Chapter 2

Review of the First Study

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Chapter 2

Review of the First Study

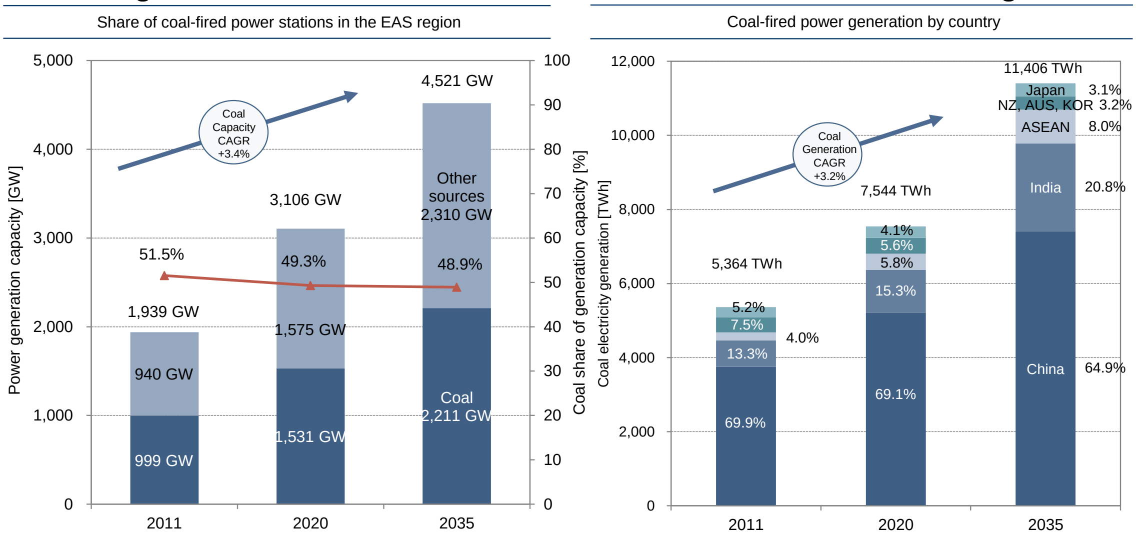
This chapter is a review of the first-year study. However, data is updated based on latest trends.

2-1. The Importance of Coal in the East Asia Summit Region

2-1-1. The trends of energy demand and the political positioning of coal

In the EAS region where economic development and growth have been remarkable, demand for electricity is forecasted to increase substantially, half of which will be met by coal-fired power generation as shown in Figure 2-1. In particular, coal-fired power generation has vastly increased in China and India, and future increases are also forecasted in the Association of Southeast Nations (ASEAN) region. As coal is priced lower compared to petroleum and natural gas, demand for coal is therefore expected to continue increasing from an economic point of view.

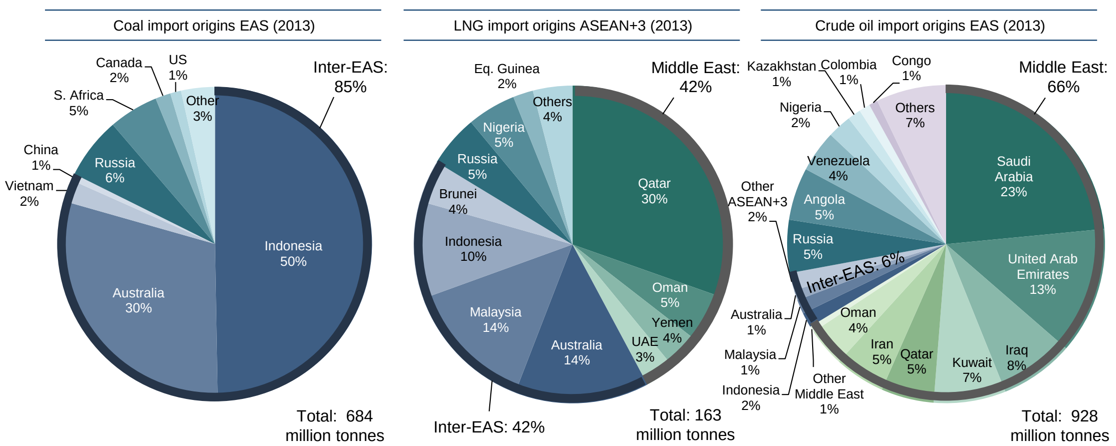
Figure 2-1. Estimate of Coal-Fired Power Plant in the East Asia Summit Region



Note: ASEAN values refer to new policies scenario. All other values are taken from the reference scenario.
Sources: International Energy Agency (IEA) (2013), *World Energy Outlook Special Report: Southeast Asia Energy Outlook*.

As such, coal has become an important energy source in the EAS region. Petroleum and natural gas are also produced in the region and will remain important energy sources in the future. Figure 2-2 shows the origin of primary energy import in the EAS region where 42 percent of liquefied natural gas (LNG) consumed is produced within the region whereas 42 percent is imported from the Middle East. A mere 6 percent of the petroleum consumed is regionally produced with 66 percent being imported from the Middle East. In contrast, coal produced in the EAS region constitutes 85 percent of the total coal consumption in the region. All these data indicate that coal, mainly produced and consumed within the region, is not dependent on the Middle East as petroleum and natural gas are. In view of political uncertainties in the Middle East, which may raise concern over transportation security at strategic pathways such as the Strait of Hormuz, coal will be of further significance in the energy security context as well.

Figure 2-2. Origin of Primary Energy Imports in the East Asia Summit Region



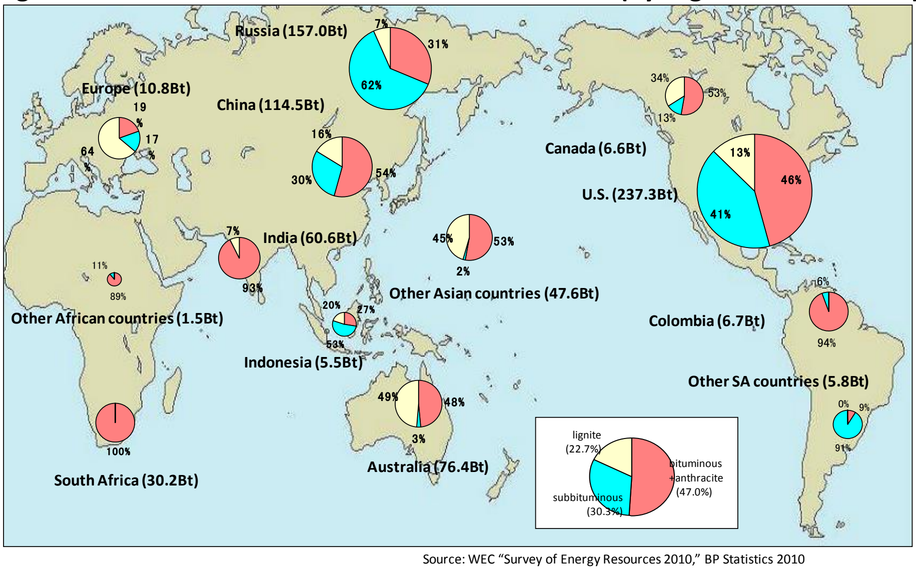
Sources: International Energy Agency (IEA), Coal Information; International Group of Liquefied Natural Gas (GIIGNL) Importers; and International Trade Centre (ITC) Trade Map.

2-1-2. Features of coal resources and their importance

(1) Coal resources

In global coal reserves, high-rank coals such as bituminous coal and anthracite that are used as cooking coal and steam coal make up around 47 percent of the reserves whereas low-rank coals constitute about half of the overall coal reserves with 30 percent sub-bituminous coal and 23 percent lignite. Figure 2-3 shows the world's mineable coal reserves by region and by coal rank. Unlike other energy sources, coal is distributed widely but unevenly throughout the world. Coal reserves are large in Oceania and in Asia, and the proportion of their lignite reserves is high. Even in the world's largest steam coal exporter Indonesia, which exports mainly to Asian countries, the amount of its bituminous coal reserves is only 27 percent of total reserves and thus its exports of sub-bituminous coal are increasing.

Figure 2-3. Recoverable Coal Reserves in the World (by region and coal rank)



Source: WEC, 'Survey of Energy Resources', BP Statistics 2010.

(2) Coal consumption in Asia

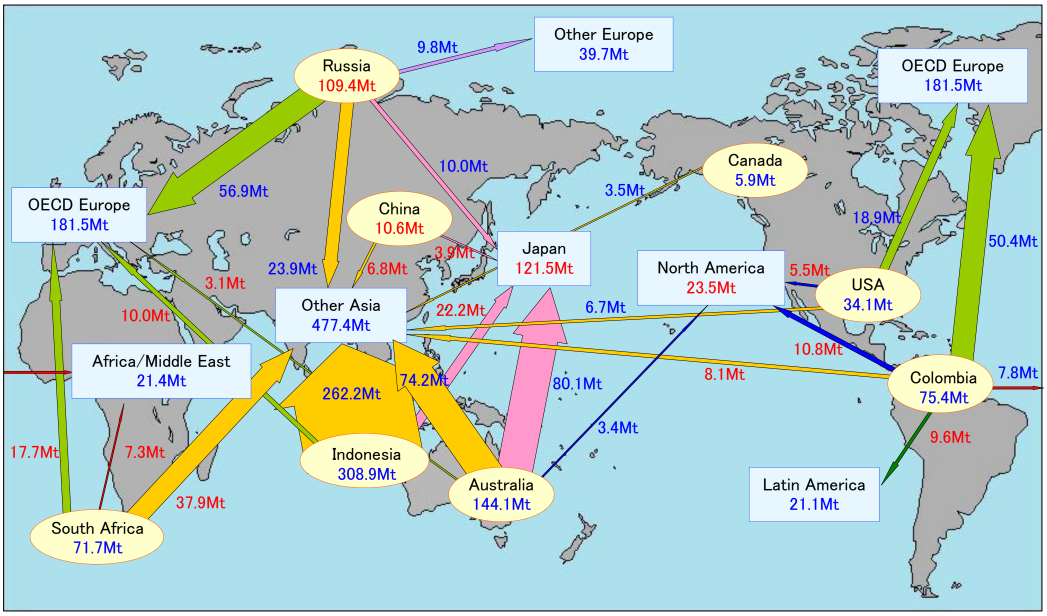
Figure 2-4 shows the flow of steam coal in 2012. Steam coal is mainly exported to Asia by Indonesia and Australia; it is also exported by South Africa and Russia as well as China, Colombia, the United States (US), and Canada, although in smaller volume.

Indonesia is the biggest steam coal exporter to China; its exports accounted for 48 percent of total Chinese imports in 2011. Republic of Korea (henceforth, Korea), Taiwan, and India also import coal from Indonesia. Of the nearly 300 million tonnes (MT) of steam coal exports from Indonesia, 96 percent are for Asia. It is estimated that other countries without adequate data also import big quantities from Indonesia.

Australia is the second largest steam coal exporter to Asia after Indonesia, with 97 percent of its steam coal exported to Asia, which totalled 144 MT in 2011. Indonesian and Australian coal exports account for three quarters of the steam coal imported by Asia. Australia exports the biggest quantity of steam coal to Japan. Its exports to China, Korea, and Taiwan exceed 15 MT but its exports to India are smaller. India imports more coal from South Africa, which is nearer than Australia.

Other Asian countries import mostly from Indonesia. According to forecasts of future coal demand, demand for energy and, in particular, electricity is expected to increase substantially as a result of the economic growth in Asia; thus, many new coal-fired power plants are being planned. Coal consumption for power generation is forecasted to increase in Asia. In Viet Nam, where anthracite used to be widespread, a plan for a new plant to be fired on blended coal, or anthracite with imported Indonesian coal, is in progress.

Figure 2-4. Flow of Steam Coal (2011 estimate)



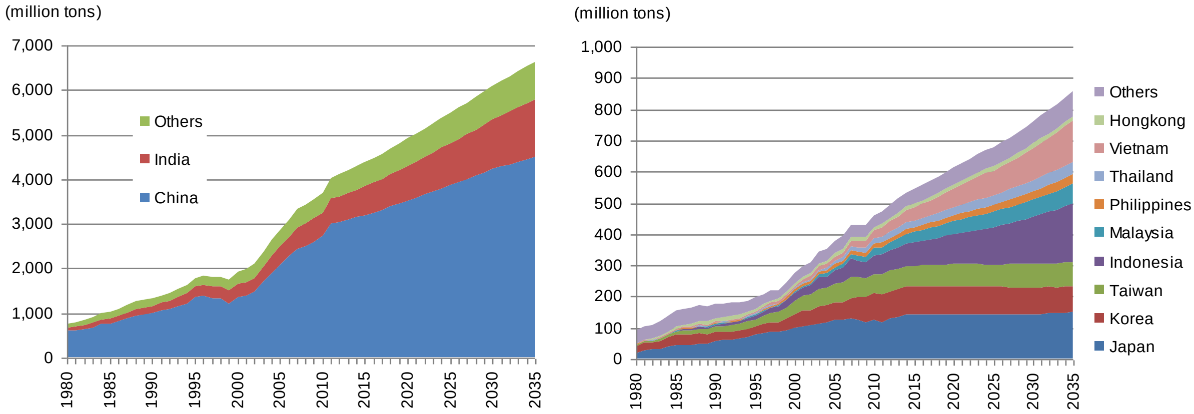
Note: The above figure does not show flows of less than 3 MT. The blue-coloured numbers show an increase relative to the previous year and the red-coloured numbers show a decrease relative to the previous year. North America as an importer includes Mexico.
Source: International Energy Agency (IEA,) Coal Information 2012.

(3) Consideration on future coal demand and supply

Demand for steam coal in Asia will increase at an annual growth rate of 2.4 percent from 2010 to 2035, and will increase by 1.8 times from 3,730 MT to 6,652 MT during the same period. Figure 2-5 shows a steam coal demand forecast in Asia. Steam coal demand in China will not show such a rapid growth as it did during the 2000s. But as the demand for electricity is expected to increase with economic growth in the future, the demand for power generation should likewise increase. The demand in India for steam coal will increase at an annual growth rate of 3.7 percent to 2035 due to a rapid increase in demand for power generation. India is expected to consume up to 1,297 MT in 2035, which is a 2.5-fold increase relative to 2010. ASEAN countries are expected to use cheap coal power in order to meet the increasing demand for power generation; hence, coal demand will increase.

Specifically, Indonesia is building a coal power generation station using low-rank coal produced domestically. Its steam coal demand will be close to 100 MT in 2020 and further increase to 190 MT in 2035. Steam coal demand in Viet Nam will increase to 132 MT in 2035 with the addition of coal power. The consumption of steam coal in other countries will increase by two to three times in 2035. On the contrary, Japan, Korea, and Taiwan, which have widely used steam coal for power generation, will still experience increases in their demand but their growth is expected to slow down.

Figure 2-5. Steam Coal Demand Forecast in Asia



Source: Actual data is from International Energy Agency (IEA) and forecast is by Japan International Cooperation Agency (JICA).

Most of these increases in coal demand in the region are expected to be addressed by Indonesia. Having abundant low-rank coal with low ash and low sulphur content that offer advantages in both price and environmental compliance, Indonesia expects its low-rank coal export to further increase in the future. Such trend has shed light on low-rank coals that used to be regarded as non-marketable; China and India have been importing low-rank coals with fuel efficiency mass lower than 4,000 kilocalorie/kilogram (kcal/kg), which have now entered the market.

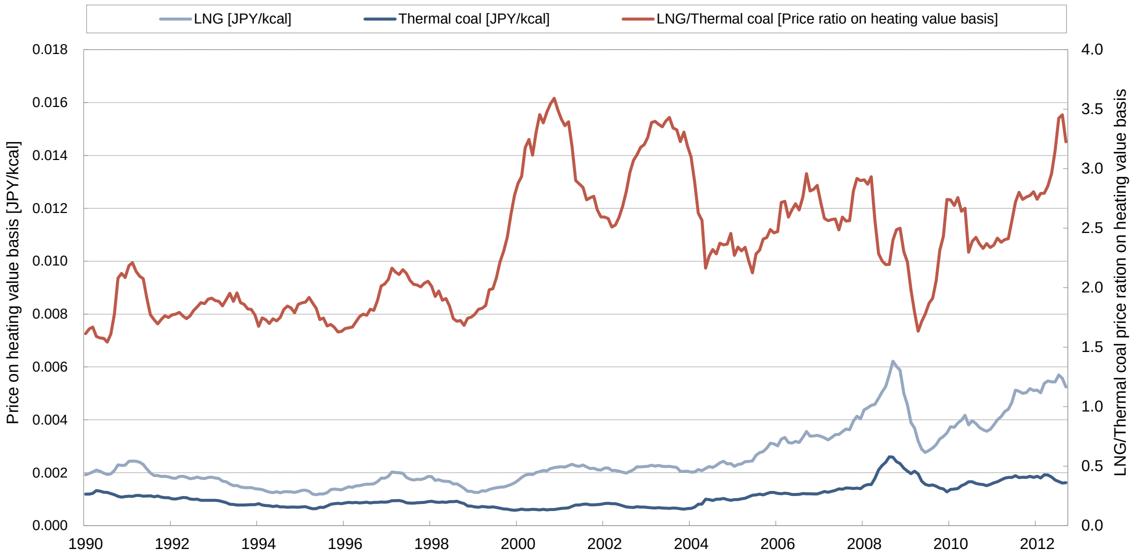
Korea has been expediting low-rank coal utilisation and expansion. Likewise, it has expedited measures such as combustion improvement through blending with high-rank coal and high efficiency clean coal technology (CCT) such as ultra super critical (USC) in consideration of high moisture and low calorific value that low-rank coals carry.

Indonesia, the major coal supplier in the region, in recent years saw a steady economic growth after having gone through the impact of the global financial crisis, which has boosted its own energy demand. Indonesia was once a member of the Organization of the Petroleum Exporting Countries (OPEC) as a major oil and gas producer; however, it has shifted its energy policy towards the effective use of domestically abundant and available energy source (i.e. coal) in view of gradually depleting oil and gas resources. To meet the increasing demand for electricity, it is planning to build many new large-scale, coal-fired power plants, which require a continuous supply of coal. More than 80 percent of Indonesia's produced coal is exported and the rest is for domestic consumption. With a surging domestic demand by the power sector, coal export in the coming years may see a sluggish growth as the policy to prioritise domestic supply to meet domestic demand has come into force. It may come up as a common agenda that Asia needs a concerted coordination towards a balanced regional demand and supply.

2-1-3. Comparison of coal and natural gas prices

Figure 2-7 shows thermal coal and LNG import prices (in cost, insurance, and freight [CIF] prices) on heating value basis as well as the price ratio of LNG/thermal coal for Japan. The price of coal on heating value basis has always been more competitive than natural gas and provides a high economic rationale. Historically, the LNG/thermal coal price ratio has been between 1.5 and 3.5. Since 2000, the price ratio has increased and consistently been around 2.3–3.5, except in 2009.

Figure 2-7. Comparison of Coal and Natural Gas Prices



Source: Japan import statistics.

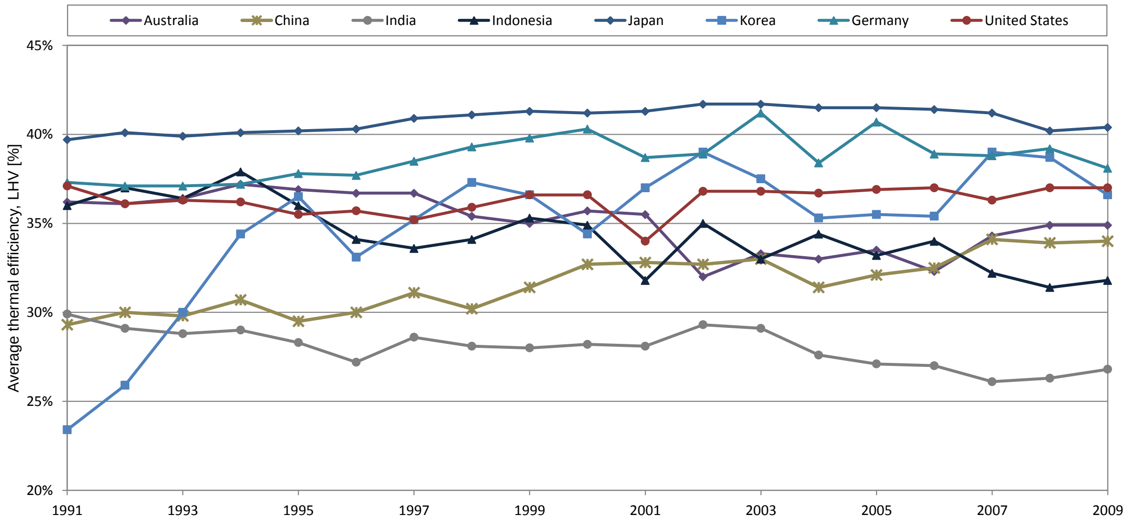
2-1-4. The importance of CCT for improving energy security

The main features of coal for the EAS region can be summarised as follows:

1. Coal is the primary energy source in the EAS region.
2. Coal is the most secure energy resource in the EAS region.
3. Coal supply potential can be further expanded by developing lower grade coal.
4. Coal is more cost-competitive than natural gas.

However, coal is not used efficiently. It is relatively abundant in the region and an important source of energy, and thus should be used as efficiently as possible. Figure 2-8 shows the thermal efficiency in Australia, China, India, Indonesia, Japan, and Korea as well as Germany and the US. In some Asian countries, thermal efficiency is still lower than 35 percent, leaving more room for improvement. In order to maximise the potential of coal, CCT should be introduced in the EAS region.

Figure 2-8. Thermal Efficiency of Coal-Fired Power Stations
in Asia, Germany, **and the United States**



Source: International Energy Agency (IEA), 2011, Energy Balances of Organisation for Economic Co-operation and Development (OECD) Countries, Energy Balances of Non-OECD Countries.

2-2. Economic Benefits of CCT Introduction in the East Asia Summit Region

2-2-1. Application benefits of the introduction of CCT in East Asia

(1) Minimisation of capital outflow

According to forecasts in the ERIA research project titled 'Analysis on Energy Saving Potential in East Asia' (hereinafter referred to as ERIA energy savings research project'), coal is expected to remain as the main source of electricity generation; yet electricity generation by natural gas is also expected to increase. If we assume that natural gas–fired power stations can be replaced by coal-fired power stations, then capital outflow can be avoided because coal is a self-sufficient natural resource in the EAS region.

Figure 2-9 displays the avoided capital outflow when new natural gas–fired power stations are replaced with coal-fired power stations. According to the ERIA energy savings research project, natural gas–fired power generation will increase by 2,300 terawatt-hours (TWh) from 981 TWh/year in 2010 to 3,281 TWh/year in 2035. Based on assumptions from the ERIA energy savings research project, the thermal efficiency of natural gas–fired power stations is expected to increase from 44.1 percent in 2010 to 46.6 percent in 2035. In British thermal unit (Btu), this means that natural gas consumption per year in 2035 will be 16.4 quadrillion Btu higher than in 2010.[1] As analysed in the previous section, 26.1 percent of

[1] The output in terawatt-hours (TWh) divided by thermal efficiency is equal to input in TWh. The conversion of TWh to British thermal unit (Btu) is based on the IEA conversion rate of 1 TWh = 3412141.1565 million Btu (MMBtu).

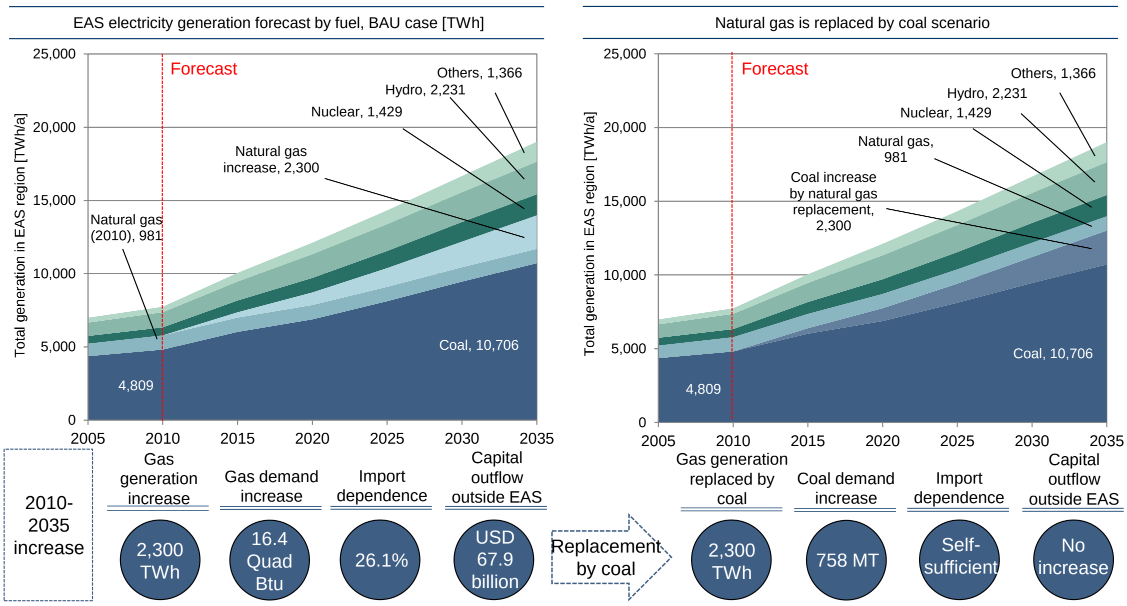
natural gas consumed in the EAS region cannot be supplied within the region (estimated value in 2013) and therefore needs to be imported from outside the region, resulting in capital outflow. At the assumed price of US$15.85/MMBtu (the LNG import price to Japan, January 2013), capital outflow in 2010 would have been US$31.4 billion. Under the given assumptions, capital outflow would be US$99.2 billion in 2035. Therefore, the increase in imports from outside the EAS region is expected to increase capital outflow up to around US$67.9 billion until 2035.

Capital outflow can be reduced by replacing natural gas–fired power stations with coal-fired power stations. If we assume that all new natural gas–fired power stations can be replaced by coal-fired power stations, the additional amount of coal required to generate 2,300 TWh is around 758 MT per year[2]. From the utilities' point of view, at the assumed price of US$117.57/tonne (Thermal coal import price to Japan, January 2013), the expected total cost for 758 MT of thermal coal would be US$89.1 billion. The total cost for 16.4 quadrillion Btu required to generate 2,300 TWh would be US$260.4 billion (at US$15.85/MMBtu). In short, disregarding the origin of natural resources, the total savings for utilities would be US$171.3 billion.

If we assume that all additional coal can be produced in the EAS region, savings due to minimisation of capital outflow would be US$67.9 billion.

[2] The amount of coal necessary was calculated by dividing 2,300 TWh by the thermal efficiency, which was assumed at 43.5 percent (USC-type boiler thermal efficiency ranges from 41.5 percent–45 percent). With 1 TWh = 859845227.86 megacalorie (Mcal), and using the heating value of American Petroleum Institute (API) 6 Newcastle thermal coal at 6,000 kcal/kg, around 758 MT are necessary to generate 2,300 TWh.

Figure 2-9. Minimisation of Capital Outflow



Note: The definition of capital outflow is: 1 – Production (EAS region)/Consumption (EAS region). The price of natural gas assumed in this graph is US$15.85/MMBtu (LNG import price in Japan, January 2013)
Sources: Compiled from the Economic Research Institute for ASEAN and East Asia (ERIA) Energy Savings Research Project; International Energy Agency (IEA) Coal Information; IEA Natural Gas Information; Japan import statistics.

(2) Environment impact reduction

Compared to other primary energy sources such as petroleum and natural gas, coal contains more sulphur, nitrogen, and ash. These components are emitted as sulphur oxide (SOx), nitrogen oxide (NOx), or particulate matter due to coal combustion, thereby exerting a negative impact on the environment. As the carbon content in coal is higher than that in petroleum or natural gas, emissions of carbon dioxide (CO_2)—one of the gases that cause global warming—are also higher than other primary energy sources. As a result, reducing and removing such components that have an impact on the environment need to be considered in coal utilisation.

Sulphur Oxide, Nitrogen Oxide, Particulate Matter

In the past when there were small-scale coal-fired power plants and other combustion facilities only, emissions from coal combustion did not affect the environment much. But the situation is now quite different due to the high and extensive growth of the economy, and energy demand and consumption. These resulted in significant negative impact on the natural environment and on public health caused by acid rain and particulate matters emitted along with large amounts of SOx and NOx.

Asian countries saw rapid economic development in recent years, which has brought about industrial and environmental pollution including air and water, all of which have become huge social issues. In addressing these issues, streamlining relevant regulations and dissemination of key technologies are the major common agenda in the region.

In Japan, denitrification equipment has become standard, aside from desulphurisation equipment, to reduce NOx emissions. The desulphurisation equipment used to be uncommon in coal-fired power plants in the Asia region because coal with low sulphur content was then used and the number of coal-fired power plants used to be relatively small. Recently built coal-fired power plants have desulphurisation equipment while denitrification equipment is yet to be a standard. NOx has two types: fuel NOx is generated by the nitrogen in the coal whereas thermal NOx is formed by the nitrogen in the air during combustion. Thermal NOx can be reduced by using a low NOx burner, hence, it has become widespread. However, to further reduce NOx in the future, the installation of denitrification equipment is indispensable.

In summary, to mitigate the environmental impact caused by an increase in coal consumption in the future, the installation of high-efficiency desulphurisation, denitrification, and dust-collecting equipment in coal-fired power plants should be required.

Carbon Dioxide

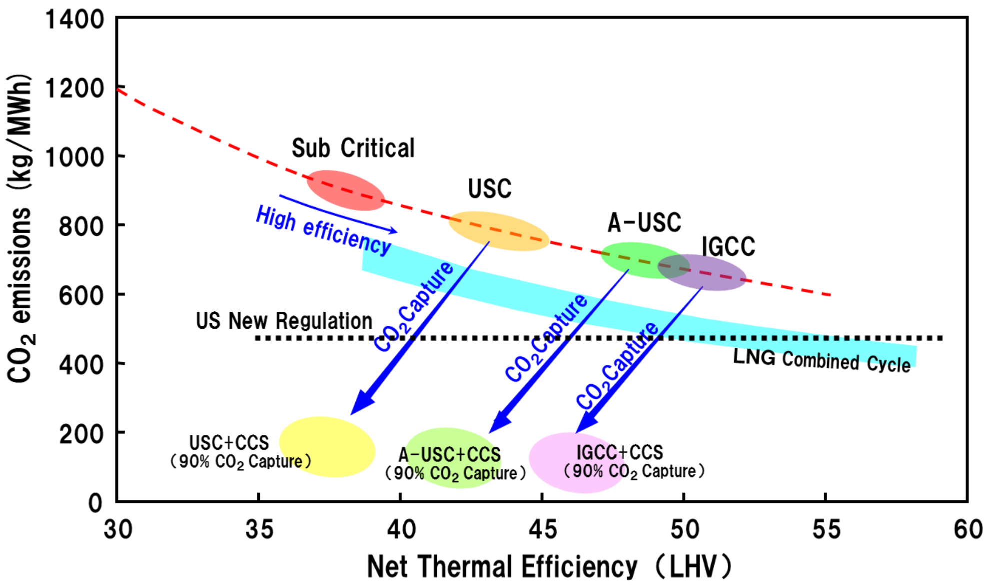
With higher carbon content than petroleum and natural gas, coal upon combustion generates the biggest amount of CO_2 per unit among all primary energy sources. The ratio of CO_2 emitted by coal, petroleum, and natural gas is 5:4:3; the amount of CO_2 emissions per kilowatt-hour (kWh) in a coal-fired power plant is twice than in a natural gas–fired power plant. It is necessary, therefore, to reduce the amount of coal used and improve the efficiency of coal-fired power plants to reduce CO_2 emissions. However, by using high efficiency CCT such as USC, integrated gasification combined cycle (IGCC) and integrated gasification fuel cell (IGFC), it is possible to reduce CO_2 emissions to the level similar to that of a petroleum-fired power plants or even less.

Figure 2-10 shows the connection between power generation efficiency and CO_2

emissions, where CO_2 emissions are evidently reduced as efficiency increases. Should a new CO_2 regulation for power plants proposed in the US on June 2014 be introduced, it is necessary to add carbon dioxide capture and storage (CCS) to CCT.

Looking into the future, CCS is supposed to have the most potential in bringing down CO_2 emissions, which may be close to zero. However, as coal storage sites are limited to sea bed and underground aquifers, coal seams, and oil fields, there are issues to be addressed such as the economic issue regarding the cost of recovery and transportation of CO_2, environmental and safety considerations required of the stored CO_2, the issue of public acceptance, among others. Accordingly, the commercialisation of CCS may be expected only around 2030.

Figure 2-10. Relationship between Power Plant Efficiency and CO_2 Emissions

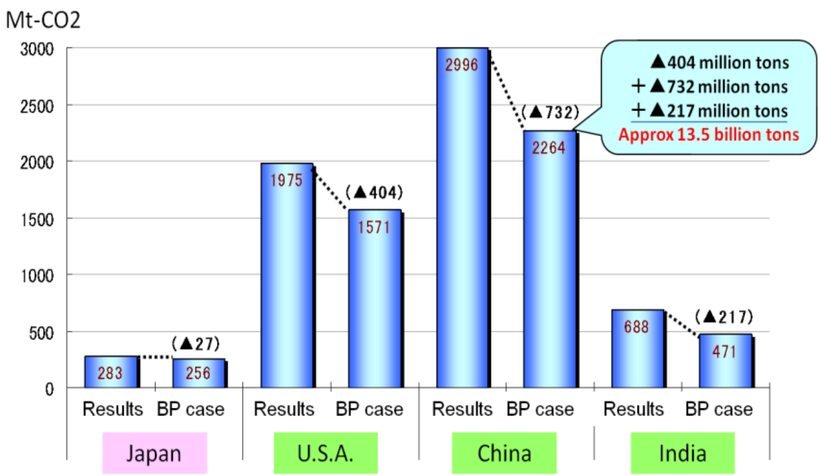


Sources: Author's compilation.

In the meantime, high efficiency CCT like USC is already commercialised and CO_2 reduction is possible either for newly constructed plants or existing power plants. Figure 2-11 indicates the expected CO_2 reduction by deploying Japanese high-efficiency CCTs at numerous existing coal-fired power plants in Japan, US, China, and India. As power plants in Japan are already working at the highest global level, it is not necessary to expect more CO_2 reduction. However, a reduction of 13.5 billion tonnes of CO_2 can be expected if high efficiency CCTs are deployed at plants in the US, China, and India. The last two in Asia are expected to contribute a total reduction of 9.5 billion tonnes of CO_2.

As discussed, high efficiency CCT utilisation at coal-fired power plants will cause considerable effects on CO_2 reduction. It is highly recommended that CCT be applied to incoming coal-fired power plants at new sites as well as in newly replaced coal-fired power plants under a replacement plan of existing power plants in the region.

Figure 2-11. CO_2 Emission and Reduction Estimates in Coal-Fired Power Plants



Sources: International Energy Agency (IEA) (2009), *World Energy Outlook*; Ecofys (2010), *International Comparison of Fossil Power Efficiency and CO_2 Intensity.*

2-2-2. Development and investment benefits

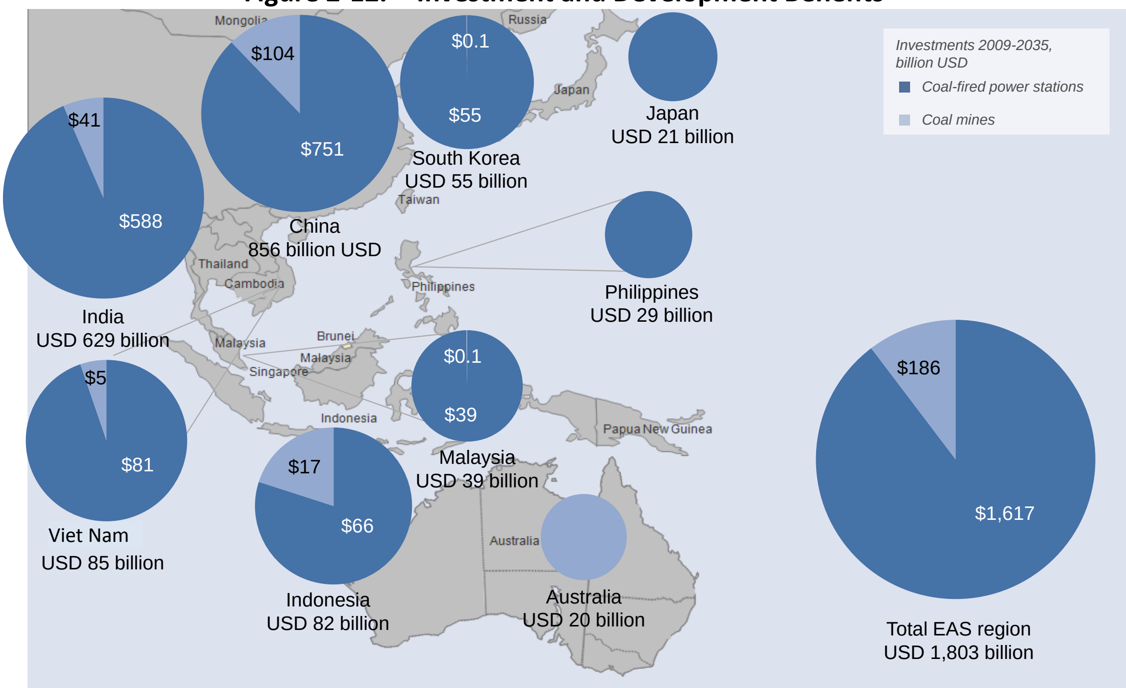
The increase in coal-fired power generation will provide ample investment opportunities within the EAS region. The investment benefits for the EAS region are assumed to be concentrated in new coal-fired power stations and new coal mines. In this section, the investment benefits for coal-fired power stations and coal mines are quantified. In reality, other investment opportunities associated with coal-fired power station development such as investment in infrastructure will also arise.

Figure 2-12 displays the investment opportunities in coal-fired power stations and coal mine development based on forecasts in the business as usual (BAU) case of the ERIA energy savings research project on energy saving potential in the EAS region. In the BAU case, electricity generated from coal per year is forecasted to increase by 5,897 TWh from 2010 to 2035. By 2035, this would require an estimated 898 gigawatt (GW) of new coal-fired capacity across the EAS region, assuming operation at 75 percent. The costs associated with utilising USC-type boilers are estimated at US$1.692 billion/GW to US$1.911

billion/GW. The total investment opportunities in coal-fired power stations across the EAS region amount to about US$1.617 trillion, with investment opportunity in China accounting for around US$751 billion.

Assuming that USC-type boilers with a thermal efficiency of 43.5 percent are installed at new coal-fired power stations, around 1,943 MT of thermal coal is required annually to generate the additional 5,897 TWh of electricity in 2035. Development costs per metric tonne can range from around US$78 million to US$113 million, depending on the type of coal mine (open-cut or underground). For the entire EAS region, the average investment cost for coal mines is therefore estimated to be US$186 billion. The coal mine investment opportunity per country was estimated based on projections of coal production in 2030, with respective country share applied to the 1,943 MT of coal necessary to generate the additional 5,897 TWh. In this approach, China, India, Australia, Indonesia, and Viet Nam account for 1,088 MT, 428 MT, 204 MT, 172 MT, and 47 MT, respectively (or in monetary terms, US$104 billion, US$41 billion, US$20 billion, US$16 billion, and US$5 billion of investment opportunity, respectively.

Figure 2-12. Investment and Development Benefits



Note: The coal amount necessary to generate 5,897 TWh was calculated using the American Petroleum Institute (API) 6 index for Newcastle free on board (FOB) coal at 6,000 kcal/kg and thermal efficiency of coal power stations at 43.5%. Values may not add up due to rounding.
Sources: Economic Research Institute for ASEAN and East Asia (ERIA) Energy Savings Research Project, Japan International Cooperation Agency (JICA), and author's own calculations.

2-2-3. Job creation benefits

New coal-fired power stations and newly developed coal mines will create jobs in the EAS region. Figure 2-13 shows an estimation of long-term job creation (excluding construction jobs) related to power stations and coal mines.

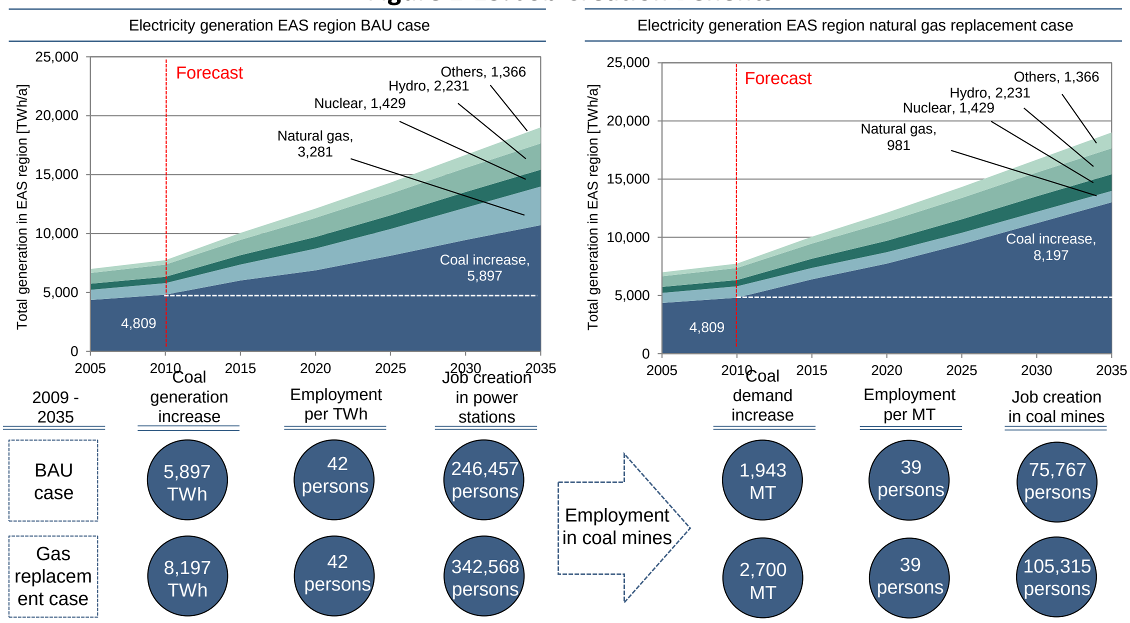
In the ERIA energy savings research project BAU case, coal-fired power generation is forecasted to increase by 5,897 TWh from 4,809 TWh/year in 2010, to 10,706 TWh/year in 2035. Assuming productivity in power stations to be about 42 persons/TWh (or 23.9 GWh/person/year) based on generation and employment data from Australia, 200,966 employees are necessary to generate 4,809 TWh/year in the EAS region. In order to generate 10,706 TWh/year, 447,423 employees are necessary. Under these assumptions, employment in coal-fired power stations is estimated to increase by 246,457 persons.

The amount of coal required to generate the additional 5,897 TWh/year by 2035 is around 1,943 MT/year. Under the assumption that employment in coal mines is 39 persons/MT,[3] new coal mine development in the EAS region is estimated to create 75,767 new jobs.

In addition to individuals required to operate power stations and coal mines, workers will be required during the construction phase of these projects.

[3] From Robert D. Humphris (1999), 'The Future of Coal: Mining Costs and Productivity,' in *The Future Role of Coal*, International Energy Agency.

Figure 2-13. Job Creation Benefits



Note: Generation productivity is calculated as total generation excluding off-grid generation in Australia/number of employees in the power generation sector in Australia for FY 2006–2007. It was applied to the 2009 coal demand necessary for coal-fired power generation and to the 2035 coal-fired power generation to estimate the total number of employees in the EAS region. The coal mining productivity value was taken from Robert D. Humphris, 'The Future of Coal: Mining Costs and Productivity' from International Energy Agency (IEA) (1999), 'The Future Role of Coal," and applied to increased annual amount of coal required in 2035.
Sources: Compiled from the ERIA Energy Savings Research Project; Bureau of Statistics, Australia; Department of Resources, Energy, and Tourism, Australia; and author's calculations.