A global energy outlook to 2035 with strategic considerations for Asia and Middle East energy supply and demand interdependencies[1]

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Abstract

This study quantitatively projects energy supply and demand in Asia and other regions of the world through 2035, focusing on the relationship between Asia and the Middle East.

An integrated group of energy economics models, including a macroeconomic model, an energy supply and demand model and a technology assessment model, are used to show that the Middle East will be able to respond to an expected substantial increase in Asian fossil fuel demand. Therefore, continuing appropriate investment in resource development in the Middle East will be indispensable to ensure stability in global energy supply and demand. The Middle East is expected to focus more on its fossil fuel exports to Asia amid a decline in exports to North America and Europe. The large energy consumption and production regions are expected to become more and more interdependent.

1. Introduction

Global energy demand has been expanding rapidly; it expanded 2.4-fold from 5000 million tons of oil equivalent (Mtoe) in 1971 to 11,700 Mtoe in 2010. The Asian region has increased its energy demand remarkably over recent years, accounting for 70% of the growth in global energy consumption since 2000. The rapid energy demand expansion in the region, poor in oil and natural gas resources, has caused major problems in and outside the region. For example, China, with the largest energy demand in the world, has taken all possible measures to secure and diversify its fossil fuel procurements, including constructing international oil pipelines, acquiring overseas oil interests, and expanding Liquefied Natural Gas (LNG) and pipeline-based natural gas imports, while introducing more nuclear and renewable energy. Energy demand, particularly fossil fuel demand, is predicted to continue expanding in the world including Asia. How the unevenly distributed fossil fuel resources will be provided to the points of demand, in a stable manner, is expected to become an increasingly important challenge.

Energy demand is also increasing in the Middle East. Demand growth in this region requires

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attention because it can undermine the export capacity needed to meet the growing demand in other regions, including Asia. For example, the Middle East consumed only 4% of its domestic oil production in 1971, but the ratio rose to 24% by 2010. As the energy demand in this region is expected to continue its rapid growth in the future, expanding the production to maintain the export capacity becomes a crucial issue for the future global energy supply.

Global energy demand projection has been performed by many organizations, including the International Energy Agency (IEA) [1], U.S. Energy Information Administration (EIA) [2] and the Organization of the Petroleum Exporting Countries (OPEC) [3]. There are similarities and dissimilarities, reflecting the different viewpoints and assumptions. For example, IEA's long-term oil demand projections have always been lower than those of OPEC and U.S. EIA for both Asia and the World, resulting in smaller oil production forecasts. But they agree in the view that in the central cases (IEA's New Policies Scenario (NPS), OPEC's Reference Case and U.S. EIA's Reference Case), global and Asia's fossil fuel demand shows a continuing growth, requiring a steady growth in production.

BP's outlook [4] has a different view of the Middle East's future crude oil production when compared to the other outlooks. According to BP, due to a slump in global oil demand and an increase in unconventional non-OPEC oil supply, oil production from OPEC will decline in the next decade. If this is true, it will greatly affect the financial situation of the Middle Eastern oil exporting countries. In the longer term, however, BP forecasts that global oil demand will surge again to surpass the increase in unconventional oil production, and oil production growth from the Middle East will be back by 2030 to reach a level 30% larger than that in 2010.

To sum up, different outlooks have different backgrounds and assumptions, but they broadly share the same vision. Demand for fossil fuels, especially oil and natural gas, will continue to grow in the future mainly in non-OECD countries in Asia. The Middle East will play a key role to increase production to meet the growing demand. Unconventional supplies will expand mainly in North America, but demand for conventional oil and natural gas from the Middle East will increase in the long term.

But some questions arise: Will the increase in exports to Asia be strong enough to sustain the economic growth of the Middle Eastern countries? What are the possible impacts of unconventional resources development in Asia as well as in North America? What happens if Asian countries take strong actions towards low-carbon societies and reduce fossil fuel consumption? What are the differences between the future evolution of crude oil and natural gas exports to Asia? As an attempt to answer these questions, we analyzed in this study the future energy supply and demand situations up to 2035, making use of a group of numerical models. This study focuses on the relationship between Asia and the Middle East in order to draw the implications for the fossil fuel exporting countries. Based on thorough reviews of the latest energy policies this study also provides detailed projections, especially for energy demand in Asian countries.

The Fukushima Daiichi nuclear power plant accident triggered by the Great East Japan Earthquake in 2011 led to changes in nuclear policies in Japan and other countries, which will greatly affect future fossil fuel demand. These latest policy changes are not always fully reflected

in the outlooks mentioned above. For example, the latest version of U.S. EIA's International Energy Outlook (IEO) was published in September 2011, and it forecasts Japan's nuclear power generating capacity to increase from 48 GWin 2008 to 55 GWin 2020 and 61 GWin 2035 in the Reference Case. New nuclear power plant (NPP) construction in the near future, however, is no longer realistic in Japan, as the government has announced its intention to reduce dependence on nuclear energy [5]. IEA's NPS assumes 70 GW nuclear capacity in 2020 in China, presumably based on the nation's most ambitious target that has ever been announced. The Chinese government, however, stopped granting licences for new NPP construction for more than one year and a half, in the wake of the Fukushima accident. This will cause a delay in nuclear power development. According to the media [6], China now sets the target at 58 GW in 2020, instead of 70 GW. Since most of the planned new NPPs are already under construction and granting licences for starting new ones has been resumed, there will be no problem for meeting the new target of 58 GW. A total of 70 GW by 2020 should be regarded as unrealistic.

In this study we reviewed thoroughly the latest energy policies of each country as well as the global energy supply and demand situation, and made detailed projections especially for Asian and Middle Eastern countries. Our Reference Scenario (described below) proposes an outlook for the future energy supply and demand situation in line with past trends, unlike IEA's NPS. Our Advanced Technology Scenario assumes the maximum diffusion of energy saving and CO_2 reducing technologies, but is not as ambitious as IEA's 450 Scenario, which is a sort of backcast from the target of halving global GHG emissions by 2050. Based on these two scenarios, we analyzed future energy situations on a country-by-country basis, especially focusing on Asian and Middle Eastern countries and the developing relationship between them.

2. Methodology and assumptions

2-1 Methodology

In this study, we built and used an integrated group of energy economics models including a core econometric model to analyze long-term energy supply and demand comprehensively and consistently. The integrated group consists of three submodels - a macroeconomic model, an energy supply and demand model, and a technology assessment model. The last one includes the automobile model, the buildings sector energy consuming equipment model and the renewable energy introduction model. Fig. 1 indicates the entire picture of the model group.

In the integrated group of models, the world is divided into 45 regions in accordance with geopolitical factors and region-by-region energy supply and demand structures as follows:

Americas: United States, Canada, Mexico, Brazil, Chile and Other Latin America.
Europe: United Kingdom, Germany, France, Italy, Other OECD Europe and Non-OECD Europe.
Former Soviet Union (FSU): Russia, Kazakhstan, Azerbaijan, Uzbekistan, Turkmenistan and Other FSU.

Africa: South Africa and Other Africa (including North African countries such as Egypt, Libya, Tunisia, Algeria and Morocco).

Middle East: Saudi Arabia, Iran, Iraq, United Arab Emirates, Kuwait, Qatar, Oman and Other Middle East (including Bahrain, Israel, Jordan, Lebanon, Syria and Yemen).

Oceania: Australia and New Zealand.

Asia: Japan, China, India, Taiwan, South Korea, Hong Kong, Indonesia, Malaysia, Philippines, Thailand, Vietnam, Singapore, Brunei, Myanmar and Other Asia.

For the purpose of analyzing Asia and the Middle East in detail, Asia is divided into 15 economies and the Middle East into eight economies. The projection period is between 2011 and 2035.

2-1-1 Macroeconomic model

The macroeconomic model consistently calculates gross domestic product components (demand items) under a set of assumptions for crude oil prices, and domestic economic, fiscal and monetary policies. It also estimates indicators including the vehicle fleet (passenger and freight vehicles) and other transportation indicators, crude steel output and other production indicators, and prices that directly and indirectly influence energy demand.

2-1-2 Energy Supply and demand model

The energy supply and demand model is the core model for the analysis. The IEA's energy balance tables [7,8] are adopted as basic data for this model. The model calculates final energy consumption (industry, transportation, buildings and agriculture, and non-energy use), energy transformation (power generation, oil refining, town gas production, etc.) and primary energy supply. This means that the model assesses primary energy supply consistently and comprehensively by estimating energy transformation sector output required to meet final energy consumption as estimated by energy source under various indicators provided by the macroeconomic model.

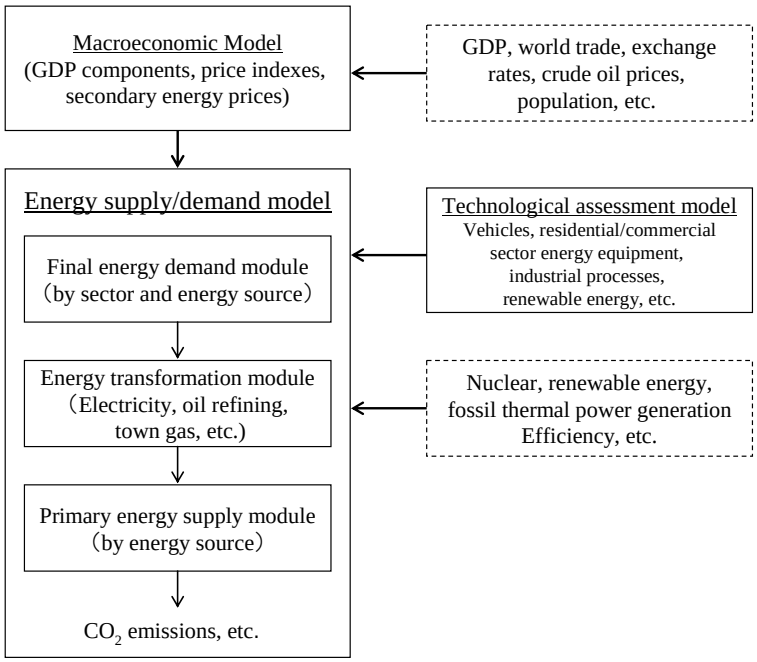

Fig.1 Model structure.

2-1-3 Technology assessment models

The technology assessment models are used for calculating energy saving potentials that are incorporated to the Advanced Technology Scenario described below under a bottom-up approach. This approach tracks the stock and replacement of a certain type of equipment and then calculates the related energy demand under assumptions of specific efficiencies, differentiated by type. In order to estimate the energy saving potentials as a whole, we developed two scenarios (the Reference Scenario and the Advanced Technology Scenario) and calculated the difference.

A detailed vehicle introduction model built by the IEEJ [9] is used for projecting the diffusion of vehicles and energy conservation effects. As for the buildings sector energy consuming equipment (including refrigerators and air conditioners) and the industry sector equipment (for steel, cement, paper and pulp, aluminium and chemical industries), we developed an assessment model referring to the literature [10-12]. We also calculated renewable energy diffusion by referring to a technology assessment model that takes into account the effect of new technologies' cost competition with older ones, as described in the literature [13].

2-2 Population and economic growth assumptions

We referred to the latest United Nations projections [14] for population growth. In many OECD (Organisation for Economic Co-operation and Development) countries where the total fertility rate has slipped below 2 births per woman, downward pressures on population will increase. Even in non-OECD countries, the total fertility rate is following a downward trend in line with income growth. But global population is expected to increase at an average annual rate of some 1% due to developing medical technologies and improving food and sanitation conditions. As

a result, global population is projected to increase from 6.8 billion in 2010 to 8.6 billion including 4.5 billion in Asia by 2035.

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

In assuming GDP growth, we referred to economic outlooks by international organizations such as the Asian Development Bank [15] and the International Monetary Fund [16] as well as economic development plans released by national governments. The global economy, which has been flagging since the collapse of Lehman Brothers in September 2008 and the resulting global financial market shock, is here assumed to get back on a growth path over a medium to long term. Asian emerging countries, including China that has already realized powerful economic growth, are not expected to see growth as tremendously as in the past. But Asia's economic growth is assumed to outdo the other regions and increase Asia's presence in the global economy. Specific assumptions are given in Fig. 2.

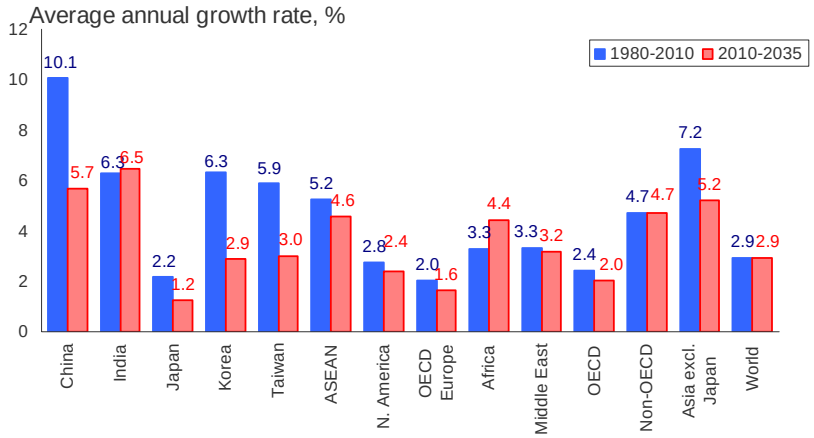

Fig.2 Economic growth assumptions (annual, %).

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

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

China, now the world's second-largest economy, will gradually shift from an investment and

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

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

2-3 International energy price assumptions

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

While mainly conventional oil is expected to continuously cover the future global oil demand increase, Canadian oil sand, U.S. tight oil, Brazilian pre-salt oil and other oil resources that had been unsuitable for commercial production have begun to play key roles in the market. In the future, oil production is also expected to shift to small and medium-sized oil fields, polar areas, deep-water oil fields and other points where production costs are relatively high. Given the past history, no powerful regulations are likely to be introduced on excessive fund flows into the oil futures market. Speculations and investment funds can be expected to continue boosting crude oil prices. Given these factors, crude oil prices are assumed to increase their short-term fluctuations and slowly rise over a medium to long term (Table 1).

Table 1 International primary energy price assumptions.

			2011	2020	2030	2035
Crude oil		$2011/bbl	109	115	122	125
Natural gas	Japan	$2011/Mbtu	14.7	14.5	14.3	14.1
	Europe	$2011/Mbtu	10.5	11.2	12.1	12.6
	U.S.	$2011/Mbtu	4.1	5.2	6.4	7.1
Steam coal		$2011/t	138	136	139	143

The LNG prices in Japan are assumed to remain linked to crude oil import prices. But LNG's

relative prices with oil prices are expected to fall over the medium to long term, in line with expanding production of unconventional natural gas and increasing pipeline gas supply for Asia. Meanwhile, U.S. natural gas prices, which have recently sharply fallen due to rising shale gas production, are assumed to rise over the medium to long term, helping narrow the interregional gas price gaps.

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

2-4 Scenarios

This study set the “Reference” and “Advanced Technology” scenarios to project energy supply and demand through 2035. The Reference Scenario is based on past trends and present and past energy and environmental policies. While policies that can be expected in line with past developments are incorporated into the Reference Scenario, no radical energy conservation or low carbon policies are assumed for this scenario. Ambitious energy conservation and low carbon technology targets declared by various countries are assumed to fall short of being achieved completely due to technological and financial difficulties.

The Advanced Technology Scenario is based on an assumption that countries will powerfully implement energy and environmental policies to further secure stable energy supplies and will enhance their climate change measures and make them successful to the maximum extent (Fig. 3).

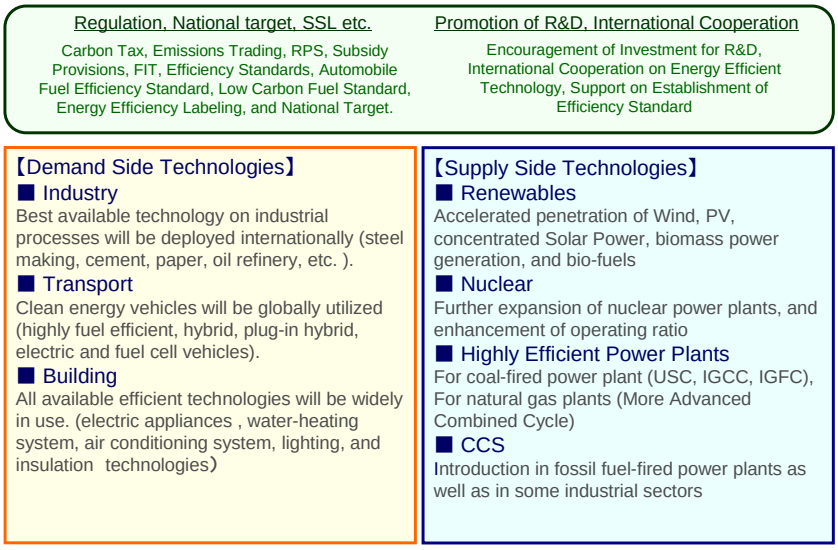

Fig.3 Policy and technology assumptions for the advanced technology scenario.

The Reference Scenario is calculated in the first place making use of the macroeconomic model and energy supply and demand model discussed in Sections 2-1-1 and 2-1-2. Then the Advanced Technology Scenario is developed by subtracting the energy saving potentials, calculated

by the technology assessment models described in Section 2-1-3, from the energy demand in the Reference Scenario.

Table 2 shows selected assumptions of technology diffusion for the two scenarios. In the industry and the buildings sectors, we assumed that historical trends in efficiency improvement will continue in the Reference Scenario, whereas all developing countries achieve the current level of OECD countries in 2035 in terms of efficiencies of appliances or equipments on the basis of sales (not stock) in the Advanced Technology Scenario.

Table 2 Selected assumptions for technology diffusion.

		Asia			World		
		2010	2035 ref.	2035 adv.	2010	2035 ref.	2035 adv.
Thermal Efficiencies	Coal	34%	38%	40%	35%	39%	41%
	Natural gas	44%	46%	48%	41%	45%	47%
CCS introduction		-	-	2.0 Gt/yr	-	-	2.6 Gt/yr
Clean viecle diffusion (sales basis)	Hybrid/Plug-in hybrid	-	33%	64%	-	34%	62%
	Electric/ fuel cell	-	<1%	19%	-	<1%	23%
Average Fuel Efficiency of new vehicle sales		7.7 L /100km	5.6 L /100km	3.8 L /100km	7.1 L /100km	5.6 L /100km	3.7 L /100km

2-5 Other assumptions

Nuclear power generation forms a key part of energy supply and its trend can greatly influence future fossil fuel supply and demand. Given that introducing or suspending nuclear power plants depends largely on political decisions, it is not appropriate to project their diffusion only through model estimation using past trends and costs. Therefore, we estimated future nuclear power generation capacity and output for all countries that already operate nuclear power plants and all those that plan to introduce such plants, based on their latest policy and energy supply and demand trends, while referring to projections in existing papers [1,3,4,17-19].

As for crude oil and natural gas production, we prepared future projections for each country or region based on oil and natural gas demand estimated through the abovementioned model estimation, taking into account past production trends, oil and gas field erosion, national production projections or targets, latest resources development trends, pipeline installation plans, gas liquefaction and LNG import terminal construction plans, etc.

Details of these projections are given along with estimation results in Section 3.

3. Results and discussion

3-1 Primary energy consumption outlook by region

Global primary energy consumption will increase about 1.5-fold from 11,743 Mtoe in 2010 to 17,517 Mtoe in 2035 (Fig. 4). During the coming period, energy efficiency improvement and conservation will accelerate from the pace of the past two decades, allowing energy consumption growth (at an annual rate of 1.6%) to slip below economic growth (at an annual rate of 2.9%). The annual energy demand growth will amount to a half of Japan's present level or one-third of the level for the entire Middle East, indicating that the world will continue to need massive amount of energy in the future. Expected national energy policies and energy conservation technology development and diffusion alone may fall far short of further decoupling energy demand growth from economic growth.

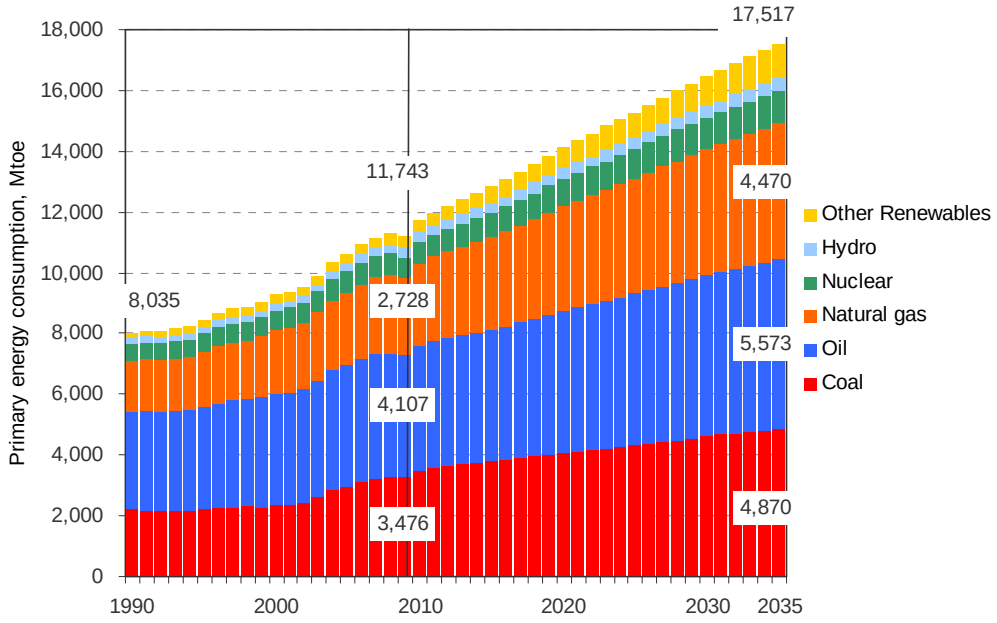

Fig.4 Global primary energy consumption (by energy source in the reference scenario).

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

While global energy consumption will increase through 2035, consumption growth will differ from region to region (Fig. 5). While OECD countries will expand energy consumption only

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

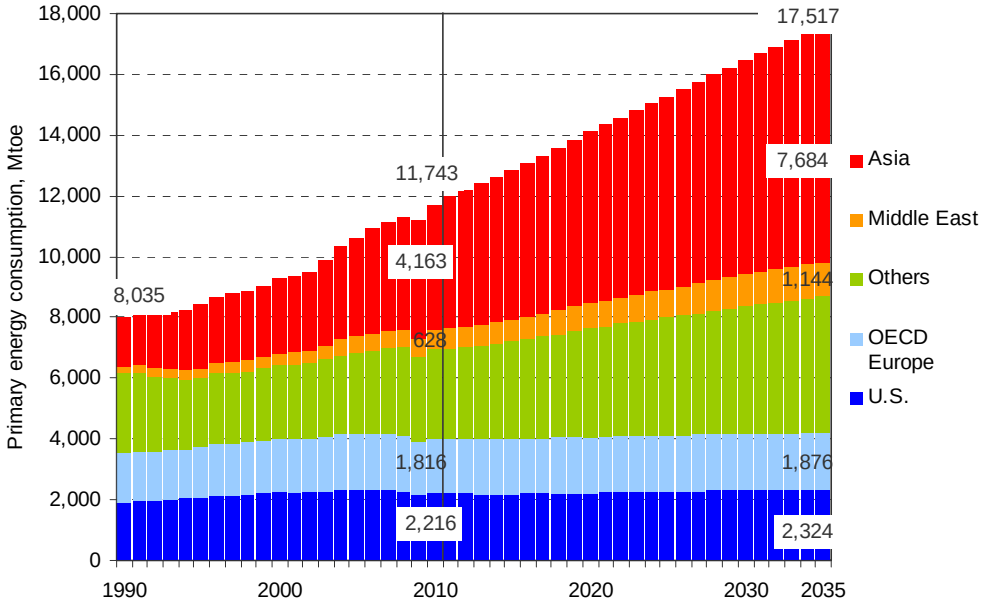

Fig.5 Global primary energy consumption (by region in the reference scenario).

Asian energy consumption will increase 1.8-fold during the next 25 years (Fig. 6). China has replaced the United States as the world's largest energy consumer and will consume 1.7-fold more energy than the United States that will be the second largest energy consumer in 2035. India's energy consumption is now almost equal to Japan's consumption and will expand 2.6-fold. India will thus become the third largest energy consumer following China and the United States. While Asia will increase its presence in the global economy more and more, the region, which is less energy efficient and consumes more energy than indicated by its economic size, will exert greater adverse and favorable influences on the international energy market. In Asia, Japan will be the only country reducing its primary energy consumption.

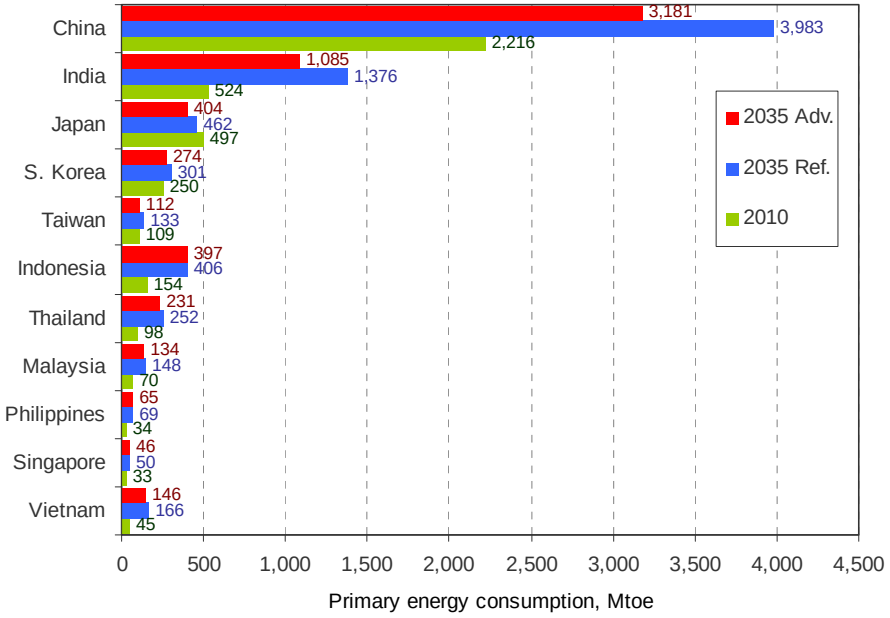

Fig.6 Asian primary energy consumption (2010, 2035).

Even in the Middle East, the largest energy exporter, energy demand has been increasing rapidly. In Saudi Arabia, for example, domestic consumption's share of its total energy production expanded from around 2% in the 1970s to some 30% in 2010. Supported by high economic growth and rising income levels, energy consumption will post a rapid expansion of 1.8-fold during the next 25 years. As noted later, therefore, the region's efforts to promote energy conservation and secure surplus export capacity will be very important for stable energy supply in the world.

In the Advanced Technology Scenario, global primary energy consumption will reduce substantially through powerful energy conservation and climate change policies. In 2035, the consumption will be limited to 15,023 Mtoe. The decline of 2493 Mtoe from the Reference Scenario will be equivalent to the combined present consumption in China and South Korea. Coal consumption will peak in the mid-2010s and reduce thereafter. Oil and natural gas consumption will continue to increase at respective annual rates of 0.6% and 1.1%, far slower than in the Reference Scenario. As a result, fossil fuels' share of primary energy consumption will fall to 77% in 2035.

In the Advanced Technology Scenario, non-OECD countries and Asia will play great roles in conserving energy. Non-OECD countries will account for 67% and Asia for 53% of the global energy savings of 2493 Mtoe in 2035. Asia will capture 72% of the coal consumption reductions. Non-OECD or Asian countries will hold the key to the global energy system reform.

3-2 Oil supply and demand outlook

3-2-1 Demand

Global oil consumption will increase at an annual rate of 1.2% from 84 million barrels per day

(Mb/d) in 2010 to 114 Mb/d in 2035. Oil will remain the largest energy source, though reducing its share of total primary energy consumption from 35% in 2010 to 32% in 2035.

Oil consumption in OECD countries has been decreasing since 2005. It will further decrease at an annual rate of 0.5% over the next 25 years. All the oil consumption increase through 2035 will originate from non-OECD countries and the international bunkers. Asian oil consumption will expand from 24.1 Mb/d in 2010 to 40.7 Mb/d in 2035 (Fig. 7). About 60% of the global oil demand increase will originate from Asia (where China will account for about 50% of the regional increase and India for about 30%). Asia will expand its share of global oil demand from 31% to 40%. The Middle East will also continue to boost its domestic oil demand rapidly, eclipsing the European Union where demand will decline on energy efficiency improvements around 2030. Oil demand in the Middle East will reach 11.5 Mb/d in 2035.

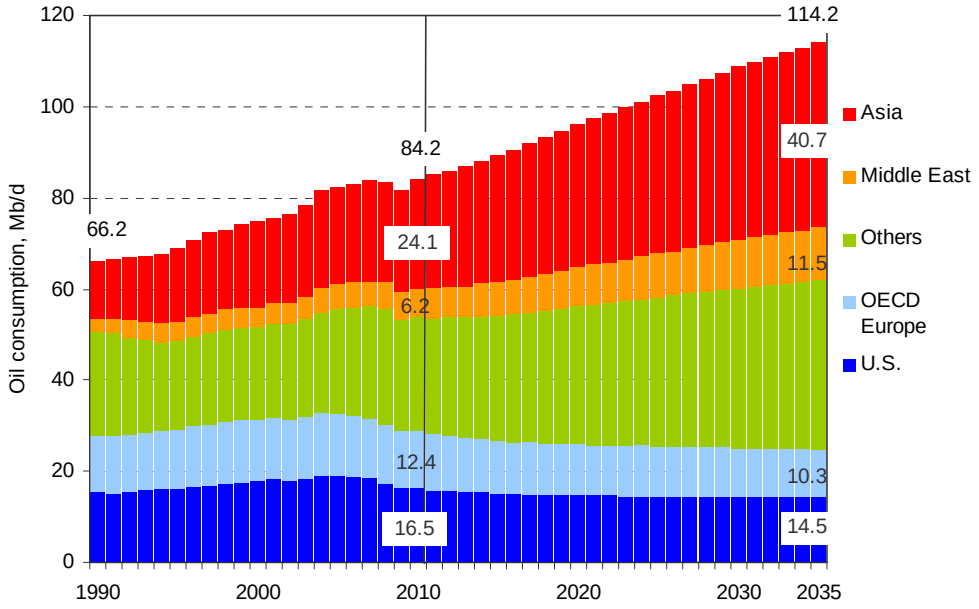

Fig.7 Global oil consumption (by region in the reference scenario).

The largest oil consumption driver will be the transportation sector. Motorization will work as the key driver. The global vehicle fleet will increase from 1.04 billion units in 2010 to1.93 billion units. Non-OECD countries' share of the global vehicle fleet will expand from 33% to 54%. By 2035, non-OECD countries' fleet will surpass OECD countries'. Particularly, non-OECD Asian countries will see rapid progress in motorization thanks to income hikes. The Asian vehicle fleet will increase from 240 million units in 2010 to 690 million units in 2035. China, which has become the world's largest new car market, will expand its vehicle fleet close to or beyond the U.S. fleet that is now the largest. Other non-OECD Asian countries have seen robust vehicle demand, including Indonesia that has the largest population among ASEAN countries and is expected to see its new vehicle annual sales top 1 million units in 2012. Some 60% of the future oil demand

increase will emerge from the transportation sector. Oil demand will concentrate more and more in the transportation sector and the non-energy sector that have less room to replace oil with any other energy source.

In the Advanced Technology Scenario, meanwhile, energy conservation measures are assumed to make great progress, with clean energy vehicles such as hybrid and electric vehicles accounting for 85% of global new vehicle sales in 2035. Oil consumption in 2035 in this scenario will be 15% less than in the Reference Scenario, standing at 97 Mb/d. Asian oil consumption will fall 17% from the Reference Scenario to 33.8 Mb/d and Middle Eastern demand will decline 12% to 10.1 Mb/d. Oil consumption savings will result from the transportation sector's fuel efficiency improvements, the rapid diffusion of alternative-fuel vehicles and an increase in biofuel consumption. Particularly, non-OECD countries, which will remarkably increase oil demand in the Reference Scenario, will make great contributions to energy conservation.

3-2-2 Production

The growth tempo of oil production in non-OPEC oil producers such as Russia and Latin America will slow due to such factors as limited resources and rising costs (Table 3). As a result, OPEC will cover about 70% of the global oil demand increase. OPEC oil output will thus increase to 53 Mb/d in 2035, expanding its share of global output from 41% at present to 46% in 2035. Unless investment is made smoothly in expanding production capacity in OPEC countries, the international oil supplyedemand relationship may tighten. As constraints emerge on access to "easy oil" resources, interests will grow more and more in tight oil, oil sand and other unconventional oil resources distributed in regions where resources development is open.

Table 3 Global oil production.

(Mb/d)

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

3-2-3 Asian oil self-sufficiency rates

In the past in Asia, mainly Indonesia, China and Brunei produced oil and contributed to a higher Asian oil self-sufficiency rate. As production growth failed to catch up with demand growth, however, China turned net oil importer in the first half of the 1990s and Indonesia did so in the early 2000s. The oil self-sufficiency rate fell rapidly from 72% in 2000 to 47% in 2010 for China, from 33% to 26% for India and from 124% to 72% for Indonesia. Among East and Southeast Asian countries, Brunei and Malaysia are now the only net oil exporters. But even in Malaysia, the oil self-sufficiency rate has steadily declined on domestic demand growth, falling from 169% in 2000 to 132% in 2010.

In the Reference Scenario, China's oil demand will increase from 8.8 Mb/d in 2010 to 17.1 Mb/d in 2035 (Fig. 8). Oil demand will expand from 3.3 Mb/d to 7.9 Mb/d for India and from 4.0 Mb/d to 7.8 Mb/d for ASEAN. The fast demand growth will reduce the oil self-sufficiency rate in 2035 to 23% for China, 9% for India and 29% for ASEAN. In the Advanced Technology Scenario, oil production will decline slightly in line with a demand fall, and their oil self-sufficiency rates will thus rise only slightly.

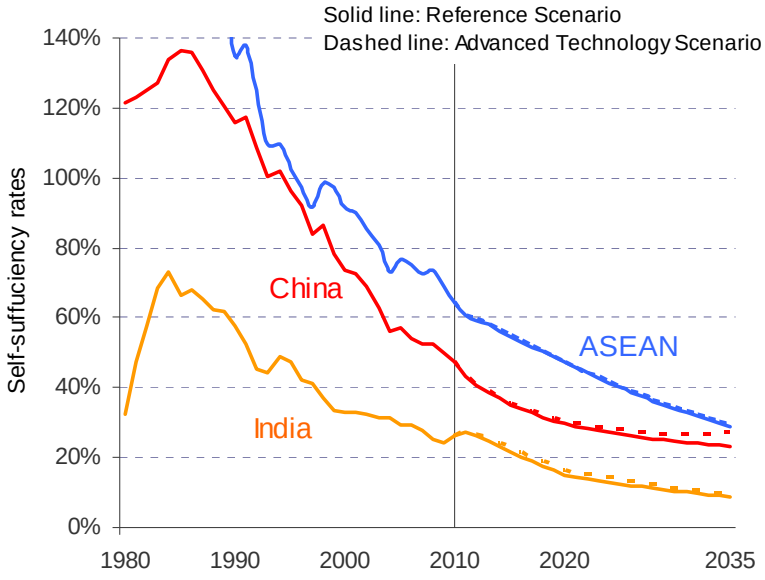

Fig.8 Asian oil self-sufficiency rates (reference scenario).

3-3 Natural gas supply and demand outlook

3-3-1 Demand

Global natural gas consumption will rise at an annual rate of 2.0% from 3,000 billion cubic metres (Bcm; 1 Bcm = 0.9 Mtoe) in 2010 to 5,000 Bcm in 2035 thanks to progress in natural gas utilization technologies and gas's environmental adaptability (Fig. 9). The growth will be the highest among fossil fuels. Accounting for about 50% of the increase is the power generation sector where natural gas combined cycle power generation is expected to increase steadily. China will account for a quarter of the natural gas demand expansion, the rest of Asia for another quarter and

the Middle East for one-eighth. Asian natural gas consumption will triple from 500 Bcm in 2010 to 1430 Bcm in 2035. The power generation sector will account for about 50% of the increase. Covering about 30% of the increase will be residential and other sectors that will expand natural gas consumption in line with progress in urbanization accompanying economic development. North America is the world's largest natural gas consumer at present. Even before 2020, however, Asia will replace North America as the world's largest natural gas consumer. Particularly, China's natural gas demand will expand sharply from 98 Bcm in 2010 to 557 Bcm in 2035 in response to policy-related measures. In India that has shifted away from its policy of using domestic gas output alone for power generation and chemical products production, natural gas consumption will triple from 59 Bcm in 2010 to 179 Bcm in 2035. ASEAN natural gas consumption will increase from 137 Bcm to 344 Bcm.

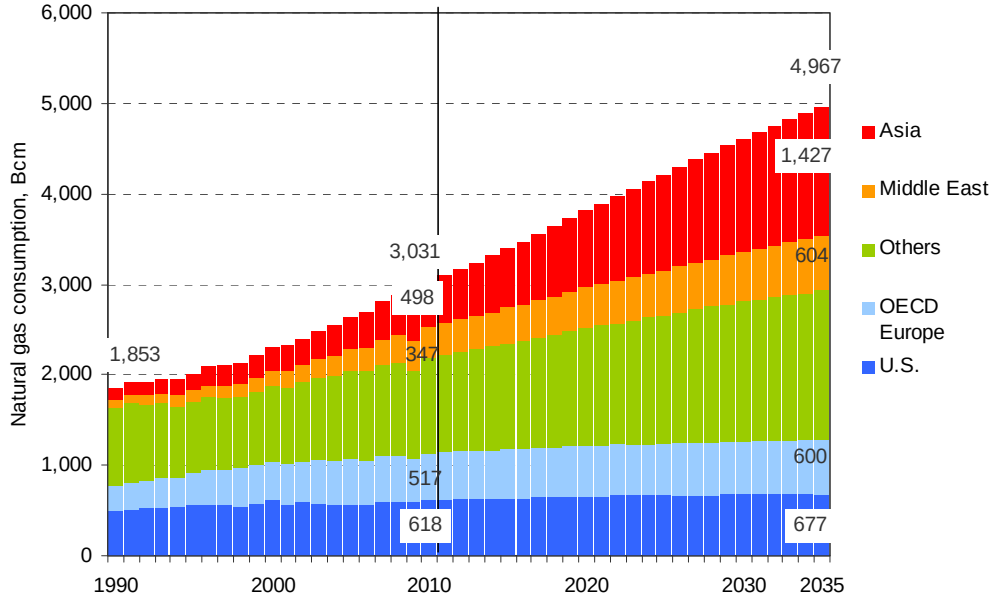

Fig.9 Global natural gas consumption (by region in the reference scenario).

In the Advanced Technology Scenario, natural gas consumption in 2035 will fall 20% from the Reference Scenario to 4000 Bcm due to electricity demand savings, improved power generation efficiency, and a drop in gas consumption for power generation amid a fuel switch.

3-3-2 Production

Natural gas production will increase substantially to meet a rapid increase in demand over the coming 25 years (Table 4). Specific regions where natural gas output will substantially increase include Qatar that has completed a large gas liquefaction plant, the FSU region that attempts to expand gas output for exports in Eastern Siberia and the Caspian Sea area, and Africa where many new natural gas fields have been discovered. In China, where demand will rise most rapidly,

although a substantial production expansion can be expected, the domestic output alone may fall short of meeting all of its demand. Australia is planning many natural gas production and liquefaction projects to become a key LNG supply source for Asia, although its planned output expansion slips below production increases expected in the abovementioned regions.

Table 4 Global natural gas production.

(Bcm)

	2011	Reference Scenario			Advanced Technology Scenario		
		2020	2035	2011-2035	2020	2035	2011-2035
Total	3,216	3,819	4,967	1,751	3,517	3,963	747
North America	763	860	950	187	810	760	-3
Latin America	203	250	350	147	220	250	47
Europe	302	244	285	-17	230	230	-72
FSU	785	855	1,120	335	847	950	165
Middle East	472	580	830	358	525	610	138
Africa	209	350	452	243	285	377	168
Asia Oceania	482	680	980	498	600	786	304
China	93	170	300	207	160	250	157
India	52	63	98	46	55	80	28
ASEAN	214	255	313	99	245	270	56
Indonesi	80	105	143	63	95	115	35
Malaysia	61	70	75	14	65	70	9
Australia	55	120	170	115	110	130	75

3-3-3 Asian natural gas self-sufficiency rates

China had been almost self-sufficient in natural gas until 2005 when it began to expand its net import position. In the five years to 2010, China's self-sufficiency rate in natural gas dropped to 87%. India began to import natural gas in 2003. Its self-sufficiency rate in 2010 fell to 80%. As demand for natural gas is expected to expand, as a clean energy source replacing coal, India is set to increase natural gas imports rapidly. ASEAN countries with abundant domestic gas resources have continued to export LNG to Japan and South Korea. In 2011, Malaysia accounted for 19% of Japan's LNG imports, Indonesia for 12% and Brunei for 8%. The three countries alone cover nearly 40% of Japan's LNG imports.

Even in ASEAN countries, however, domestic natural gas demand is increasing sharply. Their export capacity is declining. In the whole of ASEAN, the natural gas self-sufficiency rate dropped from 238% in 1990 to 183% in 2000 and 145% in 2010.

China's natural gas self-sufficiency rate will fall to 54% by 2035, despite its substantial output expansion (Fig. 10). The rate for India will also drop to 55%. While India has been expected to considerably expand gas use, we have taken the expansion into account insufficiently in the Reference Scenario and sufficiently in the Advanced Technology Scenario. Therefore, India's estimated natural gas demand in the Advanced Technology Scenario exceeds that in the Reference Scenario, resulting in lower self-sufficiency rate. Special attention should be paid to ASEAN's natural gas selfsufficiency rate. As noted above, the rate has historically continued to decline. In our estimation, the rate is projected to slip below 100% around 2030. ASEAN will thus become a

net natural gas importer. This change will be significant for global LNG supply and demand. East Asia now importing LNG from ASEAN will have to procure additional LNG from other regions such as the Middle East, Russia and Australia, while ASEAN countries will also have to import massive quantities of LNG.

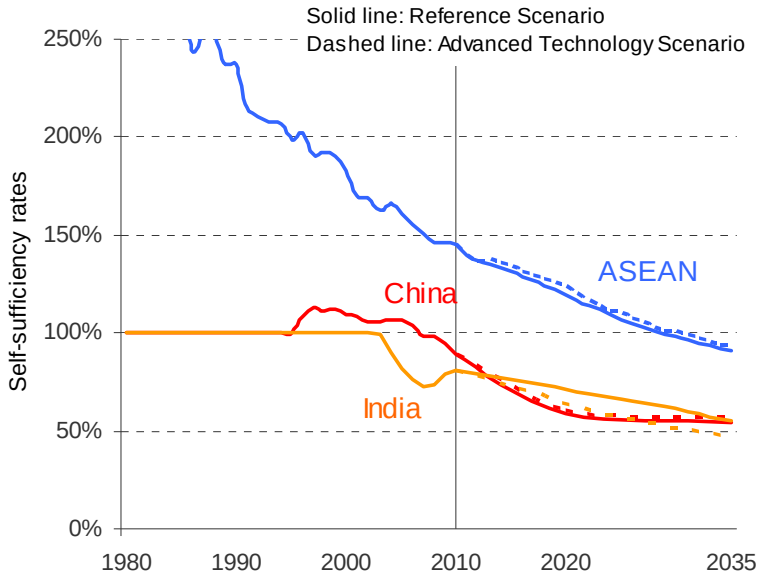

Fig.10 Asian natural gas self-sufficiency rates (reference scenario).

3-4 Coal supply and demand outlook

3-4-1 Demand

Global coal consumption will increase at an annual rate of 1.4% from 5,000 million tons of coal equivalent (Mtce) in 2010 to 7000 Mtce in 2035 (Fig. 11). Asia will account for about 90% of the global coal consumption increase. China will account for 40% of the global increase. As OECD countries reduce coal consumption, non-OECD countries will be responsible for the entire global increase in the coming 25 years. Non-OECD countries' share of global coal consumption will rise from 69% in 2010 to 78% in 2035. Of the 2000 Mtce consumption increase through 2035, 1600 Mtce will emerge from the power generation sector. Asia will account for 90% of the sector's coal consumption growth.

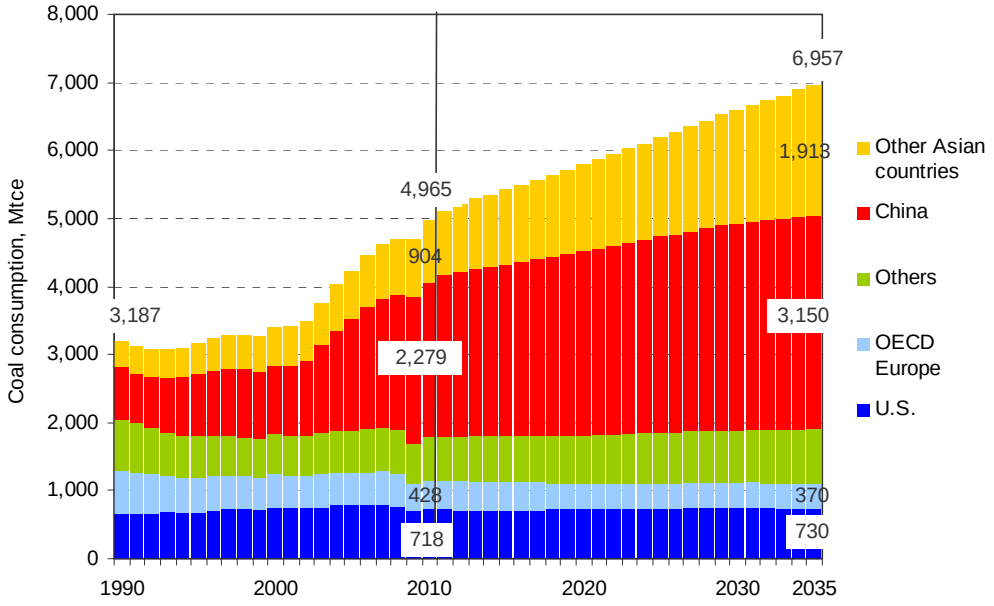

Fig.11 Global coal consumption (by region in the reference scenario).

In the Advanced Technology Scenario, coal consumption in the mid-2020s will fall to the 2010 level. Consumption in 2035 will fall to 4700 Mtce, 33% less than in the Reference Scenario and 6% less than in 2010. Asian coal consumption in 2035 will decline 33% from the Reference Scenario to 3400 Mtce, with the decline centering on the power generation sector. As in the case of natural gas, the coal consumption decline will mostly emerge from the power generation sector that will improve the thermal efficiency of coal thermal power plants and switch from coal to other fuels.

3-4-2 Asian coal self-sufficiency rates

In Asia, coal resources are more abundant than oil or natural gas resources. In China, for example, output has so far expanded to meet demand growth. Depending on prices, a substantial output expansion could be implemented in the future. Even in the Reference Scenario, China will be able to balance coal supply with demand while maintaining its coal self-sufficiency rate at around 95%. In the Advanced Technology Scenario, coal demand will decline due mainly to thermal efficiency improvements and a switch from coal to natural gas in the power generation sector, allowing China to become a net coal exporter again in 2035. Coal resources in India are also abundant, but as the rise in production failed to catch up with the demand increase due to quality and productivity problems over recent years, India has expanded imports. While demand will increase further, the government's coal production expansion policy will allow India's coal selfsufficiency rate to limit its fall from the present level of 85% to a small level. In the ASEAN region, Indonesia has taken advantage of cheap costs to substantially increase coal production and exports since the 1990s, contributing to boosting ASEAN's coal self-sufficiency rate to 260% in

2010. But it will be difficult for Indonesia to expand coal exports further as its domestic demand increases. As demand increases not only in Indonesia but also in other ASEAN countries, the region's coal self-sufficiency rate will fall gradually. Even in 2035, however, the rate will still exceed 100%.

Given the above estimates, Asia's coal self-sufficiency rate will remain higher than the oil or natural gas self-sufficiency rate (Fig. 12). Asian countries will continue to use coal over a long term from the viewpoint of not only lower prices but also energy security.

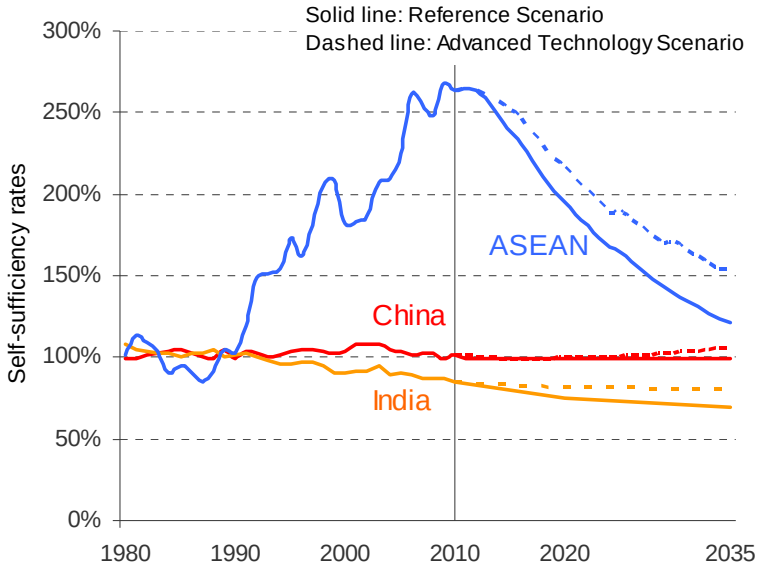

Fig.12 Asian coal self-sufficiency rates (reference scenario).

3-5 Non-fossil energy

3-5-1 Nuclear

The Fukushima Daiichi nuclear power station accident has directly affected nuclear energy policies not only in Japan but also in other countries including some European nations, leading them to withdraw from their dependence on nuclear energy. But the United States, France, Russia and South Korea, which have proactively promoted nuclear power generation, and emerging countries such as China and India have refrained from changing their respective nuclear promotion policies from such perspectives as stabilizing energy supply, addressing global environmental problems and fostering domestic nuclear industries to maintain and enhance international competitiveness.

Before the Fukushima accident, China was operating 13 nuclear reactors with a total capacity of 10.85 GW while constructing 30 reactors with a total capacity of 33 GW tripling the capacity in operation. From now on, China will expand nuclear power generation capacity most rapidly in the world. India has implemented its thorium cycle development using domestic resources and plans to introduce massive light-water reactors from abroad. Seven reactors have already been under construction.

In Southeast Asia, such countries as Vietnam, Thailand, Malaysia, Indonesia and the Philippines are considering introducing nuclear energy. While Vietnam has been proceeding with two nuclear power station construction plans in cooperation with Japan and Russia and has made no change to its proactive nuclear energy introduction policy, the others have suspended nuclear energy introduction plans. In the Middle East, the UAE has already launched new nuclear power plant construction. Saudi Arabia has put forward a plan to build 16 new nuclear reactors by 2030. New nuclear plant construction plans are thus being implemented in the Middle East, though with some delays being expected.

3-5-2 Renewable energy

Great expectations are placed on photovoltaic, wind and other renewable energy-based power generation. Some regions haveaccelerated their renewable energy diffusion, supported by rich resources and incentives for introducing renewable energy. Due to high costs as well as supply that depends on natural conditions and is unstable, however, renewable energy has fallen short of becoming a mainstay energy source as important as fossil resources on a global basis.

Introducing renewable energy can contribute to reducing carbon emissions from electricity sources, lower dependence on overseas energy resources and hold down fossil fuel price hikes. In order to diffuse renewable energy substantially, research and development operations must be continued to lower costs, increase power generation efficiency and harmonize renewable energy with energy systems.

Mainly Europe has begun to diffuse PV (Photovoltaics) power generation very rapidly, allowing the relevant global market to continue expanding. Behind the rapid diffusion are government incentives. As costs fall gradually on the market expansion and technology development, the PV power generation diffusion is expected to make progress in a full-blown manner. Although economic efficiency problems are now serious for PV power generation, PV systems can become useful energy sources for non-OECD countries as well as depopulated areas in OECD countries.

Wind power generation costs less than PV generation and has diffused smoothly throughout the world, particularly in Europe. Through 2035, European nations such as Germany, Spain and Denmark will diffuse wind power generation systems including offshore systems. In Asia, wind power generation is expected to increase mainly for China and India.

Geothermal power generation has diffused in the Unites States and other countries located close to volcanic zones. In Asia, geothermal power generation is expected to diffuse for such countries as the Philippines, Indonesia and Japan. In Japan, for example, existing geothermal power plants are estimated to cost less than fossil thermal power plants [20]. Although there are constraints on geothermal plant locations, Japan is expected to promote geothermal power generation as much as possible.

Table 5 gives an outlook for nuclear and renewable energy-based power generation.

Table 5　Nuclear and renewable energy power generation outlook.

	Nuclear			Photovoltaics			Concentrated Solar Power			Wind			Geothermal			Biomass		
Capacity, GW	2010	2035 Ref.	2035 Adv.	2010	2035 Ref.	2035 Adv.	2010	2035 Ref.	2035 Adv.	2010	2035 Ref.	2035 Adv.	2010	2035 Ref.	2035 Adv.	2010	2035 Ref.	2035 Adv.
North America	118.6	129.2	135.6	2.7	64.2	179.6	0.3	23.6	50.2	44.2	188.4	353.6	3.1	8.3	15.4	16.4	42.2	46.5
Latin America	4.4	10.6	16.7	0.1	2.3	6.8	0.0	0.0	0.0	2.0	18.1	32.6	1.5	9.1	17.6	8.7	22.6	25.5
Asia	85.7	223.0	347.1	5.5	161.3	420.6	0.0	5.9	9.9	47.3	360.4	659.5	3.7	13.4	23.3	11.7	45.2	53.6
Middle East	0.0	13.3	30.6	0.1	4.0	25.0	0.0	2.9	6.8	0.1	1.0	2.4	0.0	0.0	0.0	0.0	0.2	0.2
Europe	141.3	118.0	145.4	29.8	260.1	586.2	0.3	11.1	11.4	86.6	242.5	378.0	1.5	5.5	10.5	31.0	78.6	83.9
FSU	37.4	73.6	94.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	20.5	39.9	0.1	0.5	1.0	0.7	7.8	9.2
Africa	1.9	4.1	8.7	0.2	12.8	43.5	0.0	7.2	15.4	1.0	6.3	11.0	0.2	1.1	2.1	0.2	1.7	1.9
Oceania	0.0	0.0	0.0	0.6	20.3	40.8	0.0	0.0	0.0	2.4	21.6	29.0	0.6	1.0	1.0	1.8	4.6	5.1
Total	389.3	571.8	778.1	38.9	525.1	1,303	0.6	50.8	93.7	183.7	858.8	1,506	10.7	38.9	70.9	70.5	202.8	225.9
Electricity output, TWh																		
North America	930	1,006	1,056	3	76	214	1	62	132	105	446	838	18	47	88	84	216	238
Latin America	28	74	117	0	2	5	0	0	0	4	40	71	10	61	117	45	117	132
Asia	582	1,627	2,482	6	168	435	0	16	26	70	599	1,090	22	88	158	48	162	193
Middle East	0	93	214	0	4	26	0	8	18	0	2	4	0	0	0	0	0	0
Europe	943	804	1,001	22	182	383	1	29	30	153	426	660	11	41	78	140	356	381
FSU	262	504	642	0	0	0	0	0	0	0	41	80	1	3	6	3	41	49
Africa	12	26	55	0	5	13	0	19	40	2	16	28	1	9	17	1	9	10
Oceania	0	0	0	0	10	20	0	0	0	6	57	78	6	9	9	5	11	13
Total	2,756	4,134	5,568	32	446	1,095	2	134	246	342	1,628	2,850	68	258	473	326	912	1,015

3-6　Oil and natural gas trade balance

3-6-1　Oil

As explained above, Asia will expand oil and natural gas imports substantially to greatly influence global fossil fuel supply and demand conditions. Net oil imports in 2035 (in the Reference and Advanced Technology Scenarios) are indicated in Fig. 13.

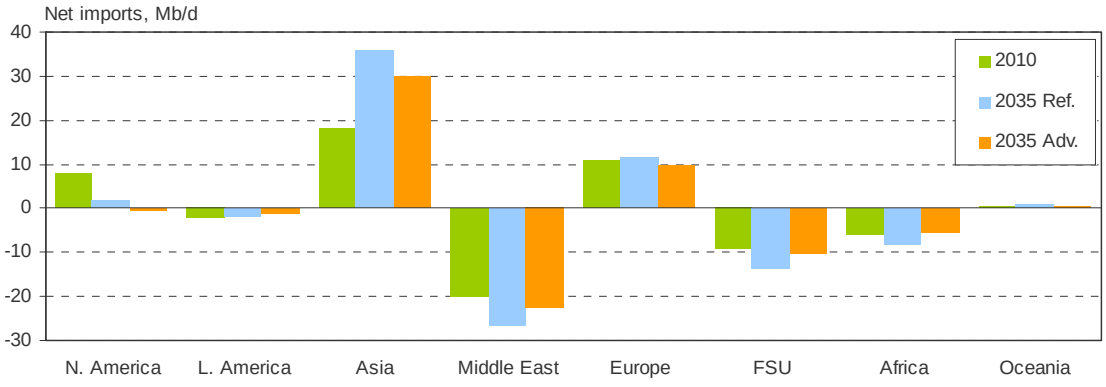

Fig.13　Net oil imports.

Net oil imports total 8 Mb/d in North America, 11 Mb/d in Europe and 18 Mb/d in Asia. Oil exporters to them include the Middle East, the FSU region and Africa. Although the United States is currently the world's largest net oil importer, oil demand in North America began to decrease after a peak in 2005 and is expected to continue a downward trend due to such factors as the effect

of fuel efficiency regulations. On the other hand, after years of inexorable declines in crude oil production, the United States suddenly experienced a surge in production since 2009. The surge is almost entirely because of the increase in the production of tight oil. U.S. EIA forecasts tight oil production at two million b/d in 2035, accounting for one third of total oil production [21]. Oil independence in North America is possible if and only if a massive increase in production, as well as a drastic reduction in demand, is achieved in the coming decades. Net oil imports in 2035 will decline from 6 Mb/d at present to 2 Mb/d in the Reference Scenario. In the Advanced Technology Scenario, North America will post net oil exports amounting to 0.6 Mb/d. It is not likely that oil exports from North America to Asia will compete with those from the Middle East in the next few decades.

Oil demand has continued declining since 2005 in Europe as well as in the United States. As local production decreases on the North Sea oilfields' erosion and other factors, Europe's net oil imports will remain almost unchanged from the present level (increasing slightly in the Reference Scenario and decreasing slightly in the Advanced Technology Scenario). As in the past, Europe will import oil mainly from the FSU region.

Unlike North America and Europe, Asia will expand net oil imports to 36 Mb/d in 2035 in the Reference Scenario and 30 Mb/d in the Advanced Technology Scenario. The rate of dependence on imports will rise from 77% to 88% in the Reference Scenario. In both scenarios, imports will increase substantially from the present level and Asia's remarkable expansion of oil imports will dramatically change the global oil market. Given its capacity to expand oil production, the Middle East is expected to increase oil output more than any other region to meet a rise in Asian oil imports. In the Reference Scenario, the Middle East will cover half of the Asian net oil import increase of 18 Mb/d. Asian countries will be required to procure more oil from not only the Middle East but also from other regions. China has already been constructing international oil pipelines from neighboring countries including FSU nations and making efforts to acquire oil interests in Africa and other foreign countries. It has taken various measures to secure oil resources and is expected to increase this tendency. As a result, the Middle East's share of Asian oil imports will fall from 77% at present to 65% in 2035. Its share of Asian oil consumption will decline from 60% to 57%. Nevertheless, it will become even more important for Asia to enhance its relationship with the Middle East in order to promote Asian energy security.

Meanwhile, the Middle East cannot expect to expand exports to Europe. Its exports to North America are set to decline rapidly. The region will cover the decline with an increase in exports to Asia. Asia now purchases 75% of crude oil exports from the Middle East. In the future, the Middle East will increase exports only to Asia, boosting Asia's share of Middle Eastern oil exports to 87% in the Reference Scenario in 2035. Asia will thus grow more important as a trading partner for the Middle East.

Fig. 14 shows net oil imports to selected Asian and Middle Eastern countries in 2035 in the Reference Scenario. Massive increase in oil import is expected, especially in China and India, which together account for 60% of total net oil imports to Asia. Indonesia, with its rapidly growing domestic demand, will also emerge as a large importer of oil. The five largest importers including

Japan and South Korea account for 80% of the total Asian imports. On the other hand, increase in net oil exports is expected, especially in Saudi Arabia, Iraq, United Arab Emirates and Kuwait. Net oil exports from these four countries are expected to increase by 10 million b/d by 2035. Special attention should be paid to Iraq, where oil producing capacity will expand the most rapidly according to the government's strategy to enhance oil exports. Iraqi oil industry, however, is facing difficulties such as delays in infrastructure improvements, and how to resolve these difficulties will be an important issue for the stability of Asian and global energy markets.

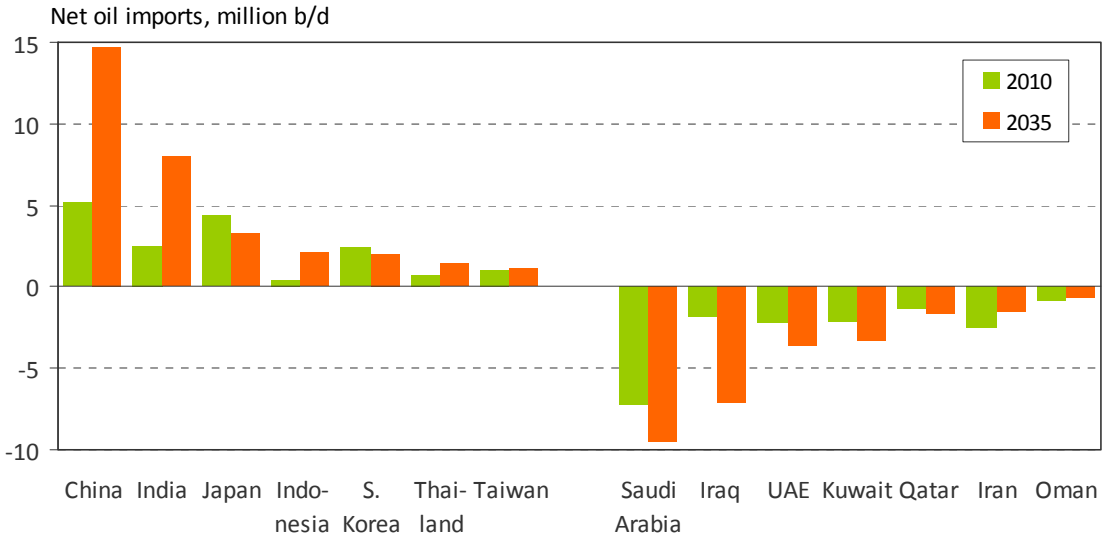

Fig.14 Net oil imports to selected countries (reference scenario, 2035).

3-6-2 Natural gas

Natural gas demand will also expand mainly in Asia. How to cover the Asian demand increase will be an important issue for balancing future global supply and demand. Asia's natural gas imports will increase from 101 Bcm in 2010 to 617 Bcm in 2035 in the Reference Scenario and 495 Bcm in the Advanced Technology Scenario (Fig. 15). As is the case with oil, Europe's natural gas imports will increase slightly from the present level in the Reference Scenario and decrease slightly in the Advanced Technology Scenario. North America will dramatically expand exports mainly due to growing unconventional natural gas output (shale gas) in both scenarios.

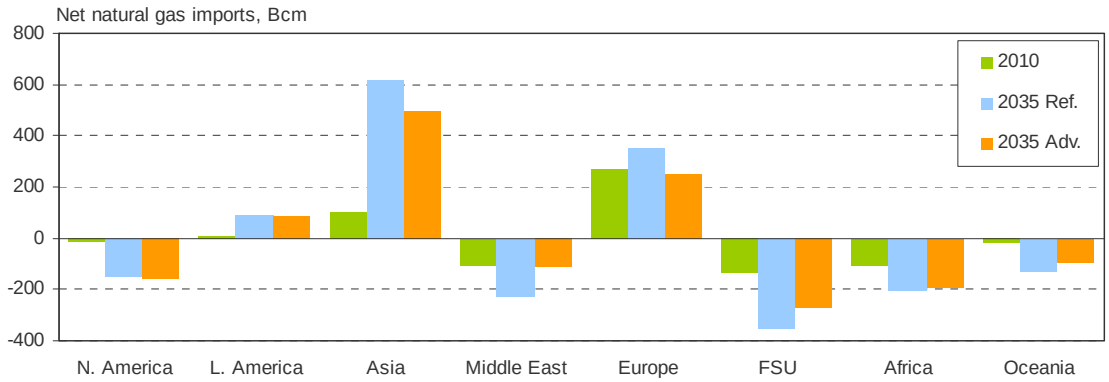

Fig.15 Net natural gas imports.

The natural gas case's largest difference with the oil case is that while Asia's natural gas import expansion is far more remarkable than its oil import growth, not only the Middle East but also many other regions such as the FSU region, Australia, Africa and North America are ready to expand gas exports to Asia. The Middle East exported 50 Bcm of natural gas to Asia in 2010, accounting for 52% of Asian natural gas imports. In line with a sharp demand increase, Asia will expand natural gas imports from the Middle East to 180 Bcm. As Asia diversifies its natural gas supply sources, the Middle East's share of Asia's imports will drop to 30%. On the contrary, Asia's share in the Middle East's exports will rise from 45% in 2010 to as high as 80% in 2035 in the Reference Scenario. The growth of Asian demand for natural gas will be crucial for the Middle Eastern natural gas exporting countries.

Natural gas production will expand drastically in Qatar and Iraq. In the Reference Scenario, net natural gas exports from Qatar increase from 123 Bcm in 2011 to almost 200 Bcm in 2035. But in the Advanced Technology Scenario, natural gas exports from Middle Eastern countries, including Qatar, will not increase considerably from the 2010 level because the Middle East will face severe competition from other exporting regions including North America, the FSU and Oceania.

Fig. 16 shows net natural gas imports for selected countries in 2035 in the Reference Scenario. Although natural gas demand shows the most rapid increase in China and in India, LNG demand in 2035 is as large or more in Japan and in South Korea, because massive pipeline imports from their neighbors cannot be expected. Japan will continue to be the largest importer of LNG as a result of the nuclear policy changes that followed the Fukushima accident. In the Reference Scenario, it is assumed that no new NPP construction will take place by 2035, and the existing NPPs will be retired after 40 years of operation. Another difference from the oil case is the net export position of Indonesia, where future resource developments will enable the country to sustain its exports of natural gas, unlike other ASEAN countries such as Thailand.

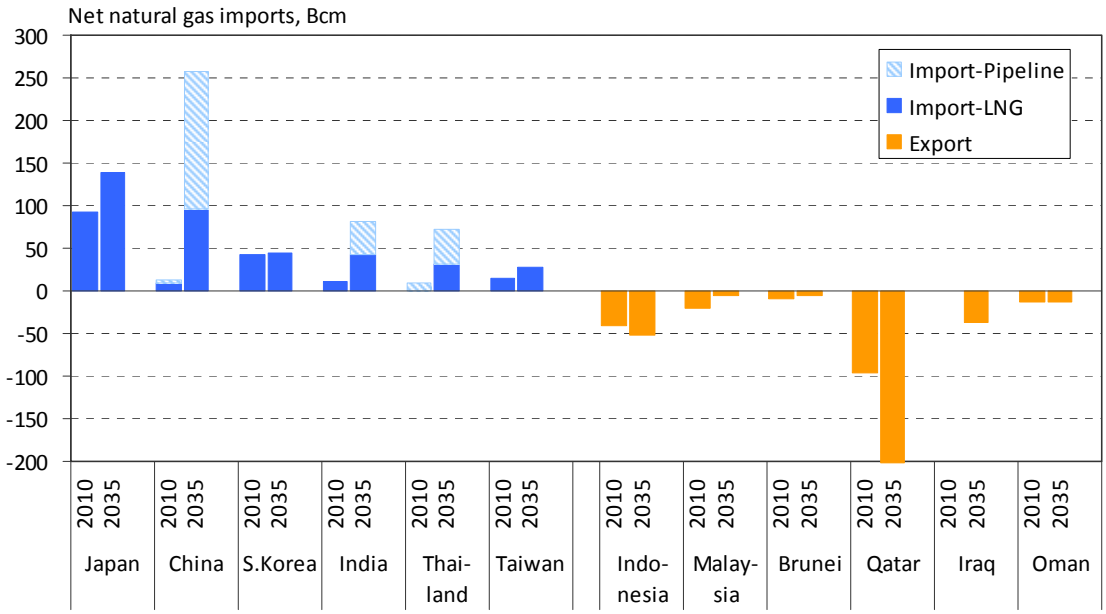

Fig.16 Net natural gas imports to selected countries (reference scenario, 2035).

Qatar is by far the largest natural gas exporter in the Middle East and will remain so until 2035. As in the case of oil, Iraq has the potential to expand natural gas production to become a large exporter.

In this study, shale gas production of 15.3 Tcf (430 Bcm) in 2035 is assumed in the United States, following U.S. EIA [21]. This results in massive natural gas exports from North America to Asia in the short term, but they are not sufficient to meet the growing demand in Asia, because demand for natural gas is also expanding in North America due to the relatively low prices. Another important issue for the global natural gas market is the shale gas development in China. The Chinese government aims to produce 100 Bcm of shale gas per year by 2020, although it will be difficult to meet this target because of the nation's complicated geology, scarce water resources and lack of foreign participation. Thus, in this study the shale gas production in China is assumed to be 10 Bcm in 2020 and 85 Bcm in 2035. Shale gas produced in China, if ever, will be consumed domestically, and will not be exported to other Asian countries. If the increase in shale gas production exceeds what has been assumed in our analysis, it would cause a smaller demand for LNG in China and lower LNG prices in the Asian market.

3-6-3 Need of economic diversification

Fig. 17 and Table 6 shows the fossil fuel export revenue of each country as a share of GDP, in 2011 real prices. In Table 6, we simply assumed the same percentage as the share of the exports to Asia in the total exports in 2035 (87% for oil and 80% for natural gas, as described above) to calculate the value of fossil fuel exports to Asia.

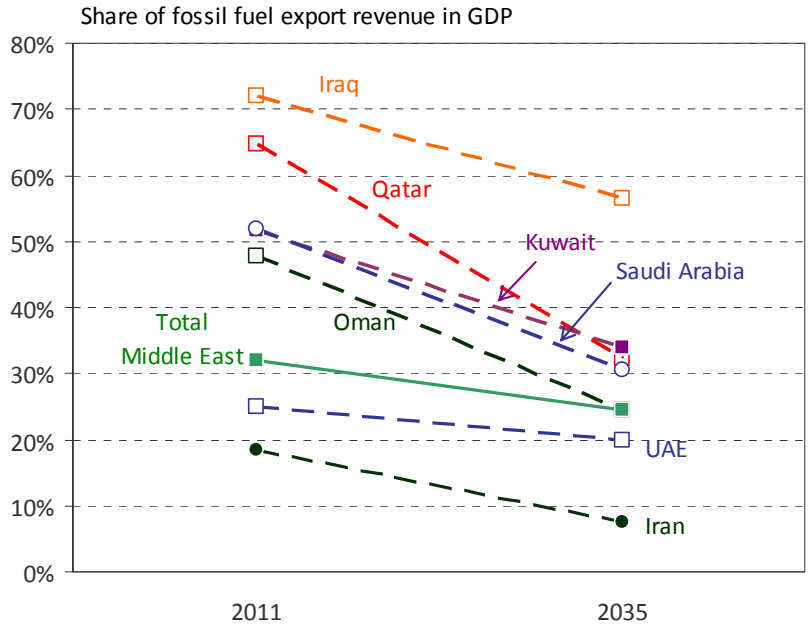

Fig.17 Fossil fuel export revenue as a share of GDP (reference scenario).

Table 6 Fossil fuel export revenue as a share of GDP (2035, reference scenario).

	Oil exports	Natural gas exports	Fossil fuel exports (oil + gas)	Fossil fuel exports to Asia
Saudi Arabia	31%	-	31%	27%
Iraq	53%	3%	56%	49%
Qatar	13%	19%	32%	27%
UAE	20%	-	20%	17%
Kuwait	34%	-	34%	30%
Iran	8%	-	8%	7%
Oman	20%	5%	24%	21%
Middle East	22%	2%	24%	21%

Natural gas exports account for more than half of the total fossil fuel export amount in Qatar and one fifth in Oman, whereas in other countries the majority of the export revenue comes from crude oil exports. The share of fossil fuel exports, and thus the economic dependence on exports to Asia, is especially high in Iraq, Qatar, Kuwait and Saudi Arabia, where the diversification of their economy should be regarded as an urgent issue. In Saudi Arabia, for example, the Ninth Development Plan (2010-2014) targets the growth of non-oil exports at an average annual rate of 10%, much higher than the growth of overall exports of goods and services at 4.5%, and increase the share of non-oil exports to 23.7% by 2014 [22]. Our study assumes that due to these efforts, the fossil fuel export share in total GDP will decline from 52% in 2011 to 31% in 2035 in Saudi Arabia. Without the success of these efforts to diversify the revenue structure, it will be difficult for fossil fuel exporting countries to continue the high economic growth experienced in recent years.

We must also pay attention to the oil and natural gas shares in Table 6, because high natural gas export share means economic fragility in the following two senses. First, natural gas exports to Asia will face competition with other regions such as North America. Second, LNG exports are more focused than crude oil exports on Japan and South Korea, where the changes in nuclear policies can greatly affect the LNG demand. Even if the LNG exports to Asia increase as a result of growing demand, the prices can decline due to competition or some other factors. The current LNG prices to Asia are much higher than the natural gas prices in Europe and in North America. In this perspective, Qatar which is heavily dependent on natural gas exports, and Oman which is aiming to expand natural gas exports instead of crude oil exports, should be regarded as more in urgent need of diversification than the other Middle Eastern countries. The fact that these two countries show steeper decline in Fig. 17 also means that they need diversification for future economic development.

Thus, Asia needs the diversification of energy supply for its energy security, whereas the Middle East needs the diversification of the economic structure for its sustainable growth. Nevertheless, the interrelationship between the two regions will become more and more important in the long term. Even if the Middle Eastern countries succeed in keeping a high economic growth, the fossil fuel export revenue of the total Middle East would still account for 24% of the total GDP in 2035. Both oil and natural gas exports from the Middle East to Asia will increase, leading Asia to capture most of the Middle East's fossil fuel exports. Oil and natural gas exports from the Middle East to Asia in value (in 2010 dollars) will expand from $400 billion in 2010 to $1.0 trillion in 2035 in the Reference Scenario. The share of these exports in GDP will rise from 21% to 24%. Thus, the relationship with Asian countries as major fossil fuel importers will become more important over the long term.

4. Conclusion

In this study, we used a set of quantitative analysis models, including econometric-type demand forecast models and bottom-up type technology assessment models, to estimate energy demand in Asia and other regions of the world through 2035 and assessed future fossil fuel supply and demand. Over a medium to long term, global energy demand will increase, with growth concentrating in Asia, particularly non-OECD Asian nations such as China, India and ASEAN countries. How to address a sharp future increase in energy demand will become an increasingly important challenge for Asian countries. These countries have promoted renewable energy and nuclear power as well as energy conservation. As indicated by this study, however, they are set to expand fossil fuel demand despite their maximum efforts to diffuse non-fossil energy. Cheap and abundant coal resources hold the key to securing a higher energy self-sufficiency rate for Asia. But Asia has refrained from depending excessively on coal in consideration of limits on coal reserves and output as well as the problem of NO_x, SO_x and CO_2 emissions. Therefore, it will be indispensable for Asian countries to expand oil and natural gas imports from the rest of the world.

Since the oil crises in the 1970s, Asia has always recognized its excessive dependence on energy sources from the Middle East as dangerous. Therefore, Asian countries will try to diversify energy supply sources in consideration of their energy security in expanding fossil fuel imports. As for natural gas, particularly, Asia will try to expand imports from Australia, the FSU region, Africa and North America as well as the Middle East. Regarding oil, however, Asia has no choice but to expand oil imports from the Middle East considerably. In this sense, Asia will inevitably become more dependent on the Middle East over the long term. By 2035, China and India will become by far the largest importers of oil due to the rapid increase in demand. Indonesia will also emerge as a new large crude oil importer. But in the case of LNG, Japan will remain the largest importer and South Korea will be the third largest after China, because these countries will be more dependent on LNG than on pipeline imports.

Although the fossil fuel trade between the Middle East and Asia will increase, the Middle East's share of Asian total imports will decline from 77% in 2010 to 65% in 2035 for oil, and from 52% to 30% for natural gas. While North America is going in the direction of energy self-sufficiency and no large growth in European demand is expected, Asia's presence will grow as the major fossil fuel export destination. Thus, Asia's share in the Middle East's exports will rise from 75% to 87% for oil, and from 45% to 80% for natural gas.

In this context, the Middle Eastern countries should recognize the great economic risk of their high dependence on fossil fuel export revenue and measures should be taken to alleviate it. Even though fossil fuel prices are expected to rise and exports to Asian countries are expected to increase, fossil fuel exports alone cannot sustain the high economic growth that the Middle Eastern countries experienced in recent years. Thus, maximum efforts to diversify the economic structures are indispensable for the Middle Eastern hydrocarbon exporting countries. This is especially true for the LNG exporting countries such as Qatar and Oman, because of the risks related to LNG exports as mentioned above. Without the success of these efforts, it will be difficult for those countries to continue to expect high economic growth.

Asia needs the diversification of energy supply for its energy security, while the Middle East needs the diversification of the revenue structure to avoid economic crisis. Nevertheless, the interrelationship between the two regions will become more and more important. In order to secure energy supply, Asia must encourage the Middle East to appropriately invest in oil resources development. By doing so, Asia will increase its contributions to the Middle East's fossil fuel exports, inevitably exerting greater influences on national finance in Middle Eastern countries.

While continuous investment in developing fossil fuel resources in the Middle East will be indispensable for Asia, prospects for stable, continuous demand are required for resource-rich countries in the Middle East to continue an appropriate level of investment. To this end, Asia and the Middle East must share a common vision of future energy supply and demand, and recognize the importance of a sustained resource development. In order to continuously enhance the mutual understanding over a long term, the two regions should seek to further deepen their interrelationship, through bilateral cooperation in fostering industries, developing human resources, promoting technical assistance, etc.

Our future work will include the estimation of impacts of energy policies and technology options. As stated above, Asian and Middle Eastern countries are promoting various kinds of energy policies such as diffusing nuclear power, renewable energy and energy saving technologies. Some of the technologies have a large room for diffusion with relatively low costs, while others do not. Thus, it would be important to estimate the potentials, costs and benefits of various technologies and economic impacts of energy policies in long-term perspectives as presented in this study.

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