405th Forum on Research Works November 1, 2010

Asia/World Energy Outlook 2010

—The Role of Technology Towards the Resolution of
Energy & Environmental Issues in Asia and the World—

The Institute of Energy Economics, Japan (IEEJ)

[Summary]

This report provides the energy demand and supply outlook for Asia and the world through 2035, based on the analysis of both historical and recent international energy trends, and new world economy trends, including the economic development of emerging countries in Asia, as well as recent global policy shift towards deployment of low-carbon technologies. Low-carbon technology may serve well to utilize energy efficiently and lower CO_2 emissions; therefore, such technology is expected to play an important role for the global efforts towards sustainable development and energy security enhancement. Thus, in addition to the "reference scenario" that considers past trends and reflects current energy and environment policies, the report analyzes "technologically advanced scenario" where advanced low-carbon technology becomes widely deployed around the world at the back of the progress in research and development and promotion of international technology cooperation.

Additionally, the report reflects the recent global move toward setting greenhouse gas emissions target in a longer time horizon beyond 2035, and attempts to estimate the impact from deployment and diffusion of advanced technologies up to 2050 on the balance between energy demand and supply and the magnitude and pace of CO_2 emissions reduction.

[Main conclusions]

In Asian countries, including China and India, demand for fossil fuels will steadily increase at the back of strong economic growth, and as a result, CO_2 emissions will increase significantly. Meanwhile in several Asian countries, much of the needs for fossil fuels – mainly oil and natural gas – would have to be met by imports given resources constraints. For sound economic development, Asian countries are required to implement energy security measures, including efficient use of fossil fuels, diversification of energy sources, and securing of oil and gas resources. Additionally, the measures against global warming – through deployment of advanced technologies – will become important policy agenda for Asia. In this regard, Japan has an important role to cooperate toward achieving sustainable economic growth in Asian countries, and contribute to resolve global warming and energy security issues through transfers of Japan's advanced energy conservation and

low-carbon-emitting technology to Asian countries.

- Main Assumptions

Economic Growth: World GDP will increase at 2.8% per year from 2008 to 2035, and Asia's GDP (excluding Japan) will register a higher rate than the world average at 5.1% per year through 2035.

Population Increase: World population will reach 8.5 billion in 2035 from 6.7 billion in 2008. Of this total, Asia's population will account for 53%, reaching 4.5 billion in 2035.

Crude Oil Price: International crude oil price will increase from $60/barrel in 2009 to $115/barrel (2009 Real Price) in 2035.

The Reference Scenario Results

- The world's primary energy demand will expand from 11.3 billion tons oil equivalent (Btoe) in 2008 to 17.3 Btoe in 2035. Fossil fuels will account for 79% of the primary energy demand growth during this period, continuing to serve as the major energy sources.
- Energy demand of Asia will increase substantially from 3,740 million tons of oil equivalent (Mtoe) in 2008 to 7,375 Mtoe in 2035, led by the increase of China and India. During this time period, incremental growth of energy demand by these two countries at 2,700 Mtoe will account for 46% of that of world.
- By energy source, oil will account for the largest share of total primary energy demand at 31% in 2035, driven by transport demand, while oil is projected to increase at a moderate yearly rate of 1.0% through 2035.
- Growing at 1.5% per year, coal – mainly for the power and industry sectors – will represent the second largest share at 29% in 2035.
- Among fossil fuels, natural gas demand will represent the fastest growth rate of 2.0% per year due to its lower environmental burden and increased access to natural gas resources resulting from the development of unconventional resources. With this growth, the natural gas share will expand from 23% in 2008 to 26% in 2035.
- Nuclear and renewable energy will respectively register a faster annual growth rate at 1.8% and 3.8% through 2035, while their respective share in total primary energy demand will remain small at 6.7% and 5.7% in 2035.
- Global CO_2 emissions will increase from 29.4 Gt (giga tons) in 2008 to 34.7 Gt in 2020 (up 64% from the 1990 level) and 42.9 Gt in 2035 (up 102% from the 1990 level). In 2020, CO_2 emissions from developed countries will increase by 200 million tons from 2008 to 2035 (up 16% from the 1990 level), while CO_2 emissions from developing countries will substantially expand by 5.1 Gt (up 118% from the 1990 level). This suggests an urgent need for developing countries to strengthen measures to reduce emissions.

The Technologically Advanced Scenario Results

- In the technologically advanced scenario, demand for oil, natural gas, and coal will be lower than in the reference scenario by 990 Mtoe (down by 19%), 770 Mtoe (17%), and 1,800 Mtoe (36%) in 2035, respectively. Oil demand will reach its peak in 2030, while natural gas demand will continue to increase.
- Nuclear and renewable energy will increase respectively at robust paces of 2.9% per year, and 4.9% per year through 2035. With these growth rates, the nuclear's share in total primary energy demand will reach 11% in 2035 up from 6.3% in 2008, and renewable's share will expand to 9.2% in 2035 from 3.2% in 2008.
- Global CO_2 emissions will reach its peak in 2024, while that of Asia will reach its peak in 2029.
- Due to the expansion of low-carbon technology, the world's CO_2 emissions in 2035 will be 14.5 Gt (or 34%) less than in the reference scenario (The reduction is equivalent to approximately 12 times as much as Japan's emissions in 2008). Of the total CO_2 emissions reduction, developed countries will be responsible for 4.4 Gt and developing countries 10.1 Gt. Thus, the CO_2 emissions reduction in developing countries will be nearly double that of developed countries. Asia's CO_2 emissions reduction will reach 7.7 Gt, accounting for approximately 50% of the world's total reduction, indicating Asia's extremely high CO_2 reduction potential. To realize this potential, it will be important for Asia to cooperate with developed countries toward introducing advanced technologies.
- Energy conservation, nuclear power, renewable energy, fuel switching and Carbon Capture and Storage (CCS) will play a central role in realizing low-carbon energy system. Of the world's CO_2 reduction of 14.5 Gt in 2035, energy conservation will be responsible for 7.0 Gt (accounting for 49% of the total reduction), nuclear power 1.7 Gt (12%), renewable energy 1.6 Gt (11%), fuel switching 1.5 Gt (10%) and CCS 2.6 Gt (18%).

Energy Outlook through 2050

- In 2050, the world CO_2 emissions from technologically advanced scenario will be lower by 41% compared with the 2008 level. Developed countries' CO_2 emissions will be reduced by 75% in 2050 compared with the 2008 level, and that of developing countries will be lower by 17% in 2050. These findings suggest that aside from the assumed technology deployment, wider applications of additional technologies, along with research and development of innovative technologies, should be critical to halve the global CO_2 emissions by 2050. In other words, further efforts are necessary to invest in research and development for nuclear power, renewable energy, CCS, fuel cell, and energy conservation technologies, toward achieving earlier commercialization of innovative technologies.

Summary of the Report

[Major assumptions]

- **Economic growth**

World: While global economic growth has slowed down following the U.S. subprime mortgage crisis, the economic stimulus measures of each country are gradually having an effect and growth will continue in the medium- to long-term. The world economy will grow at a rate of 2.8% per annum during the period between 2008 and 2035.

Asia: Asia (excluding Japan) will grow at a rate of 5.1% per annum, serving as the engine of growth for the world economy. In particular, China and India will grow at respective rates of 5.7% and 6.5%, increasing their presence in the world economy.

- **Population**

The world population will grow from 6.7 billion in 2008 to 8.5 billion in 2035. Within Asia, the population will expand to 1.46 billion in China and 1.53 billion in India by 2035. The population of the entire Asian region will increase to 4.5 billion, accounting for 53% of the world total.

- **Crude oil price**

The crude oil price (the Japanese import price on a C.I.F. basis and the 2009 real price), which stood at $60/barrel in 2009, will reach $100/barrel in 2020, $110/barrel in 2030 and $115/barrel in 2035. (Crude oil prices are projected in ranges, and are estimated to move in the range of around $90/barrel to $110/barrel in 2020 and around $110/barrel to $120/barrel in 2035. A roughly intermediate value of the range is used for the assumption of the model analysis.)

- **Scenarios**

The “reference scenario”, which serves as the basis of analysis, is based on probable policies and technology developments. The “technologically advanced scenario” assumes major global progress in technology development and the spread of innovative technology in response to strengthened energy security and measures against global warming.

[Major results] (Reference Scenario)

- **World**

Primary energy demand

The world’s primary energy demand is expected to grow at a rate of 1.6% per annum, from 11.3 billion tons oil equivalent in 2008 to 17.3 Btoe in 2035. The share of fossil fuels will account for 85% in 2035 from 88% in 2008. Fossil fuels will account for 79% of the primary energy demand growth up to 2035, remaining the major energy sources in future.

Global oil demand will increase from 82 million b/d in 2008 to 107 million b/d in 2035 at a rate of 1.0% per annum, and maintain the largest share in primary energy demand at 31% in 2035.

However, it will decline at a rate of 0.6% per annum in developed countries while rising at a rate of 2.4% per annum in developing countries. The world natural gas demand will expand at a rate of 2.0% per annum from 2.1 billion LNG tons (1 billion LNG tons = 0.82 Btoe) in 2008 to 3.6 billion LNG tons in 2035. Global coal demand will grow at a rate of 1.5% per annum from 4.7 billion tons coal equivalent (1 tce is equal to 0.7 toe) in 2008 to 7.0 Btce in 2035.

Renewable energy (Photovoltaic power generation, wind power generation, etc.)

The world's photovoltaic power generation capacity will grow sharply from 13 million kilowatts in 2008 to 165 million kilowatts in 2035, a 13-fold increase. The world's wind power generation capacity will expand from 120 million kilowatts in 2008 to 467 million kilowatts in 2035, a four-fold increase. Photovoltaic and wind power generation together accounted for 1.2% of the world's total power generation in 2008 and will reach 3.2% in 2035. In addition, the proportion of renewable energy (excluding hydroelectric power) in the world's primary energy demand will increase from 3.1% in 2008 to 5.7% in 2035.

Nuclear power

The world's nuclear power generation capacity will increase from 389 million kilowatts in 2008 to 615 million kilowatts in 2035. Nuclear power accounted for 14% of the world's total power generation in 2008 and will account for 11% in 2035.

- **Asia**

Primary energy demand

Asia's primary energy demand will grow at a rate of 2.5% per annum, accounting for 61% of the global incremental growth through 2035 (China and India together will account for 46% of global growth of primary energy demand in 2035). Fossil fuels will occupy 81% of Asia's primary energy demand growth to 2035 – 36% in coal, 23% in oil and 22% in natural gas. Particularly, Asia will remarkably increase coal demand, accounting for 81% of the global coal demand increase.

Oil demand and supply

Asia's net oil imports will expand from 700 million tons (14 million b/d) in 2008 to 1.5 billion tons (31 million b/d) in 2035, due to sluggish oil production within the Asian region while oil demand increases driven by industrialization and motorization. Asia's oil import dependence will rise from 63% in 2008 to 81% in 2035.

Progress in electrification and electricity supply

As electrification accelerates in Asia along with improvements in income levels and progress in urbanization, electricity demand will grow 2.5-fold over the next 27 years. Coal-fired power generation backed by abundant coal resources and their economic efficiency will play a central role in meeting the fast electricity demand growth (dominating 57% of total electricity generation in 2035). Natural gas-fired power generation will also increase steadily due to lower environmental

burden, boosting their share of total electricity generation from 13% in 2008 to 16% in 2035. Asia will increase nuclear power rapidly, responsible for 159 million kilowatts of the 226 million kilowatts in additional global nuclear power generation capacity to 2035.

Progress in motorization

The number of vehicle stocks in Asia will increase from 210 million units in 2008 to 690 million units in 2035 as motorization makes further progress along with rising income levels in Asian developing countries. Despite the wider diffusion of low emission vehicles and improvements in fuel efficiency, Asia's oil demand will steadily increase from 21.6 million b/d in 2008 to 38.6 million b/d in 2035 at an annual rate of 2.2%.

- **CO_2 emissions**

In parallel with the growth in fossil fuel consumption, global CO_2 emissions will increase from 29.4 Gt in 2008 to 34.7 Gt in 2020 (up 64% from the 1990 level) and 42.9 Gt in 2035 (up 102% from the 1990 level). Asia's CO_2 emissions will expand by a factor of 1.8, from 11.2 Gt in 2008 to 20.0 Gt in 2035. Asia will account for 65% of the total global CO_2 emissions increase, with China alone accounting for around 30%.

Through 2020, an important time period in the framework of post-Kyoto Protocol negotiations, CO_2 emissions will increase by 200 million tons from 2008 in developed countries (up 16% from the 1990 level), while increasing by 5.1 Gt in developing countries (up 118% from the 1990 level). Thus, there is an urgent need to strengthen measures to reduce emissions in developing countries.

[Major results] (Technologically Advanced Scenario)

- **Impact of technology development on the world**

In the technologically advanced scenario, innovative technologies are assumed to be widely utilized in the world in line with efforts to secure a stable energy supply, tackle climate change and promote international technology cooperation and technology transfers. Specifically, innovative technology will include the improved industrial process efficiency, the enhanced energy conservation effects of household appliances, and the expanded introduction of next-generation automobiles, biofuels, clean coal technology, renewable energy, nuclear power and CCS technology. Development and wider use of these technologies are considered feasible if any supporting mechanisms for international cooperation toward technology transfers and setting appropriate regulatory framework – including economic and financial incentives – are in place.

World: In the technologically advanced scenario, the world's primary energy demand in 2035 will be 2.8 Btoe (or 16%) less than in the reference scenario, which represents approximately 5.7 times as much as Japan's total energy demand of 500 million toe. Of the 2.8 Btoe in energy savings, developed countries will account for 870 million toe and developing countries 1.97 Btoe. Thus,

energy savings in developing countries will be more than double those in developed countries. The share of non-fossil energy in world primary energy mix in 2035 will be 23% in the technologically advanced scenario, in contrast to the 15% in reference scenario. Demand for oil, natural gas, and coal will be lower than the reference scenario respectively by 990 Mtoe (down by 20%), 770 Mtoe (17%), and 1,800 Mtoe (36%) in 2035. Oil demand will reach its peak in 2030, while natural gas demand will continue to increase. Savings for coal demand at 1,800 Mtoe in the technologically advanced scenario results from fuel switching to low-carbon emitting energy types and generation efficiency improvement in the power sector.

Asia: Asia's primary energy demand in 2035 will be 1.5 Btoe (or 21%) less than in the reference scenario (This energy saving is approximately thrice as much as Japan's total energy demand in 2008). Asia's energy-saving potential at 1.5 Btoe accounts for approximately half of the world's energy savings of 2.8 Btoe in 2035. The share of non-fossil energy in 2035 will be 24% in the technologically advanced scenario, compared with that in the reference scenario at 13%.

Compared with the reference scenario, demand for oil, natural gas, and coal will be lower in the technology advanced scenario respectively by 410 million ton (21%), 270 million ton (23%), and 1,200 million ton (37%) in 2035. Even in the technologically advanced scenario, oil and natural gas demand will increase steadily, while coal demand will reach its peak sometime around 2030.

- **Impact on CO_2 emissions**

World: The world's CO_2 emissions will increase by 3.5 Gt (or 13%) between 2005 and 2020 but will peak in 2024, due to further progress in energy and environmental technology. In 2035, the world's CO_2 emissions will be 14.5 Gt (or 34%) less than in the reference scenario, which is approximately twelve times as much as Japan's emissions in 2008. Of the 14.5 Gt CO_2 emissions reduction, developed countries will be responsible for 4.4 Gt and developing countries 10.1 Gt. Thus, the CO_2 emissions reduction in developing countries will be nearly double that of developed countries. Asia's CO_2 emissions reduction will reach 7.7 Gt, accounting for 53% of the world's total reduction, indicating Asia's extremely high CO_2 reduction potential.

Asia: CO_2 emissions in Asia will reach its peak in 2029 as a result of deploying advanced technology. Asia's CO_2 emissions in 2035 will be 7.7 Gt (or 39%) less than in the reference scenario, which is equivalent to approximately six times as much as Japan's emissions in 2008. Of the 7.7 Gt CO_2 reduction, China will be responsible for 4.4 Gt, India 1.8 Gt and the rest of Asia 1.5 Gt.

The role of technology: The reduction in CO_2 emissions will result from deployment of various advanced technology, and all options are equally important. Of the world's CO_2 reduction of 14.5 Gt in 2035, energy conservation will be responsible for 7.0 Gt (accounting for 49% of the total reduction), nuclear power 1.7 Gt (12%), renewable energy 1.6 Gt (11%), fuel switching 1.5 Gt

(10%) and CCS technology 2.6 Gt (18%). Out of Asia's CO_2 reduction at 7.7 Gt in 2035, energy conservation will be responsible for 4.1 Gt (54%), nuclear power 1 Gt (13%), renewable energy 900 million tons (10%), fuel switching 800 million tons (10%) and CCS 900 million tons (12%).

[Major results] (China and India)

- **China**

China's economy will shift from investments- and exports-driven growth to domestic consumption-led growth, and the Chinese GDP will grow at a rate of 5.7% per annum. China's primary energy demand will expand at a rate of 2.5% per annum, from 1.93 Btoe in 2008 to 3.79 Btoe in 2035, accounting for 22% of the global total. In 2035, China's primary energy demand will be eight times higher than that of Japan, and the country's CO_2 emissions will be 12 times bigger than that of Japan. China will be the largest energy consumer and CO_2 emitter in the world by 2035.

Oil: Oil demand will expand from 7.4 million b/d in 2008 to 18.0 million b/d in 2035 due to fast progress in motorization. As domestic oil production fails to increase, China's oil import dependence will rise from 47% in 2008 to 78% in 2035.

Coal: Chinese coal demand, mainly for power generation, will increase from 1.41 Btoe in 2008 to 2.01 Btoe in 2035. Coal will remain the largest energy source, although its share of primary energy demand will decline from current 73% to 53% in 2035. Iron and steel production, which stood at 500 million tons in 2008, will peak in the near future and decline to below 400 million tons through 2035. As a result, industrial coal demand will fall gradually.

Nuclear: Currently 26 units of nuclear power plants are under construction in China. Over the outlook period, nuclear capacity will expand to reach 48 GW in 2020 and 88 GW in 2035, and by 2035 nuclear will account for 7.9% of total power generation.

Technologically Advanced Scenario: Due to the introduction of advanced technology, in 2035, energy savings of 890 million toe or 24% of the reference scenario demand will be achieved. The energy conservation efforts, expanded introduction of nuclear power and other non-fossil energy will result in peaking China's CO_2 emissions in 2025. In 2035, CO_2 will be reduced by 4.4 Gt or 41% less than in the reference scenario.

- **India**

The Indian economy will grow steadily at a rate of 6.5% per annum reflecting on an expanding workforce population, and industrial development resulting from opening up of market. India's primary energy demand will increase at a rate of 4.0% per annum, a faster rate than China, and will almost triple from 460 million toe in 2008 to 1.33 Btoe in 2035.

Oil: Oil demand will increase from 2.9 million b/d in 2008 to 6.5 million b/d in 2035. As a large increase in domestic oil production cannot be expected, India's oil import dependence will rise

sharply from 73% in 2008 to 85% in 2035.

Natural gas: Natural gas demand will grow at a robust rate of 5.9% per annum, from 40 Mtoe in 2008 to 170 Mtoe in 2035.

Coal: Coal demand – mainly for electricity generation – will grow at a rate of 3.9% per annum, more than double from 260 Mtoe in 2008 to 730 Mtoe in 2035. Coal will thus maintain the largest share, accounting for 55% of primary energy demand. As India's dependence on coal imports increases in the future, securing coal supply sources may offer a challenge amid growing coal demand in Asian countries.

Nuclear: In addition to the continued research to domestically develop thorium fuel cycle, India will introduce light water reactors using overseas technology. With this, nuclear capacity will expand from current 4 GW to 20 GW in 2020, and 42 GW in 2035. Nuclear power will account for 6.9% of total generation by 2035.

Technologically advanced scenario: India's primary energy demand in 2035 will be 350 million toe (or 27%) less than in the reference scenario, supported by the expanded introduction of advanced energy conservation technology.

[Major results] (Energy Outlook through 2050)

The study projects energy demand and supply in a longer time horizon through 2050 and analyzes further diffusion of clean energy technology and assesses their impacts on global energy demand and supply, as well as CO_2 emissions reduction through developing both reference scenario and technologically advanced scenario.

Fossil fuels: In the technologically advanced scenario, the world demand for fossil fuels will reach its peak in 2035, and decline thereafter. Meanwhile, fossil fuels will account for the largest share in total primary energy demand at 69% in 2050; therefore, efficient use of fossil fuels and securing stable supply sources will continue to be the important policy agenda.

Natural gas: For both reference and technologically advanced scenario, natural gas demand will steadily increase through 2050. Continued investment is necessary to develop natural gas resources, and infrastructure necessary to deliver natural gas to the demand areas.

Electricity generation mix: In the reference scenario, the share of non-fossil fuels (nuclear and renewable energy) in the world electricity generation will account for 31% in 2050. By contrast, non-fossil fuel based generation will occupy 59% of the world electricity generation in the technologically advanced scenario, and that of developed countries will represent even higher share at 66% in 2050, and developing countries at 54%. Particularly in the technologically advanced scenario, renewable energy will substantially increase, with the installed capacity of wind expand by 15 times from the current level, solar power by 135 times, solar thermal power by 1190 times, and

biomass power by five times.

CO_2 emissions: In the technologically advanced scenario, the world CO_2 emissions will be reduced by 41% in 2050 compared with the 2008 level. Substantial reduction by 75% (compared with the 2008 level) is expected in developed countries, while projected CO_2 emissions reduction for developing countries will be smaller at 17% in 2050 (compared with the 2008 level). To halve the global CO_2 emissions by 2050, further efforts are necessary to introduce innovative technologies – in addition to the assumed ones in technologically advanced scenario. Much needs to be done to invest in research and development toward earlier commercialization of innovative technologies on nuclear power, renewable energy, CCS and other energy conservation technologies.

[Implications]

- **Tackling climate change issues through technology transfers**

CO_2 emissions in Asian developing countries are expected to grow at a faster pace than the world average, while these countries generally face technological and financial constraints to curb the growth trends in CO_2 emissions. Establishment of regional cooperation framework in Asia may facilitate research and development in technology between developed and developing countries, and developing Asian countries may need to create appropriate investment conditions that can allow implementation of projects for developed countries to introduce advanced technologies toward energy efficiency improvement and lower CO_2 emissions. Such cooperation can offer cost effective options to reduce CO_2 emissions in Asia as a whole. For Japan, continued efforts are necessary to be made to advance on the technological development for energy conservation, and environmental technologies, and at the same time, using these technologies, Japan will have a great role to support global efforts to reduce CO_2 emissions.

- **Ensuring energy supply security**

In Asia, ensuring a stable energy supply will become an important issue as oil demand grows sharply and the dependence on imports for oil supply rises further in the future. Countries in Asia would have to implement various measures to ensure stable energy supply. As a short-term measure, Asia may need to establish and strengthen emergency response systems as a countermeasure for oil supply disruptions; and as medium-to long-term measures, efforts are necessary to develop an international oil market that can respond flexibly to changes in supply and demand, as well as to enhance its market functions and ensure transparency. Additionally efforts need to be made to strengthen relations with countries in the Middle East as Asia's reliance on the region as oil import source may grow in the future. Aside from these, Asian countries may need to continue

implementing domestic measures for energy efficiency improvement and energy source diversifications. On the other hand, excessive pursuit of self-interest by a single country could undermine the energy security of the entire region. Because Asian countries share a common interest as major energy consuming nations, it is important that they deal with the issue as a problem concerning the entire region.

- **Challenges toward achieving the best energy mix**

Ensuring a stable supply of fossil fuels and their effective use

Fossil fuels are finite, and their consumption is accompanied by greenhouse gas emissions. Nevertheless, when economic viability and lead time for the commercialization of innovative technology are considered, it is important to strive toward the effective utilization of fossil energy. In addition to ensuring a stable supply of fossil fuels, using them in a clean and highly efficient fashion is essential from the energy security, and environmental reasons.

[Oil] A substantial expansion in oil production cannot be expected in the Asian region, and its dependence on imports for oil supply will rise to 81% in 2035. Covering some 50% of Asia's oil consumption increase will be the OPEC members in the Middle East that are rich with oil resources and can offer oil in a more cost competitive way than other oil-exporting countries. Steady investment in oil production capacity expansion to meet the rise in demand will be the key to stable supply of the international oil market. On the demand side, an important issue will be to strive for the effective use of oil through the introduction of fuel efficient and alternative energy vehicles, whose full-fledged practical use is expected over the medium- to long-term.

[Natural gas] Natural gas production in the Asian region will peak while natural gas demand will increase due to fuel switching in the electricity generation and residential and commercial sectors. Therefore, demand will expand for LNG and natural gas transported from Russia and central Asia via pipelines. As with oil, continued investment toward the expansion of production and transportation capacity will be the key to meet the projected increase in natural gas demand.

[Coal] Coal demand will increase mainly for electricity generation due to abundant resource endowment and cost competitiveness against the other energy sources. As measures to lower CO_2 emissions from coal combustion, the development and introduction of high-efficiency coal-fired power generation, clean coal technology and CCS are urgently required.

Nuclear power: Nuclear energy will play a major role in Asia, where ensuring energy security will become increasingly important to meet fast-growing energy demand. Nuclear power, which is also important for helping to tackle global warming, should be increasingly introduced as a stable energy supply source.

Technology development of renewable energy: Wind power and photovoltaic power generation

are an important option among measures to mitigate global warming. In addition, along with automobiles' fuel efficiency improvement, the introduction of biofuels is expected as a means to help reduce CO_2 emissions in the transport sector. It is necessary to enhance systems for effective and efficient promotion of renewable energy diffusion and introduce supporting policies to further expand the use of renewable energy.

It will also become important to consider the time frame with regard to technology development that contributes to ensuring energy security and enhancing measures against global warming. Progress in technology development and change in the energy supply and demand structure will be limited by 2020, while current technology development and supply-demand structural change are expected to take place around 2030. Therefore, technology strategies with a long-term outlook beyond 2030 are required.

[Conclusion]

In order to simultaneously achieve "3E objectives"—Energy (stable energy supply), Economy (economic development) and Environment (environmental conservation)—in Asia, countries in the region should enhance their efforts to attain the best energy mix by diversifying energy supply sources and promoting a shift to low-carbon energy sources through energy conservation and fuel switching.

Japan, which has technological, economic and institutional advantages over other Asian countries, has a great role to play in this respect. In particular, Japan is competitive in energy-saving and environmental conservation technologies that play a central role in achieving the 3E objectives simultaneously. Further development and utilization of these energy-saving and environmental conservation technologies should be a key option of Japan's international energy strategy. In the future, it will be important for Japan to utilize these advanced technologies to step up efforts to achieve the 3E objectives simultaneously and accomplish its sustainable economic growth as a leading technology-oriented nation.

[Position of this outlook]

This outlook represents an estimate based on theoretical and numerical integrity under certain assumptions. Given various uncertainties, estimated figures can be expected to change considerably. But we would be happy to see our outlook serve as a reference or basis for forecasting future energy supply and demand.

Contact: report@tky.ieej.or.jp