ERIA Research Project Report 2012, No.27

STUDY ON THE STRATEGIC USAGE OF COAL IN THE EAS REGION

Edited by

HIRONOBU OSHIMA

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LIST OF ABBREVIATIONS AND ACRONYMS

APEC	Asia-Pacific Economic Cooperation
API	American Petroleum Institute
ASEAN	Association of Southeast Asian Nations
A-USC	Advanced Ultra Super Critical
BAU	Business as Usual
Btu	British Thermal Unit
CAGR	Compound Annual Growth Rate
CCS	Carbon Dioxide Capture and Storage
CCT	Clean Coal Technology
CIF	Cost, Insurance and Freight
EAS	East Asia Summit
ERIA	Economic Research Institute for ASEAN and East Asia
EU ETS	EU Emission Trading System
EUR	Euro
FOB	Free on Board
IEA	International Energy Agency
IGCC	Integrated Coal Gasification Combined Cycle
IGFC	Integrated Coal Gasification Fuel Cell
JCC	Japan Customs-cleared Crude
JICA	Japan International Cooperation Agency
JPY	Japanese Yen
LHV	Low Heat Value
LNG	Liquefied Natural Gas
MRI	Mitsubishi Research Institute
NERA	National Economic Research Associates, Inc
NOx	Nitrogen Oxide
NPB	National Balancing Point
OECD	Organization for Economic Co-operation and Development
OPEC	Organization of the Petroleum Exporting Countries
O&M	Operation and Maintenance
PM	Particulate Matter
SOx	Sulfur Oxide
USC	Ultra Super Critical
USD	US Dollar

CHAPTER 1
Introduction

1. Background and Objectives of the Project

Accompanying economic development, electricity demand in the EAS region is rapidly increasing, and in order to satisfy this demand, it is thought that thermal power generation will continue to play a central role through a combination of coal and gas. As coal is cost competitive in terms of calorific value compared with gas, and large quantities of coal are produced in the EAS region, it is anticipated that as the main source of power, coal-fired power generation will increase on a broad scale. In the EAS region, Australia, Indonesia, China, India and Viet Nam produce large quantities of coal, and compared with other energy sources such as gas which in part depends on imports from outside of the EAS region, the magnification of the usage of coal in the EAS region has the merit of enhancing energy security.

However, with the increase in coal demands, notably with those of China and India, the supply demand relationship of coal has become tight in recent years. For the sustainable usage of coal, the dissemination of Clean Coal Technology (CCT) for clean and efficient usage of coal in the EAS region is of pressing importance. In addition, in order to facilitate the economic development within the region, a cost effective and sustainable electricity supply system, with CCT at its heart, should be promoted. While the necessity for the dissemination of CCT has been recognized, inefficient technology has still been widely used. It is therefore a concern that should this situation continues, valuable coal resources will be wasted by inefficient technology, environmental impact will not be sufficiently reduced and sustainability will be harmed.

A technical potential map based on the above-mentioned concerns is of vital importance in order to efficiently disseminate CCT. Namely, it is necessary to suggest a feasible efficiency level, environmental performance and maintenance criterion of each technology so that a country in the region is able to select and introduce the best technologies based on its own situation. At the same time, it is also important to propose appropriate measures so that these can be realized. Upon the completion of this proposed research, "practical" technological potential map including the above mentioned items will be developed in order that policy makers from each country are able to introduce them swiftly.

2. Methodologies of the Project

Various study items were investigated in the project. The research methodology for each item was as follows.

(1) The importance of coal in the EAS region

A) The trends of energy demands and the political positioning of coal in the EAS region

Based on the analysis of IEA data, the trends of energy demands in the EAS region was quantitatively illustrated. Additionally, through the WG meeting held in Jakarta, participating countries' opinions in regard to the direction of this study, the policies and the situation of coal in each country were summarized.

B) Features of coal resources and their importance

- Comparison of coal and natural gas self-sufficiency rates in the EAS region

- The potential for supply increase through widening of the quality range of coal to be procured
- Comparison of coal and natural gas prices

The features of coal as an energy source was quantitatively assessed through the analysis of self-sufficiency rates in the EAS region and the advantages of coal in terms of cost. The amount of coal supply which can be increased by expanding the qualities of coal procured to included lower rank coals was assessed also. In addition, impact of shale gas was considered in comparison with coal price.

C) The importance of coal and CCT dissemination with a view to improving energy security in the EAS region

Based on the results of the analysis above, the contribution of the enhanced use of coal toward the improvement of energy security in the EAS region, and the importance of the dissemination of CCT for the continuous utilization of coal was outlined.

(2) Economic benefits of the introduction of CCT in the EAS region

A) Anticipated benefit of the introduction of CCT in the EAS region

As anticipated benefits of the introduction of CCT, “minimization of capital outflow from the EAS region”, “environmental impact reduction benefits of CCT”, “development and investment benefits of CCT”, and “job creation benefits of CCT” were studied with the following methodology. Firstly, with regards to the “minimization of capital outflow from the EAS region”, the levels of capital outflow from natural gas imports was estimated via IEA trade statistics. In addition, an understanding of the potential for curbing capital outflow via the dissemination of

CCT in the EAS region was reached. For the “environmental impact reduction benefits of CCT”, a baseline case and CCT implementation case was assumed. The effects of the reduction of CO_2 via the implementation of CCT will be analyzed. “Development and investment benefits of CCT”, and “job creation benefits of CCT”, were studied through individual analysis of input-output tables etc.

B) Summary of economic benefits of the introduction of CCT in the EAS region

The items considered in A) was compiled, and the resultant economic ripple effect in the EAS region of the introduction of CCT was outlined.

(3) The development of technological potential map for CCT dissemination in the EAS region

Technical potential map for the introduction of CCT was developed. At this time, the following items was addressed.

- Necessary features of generation efficiency and CO2 emissions intensity
- Necessary technical standards on considering life cycle cost

At the WG meeting in Jakarta, the present conditions and policies regarding the promotion of CCT were heard, and the nature of the technological potential map was considered.

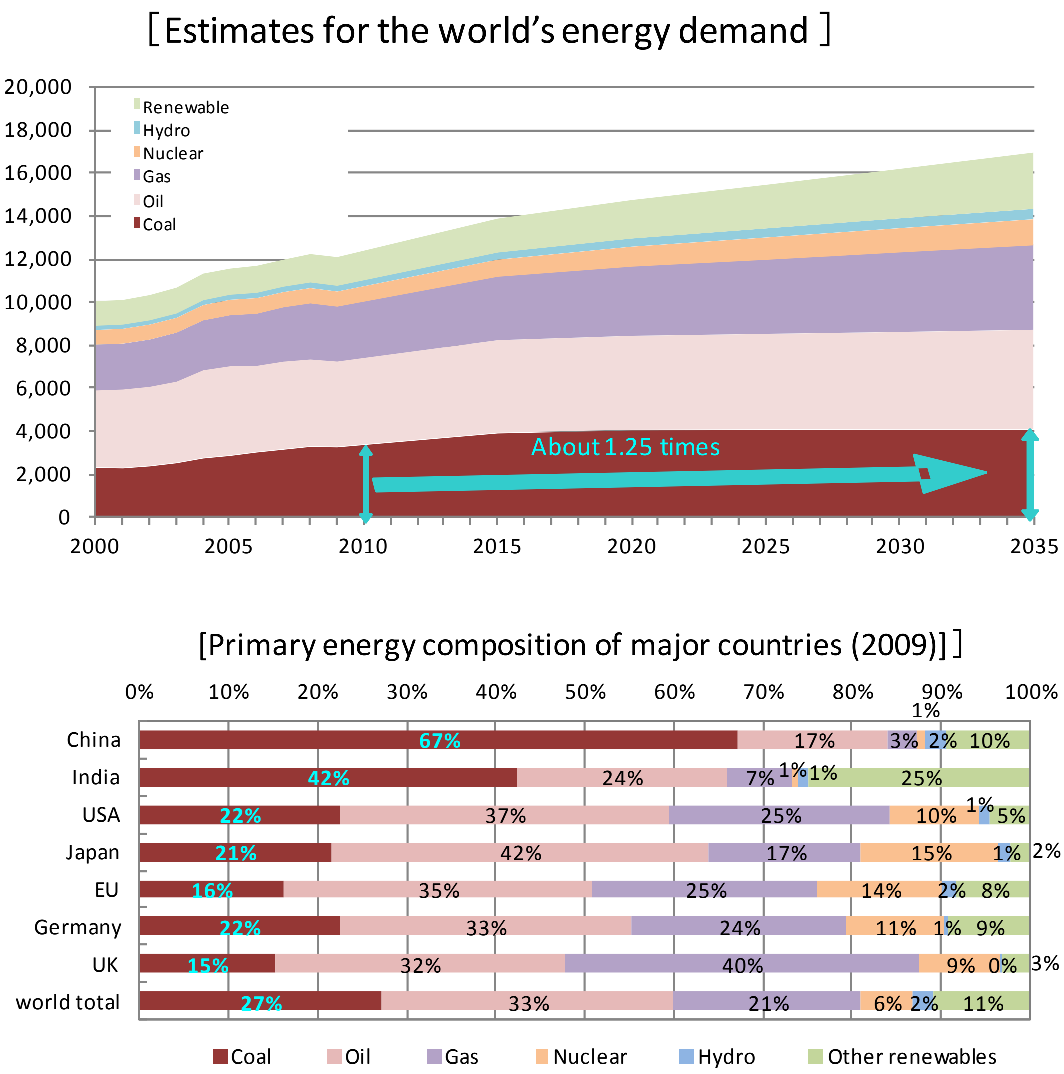
CHAPTER 2

The Importance of Coal in the EAS Region

1. The Trends of Energy Demand and the Political Positioning of Coal

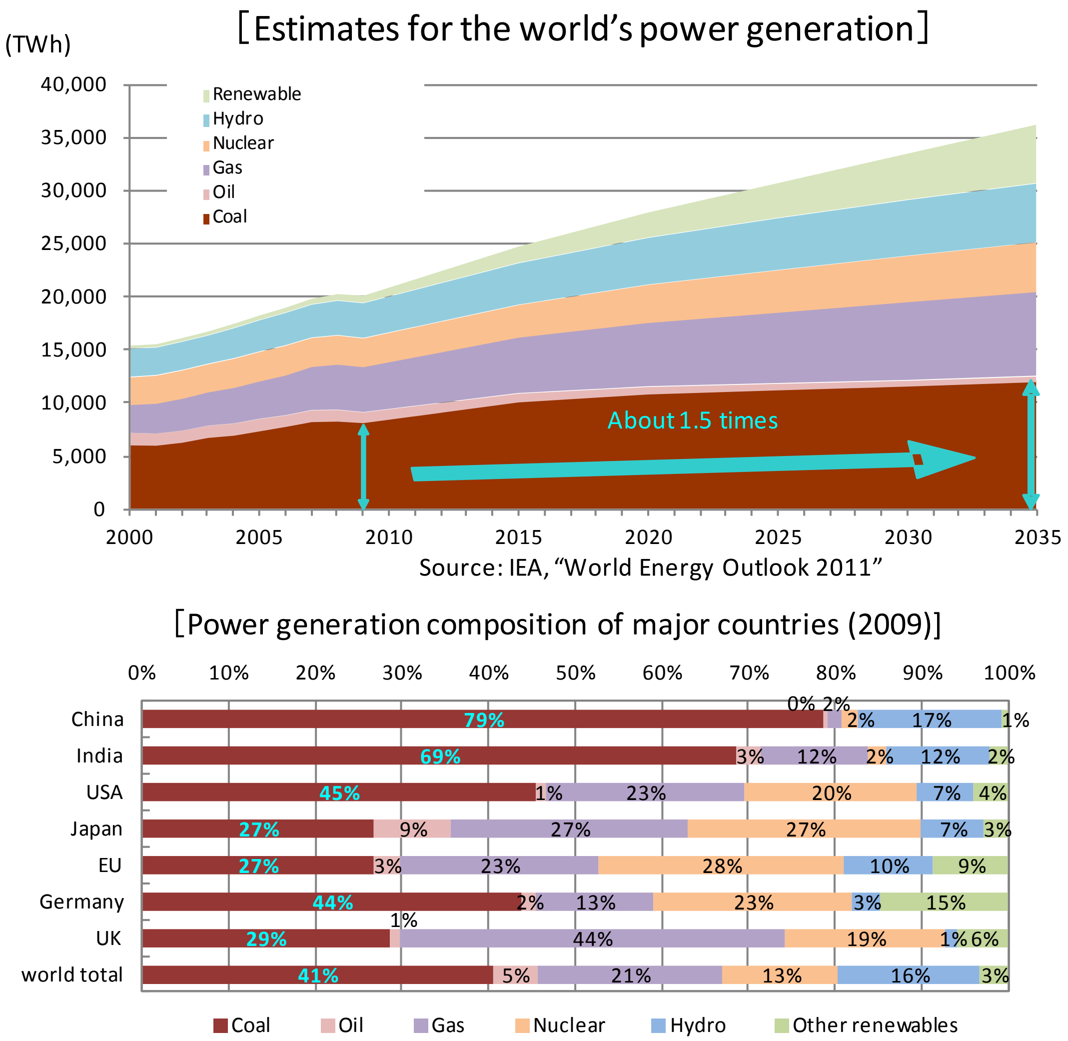
Actual and forecasted global energy demand from the year 2000 to 2035 and the composition of the energy sources in major countries in 2009 are shown in Figure 2-1. Global energy demand is expected to remain increasing steadily in line with continuing economic growth in the future. Under this scenario, coal constitutes about ¼ of the energy demand which is forecasted to increase by about 1.25 times the current level by 2035. Figure2-2 shows the global electricity demand and composition of the electrical power by energy source in the major countries; coal-fired power generation constitutes the largest share or 40% of total electricity generated which is expected to increase to 1.5 times the current level by 2035.

Figure 2-1: World's energy demand and primary energy composition of major countries



Source: IEA, "World Energy Outlook 2011" & "Energy Balances of OECD/non-OECD Countries (2011 Edition)"

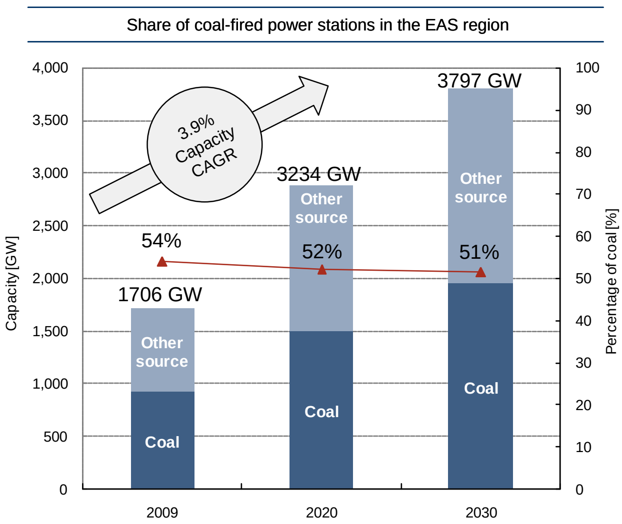
Figure 2-2: World's power generation and power generation composition of major countries

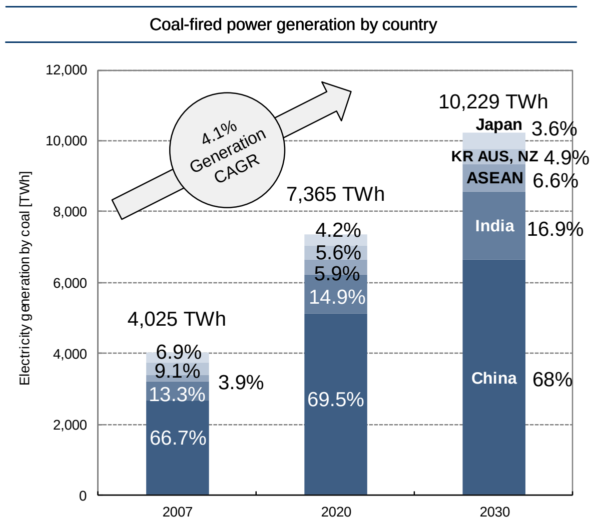


Source: IEA, "World Energy Outlook 2011" & "Energy Balances of OECD/non-OECD Countries (2011 Edition)"

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 figures 2-3. In particular, coal-fired power generation has vastly increased in China and India, and future increases are also forecasted in the ASEAN region. As coal is lower priced compared to petroleum and natural gas, demand for coal is therefore expected to continue increasing from an economic point of view.

Figure 2-3: Estimate of coal-fired power plant in the ERIA

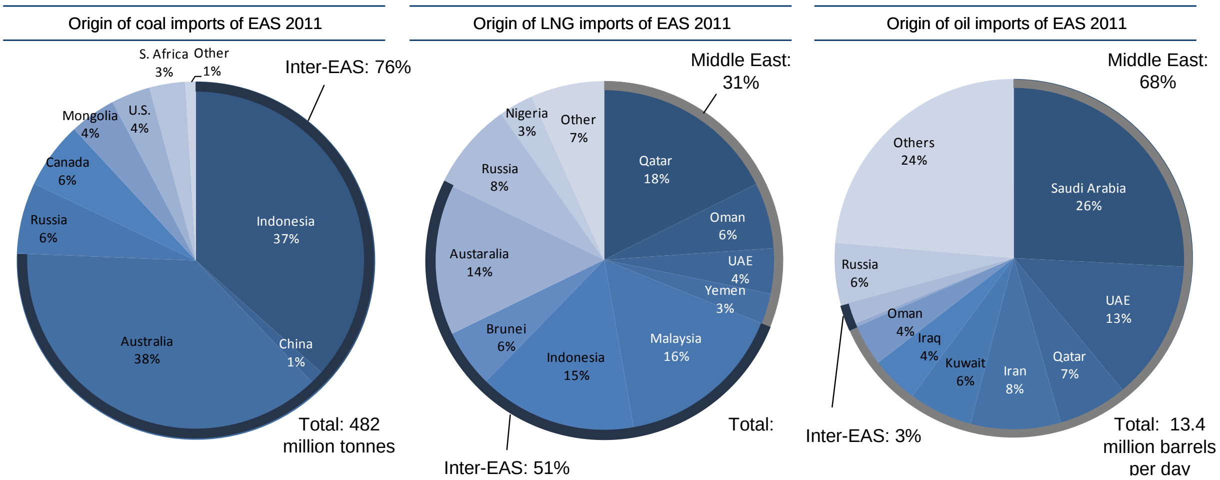




Source: Compled from IEA statistics

As such, coal has become an important energy source in the EAS region. Petroleum and natural gas are also produced in the EAS region and will remain important energy sources in the future. Figure 2-4 shows the origin of primary energy import in EAS region. In the EAS region, about 50% of the natural gas consumed is produced within the region while 31% is being imported from the Middle East. A mere 3% of the petroleum consumed is regionally produced with 68% being imported from the Middle East. In contrast, coal produced in the EAS region constitutes 76% of the total coal consumption in the region. All this indicates that coal, mainly produced and consumed within the region, does not require dependency on the Middle East as petroleum and natural gas do. In view of the political uncertainty of the Middle East region which may raise concern over transportation security at a strategic pathway such as the Strait of Hormuz, coal will be of further significance in the energy security context as well.

Figure 2-4: Origin of primary energy import in EAS region



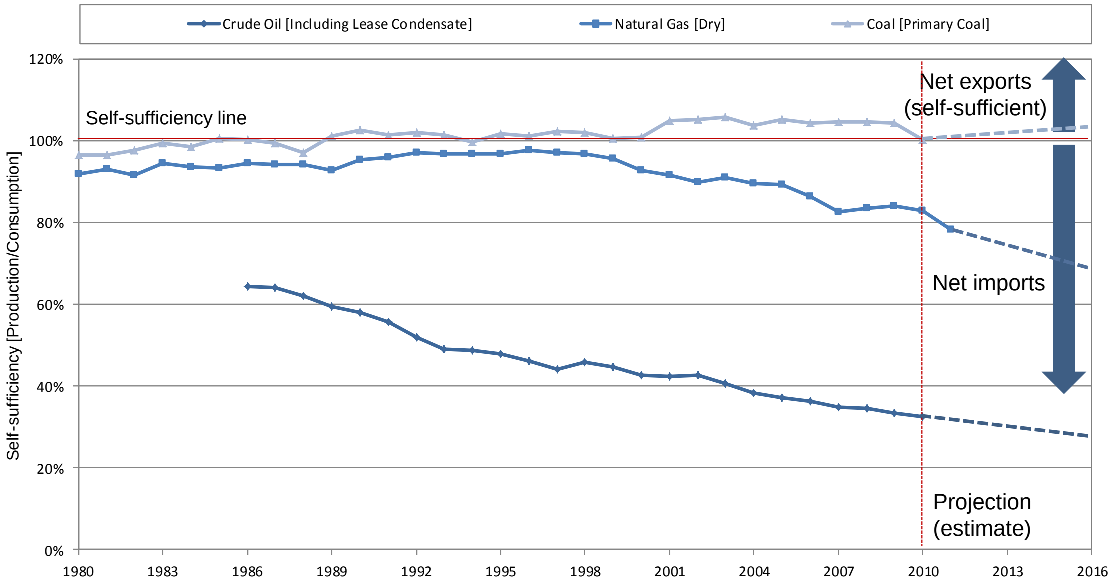
Source: Compiled from IEA Natural gas information, Coal information, GTA data, Japan's trade statistics and original estimation

2. Features of Coal Resources and Their Importance

2.1. Coal and Gas Self-sufficiency Rates in East Asia

In order to understand the energy supply security of coal and natural gas, the self-sufficiency rate was used as an indicator. Self-sufficiency in the EAS region can be defined as: the total coal or natural gas production within the EAS region divided by the total demand or consumption of coal or gas in the EAS region. If the ratio is smaller than 100, it implies that imports from outside the EAS region are necessary to satisfy demand. Figure 2-5 shows the self-sufficiency of coal, natural gas and oil in the EAS region. Coal has historically been self-sufficient in the EAS region and showed the highest self-sufficiency among all fossil fuels, and therefore, the most secure natural resource in the EAS region. Since 2000, coal has been continuously self-sufficient, meaning that there is enough production capacity to supply all coal demand in the EAS region.

Figure 2-5: Self-sufficiency of energy resources in the EAS region



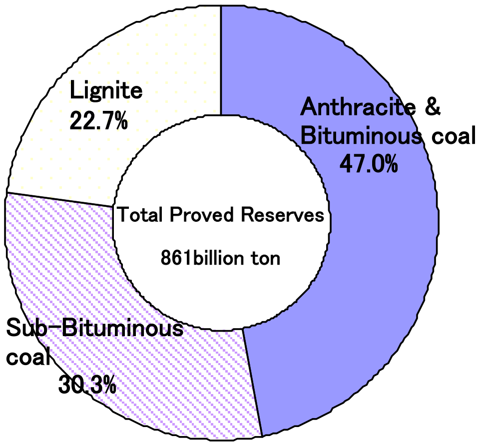
Source: Compiled from EIA International Statistics.

2.2. The Potential for Supply Increases through Expansion of Procured Coal Grades

2.2.1. Coal Resources

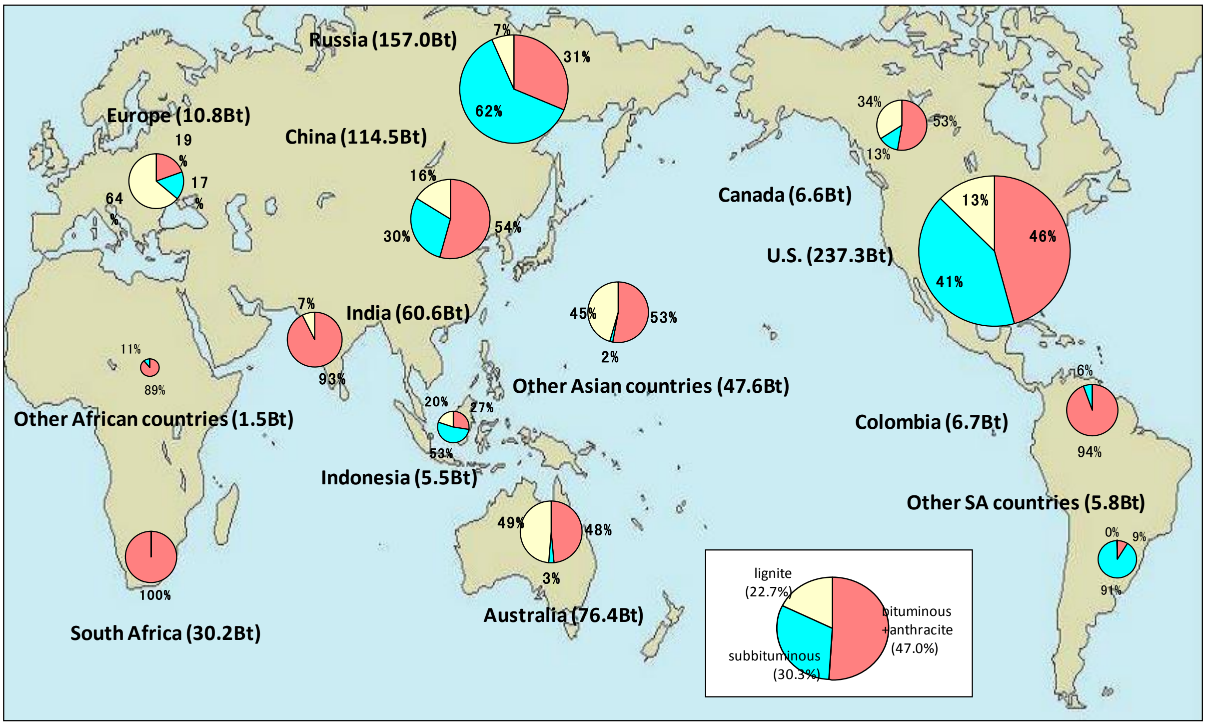
Global coal reserves are shown in Figure 2-6. High rank coals such as bituminous coal and anthracite that are used as coking coal and steam coal make up around 47% of the reserves, while low rank coals constitutes about half of the overall coal reserves with 30% being sub-bituminous coal and 23% being lignite. Figure 2-7 shows the world minable coal reserves by region and by coal rank. Unlike other energy sources, coal is distributed widely throughout the world with little uneven distribution. While coal reserves are large in Oceania and the Asia region, the proportion of lignite is high. Even in the world's largest steam coal exporter Indonesia which exports mainly to the Asian countries, the amount of bituminous coal reserves is only 27% of the total reserves and thus exports of sub-bituminous coal are increasing.

Figure 2-6: Proved reserves of coal by rank in the world



Source: BP, Statistical Review of World Energy 2012

Figure 2-7: Recoverable coal reserves in the world (by region and coal rank)



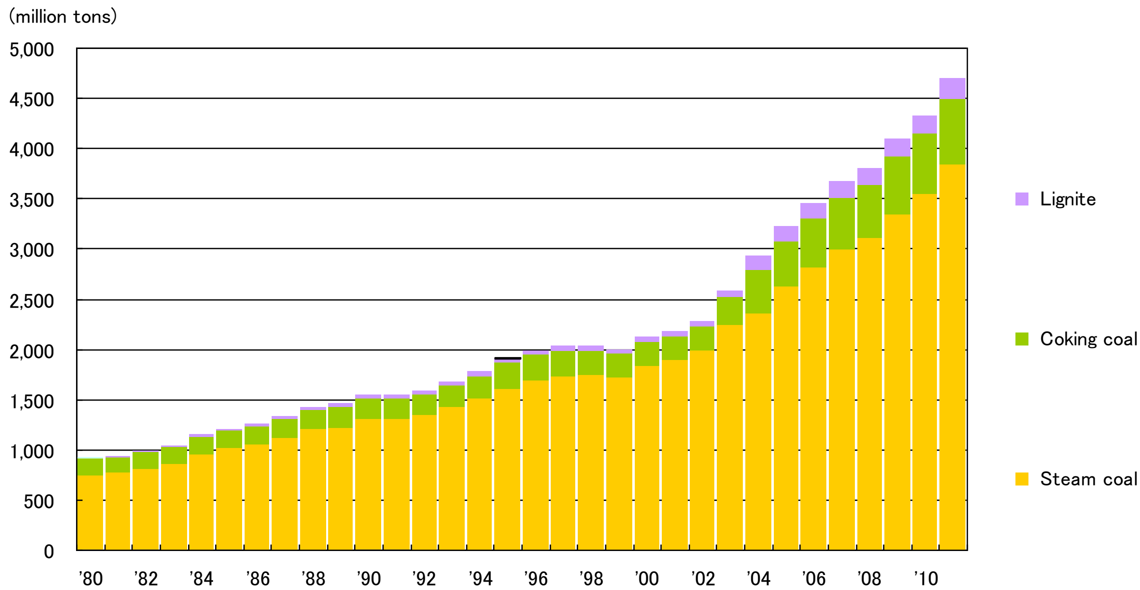
Source: WEC "Survey of Energy Resources 2010," BP Statistics 2010

Source: WEC "Survey of Energy Resources 2010", BP Statistics 2010

2.2.2. Coal Consumption in Asia

The amount of coal consumed in the Asia region reached 4.7 billion tons in 2011. In terms of coal rank, steam coal is dominant with over 80% as shown in Figure 2-8. Likewise, the amount of lignite consumption is increasing year by year. The consumption of steam coal for power generation (including in-house power generation, heat supply) in 1980 only accounted for 25 % of the total consumption of steam coal and it was mainly used for industrial purposes and consumer use. In the 2000s, however, the consumption of steam coal for power generation started to account for over 60% of the total and since 2006 it has accounted for around 70 %.

Figure 2-8: Coal consumption by coal type in Asia



(million tons)

	80	85	90	95	00	05	06	07	08	09	10	11*
Steam coal *(for Power Generation)*	740 *(186)*	1,008 *(297)*	1,304 *(484)*	1,604 *(786)*	1,831 *(1066)*	2,621 *(1738)*	2,816 *(1932)*	2,990 *(2110)*	3,105 *(2176)*	3,336 *(2284)*	3,537 *(2416)*	3,837
Coking coal	162	180	207	262	238	452	486	511	526	576	603	647
Lignite	11	19	34	46	49	150	156	165	168	179	187	206
Total	913	1,207	1,545	1,912	2,118	3,222	3,458	3,666	3,800	4,091	4,327	4,690

Note : 2011* is an estimate and Steam coal includes anthracite.

Source : IEA, “Coal Information 2012” and “Energy Statiscs OECD/non-OECD 2012”.

Figure 2-9 shows the flow of steam coal in 2011. Steam coal is mainly exported for Asia by Indonesia and Australia, and is also exported by South Africa, Russia, as well as China, Colombia, the US, and Canada, although the volume is smaller.

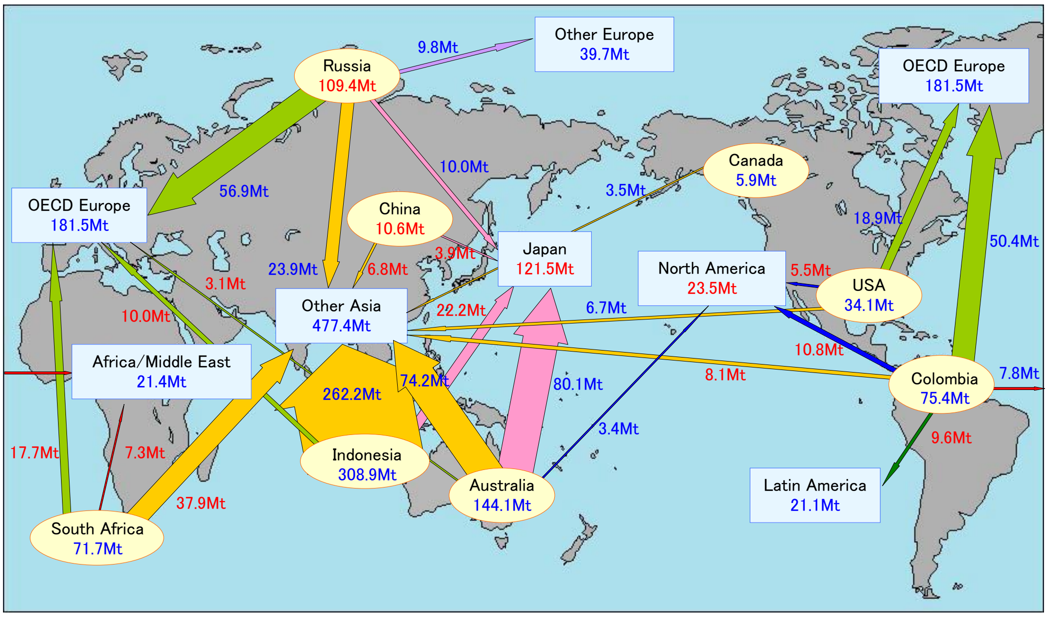
Table 2-1 shows the volume of exports by destination of exporting countries which supply the main countries in East, South and Southeast Asia in 2011 with steam coal. Indonesia is the biggest steam coal exporter to China and accounted for 48% of total Chinese imports in 2011. Korea, Taiwan and India import also from Indonesia in the same manner as China. 96% of the nearly 300 million tons in steam coal exports from Indonesia are for Asia. As the column of “others” of the exports from Indonesia exceeds 55 million tons, 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 and 97% of its steam coal is exported to Asia which totaled 140 million tons in 2011. Indonesian and Australian coal exports account for three-fourths 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 million tons, respectively, but its exports to India are smaller. India imports more coal from South Africa which is a shorter distance than Australia.

Russia exports more than 10 million tons of steam coal to Japan and Korea and ranks as the fourth largest exporter to Asia.

Other Asian countries import mostly from Indonesia. According to future coal demand forecasts, demand for energy and in particular electricity is expected to increase substantially as a result of the economic growth in Asia region, and many new coal-fired power plants are being planned. Coal consumption for power generation is forecasted to increase in Asia region. Even in Cambodia which currently does not have any coal-fired power plants and Myanmar which has only small-scale coal-fired power plants, construction of coal-fired power plants with imported coal from Indonesia are in the planning phase. In Vietnam where anthracite used to be dominant, a plan of a new plant to be fired on blended coal; i.e. anthracite with imported Indonesian coal is in progress.

Figure 2-9: Flow of steam coal (2011 estimate)



Note: The above figure does not show flows of less than 3 million tons. The blue-colored numbers show an increase relative to the previous year and the red-colored numbers a decrease relative to the previous year. The "North America" as an importer includes Mexico.

Source: IEA, "Coal Information 2012".

Table 2-1: Volumes of export of steam coal in the main exporting countries (2011)

(million tons)

Export by destination	Export Countries							
	Indonesia	Australia	South Africa	China	Russia	Colombia	USA	Canada
China	70.98 24%	17.32 12%	12.24 29%	– –	6.23 18%	1.44 55%	0.88 13%	1.31 23%
Japan	29.41 10%	66.96 48%	0.85 2%	4.21 40%	12.12 36%	0.23 9%	0.61 9%	2.04 37%
Korea	39.48 13%	28.27 20%	4.04 10%	4.46 42%	10.72 32%	0.28 11%	4.88 70%	2.23 40%
Taiwan	26.63 9%	20.12 14%	3.86 9%	1.87 18%	3.61 11%	0.66 25%	0.00 0%	0.00 0%
India	73.60 25%	0.50 0%	17.14 41%	– –	1.14 3%	0.01 0%	0.63 9%	0.00 0%
Thailand	Unknown	2.92 2%	Unknown	Unknown	Unknown	–	0.00 0%	0.00 0%
Malaysia	Unknown	3.15 2%	Unknown	Unknown	Unknown	–	0.00 0%	0.00 0%
Vietnam	Unknown	Unknown	Unknown	Unknown	Unknown	–	–	–
Philippines	Unknown	0.28 0%	Unknown	Unknown	Unknown	–	0.00 0%	0.00 0%
Others	55.39 19%	0.56 0%	3.92 9%	0.02 0%	0.05 0%	– –	0.00 0%	0.00 0%
Total of Asia	295.50 96%	140.07 97%	42.03 59%	10.55 100%	33.87 31%	2.26 3%	7.00 21%	5.58 94%
Total export	308.91	144.06	71.70	10.58	109.36	75.41	34.06	5.93

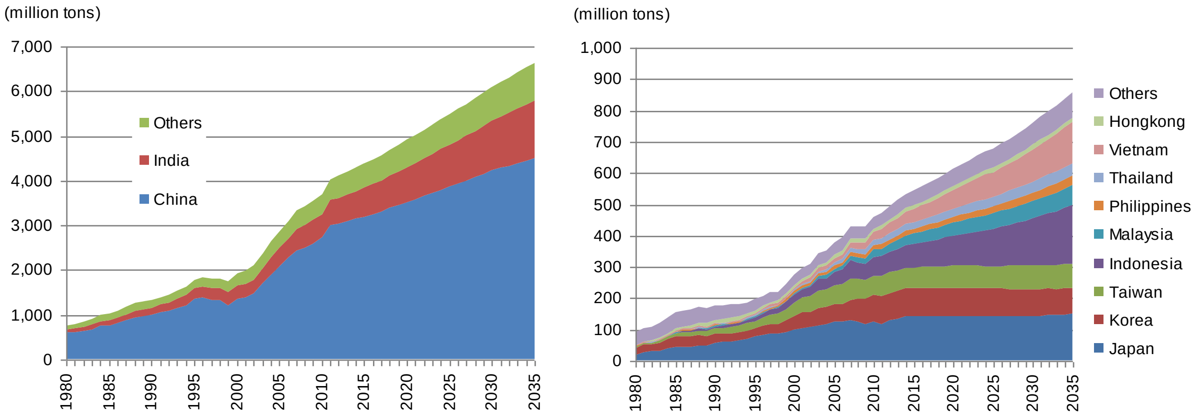
Note: Steam coal includes anthracite. The percentage shows the percentage of the volume of export to the countries surveyed relative to the export volume of steam coal to Asia (total of Asia). The percentage in the total column of Asia represents the percentage of the export volume of steam coal to Asia (total of Asia) relative to the total volume of export of each exporting country. When the volume of export is unknown, this figure is added to the column of "others".

Source: IEA, "Coal Information 2012"

2.2.3. Consideration on Future Coal Demand and Supply

Steam coal demand in Asia will increase from 2010 to 2035 at an annual growth rate of 2.4 %, and will increase by 1.8 times from 3,730 million tons in 2010 to 6,652 million tons by 2035. Figure 2-10 show 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 demand for electricity is expect to increase with economic growth in the future, the demand for power generation should increase. The demand in India for steam coal will increase at an annual growth rate of 3.7% to 2035 due to a rapid increase in demand for power generation and India is expected to consume up to 1,297 million tons in 2035, which is a 2.5-fold increase relative to 2010. In ASEAN countries, in order to meet the increasing demand for power generation, it is expected that they will use cheap coal power and that coal demand will increase. Specially, in Indonesia, which is building a coal power generation station using low grade coal produced domestically, steam coal demand will close to 100 million tons in 2020 and increase to 190 million tons in 2035. Steam coal demand in Vietnam will increase to 132 million tons in 2035 by the increment of coal power. The consumption of steam coal in other countries will increase by 2 to 3 times relative to that in 2010. On the contrary, Japan, Korean and Taiwan which have widely used steam coal for power generation will still experience increases in demand, but their growth is expected to slow down.

Figure 2-10: Steam coal demand forecast in Asia

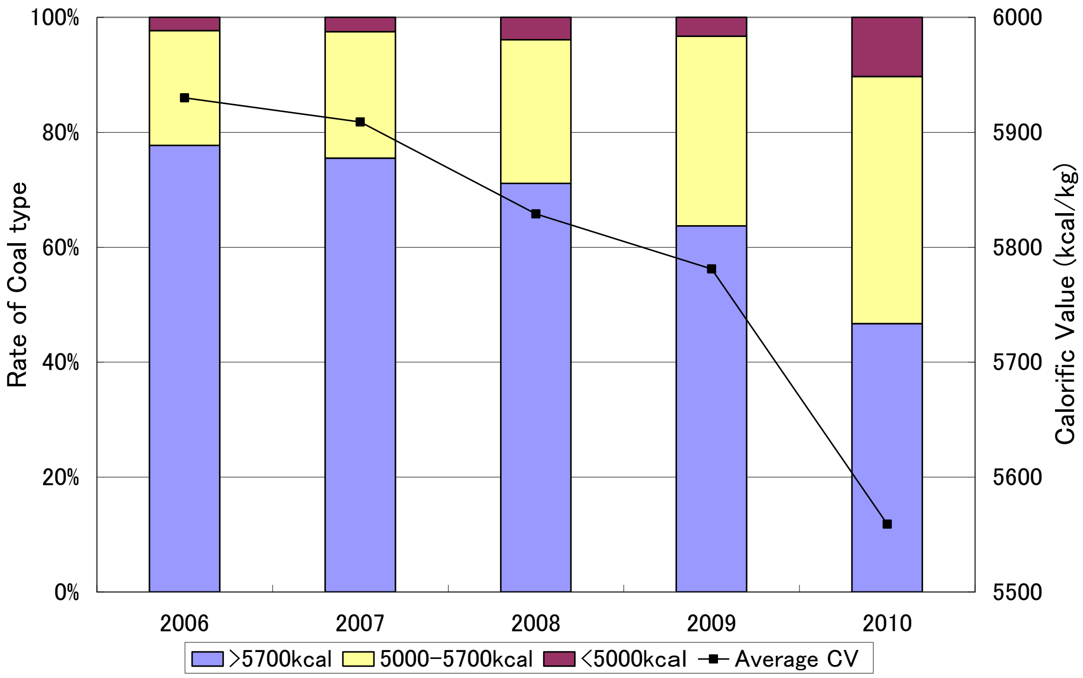


Source: The actual data is from the IEA data and the forecast was made by the JICA.

Most of these increases in coal demand in the region are expected to be addressed by Indonesia. Being abundant with low rank coal of low ash and low sulphur content offering advantages in both price and environmental compliance, Indonesia expects its low rank coal export to further increase toward 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 of lower than 4,000kcal/kg, which now have come on to the market.

Korea has been expediting low rank coal utilization and expansion. As shown in Figure 2-11, the overall calorific value of the coal used is also on a downward trend as low rank coal utilization is on the increase. Such downward trend has become more conspicuous since 2010. The Government of Korea expedites measures such as combustion improvement through blending with high rank coal and high efficiency CCT such as USC, etc. in consideration of high moisture and low calorific value that low rank coal carries.

Figure 2-11: Coal type and average calorific value used in coal-fired power plant in Korea



Source: Gyun Choi and Jiho Yoo, APEC Clean Fossil Energy Technical and Policy Seminar 2012 (Gold Coast, Australia, February, 2012).

Looking at Indonesia, the major coal supplier for the region, the country in recent years saw steady economic growth after having gone through the impact of the global financial crisis, which has boosted its own energy demand. Once joining OPEC as one of the major oil and gas producer, in view of the gradually depleting oil and gas resources, Indonesia has shifted its energy policy toward effective use of the domestically abundant and available energy source; i.e. coal. In order to meet the increasing demand for electricity, many new large-scale coal-fired power plants are being planned, which requires sustainable coal supply for such new power plants to be ensured. More than 80% of the produced coal is currently exported and the rest is for domestic consumption. It is expected with the surging domestic demand by the power sector, in the coming years coal export by Indonesia may see sluggish growth as the policy to prioritize domestic supply to meet domestic demand has come into force. It may come up as the common agenda that Asia region need concerted coordination toward balanced regional demand-supply.

2.3. Comparison of Coal and Natural Gas Prices

Figure 2-12 shows thermal coal and LNG import prices (CIF price) 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, providing 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 to 3.5, with the exception of 2009.

In January 2013, prices were 0.0056 JPY/kcal (15.85 USD/MMBtu[1]) for LNG and 0.0017 JPY/kcal (117.57 USD/ton[2]) for thermal coal, putting the LNG/thermal coal price ratio at 3.3.

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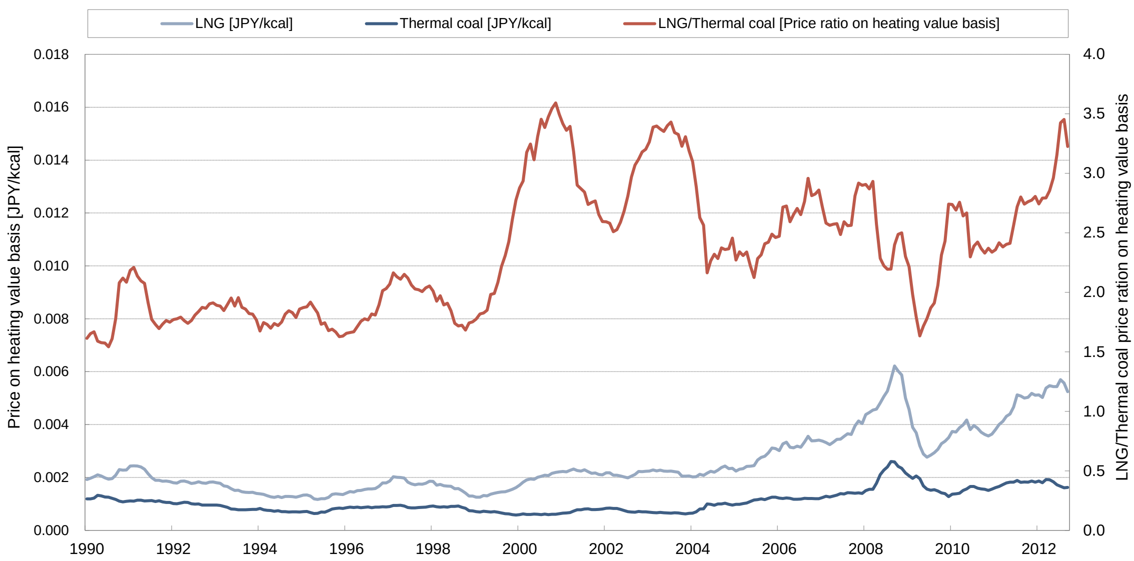
[1] For the heating value conversion, the IEA energy conversion rate was used at 1 MMBtu = 251,995.79631 kcal. The average exchange rate of the Federal Reserve for January 2013 was used at 1 USD = 89.0581 JPY.

[2] The average heating value of imported thermal coal to Japan was 6,142 kcal/kg. The same exchange rate as for the LNG conversion was used at 1 USD = 89.0581 JPY.

Figure 2-12: Comparison of coal and natural gas prices



Source: Japan import statistics.

2.3.1. Shale Gas Impact

Although the shale gas revolution has had a decreasing effect on natural gas prices in the US, and has therefore allowed for lower export prices from the US, coal is still expected to remain its cost-competitiveness.

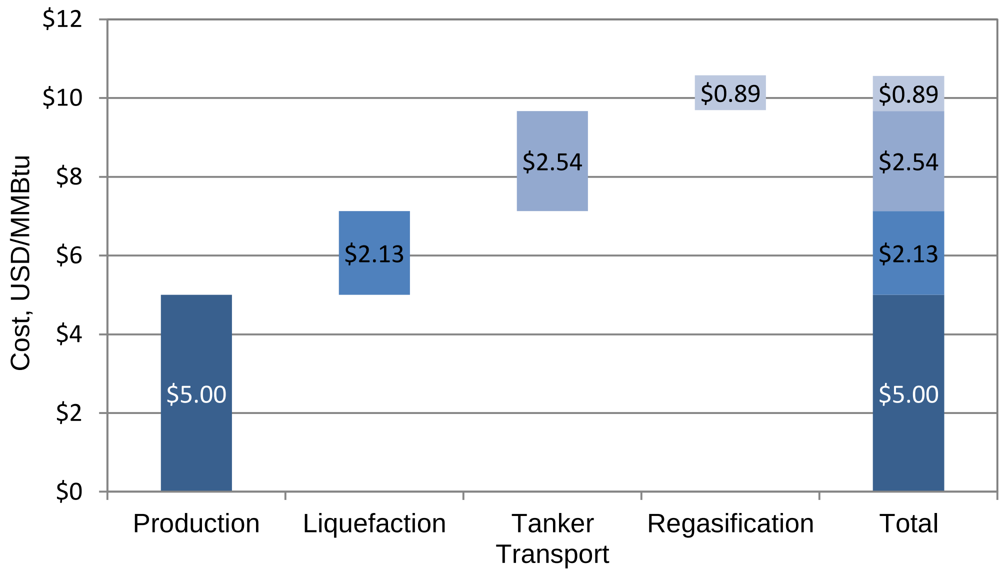
As seen in Figure 2-13, the CIF cost price of LNG to Japan can be potentially reduced to about 10.56 USD/MMBtu, assuming that the input natural gas price in the US is 5 USD/MMBtu [3]. The remaining costs consist of liquefaction (2.13 USD/MMBtu), transportation by tanker (2.54 USD/MMBtu) and regasification (0.89 USD/MMBtu).

As mentioned previously, the January 2013 price of coal imports to Japan was 117.57 USD/ton, with an average heating value of 6,142 kcal/kg. In January 2013, the LNG import price to Japan was around 15.85 USD/MMBtu, which is equivalent

[3] This assumption lies slightly above current prices in the US (around 4 USD/MMBtu), but is not unrealistic when considering that expanding exports will in all likelihood cause domestic prices in the US to rise.

to 386 USD/ton of coal, assuming the heating value of coal is 6,142 kcal/kg. LNG import prices of 10.56 USD/MMBtu would be equal to 257 USD/ton of coal on heating value basis. Therefore, even if LNG import prices are around 10 USD/MMBtu, coal is more than twice as cost-competitive on heating value basis,

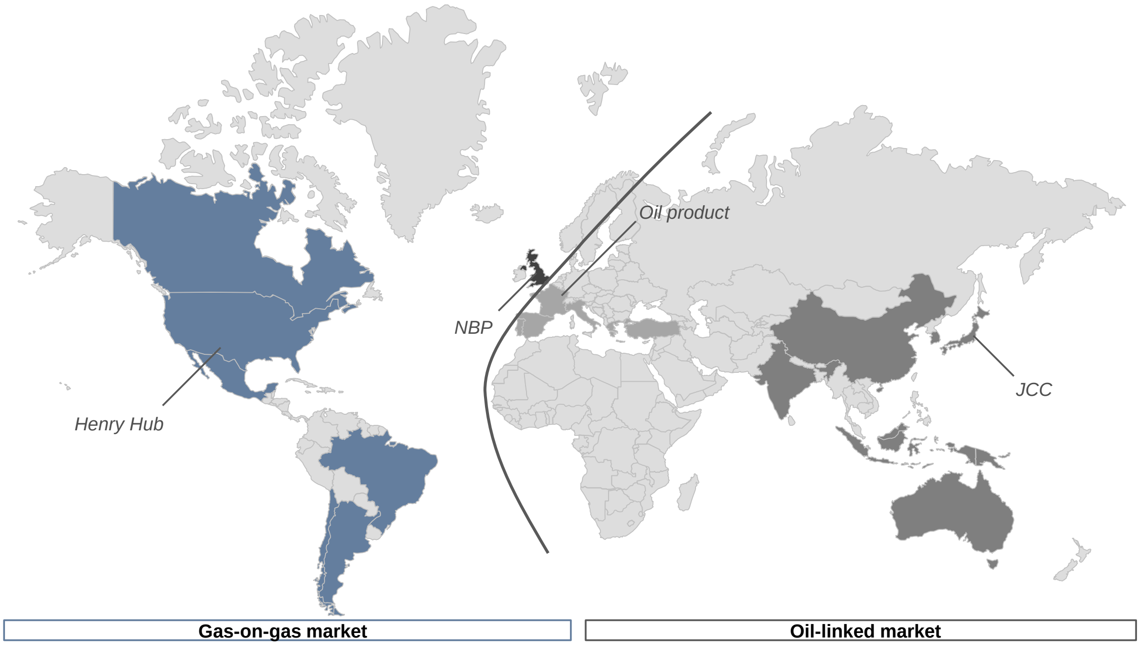
Figure 2-13: US LNG import to Japan cost breakdown



Source: Liquefaction, tanker transport and regasification values were taken from NERA. Production cost is MRI assumption.

Historically there have been 4 price mechanisms for natural gas as seen in Figure 2-14: Henry Hub in the US, National Balancing Point (NPB) in the UK, oil product in continental Europe, and the Japan Customs-cleared crude (JCC) in Asia. However, judging from Japanese participation in newly proposed LNG terminals in the US, it is expected that exports from the US to Japan will increase. This increase may cause the Henry Hub price to have a larger impact on LNG prices in Asia, and weaken the link of the LNG price to the JCC market. As a result, gas prices in Asia may decline. However, even in this shift from JCC to Henry Hub, coal is expected to remain its competitiveness, as discussed previously and as shown in Figure 2-13.

Figure 2-14: Natural gas price mechanisms



Source: Mitsubishi Research Institute from various resources.

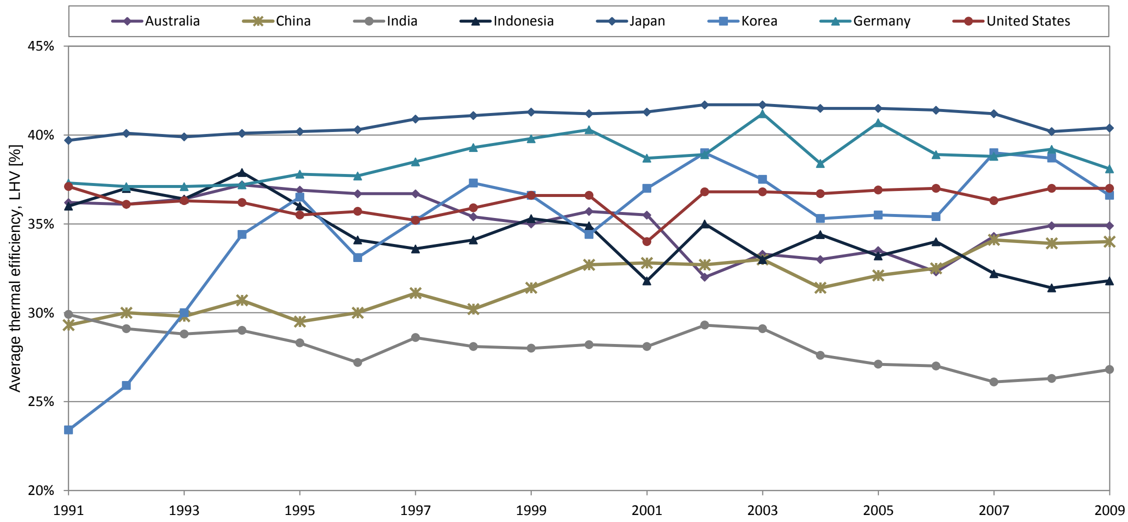
3. The Importance of Coal and CCT for Improving Energy Security

The main features of coal for the EAS region can be summarized 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, and;
4. Coal is more cost-competitive than natural gas.

However, coal is not used efficiently. Although coal is relatively abundant in the EAS region, coal is also an important source of energy, and should be used as efficiently as possible. Figure 2-15 shows the thermal efficiency in Australia, China, India, Indonesia, Japan and Korea, as well as Germany and the United States as a reference. In some Asian countries, thermal efficiency is still lower than 35%, leaving room for improvement. In order to maximize the potential of coal, CCT should be introduced in the EAS region.

Figure 2-15: Thermal efficiency of coal-fired power stations in Asia, Germany and the US



Source: Energy Balances of OECD/Non-OECD Countries 2011, IEA

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.

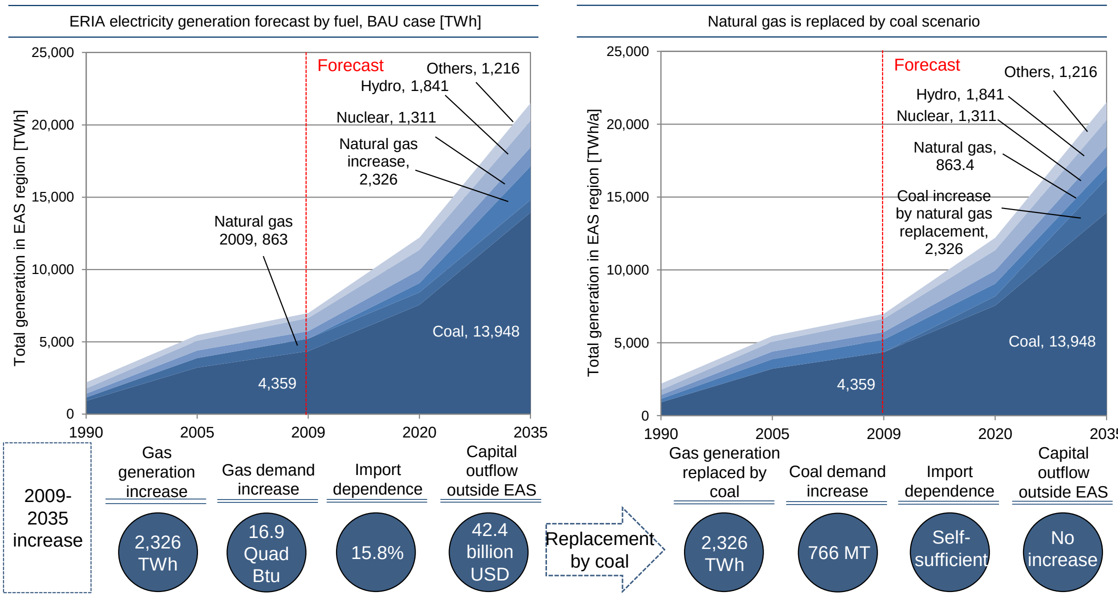
If it is assumed that all additional coal can be produced in the EAS region,

[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

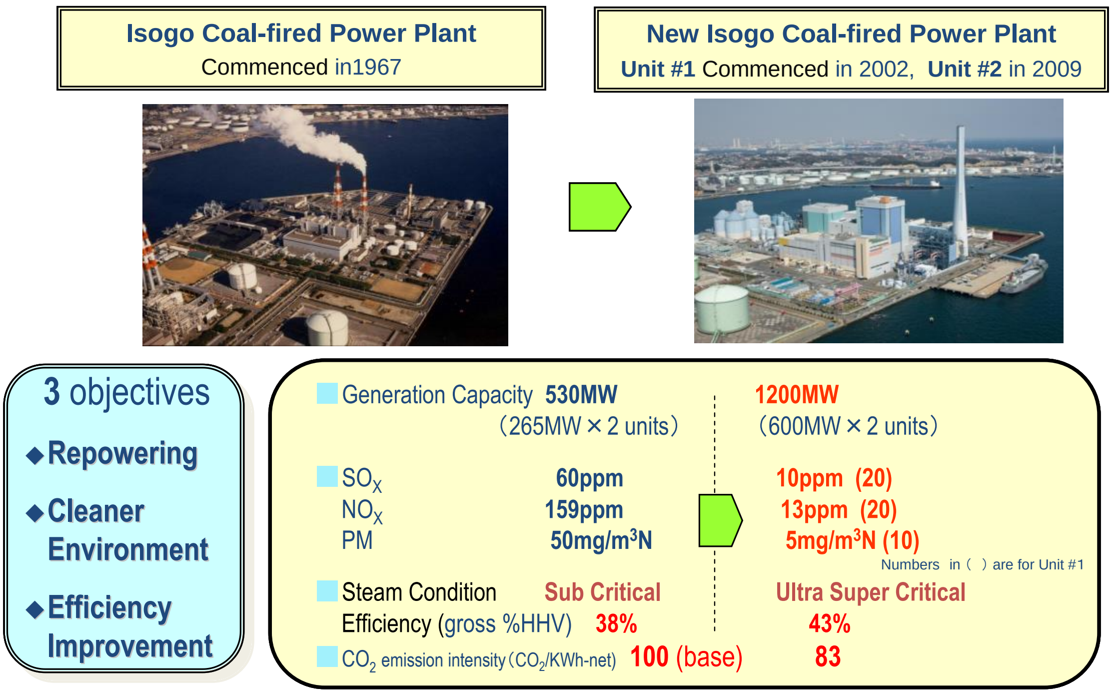
In the past when we used to have small scale coal fired power plants and other combustion facilities only, emissions from coal combustion might not have much affected the environment impact, which have turned totally different during recent years that saw high and extensive growth of economy and energy 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.

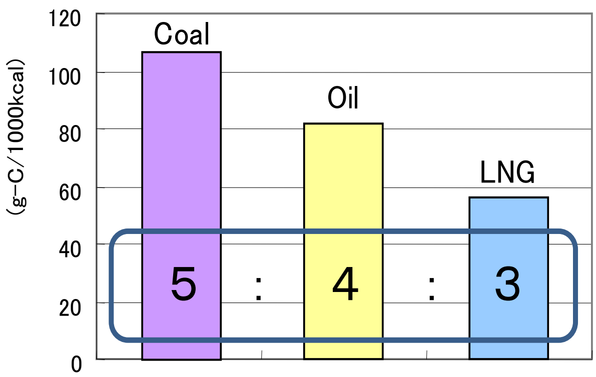
In summary, in order to mitigate environmental impact by coal consumption increase in the future, installation of high efficiency desulphurization, denitrification and dust collecting equipment to coal-fired power plants the major coal user is required.

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

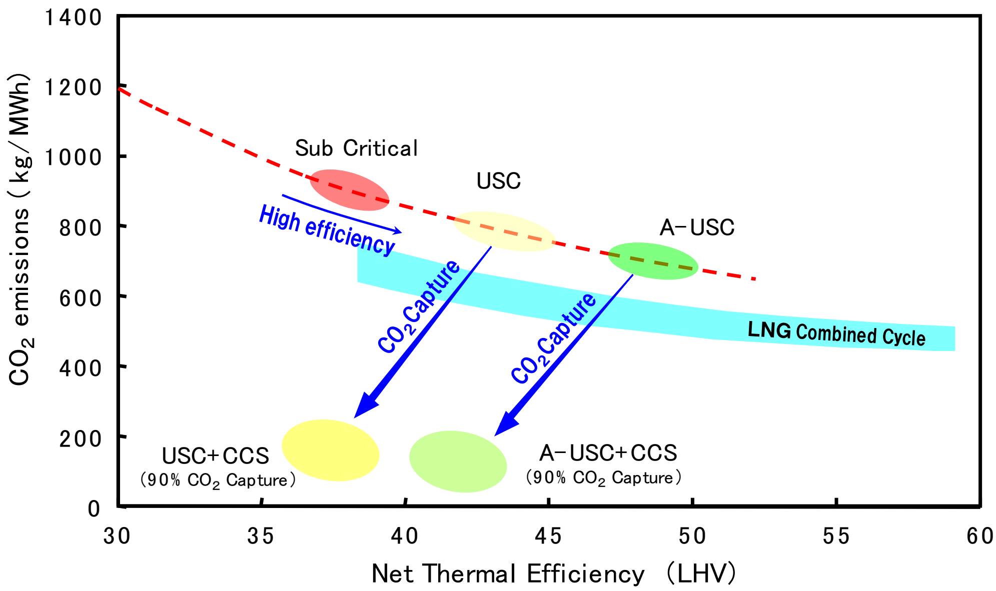
emissions are reduced as efficiency increases. Figure 3-5 compares CO_2 emissions from power plants using high efficiency CCTs such as USC, IGCC and IGFC, and those powered by petroleum and natural gas. By using high efficiency CCTs, it is possible to reduce CO_2 emissions to the level of the same by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

Figure 3-3: CO_2 emission per Thermal unit



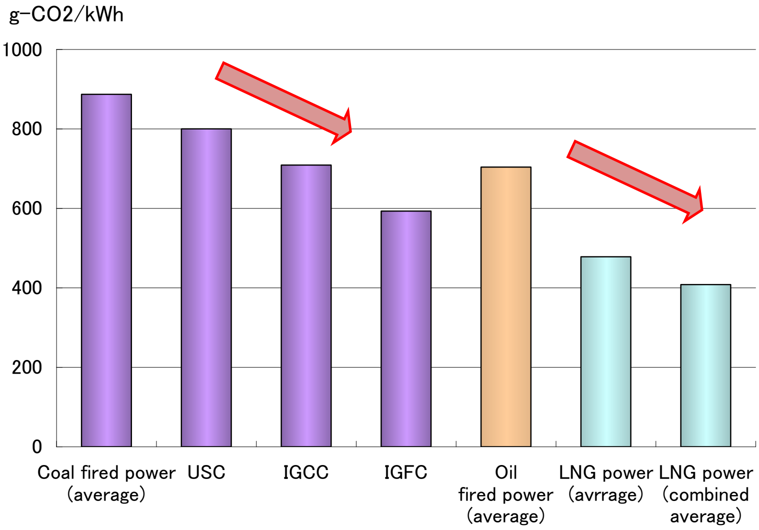
Source: based on "United nations Framework convention on Climate Change'

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

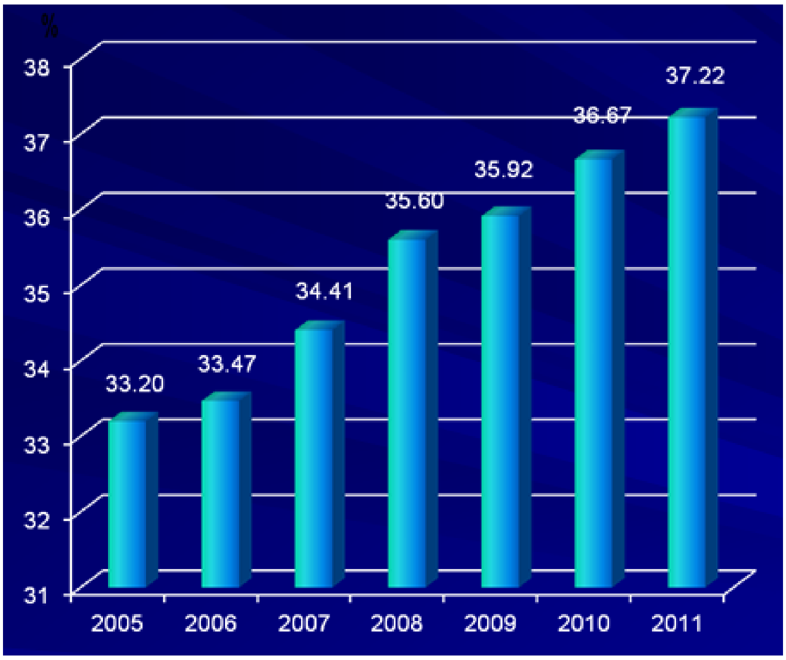


Source: Okazaki, K., Clean Coal Day in Japan 2011 International Symposium (Tokyo, Japan, September, 2011)

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.

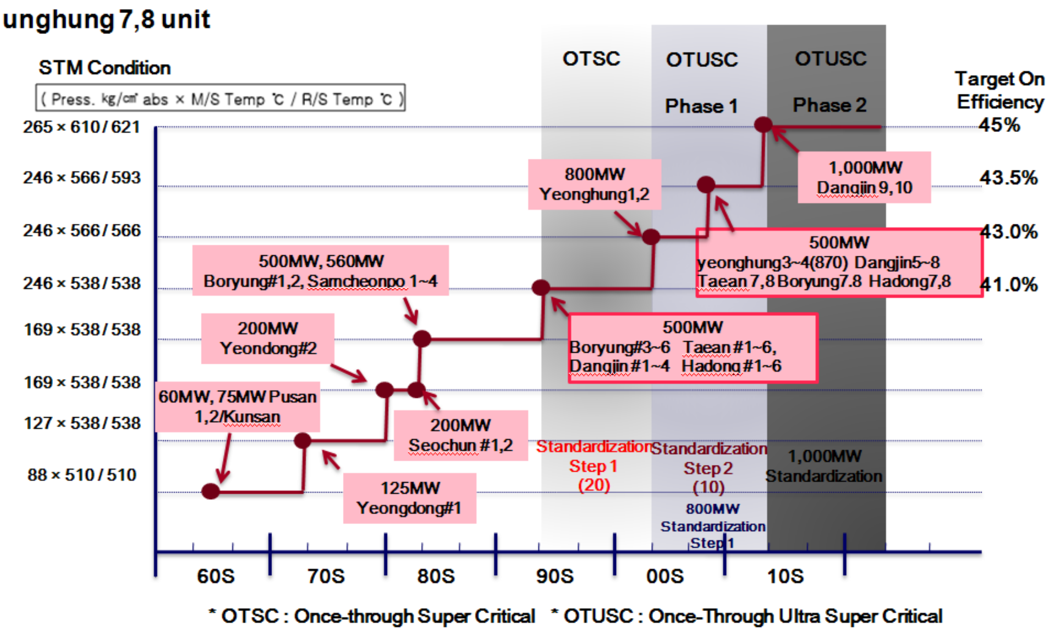
China, one of large coal consumers has shown improved efficiency at its coal fired power plants as shown in Figure 3-6. Korea is also aiming to improve the efficiency of its coal-fired power plants as indicated in Figure 3-7.

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



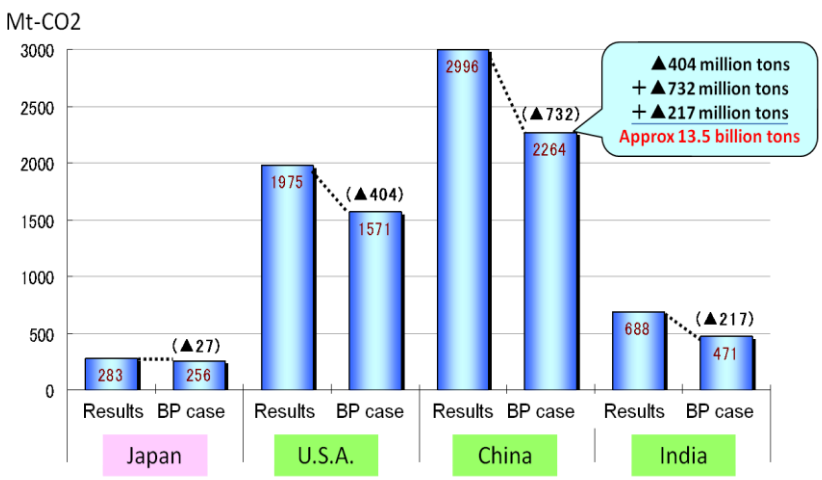
Source: Roh S., APEC Clean Fossil Energy Technical and Policy Seminar 2010 (Fukuoka, Japan, October, 2010)

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.

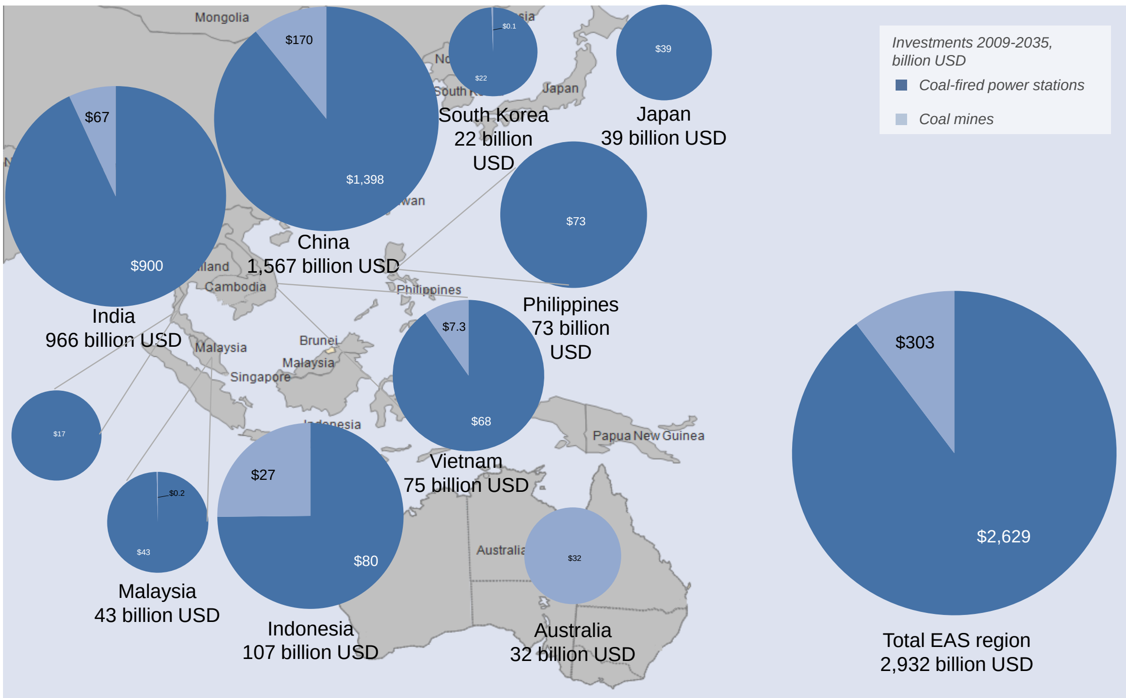
1.3. Development and Investment Benefits

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

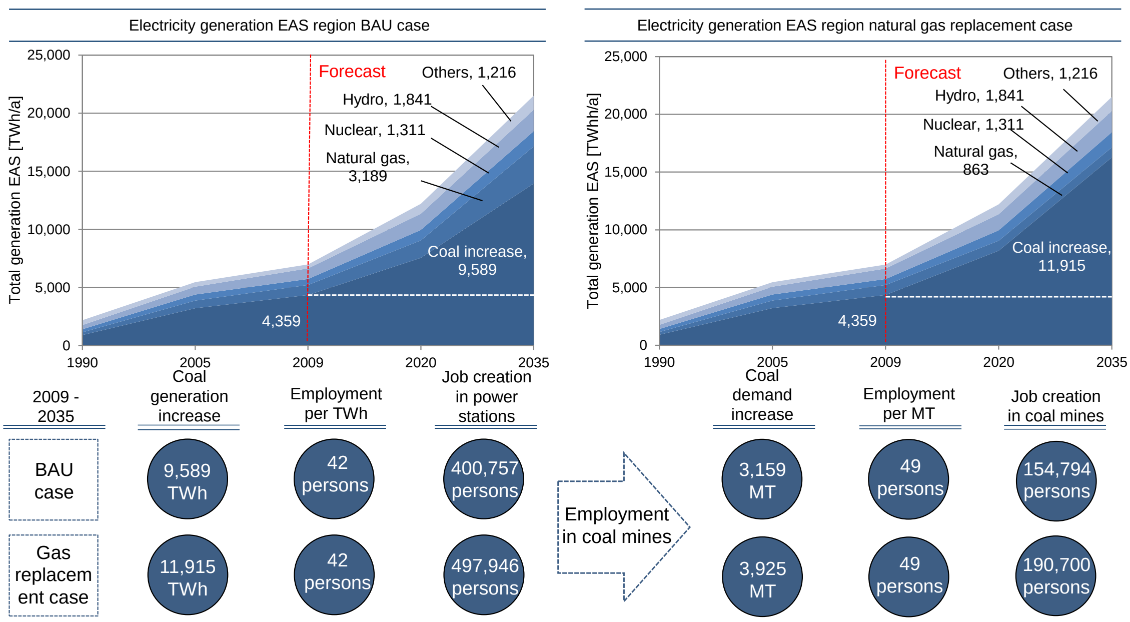
New coal-fired power stations and newly developed coal mines will create jobs in the EAS region. Figure 3-11 shows an estimation of long-term job creation (excluding construction jobs) related with power stations and coal mines.

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

CHAPTER 4

The Development of Technological Potential Map for CCT Dissemination in the EAS Region

1. Importance of the Technological Potential Map

Table 4-1 gives an overview of regulations related to coal-fired power stations in various countries in the EAS region, as well as the EU and United States as a reference. Environmental regulations on emissions from coal-fired power stations are already in place in most countries. The main difference is the stringency of the emission regulations, with developing countries often having less stringent regulations compared to regulations in developed countries.

On the contrary, regulations on the thermal efficiency of coal-fired power generators generally have not been implemented in developing countries as well as developed countries. In liberalized markets such as in Europe (and US to some extent, depending on state), the economic rationale for efficient technologies is set in the market, and therefore, the most efficient and economical technologies are usually deployed. In Asia, most markets remain regulated, and coordination of policies is necessary to promote the deployment of more advanced generation technologies.

Table 4-1:Coal-fired power station regulations

	Australia	China	India	Indonesia	Japan	Korea	Thailand	Viet Nam	EU	US
Unit capacity regulation			None	None					None	None
Efficiency regulation			None	None						
CO2 Regulation	Carbon tax AUD25$				Oil and coal Tax				CO2 certificate	Proposed
NOx and SOx regulation		(mg/m3) NOx 100 W-type, CFB 200 SOx New 100 Existing 200 Key region 50	None	(mg/m3) NOx 750 SOx 750		(ppm) NOx 80 SOx 80	(ppm) NOx 350 SOx >500MW 320 300-500MW 450 <300MW 640	(mg/m3) Cmax=C x Kp x Kv C: NOx >VM10% 650 <VM0% 1000 SOx :500 Kp(Scale factor) <300 MW : 1 300-1200MW: 0.85 >1200MW:0.7 Kv(Reginal factor): 0.6 ~1.4	(mg/m3) NOx 500 until 2015 then 200 SOx New 200 Old 400	(mg/m3) NOx New 117 NOx and SOx 160 (1997-2005) 640 (before '96)
Particulate matter regulation (mg/m3)		30 Key region 20	>210MW 150 <210MW 350	100		>500MW 20 <500MW 30	120	C: 200	50	22.5
Mercury regulation		0.03	None			None			0.03 (Germany)	0.001 0.002

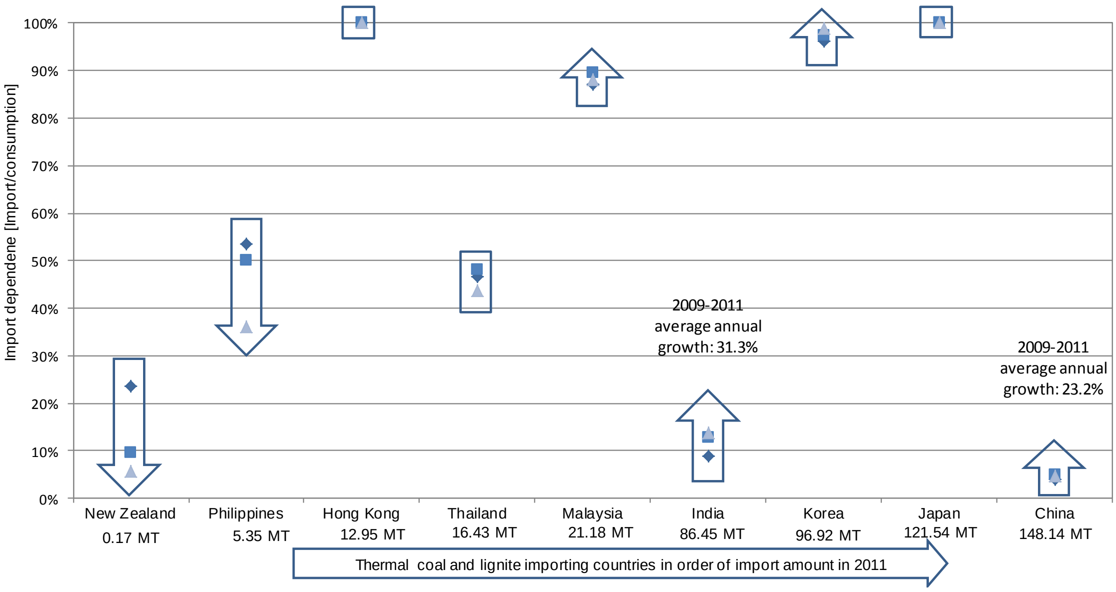
Efficiency regulation not in place

Source: From various sources.

The thermal efficiency of power stations can have a severe impact on coal imports. Figure 4-1 shows the coal import dependency of the major importing countries in the EAS region. For Hong Kong, Thailand, and Japan, import dependence remained unchanged at 100%, and Korea's import dependence is nearing the 100% mark, at 98.8% in 2011. These countries require highly efficient technologies in order to minimize imports.

Although China and India still have access to domestic coal resources, import dependence has been increasing from 2009 to 2011 (China from 4% to 5%, and India from 9% to 15%). As China's and India's coal demand is large in absolute terms, and as imports are increasing, more advanced coal-fired power stations are necessary.

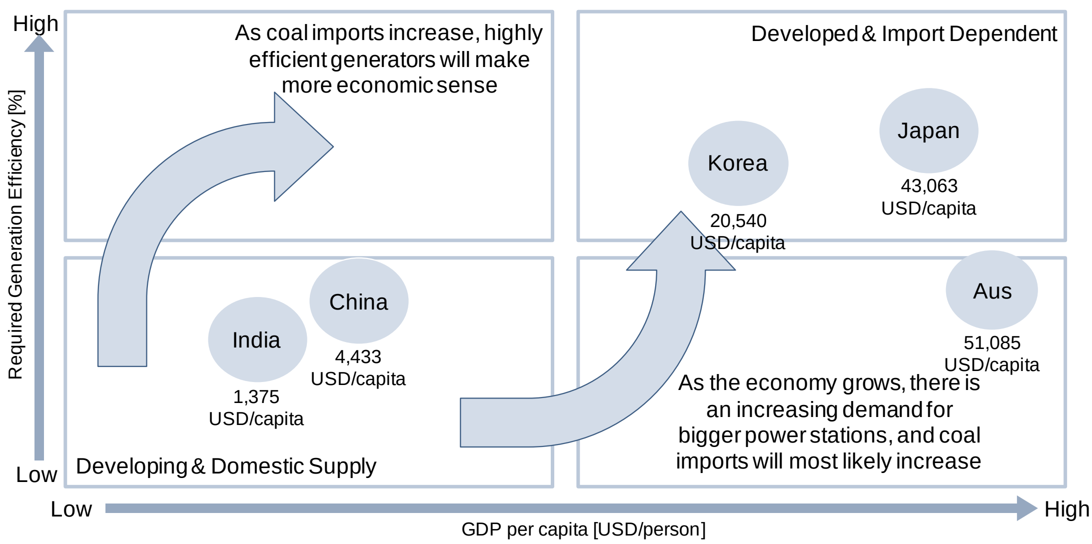
Figure 4-1:Coal import dependency



Source: Compiled from IEA Coal Information 2012

Figure 4-2 shows the need for different policies in different countries according to their respective stage of economic development. Developed countries are usually highly dependent on thermal coal imports, and therefore technologies deployed in these countries have to be as efficient as possible. For emerging countries in Asia, thermal coal imports are expected. The policy guidelines should be set at feasible levels according to the stage of economic development. As the economy develops, it is highly recommended to increase investment in efficient technologies.

Figure 4-2: Countries' status and required policy levels



Source: World Bank data.

In order to stimulate investments in highly advanced generation technologies appropriately, several technological potential maps need to be formulated, respecting the different stages of economic development across the EAS member countries. Figure 4-3 shows the necessary guidelines which need to be included in the technological potential map. By providing the technological potential map, which defines feasible efficiency levels, as well as environmental performance and maintenance criteria of CCT, EAS member countries are able to select and introduce the best CCT appropriate for their current stage of development.

Upon the completion of this research, a "practical" technological potential map including the above mentioned items will be developed.

Figure 4-3: Image of the technological potential map

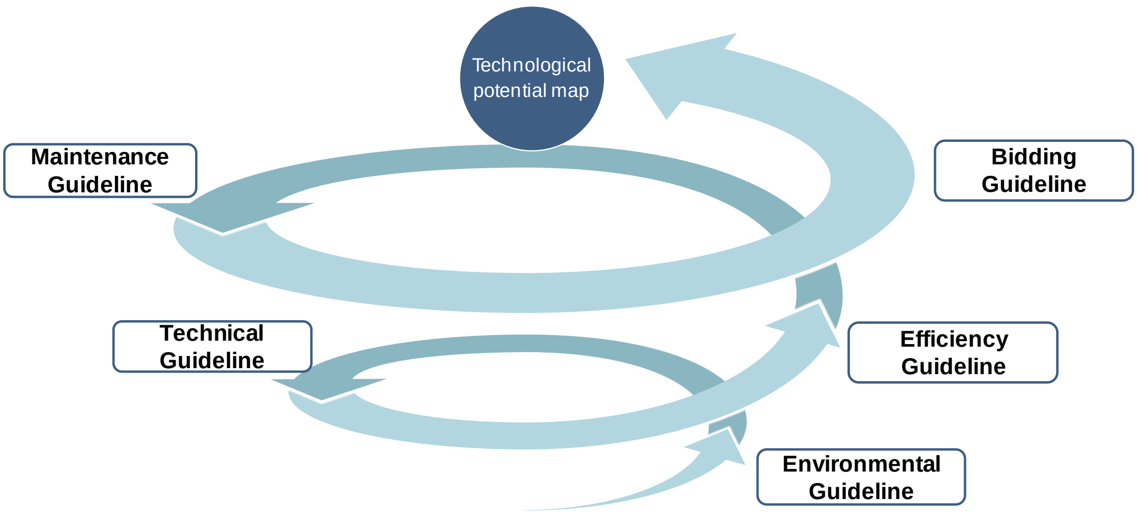


Table 4-2 gives an example of a technological potential map, in which thermal efficiency, investment costs, maintenance costs, fuel consumption and CO_2 emissions are compared for Ultra Super Critical (USC), Super Critical (SC) and Sub-critical (C) boiler types. In this case, policy makers can choose which new technology is appropriate for their country. The technological potential map will be updated based on data submitted by the Working Group members in next year's study.

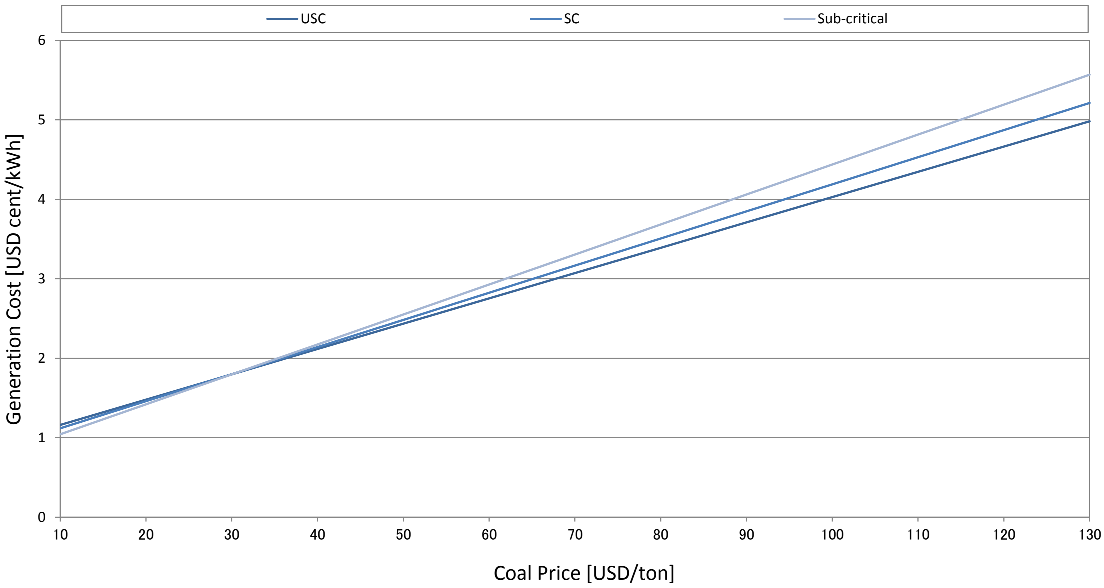
Table 4-2: Technological potential map example

	Boiler Type		
	Ultra Super Critical (USC)	Super Critical (SC)	Sub-critical (C)
Thermal Efficiency	41.5% ~ 45.0%	40.1% ~ 42.7%	37.4% ~ 40.7%
Initial Cost	1,298 mln USD	991 ~ 1,240 mln USD	867 ~ 991 mln USD
Fuel Consumption	2,229,000 tons/year (100%)	2,275,000 tons/year (+2.1%)	2,413,000 tons/year (+8.3%)
CO2 Emission (ton/year)	5,126,000 tons/year (100%)	5,231,000 tons/year (+2.11%)	5,549.000 tons/year (8.3%)
O&M Cost	3.42 mln USD/year	4.1 mln USD/year	5.0 mln USD/year
Generation Cost at USD 100/ton (USD cent/kWh)	4.03 cent/kWh (100%)	4.19 cent/kWh (+3.9%)	4.44 cent/kWh (+10.2%)
Examples	✓ "Isogo" J-POWER ✓ "Tachibanawan" J-POWER ✓ "Nordjylland", Denmark ✓ Xinchang, China	✓ "Takehara" J-POWER ✓ "Matsushima" J-POWER	✓ Taichung Power Plant ✓ Thai Binh 2

Note: Operation is assumed at 75%. Thermal efficiency is LHV. API 6 Newcastle FOB coal = 6,000 kcal/kg. CO_2 emission = 2.30 kg-CO_2/kg.

Figure 4-4 shows the generation cost of USC, SC and C type boilers compared with fuel purchase costs, based on the costs and thermal efficiency values from Table 4-2. Power plants equipped with the latest technology become more economically viable with increasing prices. In the simulation, the generation cost of USC is lower than SC and C type boilers once coal prices are higher than USD 30/ton.

Figure 4-4:Generation cost compared with fuel purchase costs



CHAPTER 5

Conclusion

Summary of Importance of Coal and CCT Benefits

From chapter 2 to 4, the importance of coal and benefits of CCT have been discussed. They can be summarized in 5 points as follows:

(1) Coal is least dependent on imports from outside the EAS region

Among fossil fuels, coal is least dependent on import from outside the EAS region, namely the Middle East. About 31% of natural gas imports, and 68% of oil import from the Middle East.

(2) Coal has always been more affordable than natural gas and oil on heating value basis

Historically, coal has always been around 1.5 – 3.5 times less expensive than natural gas. Furthermore, coal prices are less volatile than natural gas or oil prices.

(3) Strategic use of low rank coal creates opportunities to access half of coal reserves in Asia

About half (123.3 billion tons) of Asia's coal reserves are low rank coals. These reserves are largely undeveloped, but have high potential to increase coal supply in Asia.

(4) Investment possibilities in coal-fired power plants and coal mines are estimated USD 2,629 billion and USD 300 billion respectively

An estimated 1,460 GW of coal-fired power generation capacity worth USD 2,629 billion, and 3,159 MT coal per year, worth around USD 300 billion in development cost will provide ample investment opportunity.

(5) About 550,000 jobs are estimated to be created in power stations and coal mines

Operation of power stations and coal mines increase employment by an estimated 400,000 and 150,000 respectively. Additionally, construction jobs and jobs in other sectors not quantified in this study will be created.

Policy Recommendation for the Strategic Usage of Coal

CCT for Strategic Usage of Coal

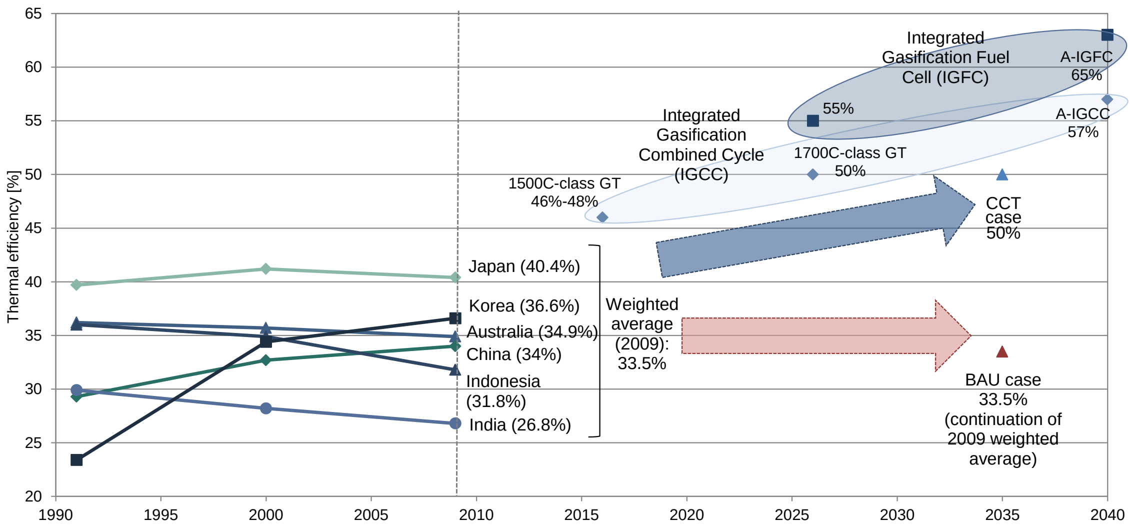
Efficiency

As discussed in section 2.3, thermal efficiency of coal-fired power stations varies greatly across Asia, leaving room for improvement in some Asian countries. Some EAS countries, such as Japan and Korea, have incentives to adopt efficient technologies from an investment point of view (in order to decrease coal imports), as well as from a social and environmental point of view. A policy package in other countries to increase the investment benefits would accelerate the adoption of more efficient technologies, and close the thermal efficiency gap.

In this section, the benefits of providing a roadmap for CCT technologies are quantified. For this purpose, 2 scenarios were assumed, the CCT case and the BAU case.

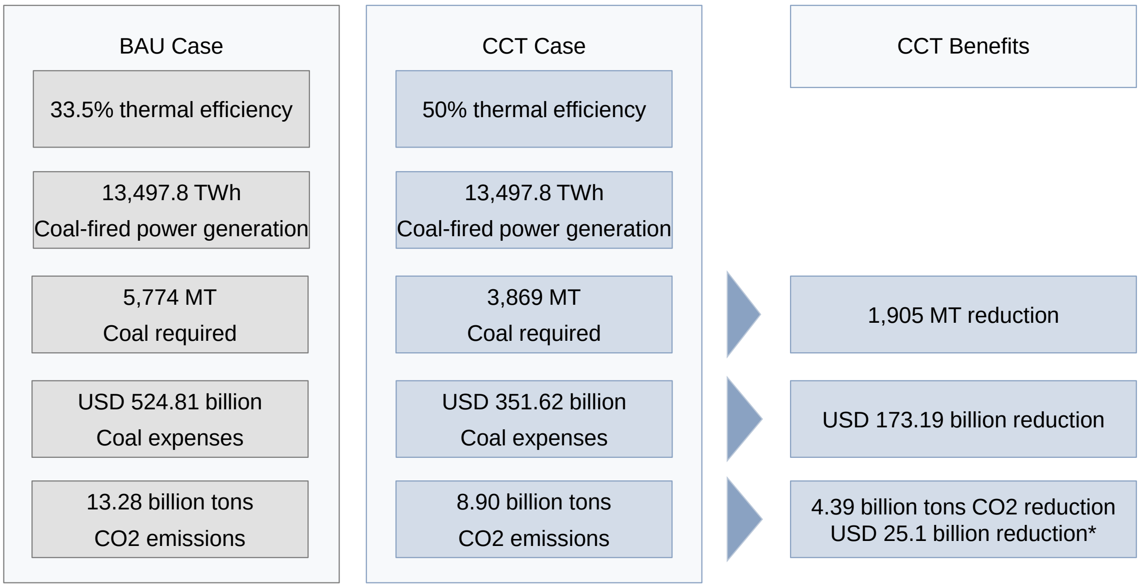
Figure 5-1 illustrates the scenarios, the technology roadmap, as well as the history of thermal efficiency values. In the CCT case, it is assumed that a thermal efficiency of 50% will be reached by 2035, through introduction of CCT. In the BAU case, it is assumed that the weighted average thermal efficiency (based on electricity generation in TWh) in 2009 will remain unchanged at 33.5% up to 2035.

Figure 5-1: Thermal efficiency history and roadmap



Quantification of benefits of the CCT case compared to the BAU case in the year 2035 is illustrated in Figure 5-2. As seen in the ERIA energy savings research project, in 2035 13,497.8 TWh of electricity is assumed to be generated from coal for both cases per year. In the BAU case, this would require around 5,774 MT of coal annually, assuming that the heating value is 6,000 kcal/kg. Under the same assumptions, 3,869 MT coal would be required in the CCT case, which is 1,905 MT less than in the BAU case. Assuming that coal prices are 90.89 USD/ton (Newcastle FOB price for 6,000 kcal/kg coal, January 2013), and that coal prices remain at this price, an estimated USD 173 billion in coal procurement costs are saved per year in the CCT case. Thirdly, the reduction of coal necessary for power generation will reduce CO_2 emissions. Assuming that 2.30 kg-CO_2/kg of coal is emitted, 4.39 billion tons of CO_2 emissions can be avoided annually. In April 2013, EU Emission Trading System (EU ETS) certificate prices were around 5.73 USD/ton (4.40 EUR/ton). Assuming the same price in 2035, around USD 25 billion could be generated from certificates.

Figure 5-2: CCT case benefits



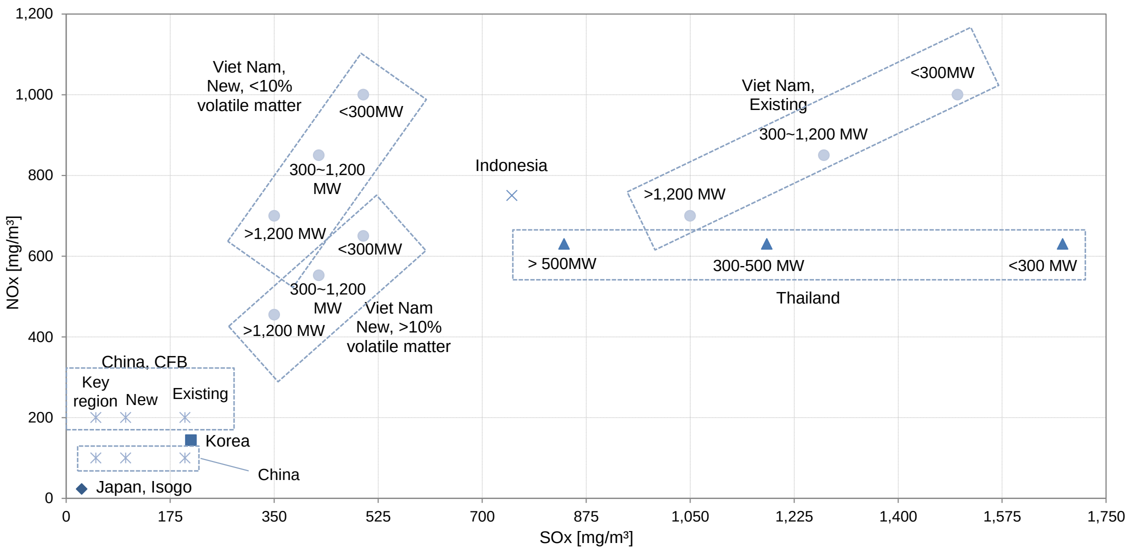
: CO_2 values were calculated using: (1) emissions are 2.30 kg-CO_2/kg, and (2) certificate prices are 4.40 EUR/ton, or 5.73 USD/ton (EU ETS price in April 2013, converted to USD using Federal Reserve average exchange rate for April 2013).

2.2.2. *Environment*

This section explains NOx, SOx regulations, which are already implemented in many EAS countries, and CO_2 regulations, which have not been introduced yet in most EAS countries.

Figure 5-3 gives an overview of NOx and SOx emissions standards applied in China, Indonesia, Korea, Thailand and Viet Nam, as well as the NOx and SOx emissions of the New Isogo plant in Japan. As can be seen in the figure, standards vary greatly across the countries. Therefore, harmonization of emission standards across Asia is necessary. Furthermore, a roadmap for future emissions standards is necessary.

Figure 5-3: Comparison of SOx and NOx emission standards from coal-fired power stations



Note: A regional factor applies to power stations in Viet Nam, ranging from 0.6 (urban areas) to 1.4 (remote areas). Factor 1 is applied in this figure.

Within the EAS region, Australia is the only country which has implemented a direct regulation on CO_2 emissions. In Japan, CO_2 are indirectly regulated, through a tax on coal and oil. The tax on coal is higher, accounting for the higher CO_2 emissions from coal use. In other EAS countries, CO_2 emissions are not regulated.

If CO_2 emission regulations would be implemented in countries across the EAS region, deployment of more advanced technologies such as CCS, IGCC or IGFC, in addition to USC and SC, would be incentivized, and commercialization of such technologies could be accelerated.