Chapter 3

Economic Benefits of the Introduction of CCT in the EAS Region

Study on the Strategic Usage of Coal in the EAS Region Working Group

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CHAPTER 3

Economic Benefits of the Introduction of CCT in the EAS Region

1. Application Benefits of CCT Introduction in East Asia

1.1. Minimization of Capital Outflow

The self-sufficiency rate, as explained in section 1.2.1, was used in order to understand the potential capital outflow due to natural resource imports from outside the EAS region.

According to the forecasts made in the ERIA research project "Analysis on Energy Saving Potential in East Asia Region (FY 2011)" (hereinafter referred to as "ERIA energy savings research project"), coal is expected to remain the main source of electricity generation, but electricity generation by natural gas is also expected to increase. If it is assumed that natural gas-fired power stations can be replaced by coal-fired power stations, capital outflow can be avoided, because coal is a self-sufficient natural resource in the EAS region.

Figure 3-1 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 2,326 TWh from 863.4 TWh/year in 2009, to 3188.9 TWh/year in 2035. Under the assumptions made in the ERIA energy savings research project, thermal efficiency of natural gas-fired power stations is expected to increase from 43.5% in 2009 to 45.9% in 2035. In Btu basis, this means that natural gas consumption per year in 2035 is

16.9 Quadrillion Btu higher than in 2009.[1] As analysed in the previous section, 15,7% of natural gas consumed in the EAS region cannot be supplied within the region (in 2009), and therefore needs to be imported from outside the EAS region, resulting in capital outflow. At the assumed price of USD 15.85/MMBtu (the LNG import price to Japan, January 2013), capital outflow in 2009 would have been USD 16.9 billion. Under the given assumptions, capital outflow would be USD 59.3 billion in 2035. Therefore, the increase in imports from outside the EAS region is expected to increase capital outflow up to around USD 42.4 billion per year in 2035.

Capital outflow can be reduced by replacing natural gas-fired power stations with coal-fired power stations. If it is assumed that all new natural gas-fired power stations can be replaced by coal-fired power stations, the additional amount of coal required to generate 2,326 TWh is around 766 MT/year[2]. From the utilities' point of view, at the assumed price of USD 117.57/ton (Thermal coal import price to Japan, January 2013), the expected total cost for 766 MT of thermal coal would be USD 90.1 billion. The total cost for 16.9 Quadrillion Btu required to generate the 2,326 TWh, would be USD 268.3 billion (at 15.85 USD/MMBtu). In short, disregarding the origin of natural resources, the total savings for utilities would be USD 178.2 billion.

If it is assumed that all additional coal can be produced in the EAS region,

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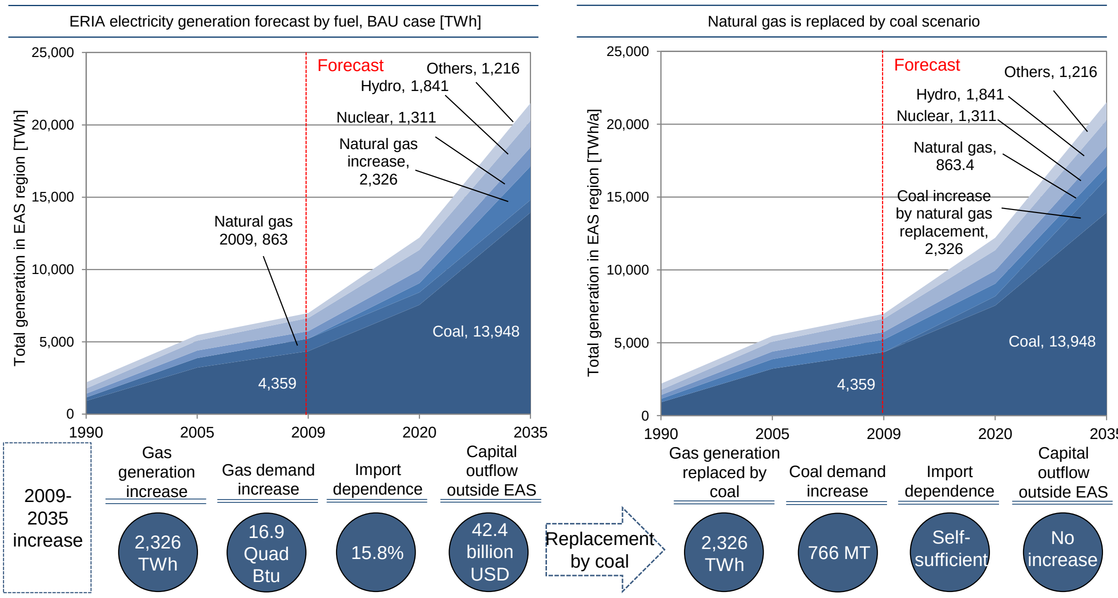
[1] The output in TWh divided by thermal efficiency is equal to input in TWh. The conversion from TWh to Btu can be made using the IEA conversion rate of: 1 TWh = 3412141.1565 MMBtu.

[2] The amount of coal necessary was calculated by dividing 2,326 TWh by the thermal efficiency, which was assumed at 43.5% (USC type boiler thermal efficiency is ranging from 41.5% ~ 45%). With 1 TWh = 859845227.86 Mcal, and using the heating value of API 6 Newcastle thermal coal at 6,000 kcal/kg, around 711 MT are necessary to generate 2,326 TWh.

savings due to minimization of capital outflow would be USD 42.4 billion.

Figure 3-1: Minimization 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 15.85 USD/MMBtu (LNG import price in Japan, January 2013)

Source: Compiled from ERIA report, IEA Coal Information and IEA Natural Gas Information, Japan import statistics.

1.2. Environment Impact Reduction

Compared to other primary energy sources such as petroleum and natural gas, coal contains more sulphur and nitrogen and it also contains ash. These components are emitted as SOx, 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 CO_2, which is one of the gases that cause global warming, are also higher than the other primary energy sources. As a result, reducing and removing such components that have an impact on the environment needs to be considered in coal utilization.

SOx, NOx, Particulate Matter

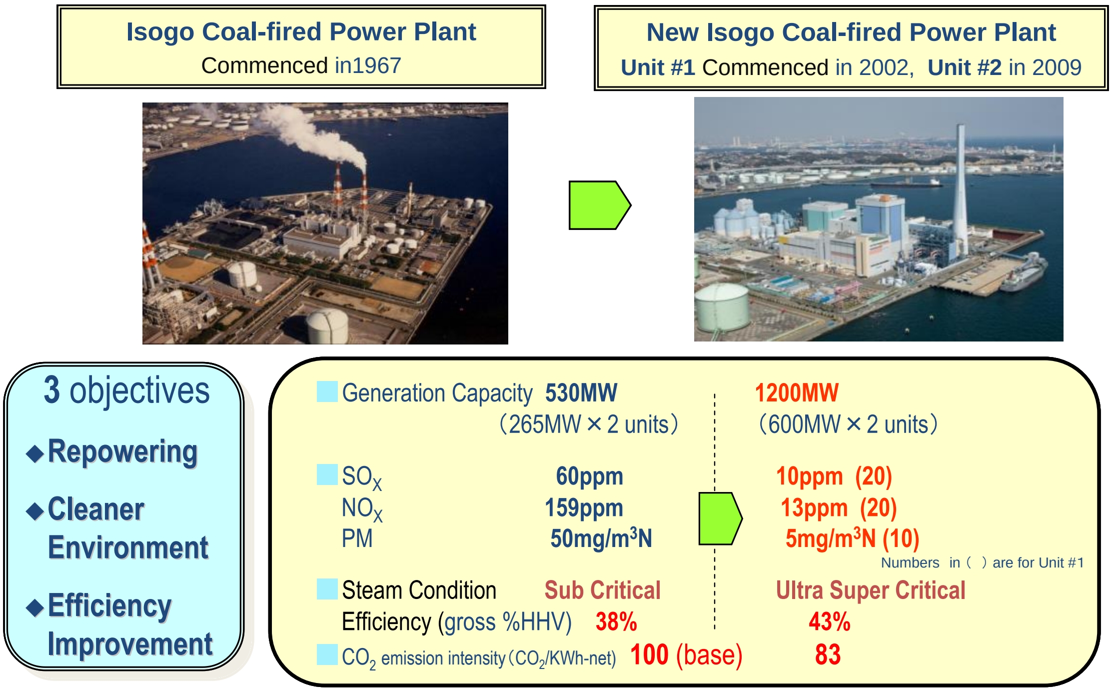
In the past when we used to have small scale coal fired power plants and other combustion facilities only, emissions from coal combustion might not have much affected the environment impact, which have turned totally different during recent years that saw high and extensive growth of economy and energy demand and consumption, which may incur or have incurred significant negative impact on natural environments like forests and public health through acid rain and particulate matter by emitted SOx and NOx. Having experienced severe pollution problems in the past, Japan managed to overcome these pollution problems through the joint efforts of the central government, municipalities and private companies through enacting environmental protection laws as well as developing and investing in technology for environmental compliance.

Asian countries saw rapid economic development in recent years, which has brought down industrial pollution such as air pollution, water pollution, etc. or pollution of living environment, all of which have been emerging as huge social issues. In addressing such issues, streamlining relevant regulations and dissemination of key technologies are the major common agenda in the region.

While standards for emission gas of various countries vary considerably by respective energy utilization situations, overall, relevant standards have been tightened in recent years. Many countries are yet to regulate by the overall amount of emissions like Japan and remain regulating by concentration only. However, some have started regulating by the overall amount of emissions. It is to be noted that in Japan local governments set tighter standards apart from the central government's regulation. In this context, construction and operation of a new coal fired power plant require advanced process of agreement with the local authorities.

Figure 3-2 shows the SOx, NOx and particulate matter emissions of Japan's state-of-the-art Isogo coal-fired power plant in the city of Yokohama which is adjacent to Tokyo. The Isogo Power Plant was constructed in 1967 and the then existing old sub-critical pressure power plant were replaced by an ultra-supercritical pressure power plant. High efficiency desulphurization, denitrification and dust collection equipments have been installed which achieves a emission level that is even lower by 1/6 to 1/10 of the existing Japanese standards. Given much space constraint and high demand for environmental compliance as the plant is situated in the urban area, Isogo uses a silo to store the coal instead of a conventional yard for dust control. Besides, a wide range of environmental measures are taken; not only air and water quality control but also others such as making the chimney elliptic-shaped to ensure each resident's right to a view.

Figure 3-2: Emission of Isogo coal-fired power plant in Japan



Source: Fujitomi, M., Clean Coal Day in Japan 2010 International Symposium (Tokyo, Japan, September, 2010).

In Japan denitrification equipment is also a standard besides desulphurization equipment with NOx emissions are stringently regulated. In the meantime, even desulphurization equipment used to be uncommon with coal fired power plants in Asia region as coal with low sulphur content was used and the number of coal-fired power plants used to be relatively small. Recently built new coal-fired power plants are with desulphurization equipment, while denitrification equipment is yet to be a standard. NOx has two types; Fuel NOx is generated by the nitrogen in the coal while thermal NOx is formed by the nitrogen in the air during combustion. Thermal NOx can be reduced by using a low NOx burner so low NOx burners have become widespread. However, to further reduce NOx in the future, the installation of denitrification equipment is indispensable.

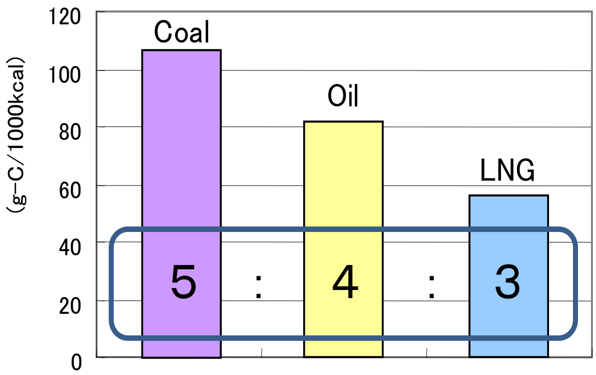
In summary, in order to mitigate environmental impact by coal consumption increase in the future, installation of high efficiency desulphurization, denitrification and dust collecting equipment to coal-fired power plants the major coal user is required.

CO_2

Containing 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. As shown in Figure 3-3, the ratio of CO_2 emitted by coal, petroleum and natural gas is 5:4:3; the amount of CO_2 emissions per kWh in a coal-fired power plant is twice the same in a natural gas-fired power plant. It is necessary to reduce the amount of coal used and improve the efficiency of the power plant for reduction of CO_2 emitted by a coal-fired power plant. Figure 3-4 shows the relation between power generation efficiency and CO_2 emissions, by which it is evident that CO_2

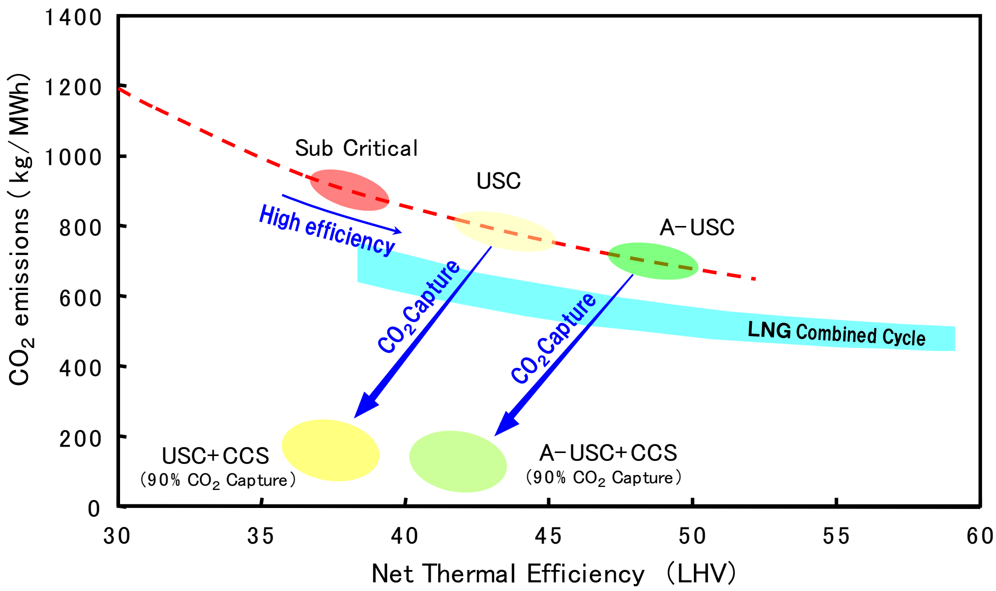
emissions are reduced as efficiency increases. Figure 3-5 compares CO_2 emissions from power plants using high efficiency CCTs such as USC, IGCC and IGFC, and those powered by petroleum and natural gas. By using high efficiency CCTs, it is possible to reduce CO_2 emissions to the level of the same by petroleum-fired power plants or even less.

Figure 3-3: CO_2 emission per Thermal unit



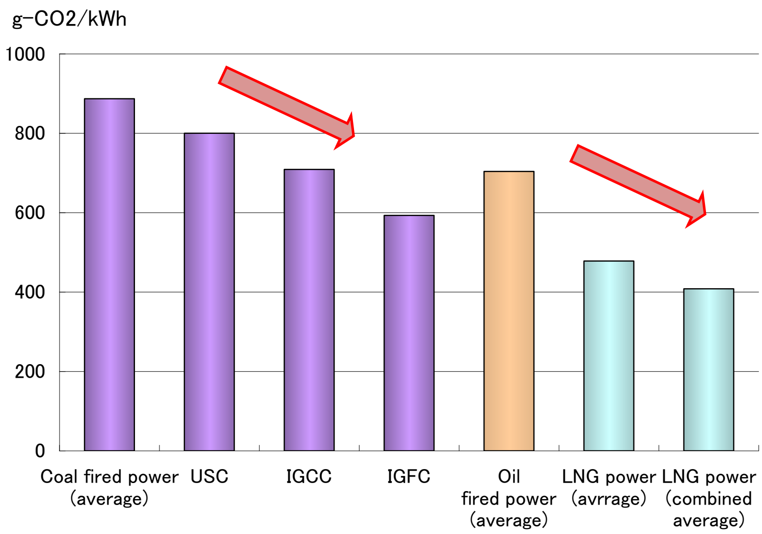
Source: based on "United nations Framework convention on Climate Change'

Figure 0-1: Relationship between power plant efficiency and CO_2 emission



Source: Aburatani, Y., Clean Coal Day in Japan 2010 International Symposium (Tokyo, Japan, September, 2010).

Figure 3-5: CO_2 emission in power generating fuel

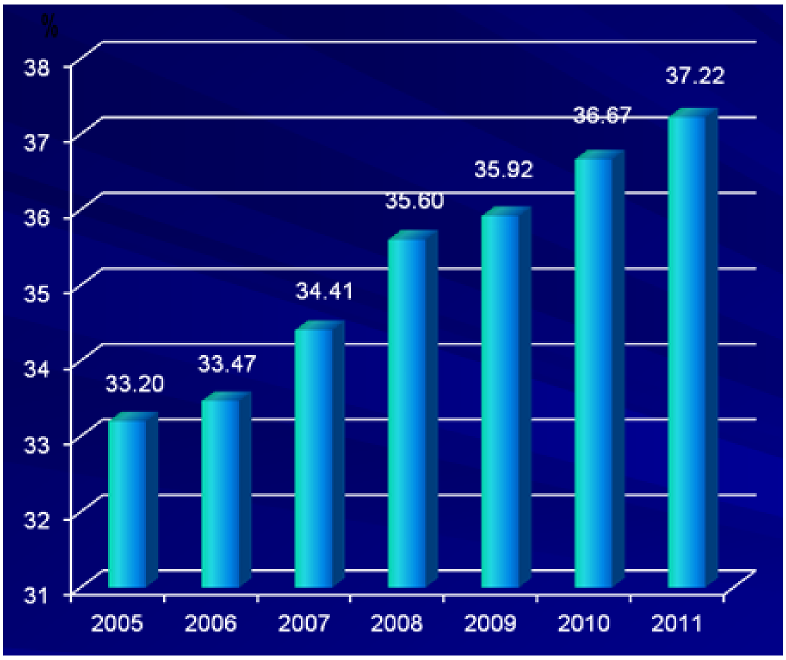


Source: Okazaki, K., Clean Coal Day in Japan 2011 International Symposium (Tokyo, Japan, September, 2011)

Japan, having deployed USC at most of its coal-fired power plants, keeps the world highest efficiency at its coal fired power plants as shown in Figure 2-15.

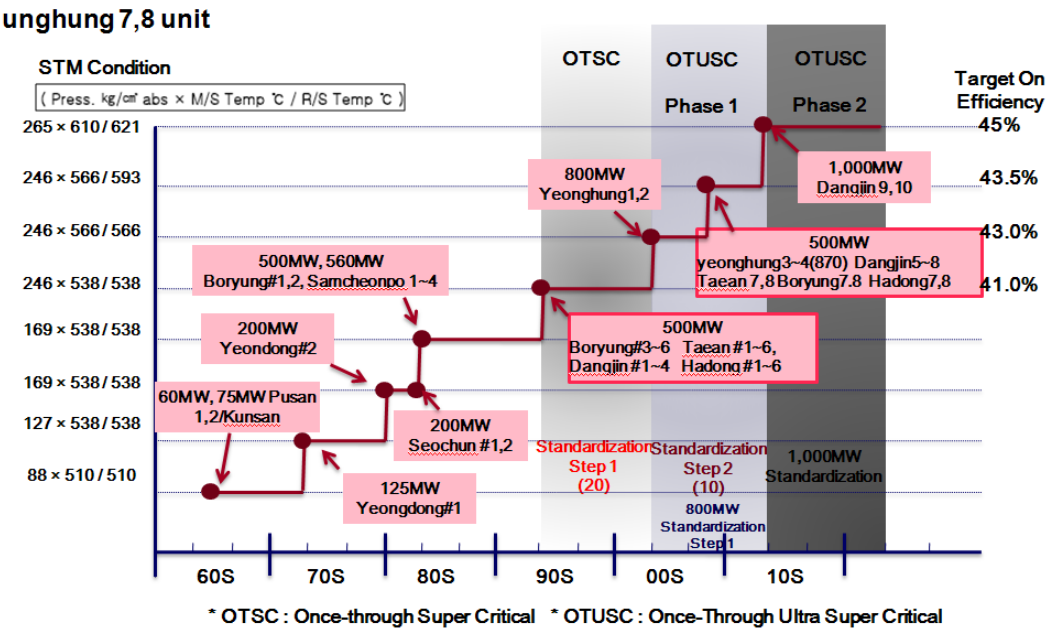
China, one of large coal consumers has shown improved efficiency at its coal fired power plants as shown in Figure 3-6. Korea is also aiming to improve the efficiency of its coal-fired power plants as indicated in Figure 3-7.

Figure 3-6: Average efficiency of coal-fired power plant in China



Source: Mao J., *et al.*, Workshop on Advanced USC Coal-fired Power Plant (Vienna, Austria, September 2012)

Figure 3-7: Change in steam condition of coal-fired power plant in Korea



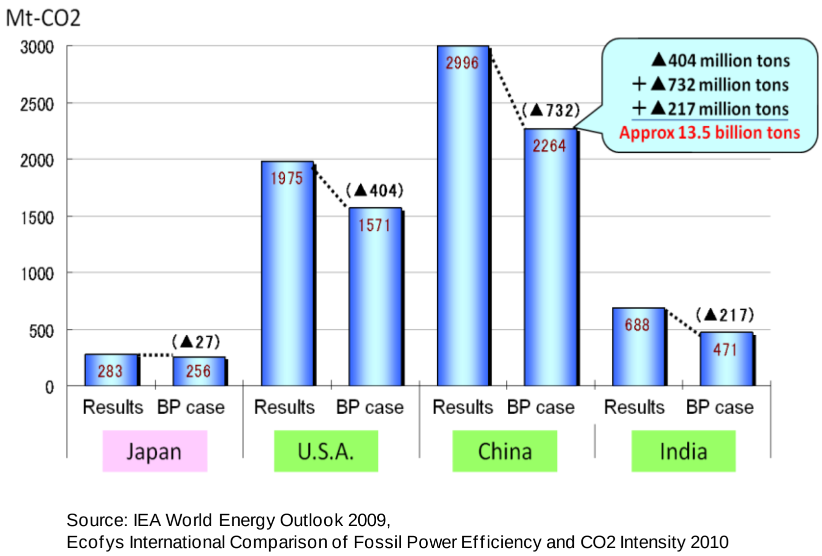
Source: Roh S., APEC Clean Fossil Energy Technical and Policy Seminar 2010 (Fukuoka, Japan, October, 2010)

Looking into the future, CCS is supposed to be the most potential as CO_2 emissions may be close to zero with the technology. By storing the CO_2 into an oilfield or a coal seam, petroleum and coal seam methane gas which could not be recovered with conventional way may be recovered, through which production will be further enhanced. However, as the storage sites are limited to the 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, etc.. Accordingly, commercialization may be expected only around 2030.

In the meantime, high efficiency CCTs like USC are already commercialized and CO_2 reduction is possible either for new constructions or for replacement of existing power plants. Figure 3-8 indicates the expected CO_2 reduction by deploying Japanese high efficiency CCTs at existing coal-fired power plants in Japan, US, China and India that have many coal-fired power plants. As power plants in Japan are already working at the world highest level, no more additional CO_2 reduction may be expected; 13.5 billion tons of CO_2 can be expected if high efficiency CCTs are deployed at plants in the US, China and India, the latter two of which in Asia expect 9.5 billion tons of CO_2 reduction on their own.

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

Figure 3-8: CO_2 emission and reduction estimates in coal-fired power plant



Source: IEA World Energy Outlook 2009, Ecofys International Comparison of Fossil Power Efficiency and CO2 Intensity 2010.

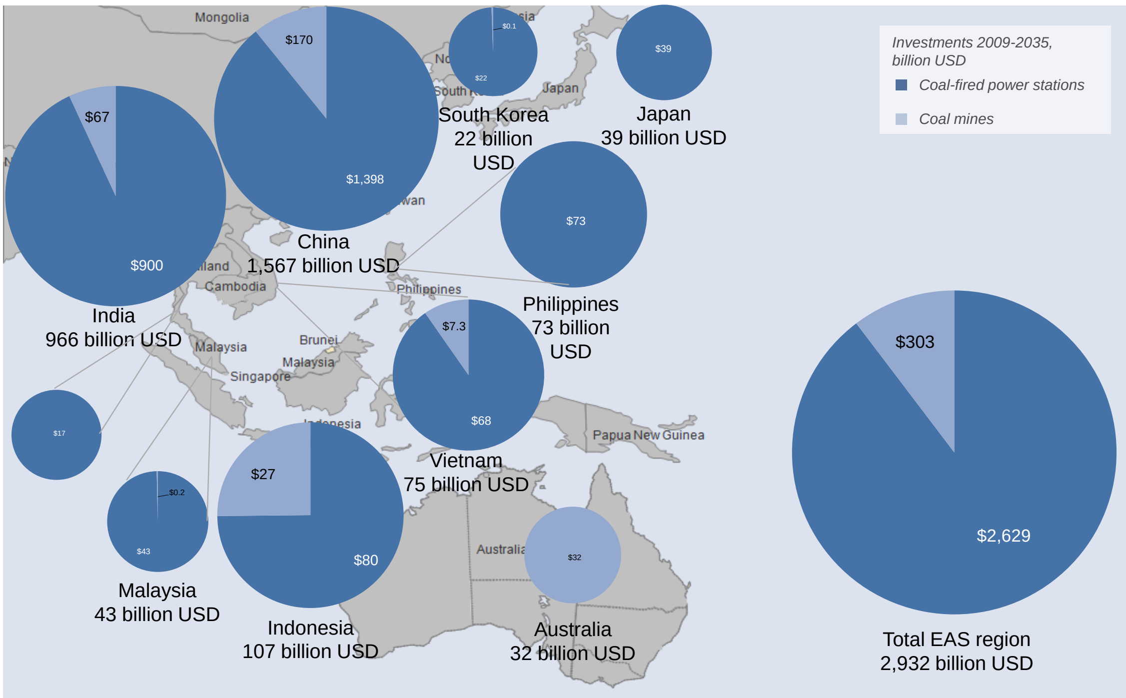
1.3. Development and Investment Benefits

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

Figure 3-9 displays the investment opportunities in coal-fired power stations and coal mine development, based on the forecast made in BAU case of the ERIA energy savings research project on energy saving potential in the EAS region. In the BAU case of the ERIA energy savings research project, electricity generated from coal per year is forecasted to increase by 9,589 TWh from 2009 to 2035. By 2035, this would require an estimated 1,460 GW of new coal-fired capacity across the EAS region, assuming operation at 75%. The costs associated with USC type boilers are estimated between USD 1,692 million/GW and USD 1,911 million/GW. The total investment opportunities in coal-fired power stations across the EAS region amount to about USD 2,629 billion, with investment opportunity in China accounting for around USD 1,397 billion (also see table 3-1 for background information for EAS member countries).

Assuming that USC type boilers with a thermal efficiency of 43.5% are installed at new coal-fired power stations, around 3,159 MT of thermal coal is required annually to generate the additional 9,589 TWh of electricity in 2035. Development costs per MT can range from around USD 78 million to USD 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 around USD 303 billion. The coal mine investment opportunity per country were estimated based on projections of coal production in 2030, with the respective country share applied to the 3,159 MT of coal necessary to generate the additional 9,589 TWh. In this approach, China, India, Australia, Indonesia and Viet Nam account for 1,770 MT, 696 MT, 332 MT, 280 MT, and 76 MY respectively. In monetary terms, this means USD 170 billion, USD 67 billion, USD 32 billion, USD 27 billion, and USD 7 billion of investment opportunity, respectively.

Figure 3-9: Investment and development benefits



Note: The coal amount necessary to generate 9.589 TWh was calculated using the API 6 index for Newcastle FOB coal at 6,000 kcal/kg, and thermal efficiency of coal power stations at 43.5%.

Source: Compiled from ERIA energy savings research project, JICA, and own calculations.

Table 3-1 outlines the background information of the ERIA energy savings research project forecast regarding coal-fired power generation, and the investment opportunities in coal-fired power stations for all EAS member countries.

Table 3-1: Coal-fired power generation forecast and coal-fired power station investment

	Coal generation 2009 [TWh]	Coal generation 2020 [TWh]	Coal generation 2035 [TWh]	Coal generation increase 2009-2035 [TWh]	Coal generation share 2009 [%]	Coal generation share 2035 [%]	New capacity required [GW]	Investment [billion USD]
Australia	182.0	178.0	134.0	0,0	74.3%	38.5%	0,0	0,0
Brunei	0.0	0.0	0.0	0,0	0%	0%	0,0	0,0
Cambodia	0.0	2.5	3.8	3.8	0%	22%	0.58	1.04
China	2,913.1	5,029.1	8,010.1	5,097.0	78.8%	74.7%	775.80	1,397.68
India	616.6	1,310.7	3,897.1	3,280.5	68.5%	70.9%	499.32	899.57
Indonesia	65.0	107.8	355.9	290.9	41.8%	39.2%	44.28	79.77
Japan	279.5	373.9	422.0	142.5	26.8%	31.9%	21.69	39.08
Korea	208.9	276.0	289.0	80.1	46.3%	41.9%	12.19	21.96
Lao PDR	0.0	11.8	11.8	11.8	0%	32.1%	1.80	3.24
Malaysia	32.5	62.3	189.1	156.6	30.9%	52.2%	23.84	42.94
Myanmar	0.0	0.5	0.5	0.5	0%	0.4%	0.08	0.14
New Zealand	3.3	2.2	0.0	0,0	7.6%	0%	0,0	0,0
Philippines	18.4	76.3	284.1	265.7	27.7%	61.3%	40.44	72.86
Singapore	0.0	0.0	0.0	0,0	0%	0%	0,0	0,0
Thailand	28.7	50.4	90.9	62.2	19.5%	24.3%	9.47	17.06
Viet Nam	10.9	76.0	259.5	248.6	13.7%	51.0%	37.84	68.17
EAS	4,358.7	7,557.5	13,947.8	9,589.1	62.3%	64.9%	1,459.53	2629.49

Note: The coal-fired power generation forecast and shares were taken from the ERIA energy savings research project "Analysis on Energy Saving Potential in East Asia Region (FY 2011)", BAU case. The new capacity required was calculated with operation assumed at 75%.

1.4. Job Creation Benefits

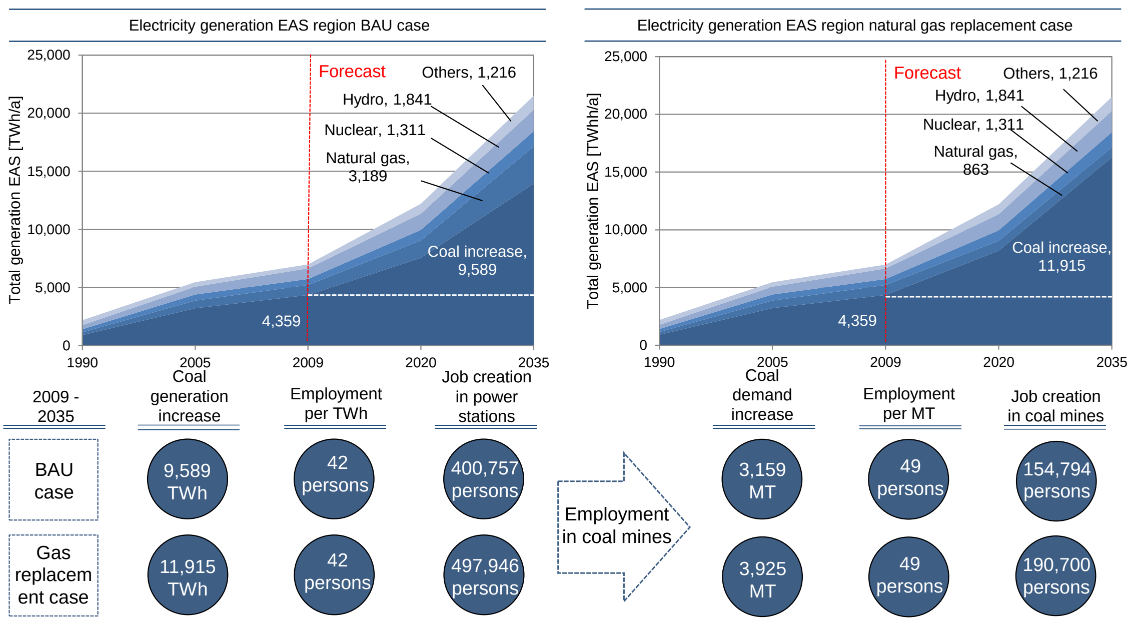
New coal-fired power stations and newly developed coal mines will create jobs in the EAS region. Figure 3-11 shows an estimation of long-term job creation (excluding construction jobs) related with power stations and coal mines.

In the ERIA energy savings research project BAU case, coal-fired power generation will increase by 9,589 TWh from 4,359 TWh/year in 2009, to 13,948 TWh/year in 2035. Assuming productivity in power stations to be around 42 persons/TWh (or 23.9 GWh/person/year), based on generation and employment data from Australia, 182,163 employees are necessary to generate 4,359 TWh/year in the EAS region. In order to generate 13,948 TWh/year, 582,920 persons are necessary. Under these assumptions, employment in coal-fired power stations is estimated to increase by 400,757 persons.

The coal required to generate the additional 9,589 TWh/year by 2035 is around 3,159 MT/year. Under the assumption that employment in coal mines is 49 persons/MT[3], new coal mine development in the EAS regions is estimated to create around 154,794 new jobs.

In addition to people required for the operation of power stations and coal mines, employees will be required for the construction phase of these projects.

Figure 3-10: Job creation benefits



[3] From Robert D. Humphris, "The future of coal: mining costs & productivity", "IEA, The Future Role of Coal, 1999"

Note: Generation productivity is calculated by: total generation, excluding off-grid generation in Australia / number of employees in the power generation sector in Australia, for the FY 2006-2007. It was applied to the 2009 coal demand necessary for coal-fired power generation, and 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 & productivity", "IEA, The Future Role of Coal, 1999", and applied to the increased annual amount of coal required in 2035.

Source: Compiled from ERIA energy savings research project, Australian Bureau of Statistics, Australia Department of Resources, Energy, and Tourism, and own calculations

Table 3-2 gives an overview of the country-wise job creation. The assumed mining development per country was explained in section 3.1.3, with the country share of forecasted production in 2030 applied to the 3,159 MT/year necessary by 2035.

Table 0-1: Employment creation in power stations and coal mines

	Coal generation increase 2009-2035 [TWh]	Assumed productivity [GWh/person/year]	Employment opportunities	Assumed mining development [MT]	Assumed employment [person/MT]	Employment opportunities
Australia	0,0	23.9	0	331.5	39	12,929
Brunei	0,0	23.9	0	0	39	0
Cambodia	3.8	23.9	159	0	39	0
China	5,097.0	23.9	213,019	1769.9	39	69,026
India	3,280.5	23.9	137,102	696.2	39	27,153
Indonesia	290.9	23.9	12,158	279.8	39	10,911
Japan	142.5	23.9	5,955	0	39	0
Korea	80.1	23.9	3,348	1.4	39	53
Lao PDR	11.8	23.9	493	0	39	0
Malaysia	156.6	23.9	6,545	1.6	39	61
Myanmar	0.5	23.9	21	0.7	39	29
New Zealand	0,0	23.9	0	1.6	39	64
Philippines	265.7	23.9	11,104	0	39	0
Singapore	0,0	23.9	0	0	39	0
Thailand	62.2	23.9	2,600	0	39	0
Viet Nam	248.6	23.9	10,390	76.3	39	2,977
EAS	9,589.1	23.9	400,757	3,159	39	123203

Source: Compiled from ERIA energy savings research project, Australian Bureau of Statistics, Australia Department of Resources, Energy, and Tourism, Robert D. Humphris, and own calculations