Asia/World Energy Outlook 2013

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—Analyzing Changes Induced by the Shale Revolution—

Introduction

Forty years have passed since the oil crisis of 1973. During those 40 years, the world has been facing various events such as the Asian currency crisis, the Lehman Shock, the European sovereign debt problem and the global economic slowdown, while energy-related technologies have steadily progressed mainly in developed regions.

Meanwhile, China and other emerging countries have realized relatively firmer economic growth and Asia is expected to continue driving the world economy and remain the world's energy growth center.

Global energy consumption has restored an upward trend after a decline in 2009. Consumption more than doubled in 40 years from 5 billion tons of oil equivalent in 1971 to 13 Btoe in 2011. Asia's share of global energy consumption has risen from 13% in 1971 to more than two-thirds at present. Since the early 2000s, Asia has been driving the global primary energy consumption, being responsible for more than 70% of the increase in demand. The sharp energy demand growth in the region could dramatically change the global energy supply-demand balance and destabilize international energy markets.

Asian countries are expected to intensify competition for obtaining cheaper and more abundant energy sources to satisfy their increasing energy demand. China has been taking all possible measures to secure and diversify crude oil procurements, including constructing international oil pipelines and acquiring interests in overseas oil fields. India, Indonesia and Thailand are increasing oil imports despite domestic energy expansion efforts in order to meet their rising oil demand associated with rapid increases in car ownership. Even Malaysia, though being a net oil exporter until now, is expected to soon reduce exports and turn a net oil importer in the near future. Amid these tidal changes, Asia is expected to further strengthen its relations with the Middle East as the energy supplier for the world. The Middle East will progressively consider Asia as an energy consumer, while Asia will increasingly view the Middle East as their supplier. In this sense, Asian countries have great roles to play in securing stable energy supplies and in stabilizing international energy markets. They will be required to build good relationships with resources exporters, utilize nuclear and renewable energy and hold down demand through energy conservation efforts, while being forced to use relatively abundant coal.

Meanwhile, international politics involving climate change issues have grown more complicated and the international community struggles to develop a system for reducing greenhouse gas emissions that would accommodate the varying positions of countries. It may be difficult for the world, including both developing and developed countries, to produce a meaningful agreement. While countries are shifting their priority to economic measures, the negotiations on climate change are making little progress. Already, China has replaced the United States as the world's largest energy-related CO_2 emitter and other Asian countries are also boosting energy consumption rapidly, with CO_2 emissions increasing. Asia is expected to grow more and more responsible for the climate change problem.

The Fukushima Daiichi nuclear power plant accident in Japan continued to affect nuclear and energy policies in the world which is seeking the next generation energy resources mix which would not be dependent on nuclear energy alone. Under such situation, the development of unconventional oil and natural gas has attracted much attention. Dramatic progress in unconventional resources development in the United States has eased the country's domestic energy supply-demand balance and induced great changes that are not limited to those in energy markets. These changes are still ongoing and many regions other than the United States are also expected to launch commercial shale gas and oil production to diversify gas and oil supply sources.

Based on the abovementioned conditions, this study assesses the world economy trends, including emerging countries, mainly in Asia. The study also provides insights regarding the developing international energy landscape changes induced by the shale revolution and the nuclear policy revisions, and it comments on the trends in low-carbon technologies accompanying enhanced climate change measures. It analyzes the Asian and world energy supply and demand from a long-term perspective. The detailed country-by-country analysis of the research findings focusing on Asia is highly dependant on IEEJ's network of relevant organizations within the region.

This analysis takes into account past trends and policies, and considers the economic and social structures for each country in order to quantitatively analyze the energy supply and demand situation. The analysis focuses mainly on Asian countries over the long term, through 2040. Using that scenario, we analyze how progress in unconventional resources development, overcoming infrastructure and technological barriers in each region would impact natural gas and oil output, energy prices, energy demand, energy trade and the entire macro economy for each region. Using the same scenario, we project the introduction and diffusion of innovative technologies through 2050 and analyze their potential impact on global energy supply and demand, and greenhouse gas emissions.

1. Scenarios and Major Assumptions

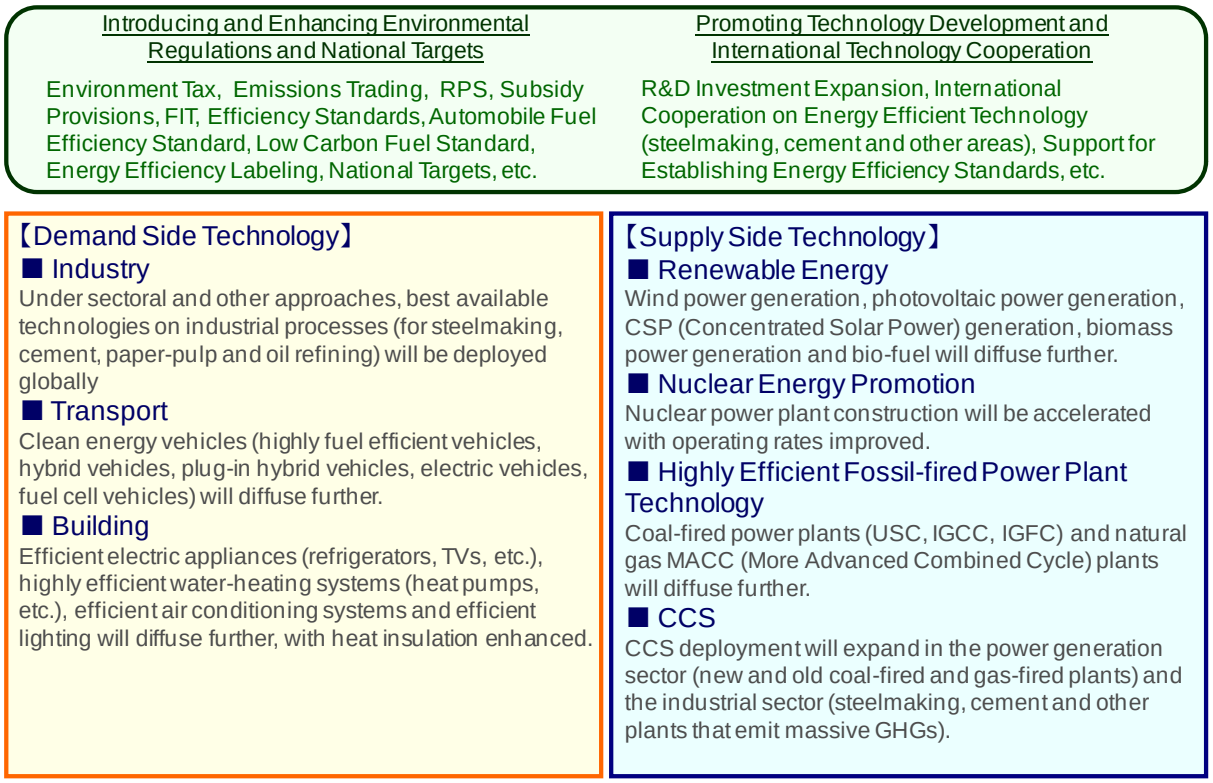
1.1 Scenarios

In our Asia/World Energy Outlook 2013, we forecast world energy supply and demand through 2040 for three scenarios: the Reference Scenario, the Enhanced (Unconventional Resources) Development Scenario and the Advanced Technology Scenario.

As in the past series of our outlooks, the Reference Scenario assumes the past trends for the future under energy and environment policies that have been in place so far. No aggressive policies for energy conservation or low-carbon measures are assumed for the future. In this scenario, each country's ambitious energy conservation and low-carbon technology targets will fall short of being fully accomplished due to technological or financial difficulties. Depending on policy, and technology development and diffusion conditions, future energy demand could be larger or smaller than in the Reference Scenario.

In the Advanced Technology Scenario, each country will forcefully and successfully implement energy and environment policies that will contribute to further securing stable energy supply and enhance climate change measures (Figure 1). To this end, the development and introduction of innovative technologies will have to be accelerated on a worldwide basis.

Figure 1 Policies and Technologies Assumed in the Advanced Technology Scenario



At present, countries outside the Organization for Economic Cooperation and Development (OECD) give a lower priority status to energy and environment policies than OECD members. In the Advanced Technology Scenario, these non-OECD countries are assumed to accelerate energy efficiency improvements through technology transfers, spillover effects and Clean Development Mechanisms. They are also assumed to expand non-fossil energy consumption including nuclear and renewable energy while the uses of unconventional energy resources remain unchanged from the Reference Scenario.

In the Enhanced Development Scenario, the utilization of unconventional resources including shale gas and oil will progress not only in North America but also in the rest of the world as unconventional resources supply technology and infrastructure systems are improved. The diffusion of energy conservation and low-carbon measures are assumed to remain unchanged from the Reference Scenario.

1.2 Major Assumptions

The future energy supply and demand structure will be subject to population changes, economic growth (including other social and economic factors), energy prices, energy utilization technologies, and energy and environment policies. Assumptions for population changes and their economic growth are common to the three scenarios.

Population

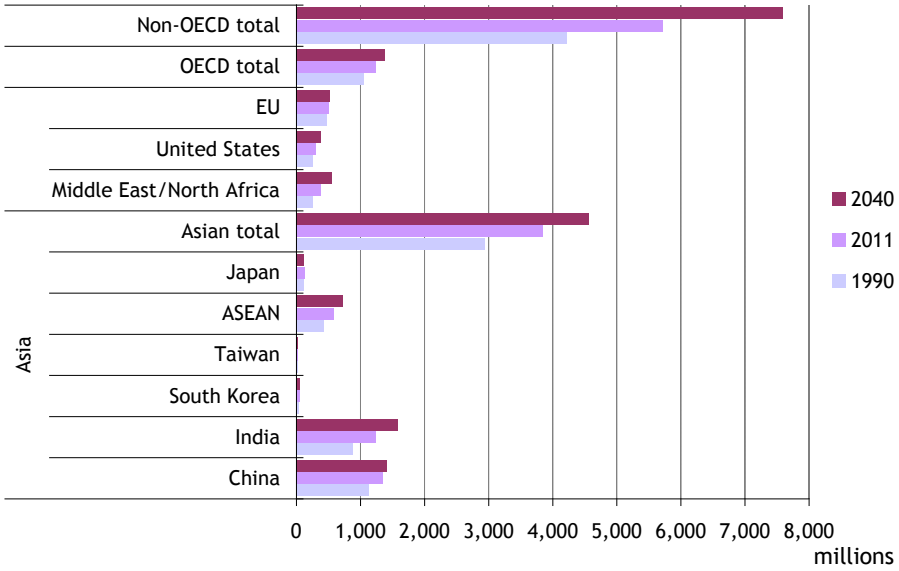
In assuming population changes, we referred to the United Nations' "World Population Prospects". The population of OECD countries where the total fertility rate (or the average number of children that would be born to a woman during her lifetime) has slipped below 2, is slowly showing signs of deceleration and will soon decrease. In non-OECD countries, the TFR is trending down in line with income growth, but the mortality rate is declining due to developing medical technologies and improving food and sanitation conditions. Overall, global population is thus expected to increase in the future at an average annual rate of around 1%, expanding to 9 billion in 2040 from 4.4 billion in 1980 and 7 billion in 2011 (Figure 2).

Among OECD countries, the United States will post a relatively steady but moderate population increase due to a population influx from non-OECD countries and a high TFR. Its share of global population will fall short of rising though. Japan, where population began to fall in 2011, will experience the fastest population drop in the world. Western Europe, including France where the TFR has risen, will see population turning downward in 2019. Russia, which has been plagued with a population decline since the

collapse of the Soviet Union, will continue its downward trend in population. China, currently the most populated country in the world, will see its population peaking at 1.4 billion around 2030 before decreasing by more than 17 million by 2040.

Meanwhile, population will continue increasing in many other non-OECD countries and will account for most of the global population growth through 2040. Africa will experience a rapid average annual population increase of 2.2%. The Middle East population will expand 1.5-fold in about 30 years and India will maintain its high population growth and replace China as the most populated country in the world in the mid-2020s. Its population will reach 1.59 billion in 2040. The whole of Asia will continue expanding population, but its share of global population will fall gradually to reach about 50% in 2040.

Figure 2 Population



Economic Growth

The economic slump that has originated from the sovereign debt crisis in European countries including southern nations has affected not only Europe but also the entire world economy, including emerging countries. Due to overcapacity resulting from earlier large-scale economic stimulus packages and monetary easing, China has failed to offer any more large-scale stimulus package even in response to an economic growth slowdown. India has seen less economic policy freedom as import prices have soared on its rupee's depreciation against other currencies under capital unwinding. Russia, Brazil and Australia that heavily depend on primary goods for export revenues are benefitting less from the resources boom. Meanwhile, crude oil prices have remained high, squeezing oil-importing economies. Ironically, the U.S. economy indicates a relative firmness after triggering a

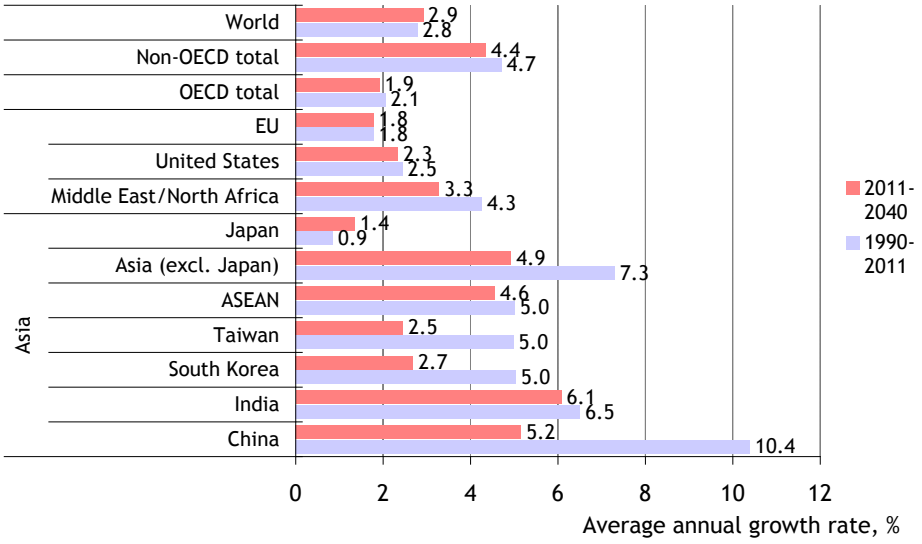
global slump with the subprime loan problem and the Lehman Shock.

Over a medium to long term, however, the world economy is expected to return to a growth path. But the world economy is unlikely in the near future to become as brisk as in the 1990s and the first half of the 2000s. Some regions may take considerable time to recover growth lost over the past several years.

China and other Asian emerging countries, which have realized powerful economic growth, are expected to remain at the center of the global economic expansion. As wage levels have risen with citizens growing more conscious of their civil rights, however, these countries are now required to shift away from an export-led economic growth pattern in which they have taken advantage of abundant surplus labor and lower costs to drive exports. The present economic growth slowdown does not necessarily indicate any limit on growth, but as the circumstances that supported high economic growth turned around, Asian emerging countries including China are now required to become vigilant against a "middle income country trap".

Given the abovementioned situation, we assumed real gross domestic product as shown in Figure 3. These assumptions take into account outlooks of international organizations, including the International Monetary Fund and the Asian Development Bank, and reflect each government's economic development programs.

Figure 3 Economic Growth



International Energy Prices

Two kinds of assumptions are set for international energy prices, which is not the case for population or economic growth. In the Enhanced Development Scenario, progress

in the development and diffusion of technologies for unconventional resources is assumed to ease the energy supply-demand balance. This means that energy prices in the Enhanced Development Scenario are assumed to be lower than in the Reference Scenario.

Crude oil prices are rising again after wild fluctuations in which they hit a record high close to $150 per barrel in the middle of 2008 and plunged close to only $30/bbl within the next six months. These prices accelerated their hike particularly in European and Asian markets due to the Arab Spring democratic movements that emerged in early 2011 and Iran's nuclear problem. Since 2012, side effects of monetary easing and influences of speculations and investment funds combined with rising tensions in Syria, Egyptian demonstrations and other developments raised geopolitical risks in 2013, leading crude oil prices to continue to rise.

If oil importing countries increase their dependence on a small number of oil exporters including Russia as well as the Organization of the Petroleum Exporting Countries (OPEC) dominated by Middle Eastern nations, it will lead OPEC to expand its market control. At the same time, marginal costs of production will increase due to a shift to smaller-scale, polar and deepwater oil fields. Given past experiences, regulations on excessive money inflow into futures markets are unlikely to be toughened and speculations and investment funds can be expected to continue to drive up crude oil prices. Given these factors, crude oil prices are assumed to gradually rise over a medium to long term while making wilder short-term fluctuations.

Real crude oil prices (in 2012 US dollars) will reach $117/bbl in 2020 and $127/bbl in 2040 (Table 1). Nominal crude oil prices will reach $137/bbl in 2020 and $221/bbl in 2040 under an assumed annual inflation rate of 2%.

Table 1 International Energy Prices (Reference and Advanced Technology Scenarios)

Real prices			2012	2020	2030	2040
Crude oil		$2012/bbl	115	117	122	127
Natural gas	Japan	$2012/MBtu	16.7	13.9	14.0	14.4
	United States	$2012/MBtu	2.8	4.3	5.6	8.0
	Europe	$2012/MBtu	10.5	11.1	12.0	12.8
Steam coal		$2012/t	134	136	141	146
Nominal prices			2012	2020	2030	2040
Crude oil		$/bbl	115	137	174	221
Natural gas	Japan	$/MBtu	16.7	16.3	19.9	25.1
	United States	$/MBtu	2.8	5.1	8.0	14.0
	Europe	$/MBtu	10.5	13.0	17.2	22.3
Steam coal		$/t	134	160	202	254

Note: The annual inflation rate is assumed at 2%.

Meanwhile, shale gas has allowed North America to become self-sufficient in natural gas. Expanding shale gas production is projected to sustain low levels of natural gas prices in the future. Liquefied natural gas planned for exports from the Middle East to the United States has begun to flow into Europe, leading natural gas prices to become lower. In Japan, a gas price drop as large as seen in North America will not emerge due to limits on cuts in liquefaction and maritime transportation costs. In the Reference Scenario, Japan's imported natural gas prices are expected to fall from $16.7 per million British thermal units (MBtu) to $14.4/MBtu in 2040. But a price gap with European and North American levels will still remain.

Coal prices have long featured far more moderate fluctuations than crude oil and natural gas prices. For the future, coal prices, though under less resource constraints, will slowly increase on a global demand hike for power generation and steelmaking. If a carbon tax is imposed on coal prices to help prevent climate change, however, consumer coal prices may rise far more sharply than international prices.

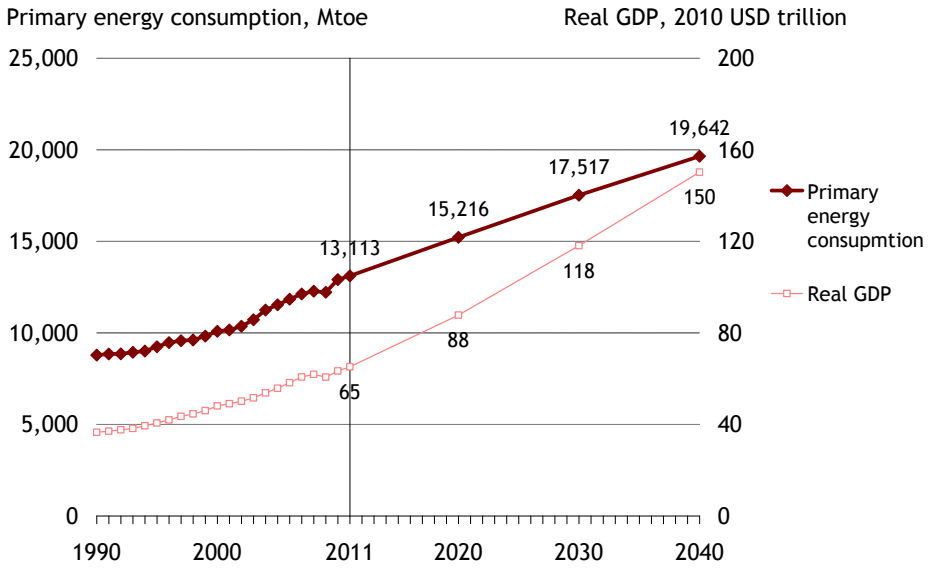
2. World/Asia Energy Supply/Demand Outlook

2.1 Primary Energy Consumption

World

Global primary energy consumption will increase about 1.5-fold from 13,113 Mtoe in 2011 to 19,642 Mtoe in 2040 (Figure 4). Energy consumption growth during the period will thus be slower than the 2.3-fold economic expansion. The projection indicates that new energy demand equivalent to Japan's present consumption will emerge every two years and the world will thus continue to need massive amounts of energy. Expected national energy policies and energy conservation technology development and diffusion alone may fall far short of further decoupling energy consumption growth from economic growth.

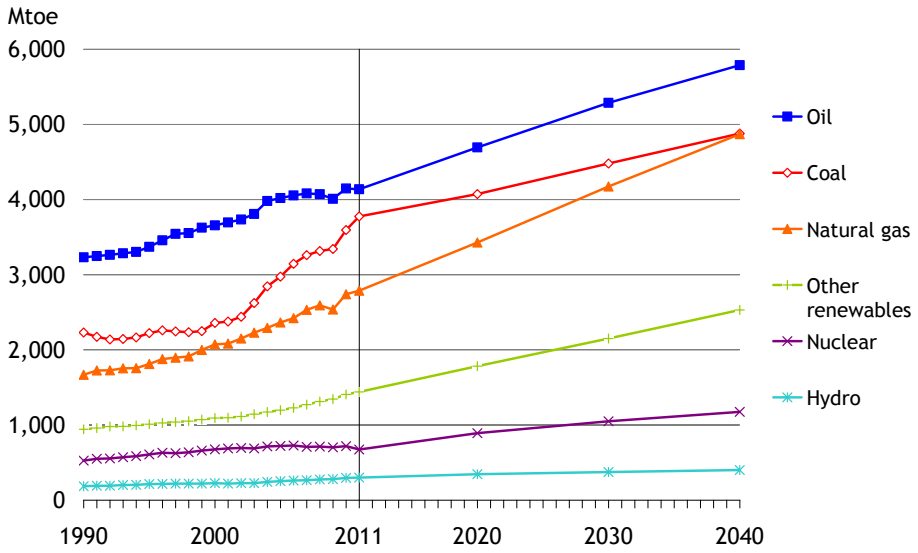
Figure 4 Global Primary Energy Consumption and Real GDP (Reference Scenario)



Fossil fuels (oil, coal and natural gas) which currently represent about 80% of primary energy consumption will account for some three-quarters of future energy consumption growth (Figure 5). The world will thus remain heavily dependent on fossil fuels until 2040 but there will be some changes. Oil will maintain the largest share of primary energy supply, followed by coal as at present. The oil dependence rate will gradually diminish from 32% at present to 29% in 2040 and the coal consumption expansion, which has been rapid in China and India over the past decade, will decelerate in the future. Among fossil fuels, natural gas will post the largest consumption growth over the coming 30 years and expand substantially in terms of both final consumption and power generation. Natural gas will rival coal consumption in 2040 and later replace coal as the second largest

energy source after oil.

Figure 5 Global Primary Energy Consumption by Source (Reference Scenario)

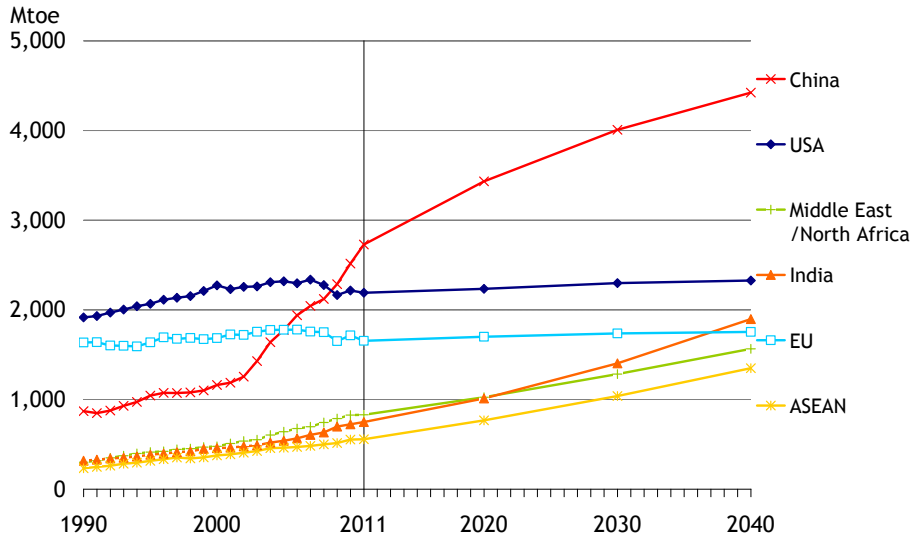


Consumption growth for wind and solar energy, and biofuel for transport will be faster than for any other energy sources. Renewable energy consumption, including hydro, will expand 1.7-fold over the next 30 years but its share of total electricity generation in 2040 remains limited to a little more than 20%. Excluding hydro, renewables will account for less than 10% of the total. Biofuel consumption will accelerate as the development for the next-generation of (cellulosic) biofuel which poses less food and land utilization problems, makes progress. Biofuel will be mainly used as a substitute for oil in the transport sector at a rate that will exceed 10% in the United States and many European countries and a rate as high as 33% in Brazil. Fuelwood consumption at home in South Asia and sub-Saharan Africa will increase in line with population growth. Fuelwood's share of total energy consumption will decline due to income growth and the expansion of modern energy supply chains.

Nuclear power will be deployed proactively in Russia, South Korea, the Middle East and the United States, as well as in China, India and other emerging countries where electricity demand will expand. OECD countries' nuclear power generation capacity will remain almost unchanged through 2040 as an increase in South Korea, the United States and some others is offset by a decline in countries such as Germany and Japan. Non-OECD countries will thus be responsible for the increase in global nuclear power generation capacity. Although on average a new (one gigawatt) reactor will be built every month, the nuclear energy's share of total primary energy consumption will remain stable at around 6% through 2040.

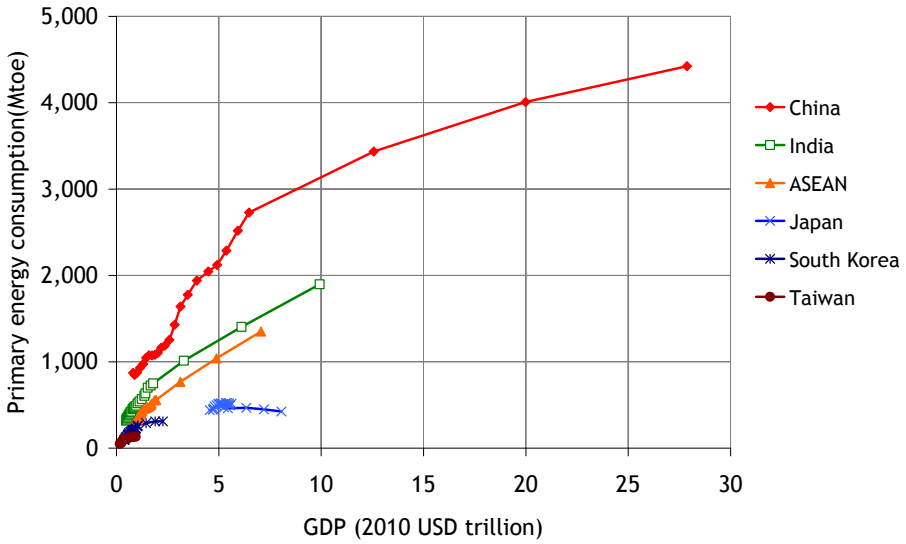
While global primary energy consumption will grow at an annual rate of 1.4% through 2040, growth rates will differ from region to region (Figure 6). Consumption in OECD countries will grow at a very small rate while it will sharply expand in non-OECD countries accounting for about 90% of the global increase. As a result, non-OECD countries' share of global energy consumption will expand from a little more than 50% at present to two-thirds in 2040.

Figure 6 Primary Energy Consumption in Major Countries/Regions (Reference Scenario)



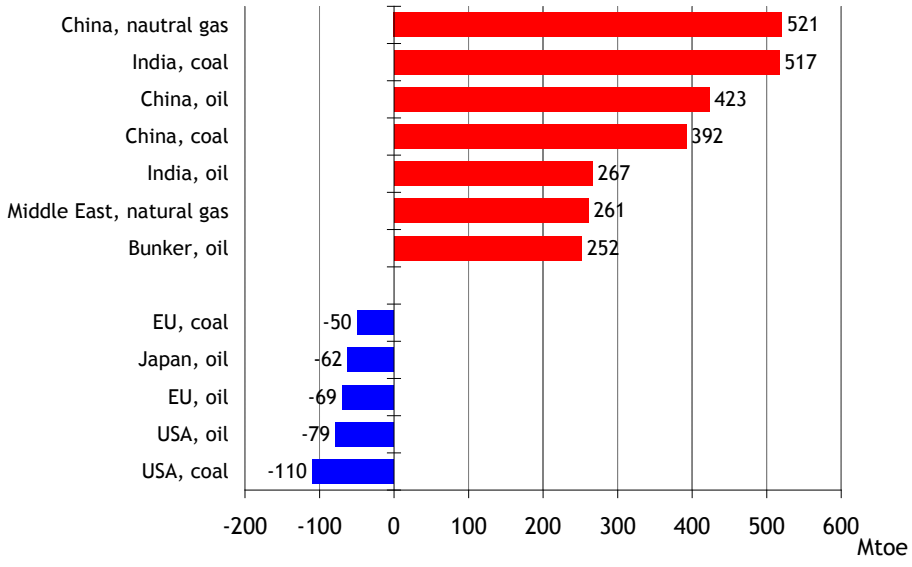
Asia will increase energy consumption 1.8-fold over the next 30 years, accounting for about 60% of global energy consumption growth. Due to high economic growth somewhat a little slower than in the past, energy consumption will grow 1.6-fold in China and by more than two-fold in India and ASEAN (Figure 7). While improvements in energy efficiency will slow down the consumption increase, the contributions from the economic growth will be far greater. Meanwhile, energy consumption in Japan, South Korea and Taiwan will post a small increase or even a decline. At present, GDP intensity in China, India and ASEAN is 1.7 times as large as in Japan, South Korea and Taiwan and some gap will still remain even by 2040.

Figure 7 Asian GDP and Primary Energy Consumption
(1990-2011, Reference Scenario for 2020, 2030, 2040)



Primary energy consumption changes by region and energy source over the coming 30 years indicate that China and India will be responsible for the five largest fossil fuel increases (Figure 8). The fossil fuel consumption growth is equivalent to five times the consumption of Japan. In contrast, the five largest decreases are seen in oil and coal consumption in developed regions including the United States, the European Union and Japan. Fuel efficiency improvements in the transport sector will be the main contributor to the reduction in oil consumption. The major contributors to the U.S. coal consumption decline will be tough environmental regulations in the power generation sector combined with the shale revolution.

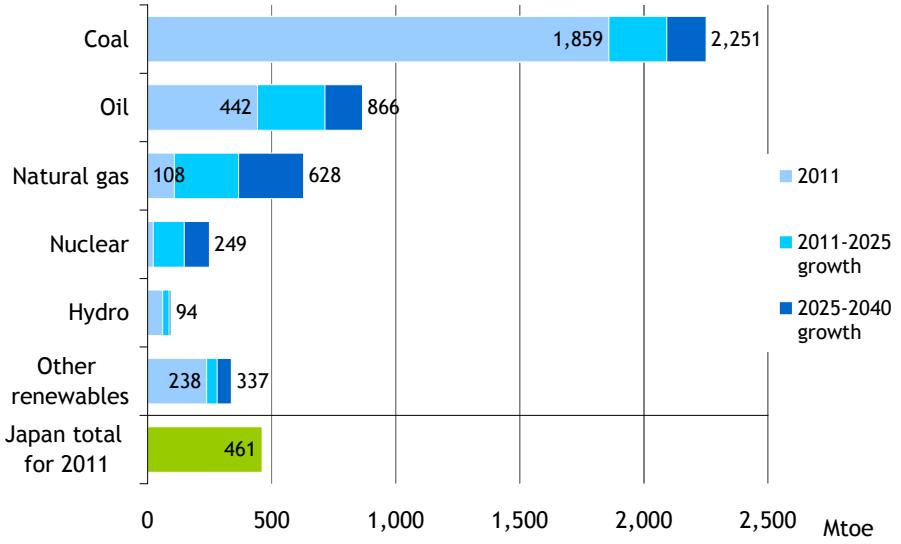
Figure 8 Largest Primary Energy Consumption Changes by Region/Source
(2011-2040, Reference Scenario)



China

China, the world's largest energy consumer, will expand its primary energy consumption at an annual rate of 1.7% from 2,728 Mtoe in 2011 to 4,423 Mtoe in 2040 (Figure 9). But the situation will change from the first half of the projection period to the second half as China's energy consumption growth will decelerate due to an economic growth slowdown, continuous energy conservation efforts and demographic changes.

Figure 9 China's Primary Energy Consumption by source (Reference Scenario)



The share of coal which currently accounts for about 70% of China's primary energy consumption will decline to 51% by 2040. As crude steel production will not rise greatly, the industry sector's coal consumption will soon decline, slipping below the 2011 level at 343 Mtoe by 2040. While coal consumption will shift to power generation, coal demand growth will decelerate due to air pollution and environmental policies. Demand for coal for power generation, which posted an average annual increase of 11% over the past decade, will slow down to an average annual increase of only 0.5% from 2030. In anticipation of the decelerating growth in China's demand for coal, some countries and companies have scaled down their plans for coal supply to China. Even so, coal will remain a mainstay energy source in China.

China's oil consumption will almost double over the coming 30 years, reaching 866 Mtoe in 2040. During the period, China will replace the United States as the world's largest oil consumer. Driving the increase will be the transport sector including road transport. As air pollution is seriously growing, China has been promoting the electrification of motorcycles and by 2014, China plans to make fuel efficiency regulations as tough as in developed countries. But with China's great potential to expand its vehicle market, from

the current 7% vehicle ownership rate, the number of vehicles in China will increase to 360 million in 2040, leading the transport sector to double oil consumption. China's share of global gasoline consumption will expand from 8% at present to 18%, exceeding its share of global population.

As China has a policy of promoting natural gas consumption and is expanding its natural gas supply sources and means, its natural gas consumption in 2040 is expected to reach 628 Mtoe, far more than Japan's entire energy consumption. Although all sectors will expand natural gas consumption, the building sector will post a remarkable increase in the first half of the projection period. In the sector, natural gas consumption will increase 2.7-fold by around 2020, exceeding coal or oil consumption and becoming the second largest energy source after electricity. Natural gas consumption for power generation will also post noticeable growth. While the government intends to proceed with shale gas development, there remains geological, water and many other problems that must meet Chinese conditions.

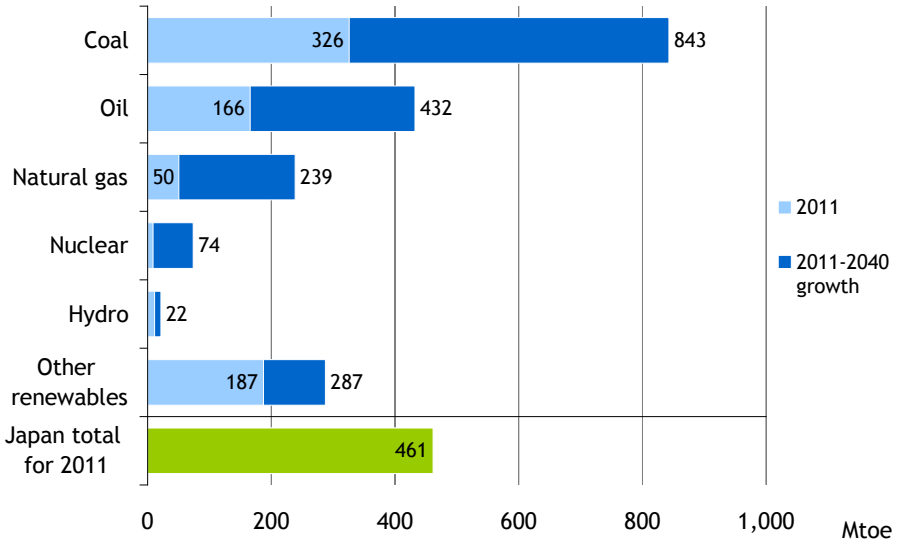
In Asia, China has the third largest nuclear power generation capacity after Japan and South Korea. Its 12th five-year development plan for the period through 2015 includes a target of constructing nuclear power plants with a total capacity of 40 GW. In 2040, China will have the world's largest nuclear power generation capacity and will account for half of the increase in global nuclear generation capacity between 2011 and 2040.

Renewable energy will account for 9.7% of China's primary energy consumption in 2040. China has the world's largest hydro power plant, the Three Gorges Dam, and the large Xiluodu Dam is under development, boasting the biggest hydro generation capacity in the world. As a result, hydro captures most of the current renewable energy generation. China is also positively supporting wind and photovoltaic power generation. Since 2008, the government has refunded the value added tax on sales of electricity generated with wind energy and a plan to provide photovoltaic generation with the same incentive is now under discussion. By 2040, wind and photovoltaic generation will be given the same priority as nuclear, hydro and natural gas generation.

India

India, the third largest energy consumer in the world, will increase its primary energy consumption at an annual rate of 3.3% from 749 Mtoe in 2011 to 1,896 Mtoe in 2040 through high economic and population growth and infrastructure development. The increase is equivalent to more than twice Japan's current entire energy consumption. With such an energy consumption expansion, also resulting from the replacement of massive biomass energy with modern energy sources in the residential sector, India will increase its influences on the international energy market (Figure 10).

Figure 10 India's Primary Energy Consumption by source (Reference Scenario)



In India, coal accounts for more than 40% of primary energy consumption and that percentage will remain unchanged until 2040. Although India has leading coal deposits, its domestic coal is of lower quality with high ash content. India's development of its domestic coal resources and relevant transport infrastructure has not so far been smooth. Environmental considerations will grow even more important as future resources development are considered to the point where any coal demand increase will have to be covered by imports of higher quality. India's dependence on imported coal will increase further toward 2040.

India's oil consumption will expand 2.6-fold in the coming 30 years reaching 432 Mtoe by 2040, with the growth concentrated on the transport sector. Oil is India's largest import item, followed by gold and those imports are major factors to its trade deficit. As India posts the highest fossil fuel imports as a percentage of GDP among major countries, energy conservation including oil consumption savings has become very important for both security and economic reasons.

India had a policy of expanding natural gas consumption and of consuming domestically produced natural gas until imports of LNG began in 2004. Even if for the immediate future, natural gas consumption is limited to large industrial users including power generators and chemical companies, the consumption will continue to increase at an annual rate of 5.5% until 2040.

The Indian government was planning to build 18 nuclear reactors by 2020, but after the Japanese nuclear plant accident, India postponed the launching of new reactors by a few years. As Japan-India negotiations are progressing on a bilateral nuclear cooperation agreement, India is growing eager again to expand nuclear power generation and its

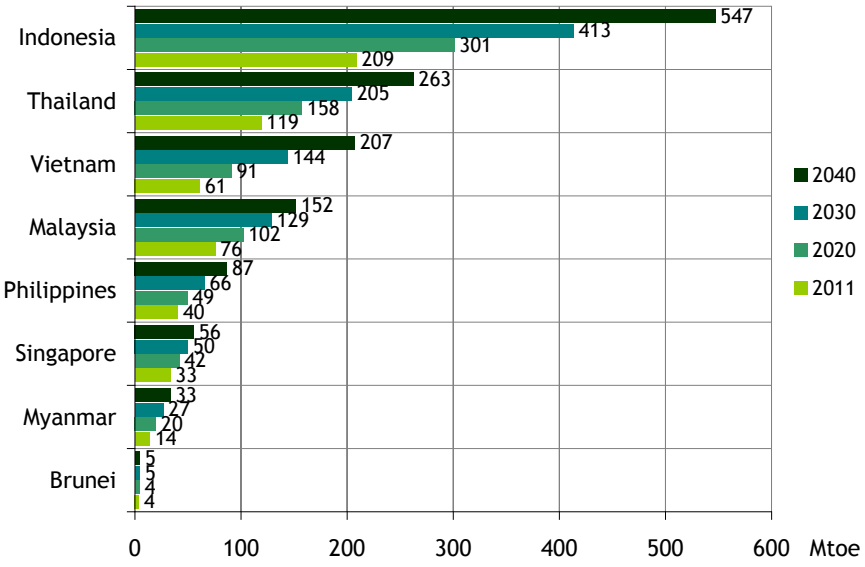
additional nuclear generation capacity through 2040 will exceed the planned increase for South Korea. Along with China, India will drive the growth in world's nuclear generation capacity.

Renewable energy consumption other than biomass has been limited in India. Wind and photovoltaic energy accounts for only 0.3% of its primary energy consumption and the share will still be limited to only 0.8% in 2040. The Indian government introduced renewable energy promotion measures, such as tax incentives, to greatly expand wind power generation despite unresolved challenges. The remaining issues include the induced sharp rise in electricity costs and grid destabilization through the massive expansion of renewable energy power generation.

ASEAN

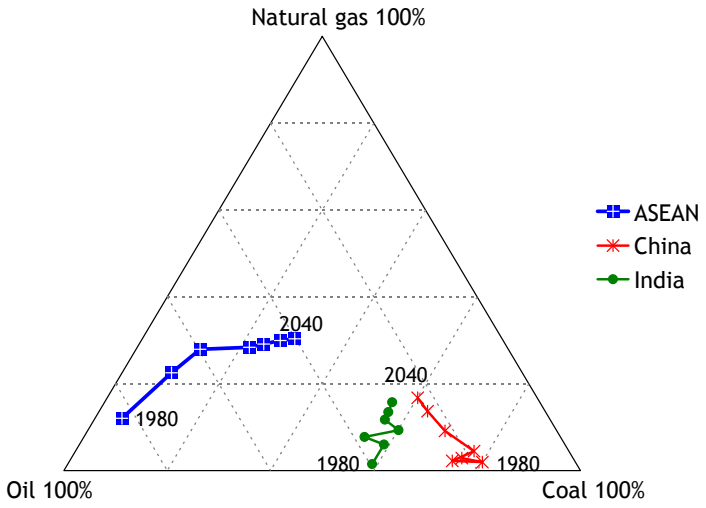
ASEAN's primary energy consumption has increased rapidly due to high economic and population growth. Excluding biomass consumption mainly in households, its primary energy consumption in 2011 totaled 444 Mtoe, equivalent to Japan's. ASEAN energy consumption will expand at an annual rate of 3.1% to 1,186 Mtoe in 2040, rivaling EU consumption. Indonesia, with a population of 240 million, will surpass Japan's energy consumption and become the fifth largest energy consumer in the world by 2035. Malaysia and Thailand proactively introduced foreign capital mainly for electric machinery, electronics and an auto industry through the 1990's, providing the base for today's economic growth. Their economies are more mature than other ASEAN economies but their population growth will decelerate from around 2025. Therefore, primary energy consumption growth in these countries will be slower than in other ASEAN countries including Indonesia. Over recent years, some industries that have had difficulties in earning profit amid labor cost hikes in Thailand and Malaysia have shifted operations to Myanmar and other neighboring countries. Myanmar's primary energy consumption will increase 2.4-fold from the present level in the coming 30 years.

Figure 11 ASEAN's Primary Energy Consumption (Reference Scenario)



In the ASEAN energy mix, the mainstay energy source will shift from oil in the 1980s to coal while natural gas's share will remain almost unchanged. These changes will not be the case with China and India that will reduce their coal's share of total fossil fuel consumption while raising the natural gas share. The changes in the ASEAN energy mix will be steeper than those for China or India. Although ASEAN will introduce nuclear power generation around 2025, it will fall short of playing any major role in the mix.

Figure 12 Fossil Fuel Mix in ASEAN, China and India
(1998, 1990, 2000, 2011, Reference Scenario for 2020, 2030, 2040)



Coal which currently accounts for 16% of the ASEAN primary energy consumption will expand to capture 24% of primary consumption in 2040 due to energy-consuming industries' development, including the construction of blast furnaces for steelmaking, and a shift to cheaper coal-fired power generation.

ASEAN's oil consumption will double over the next 30 years to 436 Mtoe in 2040. Oil will remain the largest energy source while seeing its share of total primary energy consumption declining. The transport sector will expand oil consumption as vehicle ownership increases in line with income growth and the development of a transport infrastructure. While Brunei Darussalam and Malaysia are now net oil exporters, other ASEAN countries are increasing imports due to a domestic production stalemate combined with rising demand. By 2040, ASEAN will grow more dependent on oil imports.

ASEAN's natural gas consumption will increase mainly in the power generation sector toward 2040. As Myanmar is expected to develop natural gas resources, other ASEAN countries such as Thailand are making plans to import gas from Myanmar. Singapore uses natural gas for 80% of its power generation and is fully dependent on imports from countries such as Thailand and Malaysia. Given a past incident where a supply interruption caused a blackout, Singapore is constructing an LNG hub in order to diversify its natural gas supply sources. Malaysia, though being a leading natural gas producer in Asia, is also expanding overseas operations for gas imports.

Malaysia, Thailand and Vietnam are planning to introduce nuclear power generation not only to address environmental issues but also to diversify the energy balances of regional economies. ASEAN countries will begin to introduce nuclear energy on a full-fledged basis around 2030 through enhanced interregional cooperation and the preparation of safety standards.

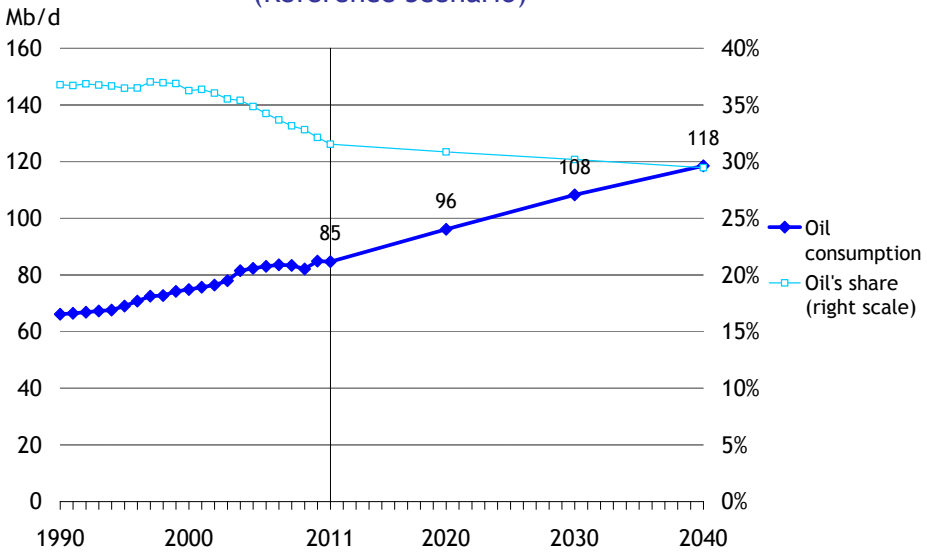
Renewable energy consumption in ASEAN will center on biofuel rather than power generation. The transport sector's biofuel substitution ratio will rise to 7% and will help promote agriculture, poverty reduction and job creation over a short term while reducing the dependence on oil imports over a long term. Many ASEAN countries have adopted a policy of gradually increasing the content of palm oil or biofuel from jatropha and cassava in gasoline. Thailand created a market for ethanol-mixed gasoline called gasohol and is the largest biofuel consumer among ASEAN countries. The market is expanding as gasohol's price gap with pure gasoline is increasing but the government target has not yet been achieved as insect pest control for cassava has failed to be successful. As such, biofuel consumption growth in Thailand will be slower than in other ASEAN countries. ASEAN countries such as Malaysia and Indonesia will gradually increase the mandatory biofuel contents of gasoline and Indonesia will replace Thailand as the largest biofuel consumer

among ASEAN countries by 2040. In Asia, it will be the second largest biofuel consumer after China.

Oil

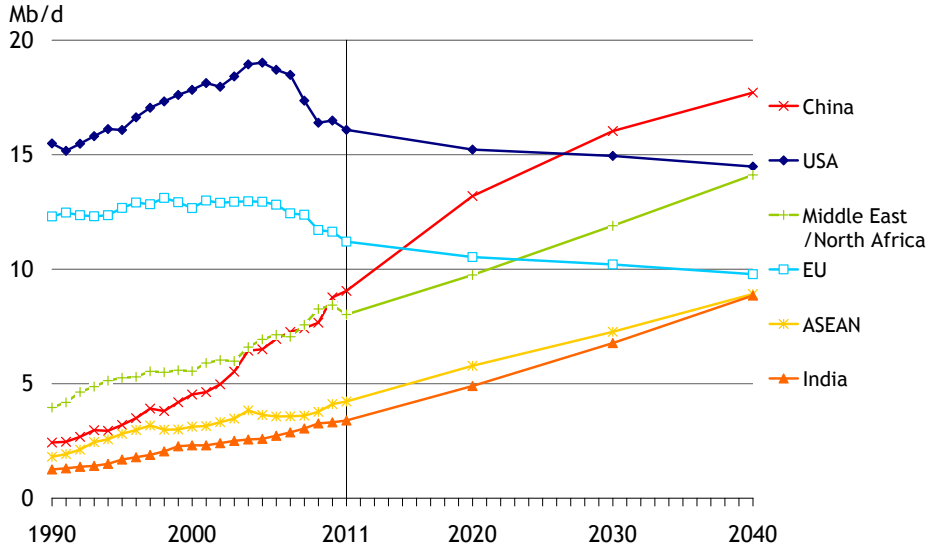
Global oil consumption will expand at an annual rate of 1.2% from 85 million barrels per day (b/d; 1 million b/d=48.85 Mtoe per year) in 2011 to 118 million b/d in 2040 (Figure 13). Although oil's share of primary energy consumption will fall from 32% in 2011 to 29% in 2040, oil will remain the largest energy source.

Figure 13 Global Oil Consumption and Its Share of Primary Energy Consumption (Reference Scenario)



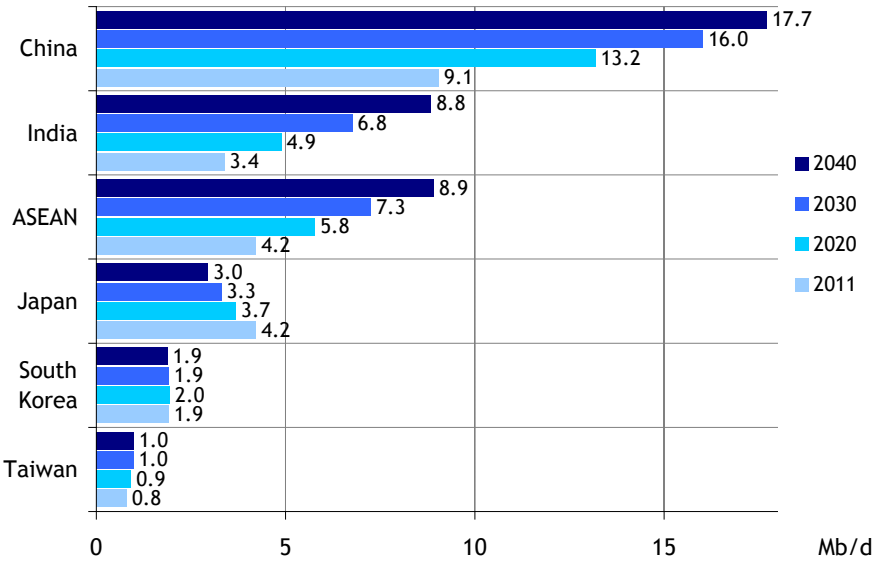
Oil consumption in industrialized countries represented by OECD members has been decreasing since 2005 and is projected to fall at an annual rate of 0.3% over the next 30 years (Figure 14). Non-OECD countries and international bunker oil will be fully responsible for the increase through 2040. The Middle East and North Africa, known as oil producing regions, will expand their oil demand to almost catch up with the United States by 2040. OECD countries' share of global oil consumption will decrease from 46% in 2011 to 30% in 2040. At the same time, the United States currently the world's largest oil consumer will rapidly reduce oil imports due to its oil demand decline and its expansion of shale oil output. As a result, its strategic oil reserve requirements will decline, leading the present oil reserve scheme of the International Energy Agency to reduce its role as a response to emergency.

Figure 14 Oil Consumption in Major Countries/Regions (Reference Scenario)



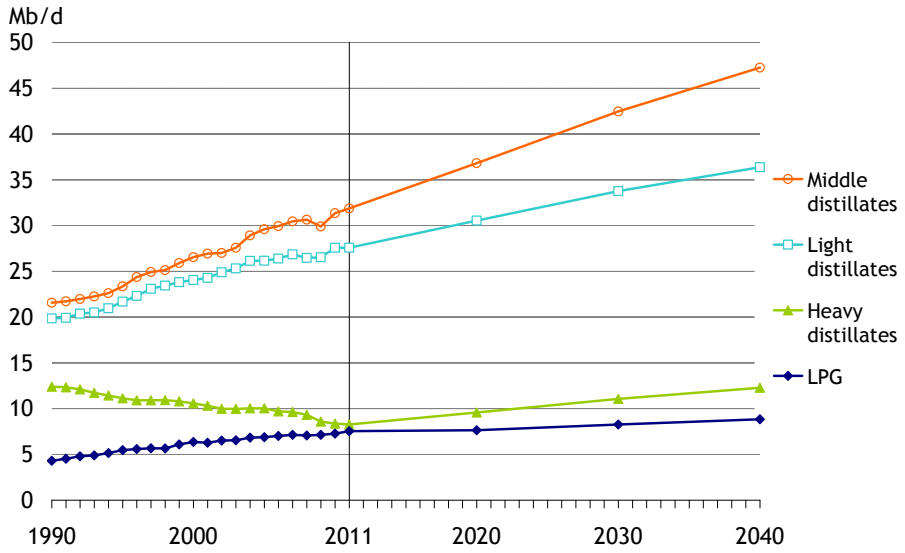
Asian oil consumption will increase at an annual rate of 2.0% from 24.5 million b/d in 2010 to 43.0 million b/d (Figure 15). Asia will account for more than 50% of the global oil demand increase and its share of global oil demand will rise from 29% to 36%. China will soon become the world's largest oil importer and by 2027, it will replace the United States as the largest oil consumer in the world.

Figure 15 Asian Oil Consumption by region (Reference Scenario)



The transport sector will account for about 60% of the future global oil consumption growth. As oil demand further concentrates in the transport and non-energy sectors, the need for light and middle distillates (naphtha, gasoline, diesel, etc.) among petroleum products will increase (Figure 16).

Figure 16 Petroleum Product Demand (Reference Scenario)

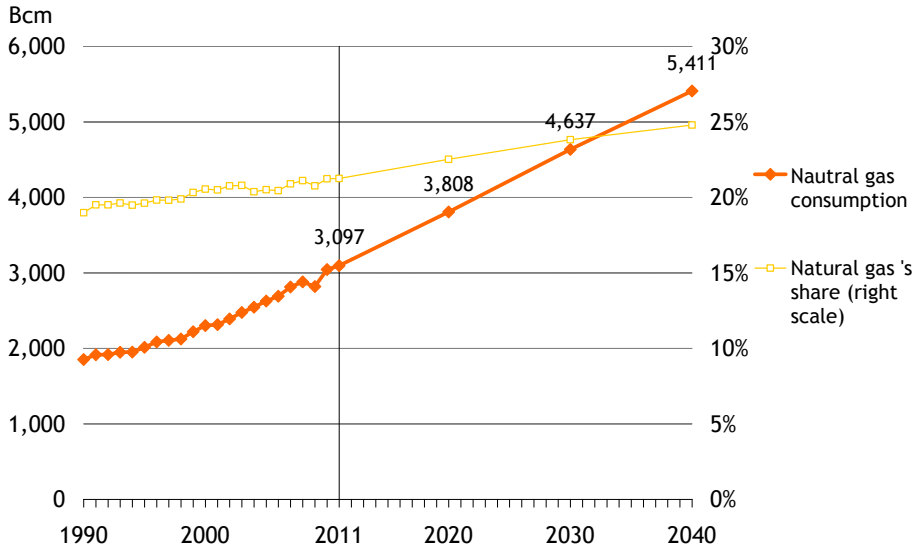


Plans to increase production of ethylene from ethane associated with shale gas are under way in North America. Given that ethane costs less than naphtha, it may flow into Asia and lead local oil refiners to lose naphtha buyers. Ethylene production capacity has already begun to shrink in Japan and refiners are making arrangements to efficiently produce transport fuels and basic chemicals for which demand will rise in Asian emerging countries. At the same time, Asia is increasing its petrochemical production capacity as indicated by the growing needs for expanding or opening petrochemical complexes in Indonesia and Vietnam. The oil industry must accurately figure out the future markets for petroleum products.

Natural gas

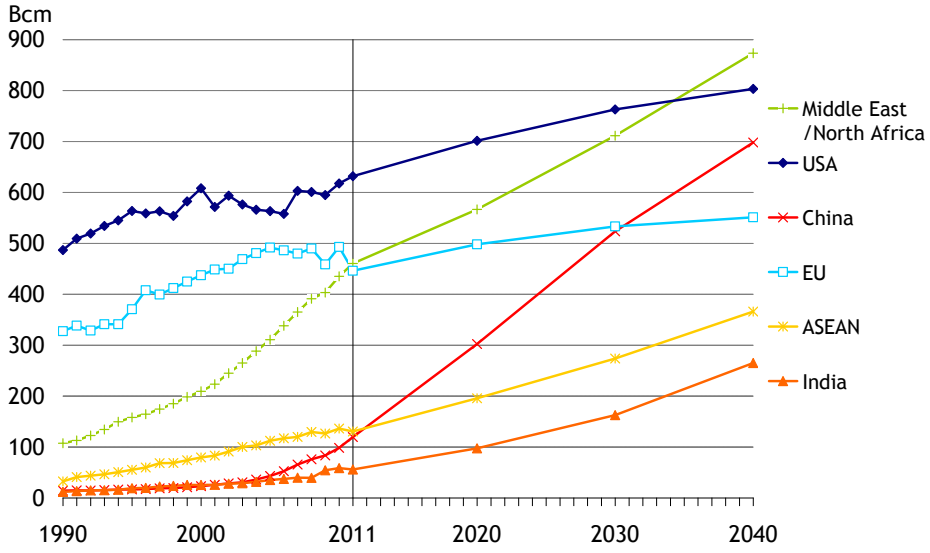
Global natural gas consumption will increase at an annual rate of 1.9% from 3,097 billion cubic meters (Bcm) in 2011 to 5,411 Bcm in 2040 (Figure 17). As the annual growth rate is the largest among fossil fuels the natural gas's share of primary energy consumption will rise from 21% in 2011 to 25% in 2040. Shale gas development will stimulate an increase in natural gas demand. In countries such as China, rich shale gas deposits have been proven, with their development under way but due to water, geological formation and pricing problems, shale gas development in China will not progress as rapidly as in North America.

Figure 17 Global Natural Gas Consumption and Its Share of Primary Energy Consumption (Reference Scenario)



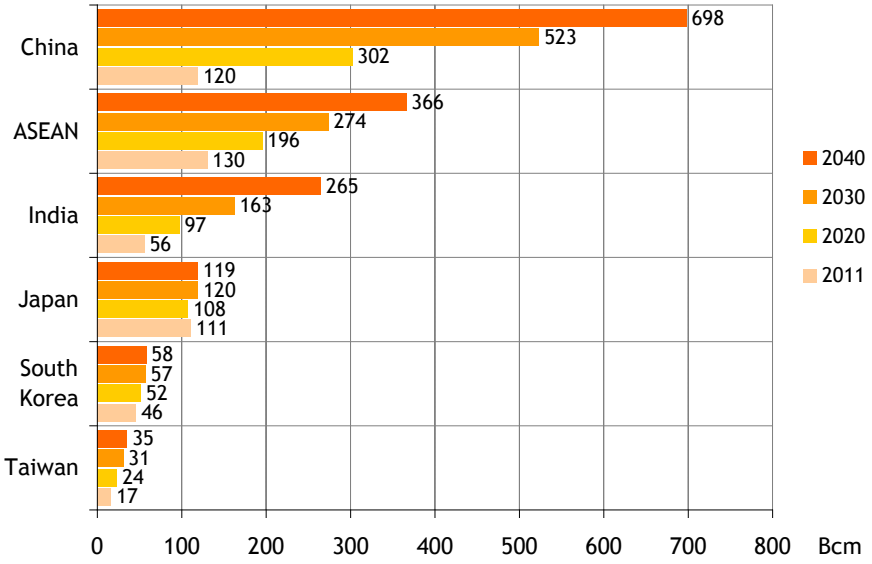
OECD countries will account for only 18% of the global natural gas consumption growth, while non-OECD countries will capture most of the growth (Figure 18). Non-OECD countries will expand their share of global natural gas consumption from a little more than 50% at the moment to two-thirds of the market by 2040. Among regions, the Middle East, North Africa and China will remarkably expand their consumption. The Middle East and Africa combined will exceed the U.S. consumption in the 2030s.

Figure 18 Natural Gas Consumption in Major Countries/Regions (Reference Scenario)



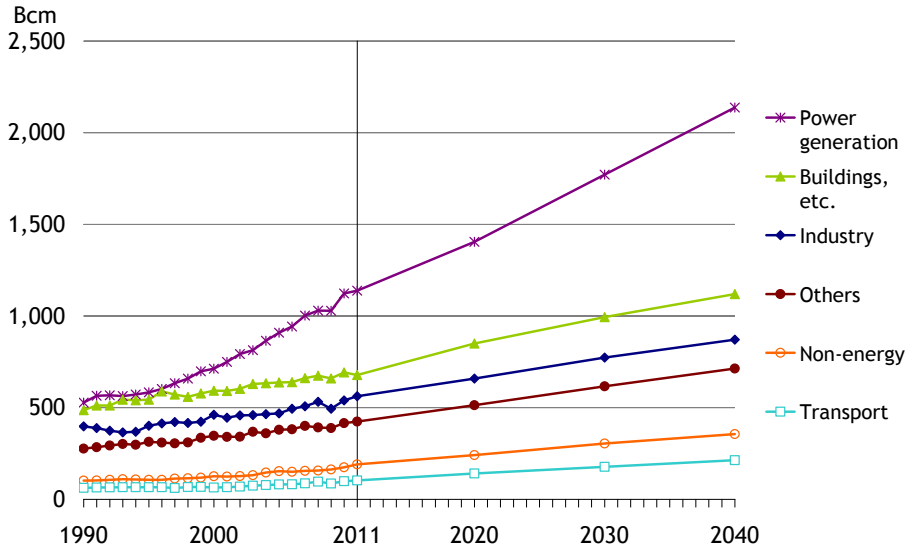
Asian natural gas consumption will more than triple from 531 Bcm in 2011 to 1,676 Bcm cubic meters in 2040 (Figure 19). Among the many countries that will expand consumption, China in 2040 will consume more natural gas than currently consumed by the whole of Asia. In Japan and South Korea, now major LNG importers, natural gas consumption growth will be moderate due to maturing economies and pricing factors.

Figure 19 Asian Natural Gas Consumption by region (Reference Scenario)



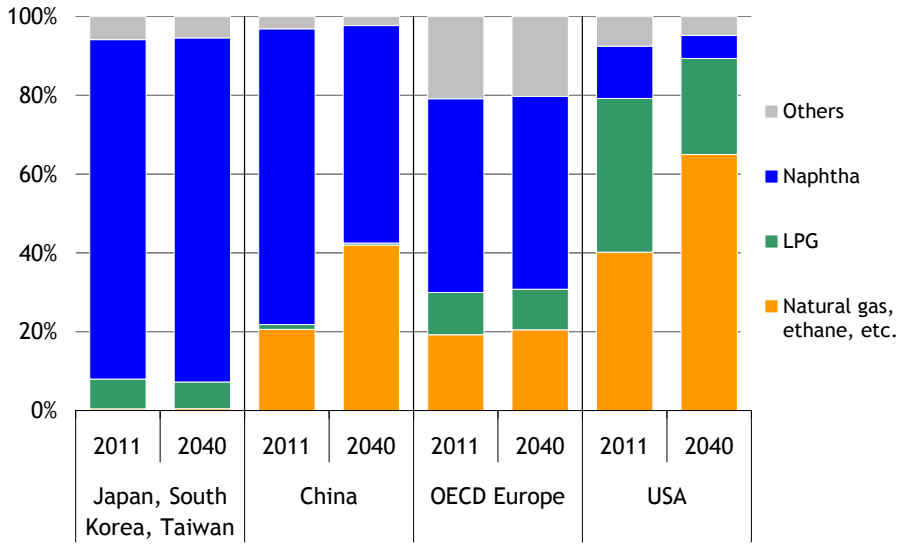
Natural gas combined cycle power generation will steadily increase, thanks to their high efficiency and their environmental suitability. High oil power generation costs and environmental problems with coal will lead the power generation sector's fuel consumption to shift to natural gas and as a result, the power generation sector will account for a little more than 40% of the growth in natural gas consumption (Figure 20). Natural gas will account for 27% of total electricity generation in 2040, becoming the second most important electricity source after coal. The industry sector will increase natural gas consumption as the U.S. petrochemical industry uses cheap gas for its growth. But the natural gas consumption rise in this sector may have no major impact compared to other sectors. The building sector will expand natural gas demand due to progress in urbanization amid high economic growth in emerging countries.

Figure 20 Global Natural Gas Consumption by sector (Reference Scenario)



The shale revolution has led ethane, a type of fuel associated with natural gas, to attract attention as a petrochemical feedstock for the regions where domestic natural gas is available at low cost. It will differ sharply in regions dependent on natural gas imports (Figure 21). The United States and the Middle East will take advantage of cheaper natural gas for increasing their competitiveness for petrochemical products while Asia that uses mainly naphtha for petrochemical production, will face higher production costs.

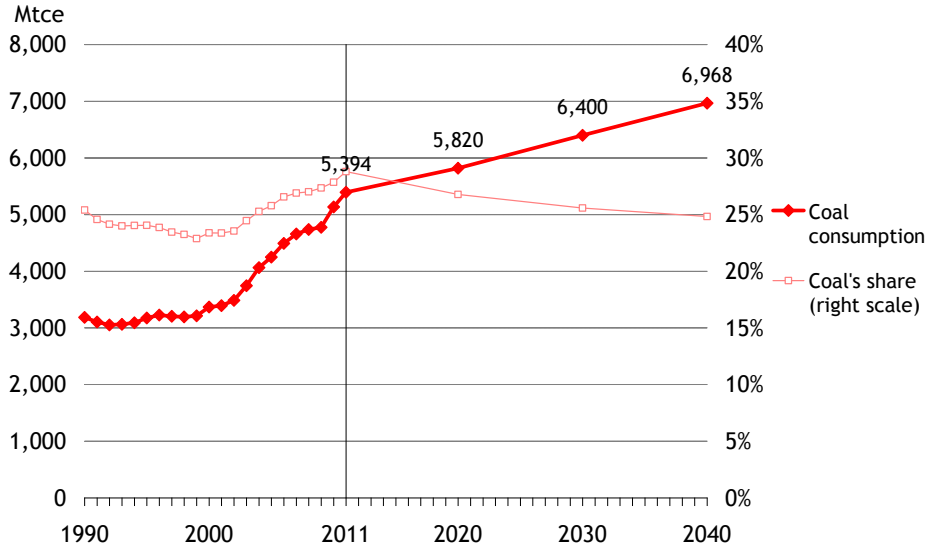
Figure 21 Petrochemical Material Mix in Major Regions (Reference Scenario)



Coal

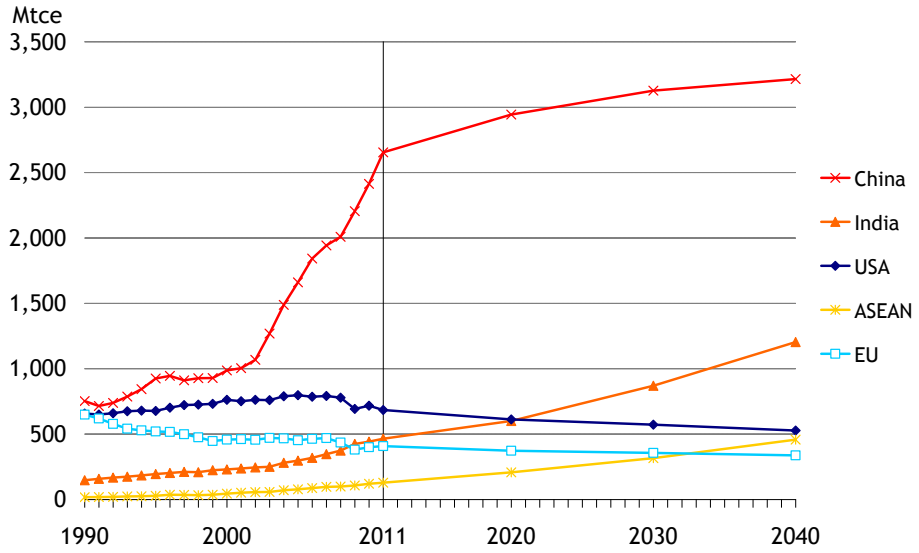
Global coal consumption will increase at an annual rate of 0.9% from 5,394 million tons of coal equivalent (Mtce) in 2011 to 6,968 Mtce in 2040 (Figure 22). While coal consumption will grow more slowly than oil or natural gas consumption, coal will still account for 25% of primary energy consumption even in 2040.

Figure 22 Global Coal Consumption and Its Share of Primary Energy Consumption (Reference Scenario)



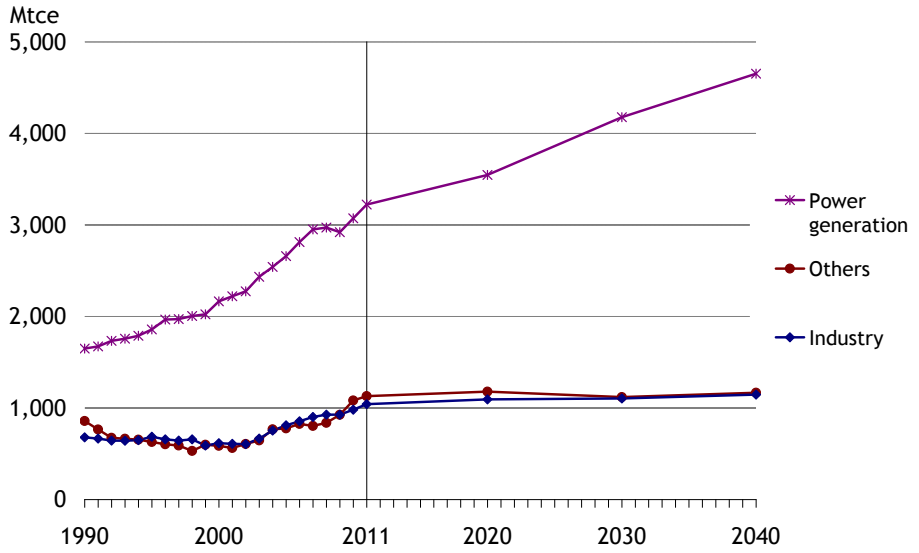
Asia will account for about 90% of the global coal consumption growth with China alone capturing more than 30% of the global growth. India will replace the United States as the world's second largest coal consumer after China in the first half of the 2020s. OECD countries will reduce coal consumption so that non-OECD countries will be responsible for all of the global coal consumption growth over the next 30 years. Non-OECD countries' share of global coal consumption will rise from 72% in 2011 to 82% in 2040. The United States has expanded natural gas consumption for power generation over recent years in response to a decline in natural gas prices through shale gas development. The U.S. government has drafted environmental standards that would ban coal-fired power plants without carbon capture and storage (CCS) systems, indicating that tougher environmental regulations would work to reduce U.S. coal consumption.

Figure 23 Coal Consumption in Major Countries/Regions (Reference Scenario)



As many areas in the world are endowed with vast coal resources, it becomes far less risky as a resource to develop than oil or natural gas resources that are found only in a limited number of regions. Due to lower prices for coal, consumption will increase mainly in the power generation sector where fuel costs are significant for economic efficiency. Asia including China and India will drive the global coal consumption growth of 1.3% per year through 2040, for a total rise of 1.4-fold.

Figure 24 Global Coal Consumption by sector (Reference Scenario)



Note: Coke production and coke consumption in blast furnaces are included into “others.”

The Intergovernmental Panel on Climate Change (IPCC) published reports describing the impact of coal consumption on future global warming and the need for relevant countermeasures. The challenge is how to reduce coal's disadvantage of greater carbon dioxide emissions through cleaner combustion and processing.

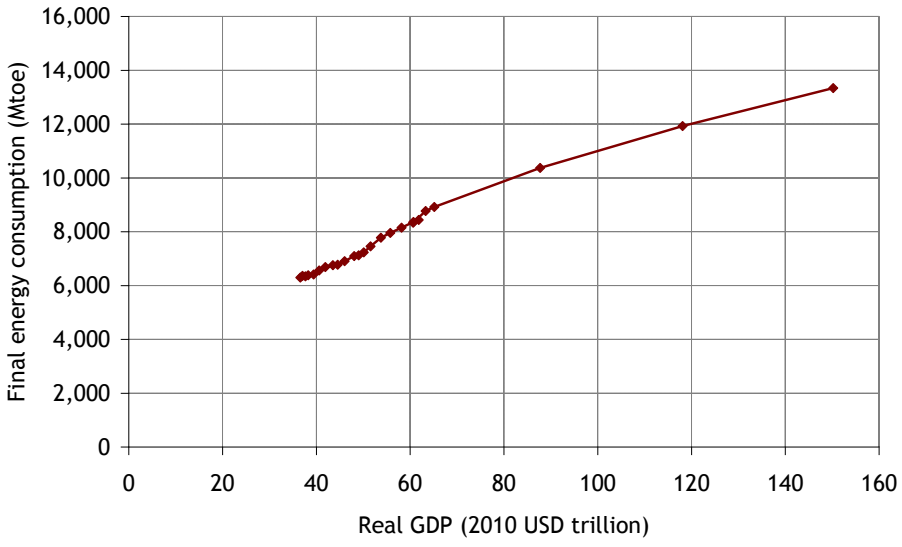
2.2 Final Energy Consumption

By Region

The average annual growth rate for final energy consumption in OECD countries between 1990 and 2011 was limited to 0.8% as consumption was held down by an economic slowdown and by progress in energy conservation. In contrast, non-OECD countries boosted final energy consumption by an average annual rate of 2.4% through high economic and industrial production growth. These trends will continue in the future and global final energy consumption, which totaled 8,918 Mtoe in 2011, will surpass 10,000 Mtoe by 2020 and reach 13,337 Mtoe in 2040 (Figure 25).

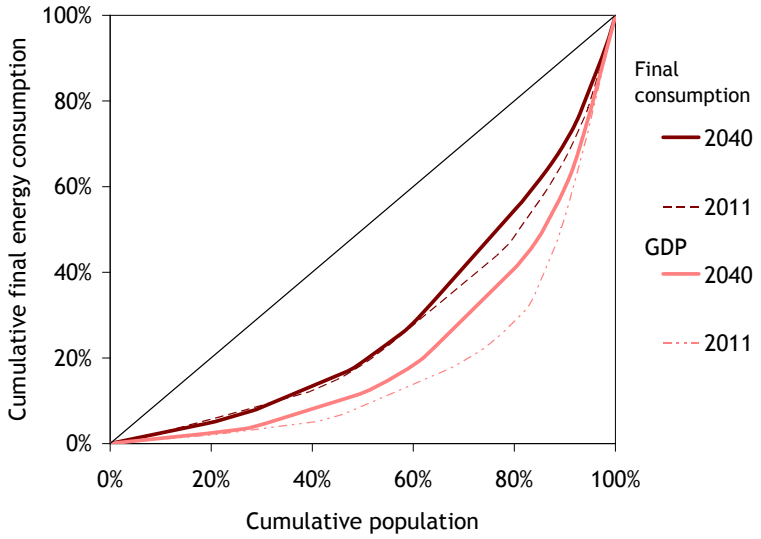
Asian final energy consumption will increase at an annual rate of 1.9% from 3,232 Mtoe in 2011 to 5,620 Mtoe in 2040 due to its developing industrial structure, urbanization progress and living standard improvements through rapid economic development. Asia will account for 2,388 Mtoe or slightly more than half of the global final energy consumption growth of 4,419 Mtoe through 2040.

Figure 25 Global GDP and Final Energy Consumption
(1990-2011, Reference Scenario for 2020, 2030, 2040)



Toward 2040, interregional income and energy gaps will shrink but not disappear. The Lorenz Curve for 2040 deviates far below the 45-degree-angle line (the no-gap line), indicating that income and energy gaps will still exist in 2040 (Figure 26). Developing countries have introduced renewable energy and other new technologies to create jobs in unelectrified and other areas where energy poverty is serious, attempting to ease income gaps and energy poverty. Unfortunately, unless the vicious circle of energy scarcity, less economic development and delay in energy infrastructure development is solved, the energy gaps will remain a challenge even in 2040.

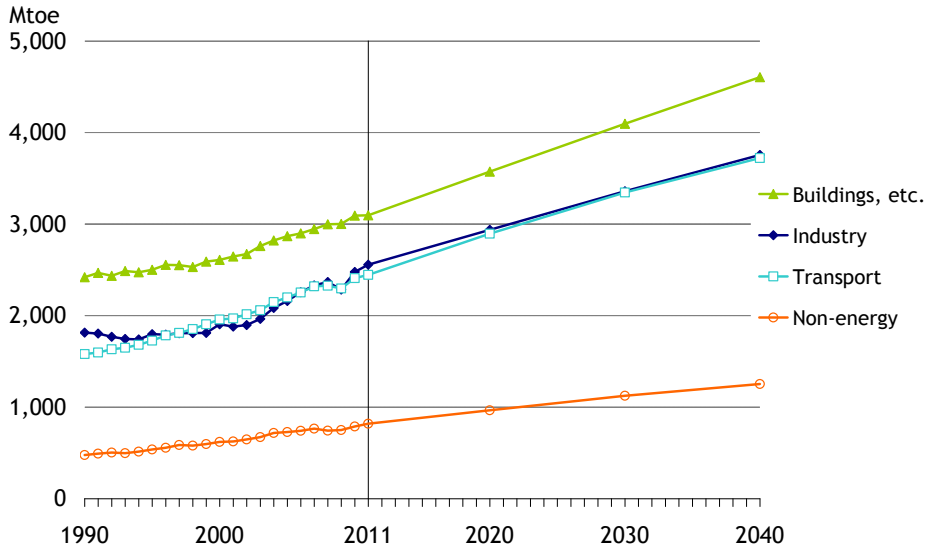
Figure 26 Global Final Energy Consumption and Lorenz Curve for GDP (2011 and 2040 for the Reference Scenario)



By Sector

The annual final energy consumption growth rate will stand at 1.3% for the industry sector, 1.5% for the transport sector and 1.4% for the building sector. In each sector, non-OECD countries' rapid expansion in energy consumption will make great contributions to the growth (Figure 27). As societies mature in non-OECD countries, the transport and building sectors will increase their respective shares of final energy consumption. These countries will thus gradually shift to the energy consumption path that OECD countries have followed.

Figure 27 Global Final Energy Consumption by sector (Reference Scenario)



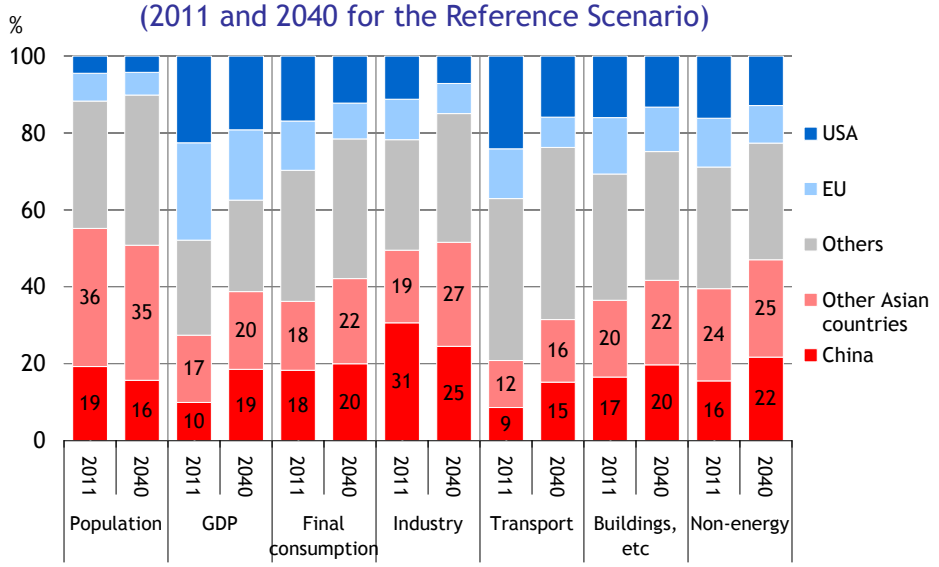
Even in OECD countries where societies have matured, the building sector will slightly expand its share of final energy consumption in line with a further shift to services and lifestyle changes. Energy conservation in the building sector is linked to household or personal lifestyles and behaviors and is relatively difficult to induce, in contrast to the industry sector where the replacement of small machines with large ones and technological advancement can easily produce energy conservation effects. In non-OECD countries, energy consumption in the transport and building sectors will firmly increase thanks to economic and population growth. The transport and building sectors in non-OECD countries will account for more than 50% of final energy consumption in 2040. Therefore, these sectors are most important as targets for energy conservation.

Progressing motorization will drive the transport sector's energy consumption growth. The global vehicle fleet will expand from 1,134 million vehicles in 2011 to 2,115 million vehicles in 2040. As motorization makes further progress on income growth in non-OECD Asian countries, the Asian vehicle fleet will expand from 266 million vehicles in 2011 to 797 million vehicles in 2040. Asia will thus account for a little more than 50% of the global fleet expansion. Around 2030, the non-OECD vehicle fleet will surpass the OECD fleet.

The building sector's energy consumption will increase in most countries except Japan. Improved living standards and broader diffusion of electrical appliances in line with income growth for China, India and ASEAN countries, will push their energy consumption growth rate to 2% per year, a much higher rate than for other countries. For China it will represent a remarkably large increase of 395 Mtoe between 2011 and 2040, easily surpassing Japan's total final energy consumption. Despite population peaking in 2030, China still

accounts for about 20% of the global population, and the energy consumption in the Chinese building sector will be large enough to exert great impacts on the world energy market and the global climate change issue.

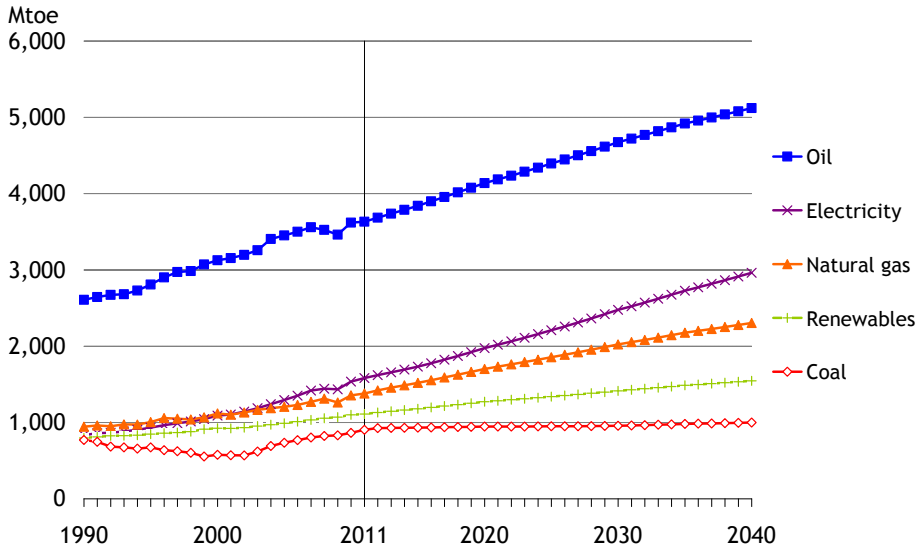
Figure 28 Asia's Share of Global Final Energy Consumption by sector (2011 and 2040 for the Reference Scenario)



By Energy Source

A breakdown of global final energy consumption by energy source for the coming 30 years indicates an average annual consumption growth rate of 2.2% for electricity and 1.2% for fossil fuels (Figure 29). Electricity will expand its share of total final energy consumption from 18% in 2011 to 22% in 2040, while coal and oil will reduce their respective shares.

Figure 29 Global Final Energy Consumption by energy source (Reference Scenario)



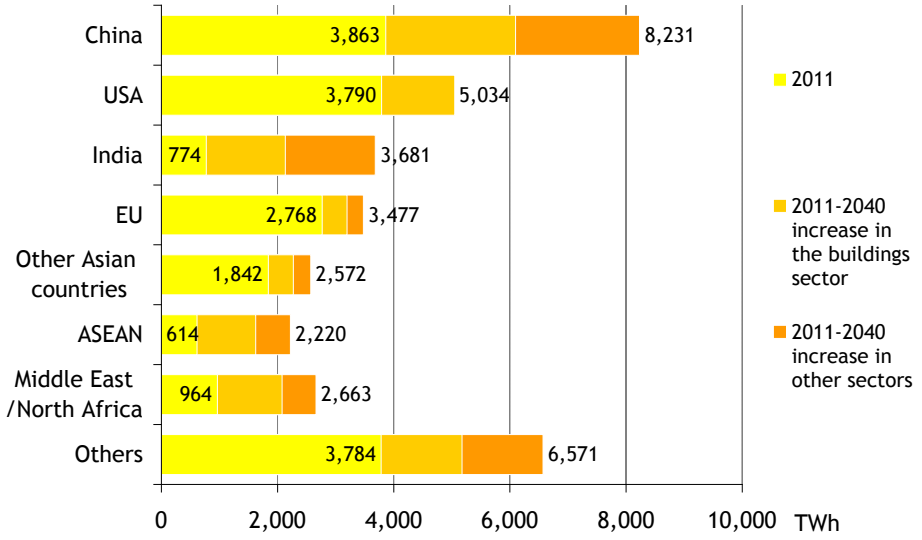
Nevertheless, oil will post the largest increase in volume and will account for more than 30% of total final energy consumption in 2040, remaining the most important energy source. The transport sector and non-energy use, including petrochemical materials in China, India and the Middle East, will be driving the overall oil consumption growth and a shift towards light petroleum products. Given that oil consumption becomes more concentrated in the two sectors where demand is less elastic to prices and substitutes are limited, oil is expected to grow more strategic.

Natural gas consumption will increase substantially in the building sector of China and in the industry sector of the Middle East and Latin America. In China, natural gas will expand its share of final energy consumption from 4% in 2011 to 14% in 2040 as households switch from using coal and biomass fuels (including firewood and livestock manure) to cleaner town gas in response to income growth and lower health risks and sanitation problems. In Latin America, Brazil and Mexico will switch fuel to natural gas for energy intensive industries including steel, chemicals and cement. Middle Eastern countries will promote fuel switching from oil to natural gas while giving priority to oil exports. In an effort to create jobs, they will expand their petrochemical plants using natural gas as a feedstock. In the United States, natural gas has traditionally been used for ethylene production and petrochemical projects using cheaper natural gas are increasing.

China's drop in coal use drives global final coal consumption to decline at an annual rate of 0.7% toward 2040. In China, the industry sector's share of final coal consumption will decline from 48% in 2011 to 35% in 2040, as steel and nonferrous metal production peaks out after accounting for 50% of the sector's energy consumption in 2011. The introduction of electric furnaces and the replacement of old equipment will also help cut coal consumption. In India and ASEAN countries, blast furnace steel production will expand due to steel demand growth accompanying motorization. Therefore, coal consumption will increase at an annual rate of 1.9% in India and at 4.0% in ASEAN countries.

Usually, electricity demand increases in line with income growth and this trend will remain unchanged for the projected period. Among major energy sources, electricity will post the largest consumption growth in both OECD and non-OECD countries. Global electricity consumption will expand at an annual rate of 2.2% and raise its share of total final energy consumption to 22%. Driving the growth will be the Asian region including China and India, and other emerging countries like Russia and Brazil. Demand growth in urban regions, growing electricity infrastructure investment in rural regions and the diffusion of electrical appliances such as air conditioners and televisions associated with income growth, will drive the increase in electricity consumption. The commercial sector will also increase its energy consumption due to a structural shift from secondary industries to tertiary industries including services. Office automation of buildings will particularly boost electricity consumption of the sector.

Figure 30 Global Final Electricity Consumption by region (Reference Scenario)



OECD countries currently account for 51% of global final electricity consumption. China, the world's largest electricity consumer, will increase consumption by 1,575 trillion watt-hours within the decade through 2020. That's more than the combined consumption of the United Kingdom, Germany, France and Italy. Non-OECD countries are rapidly increasing electricity consumption and within several years, their share of global electricity consumption will exceed that of OECD countries. Non-OECD countries will account for 80% of the growth in global electricity consumption through 2040. In 2040 China will consume 8,231 TWh, more than 1.6 times as much as U.S. consumption. India's consumption will increase at an annual rate of 5.5% to 3,681 TWh.

As seen in the past, economic expansion and income growth have induced an increase in electricity consumption that energy conservation efforts have failed to completely offset or drag down. One reason for this phenomenon is that electricity is a very convenient energy source and can lead to an increase in machines that use electricity as a power source or an energy source for control. Another reason is that some energy conservation technologies include electric vehicles, heat pumps and integrated coal gasification combined cycle (IGCC) systems that additionally consume electricity and reduce fuel consumption by more than the additional consumption.

2.3 Oil and Biofuel Supply

Oil Production

A major change in the oil market over recent years has been related to the shale oil production trends. While no accurate shale oil deposit estimate has yet been given, the U.S. Energy Information Administration has estimated global deposits at 345 billion barrels. But as shale oil developments require massive quantities of water for the hydraulic fracturing technology and production locations need to be close to consumption areas, not all deposits are suitable without new transportation measures. In this respect, the United States has taken advantage of an abundant water supply and of existing oil pipelines to initiate massive shale oil production ahead of other countries. Shale oil production can be profitable at a time when conventional crude oil prices exceed $100/bbl. Consequently, not all shale oil resources are available for development unless challenges including massive water supply, production technology, transportation means and high prices are overcome.

Meanwhile, key factors affecting conventional crude oil production include oil policies of the OPEC countries including Saudi Arabia, Iraq's oil production restoration policy and the recent trade embargo on Iranian oil. In addition, trends of non-OPEC countries that have massive oil deposits are a key factor.

Saudi Arabia, seen as a central OPEC player, is expected to serve as a swing producer in crude oil to secure stable crude oil supply and prices. Saudi Arabia has announced that its present oil production capacity stands at 12.5 million b/d and has adopted a policy of expanding oil production capacity further. Iraq had vowed to expand oil production rapidly toward a target capacity of 12 million b/d. But a delay in enhancing shipment capacity and worries about a rapid production increase leading to shorter oil field service lives have prompted Iraq to revise its production capacity target for 2017 down to 7-8 million b/d. Western countries have imposed a trade embargo on Iranian oil but it would be reasonable to expect the embargo will be lifted in the future. However, if Iran fails to sufficiently develop or maintain its oil fields during the embargo, it may take some time to restore normal oil production once the trade embargo is lifted.

Attracting attention among non-OPEC oil producing countries are Russia boasting massive crude oil deposits, Kazakhstan expected to expand crude oil production in the future and Brazil promoting deepwater oil development. Russia has seen a sign of decline in oil exports to Europe and views Asia, including China, as a major oil export destination. In this respect, it has geared up for oil development in the Russian Far East including Siberia. After a long delay in development, Kazakhstan started oil production at its Kashagan oil field in September 2013. It is expected to expand oil supply in the future. In Brazil, known as a pioneer in deepwater oil development, state-run oil company Petrobras has released a plan to increase crude oil output from 2 million b/d in 2011 to 4.9 million b/d in 2020.

North America with shale oil production and Brazil with deepwater oil production will contribute to expanding oil output in response to an oil demand increase through 2040. However, the international oil supply-demand balance could tighten without smooth investment in expanding production capacity primarily in the Middle Eastern OPEC countries which have seen remarkable growth in their domestic oil demand. As constraints on access to "easy" oil resources are emerging, interests are expected to grow in shale oil, oil sand and other unconventional oil resources in areas left open for resources development.

In the Reference Scenario, shale oil output will total 3.35 million b/d in 2020, 4.88 million b/d in 2030 and 7.4 million b/d in 2040. Shale oil output includes some 3 million b/d in North America while no rapid increase in output is expected from Russia and China where massive shale oil deposits reportedly exist.

Table 2 Global Oil Production (Reference Scenario)

Mb/d

	2011	2020	2030	2040	2011-2040 increase
Total	85.79	96.08	108.24	118.51	32.72
OPEC	35.50	39.69	46.43	53.19	17.69
Middle East	25.90	27.59	32.68	37.70	11.80
Others	9.60	12.10	13.75	15.49	5.89
Shale oil	0.00	0.00	0.20	0.40	0.40
Non-OPEC	48.20	53.86	58.76	61.87	13.67
North America	11.50	16.00	16.60	17.00	5.50
Shale oil	0.00	3.00	3.00	3.50	3.50
Latin America	7.10	8.50	10.15	10.75	3.65
Shale oil	0.00	0.00	0.40	0.80	0.80
Europe/Eurasia	17.35	17.10	19.15	20.57	3.22
Shale oil	0.00	0.30	0.50	1.00	1.00
Middle East	1.60	1.60	1.60	1.60	0.00
Africa	2.40	2.75	2.90	2.95	0.55
Asia	7.75	7.36	7.58	8.00	0.25
China	4.10	4.00	4.30	4.80	0.70
Shale oil	0.00	0.00	0.50	1.20	1.20
Indonesia	0.95	1.00	1.03	1.05	0.10
India	0.90	0.80	0.70	0.65	-0.25
Oceania	0.50	0.55	0.78	1.00	0.50
Shale oil	0.00	0.05	0.28	0.50	0.50
Processing gains	2.09	2.53	3.05	3.45	1.36

Russia will see slow growth in domestic oil demand and will export most of any output increase. Since oil exports to Europe have indicated a sign of decline, Russia may have no choice but to export oil to Asia where demand is expected to increase. As Middle Eastern exports are more advantageous for Southeast Asia, Russia may have to destine any

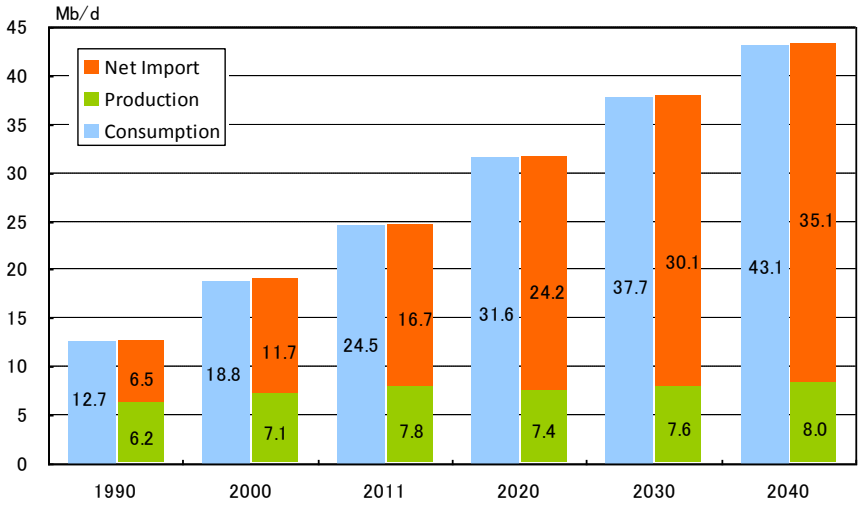
oil output increase to East Asia, particularly China. Russia will have difficulties in securing export destinations even if it increases oil output, consequently, Russia may shy away from large-scale shale oil development until the 2020s.

China is attempting to maintain domestic oil production to help meet its robust domestic demand. But the Daqing and Shengli oil fields have seen stagnant production in the absence of new promising oil field discoveries, leading China's oil self-sufficiency rate to fall year by year. The fact that it is difficult to secure sufficient water supply for shale oil development in China may limit China's shale oil development. As in Russia, full-fledged shale oil development may not come before the 2020s and China can be expected to import oil from neighboring Russia, if considerations to minimize its dependence on Russia from the viewpoint of energy security are excluded.

Argentina, Libya and Venezuela also have potential to develop shale oil resources. At a time when Latin American oil exports to North America are declining, however, Argentina and Venezuela as is the case with Russia may have difficulties in securing export destinations. Libya is expected to give priority to restoration after the civil war and may not launch unconventional oil development in the immediate future.

In Asia, oil consumption will increase on progressing motorization. As local crude oil production has already peaked out, Asia is expected to expand oil imports mainly from the Middle East and Africa and increase its dependence on oil imports. Asia's net oil imports will increase from 16.7 million b/d in 2011 to 35.1 million b/d in 2040, with its oil self-sufficiency rate declining to 18.5% in 2040.

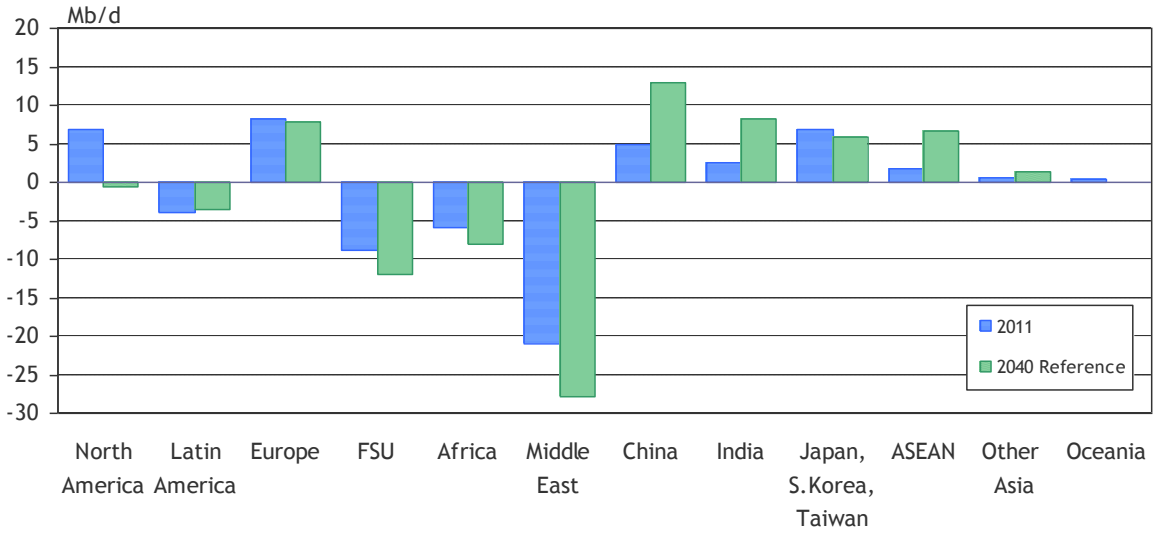
Figure 31 Asian Oil Production-Consumption Balance (Reference Scenario)



Oil Trade

North America will reduce net oil imports through progress in shale oil development. Asia including China, India and ASEAN will substantially expand their net oil imports to meet demand growth and the Middle East, the Former Soviet Union and Africa will increase net oil exports.

Figure 32 World Net Oil Imports/Exports



Global crude oil trade will firmly increase from 39 million b/d in 2012 to 45 million b/d in 2030 and 50 million b/d in 2040. China, South Asia (including India) and ASEAN will remarkably expand oil imports, increasing their dependence on resource-rich countries to meet their substantial demand growth in the absence of growth in their domestic crude oil production. Meanwhile, developed countries are expected to reduce crude oil imports due to a shale oil output expansion in North America and stagnant demand for petroleum products.

Figure 33 Crude Oil Trade Flows between Major Regions (2012)

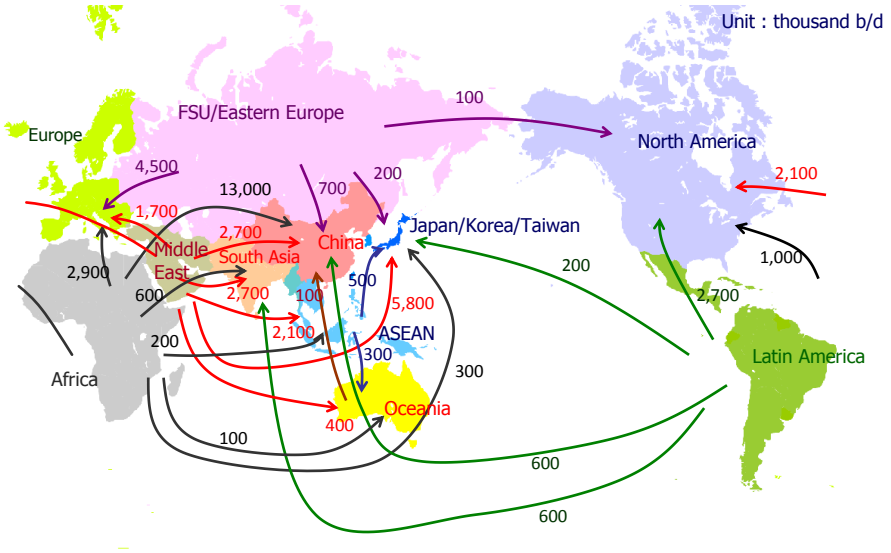
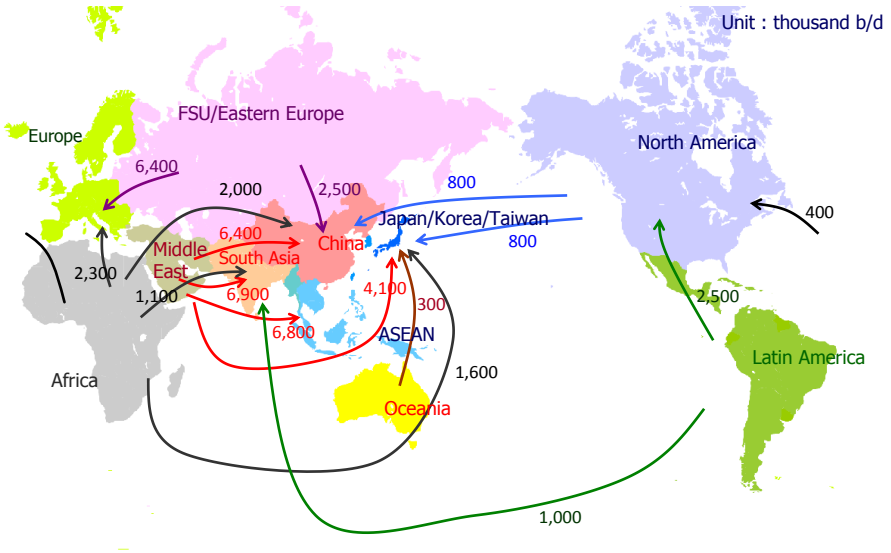


Figure 34 Crude Oil Trade Flows between Major Regions (2040 in the Reference Scenario)



Note: Only crude oil trade, excluding petroleum products trade

As the United States expands domestic oil output and maintains oil imports from Latin America and Canada, the Americas will be almost self-sufficient in oil except for a small amount of required imports of about 0.4 million b/d from Africa in 2030 or 2040. In 2012, the United States imported 2 million b/d of crude oil from the Middle East. Under pressures from Latin America and Canada it will gradually reduce imports from the Middle East and by 2030, the United States will no longer import oil from the Middle East.

By 2030, the United States is assumed to begin the export of 0.6 million b/d of high-quality shale oil to mainly Northeast Asia increasing that amount to 0.8 million b/d in 2040. The Northeast Asia market requires high quality crude oil to meet tougher petroleum products standards than in other markets.

Europe will see domestic oil demand decline faster than domestic oil output, slightly decreasing its crude oil import requirements from 9.1 million b/d in 2012 to 8.3 million b/d in 2030. In 2012, the Former Soviet Union accounted for the largest share of oil exports to Europe, with the remainder captured almost equally by Africa and the Middle East. In the future, pressures will grow on Europe to import African crude oil whose exports to the United States will decrease and crude oil pipelined from the Former Soviet Union will have greater cost competitiveness. Consequently, African and Former Soviet Union crude oil exports to Europe will thus be maintained while Middle Eastern crude oil exports to Europe will decline to 0.5 million b/d in 2030 and zero in 2040.

China will double its crude oil imports from 5.4 million b/d in 2012 to 10.6 million b/d in 2030, becoming the world's largest crude oil importer. China's crude oil import mix will remain very diverse. Imports from North America will increase from 0.4 million b/d in 2030 to 0.8 million b/d in 2040, pipeline and other crude imports from Russia and Central Asia will expand to 2 million b/d in 2030 and 2.5 million b/d in 2040, ASEAN and African countries will continue to export crude oil and the Middle East will export a total of 6 million b/d in 2030 and 2040. Crude oil from throughout the world will thus come into the Chinese market but the Middle East will remain the largest crude supply source for China.

The Middle East will also remain the largest crude oil supplier for Japan, South Korea and Taiwan. Although the combined crude imports for those countries will slightly decline from 7 million b/d in 2012 to 6.9 million b/d in 2030, crude imports from Africa will expand from 0.3 million b/d in 2012 to 1.2 million b/d in 2030 and 1.6 million b/d in 2040. Consequently, the three economies' rate of dependence on Middle Eastern crude oil imports will decline from 68% in 2030 to 60% in 2040. African exports will increase mainly to South Korea for the production and export of middle distillates, including kerosene and diesel oil.

In the Southeast Asian market including Singapore, crude oil produced in the region will continue to be refined within the region as in the past. As state-run oil companies from oil-producing Middle Eastern countries take part in Southeast Asian refinery construction and expansion plans (including those in Indonesia and Vietnam) those refineries are expected to refine crude oil mainly from the Middle East. Although Singapore refineries may still refine some African crude oil in 2040, other crude imports into Southeast Asia will all be from the Middle East.

South Asia will refine mainly Middle Eastern crude oil with crude imports from that region expanding from 2.7 million b/d in 2012 to 4.5 million b/d in 2030 and 6.9 million b/d in

2040. South Asia's crude imports from the Middle East will rival China's imports from the region in 2040. Indian oil refineries with advanced refining systems will continue to accept Latin American crude oil such as Venezuelan heavy crude oil and Brazilian output from deepwater oil fields.

Biofuels

The diffusion of liquid biofuels including bioethanol and biodiesel has been promoted as part of measures on climate change, energy security and agriculture promotion. Currently, biofuels are mostly used as substitutes for gasoline or diesel for vehicles but mixing biofuels with jet fuel is also under testing. Since biofuel production is feared to compete with food production, biofuels will have to shift to cellulosic fuels made from non-food plants, wastes and untapped biomass resources.

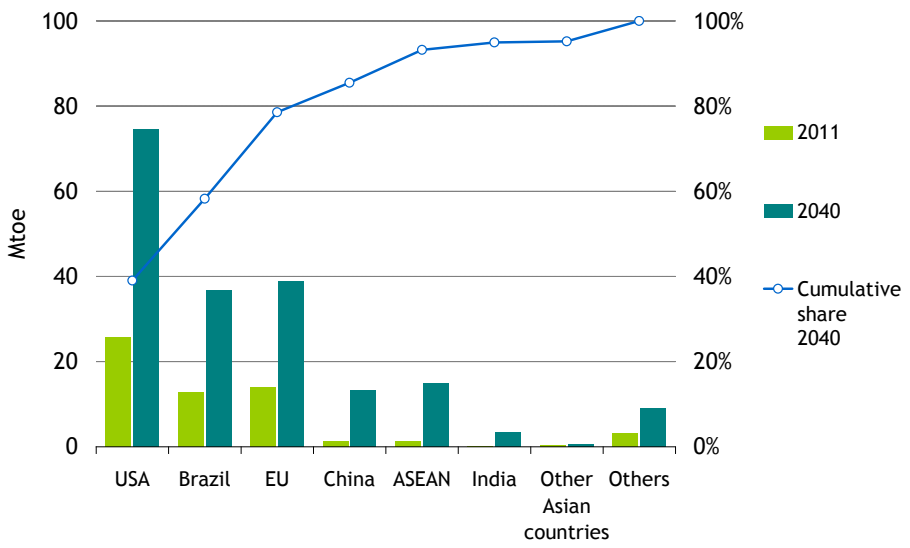
The United States has been diffusing gasoline mixed with biofuels to help address air pollution. In 2020[1], production may reach 36 billion gallons of biofuels of which 16 billion gallons would be from cellulosic ethanol. In Brazil, gasoline is required to have an ethanol content of 20-25%. In addition to those two countries, Europe, Canada and Australia are introducing bioethanol-mixed gasoline along with Asian countries such as India, China, Thailand and the Philippines. Furthermore, vehicles that can run on ethanol alone or can be adapted to variable ethanol contents are being diffused.

Biodiesel has diffused in Europe where diesel vehicles are more abundant. The Renewable Energy Directive[2] has adopted a target of expanding biofuels' share of transportation fuels to 10%[3] by 2020 in the European Union.

In the Reference Scenario, global biofuel consumption will increase from 60 Mtoe in 2011 to 190 Mtoe in 2040 (Figure 35). The 2040 estimate is equivalent to oil output in Kuwait and Oman. China, India and Japan are consuming mainly bioethanol, while South Korea, Indonesia and Malaysia are using biodiesel. In the whole of Asia, biofuel consumption will reach 33 Mtoe, but Asia's share of global biofuel consumption is lower than that of global oil consumption. China will consume 13 Mtoe in biofuels, the largest among Asian countries.

[1] The U. S. Environmental Protection Agency, National Renewable Fuel Standard 2 (February 2010)
[2] Renewable Energy Directive (2009/28/EC).
[3] The European target is biofuels' share of energy content instead of volume.

Figure 35 Biofuel Consumption (Reference Scenario)



2.4 Natural Gas Supply

Natural Gas Production

Over the next quarter century, mainly the Middle East, the Former Soviet Union including Russia, Africa, China and Australia will expand natural gas production to meet growing demand. These regions will account for two-thirds of the global production growth.

Commercial production of shale and other unconventional natural gas will begin in Argentina and Mexico after 2018 and in the Middle East, Europe, the Former Soviet Union and Africa after 2021. In Asia-Pacific, Australia will expand coalbed methane production after 2014 and China and Australia will begin to increase shale gas production after 2021.

China's production growth will slip below its demand growth while the Middle East's production growth will be partially absorbed by its demand growth. Sources for additional natural gas supply to the international market will include the Former Soviet Union, Africa, and Australia. Australia is expected to become the world's largest liquefied natural gas exporter. North America will take advantage of shale gas output growth to gradually expand net gas exports.

Given these forecasts, unconventional natural gas is expected to account for a quarter of global natural gas output in 2040.

Table 3 World Natural Gas Production (Reference Scenario)

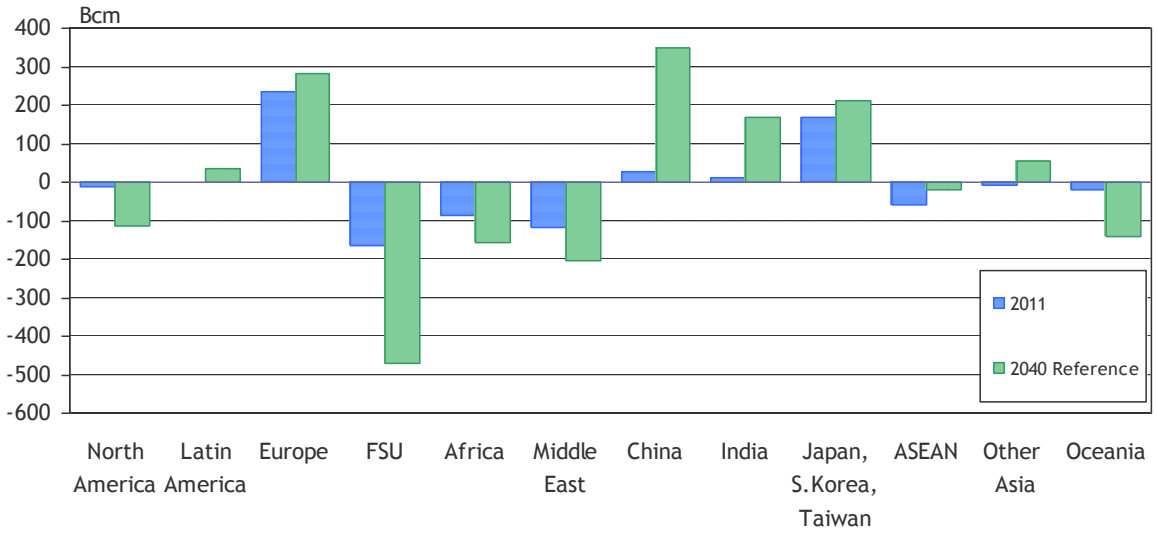
Bcm

	2011	Unconven-tional	Unconven-tional share	2040	Unconven-tional	Unconven-tional share
North America	808	364	45%	1,043	782	75%
Latin America	218	0	0%	449	127	28%
Middle East	523	0	0%	871	24	3%
Europe	287	0	0%	300	19	6%
FSU	868	0	0%	1,229	66	5%
Africa	200	0	0%	420	80	19%
China	103	0	0%	352	127	36%
India	46	0	0%	96	29	30%
ASEAN	203	0	0%	385	80	21%
Indonesia	81	0	0%	126	22	17%
Malaysia	56	0	0%	85	8	10%
Other Asia	75	0	0%	74	5	6%
Australia	51	6	12%	193	103	53%
World	3,384	370	11%	5,411	1,442	27%

Natural Gas Trade

Natural gas trade will expand faster than global natural gas demand will increase. North America, the Former Soviet Union and Oceania (Australia) will be expanding exports to 115 Bcm, 470 Bcm and 141 Bcm by 2040. On the receiving end China and India will be importing substantially more than before to meet their domestic demand growth. In 2040, net natural gas imports will increase to 350 Bcm in China and 169 Bcm in India.

Figure 36 World Net Natural Gas Exports (Reference Scenario)



The trade flows will change in the future. Natural gas trade flows between major regions in 2012 included pipeline gas export flows from the Former Soviet Union to Europe

and LNG flows from Southeast Asia, Australia and the Middle East to Northeast Asia.

In 2040, a major export flow will be established from North America (the United States and Canada) and Australia, both regions with great gas export potential. The sharp increase in net exports from North America, the Former Soviet Union and Australia will be destined mainly to Asia.

Figure 37 Natural Gas Trade Flows between Major Regions (2012)

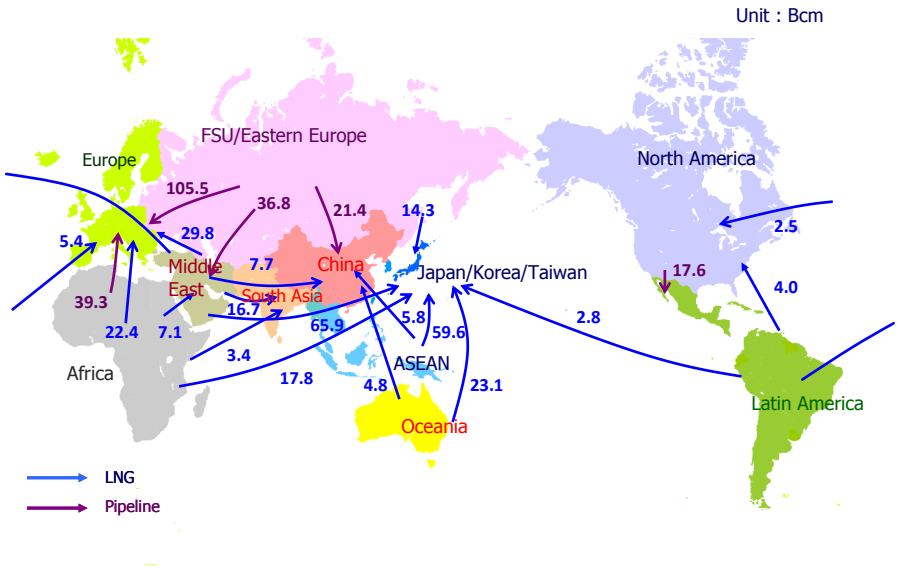
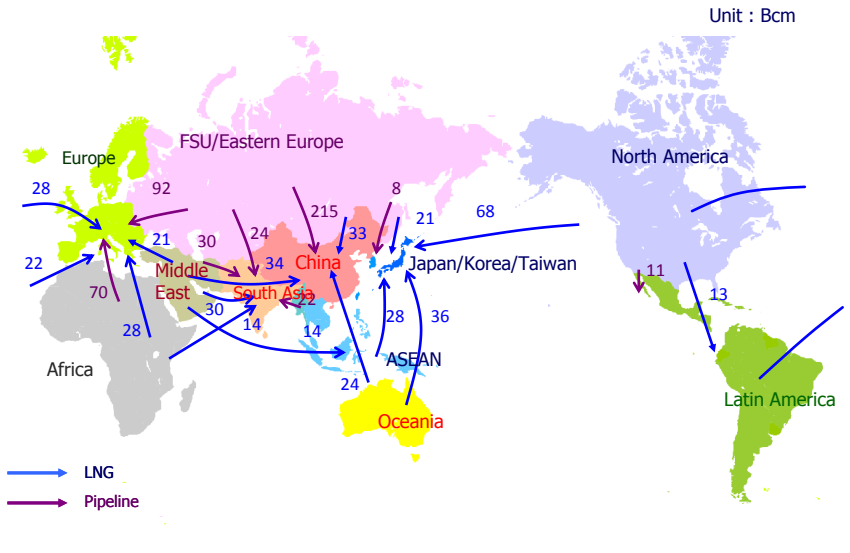


Figure 38 Natural Gas Trade Flows between Major Regions (2040 in the Reference Scenario)

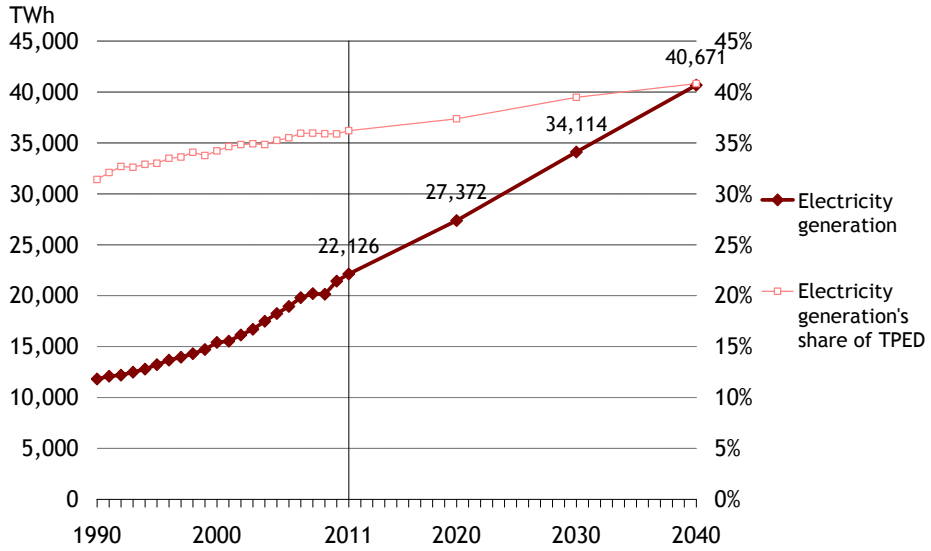


2.5 Electricity Supply

Electricity Generation

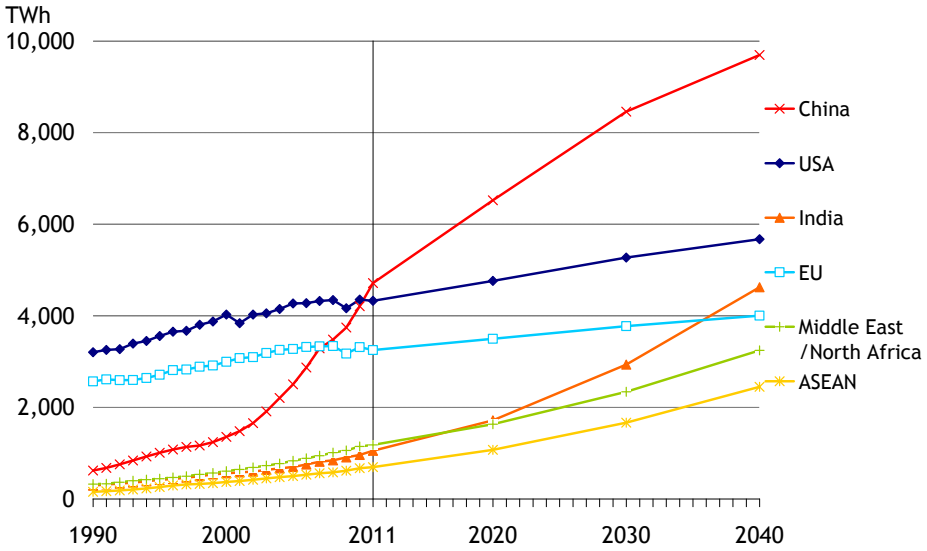
In line with electricity demand growth, global electricity generation will increase from 22,126 terawatt-hours in 2011 to 40,671 TWh in 2040 (Figure 39). The annual electricity generation growth rate of 2.1% is somewhat lower than the final electricity consumption growth rate of 2.2% due to a decline in own-use and losses.

Figure 39 Global Electricity Generation and Its Share of Primary Energy Consumption (Reference Scenario)



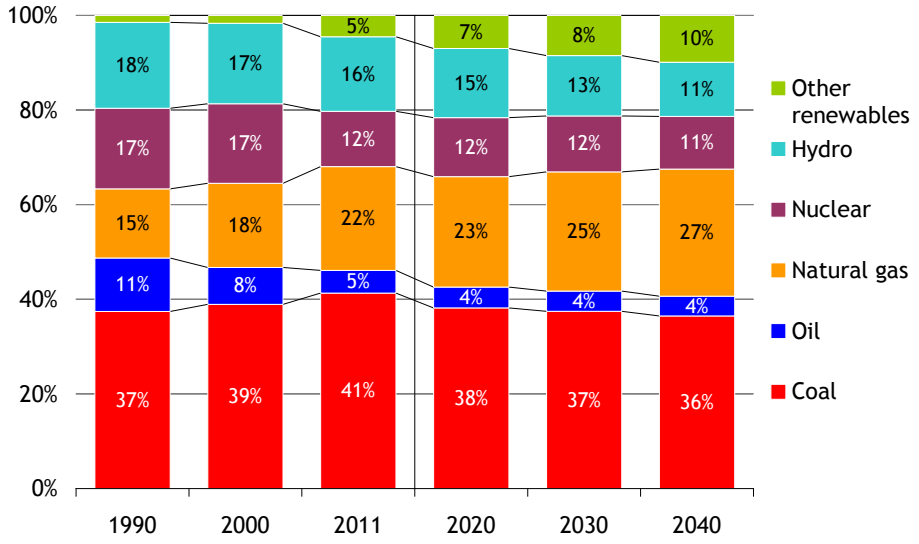
Non-OECD countries will account for more than 80% of the electricity generation growth through 2040 (Figure 40). Asian electricity generation will increase at an annual rate of 2.9% from 8,517 TWh in 2011 to 19,612 TWh in 2040. Cross-border trade in electricity should increase because some ASEAN countries have plans to develop rich hydroelectric resources for exports to earn foreign currencies and because of progress in grid enhancement to accommodate the expansion in renewable energy (wind power, photovoltaic, etc.) generation.

Figure 40 Electricity Generation in Major Countries/Regions (Reference Scenario)



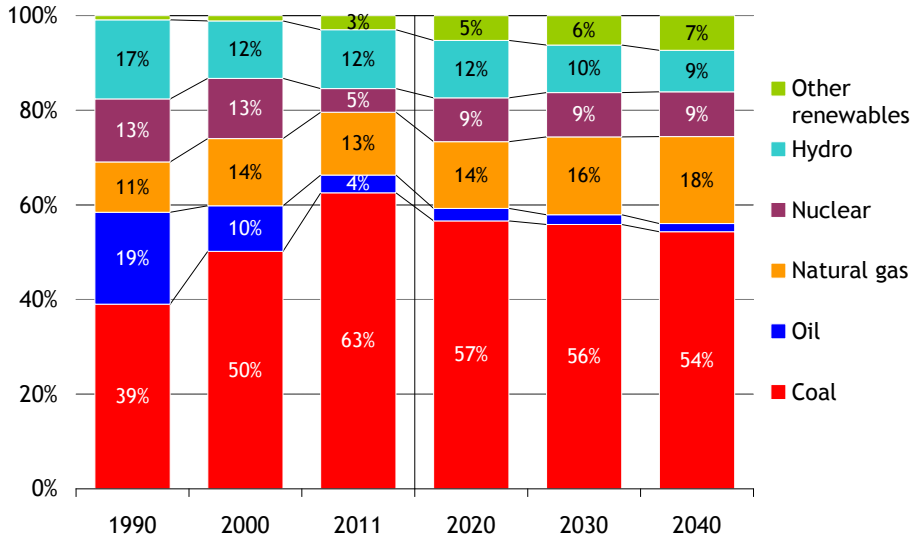
Coal accounts for the largest share of the present global electricity generation at 41%. It is followed by natural gas at 22%, hydro at 16% and nuclear at 12%. Through 2040, coal will retain the largest share, continuing to serve as a mainstay electricity source (Figure 41). As combined cycle gas turbines (CCGTs) have become more technologically advanced and flexible to adjust for volatile renewable energy generation, natural gas will make progress as the preferred fuel. The share for natural gas will thus expand from 22% in 2011 to 27% in 2040. The share for oil will trend down in industrial countries as well as in the oil-rich Middle East. Nuclear plant construction will make progress mainly in Asia as a measure to ensure energy security and prevent climate change, but the increase in nuclear power generation cannot be expected to cover the electricity demand rise through 2040. Nuclear's share of electricity generation will fall slightly from 12% in 2011 to 11% in 2040. Wind power, photovoltaic and other renewable energy generation will expand at an annual rate of 4.9% on the strength of policy support and cost reduction. Although the growth will be faster than any other electricity generation, the renewable energy's share of electricity generation in 2040 will be limited to 10%.

Figure 41 Global Electricity Mix



In Asia including China and India, coal-fired generation will remain a mainstay electricity source in response to the rapid electricity demand growth (Figure 42). ASEAN has made a great shift from oil to natural gas as electricity generation fuel since the 1990s due to natural gas development in the Bay of Thailand and other locations. As natural gas production peaked out and gas demand emerged in sectors other than electricity generation in the 2000s, natural gas supply capacity for electricity generation has become short, prompting ASEAN countries as well as China and India to go ahead with plans to import natural gas. As coal's share of electricity generation decreases while being the highest, natural gas's share will increase from 13% to 18%.

Figure 42 Asian Electricity Mix



Nuclear

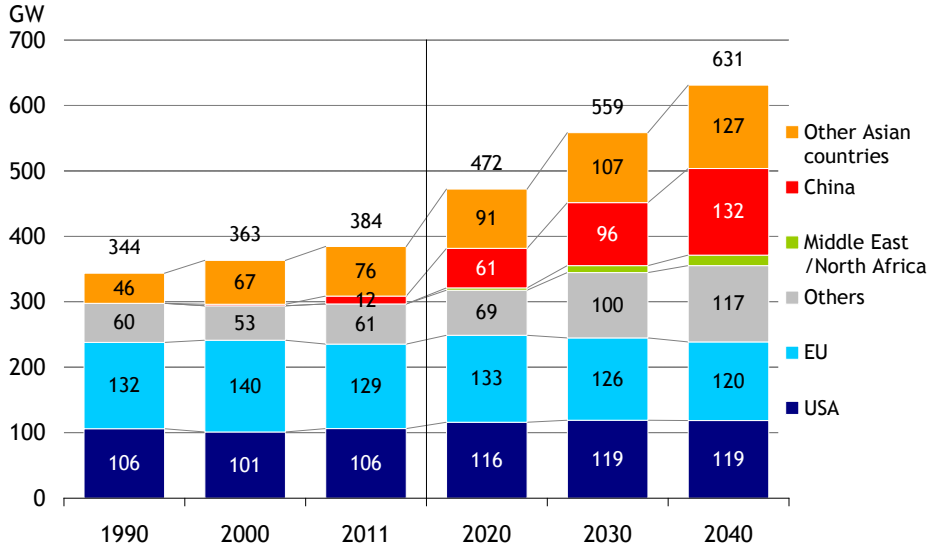
The Fukushima Daiichi nuclear power plant accident has directly affected nuclear energy policies in Japan and in some European countries. But the United States, France, Russia and South Korea are still proactively promoting nuclear power generation, and emerging countries like China and India have made no change to their respective nuclear promotion policies aimed at securing stable energy supply, preventing global warming, and maintaining and enhancing international competitiveness through their nuclear industry development.

New nuclear plant construction has slowed down in the United States as a result of the energy resources' economic advantages of shale gas and oil developments. The United States, however, will retain the policy of maintaining nuclear plants given the fuel price fluctuation risks accompanying a shift to natural gas, and the need for climate change measures.

France, the largest nuclear energy promoter in Europe, aims to reduce its nuclear energy's share of electricity generation to 50% by 2050. But the target could fail to be achieved as it would cause some employment problems and electricity rate to rise. At least the present situation will be maintained for the immediate future. Germany, Switzerland and Belgium have clearly announced their nuclear phase-out plans in response to the Fukushima accident and are expected to eliminate nuclear power generation by 2040. While outdated nuclear reactors are decommissioned, moves to construct new reactors in other countries are seen in Europe; therefore, Europe's nuclear power generation capacity will remain almost unchanged from 2011 to 2040.

Asia including China and India will increase substantially their nuclear power generation and by 2040, China will be the largest nuclear power generator in the world. Asian nuclear power generation capacity will surpass the combined EU and U.S. capacity in 2040. The Middle East, North Africa and Latin America will slowly rise in the nuclear power generation market.

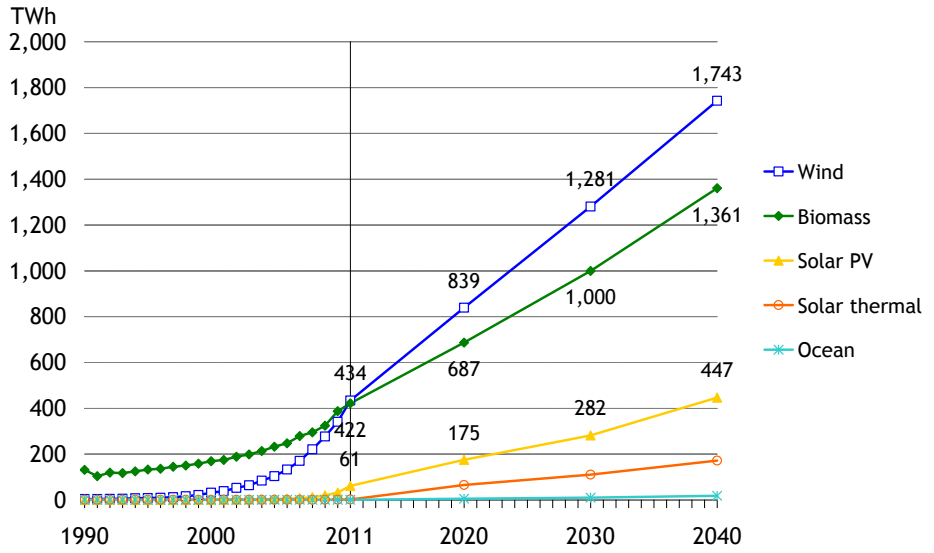
Figure 43 Nuclear Power Generation Capacity



Renewable Energy

Great expectations are placed on renewable energy such as solar and wind energy. Renewable energy diffusion will accelerate thanks to rich resources and government incentives in some regions. But renewable energy-based electricity generation, which costs more and is highly dependant on natural conditions, will fall short of becoming a mainstay electricity source rivaling fossil resources on a global scale.

Figure 44 Global Renewable Energy Power Generation (Reference Scenario)



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

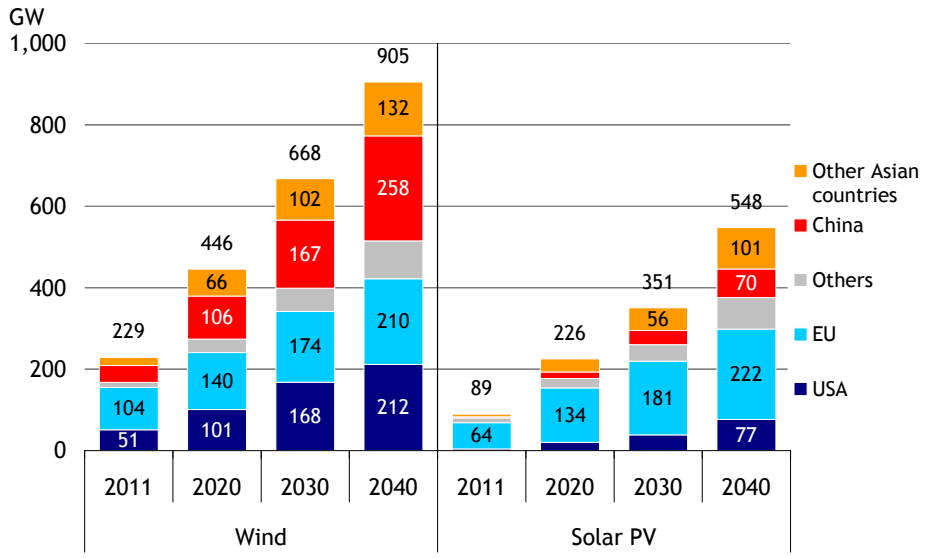
Wind

Through 2040, mainly offshore wind electricity generation will diffuse in Europe including Germany, Spain and Denmark. Development will also take place in China and India among Asian countries. Wind electricity generation capacity will increase five-fold from 229 gigawatts in 2011 to 905 GW in 2040 and will accelerate particularly in Europe, Asia and North America.

Photovoltaics

Photovoltaics are rapidly diffusing mainly in Europe and the global photovoltaic market is likely to continue expanding (Figure 45) mainly as a result of government incentives and cost cuts through market expansion and technological development. Photovoltaics, while still having economic efficiency problems, are seen as a useful electricity source for low-population areas where electricity infrastructure has yet to be developed. In the Reference Scenario, global photovoltaic electricity generation capacity will expand six-fold from 89 GW in 2011 to 548 GW in 2040. Particularly, Europe and Asia will see rapid growth in photovoltaic electricity generation.

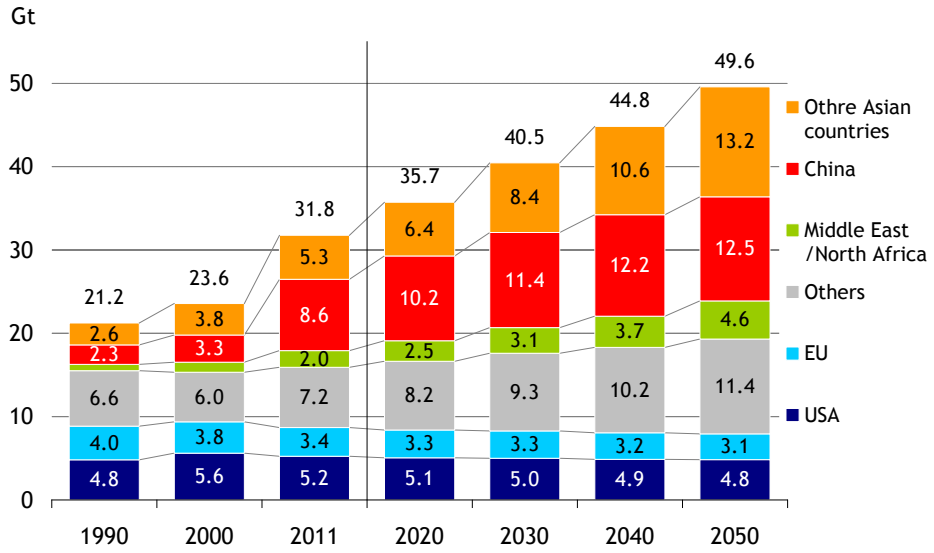
Figure 45 Wind and Photovoltaic Electricity Generation Capacity



2.6 CO_2 Emissions

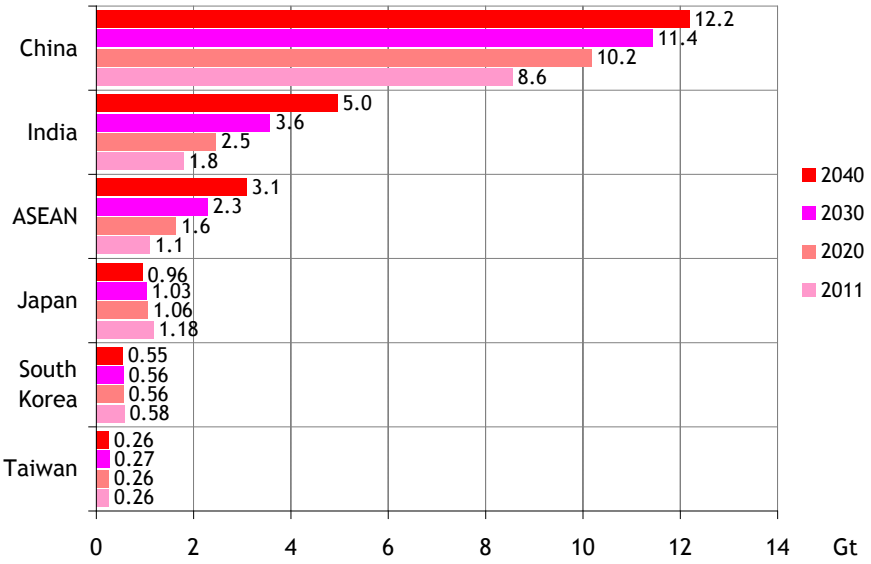
As fossil fuel consumption accounts for about 80% of global primary energy consumption through 2040, carbon dioxide emissions will increase 1.4-fold from 31.8 gigatons in 2011 to 44.8 Gt in 2040 (Figure 46). Of the increase, Asia will account for about 70% and non-OECD countries' share of global CO_2 emissions will rise to 70% in 2040.

Figure 46 Global CO_2 Emissions by region (Reference Scenario)



Given that China will use mainly coal to cover its growing energy demand, China will account for about 30% of the global emission increase. The diffusion of nuclear power and renewable energy including hydro will allow China to post a slower average annual CO_2 emission growth rate than other Asian emerging countries. In India and ASEAN countries, CO_2 emissions will grow at an annual rate of more than 3%. Japan is currently expanding CO_2 emissions as fossil fuel power generation is increasing to cover a substantial drop in nuclear generation. Japan's CO_2 emissions will decline in the future as nuclear reactors are restarted and energy conservation promoted.

Figure 47 Asian CO_2 Emissions by region (Reference Scenario)

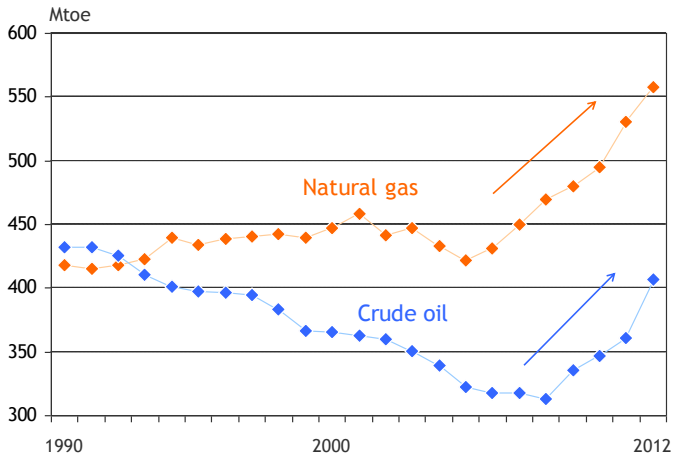


3. Impacts of Unconventional Resources Development

3.1 Enhanced Development Scenario

The United States has rapidly increased unconventional natural gas and crude oil production over recent years. Its natural gas production expanded from 421 Mtoe in 2005 to 558 Mtoe in 2012 and oil output from 313 Mtoe to 407 Mtoe. The dramatic progress in U.S. unconventional resources development has eased the energy supply-demand balance in the country, inducing great changes even beyond the energy market. These changes are progressing even now, imposing great impacts on the international energy market. Most of the LNG planned for the United States has flowed into Europe and Asia, causing discussions on revisions to the traditional international natural gas pricing approach linked to oil prices. Coal, which has been replaced by natural gas in the United States, flowed into Europe to greatly change its electricity mix. Furthermore, U.S. LNG exports will start in 2015, meaning that U.S. shale gas will impose direct impacts on the global natural gas market.

Figure 48 U.S. Crude Oil and Natural Gas Production



Source: IEA "Energy Balances of OECD countries"

Depending on the development of technologies, infrastructure logistics, water supply and relevant laws, the shale revolution in the United States is expected to expand beyond North America and lead to unconventional resources development in other countries. The shale revolution expansion is likely to impact not only national and international energy markets but also national macroeconomic profiles and industrial competitiveness.

The Asia/World Energy Outlook 2013 compares the Scenario for Enhanced Development of Unconventional Resources with the Reference Scenario and projects impacts that enhanced unconventional resources development would exert on regional natural gas

and oil production, energy prices, energy demand and macroeconomic profiles. As shale resources development has just started, the future pace of development and production is still uncertain. The Enhanced Development Scenario takes such high uncertainties into account and assesses how energy supply and demand and trade flows will change if unconventional resources production expands far more rapidly than expected at present.

3.2 Natural Gas Resources and Outlook for Development

World

In the Scenario for Enhanced Development of Unconventional Resources, the development of shale gas, coalbed methane and other unconventional natural gas resources will substantially accelerate from 2020. In this scenario, unconventional natural gas resources development and production costs are assumed to decline to the same level as conventional natural gas costs and unconventional resource potential is expected to be utilized fully.

In addition to North America where unconventional natural gas is expected to account for more than three-quarters of total natural gas production, China, Australia and Latin America will substantially expand unconventional gas's share of total natural gas output. In Europe as well, a certain scale of unconventional gas production is projected. Given that China, Australia and Indonesia have great unconventional natural gas resource potential, the Asia-Pacific region will account for more than one-third of a global natural gas production increase.

These developments will boost unconventional gas's share of global natural gas output to around 36%. Technically recoverable shale gas reserves in the world are estimated at some 200 trillion cubic meters (Tcm), indicating great potential. As shale gas reserves are widely distributed, various countries' shale gas development in the Enhanced Development Scenario will further change the global natural gas market.

Whether shale gas development will be activated may depend on geological and infrastructure conditions, and government and corporate efforts. Technically recoverable shale gas reserves projected by various organizations represent probabilistic estimates of shale gas output from seemingly promising sedimentary basins. They may differ from relevant countries' respective estimates. Shale gas reserves will be assessed in the future.

Conditions that have allowed the United States to implement large-scale shale gas development have yet to be met in other countries, indicating that countries other than the United States will launch full-scale shale gas development after 2020. Undoubtedly, however, shale gas reserves are very promising energy resources for the future and shale gas

development will exert great pressures on the global energy market, depending on the degrees of its progress and output sizes.

Country-by-Country Conditions

China

The Chinese Ministry of Land and Resources has estimated China's in-place shale gas resources at 134.42 Tcm including 25.08 Tcm in recoverable reserves. Promising shale gas resources locations include the Sichuan Basin in the Southwest, the Tarim Basin and the Dzungarian Basin in the Northwest, and the Songliao Basin in the Northeast. China conducted shale gas development bidding in 2011 and 2012, but no full-fledged development project has come forward yet.

The Chinese government released a shale gas development plan for 2011-2015 in March 2012, coming up with an ambitious target of boosting shale gas output to 6.5 Bcm in 2015 and to 60-100 Bcm in 2020. The government has readied output-based subsidies for promoting initial shale gas and coalbed methane development but the Ministry of Land and Resources has projected shale gas output in 2013 at some 200 million cubic meters, far less than the 2015 target.

Geological conditions in China are more complicated than in the United States. Shale layers are frequently deeper, indicating that huge investment would be required for shale gas development. Investment incentives failed to work as domestic natural gas prices are held down to low levels under energy price control. Given that major shale gas resources locations are in China's inland areas with less precipitation, how to secure massive water resources for hydraulic fracturing is a challenge. China may also have to expand pipeline networks as these locations are separated from existing pipelines. In June 2013, China National Petroleum Corporation (CNPC) announced a plan to construct China's first pipeline for shale gas. The government has also vowed to quadruple gas pipelines to 150,000 kilometers by 2020, a target equivalent to only 40% of U.S. pipelines. While great expectations are placed on rich shale gas resources in China, there are many challenges that may have to be solved for expanding shale gas output in line with the target.

India

The U.S. Energy Information Administration (EIA) has reported that India's technically recoverable shale gas reserves are estimated at 96 trillion cubic feet (Tcf; equivalent to 2.7 Tcm). Shale gas layers in India are reportedly more complicated than in the United States. India gives priority to shale gas development from a long-term viewpoint as natural gas demand has increased rapidly in line with economic growth. The Indian government is working out its future shale gas development policy, planning to conduct shale gas development bidding by the end of 2013.

Indonesia

The U.S. EIA has reported that Indonesia's technically recoverable shale gas reserves are estimated at 46 Tcf (1.3 Tcm). Shale gas resources are located mainly on Sumatra, Kalimantan and New Guinea Islands. While these islands have shale gas reserves in onshore sedimentary basins, offshore shale gas resources are believed massive. Indonesia's shale gas resource potential is thus very great. As domestic natural gas demand is increasing in line with economic growth, Indonesia gives priority to developing coalbed methane, shale gas and other unconventional gas resources. Indonesia has implemented shale gas development bidding on Sumatra and Kalimantan Islands but so far no specific shale gas development schedule has been fixed.

Australia

Australia has great potential for unconventional natural gas resources including coalbed methane, shale gas and tight gas and is expected to expand unconventional gas production over a long term. The EIA has estimated Australia's technically recoverable shale gas reserves at 437 Tcf (12.3 Tcm), the seventh largest in the world. The estimate has been revised upward from 396 Tcf as given in 2011. But Geoscience Australia reviewed the 2011 EIA estimate of 396 Tcf in its 2012 gas resources assessment report and noted that the recoverable reserves estimate could decline as geological surveys make progress.

Full-fledged commercial production of coalbed methane started in 2000 for domestic supply. In or after 2014, massive coalbed methane supply for the LNG export market is expected to begin. Small-scale commercial production of shale gas started in late 2012.

A challenge for Australia's shale gas development may be how to overcome infrastructure development, high labor costs, hydraulic fracturing costs and other problems. A study by the Australian Council of Learned Academies notes that natural gas prices should be 6 to 9 Australian dollars per gigajoule to secure profit on shale gas production and transport in Australia.

The federal government has no special regulations on unconventional natural gas development but some states have put in place their respective regulations including a moratorium on hydraulic fracturing. Federal and state policies must be made transparent in order to promote unconventional natural gas development.

U.K.

While the EIA has reported that the United Kingdom's technically recoverable shale gas reserves are estimated at 26 Tcf (0.73 Tcm), the British Geological Survey has estimated in-place shale gas resources mainly in Bowland, northern England, at 1,329 Tcf (37.6 Tcm).

Estimation standards differ sharply and shale gas estimates in the United Kingdom have thus yet to be fixed and remain very uncertain.

Shale gas resources are distributed in two regions -- northern England and southern Scotland, and southern England. Geological layers there are more complicated than in North America, indicating that drilling would cost more.

In the United Kingdom that began to reduce natural gas output from 2001 and became a net natural gas importer in 2004, great expectations are placed on shale gas development. But as some residents are opposed to the development for environmental reasons, the country has thus fallen short of launching full-fledged shale gas development.

France

The EIA has reported that France's technically recoverable shale gas reserves are estimated at 137 Tcf (3.9 Tcm). As France has banned hydraulic fracturing since June 2011, no shale gas development is expected for the immediate future.

Germany

The EIA puts Germany's technically recoverable shale gas reserves at 17 Tcf (0.48 Tcm). The German Federal Institute of Geology and Natural Resources announced the German reserves at 0.7-2.3 Tcm (24-81 Tcf) in June 2012. An area covering Belgium on the North Sea coast and eastern Germany is endowed with shale gas resources. Federal law on shale gas digging technologies has yet to be developed.

Poland

The EIA has reported that Poland's technically recoverable shale gas reserves are estimated at 146 Tcf (4.1 Tcm). The Polish government hopes to develop shale gas resources due to the country's heavy dependence on natural gas imports but private companies' exploration has failed to provide remarkably good results. At present, no full-fledged commercial production is anticipated.

Russia

The EIA has reported that Russia's technically recoverable shale gas reserves are estimated at 285 Tcf (8.1 Tcm). It has also given a Russian shale resources estimate of technically recoverable shale oil resources in Russia of 75 billion barrels, the largest in the world. These shale gas and oil estimates have been made only for Western Siberia. Other regions in Russia are expected to have shale gas potential.

Coalbed methane reserves in Russia are estimated at 83.7 Tcm, according to Gazprom, which has produced coalbed methane mainly in Kuzbass, Southern Siberia, since 2003.

Ukraine

The EIA has reported that the Ukraine's technically recoverable shale gas reserves are estimated at 128 Tcf (3.6 Tcm). But its government has estimated the reserves at some 7 Tcm. In a bid to reduce the Ukraine's dependence on natural gas imports from Russia, the Ukrainian government is about to proactively invite foreign companies to take part in domestic shale gas resources development.

Mexico

While boasting one of the world's largest natural gas resources, Mexico depends on imports, including pipeline gas from the United States, for one-third of its domestic natural gas supply. As domestic natural gas demand increases, the expansion of domestic production will grow more important. According to the EIA, Mexican shale gas reserves are estimated at 545 Tcf (15.4 Tcm) for the Gulf of Mexico area. Meanwhile, Mexican state-run oil company Pemex has estimated Mexico's shale gas resource potential at 141-459 Tcf.

No investment has been made in shale gas development in Mexico. Given Pemex's monopoly on the gas upstream sector, high development costs and cheap U.S. natural gas, Mexico depends on imports for any additional demand.

The pending energy policy reform bill for attracting foreign and other private investment in the upstream sector would be the key to invigorating natural gas development in Mexico.

Argentina

The EIA has reported that Argentina's technically recoverable shale gas resources are estimated at 802 Tcf (22.7 Tcm). The Vaca Muerta shale layers of Neuquén are viewed as the most promising candidate site for shale gas development.

Impediments to shale gas development in Argentina include hydrocarbon prices controlled at low levels, high inflation rates, foreign exchange control, unstable and unpredictable economic policies, and developers' obligations to procure local goods and return profit to local communities. But efforts to promote shale gas development have been seen, including foreign companies' participation in joint venture projects and raising natural gas prices to stimulate investment.

3.3 Oil Resources and Outlook for Development

World

Under the assumption that countries with rich proven shale oil resources will promote shale oil development ahead of other countries, we project their production. Specifically, we take into account country-by-country conditions and assume very rapid shale oil development under the premise that the development of technically recoverable shale oil resources is likely to make progress in the Top 10 holders of technically recoverable shale oil resources as assessed by the EIA.

In projecting the development and production in the 10 countries, we take into account the following country-by-country conditions (Table 4).

Political factors: Government policies on shale oil development, diplomatic conditions, security conditions in areas subject to shale oil development.
Economic factors: Resources development costs (geological, meteorological and geographical conditions, etc.), pipeline and other infrastructure development conditions, current development investment and maturity of the technical services industries.

Table 4 Top 10 Holders of Technically Recoverable Shale Oil Resources

Country	Technically recoverable resources (billion barrels)	Major shale formations
Russia	76	Bazhenov Central, Bazhenov North
USA	58	Bakken, Eagle Ford, Utica, Niobrara, Monterey, etc.
China	32	Longmaxi, Permian, Qiongzhusi, L. Silurian, etc.
Argentina	27	Vaca Muerta, Los Molles, La Luna/Capacho, etc.
Libya	26	Etel Fm, Sirte/Rachmat Fms, Tannezuft, etc.
Australia	18	Goldwyer, Nappamerri, Carynginia, etc.
Venezuela	13	Capacho
Mexico	13	Eagle Ford, Tithonian, Pimienta, etc.
Pakistan	9	Sembar, Ranicot
Canada	9	Lower Besa River, Duvernay, Muskwa/Otter Park, etc.

Source: U.S. Energy Information Administration

Country-by-Country Conditions

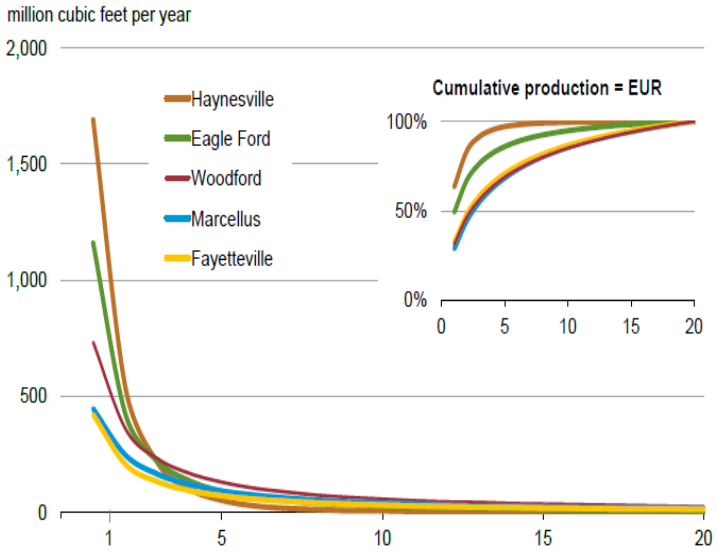
USA

Since the early 2010s, U.S. shale oil production has increased far more rapidly than expected. The International Energy Agency (IEA) in 2011 had projected U.S. shale oil

output in 2013 at 0.86 million b/d but actual output in the year is now expected to reach 1.7 million b/d. Given the current shale resources development pace, shale oil production is predicted to continue the current rapid growth for several years. This is because proven underground reserves have increased sharply in line with shale oil development and output expanded rapidly at the Eagle Ford shale in western Texas in addition to North Dakota's Bakken shale that had been a mainstay shale oil production site.

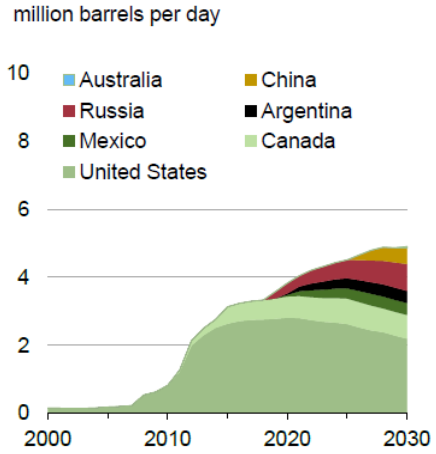
Shale gas and oil development has indicated a per-well production pattern where output increases in the initial phase and declines later more rapidly than conventional oil production (Figure 49). Given the constraint that more wells must be dug to maintain or increase production, the EIA has projected U.S. shale oil output to peak around 2020 and decline moderately later (Figure 50).

Figure 49 Shale Gas Production Pattern



Source: U.S. Energy Information Administration

Figure 50 EIA's Shale Oil Production Outlook



Source: U.S. Energy Information Administration

The production pattern problem was likely to become greater as U.S. shale oil production increases further. In fact, however, productivity has dramatically improved with better knowledge on well-digging periods, horizontal well-digging distance, water treatment costs and other shale oil development. The shale oil field production pattern, though with high depletion rates, features long production durations, called a long tail, that could be accumulated to support the maintenance of production volume. Such productivity improvement in the development phase is assumed to continue in the Enhanced Development Scenario.

Furthermore, U.S. shale development is expected to make further progress after the Bakken and Eagle Ford shales support oil production. At present, shale oil development has been activated in the Permian Basin, western Texas. The zone is emerging as one of the core shale oil development sites. The development of the Utica shale spreading in the Northeast including Pennsylvania is expected to make progress in the future, although geological data have yet to be accumulated sufficiently. In addition, there are many other shale formations that could become subject to major development projects, including Niobrara and Monterey. In the Enhanced Development Scenario, the development of various U.S. shales is assumed to make smooth progress to enable high-level production in 2030 and 2040.

Russia

Russia has the world's largest technically recoverable shale oil resources, surpassing U.S. resources. Particularly, the Bazhenov shale in Western Siberia is viewed by some people as having more reserves than the U.S. Bakken shale, consequently, great expectations are placed on the future development of this shale. It may be needless to say that advanced

technologies and skilled knowhow are required for developing shale oil resources. Backed by a long history of oil development, Russia has a pool of excellent engineers and skilled workers. In June 2012, Russian state-run oil company Rosneft agreed on a strategic alliance with ExxonMobil. The Russian government has thus indicated its willingness to proactively introduce foreign knowhow for shale development. Russia is gradually making arrangements to realize shale oil development at an early date.

In Russia, a domestic oil tax working as a disincentive to corporate investment and an unclear decision-making process for oil development have long been cited as factors that lead oil development to be delayed. Whether Russia can solve these problems will be the key to shale oil development. As domestic shale oil output increases, investment will be required in pipelines and shipping facilities for oil transportation to export destinations including Asia. In the Enhanced Development Scenario, Russia is assumed to solve many of these constraints or problems and produce 2 million b/d in shale oil in 2030 and 3 million b/d in 2040.

China

With 32 billion barrels in technically recoverable shale oil resources, China is one of the world's largest holders of shale oil resources. China has many challenges with shale oil development, including how to secure water resources for hydraulic fracturing, difficult-to-develop geological formations and infrastructure development for transporting oil from shales to oil-consuming areas. Despite such many constraints, however, China is placing greater importance or urgency of domestic energy resources development than any other country. China, while having yet to sufficiently accumulate shale resources development knowhow, has obtained many excellent engineers and workers through its oil development at home and abroad. The Chinese government could adopt domestic shale resources development as a national policy and mobilize massive policy resources to resolve the abovementioned challenges and realize high growth in shale oil production. In the Enhanced Development Scenario, the Chinese government's strong support is assumed to make great achievements in shale oil development, and production is assumed to reach about 2 million b/d in shale oil output in 2030 and 3 million b/d in 2040. These production levels are not necessarily high but China is projected to steadily develop shale oil resources.

Argentina

Argentina is the fourth richest in shale oil resources in the world, following Russia, the United States and China. As one of the oil producing countries, Argentina's production peaked at 0.89 million b/d in the 1990s and turned out 0.66 million b/d in 2012. The Vaca Muerta shale in central Argentina is seen as promising for future development with many

Argentine and foreign enterprises indicating interests in developing the shale. But there are some matters of concerns. In Argentina, Repsol-YPF was nationalized again in May 2012 after being privatized and coming under the umbrella of Spain's Repsol in the early 1990s. Uncertainties about the government's oil development policy are a major matter of concern in respect to shale resources development for which huge investments are required. Given that petroleum products prices are controlled in Argentina, how to sell crude oil output is also a challenge. In the Enhanced Development Scenario, Argentina is assumed to continue shale oil development without delay despite such matters of concerns, producing 1 million b/d in shale oil in 2030 and 2.5 million b/d in 2040.

Mexico

Mexico is also a promising shale resource-rich country. Mexico's crude oil production has been steadily declining since output reached 3.8 million b/d in 2004. Its Constitution prohibits foreign oil companies from investing in domestic resources development, bringing about a delay in the introduction of sophisticated oil development technology, which has partially caused the recent oil production slump. In this respect, Mexican President Enrique Peña Nieto in August 2013 indicated his intent to implement a fundamental oil policy reform that could include a constitutional amendment, which is unlikely to be realized over a short time. If Mexico improves conditions for foreign companies' participation in oil development within the present legal framework, however, shale oil development may make progress. Particularly, the Eagle Ford shale, of which the U.S. side has made progress in oil development, straddles the U.S.-Mexico border and spreads into Mexico. In this way, Mexico has potential to expand shale oil output rapidly once conditions for investment are met. In the Enhanced Development Scenario, Mexico is assumed to meet conditions for investment and produce 1 million b/d in shale oil in 2030 and 2 million b/d in 2040.

Canada

Canada is one of a few countries where full-fledged shale development is underway, other than the United States. The Bakken shale, of which the U.S. side has continued active development, spreads into Canada. There are many other shale resources confirmed in Canada, including the Utica shale seen as promising for future development and production, as well as the Horn River shale in British Columbia. Canada neighbors the United States and has a long history of oil development, having easy access to advanced technology for shale development and is likely to further promote shale development. At present, market access for shale oil as well as oil sand is a major challenge for Canada. In the Enhanced Development Scenario, Canada is assumed to resolve such challenges over time and produce 2 million b/d in shale oil in 2030 and 4 million b/d in 2040.

Australia

Australia has massive shale resources. With technically recoverable shale oil resources estimated as the sixth largest in the world. But Australia has yet to sufficiently accumulate shale development knowhow and its relevant infrastructure development is expected to be expensive. Much time may be required before its full-fledged shale oil development. In the Enhanced Development Scenario, Australia is assumed to produce 0.5 million b/d in shale oil in 2030 and 1 million b/d in 2040.

Libya

In Libya, technically recoverable shale oil reserves are estimated at 26 billion barrels. Libyan politics has grown even more uncertain since anti-government rebels and the U.S.-led allied forces overthrew the Muammar Qaddafi regime in 2011. Particularly, the confrontation is deep between the eastern region rich with oil fields and the western region including the capital city of Tripoli. The domestic confrontation could grow even more serious, leaving the Libyan political situation unstable. Overall shale oil development in Libya is assumed to take more time than in other shale resource-rich countries in the Enhanced Development Scenario. Its shale oil production is projected at 0.5 million b/d in 2030 and 1 million b/d in 2040.

Venezuela

Venezuela has so far proactively promoted the development of very heavy crude oil in the Orinoco belt while it also has technically recoverable shale oil resources estimated at 13 billion barrels. As Venezuela continued a foreign policy of maintaining some distance from the United States and Europe under then President Hugo Chavez, American and European oil companies withdrew from Venezuela, leading its oil production to continue a downward trend since the mid-2000s. Incumbent President Nicolás Maduro, elected after the death of Chavez in March 2013, has made moves to take over the Chavez foreign policy, indicating that the situation will remain unchanged for the time being. In the Enhanced Development Scenario, however, Venezuela is assumed to change the foreign policy over the long-term and make progress in developing shale resources as well as very heavy crude oil. It is projected to produce 0.5 million b/d in shale oil in 2030 and 1 million b/d in 2040.

Pakistan

Pakistan's technically recoverable shale oil resources are estimated as the ninth largest in the world. But Pakistan does not have oil and technical services companies that own sufficient technology for and experiences with shale development and the infrastructure for shale oil production remains to be developed. Therefore, many constraints apparently

exist on shale oil development and production. Given the situation, Pakistan is projected to produce 0.5 million b/d in shale oil between 2030 and 2040 in the Enhanced Development Scenario.

3.4 Quantitative Analysis of Unconventional Resources Utilization

Production

In the Enhanced Development Scenario, natural gas production will increase in all regions and total 6,180 Bcm in 2040 in the world, 765 Bcm cubic meters more than in the Reference Scenario. Regions with remarkably higher production growth than in the Reference Scenario will be North America, China, Latin America and Oceania. North America will post a high production level even in the Reference Scenario and raise production in 2040 by 153 Bcm from the Reference Scenario to 1,196 Bcm in the Enhanced Development Scenario. From the 2011 production level, the 2040 level in the Enhanced Development Scenario will increase by 459 Bcm. China, Latin America including Argentina, and Oceania are expected to promote shale gas and coalbed methane development. Natural gas output in 2040 in the Enhanced Development Scenario will be 229 Bcm more than in the Reference Scenario for China, 85 Bcm more for Latin America and 93 Bcm more for Oceania. If China resolves its drilling technology and infrastructure development challenges and provides government support, it will become the world's third largest natural gas producer after the United States and Russia.

Table 5 Global Natural Gas Production (Enhanced Development Scenario)

Bcm

	2011	Unconven-tional	Unconven-tional share	2040	Unconven-tional	Unconven-tional share
North America	808	364	45%	1,200	939	78%
Latin America	218	0	0%	538	217	40%
Middle East	523	0	0%	878	31	4%
Europe	287	0	0%	324	43	13%
FSU	868	0	0%	1,249	86	7%
Africa	200	0	0%	444	104	23%
China	103	0	0%	581	356	61%
India	46	0	0%	119	52	44%
ASEAN	203	0	0%	457	152	33%
Indonesia	81	0	0%	145	41	28%
Malaysia	56	0	0%	88	11	12%
Other Asia	75	0	0%	105	35	33%
Australia	51	6	12%	285	196	69%
World	3,384	370	11%	6,180	2,211	36%

Global oil production in 2040 in the Enhanced Development Scenario will be 114 million b/d, 1 million b/d less than in the Reference Scenario. Non-OPEC output will

increase from the Reference Scenario while OPEC production will decline.

In line with the shale oil production growth, non-OPEC oil output in 2040 will increase from 61.9 million b/d in the Reference Scenario to 71.2 million b/d in the Enhanced Development Scenario. North America will post a large production increase while Russia, Latin America and China will also boost overall oil output by expanding shale oil production. On the other hand, the North Sea region and Southeast Asia that produces light, low-sulfur crude similar to shale oil among non-OPEC regions will be forced to reduce output.

In the Reference Scenario, OPEC countries will produce 53.2 million b/d in 2040. In the Enhanced Development Scenario, however, OPEC output in the year will be lower at 43.2 million b/d. Those being affected directly and greatly by the shale oil production expansion will be African oil producing countries including Nigeria and Angola that have produced light, low-sulfur crude oil similar to shale oil. As shale oil production increases toward 2040, oil refineries in the world will renovate their light distillate processing capacity to optimize their operations, affecting Middle Eastern oil producing countries turning out crude oil that is characteristically different from shale oil.

Table 6 Global Oil Production (Enhanced Development Scenario)

Mb/d

	2011	2020	2030	2040	2011-2040 increase
Total	85.79	96.19	107.48	117.01	31.22
OPEC	35.50	36.80	39.40	42.55	7.05
Middle East	25.90	25.90	27.00	29.20	3.30
Others	9.60	10.90	12.40	13.35	3.75
Shale oil	0.00	0.00	1.00	2.00	2.00
Non-OPEC	48.20	56.86	65.05	71.05	22.85
North America	11.50	18.70	22.40	25.60	14.10
Shale oil	0.80	6.00	9.00	12.00	11.20
Latin America	7.10	8.65	10.60	12.70	5.60
Shale oil	0.00	0.50	2.00	4.50	4.50
Europe/Eurasia	17.35	16.80	17.70	18.00	0.65
Shale oil	0.00	0.50	2.00	3.00	3.00
Middle East	1.60	1.60	1.60	1.30	-0.30
Africa	2.40	2.75	2.90	2.95	0.55
Asia	7.75	7.86	8.85	9.00	1.25
China	4.10	4.50	5.60	6.40	2.30
Indonesia	0.95	1.00	0.75	0.50	-0.45
India	0.90	0.80	0.70	0.60	-0.30
Shale oil (China)	0.00	0.50	2.00	3.00	3.00
Shale oil (other Asia)	0.00	0.00	0.50	0.50	0.50
Oceania	0.50	0.50	1.00	1.50	1.00
Shale oil	0.00	0.00	0.50	1.00	1.00
Processing gains	2.09	2.53	3.03	3.41	1.32

Prices

As all major gas importing regions such as Asia, Europe and North America expand natural gas production, the natural gas import price in 2040 will be held down to $10.9/MBtu for Japan, $9.0/MBtu for Europe and $4.5/MBtu for the United States. In this process, the Asian natural gas import pricing formula can be expected to change. Also, crude oil prices are expected to fall to $100/bbl in 2040.

Table 7 International Energy Prices (Enhanced Development Scenario)

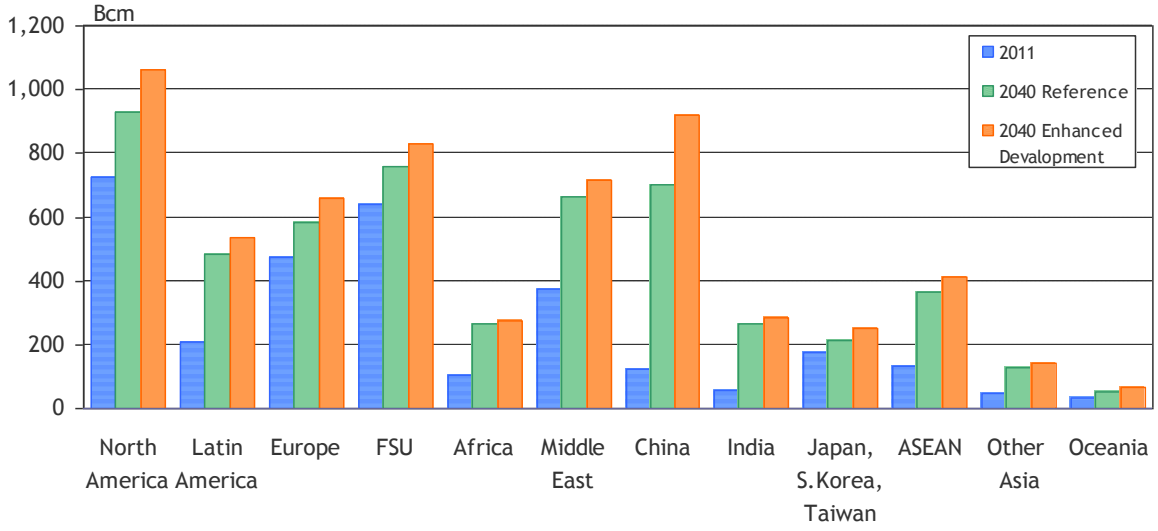
Real prices			2012	2020	2030	2040
Crude oil		$2012/bbl	115	110	105	100
Natural gas	Japan	$2012/MBtu	16.7	12.5	11.5	10.9
	United States	$2012/MBtu	2.8	2.9	3.5	4.5
	Europe	$2012/MBtu	10.5	10.0	9.4	9.0
Steam coal		$2012/t	134	133	134	135
Nominal prices			**2012**	**2020**	**2030**	**2040**
Crude oil		$/bbl	115	129	150	174
Natural gas	Japan	$/MBtu	16.7	14.6	16.5	18.9
	United States	$/MBtu	2.8	3.4	4.9	7.9
	Europe	$/MBtu	10.5	11.8	13.4	15.7
Steam coal		$/t	134	156	192	235

Note: The annual inflation rate is assumed at 2%.

Demand

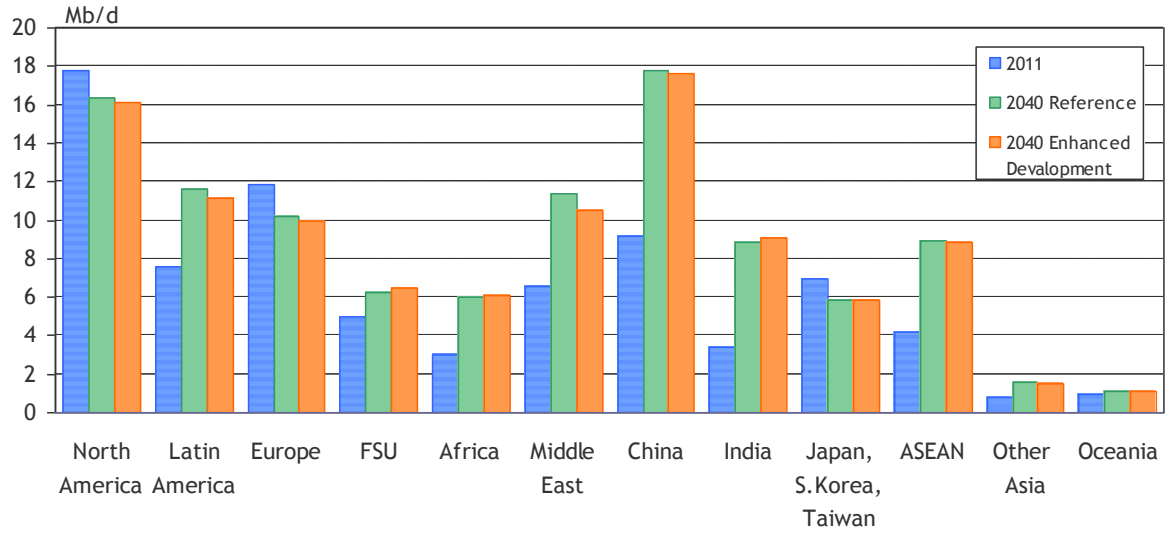
Global natural gas demand in 2040 will increase by 753 Bcm in line with price declines through the output expansion. Demand will increase in all regions, particularly, in China where it will increase by 24% to 922 Bcm. In North America, 88.6% of the production increase will be used to cover a domestic demand rise. In Oceania, demand will increase by only 18% of a production rise, with most of the production rise destined for exports.

Figure 51 Natural Gas Demand by region
(Reference and Enhanced Development Scenarios)



Oil demand in 2040 will decrease by 0.2 million b/d in North America, by 0.4 million b/d in Latin America and by 0.2 million b/d in China as these regions develop unconventional resources. But oil demand in the Former Soviet Union will expand by 0.2 million b/d and in India that produces no unconventional resources and consumes mainly coal, oil demand in 2040 will increase by 0.3 million b/d in line with the crude oil price fall.

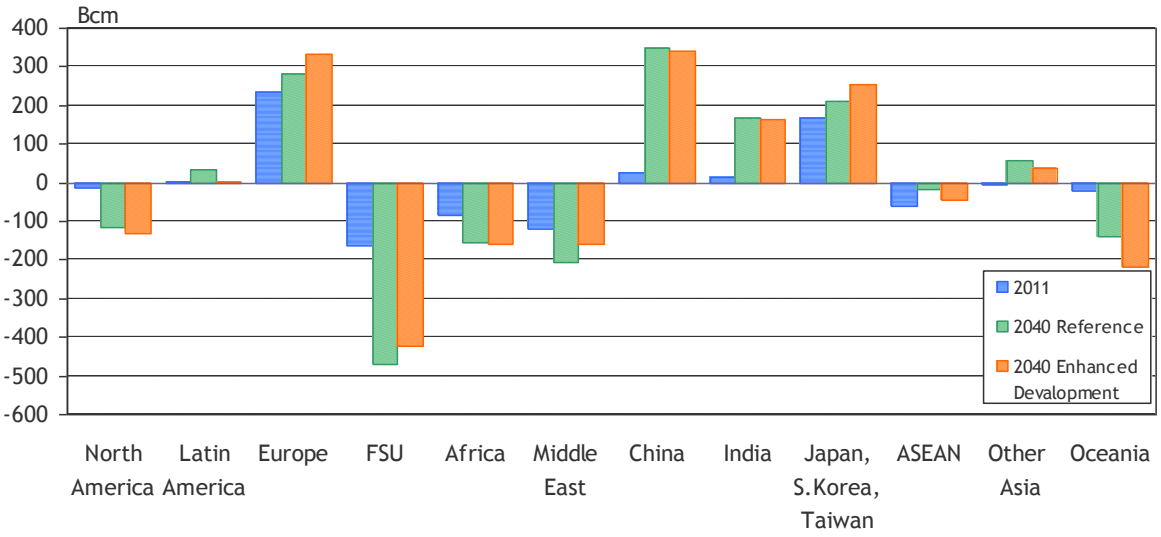
Figure 52 Oil Demand by region (Reference and Enhanced Development Scenarios)



Trade

In the Enhanced Development Scenario, net natural gas exports will increase to 132 Bcm in North America in 2040 and 216 Bcm in Australia. But the Former Soviet Union's net exports will be held down to 421 Bcm due to a production expansion in China. Net imports will be held down to 342 Bcm in China and 164Bcmin India as their domestic natural gas output increases substantially.

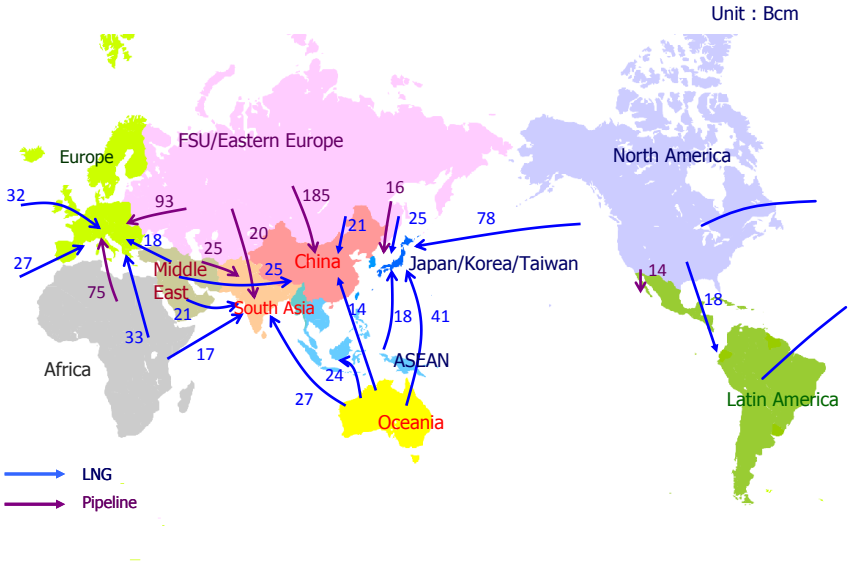
Figure 53 Net Natural Gas Imports by region
(Reference and Enhanced Development Scenarios)



Pipeline gas exports from North America to Latin America in the Enhanced Development Scenario will increase by 3 Bcm from the Reference Scenario and LNG exports by 5 Bcm. Exports to Europe will expand by 4 Bcm and those to Asia by 10 Bcm. Europe, which now imports gas mainly from Russia and North Africa, will expand imports from Latin America to diversify gas import sources.

China will reduce natural gas imports as its domestic production expands on shale development; its natural gas imports from Australia will decrease sharply. Japan, South Korea and Taiwan will expand imports from Russia and Australia and South Asia's imports will post great structural changes. Natural gas supply sources for India will be quite diversified in the future with unconventional natural gas coming from the Middle East and the Former Soviet Union to Africa and Oceania.

Figure 54 Natural Gas Trade Flows between Major Regions in 2040 (Enhanced Development Scenario)



In the Enhanced Development Scenario where shale oil development will make very rapid progress, oil trade flows will change dramatically due to a shift in the geographical distribution of supply sources, though the impact on reducing oil demand will be limited.

Global crude oil trade in the Enhanced Development Scenario will total 40 million b/d in 2030 and 45 million b/d in 2040, some 10% less than in the Reference Scenario for the respective years. This is because global oil demand will decline from the Reference Scenario to the Enhanced Development Scenario due to fuel switching on the introduction of natural gas-fueled vehicles and the United States and China as major oil consumers will reduce oil imports by expanding their shale oil output.

By region, the United States will reduce oil imports in 2040 from 6.6 million b/d in the Reference Scenario to 2.8 million b/d in the Enhanced Development Scenario. Major import sources will be Canada and Latin America, almost unchanged from the Reference Scenario. As of 2030, the Americas will have become self-sufficient in oil, the United States is expected to lift its crude oil export ban in the Enhanced Development Scenario as was also assumed in the Reference Scenario. Its crude oil exports in 2040 will total 4.1 million b/d against 2.8 million b/d in imports. The United States will thus become a net oil exporter in 2040 in the Enhanced Development Scenario.

Major oil suppliers for Europe will remain the Former Soviet Union and Africa as in the Reference Scenario. Although Europe will import small volumes of Middle Eastern crude oil in the Reference Scenario, no Middle Eastern crude will be imported into Europe in 2030 in the Enhanced Development Scenario, due to intensifying competition from the

Former Soviet Union and Africa. Both Europe and the United States will no longer depend on the Middle East for any crude oil supply in the Enhanced Development Scenario.

China will reduce its oil imports by 10-20% from the Reference Scenario by expanding domestic shale oil production. From the viewpoint of energy security and diversification of oil supplies, China will lower (but maintain) its oil pipeline imports from the Former Soviet Union, lower its oil procurements from Africa and continue to import Middle Eastern crudes. As Canadian oil exports to the Asian market will progressively increase (the result of lower exports to the US), they will eventually exceed those from the Middle East to China, reaching as much as 3 million b/d by 2040.

Domestic demand and production in Japan, South Korea and Taiwan in the Enhanced Development Scenario will remain almost unchanged from the Reference Scenario, imposing no major impact on their oil import volume, but their oil import mix will change and their crude oil supply sources will diversify. By 2030, U.S. crude oil will begin to flow into those three countries while Canada and Latin America will also begin to export crude oil to these Asian countries as a result of a drop in exports to the United States. While Japanese oil refineries will continue to process Middle Eastern crude, South Korean refineries equipped with deep conversion capacities will be able to accept heavy crude oil from Latin America.

The crude oil supply mix for Southeast Asia and South Asia in the Enhanced Development Scenario will remain almost unchanged from the Reference Scenario. These regions' crude oil demand and imports in the Enhanced Development Scenario will expand from the Reference Scenario due to oil price falls. Crude oil imports from Latin America will increase at South Asian (Indian) refineries that have deep conversion capacities originally designed to process heavier Middle Eastern crude oil.

Figure 55 Net Oil Imports by region (Reference and Enhanced Development Scenarios)

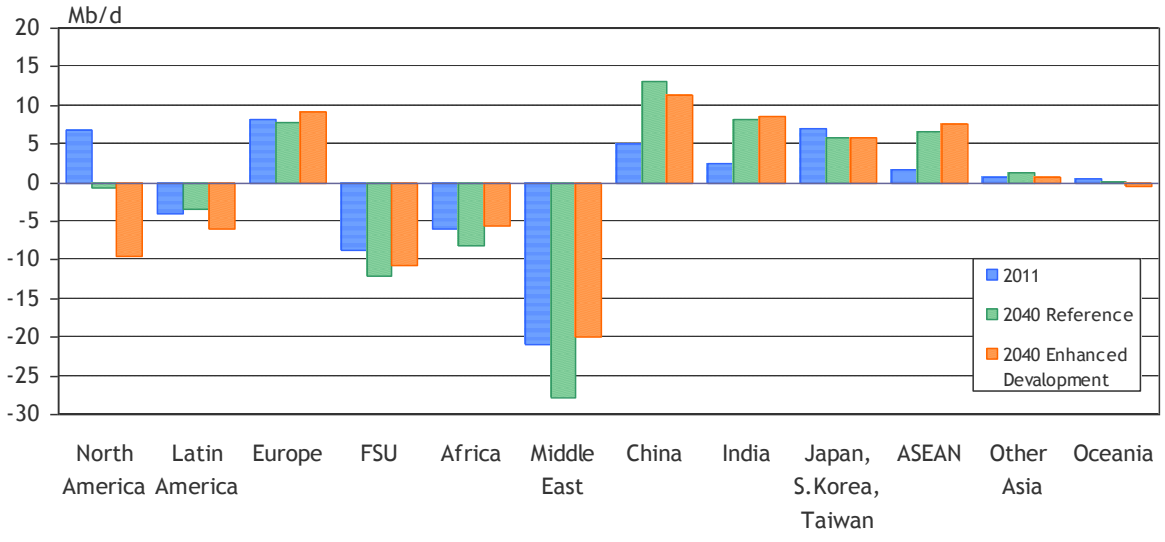
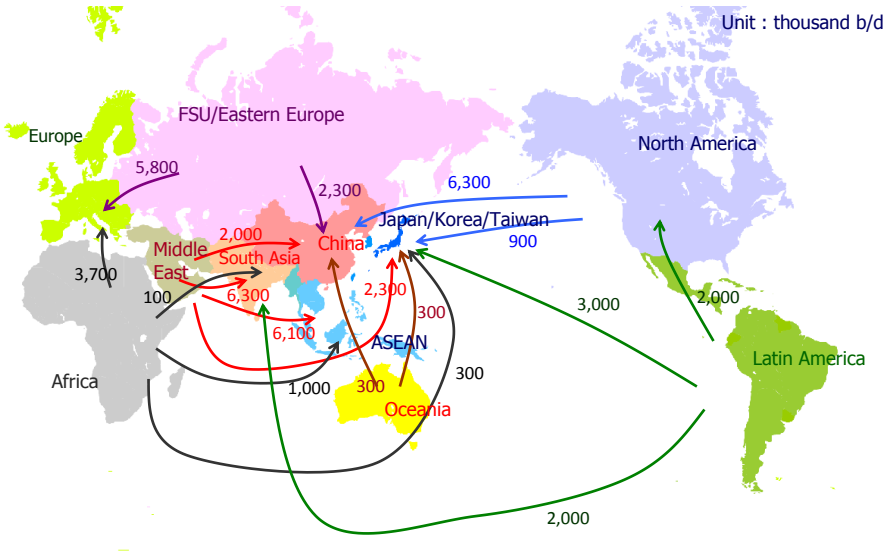


Figure 56 Crude Trade Flows between Major Regions in 2040
(Enhanced Development Scenario)



3.5 Impacts on National Economies

We defined and assessed the economic impacts of the enhanced unconventional resources development as gaps between the Enhanced Development and the Reference Scenarios[4].

Robust production of natural gas and oil and relevant falls in international energy prices will reduce economic costs in gas and oil importing countries. For example, the United States spent $330 billion (in 2012 prices) on net oil and natural imports in 2011 and will log a net receipt of more than $180 billion in 2040, when it will become a net exporter. China's net oil and natural gas imports in 2040 will decline from $780 billion in the Reference Scenario to $540 billion in the Enhanced Development Scenario. Japan, though not expected to develop unconventional resources and despite an increase in natural gas imports, will see its spending on oil and natural gas imports decline from $200 billion to $160 billion, thanks to international energy price falls.

Unconventional resources development will help expand the oil and gas industry. Their prosperity will stimulate consumption and investment through income growth. Furthermore, the multiplier effect will boost domestic production by an amount that will exceed an oil and natural gas output increase. Energy price falls will contribute to enhancing international competitiveness mainly for energy-consuming industries such as

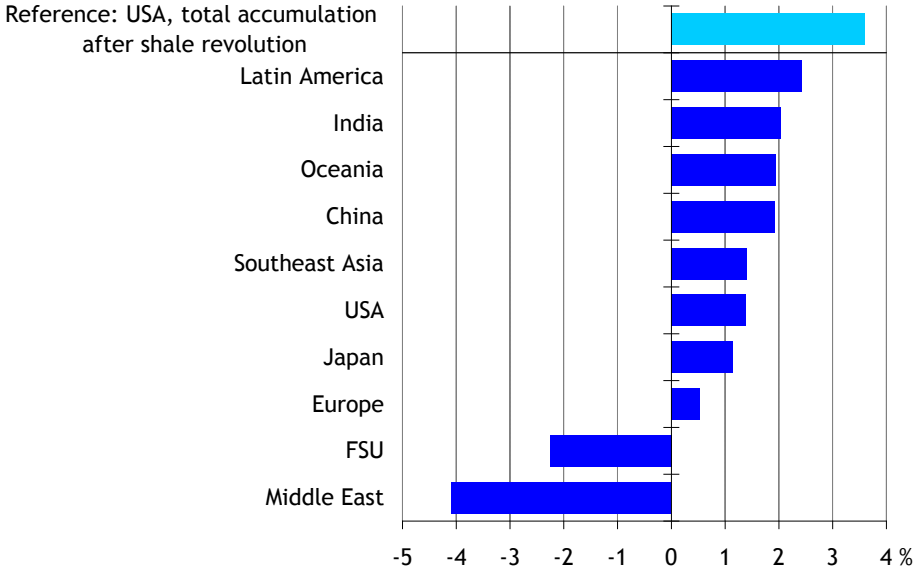
[4] Even in the Reference Scenario, North America will make considerable progress in developing unconventional resources and some other regions will promote such development to some extent. The economic impacts of such development in the Reference Scenario are left out of the assessment.

chemical and steelmaking sectors. Increased production to meet foreign demand, production facilities' expansion and their transfer from abroad will boost economic growth. Countries promoting the development of unconventional resources are thus expected to enjoy a virtuous circle based on three kinds of benefits -- lower net energy imports, the expansion of oil, natural gas and relevant industries, and lower domestic energy prices.

Even Japan, for which massive methane hydrate production is not assumed, will benefit from energy import price falls and indirect effects including an export expansion emerging from more robust economic or industrial operations in the United States and other unconventional resources developing countries, although these benefits will be relatively small.

The economic effects of the enhanced unconventional resources development depend on various factors including not only an increase in resource production. It also depends on relevant energy price falls, energy supply-demand structures, economic sizes and industrial structures, external demand changes in trading partner countries, and so on.

Figure 57 Economic Impacts of Unconventional Resources Production Expansion (Enhanced Development Scenario)



Enhanced unconventional resources development will work to expand real GDP in major regions by 1-2% (Figure 57). Although the U.S. shale revolution started with shale gas development, shale oil production will have greater economic impacts. The economy-boosting effects will be greater in countries and regions with more additional development but it will be substantial in non-OECD countries and others with lower energy

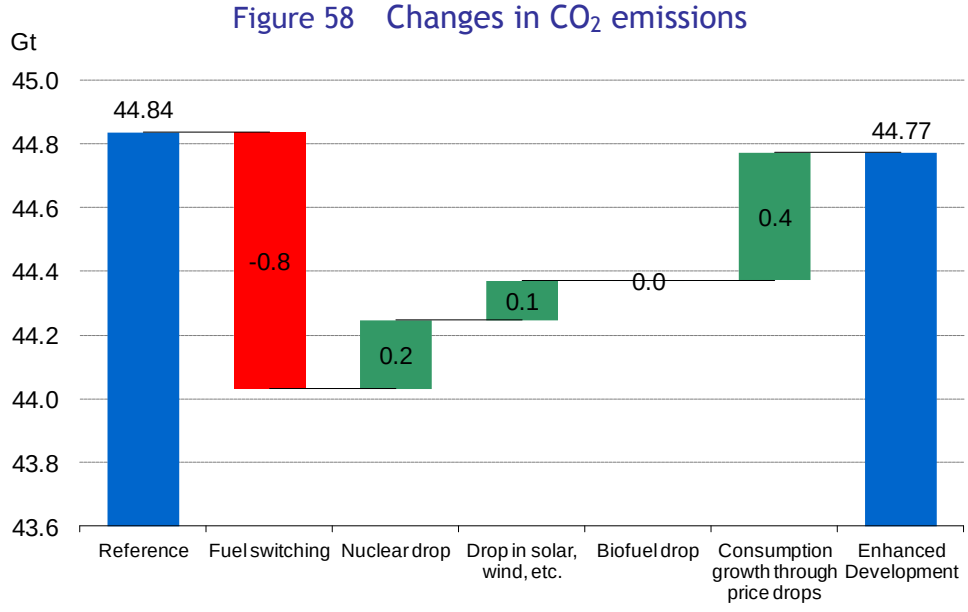
efficiency and higher energy cost weights. U.S. GDP will be lifted by 1.4% while the Japanese GDP, benefitting mainly from indirect effects, will expand by a smaller margin of 1.1%. The GDP of traditional energy producers such as the Middle East and the Former Soviet Union, will decline by 4.1% and 2.3%, respectively, due to their loss of some oil and natural gas export destinations and lower export prices. A GDP expansion will be held down to 0.5% for Europe on which external demand drops for the Middle East and the Former Soviet Union will have relatively greater impacts. Global GDP will expand by around 1%.

3.6 Impacts on CO_2 Emissions

The expansion of shale gas and other unconventional resources production will promote switching from coal-fired power generation to natural gas-fired generation and from gasoline or diesel vehicles to natural gas vehicles, substantially reducing CO_2 emissions by 0.8 Gt. At the same time, however, any drop in natural gas prices under the shale revolution scenario will expand natural gas demand (+0.4 Gt) and dampen nuclear and renewable energy development (+0.3 Gt), working to limit any decline in energy-related CO_2 emissions.

In this way, we must take note of the possibility that unconventional resources development, while contributing to partially holding down energy-related CO_2 emissions over a short term, could fall short of bringing about any substantial emission cuts over a long term and even impede the diffusion of non-fossil energy.

Figure 58 Changes in CO_2 emissions



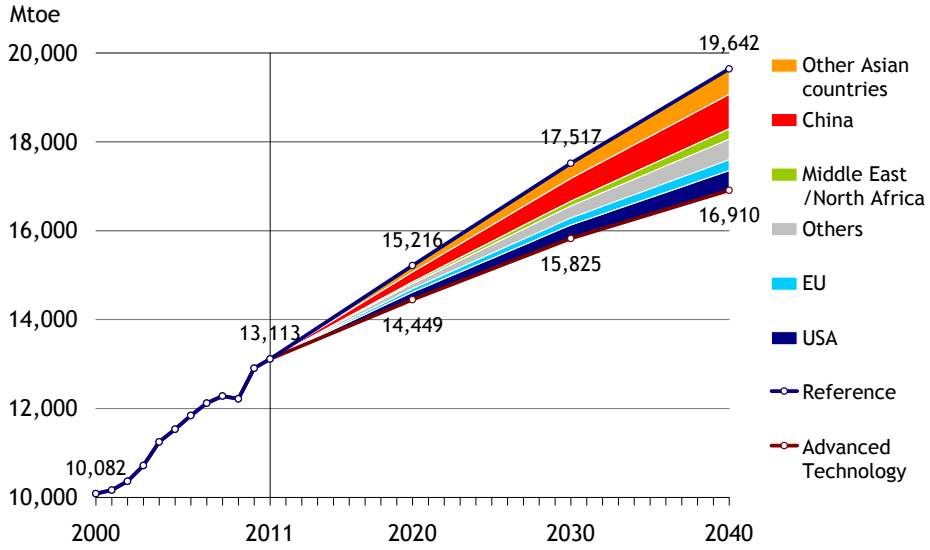
4. Maximum Energy Conservation and Realistic Climate Change Measures

4.1 Energy Conservation

Primary Energy Consumption

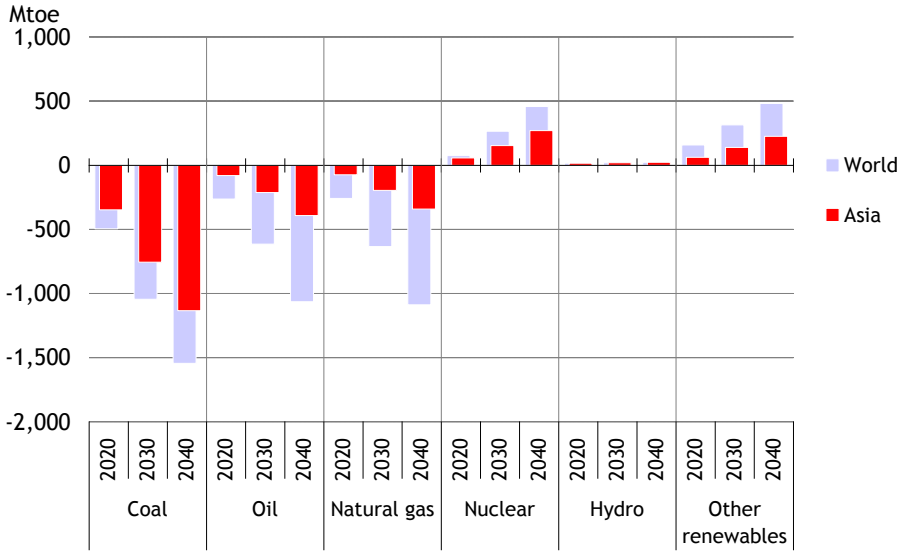
Strong energy conservation and climate change measures will substantially reduce primary energy consumption (Figure 59). The world's primary energy consumption in 2040 in the Advanced Technology Scenario will total 16,910 Mtoe, down 2,731 Mtoe from the Reference Scenario, equivalent to China's present energy consumption. In the Advanced Technology Scenario, non-OECD or Asian countries that are expected to expand energy demand and have greater energy conservation potential will play a major role in energy conservation. Non-OECD countries or Asia will hold the key to global energy system reform as non-OECD countries will account for 67% and Asia for 49% of the potential global energy savings in 2040.

Figure 59 Global Primary Energy Consumption and Region-by-Region Energy Savings (Reference and Advanced Technology Scenarios)



Coal consumption will peak in the mid-2010s and turn downward later (Figure 60). Among the energy sources, coal will post the largest consumption savings. Oil and natural gas consumption will continue increasing but their respective annual rates of increase will be lower than in the Reference Scenario at 0.5% and 1.1%. While overall energy consumption will decrease, nuclear and renewable energy consumption will each increase by about 500 Mtoe from the Reference Scenario. As a result, fossil fuels' share of total primary energy consumption will fall to 70% in 2040.

Figure 60 Global Primary Energy Consumption Changes by Source (changes from the Reference Scenario to the Advanced Technology Scenario)



Asia including China and India will account for two-thirds of coal consumption cuts and of the nuclear energy consumption growth. Asia's cooperation in energy conservation will be indispensable and it will help ease the supply-demand balance and enhance energy security for all energy consuming countries.

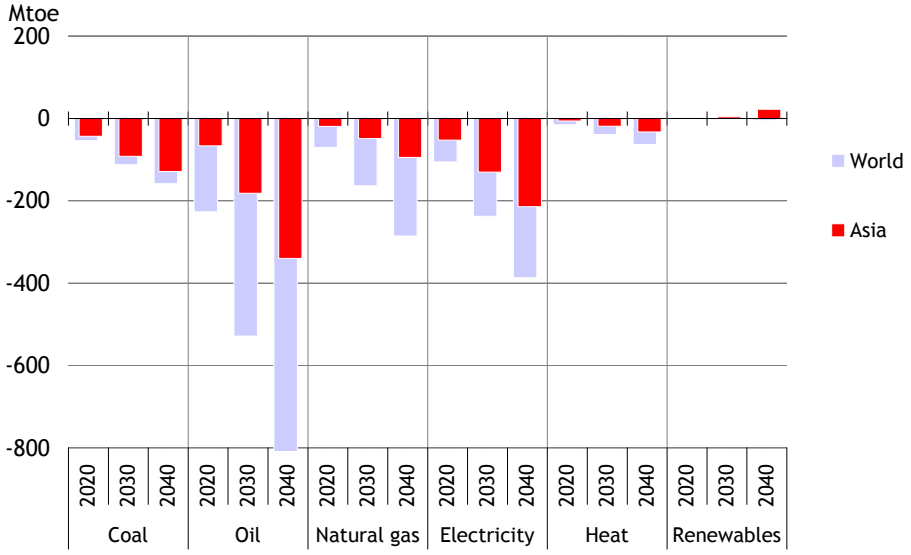
Forums and other events through cooperation between developed and emerging countries are part of key energy conservation efforts. While the effects of these events are less visible than the direct energy conservation effects of technology transfers through the deployment of advanced products and equipment, they can provide good opportunities for energy sellers and suppliers and various sectors such as industry, building and transport to pay attention to the significance of energy conservation. These efforts have potential to bring about great energy savings effects over the long -term. It is important for developed countries to cooperate with Asia in promoting technological and institutional energy conservation measures while securing the protection of intellectual property rights.

Final Energy Consumption

Final energy consumption savings in 2040 will total 1,814 Mtoe, including 917 Mtoe (51%) in oil, 387 Mtoe (21%) in electricity and 285 Mtoe (16%) in natural gas. The three energy sources account for 88% of the total energy savings (Figure 61). In emerging countries, improved fuel efficiency for a growing number of vehicles and the utilization of public transport systems will lead to energy conservation that will contribute much to the oil consumption savings.

Asia will make great contributions to final coal consumption savings. In the future, steelmakers' energy conservation will be important in India and other countries where crude steel production will expand rapidly. Japan's energy efficiency for steelmaking is one of the highest levels in the world with energy consumption some one-third of the Indian level, indicating that Japan has great potential to expand technology transfers. Japan can contribute to energy conservation not only through the provision of energy-saving equipment but also in terms of operational support.

Figure 61 Global Final Energy Consumption Changes by Source
(changes from the Reference Scenario to the Advanced Technology Scenario)



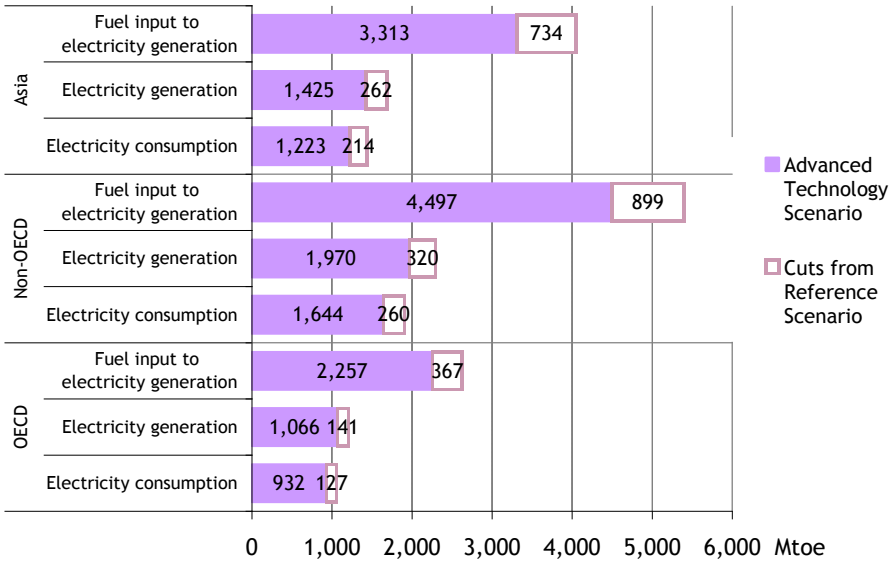
Final electricity consumption savings amounting to 387 Mtoe will allow electricity generation to be cut by 461 Mtoe. This cut will be coupled with electricity generation efficiency improvements to reduce primary energy consumption by 1,266 Mtoe (Figure 62), equivalent to 46% of the total primary energy consumption savings. Contributing much to the reduction will be Asia.

Asian emerging countries will improve their efficiency levels to almost the same as those in developed countries in 2040. Emerging countries frequently fail to take into account environmental considerations while giving top priority to high economic growth. They also hesitate to address air pollution as nationwide efforts to solve air pollution problems are likely to suppress economic growth.

Therefore, developed countries will have an even greater role to play as they can take advantage of their accumulated highly efficient electricity generation technology for

expanding business operations in emerging countries. It is important for developed countries to cooperate with emerging countries in improving the electricity generation sector's efficiency as well as pollution.

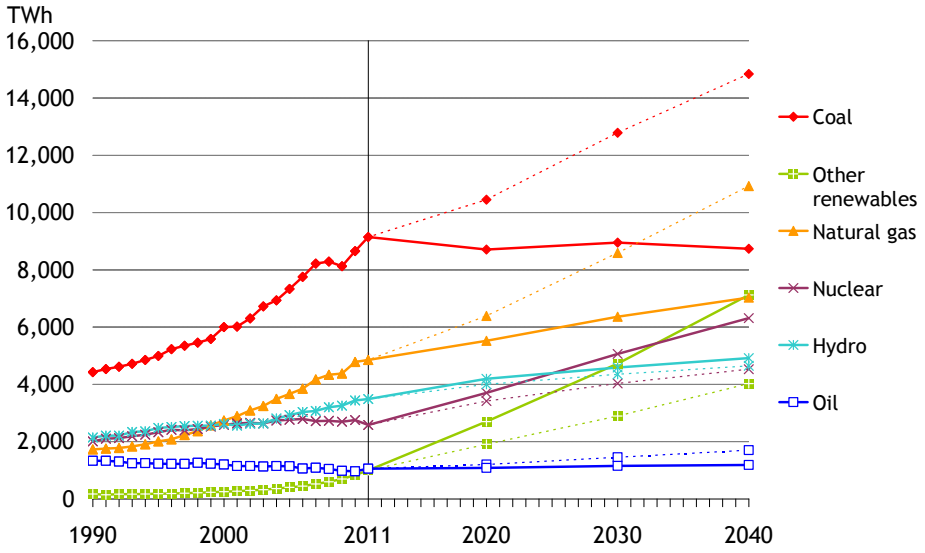
Figure 62 Primary Energy Consumption Cuts Accompanying Final Electricity Consumption Savings (2040)



Electricity Generation Mix

In the Advanced Technology Scenario, final energy consumption savings will work to cut electricity generation by 5,360 TWh, five times more than Japan's electricity generation. The integrated gasification combined cycle (IGCC) for coal-fired electricity generation and the development of technology for mixing coal with biomass energy will contribute to cutting coal consumption for electricity generation. Natural gas, nuclear energy and renewable energy will increase their presence in electricity generation.

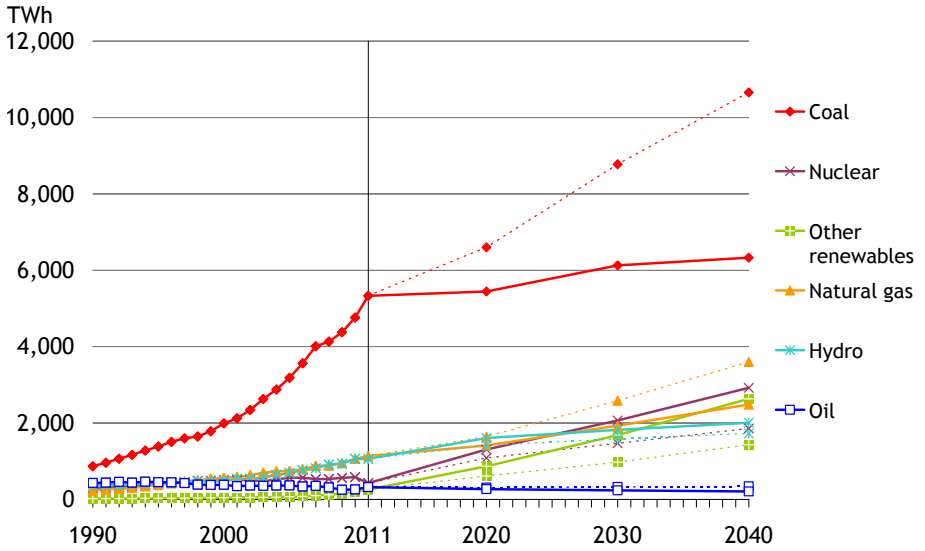
Figure 63 Global Electricity Generation by Source



Note: Solid lines: the Enhanced Development Scenario, dotted lines: the Reference Scenario.

Although technological advancement could substantially reduce coal consumption for electricity generation, coal will continue to account for a remarkably large share of Asian electricity generation in 2040. China and other Asian countries, which are promoting the introduction of renewable energy technology, must also address the use of cleaner coal-fired electricity generation technologies.

Figure 64 Asian Electricity Generation by Source



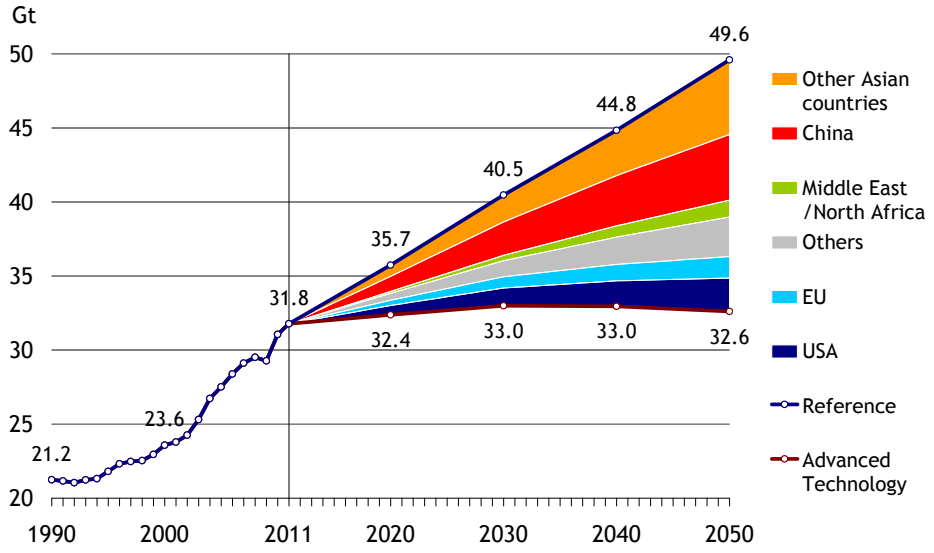
Note: Solid lines: the Enhanced Development Scenario, dotted lines: the Reference Scenario.

Technology will also be required to reduce electricity consumption. How to conserve electricity consumption in the building sector that increases in line with living standard improvements is a key policy challenge in developed countries as well. In the future, energy consumption control technology in addition to energy-saving technology will be important. Developed countries are expected to proactively export advanced infrastructure to developing countries.

4.2 CO_2 Emission Reduction

In the Advanced Technology Scenario, further progress in energy saving and low-carbon technology development will allow global CO_2 emissions in 2050 to decline close to the level for 2011 (Figure 65). The reduction from the Reference Scenario will total 17 Gt, equivalent to the present combined U.S. and Asian emissions. Non-OECD countries will account for some 70% of global CO_2 emission cuts while China alone accounting for about 50% of the Asian emission cuts. China, the world's largest CO_2 emitter, would reduce emission by 4.0 Gt, equivalent to three times the current Japanese emission level. This indicates that developed countries' energy conservation support for non-OECD countries through technology transfers and institutional development support will be very important.

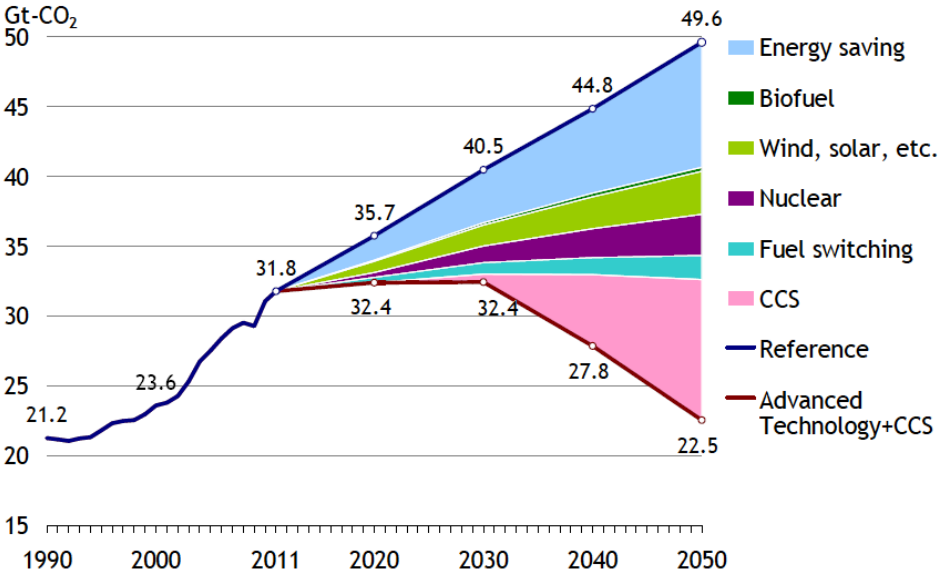
Figure 65 Global CO_2 Emissions and Each Region's Contribution to Emission Cuts (Reference and Advanced Technology Scenarios)



Of the global CO_2 emission reduction from the Reference Scenario to the Advanced Technology Scenario in 2050, energy conservation will account for the largest share at 9.4 Gt, renewable energy diffusion for 3.1 Gt, nuclear energy diffusion for 2.9 Gt and fuel switching

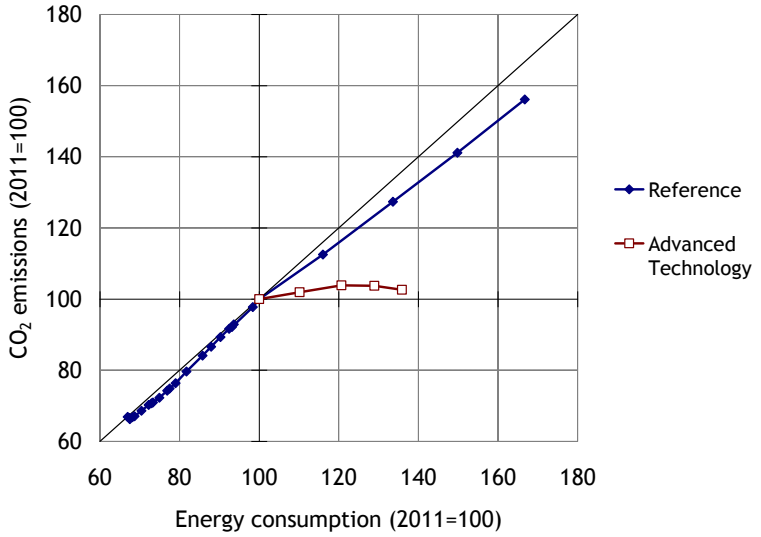
for 1.6 Gt (Figure 66). The CO_2 capture and storage technology will account for 10.1 Gt mainly in the electricity generation sector. There exists no single measure able to lead global CO_2 emissions to turn down. Energy conservation will have to be integrally and widely combined with electricity generation efficiency improvements, non-fossil energy diffusion, fuel switching and CCS systems to effectively reduce CO_2 emissions.

Figure 66 Global CO_2 Emissions and Each Measure's Contribution to Emission Cuts (Reference Scenario and Advanced Technology + CCS Scenario)



From the viewpoint of the carbon content of primary energy consumption, the technologies assumed for the Advanced Technology Scenario may lead the world to pursue low-carbon technologies and measures. In the Reference Scenario, the diffusion of nuclear and renewable energy will lead CO_2 emission growth to slip only slightly below primary energy consumption growth. This means that the current energy policy promotion pace may fall short of bringing about a low-carbon society for the world. But in the Advanced Technology Scenario, CO_2 emission growth will be far slower than primary energy consumption growth.

Figure 67 Global Primary Energy Consumption and CO_2 Emissions (1990-2011, 2020, 2030, 2040, 2050)



The Kyoto Protocol adopted in 1997 gave the world an opportunity to pay attention to the importance of energy conservation and was very significant for reducing greenhouse gas emissions. More than 15 years after its adoption, however, emerging countries have replaced developed countries as the driver of global economic growth. The top-down approach giving priority to emission controls led by developed countries is unlikely to impose any effective constraint on global GHG emissions. The world now must focus on a bottom-up review approach in which countries will report their emission control efforts at an international arena and review their implementation of specific measures with priority given to energy efficiency.

Among Asian countries including major emerging economies, there are wide gaps not only in economic development but also in environmental regulations and administrative systems. As Asian developing countries are expected to absorb investment from developed countries in the future, they should also further promote cooperation in environmental areas. The bottom-up approach focusing on technology transfers features an advantage in which country-by-country characteristics can be taken into account. Each country should fully understand risks emerging from interregional gaps and take flexible and fine-tuned measures to really prevent global warming. Japan should cooperate with the United States and Europe to diffuse advanced model cases in Asia.

Japan's technology transfers to emerging countries will grow even more important. Recently, air pollution from some emerging countries has affected not only their domestic environment but also their neighbors. Japan's technology transfers must aim not only to explore fast-growing Asian markets but also must help solve pollution problems in

developed countries. Technology transfers are not limited to systems or equipment, they should also cover processes for commercialization of systems and equipment, law and regulations, human resources and organizations, the plan-do-check-act cycle and energy management. Japan is expected to take advantage of its past experiences for diffusing technologies for goods and experience-based knowhow overseas.

4.3 Atmospheric GHG Concentration

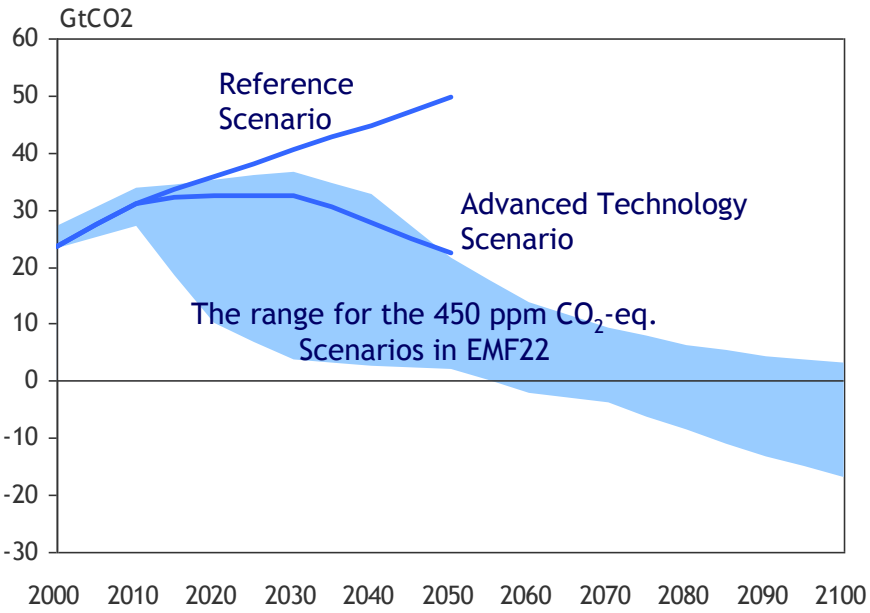
We compared CO_2 emission pathways in the EMF22 450 ppm overshoot scenario with energy-related CO_2 emissions in the Reference and Advanced Scenarios.

The EMF22 (Energy Modelling Forum's Working Group 22) is in charge of climate change scenario analysis. It consists of 18 integrated assessment models and science/technology experts. The EMF22 intentional scenario engaged 10 leading integrated assessment models to consider impacts of three factors -- (1) long-term GHG reduction target, (2) whether or not this target can be temporarily exceeded prior to 2100 ("overshoot") and (3) the nature of international participation in emissions mitigation.

GHG emission cuts in the Advanced Technology Scenario will fall short of halving global GHG emissions in 2050. Given that energy–related CO_2 emissions in 2050 in the Advanced Technology Scenario still slightly exceed the maximum estimate by the EMF22, it would appear difficult to reduce the atmospheric GHG concentration to 450 ppm (CO_2 equivalent) by the end of the 21st century. However, it will still be possible.

To achieve the target, drastic and innovative technologies, including bioenergy with CCS (BECCS) to reduce the CO_2 concentration on a net basis, will have to be developed to substantially reduce CO_2 emissions in the second half of the century. Given that the target involves a very long term, we may have to pay close attention to uncertain factors (including the future expansion and deepening of scientific knowledge, the timing for the diffusion of global emission reduction measures affecting accumulated emissions, and the reduction of GHG emissions other than energy-related CO_2).

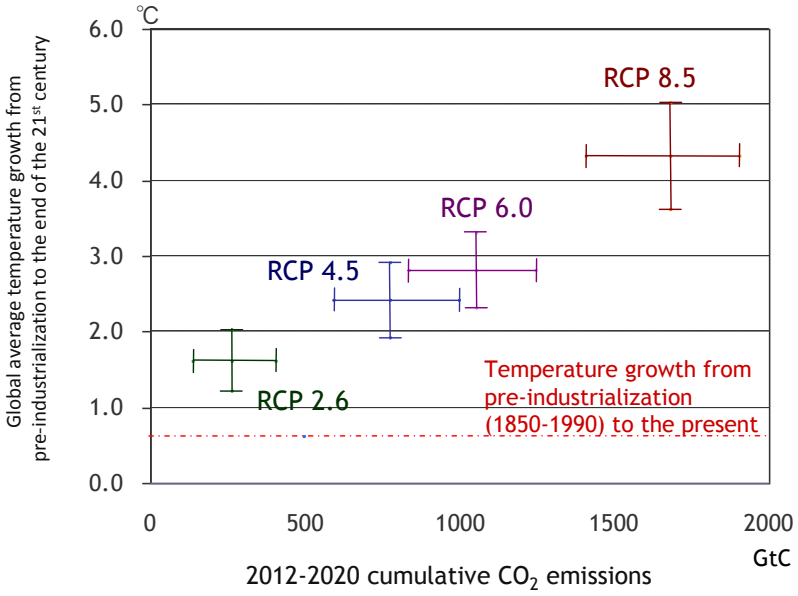
Figure 68 Energy-related CO_2 Emission Pathways for the Overshoot Scenario and the Reference and Advanced Technology Scenarios



Source: Clarke et al. (2009), "International climate policy architectures: Overview of the EMF 22 International Scenarios", Energy Economics, vol. 31, pp. 64-81.
Note: In the scenario, all countries will participate in GHG emission cuts without delay.

The Intergovernmental Panel on Climate Change (IPCC) held its 36th general conference and the 12th meeting of its Working Group I in Stockholm on September 23-26, 2013, where the working group's report as part of the IPCC's Fifth Assessment Report under preparation was adopted. The Working Group I report states that the global average temperature hike is approximately proportional to the cumulative CO_2 emissions (Figure 69). Also, future global average temperature and sea level rise forecasts are given for four RCPs (Representative Concentration Pathways) developed by radiative forcing level (Table 8).

Figure 69 2012-2100 Cumulative CO_2 Emissions and Projected Global Average Temperature Growth from Pre-industrialization to the End of the 21st Century



Source: IPCC (2013), Working Group I Contribution to the IPCC Fifth Assessment Report: Summary for Policymakers

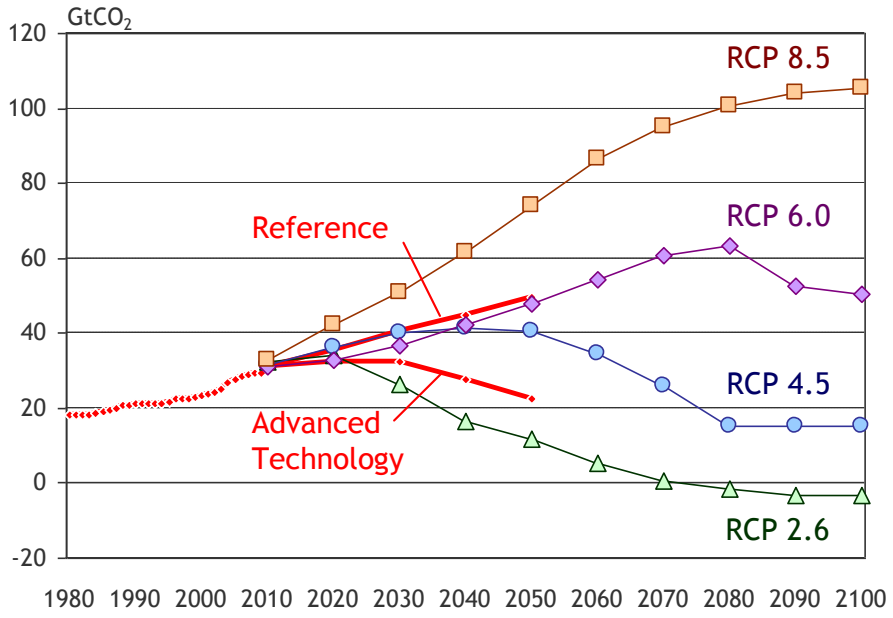
Table 8 Average Temperature Growth from Pre-industrialization to the End of the 21st Century by RCP

	GHG concentration to be reached by 2100 (ppm)	Average temperature growth from pre-industrialization to the end of the 21st century (℃)	Sea level rise through the end of the 21st century (m)
RCP2.6	475	1.6±0.4	0.26～0.55
RCP4.5	630	2.4±0.5	0.32～0.63
RCP6.0	800	2.8±0.5	0.33～0.63
RCP8.5	1,313	4.3±0.7	0.45～0.82

Sources: IPCC (2013), Working Group I Contribution to the IPCC Fifth Assessment Report: Summary for Policymakers; IPCC (2013), "Summary for Policymakers"; "Chapter 12: Long-term Climate Change," in IPCC, Working Group I Contribution to the IPCC Fifth Assessment Report
Note: The range of average temperature growth is within a standard deviation.

Figure 70 compares RCPs with the Reference and Advanced Technology Scenarios. CO_2 emissions in the Reference Scenario exceed those in the RCP 6.0 scenario. In the Reference Scenario, a temperature rise from pre-industrialization is very likely to exceed 2 degrees Celsius. Meanwhile, global CO_2 emissions in the Advanced Technology Scenario will fail to be halved in 2050 but will follow a pathway that will be between the RCP 4.5 and 2.6 and closer to the RCP 2.6.

Figure 70 Comparing RCP Scenarios with the Reference and Advanced Technology Scenarios



Source: RCP Database. CO_2 emissions for RCP scenarios are from fossil fuels and industry and those for the IEEJ scenarios are related to energy.

Conclusion

Against the backdrop of economic and population growth, global energy demand, including demand in non-OECD countries like China and India, will continue to expand. Non-OECD Asian countries will account for 59% of global energy consumption growth and Asia will grow more and more dependent on energy imports, absorbing 77% of the crude oil traded between major regions in 2040 and 71% of the natural gas trade. Asia will strengthen relations with the Middle East for oil imports while promoting natural gas procurement from various regions.

Non-fossil energy consumption including nuclear and renewable energy will increase steadily. Russia, South Korea, the Middle East and the United States will proactively diffuse non-fossil energy while China, India and other emerging countries, where electricity demand will grow sharply, will also actively promote non-fossil energy. On average, one nuclear reactor (with a capacity of 1 GW) will be constructed every month. Electricity generation with solar, wind and other renewable energy sources, on which great expectations are placed, will expand 3.9-fold by 2040. Renewable energy, even excluding hydro, will account for 10% of electricity generation.

In this way, energy use conditions in the world will change dramatically, but the world will remain heavily dependent on fossil fuels. The so-called Three Es -- energy security, environmental protection and economic efficiency -- plus S (security) will remain important. It will become even more important for Japan, poor in fossil energy resources, to enhance collaboration and cooperation with other Asian energy consuming countries and relations with Middle Eastern and other resource-rich countries. Japan must contribute to energy security and global environmental conservation by further developing energy conservation and environmental technologies.

The shale revolution originating in the United States will structurally change global energy supply and demand. If rapid unconventional energy resources development spreads throughout the world, natural gas will become the second most consumed energy source after oil in the second half of the 2030s, greatly affecting demand for other energy sources.

The shale revolution will ease the global energy supply-demand balance and help the world economy turn briskly. In the Americas and other regions where the shale resources development will make smooth progress, the revolution will help expand net fossil fuel exports, bringing about great economic benefits. In net fossil fuel import countries, such as China, shale development progress will work to hold down fossil fuel imports to the advantage of their economies. Japan, South Korea and Taiwan will reduce fossil fuel imports in value due to price drops while expanding such imports in volume. They will also

benefit from their export expansion in the more prosperous world economy under the shale revolution.

Meanwhile, the Middle East and Russia will suffer economic deterioration due to a decline in fossil fuel exports and lower fossil fuel prices. Only the Middle East will have sufficient capacity to meet the fast energy demand growth in Asia. The shale revolution has led U.S. foreign and defense policies to slowly shift away from the Middle East while Asian countries must build comprehensive relations with the Middle East. If the United States reduces its engagement in the Middle East further, the security of sea lanes for energy transportation may be at stake.

The expansion of shale gas and other unconventional resources production will promote switching from coal-fired power generation to natural gas-fired generation and from gasoline or diesel vehicles to natural gas vehicles. At the same time, however, any drop in natural gas prices under the shale revolution scenario will expand natural gas demand and dampen nuclear and renewable energy development, working to limit any decline in energy-related CO_2 emissions.

In this way, we must take note of the possibility that unconventional resources development, while contributing to partially holding down energy-related CO_2 emissions over a short term, could fall short of bringing about any substantial emission cuts over a long term and even impede the diffusion of non-fossil energy.

In order to address the climate change problem, the world should make maximum efforts to conserve energy consumption and diffuse non-fossil energy. These efforts will allow the world to reduce energy-related CO_2 emissions substantially, hold down fossil fuel consumption and stabilize energy supply. Even in the Advanced Technology Scenario where existing energy conservation and climate change measures will be promoted to the maximum, the drop in energy-related CO_2 emissions from 2010 to 2050 will be limited to 20%. In the scenario, the world will fall short of halving such emissions under one of global targets. Even in this scenario, however, the atmospheric GHG concentration could be held down to 450 ppm of CO_2 equivalent by the end of this century. To this end, however, the world will have to develop even more innovative technologies including bioenergy with CCS (BECCS) and carbon capture and use (CCU) systems for a substantial emission reduction in the second half of the century.