Energy Supply and Demand Analysis for Asia and the World up to 2035 and 2050

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1. Introduction

This paper analyzes the long-term perspective of energy supply and demand for Asia and the world, up to 2035 and 2050, taking into account the 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" 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, this paper 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.

2. Methodology and Assumptions

2.1 Basic framework

Energy model developed here for this world energy projection over forecast horizon is mathematically formulated with econometric method in a country-by-country basis. Figure1 illustrates the schematic diagram of model structure. The model makes use of the historical energy balance data of IEA [1][2], and is composed of a macroeconomic sub-model and an energy supply-demand sub-model, the structural specifications of which are roughly explained as follows.

The macroeconomic sub-model is developed to mainly identify the economic indicators influencing energy supply-demand balances. In this sub-model, numerous indicators relating to crude oil price, population, fiscal policy, world trade, and exchange rates are assumed as exogenous variables. Endogenous variables, implicitly determined through the model, incorporate macroeconomic parameters such as the demand for goods and services etc.; industrial activity indicators such as the production of steel, cement and other energy-intensive products, vehicle ownership, passenger-kilometers and freight ton-kilometers, etc; price indicators such as deflators for GDP and its components, WPI, CPI, and secondary energy price indexes.

The energy supply-demand sub-model, playing a central role for energy projection, allows us to specify the energy flow from final energy consumption to primary energy supply in a consistent way, following which step anthropogenic CO_2 emissions are eventually calculated. In the first step, final energy demand is identified by sector and by energy source, on the basis of the economic activity indicators and price indicators, the majority of which are obtained from the macroeconomic sub-model. The economic activity indicators mainly determine the demand by sector, and the price indicators, by energy source. The computational process in energy conversion sector calculates the required energy input for the output of transformed

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energy carriers such as electricity and oil products. Finally, primary energy consumption can be derived by aggregating the energy requirements from end use sectors and transformation sectors. Concerning energy related data in this projection, energy balance statistics compiled by IEA are basically adopted. The model simulates the world energy development path at a 1-year interval up to the year 2030.

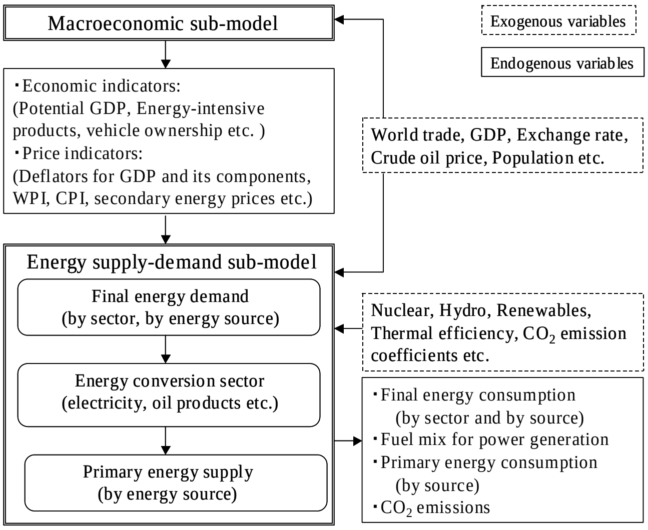


Figure 1 Structure of energy projection model

Regarding geographical disaggregation, the developed model is basically formulated on a country-by-country basis, where the whole world is geopolitically divided into 41 countries or regions, where the energy balance statistics compiled by IEA are available. Although there have been scores of attempt to simulate world energy projections [3][4][5], Asian region in this model is disaggregated into 14 countries or regions, more elaborate division than other energy outlooks, in order to implement an in-depth analysis of Asia and provide the detailed portrait of its energy demand and supply.

2-2 World population and economic growth

The analysis incorporates the latest world's population forecast from the UN [6] 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 and Russia's population already peaked and is projected to continue its rapid decline.

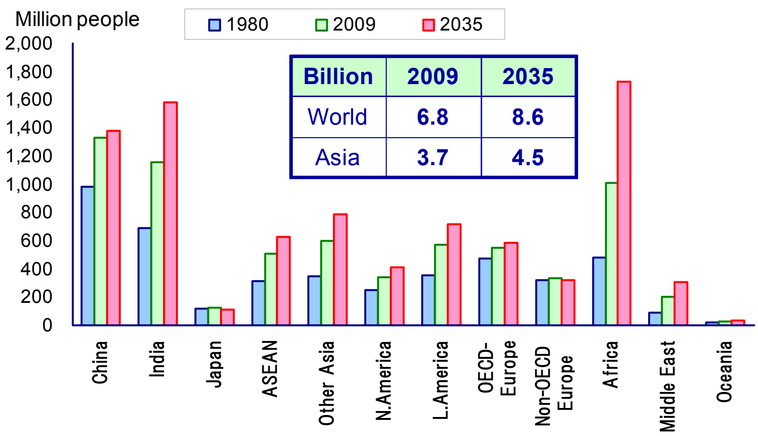
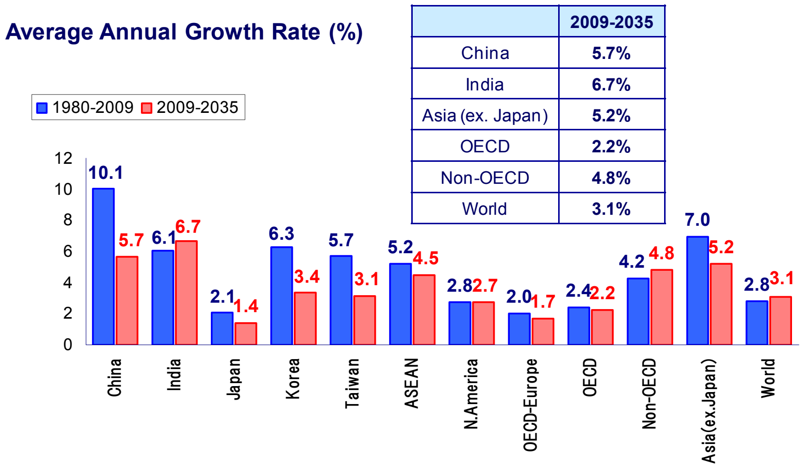


Figure 2 Population projection by region

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. 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.

The GDP growth assumptions for this study are based on forecasts provided by such international organizations as the Asian Development Bank [7] and the International Monetary Fund [8], 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. 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.

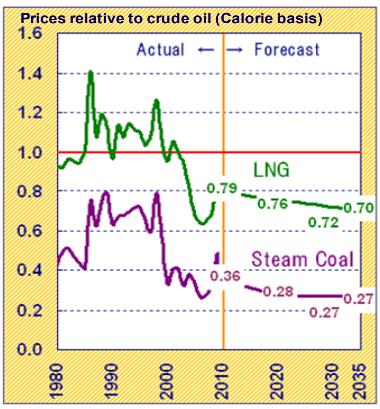


	2009-2035
China	5.7%
India	6.7%
Asia (ex. Japan)	5.2%
OECD	2.2%
Non-OECD	4.8%
World	3.1%

Figure 3　Economic Growth projection by region

2-3 Energy prices

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. As oil exploration and development are dependent on future oil prices, there are concerns for the balance between demand and supply in the future. 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.



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

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

Figure 4　Energy Price Outlook (CIF import prices for Japan)

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.

2-4 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.

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 [9]. In this 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 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.

Table 1 Assumptions for the Advanced Technologies Scenario

【Demand Side Technologies】	【Supply Side Technologies】
■ Industry Best available technology on industrial processes will be deployed internationally (steel making, cement, paper, oil refinery, etc.).	■ Renewables Accelerated penetration of Wind, PV, concentrated Solar Power, biomass power generation, and bio-fuels
■ Transport Clean energy vehicles will be globally utilized (highly fuel efficient, hybrid, plug-in hybrid, electric and fuel cell vehicles).	■ Nuclear Further expansion of nuclear power plants, and enhancement of operating ratio
■ Building All available efficient technologies will be widely in use. (electric appliances , water-heating system, air conditioning system, lighting, and insulation technologies)	■ Highly Efficient Power Plants For coal-fired power plant (USC, IGCC, IGFC), For natural gas plants (More Advanced Combined Cycle)
	■ CCS Introduction in fossil fuel-fired power plants as well as in some industrial sectors

2-5 Assumptions through 2050

A very-long-term assessment covering the period 2035-2050 has also been prepared under the same methodologies. GDP, population and crude oil price are assumed as shown in Table 2.

Table 2 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)

3. Simulation Results

3-1 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 will account for about 60% of the increase with China alone responsible for about 30%.

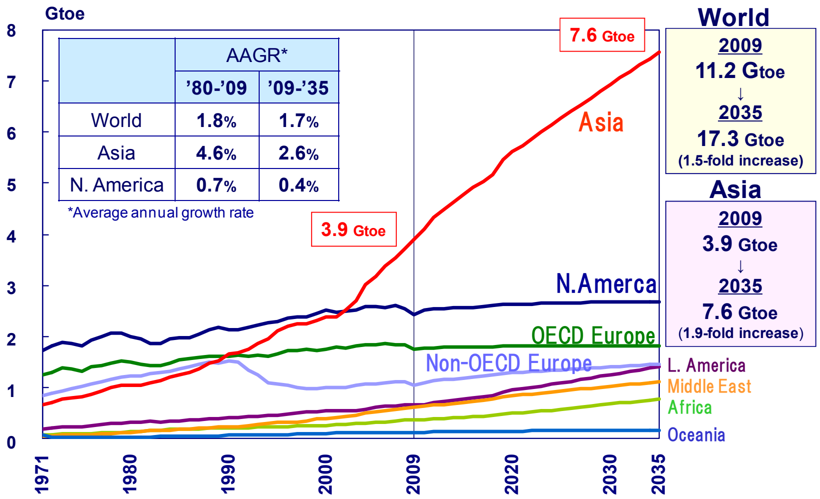
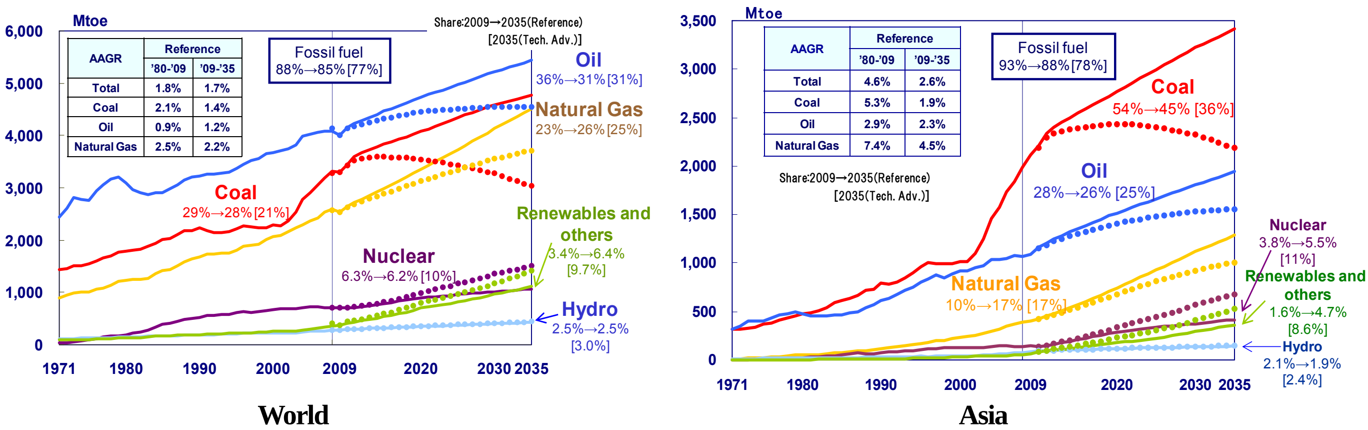


Figure 5　World Primary Energy Demand by Region

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. Supported by steady economic growth, China and India will account for about 30% of the world's primary energy demand by 2035.

Oil will continue to account for the largest share until 2035 in both the Reference and Advanced Technologies Scenarios. 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.



Solid lines: Reference Scenario, Dotted lines: Advanced Technologies Scenario

Figure 6　Primary Energy Demand for Asia and the World

3-2 Nuclear power after Fukushima Daiichi NPT accident

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 decided to decommission these reactors and phase out the remaining nuclear reactors from 2013 to 2021. 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 2011, making it impossible for the Italian government to revive nuclear power generation.

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 [10] .

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.

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 2011, 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.

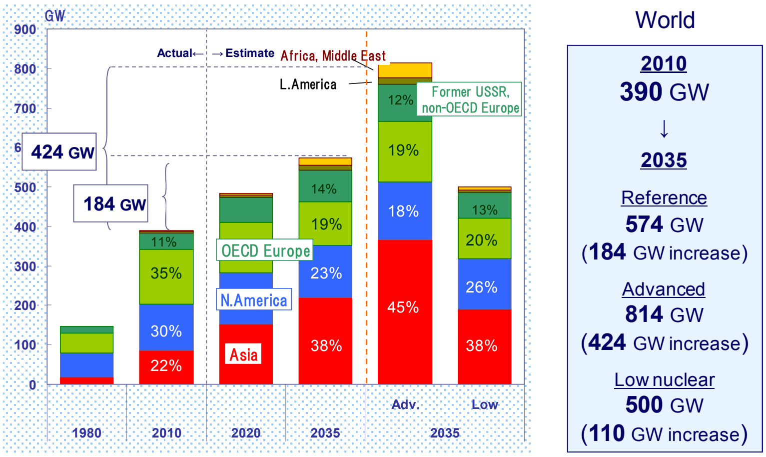


Figure 7 World Nuclear Power Generation Capacity

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 79 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.

3-3 Electricity generation

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. Coal-fired generation's share will not change from 41% in 2009 through 2035, remaining as the largest electricity supply source.

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.

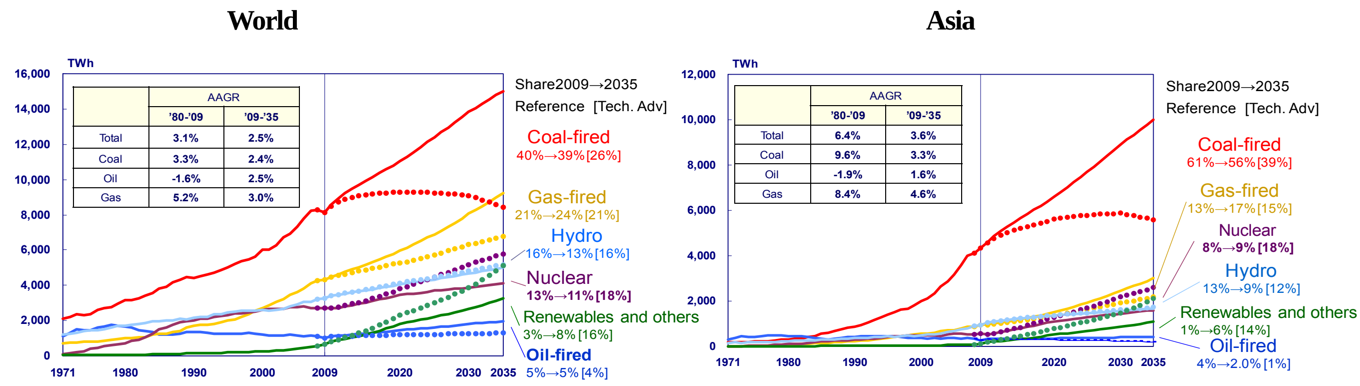


Figure 8 World and Asia's Electricity Mix

3-4 CO_2 emission

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 in the Reference Scenario. OECD countries' share of global CO_2 emissions will decline from 41% in 2009 to 29% in 2035, while non-OECD countries' share will rise close to 70% in 2035. Non-OECD countries will account for about 90% of the global CO_2 emission growth with Asia accounting for about 70% of the growth.

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.

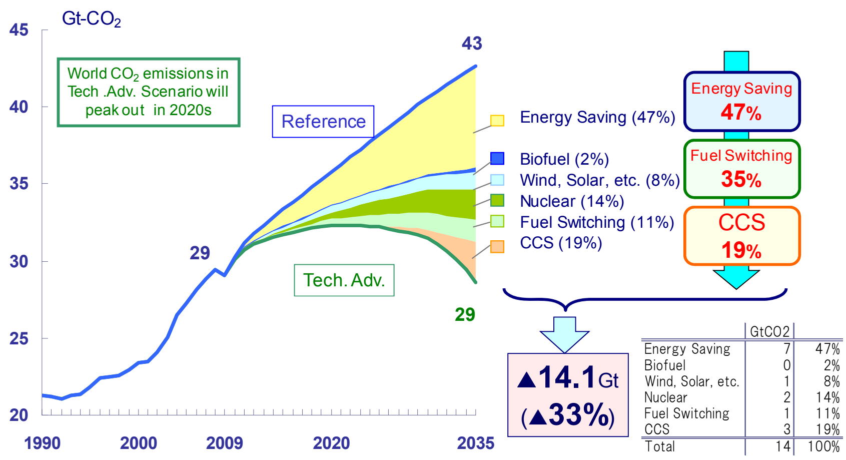


Figure 9 Global CO_2 Emissions Reduction

3-5 Cumulative investment through 2035 and implications of the Low Nuclear Case

(1) Cumulative investment through 2035

Figure 10 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.

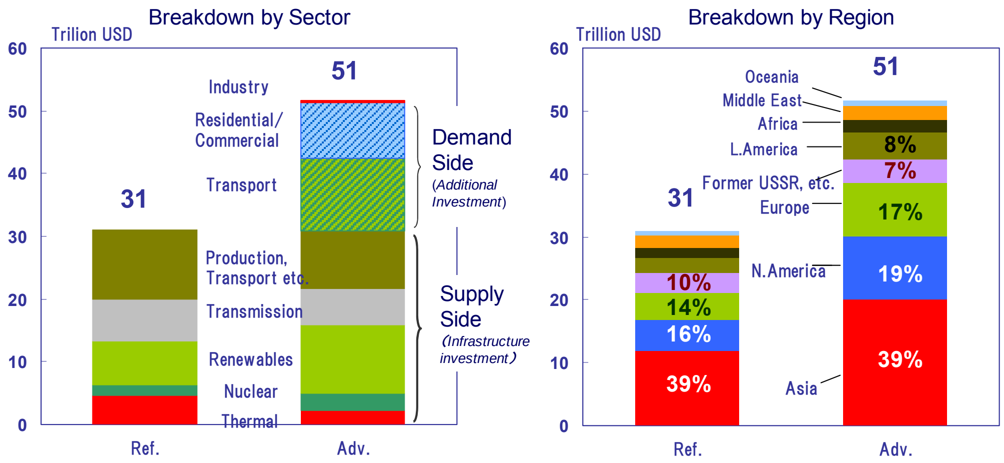


Figure 10 Cumulative Investment through 2035

(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.

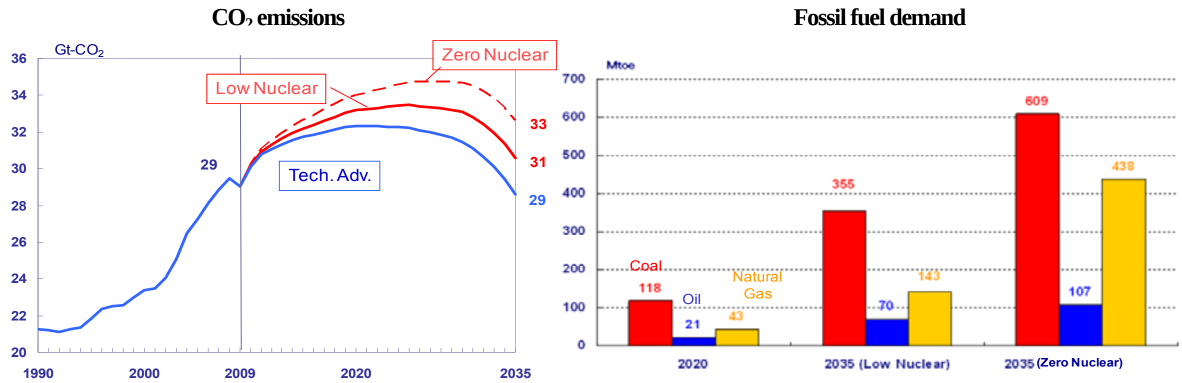


Figure 11 Implications of Low Nuclear Scenario

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. Fuel cost is estimated to account for more than 70% of fossil-fuel fired electricity generating costs [11], thus excessive depencence on thermal power generation has some risk in terms of energy security.

If the decline is covered by renewable energy power generation (wind , PV etc.), 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.

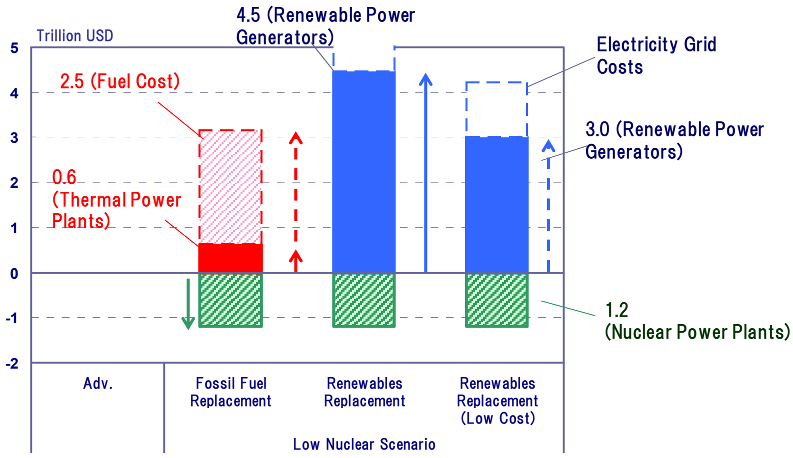


Figure 12 Cumulative Investment through 2035 (Low Nuclear Case)

3-6 Long-term world energy supply/demand outlook through 2050

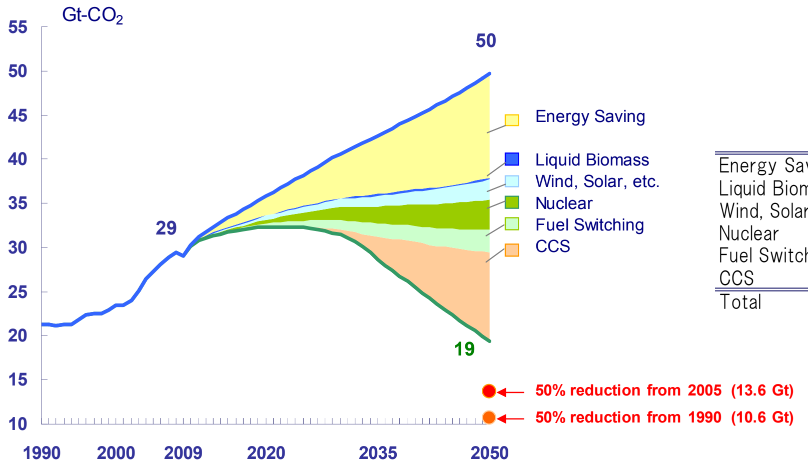
In the Reference Scneario, Global primary energy demand will increase by 9.5 Gtoe or 1.9-fold from 10.9 Gtoe in 2009 to 20.4 Gtoe in 2050. Of the 9.5 Gtoe increase, developing countries will be accounting for 8.8 Gtoe and industrial countries for 0.7 Gtoe. Developing countries' share of global primary 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%.

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, 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.

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). OECD 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 coutries, 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.



	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%

Figure 13 CO_2 Emissions Reduction Potential by Technology

4. Concluding remarks

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. Thus, the enhancement of nuclear plant safety is therefore indispensable.

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.

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. Especially, energy conservation, effective fossil fuel use and expanded use of renewable energies will be particularly important:

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.

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