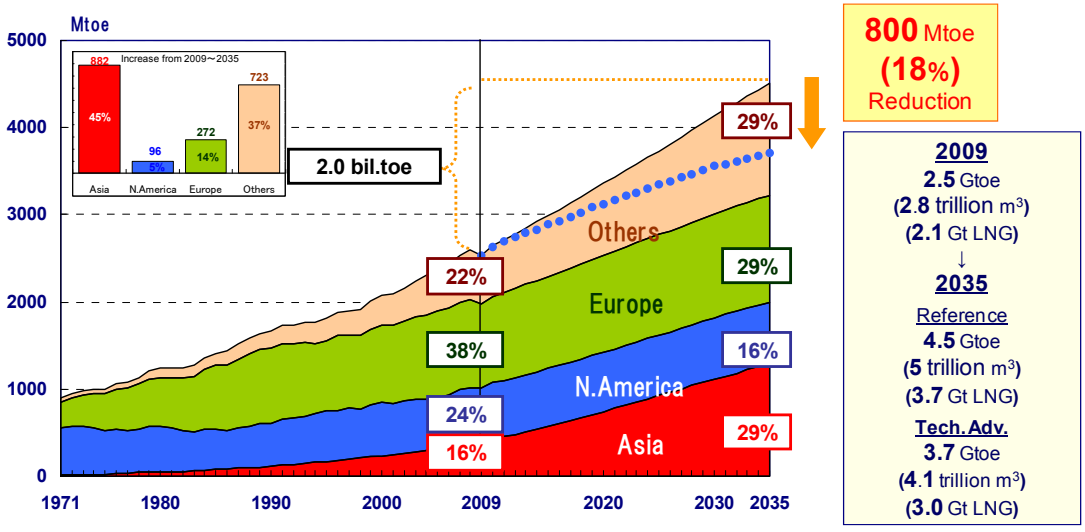
The world's natural gas demand increased fast from 2.8 trillion cubic meters in 2009 to 3.2 trillion m^3 in 2010, according to CEDIGAZ. Natural gas demand will increase faster than the other fossil fuels, at an average annual rate of 2.2%, reaching 5 trillion m^3 by 2035. Asia will account for 45% of the increase and Europe for 14%; Asia will therefore post the largest growth in natural gas demand. Industrial countries will account for 16% of the natural gas demand growth between 2009 and 2035 and developing countries for 84%. The share of world natural gas demand in developing countries will rise from 51% to 65%.

In the Advanced Technologies Scenario, the world's gas demand in 2035 will be 0.8 trillion m^3 (18%) less than in the Reference Scenario reaching 4.1 trillion m^3. Gas demand savings are concentrated in the power generation sector. In Asia, gas demand will be 22% less at 1.12 trillion m^3, but as Asian demand expands rapidly, appropriate resources development will need to be sustained.

Industrial countries' share of world gas demand will fall from 49% in 2009 to 35% in 2035, while developing countries' share will rise from 51% to 65%. Natural gas combined cycle plants are expected to steadily increase on technological advancement and environmental protection requirements. The power generation sector will account for about 50% of the natural gas demand growth and as gas demand expands, its share of primary energy demand will widen from 23% in 2009 to 26% in 2035. In Asia, natural gas demand will triple from 450 billion m^3 in 2009 to 1.43 trillion m^3 in 2035. Natural gas demand in Asia will post an annual average growth rate of 4.5%, the highest among fossil fuels. Of the Asian natural gas demand growth, about 50% will be attributable to fuel demand in the power generation sector and about 30% to demand growth in the residential/commercial sector (including agriculture) amid progress in urbanization accompanying economic development. Natural gas's share of Asian primary energy demand will increase from 10% in 2009 to 17% in 2035.

Global LNG demand, which expanded rapidly from 182 Mt in 2009 to 220.21 Mt in 2010, will double to 454 Mt by 2035. Asian LNG demand will expand by 167 Mt, accounting for 61% of global LNG demand growth. The LNG demand expansion will thus center on Asia. European LNG demand will swell by 62 Mt on the power generation sector's growing demand and energy sources diversification policies. On the other hand, North American LNG demand will change little as local gas output, including shale gas production, increases. If the new LNG projects that are being planned at various locations in the world are launched smoothly, global LNG supply capacity will fully meet growing demand.

Figure 4-6 World Natural Gas Demand



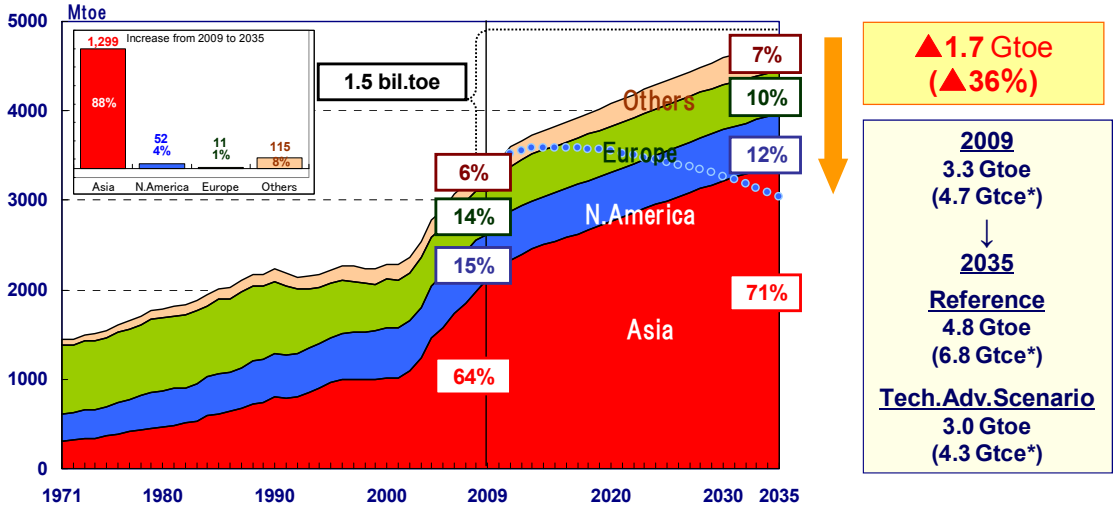
(3) Coal supply/demand outlook

Global coal demand will increase at an annual rate of 1.4% from 4.7 gigatons coal equivalent in 2009 to 6.8 Gtce. Asia will account for about 90% of global coal demand growth, with China responsible for about 40% of global growth. Developing countries will account for 97% of global coal demand. Industrial countries' share of global coal demand will decline from 31% in 2009 to 23% in 2035, while developing countries' share will expand from 69% to 77%.

Among sectors, the power generation sector will account for almost all of the coal demand growth. As coal's share of global primary energy demand levels off at 29% during the projection period, coal will remain as the second most important fuel after oil even in 2035. Asian coal demand will increase at an annual rate of 1.9% from 3 Gtce in 2009 to 4.9 Gtce in 2035. China will account for about 40% of Asian coal demand growth. The power generation sector will absorb about 90% of the demand growth and coal's share of primary energy demand will fall from 54% in 2009 to 45% in 2035, remaining still the largest among primary energy sources.

In the Advanced Technologies Scenario, global coal demand in 2035 will be 36% less than in the Reference Scenario, dropping from 6.8 Gtce to 4.3 Gtce. In Asia, coal demand in 2035 will also be 36% less than in the Reference Scenario, standing at 3.1 Gtce, with the decline centering on the power generation sector. The annual average growth rate for coal will be 0.1%, down 1.8 percentage points from the level in the Reference Scenario. The fall in coal demand will be attributable to additional efficiency gains at coal-fired power plants and switching to other fuels in the power generation sector.

Figure 4-7 World Coal Demand



(4) Nuclear energy outlook

The Fukushima Daiichi nuclear plant incident directly affected nuclear energy policies in foreign countries including some European nations, as well as Japan, prompting these countries to depart from dependence on nuclear energy. Germany suspended seven nuclear reactors that had been launched in or before 1980. Although the suspension was initially designed for safety checks only, Germany decided on June 6 to decommission these reactors and phase out the remaining nuclear reactors from 2013 to 2021. In 2002, Germany first came up with a policy to phase out nuclear reactors as the expected 32-year service life ends, vowing to promote renewable energy development rather than nuclear energy. Later, as fossil fuel prices soared and power generation cost increased on the substantial expansion of wind power generation and as other new problems emerged, Germany revisited its denuclearization policy. But the June decision revived the denuclearization policy. In Italy, which halted all nuclear reactors and later began to consider constructing new nuclear plants, more than 90% of voters

voted against nuclear plant construction in a national referendum in June, making it impossible for the Italian government to revive nuclear power generation.

While these countries have made policy shifts, many others have not changed their nuclear energy promotion policies. As indicated by the different nuclear energy policies of Germany and its neighbor France, nuclear policies can easily differ from country to country. Countries can be divided into four groups based on their nuclear policies and positions.

The first group, including the United States, France, Russia and South Korea, proactively promotes nuclear power generation over a long term. Russia and South Korea have not changed their respective plans to construct many new nuclear power plants even in the wake of the Fukushima incident. In France, where nuclear power generation has reached saturation, nuclear energy utilization is expected to continue. This may be because France aims not only to achieve stable domestic energy supply and GHG emission cuts but also to maintain and enhance its international competitiveness to increase its presence in the world market where massive new plants may be constructed. In the United States, however, the "Nuclear Renaissance" momentum may have been lost due to the availability of unconventional natural gas and rising nuclear plant construction costs. Nevertheless, no change has been made to its plan to make maximum use of existing nuclear reactors, including service life extension. In this sense, the United States has maintained its nuclear energy utilization policy.

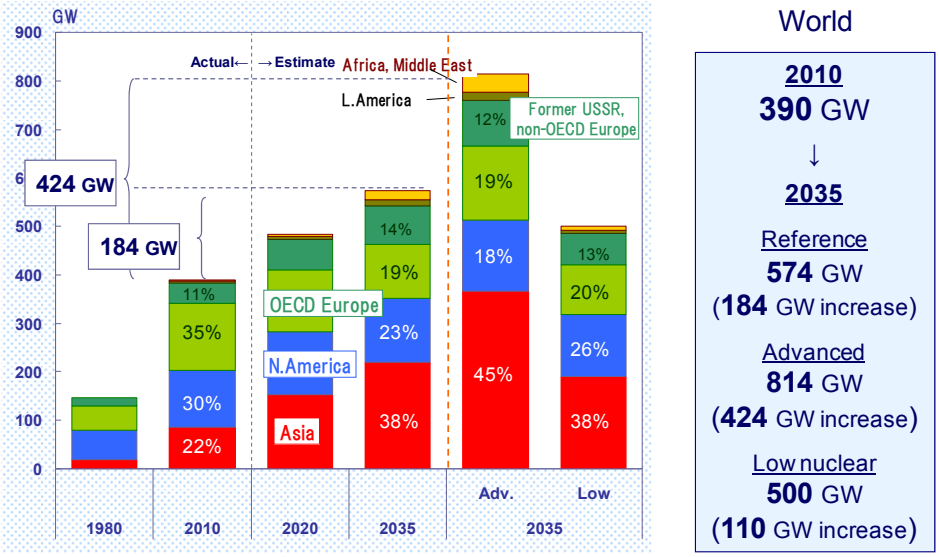
The second group covers China, India and other emerging countries. At the beginning of 2011, before the Fukushima incident, 13 nuclear reactors with a total capacity of 10.85 GW in China were in operation with 30 others under construction for a total capacity of 33 GW, three times as large as the existing capacity. Just after the incident, Premier Wen Jiabao convened a meeting of the State Council Standing Committee, deciding to conduct emergency safety checks on all nuclear power plants in operation and freeze new nuclear plant construction projects until a new nuclear safety program is developed. As a result, the plan to build nuclear reactors with a total capacity of 70-80 GW by 2020 is expected to be set back. Nevertheless, earlier approved nuclear plant construction projects have continued to be implemented steadily. On August 9, the No. 2 reactor (with a capacity of 1.08 GW) for the second phase program at the Lingao nuclear plant started commercial operation. The current freeze on new nuclear reactor construction approvals is expected to be lifted in the near future. Similarly, India has made no change to its nuclear plant construction program. It has sought to promote its thorium cycle development and introduce massive light-water reactors from abroad. In July, India launched the construction of the No. 7 and 8 reactors at its Rajasthan nuclear plant and has not made any change to its nuclear plant construction program even in the wake of the Fukushima incident.

The third group covers countries that do not currently operate nuclear power plants but plan to do so, including ASEAN members such as Vietnam and Indonesia, and Middle Eastern countries such as the United Arab Emirates and Saudi Arabia. Of these countries, the UAE and Vietnam have taken actions to build nuclear plants and attested to their policy of promoting their plans as in the past. In June, Saudi Arabia announced a new plan to construct 16 nuclear reactors. These countries have made no revisions to their nuclear plant construction plans while indicating their interests in improving nuclear plant safety based on the Fukushima incident. But fears have grown about nuclear plant safety in such ASEAN members as Indonesia and the Philippines that are as prone to earthquakes as Japan. These countries could revise their construction plans, delaying the construction substantially. Future outlooks for this group may differ from country to country.

The fourth group covers denuclearization policy countries including Belgium, Switzerland and Germany, as mentioned above.

While nuclear energy policies greatly differ from country to country, most existing nuclear power plants are in the first and second groups. As the two groups proceed with their earlier nuclear energy generation plans, global nuclear power generation capacity is expected to continue increasing.

Figure 4-8 World Nuclear Power Generation Capacity



By 2035, global nuclear power generation capacity is projected to rise by 184 GW from 390 GW in 2010 to 574 GW in 2035. As Asian countries including China, India and South Korea account for 134 GW of the increase, Asia can be viewed as the future nuclear investment and development center. Particularly, China will expand its nuclear power generation capacity by 95 GW from 9 GW in 2010 to 104 GW in 2035 and the nuclear power generation's share of its total electricity generation will increase from about 2% in 2009 to about 9% in 2035. China will thus post the largest growth in nuclear power generation capacity, followed by India which is expected to increase its capacity from 4 GW to 35 GW with nuclear energy's share of its total power generation output growing from about 2% in 2009 to about 5% in 2035.

In the Advanced Technologies Scenario (High Nuclear Case), nuclear power generation capacity will increase even further mainly in Asia, reaching 814 GW in 2035. Even in the Low Nuclear Case where nuclear energy development posts the maximum stagnation, global nuclear power generation capacity would continue increasing, reaching 500 GW in 2035.

(5) Renewable energy outlook

As renewable energies feature lower environmental constraints, great hopes are placed on photovoltaic, wind and other renewable energy power generation. Renewables (including hydro and geothermal energy) will expand their share of primary energy demand from about 4% in 2009 to about 7% in 2035. Some regions may accelerate the dissemination of renewable energies, thanks to abundant resources and policy incentives. On a worldwide basis, however, renewables may fall short of expanding their share of total energy supply to a level equal to the share for fossil energy resources due to high supply costs and unstable supply dependent on natural conditions. But the introduction of renewables featuring lower environmental constraints can contribute to reducing carbon emissions from power generation and stabilizing overall energy prices. Therefore, continuous research and development efforts to realize lower costs and higher efficiency for renewables and to harmonize them with energy systems will be a key challenge for the future.

[Photovoltaic power generation]

The world's photovoltaic power generation capacity stood at 23 GW in 2009. Of the total capacity, Germany, Spain, Japan and the United States account for about 80%. As Germany rapidly expanded its PV capacity in 2005, it replaced Japan which was world's No. 1 until then. With the introduction of about 2.7 GW in PV capacity, Spain replaced Japan as the world's No.

2, in 2008. Asian countries including South Korea and China have also been rapidly expanding their PV capacity. In Germany and other European countries, the feed-in tariff system has served as a great incentive for expanding PV capacity. The United States has positioned PV power generation as a new industry and earmarked funds in its budget for promoting the PV diffusion to expand the market for this industry.

The PV capacity outlook through 2035 indicates that it will continue expanding in part due to government incentives in various countries, mainly in Europe and the United States. From now on, PV costs will decline as market expands and technology improves, paving the way for full-fledged PV deployment. Despite the present problem of economic efficiency regarding PV systems, OECD countries view PV power generation as a useful energy for their depopulated regions and developing countries. Japan's long-term energy supply/demand outlook, as revised in August 2009, envisioned a 20-fold increase from 2005 to 2020 in PV capacity, and the government is expected to revise the expansion substantially upward in response to the Great East Japan Earthquake.

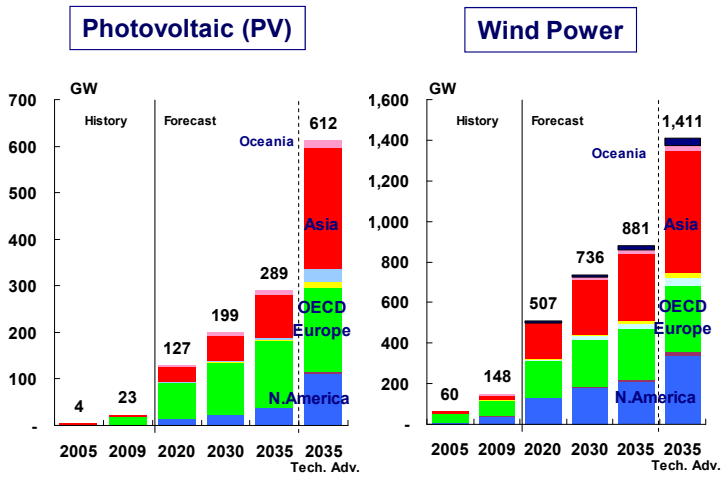
In the Reference Scenario, the world's PV capacity will increase 12-fold from 23 GW in 2009 to 289 GW in 2035. Particularly, Europe and Asia will post great growth in PV capacity. In the Advanced Technologies Scenario, the deployment is accelerated and the world's PV capacity will expand much faster reaching 612 GW in 2035.

[Wind power generation]

In 2009, the world's wind power generation capacity totaled about 150 GW. The global capacity increased as commercial wind power generation has grown prosperous on renewable energy business promotion policies (including feed-in tariff and quota obligation systems) and a decline in unit wind power generation cost amid the enlargement of windmills and the development and diffusion of relevant equipment. The United States, Germany and Spain feature particularly large wind power generation capacities. More recently, India and China have rapidly increased their capacities. Japan's capacity has also grown rapidly over recent years as the Japanese government launched a wind power development field test subsidy system in 1995 and a feed-in tariff system featuring long-term fixed prices in 1998. These systems have reduced initial investment costs, encouraging businesses to build large wind power generation facilities for electricity sales. At the end of FY 2009, Japan's wind power generation capacity reached 2.19 GW, with facilities concentrating in Hokkaido, Tohoku, Kyushu and other regions where wind conditions are favorable.

Wind power generation has been expanding primarily in Europe. In the future, European countries such as Germany, Spain and Denmark will play a leading role in further expanding wind power generation capacity particularly by constructing offshore facilities. Asia is also expected to rapidly increase such capacity on fast progress in China and India. In the Reference Scenario, global wind power generation capacity will expand six-fold from 148 GW in 2009 to 881 GW in 2035 as Europe and Asia will rapidly boost their respective capacities. In the Advanced Technologies Scenario, global wind power generation capacity will accelerate its expansion 10-fold from 2009 to 1,411 GW in 2035.

Figure 4-9 Photovoltaic and Wind Power Generation Capacity Outlook (World)



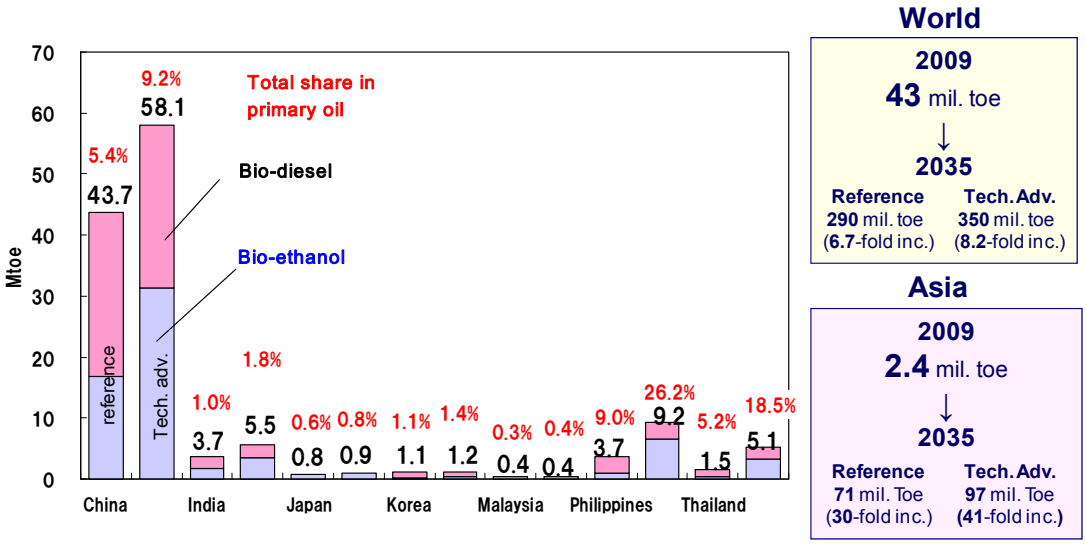
(6) Biofuel energy outlook

In an effort toward environmental conservation, many countries have increasingly blended ethanol from plants into gasoline. Global fuel ethanol production peaked in 1997, decreased slightly until 2000 and has been increasing ever since, reaching about 73 million kilolitres (m^3) in 2009. Brazil has produced bio-ethanol from sugar cane since 1975, leading world production for many years. Bio-ethanol output in the United States expanded fast from 2002 and replaced Brazil as the world's largest bio-ethanol producer in 2005. Brazil requires bio-ethanol to be blended with gasoline up to 20-25%. The United States originally introduced ethanol as a gasoline additive to help reduce air pollution and since the Energy Policy Act of 2005 which requires renewable fuels to be used, ethanol has diffused rapidly. In addition to those two countries, India, China, Thailand, the Philippines and other Asian countries, Canada and Australia, as well as Europe, have introduced bio-ethanol-blended gasoline. In support to the industry, 100% ethanol vehicles have been produced and more recently, flexible fuel vehicles that can run at any ethanol content level have also been introduced.

In Japan, the Act on the Quality Control of Gasoline and Other Fuels allows ethanol to be blended into gasoline up to 3% (oxygen content at 1.3 weight percent). Given qualitative problems such as phase separation accompanying the inclusion of air, the Petroleum Association of Japan has adopted a guideline to combine ethanol with isobutylene to synthesize ETBE (ethyl tertiary butyl ether) for blending with gasoline, instead of mixing ethanol directly into gasoline. As other Asian countries have paid attention to bio-ethanol for environmental conservation, bio-ethanol is expected to diffuse even further.

Bio-diesel has widely been used mainly in Europe where diesel vehicles are more abundant. In 2003, the European Union's Directives on the promotion and use of biofuels and other renewable fuels for transportation called for increasing biofuel's share of transportation fuel consumption to 5.75% by 2010. In 2007, the EU also proposed a higher target of 10% for 2020, indicating that biofuel will diffuse even further. While the United States has focused on bio-ethanol, Europe has introduced the B20 diesel with a 20% content for bio-diesel made from soybean and bio-diesel consumption has been growing. Malaysia, Indonesia, Thailand, the Philippines and other Asian countries have also proceeded with the deployment of bio-diesel made from domestically produced vegetable oil including palm and coconut oil.

Figure 4-10 Asian Biofuel Deployment Outlook



As existing biofuel competes with food, grain and edible, price hikes have become a global problem. Therefore, future biofuel development will focus on non-food wastes and untapped biomass resources. As for bio-ethanol, costs must be reduced for a next-generation technology to use non-food cellulose biomass resources. The United States has set a biofuel production target of 36 billion gallons for 2020, including 21 billion gallons in cellulose-based ethanol. It is also developing

bio-butanol that is convenient for improving fuel quality. Mainly in Asia and Africa, *Jatropha curcas* has attracted attention as a non-food plant that can be used for producing bio-diesel with existing technologies. Europe is considering developing BTL (biomass to liquid) and in a more advanced biofuel development effort, the United States, Australia, Thailand and other Asia-Pacific countries are planning to use micro algae containing abundant oil.

In the Reference Scenario, biofuel production will increase from 43 million tons oil equivalent in 2009 to 290 Mtoe in 2035. The biofuel diffusion must be accompanied by efforts to solve relevant problems including biofuel's competition with food, eco-system destruction, lower economic efficiency and unstable supply. China, India and Japan will most probably focus mainly on bio-ethanol, while South Korea, Indonesia and Malaysia will promote bio-diesel. Asian biofuel production in 2035 will reach 71 Mtoe (1.42 million bpd), amounting to 3.7% of Asian oil demand. China's production is estimated to reach as much as 43.7 Mtoe, equivalent to 5.4% of 810 million tons in oil demand. In the Advanced Technologies Scenario, biofuel production in 2035 will increase by about 20% to 350 Mtoe in the world, including 97 Mtoe in Asia.

4-3 Final energy demand and electricity mix outlook

(1) Final energy demand outlook

Global final energy demand will increase at an annual rate of 1.7% from 7 Gtoe in 2009 to 11.1 Gtoe in 2035. Demand will expand at an annual rate of 1.5% in the industry sector, at 1.7% in the transportation sector and at 2.0% in residential/commercial and other sectors. In developing countries, each sector will feature substantial demand growth and as developing societies mature through 2035, transportation, residential/commercial and other sectors' shares of global demand will gradually increase. Developing countries will thus slowly shift to the energy demand path that industrial countries previously followed.

Although final energy demand will see a growing switch toward electricity and gas, oil will still boast the largest share of final energy demand at 40%. Oil demand will grow at an annual rate of 1.3% to 4.4 Gtoe in 2035, accounting for about 90% of final energy demand in the transportation sector, 12% in the industry sector and about 20% in residential/commercial and other sectors. A change in the demand pattern will cause a shift to lighter, more refined petroleum products.

Driven by Asia, Europe and the Middle East, final natural gas demand will increase at an annual rate of 2.1% to 2.2 Gtoe in 2035. Gas demand increases to fulfill requirements mainly from the industry sector and other sectors. Despite steelmakers' persistent coal demand, coal's share of final energy demand will follow a downward trend as the annual growth rate slows to 0.6% because of the industry and residential/commercial sectors' growing switch from coal to other fuels. Electricity demand linked closely to economic development will post the largest growth among major energy categories both in industrial and developing countries. Global electricity demand will increase at an annual rate of 2.6%, accounting for 25% of total final energy demand.

Asian final energy demand will increase at an annual rate of 2.6% from 2.4 Gtoe in 2009 to 4.7 Gtoe in 2035 as dramatic economic development leads to the advancement of industrial structure, urbanization and the improvement of living standards. Asia will account for 2.3 Gtoe of the global increase at 4 Gtoe. Among sectors, industry will post the slowest annual energy demand growth rate at 1.8%. Energy demand in the transportation sector will rise at an annual rate of 3.5% and residential/commercial and other sectors at 3.3%. In Asia, energy demand will substantially increase in the transportation sector on motorization and in the residential/commercial sector on living standard improvements.

Asian final energy demand also sees a growing switch to electricity and gas. The switch in Asia is more remarkable than in the

rest of the world. While overall final energy demand will increase at an annual rate of 2.6%, electricity demand will grow at a faster rate of 3.6% on the advancement of the industrial structure and increasing electrical appliance consumption associated with income growth. Electricity's share of overall final energy demand in Asia will rise from 22% in 2009 to 28% in 2035 and gas' share will also increase from 7.7% to 13% while oil's share will level off at 39%. Coal's share will fall from 29% to 17%, reflecting its drop particularly in the industry and residential/commercial sectors in such countries as China and India.

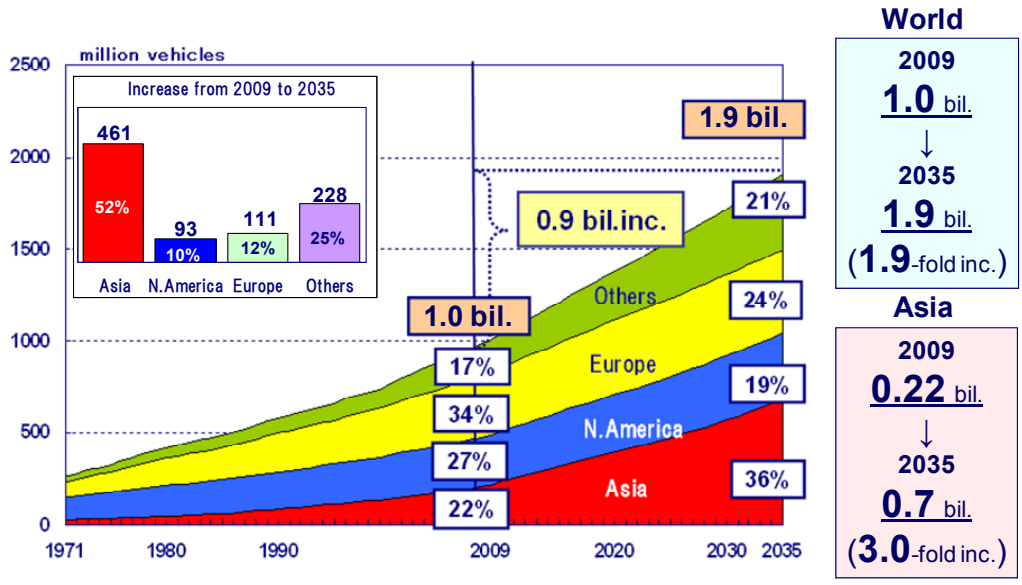
(2) Motorization

Global vehicle stocks will increase from 1.0 billion units in 2009 to 1.9 billion units in 2035. Asian vehicle stocks will expand from 220 million units in 2009 to 680 million units in 2035 as motorization makes further progress on income level improvements in developing countries. Asia will thus account for almost 50% of the global vehicle stock growth through 2035. Industrial countries' share of global vehicle stocks will decline from 69% in 2009 to 47% in 2035, while developing countries' share will increase from 31% to 53%. Vehicle stocks in developing countries will thus exceed those in industrial countries by 2035.

Just as motorization in industrial countries had paused and is expected to mature, developing Asian countries enters the motorization phase, with demand exploding for such transportation fuels as gasoline and diesel. Vehicle sales and home electrical appliance sales are the most symbolic indicators of living standard improvements. Motorization in Asian countries is a natural phenomenon associated with economic development. In 2035, the Asian vehicle market could become the world's largest, surpassing North America or Europe. Brazil, supported by favorable factors such as the 2016 Rio de Janeiro Olympic Games, is also likely to expand its vehicle stock and vehicle demand may exceed its domestic production capacity.

In this way, motorization in developing countries which is still at low levels, is likely to continue to grow in the future. Their motorization is expected to have a great impact on the international oil market. At the same time, however, the transportation sector's CO_2 emissions are feared to increase explosively on population and economic growth in developing countries. Developing countries may expand efforts to diffuse compressed natural gas vehicles and biofuel to reduce CO_2 emissions. Industrial countries may promote their domestic diffusion of eco-friendly vehicles and accelerate relevant investment in developing countries.

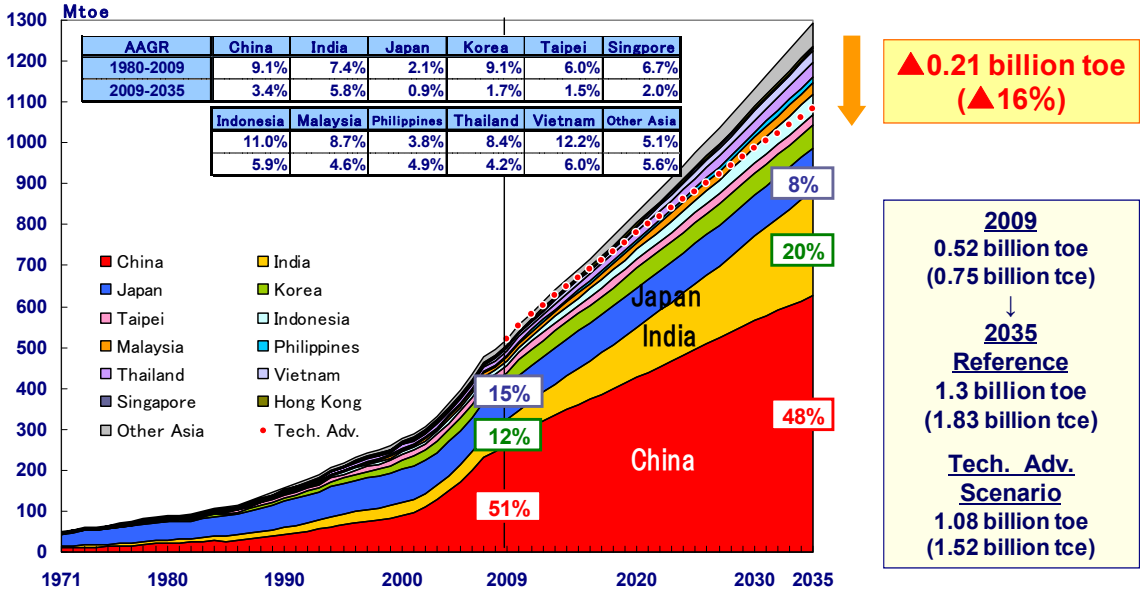
Figure 4-11 Global Vehicle Stocks



(3) Growing demand switch to electricity and electricity generation mix outlook

As energy consumption advances on economic and income growth in Asia, electricity demand will steadily increase. China's electricity demand will increase at an annual rate of 3.5% to 8,500 terawatt-hours in 2035, 2.4 times more than the current level and about 8 times more than Japan's current level. India's electricity demand will grow at an annual rate of 5.9% to 3,700 TWh in 2035, about 4.6 times more than the present level. Industrial countries will account for some 20% of electric demand growth through 2035 and developing countries for about 80%.

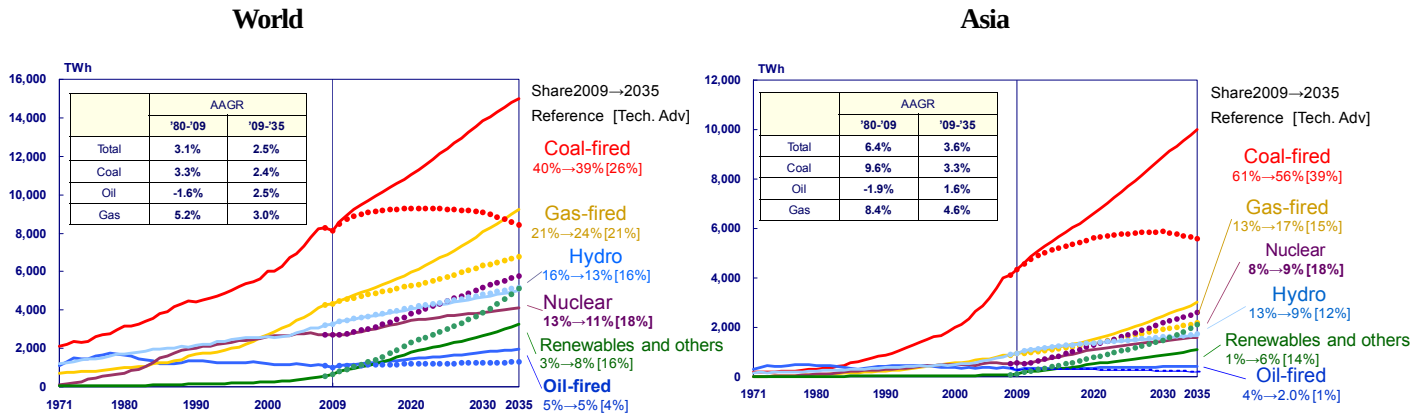
Figure 4-12 Asian Electricity Demand



Reflecting steady electricity demand growth, global electricity generation will increase at an annual average rate of 2.5% from 20,100 TWh in 2009 to about 39,000 TWh in 2035. Developing countries will account for more than 70% of the electricity generation growth through 2035, as electricity output will grow at an annual rate of 3.6% from 6,900 TWh in 2009 to about 18,000 TWh in 2035.

Coal-fired power generation accounted for the largest share at 41% of global electricity output in 2009, followed by natural gas, hydro, nuclear and oil-fired generation. The electricity generation mix through 2035 will see a growing share for natural gas-fired generation as natural gas combined cycle and other plants are introduced to reduce the power plants' environmental load. Natural gas-fired generation's share of the entire electricity output will increase from 22% in 2009 to 24% in 2035. Coal-fired generation's share will not change from 41% in 2009 through 2035, remaining as the largest electricity supply source. In China and India, coal-fired plants will become a major electricity source meeting fast-growing demand. Oil-fired plants' share will follow a downward trend particularly in industrial countries. As for nuclear power generation, Asian and some other countries are expected to build new plants in an attempt to achieve some energy security and help prevent global warming but new nuclear plants will fall short of covering all electricity demand growth through 2035. Nuclear power generation's share of total electricity output will thus fall slightly from 13% in 2009 to 11% in 2035. Renewable energy power plants other than hydro facilities will expand their share of total electricity generation from 3.3% to 8.5% as many countries expand the deployment of wind and PV power generation facilities to secure stable international energy supply and enhance global warming measures. As living standards are improved in Asia, demand for convenient electricity will increase. The estimated electricity generation mix to meet the demand growth indicates that Asian countries will steadily increase coal-fired power generation using their abundant domestic resources and exports their oil and natural gas resources to earn foreign currencies. Although coal-fired plants will remain the largest electricity source in Asia, its share of total electricity output will fall slightly from 61% in 2009 to 56% in 2035.

Figure 4-13 World and Asian Electricity Mix



Natural gas' share of total power generation in Asia will steadily but slowly expand from 13% to only 17%. As more natural gas combined cycle plants are built, more coal-fired plants will also be added under policies that provide priority to the effective use of available domestic resources. Given this competition between coal and gas, the progress of gas-fired power generation in Asia will be slower than in the world. Nuclear power generation is not expected to increase in Japan but China, India, South Korea and some other Asian countries will expand nuclear power generation to some extent. Nuclear energy's share of electricity generation in Asia will rise from 8% in 2009 to 9% in 2035. Nuclear power plants will thus play a steady role in supplying electricity in Asia.

In the world, coal-fired power generation will maintain a certain share of overall electricity output, while natural gas-fired generation will increase faster than hydro and nuclear generation. Renewable energy generation will also expand gradually. In Asia, coal-fired and nuclear power plants will maintain certain shares of total electricity output, while natural gas-fired plants will expand their share.

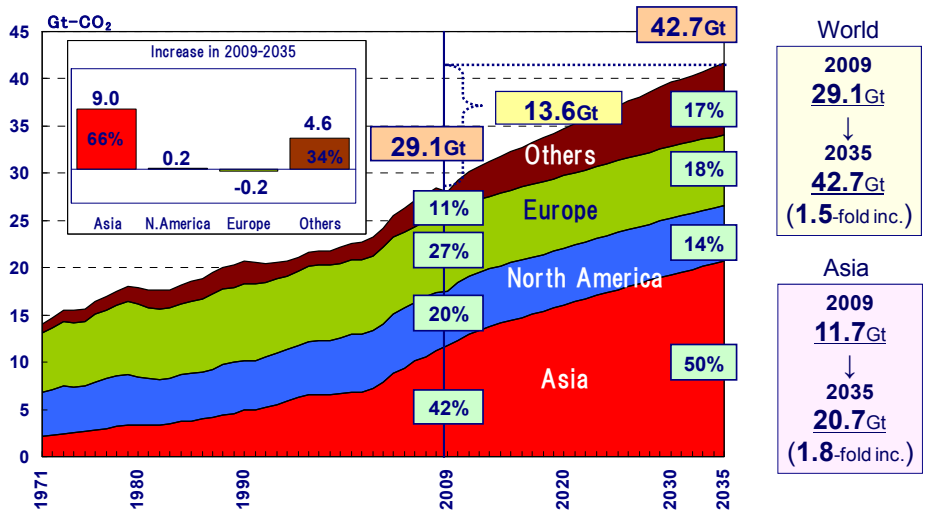
CO_2 emissions from coal-fired power plants in the world will increase by a total of 5.0 gigatons from 8.1 Gt in 2009 to 13.1 Gt in 2035, accounting for about 38% of global CO_2 emission growth. CO_2 emissions from coal-fired power plants in Asia will increase by 4.3 Gt from 4.5 Gt in 2009 to 8.8 Gt in 2035, accounting for about 33% of global CO_2 emission growth through 2035. Therefore, more efficient use of coal with clean coal technologies in the world and mainly in developing Asian countries will be a very important challenge.

In the Advanced Technologies Scenario, coal will account for 26% of global electricity generation in 2035, natural gas for 21%, nuclear for 18%, hydro for 16%, renewables for 16%, and oil for 4%. Nuclear and renewable energies will expand their shares, while coal will substantially reduce its share. A similar trend will be seen in Asia with coal's share declining from 61% to 39%, while nuclear and renewables will increase their shares from 8% to 18% and from 2% to 15%, respectively.

4-4 CO_2 emission outlook

As fossil fuels account for about 80% of global primary energy demand through 2035, global CO_2 emissions will increase about 1.5-fold from 29.1 Gt in 2009 to 42.7 Gt in 2035. The annual average increase will be 1.5%, almost the same as that for primary energy demand. Industrial countries' share of global CO_2 emissions will decline from 41% in 2009 to 29% in 2035, while developing countries' share will rise close to 70% in 2035. Developing countries will account for about 90% of the global CO_2 emission growth with Asia accounting for about 70% of the growth. China will continue to depend primarily on coal with a higher CO_2 emission intensity for primary energy supply and account for about 30% of the global CO_2 emission expansion.

Figure 4-14 Global CO2 Emissions



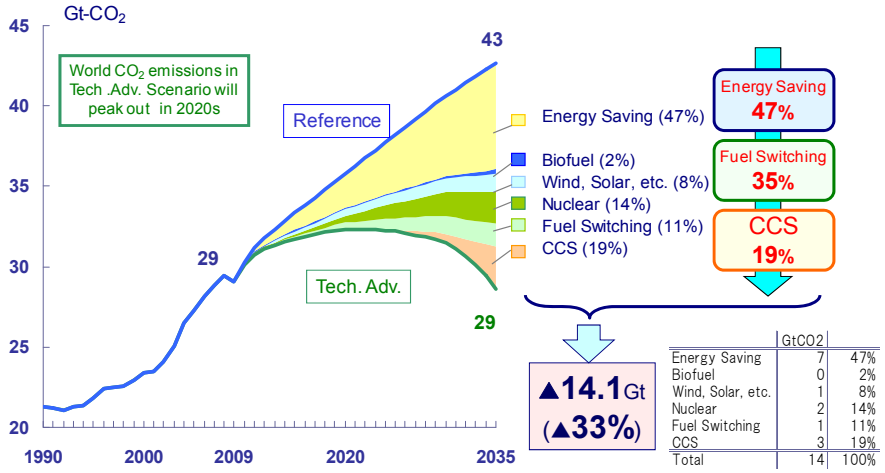
In the Advanced Technologies Scenario, global CO_2 emissions will increase by 5.1 Gt or 19% from 2005 to 2020 and then peak out, thanks to the further development of energy and environment technologies. CO_2 emissions in 2035 in this scenario will be 28.6 Gt, 14.1 Gt or 33% less than in the Reference Scenario.

Energy conservation, the improvement of power generation efficiency, the introduction of non-fossil energies, fuel switching, CO_2 capture and storage, and other measures may be combined to make substantial contributions to reducing CO_2 emissions. But there is no single or simple means to effectively reduce CO_2 emissions.

Japan's share of CO_2 emissions in Asia will gradually decline on a population decline and moderate economic growth, slipping below 10% in 2035. CO_2 emissions in China and India are expected to rapidly increase as they continue to consume more fossil fuels, including coal. China will account for about 50% of Asian CO_2 emission growth between 2009 and 2035 and India for about 30%.

Fossil fuel-based CO_2 emissions in developing countries will account for 87% of global emission growth between 2009 and 2035 and those in Asia for 66%. Therefore, the clean use of fossil fuels will be important. Among fossil fuel-based CO_2 emissions, oil related emissions in developing countries will account for 30% of global emission growth and Asia will account for 17% of the global growth. Natural gas related emissions in developing countries will account for 26% of global emission growth, indicating that more efficient gas consumption will also be a key challenge. Given that Asian coal-based emissions will account for 37% of global emission growth, the environmentally-friendly use of coal in Asia will be very important.

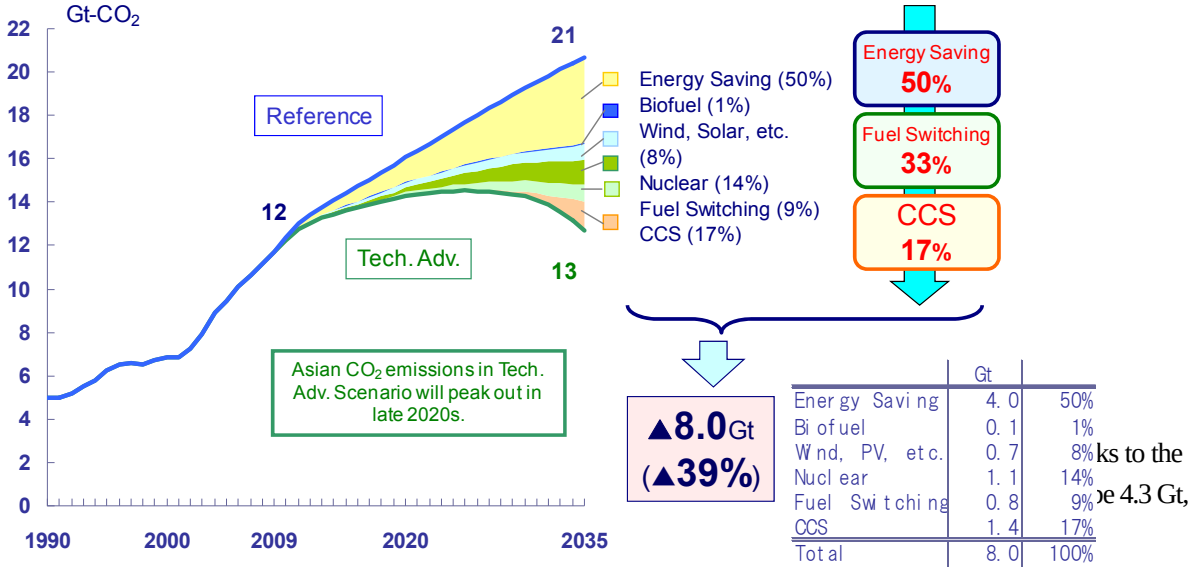
Figure 4-15 Global CO2 Emissions Reduction



In the Advanced Technologies Scenario, the CO_2 emission reductions in industrial countries total 4.2 Gt in 2035. Energy conservation will account for 39% of the reductions (1.6 Gt), nuclear energy for 17% (0.7 Gt), renewables for 18% (0.8 Gt), fuel switching for 11% (0.5 Gt) and CCS for 15% (0.6 Gt).

In the Advanced Technologies Scenario, CO_2 emissions in developing countries will peak out in the second half of the 2020s. Of the CO_2 emission cuts totaling 9.9 Gt in 2035, energy conservation will account for 51% (5.0 Gt), nuclear energy for 12% (1.2 Gt), renewable for 6% (0.6 Gt), fuel switching for 11% (1.0 Gt) and CCS for 20% (2.0 Gt). Energy conservation efforts will make great contributions to reducing CO_2 emissions, accounting for 5 .0 Gt or about 40% of global cuts totaling 14.1 Gt. This means that technology transfer, institutional development and other measures to support energy conservation in developing countries will be very significant.

Figure 4-16 Asian CO2 Emissions Reduction



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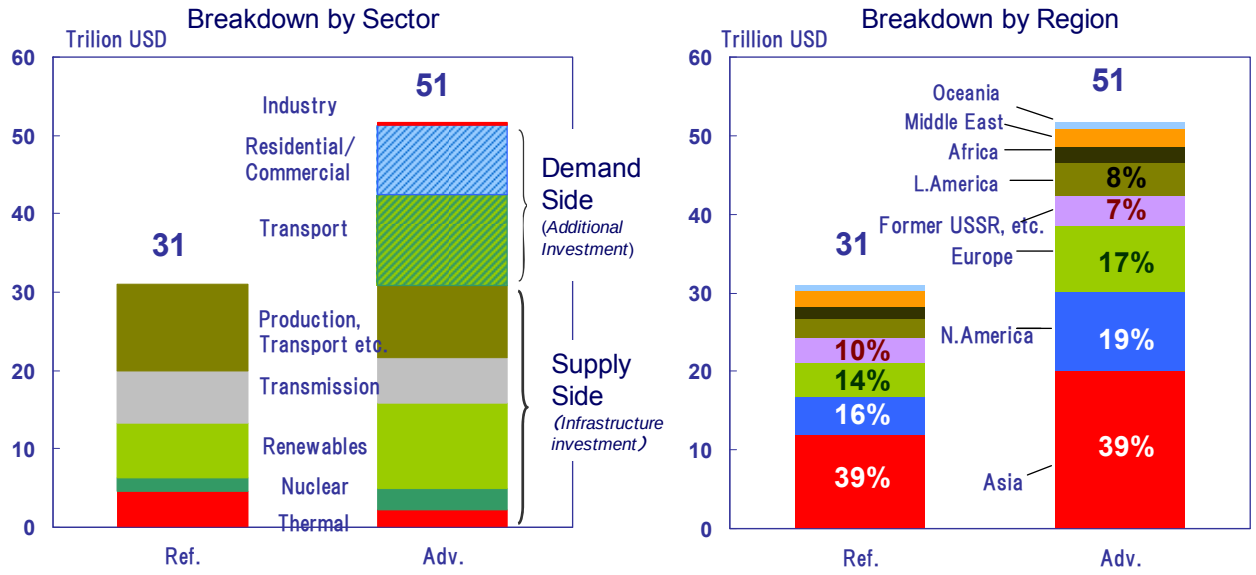
4-5 Cumulative investment through 2035 and implications of the Low Nuclear Case

(1) Cumulative investment through 2035

Figure 4-17 shows the estimated cumulative investment through 2035 from the energy supply side. They include investments required in power plant construction and other infrastructure development projects, in order to meet the estimated electricity demand and primary energy demand. The energy supply side's cumulative investment is estimated at $31 trillion for the Reference Scenario. In the Advanced Technologies Scenario, investment in fossil fuel-fired power plant construction and upstream infrastructure development will be less, while additional investments in renewable energy will be required. As a result, the energy supply side's investments in this scenario are estimated at almost the same level as in the Reference Scenario. But the energy demand side in the Advanced Technologies Scenario will require additional investment to support energy conservation efforts in each of the energy demand sector. Total cumulative investment in this scenario thus comes to about $51 trillion. Of the total, Asia will account for the largest share at about 40%, followed by North America and Europe.

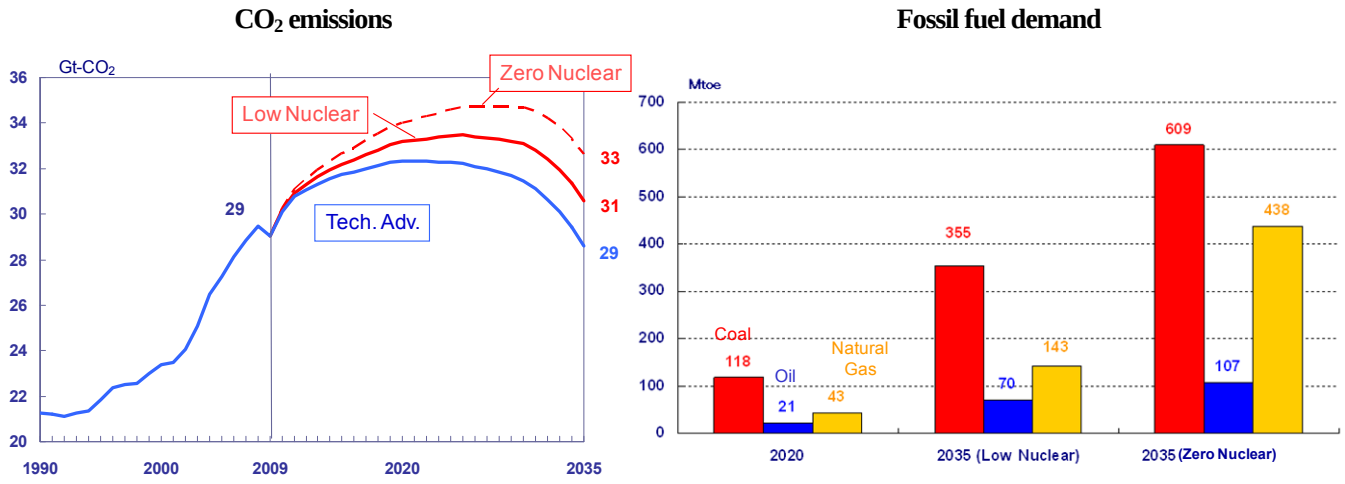
Figure 4-17 Cumulative Investment through 2035



(2) Implications of the Low Nuclear Case

If nuclear power generation falls from the Advanced Technologies Scenario level to the Low Nuclear Case level, the additional fossil fuel-fired power generation required to cover the fall would increase global CO_2 emissions in 2035 by about 2 Gt or 7%. Coal demand would expand by about 500 Mt (or 360 Mtoe), oil demand by about 1.4 million bpd (or 70 Mtoe) and natural gas by about 140 bcm (or 140 Mtoe, amounting to half the present global LNG trade). Such demand expansion would greatly affect the global fossil fuel supply/demand balance. If nuclear power generation is pushed further down for 2035, the increases in CO_2 emissions and fossil fuel demand would be even greater.

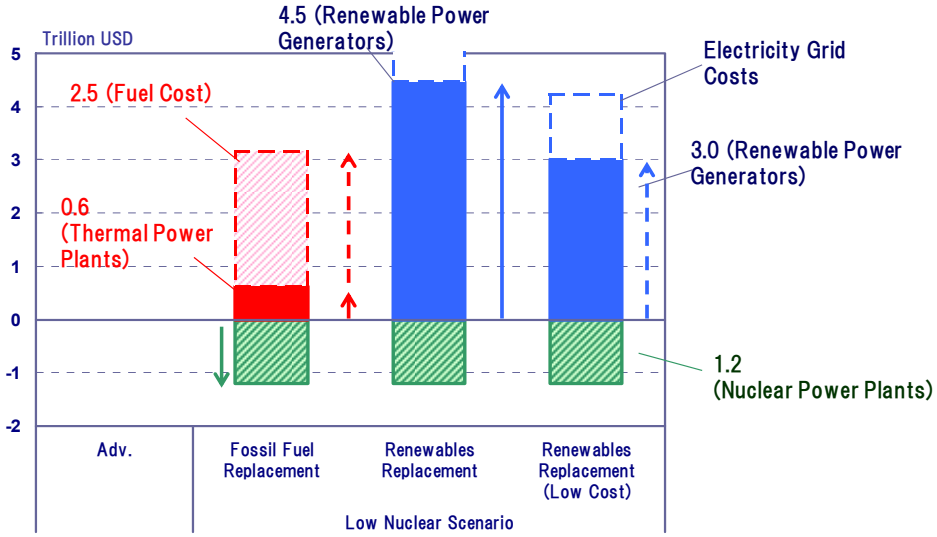
Figure 4-18 Implications of Low Nuclear Scenario



If the decline in nuclear power generation is assumed to be replaced by fossil fuel-fired generation, investments for new power generation facilities may decrease by $0.6 trillion but additional investments in fossil fuel supply would be required, resulting in $2.5 trillion in cumulative costs. If the decline is covered by renewable energy power generation (including wind and PV power generation), cumulative investments at current costs in new power generation facilities may increase by $4.5 trillion. If

costs are reduced substantially (PV equipment production and installment costs are halved from $5,000 per kilowatt on a 25-year average basis and installation costs for offshore wind power generators are reduced to the same level as for onshore generators), the investment in renewable energy power generation facilities would fall to almost the same level as for fossil fuel-fired facilities. Massive deployment of renewable energy power generation could destabilize electricity grids, resulting in some additional grid improvement costs.

Figure 4-19 Cumulative Investment through 2035 (Low Nuclear Case)



5. Long-term World Energy Supply/Demand Outlook through 2050

A very-long-term assessment covering the period 2035-2050 has also been prepared Extending the 2035 outlook through 2050 provides sufficient insights to conduct an impact analysis of enhanced global warming measures and of further diffusion of innovative technologies. The outlook through 2050 is similar to the world energy supply/demand outlook until 2035 and the 2035-2050 period has been estimated based on the energy and environmental technology trends.

5-1 Assumptions

As developing countries are expected to gradually slow down their economic growth past 2035, global GDP is assumed to grow at an annual average rate of 1.9% between 2035 and 2050 or an average of 2.7% between 2009 and 2050. Global population is projected to increase to 8.6 billion in 2035 and is assumed to further expand by 0.7 billion to 9.3 billion in 2050. Crude oil prices are assumed to rise from $120/barrel in 2035 to $125/barrel in 2050 on a continued production cost increase despite slow global demand growth.

Table 5-1 Socio-economic Outlook through 2050

	2009	2035	2050
GDP (2000 real price)	**40** tril. $ (AAGR in 1990-2009:2.6%)	**87** tril. $ (AAGR in 2009-2035:3.1%)	**116** tril. $ (AAGR in 2035-2050:1.9%) (AAGR in 2009-2050:2.7%)
Population	**6.8** bil.	**8.6** bil. (1.8 bil. increase from 2009)	**9.3** bil. (2.5 bil. increase from 2009)
GDP per Capita	**6** thousand $	**10** thousand $	**13** thousand $
Oil Price (On a Japanese CIF basis、2010 real price)	(2010) **79 $/bbl**	**120 $/bbl** (Nominal price:197 $/bbl)	**125 $/bbl** (Nominal price:276 $/bbl)

Table 5-2 Technological Assumptions through 2050

	2009	2035		2050	
	Actual	Reference	Tech. Adv.	Reference	Tech. Adv.
Nuclear	390 GW	574 GW	814 GW	725 GW	1,140 GW
Conversion Efficiency	Coal:34% Gas:40%	Coal: 39% Gas: 45%	Coal: 42% Gas: 47%	Coal: 41% Gas: 46%	Coal: 45% Gas: 50%
Photovoltaic	23 GW	289 GW	612 GW	448 GW	1,239 GW
CSP	0.6 GW	58 GW	113 GW	103 GW	426 GW
Wind	148 GW	881 GW	1,411 GW	1,211 GW	2,266 GW
Biomass Power Gen.	62 GW	200 GW	223 GW	255 GW	274 GW
Biofuel	43 Mtoe	287 Mtoe	350 Mtoe	473 Mtoe	540 Mtoe
CCS	-	0	2.6 bil. Ton	0	10.1 bil. Ton
Next-generation vehicles' share of sales PHEV EV/FCV	-	5% 0%	22% 16%	11% 2%	30% 31%
Average fuel efficiency of new vehicles	(2010) 14 km/L	18 km/L	25 km/L	20 km/L	30 km/L

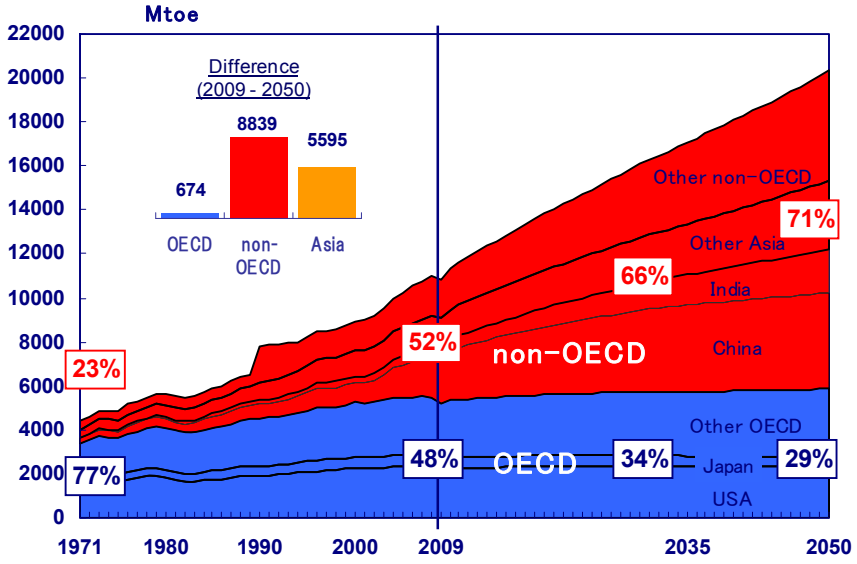
Energy and environmental technology deployment assumptions have also been set for the period from 2035 to 2050. Global nuclear power generation current capacity is assumed to almost double by 2050 in the Reference Scenario and triple in the Advanced Technologies Scenario. Renewable energy power generation capacity in 2050, excluding hydro, is assumed to expand about 14-fold from 2009 to 2050 in the Advanced Technologies Scenario. In the scenario, wind power generation capacity in 2050 is projected to expand by 15-fold, PV 54-fold, CSP 710-fold, ocean power 100-fold, and biomass power four-fold.

Other assumptions include Electric, plug-in hybrid and other next-generation vehicles expanding their share of new vehicle sales in 2050 from 13% in the Reference Scenario and to 61% in the Advanced Technologies Scenario. Annual global CCS volume is assumed to quadruple from 2035 reaching 10.1 Gt in 2050.

5-2 Results through 2050

Global primary energy demand will increase by 9.5 Gtoe or 1.9-fold from 10.9 Gtoe in 2009 to 20.4 Gtoe in 2050. Of the 9.5 Gtoe increase, developing countries will be accounting for 8.8 Gtoe and industrial countries for 0.7 Gtoe. Developing countries' share of global primary energy demand will expand form 52% in 2009 to 71% in 2050. China's share will increase from 19% to 21% and India's from 5% to 10%, while Japan's share will fall from 4% to 2%.

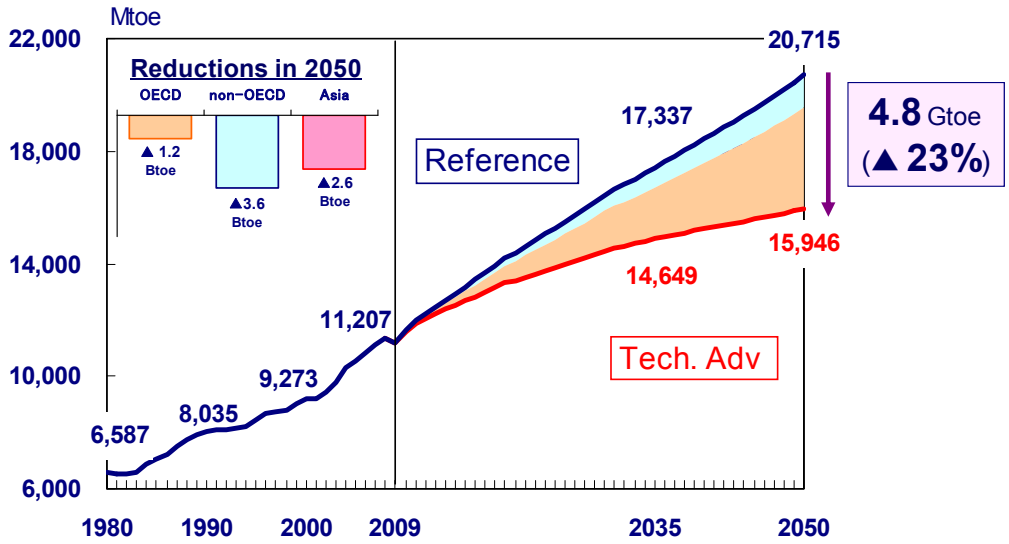
Figure 5-1 Global Primary Energy Demand through 2050



In the Advanced Technologies Scenario, global primary energy demand will peak out around 2050. Demand will be 4.8 Gtoe or 23% less than in the Reference Scenario. The gap includes 1.2 Gtoe for industrial countries and 3.6 Gtoe for developing countries, indicating that the diffusion of innovative technologies will contribute to a substantial reduction in energy demand in developing countries.

In the Reference Scenario, demand will increase from 2009 to 2050 for all energy sources, such as, coal, oil, gas, nuclear and renewables. Even in the Advanced Technologies Scenario, fossil fuels will still account for most (69%) of the global primary energy demand and continue to play a key role. Therefore, sufficient investments in fossil fuel production to secure stable supply will still be required.

Figure 5-2 Global Primary Energy Demand Reduction through 2050

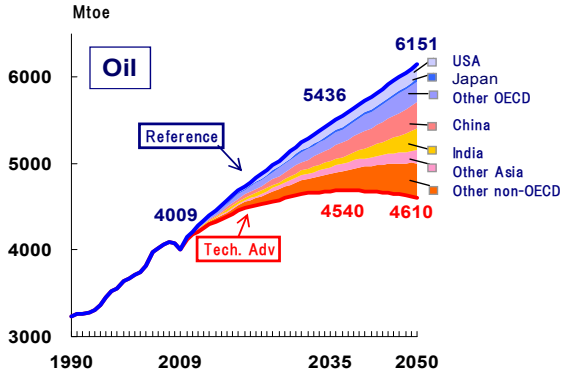


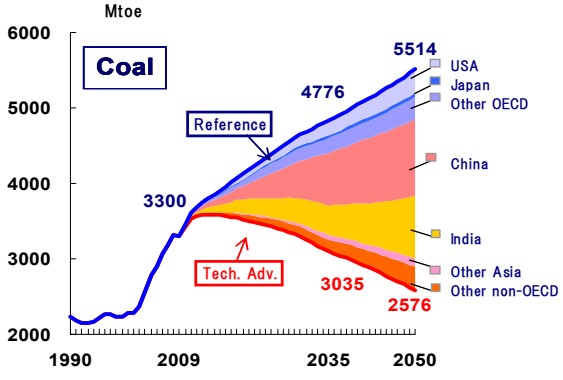
In the Advanced Technologies Scenario, global coal demand in 2050 will decline by 27% from 2009 and global oil demand by 5%. Global oil demand will decrease from 83 million bpd in 2009 to 79 million bpd in 2050 and global coal demand from 4.7 Gtce to 3.4 Gtce. Natural gas is expected to play a major role in global energy markets in the future, with demand in 2050 increasing by 56% from 2009, expanding its share of global primary energy supply from 23% in 2009 to 27% in 2050. Non-fossil energy sources' share in 2050 will reach 16% in the Reference Scenario and 31% in the Advanced Technologies Scenario. Nuclear and renewable energies are thus expected to grow more important in the Advanced Technologies Scenario.

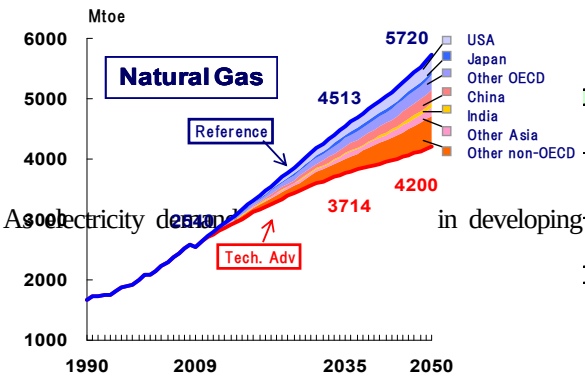
In the Reference Scenario, global oil demand will increase mainly in developing countries. On the other hand, the Advanced Technologies Scenario shows that global fossil fuel demand will peak in 2030 with developing countries' coal demand peaking in 2021 and declining later.

The potential for fossil fuel demand reduction in Asia between the two scenarios is relatively larger than in any other regions. Developing Asian countries account for 46% of global oil demand cuts in 2050, 67% of coal demand cuts and 29% of gas demand cuts. The diffusion of clean coal and other alternative technologies for more efficient use of fossil fuels will be an important challenge for developing Asian countries.

Figure 5-3 Primary Energy Demand Breakdown by Source (in Reference and Technologically Advanced Scenarios)







Reduction in 2050 (Regional Breakdown)

(Oil)

	Mtoe	Share
USA	168	11%
Japan	33	2%
Other OECD	242	16%
China	296	19%
India	257	17%
Other Asia	151	10%
Other non-OECD	394	26%
OECD	442	29%
non-OECD	1,099	71%
Developing Asia	705	46%
World	1,541	100%

(Coal)

	Mtoe	Share
USA	316	11%
Japan	56	2%
Other OECD	287	10%
China	1,021	35%
India	829	28%
Other Asia	114	4%
Other non-OECD	316	11%
OECD	659	22%
non-OECD	2,280	78%
Developing Asia	1,964	67%
World	2,938	100%

(Natural Gas)

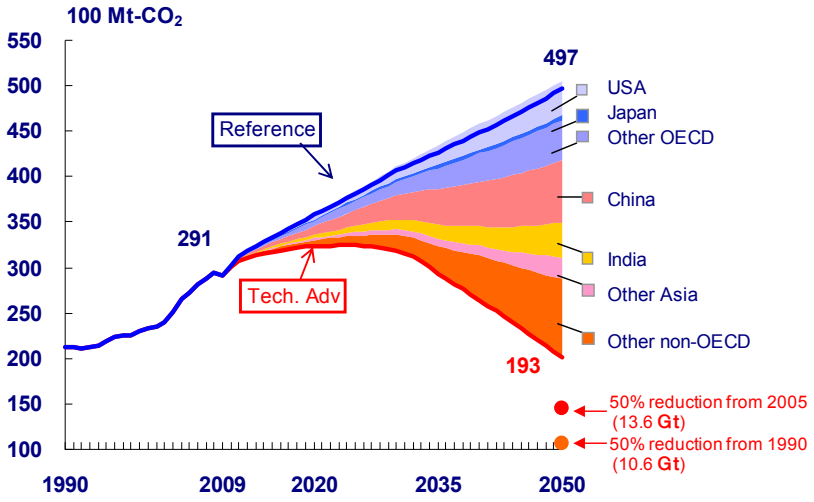
	Mtoe	Share
USA	271	18%
Japan	63	4%
Other OECD	238	16%
China	211	14%
India	81	5%
Other Asia	142	9%
Other non-OECD	514	34%
OECD	572	38%
non-OECD	948	62%
Developing Asia	434	29%
World	1,520	100%

As electricity demand in developing countries achieving economic growth over longer time, global

electricity generation will increase by 30,000 TWh from 20,000 TWh in 2009 to about 50,000 TWh in 2050. In the Advanced Technologies Scenario the growth is substantially less and the required electricity generation expands by 19,000 TWh (instead of 30,000 TWh) to reach 39,000 TWh in 2050. As nuclear and renewable energy power generation expands substantially in this scenario, non-fossil electricity generation expands its share of total electricity output from 31% in the Reference Scenario to 58% in the Advanced Technologies Scenario.

In the Reference Scenario, global CO_2 emissions will increase by about 1.7-fold from 29 Gt in 2009 to almost 50 Gt in 2050. All of the increase occurs in developing countries, with CO_2 emissions growing from 16 Gt to 36.7 Gt. Asian CO_2 emissions are expanding by 13.8 Gt, accounting for about 70% of the global CO_2 emission growth. Therefore, industrial countries' share of global CO_2 emissions will decline rapidly from 42% in 2009 to 24% in 2050. Japan's share will fall from 4% to 2% while China's share will almost level off and India's share will increase from 6% to 13%.

Figure 5-4 CO2 Emissions Reduction Potential by Region



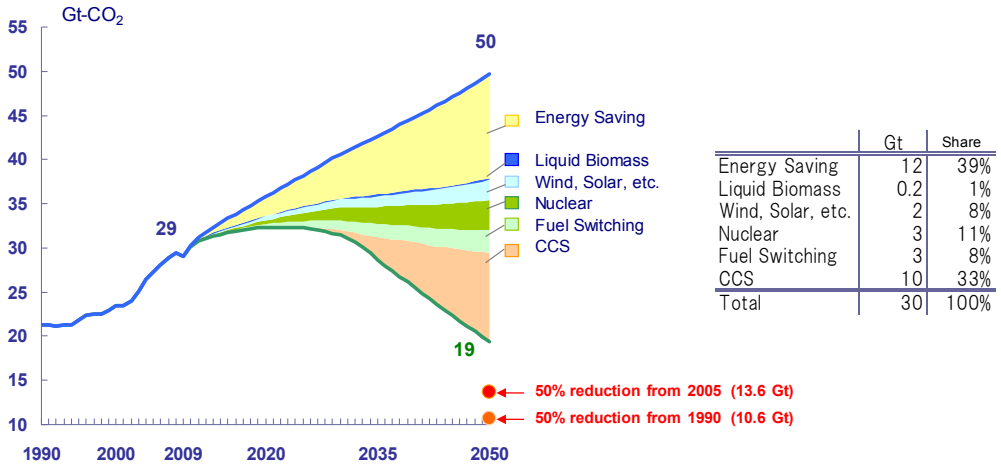
CO_2 emissions reduction in 2050

	100 Mt	比率 Share
USA	38	13%
Japan	5	2%
Other OECD	45	15%
China	68	22%
India	38	13%
Other Asia	24	8%
Other non-OECD	86	28%
OECD	88	29%
non-OECD	216	71%
Developing Asia	130	43%
World	304	100%

In the Advanced Technologies Scenario, global CO_2 emissions for 2050 will be 60% lower than in the Reference Scenario, down from 50 GT to less than 20 Gt (about 30% less than the 2005 levels). Industrial countries CO_2 emissions will be down by 8.8 Gt and developing countries down by 21.6 Gt, for a total decline of 30.4 Gt in 2050. The estimation of the CO_2 emission reduction potential indicates that the potential is larger in developing countries than in industrial countries (71% of the global potential). This supports the argument that promoting climate change measures in developing countries will be very important. Among developing countries, Asia provides for great reduction potentials, accounting for 13 Gt or 43% of the global potential. China alone will account for half of them at 6.8 Gt (or 22% of the global potential).

A breakdown of the global CO_2 emission reduction potential by technology category indicates that the promotion of energy savings technologies will make the greatest contribution, accounting for 40% of the global potential. Fuel switching from coal and oil to natural gas, nuclear or renewables (accounting for 30% of the global potential) and the CCS (accounting for 30%) will also play key roles in achieving reductions. In order to further cut CO_2 emissions to reach 50% of the 2005 levels by 2050, the world will require additional measures including such long-term measures as innovative technology development and environment-friendly urban development.

Figure 5-5 CO2 Emissions Reduction Potential by Technology Category



	Gt	Share
Energy Saving	12	39%
Liquid Biomass	0.2	1%
Wind, Solar, etc.	2	8%
Nuclear	3	11%
Fuel Switching	3	8%
CCS	10	33%
Total	30	100%

6. Concluding remarks

■ Implications of the Fukushima Daiichi nuclear plant incident

The Great East Japan Earthquake and the subsequent Fukushima Daiichi nuclear plant incident have raised the global issue of safety regarding nuclear power generation. As a result, various countries in the world reviewed and changed their national nuclear energy policies.

Amid such growing fears about safety, a few countries have decided to phase out or reduce nuclear power generation and others have set back their nuclear plant construction plans. In the entire world, however, nuclear power generation will be maintained or expanded in order to achieve the three "**Es**" – energy security, environmental protection and economic growth – over a medium to long term. Particularly, Asian and other emerging countries will play a key role in expanding nuclear power generation. The enhancement of nuclear plant safety is therefore indispensable. It is important for Japan to make proactive contributions to building global arrangements for an international cooperation in safety management.

Another major challenge is to secure alternative electricity sources covering electricity generation capacity losses on delays or setbacks in nuclear power generation plans. For the immediate future, natural gas and other fossil fuel power generation will cover such losses with considerations given to costs. Over a medium to long term, however, it will be important to reduce costs for more diffusion of renewable energy power generation free from CO_2 emissions.

■ Fast-growing energy demand, stable supply security and global environmental protection measures

Energy demand, particularly fossil fuel demand, will continue expanding in line with economic growth mainly in Asia. As fears grow about constraints on fossil fuel supply, it will become more important for countries to secure stable energy supplies. At the same time, global warming is a globally important problem linked to the world's sustainable development. Medium to long-term efforts must be comprehensively enhanced to resolve the three "**Es**" and safety challenges.

There is no single mean to resolve all these challenges and all possible means must be mobilized, including further energy conservation on the demand side, as well as safer nuclear plants, cleaner fossil fuel consumption and lower renewable energy costs on the supply side. The following three points are particularly important:

(1) Energy conservation

Energy conservation is the most effective mean toward the objectives. Promoting energy conservation in developing countries, where energy demand is fast increasing, will have major impacts on global energy security and global warming. The problem of energy demand growth is not limited to energy consuming or importing countries. In the Middle East and other energy-supplying regions, economic growth and lower domestic energy prices have stimulated a substantial increase in their domestic energy demand. The problem is that any increase in domestic demand reduces by a similar amount their energy export capacity. Energy conservation is thus universally important and particularly effective for Asian, Middle Eastern and other countries that have greater room or potential to conserve energy.

(2) Effective use of fossil fuels

Even in the Advanced Technologies Scenario, fossil fuels will account for most of energy demand through 2035 or 2050. Therefore, cleaner and more efficient use of fossil fuels and their stable supply will be important challenges for a long term. The accelerated development of CCS+U (CO_2 capture and storage, and effective use of CO_2) technologies will also be important for long-term efforts to address global warming.

(3) Expanded use of renewable energies

Given energy security and global warming issues, the use of renewable energies is expected to grow in importance. Therefore, it is urgent to undertake efforts such as, policy, research and infrastructure developments to diffuse renewable energies. Renewable energy cost reduction measures as well as electric grid improvements to solve supply stability problems must also be addressed.

■ Outlook through 2050

Even in the Advanced Technologies Scenario where all potentially practicable technologies will be deployed as much as possible including nuclear power generation, it will be very difficult to achieve the target of halving global 2005 CO_2 emissions by 2050. If nuclear power generation stagnates, it will be even more difficult. More innovative technologies than assumed for this scenario will have to be developed and diffused to achieve the target.

■ Implications for Japan

The Great East Japan Earthquake and the Fukushima incident are forcing Japan to substantially revise its energy policy. As the question of nuclear power generation safety grows more important, Japan will be required to be proactively engaged in developing international safety regulation standards from the lessons learned, transferring any safety technologies and providing training to relevant personnel. For Japan, poor in energy resources, energy security is a very important challenge. While proceeding with the deployment of renewable energy sources, Japan should secure its procurement of fossil fuels even amid intensifying competition for resources. It is desirable for Japan to promote energy security through cooperation with foreign countries, particularly Asian nations.

Japan, with its technological and institutional advantages, has a great role to play in promoting energy security. A key pillar of Japan's international energy strategy will be to develop and utilize energy conservation and environmental technologies that are Japan's advantages and play a central role in achieving the three **"Es"** and security. It will be important for Japan to strengthen its domestic economic infrastructure as a technology-oriented country.

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