Long-term Trends and Outlook for Global Coal Supply and Demand

Yasuaki Kawakami[1], Yuhji Matsuo[1], Lu Zheng[1], Atsuo Sagawa[2]

Summary

Japan depends on other countries for most of its coal supply, of which more than 80% comes from Australia and Indonesia. While coal supply has remained relatively stable, the environment for coal supply has changed dramatically. In this paper the authors projected future trends for steam and coking coal and assessed international coal trade flows through 2040 using a trade flow model built with the linear programming (LP) method.

Global coal consumption has persistently increased particularly over the past decade while interests have grown in the climate change problem. The upward trend in coal consumption, which has been driven by China so far, will continue through 2040 with India replacing China as the demand growth center. Given a deceleration of coal demand growth in China and a decline in coal demand in many OECD countries, the annual average global coal demand growth through 2040 will be slower than in recent years. But demand for steam coal for power generation will continue increasing. A coal demand increase anticipated through 2040 will rival the remarkable growth seen in the decade between 2002 and 2012.

As it is difficult for most countries to cover growing coal demand with domestic output alone, international coal trade will expand. New major coal flows including those from Mozambique to India and from Russia to Asia will be created, while Indonesia, now one of the major exporters, will refrain from expanding exports so much due to domestic demand growth and its policy of protecting coal resources for their effective use.

In Japan, coal will remain a key energy source mainly for power generation, taking into account the need for mitigation measures for climate change at the same time. This paper indicated the emergence of Mozambique as a new coking coal supplier for Japan amid future changes in coal producing and consuming countries.

1. Introduction

Japan depends on other countries for most of its coal supply, of which more than 80% comes from Australia and Indonesia. Coal has been viewed in Japan as featuring greater supply stability than other fossil fuels, i.e. oil and natural gas. Since the early 2000s, however, the environment for coal has seen great changes including a rapid China-led increase in global coal demand, sharp coal price hikes, a coal trade flow change through the recent shale gas output expansion in the United States and signs of coal policy changes in Indonesia, now one of the biggest coal exporters in the world. Given these changes, it may be dangerous to view coal as remaining a stable fuel in the future. How will coal demand change in the future? How will coal supply respond to such change? How will coal trade flows change if coal supply and demand centers in the world shift? This paper aims to answer these questions.

This paper is organized as follows: It details historical coal supply and demand data (demand, supply and trade flows) by coal type and region through 2012 first before predicting coal demand and supply thorough 2040 based on the trends and policy information available at present. Later, the paper forecasts steam and coking coal trade flows in 2025 and 2040 using a trade flow model, which were built based on the linear programming method.

There are many studies that predict coal demand over a medium to long term. But only a limited number of studies may indicate quantitative coal trade flows while securing the flows' consistency with demand. Figuring out how the global coal demand center will change from the present to 2025 and 2040 and how the coal trade flows will change may help policymakers to specify challenges for securing stable coal supply for the future and consider how to secure supply sources.

2. Global Coal Supply/Demand Trends

2.1 Consumption

Global coal consumption increased from 3,756 million tons in 1980 to 4,734 million tons in 1989, fluctuated in the 1990s and reached 7,697 million tons in 2012[1)2)] (Figure 2-1). Growth from 2002 has been particularly remarkable. The annual average growth rate from 2002 to 2012 reached 4.6%. Leading the demand growth were Asian countries including China. Asian coal consumption expanded from 2,255 million tons in 2002 to 5,023 million tons in 2012, as shown in Figure 2-2. The increase during the decade stood at 2,768 million tons (accounting for 100%[3] of the net global coal consumption increase in the decade). Asia's share of global coal consumption rose by 19.5 percentage points to 65.3%. China accounted for about 80% of the Asian coal consumption increase. As a result, China logged the world's largest coal consumption at 3,666 million tons in

---

[3] This does not necessarily mean that there were no countries posting coal consumption increases in other regions than Asia. Attention must be paid to consumption declines during the period in some countries including the United States, which logged a coal consumption drop of 149.7 million tons for the period.
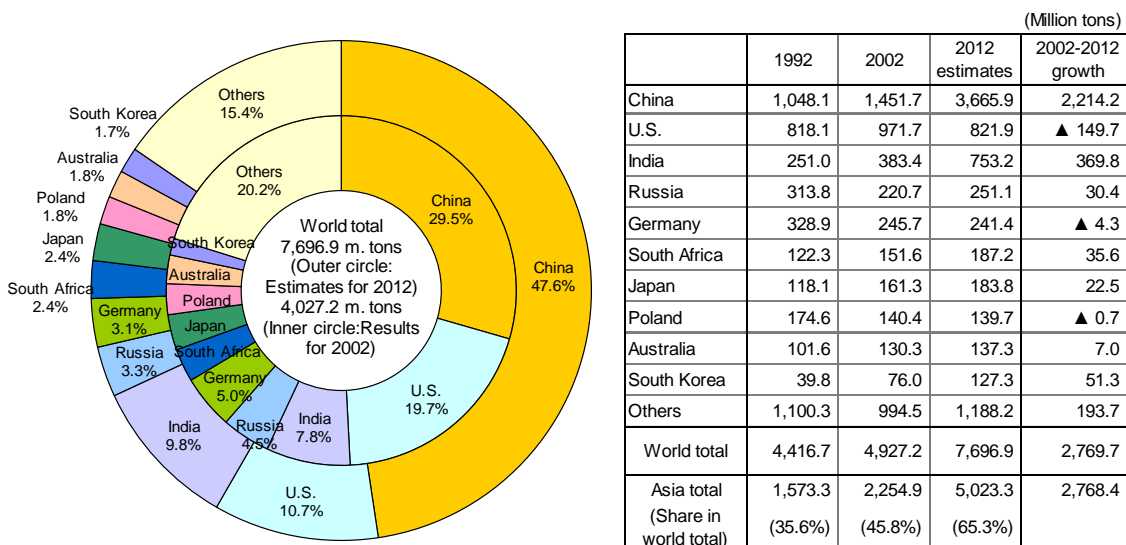
2012, far more than 822 million tons for the United States as the second largest coal consumer in the world and 753 million tons for India as the third.
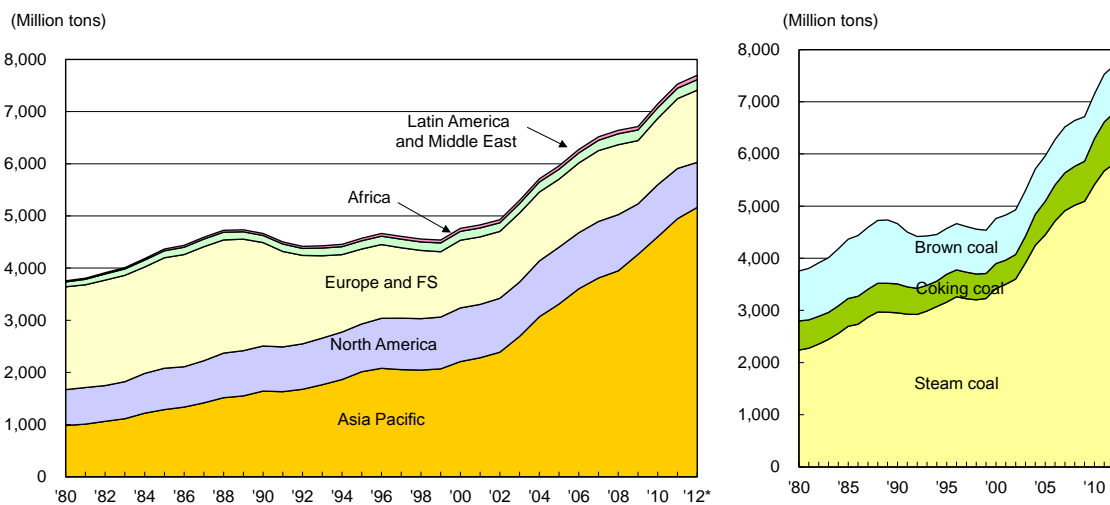
Note: Data for 2012 are estimates. Anthracite is included in steam coal.

Source: IEA, "Coal Information 2013"[3]

Figure 2-1. Global Coal Consumption (by region and coal type)

	1992	2002	2012 estimates	2002-2012 growth
China	1,048.1	1,451.7	3,665.9	2,214.2
U.S.	818.1	971.7	821.9	▲ 149.7
India	251.0	383.4	753.2	369.8
Russia	313.8	220.7	251.1	30.4
Germany	328.9	245.7	241.4	▲ 4.3
South Africa	122.3	151.6	187.2	35.6
Japan	118.1	161.3	183.8	22.5
Poland	174.6	140.4	139.7	▲ 0.7
Australia	101.6	130.3	137.3	7.0
South Korea	39.8	76.0	127.3	51.3
Others	1,100.3	994.5	1,188.2	193.7
World total	4,416.7	4,927.2	7,696.9	2,769.7
Asia total	1,573.3	2,254.9	5,023.3	2,768.4
(Share in world total)	(35.6%)	(45.8%)	(65.3%)	

(Million tons)

Note: Data for 2012 are estimates.

Source: IEA[3]

Figure 2-2. Coal Consumption by Region (10 largest coal consuming countries)

A coal consumption breakdown by use indicates a significant increase in demand for power generation, as shown by Figure 2-3. The increase covered robust growth in electricity demand

mainly in Asia. Coal for power generation accounted for 65.0% of total coal consumption in 2011, indicating a sharp rise from 49.9% in 1980.

By coal type, steam coal consumption in 2012 stood at 5,814 million tons (accounting for 75.5% of total coal consumption) and coking coal at 976 million tons (12.7%). Figures 2-4 and 2-5 show country-by-country coal consumption. Steam coal consumption increased remarkably as demand expanded for coal as fuel for power generation. Annual steam coal consumption expanded by 2,213 million tons during the decade between 2002 and 2012, accounting for 80.5% of the total coal consumption growth during the period. By country, China consumed 3,087 million tons in steam coal in 2012 (accounting for 53.1% of world total steam coal consumption), the United States 731 million tons (12.6%) and India 626 million tons (10.8%). The three countries captured 76.4% of the world total.

Coking coal demand scored a greater growth rate than steam coal demand. Annual coking coal consumption increased by 505 million tons in the decade from 2002. China accounted for 59.3% of world total coking coal consumption in 2012. Coking coal features massive consumption in Asia including India, Japan and South Korea. Asian coking coal consumption aggregated 756 million tons in 2012, capturing 77.4% of the world total.
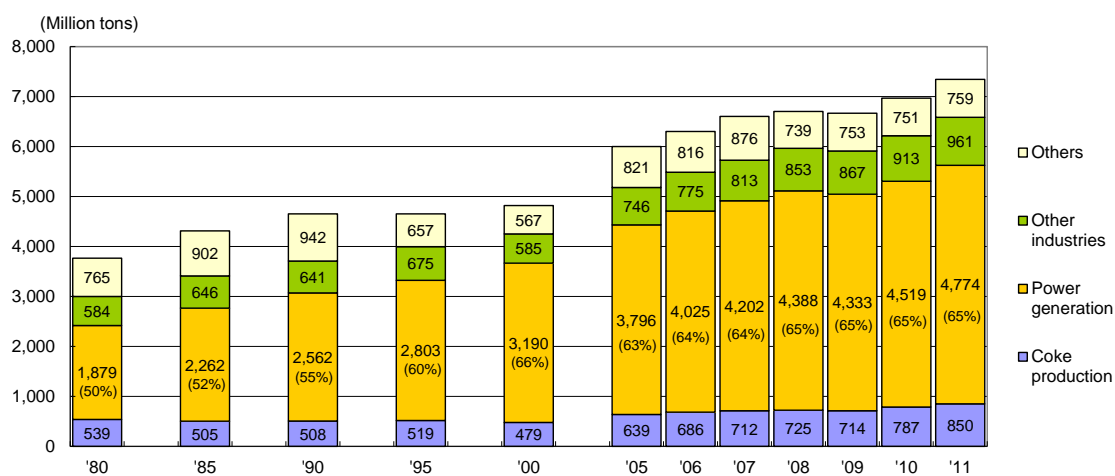
Note: Coal consumption for power generation includes consumption at combined heat and power plants.

Sources: IEA, "Energy Statistics of OECD countries 2013"[4), "Energy Statistics of Non-OECD countries 2013"[5)

Figure 2-3. Coal Consumption by Use
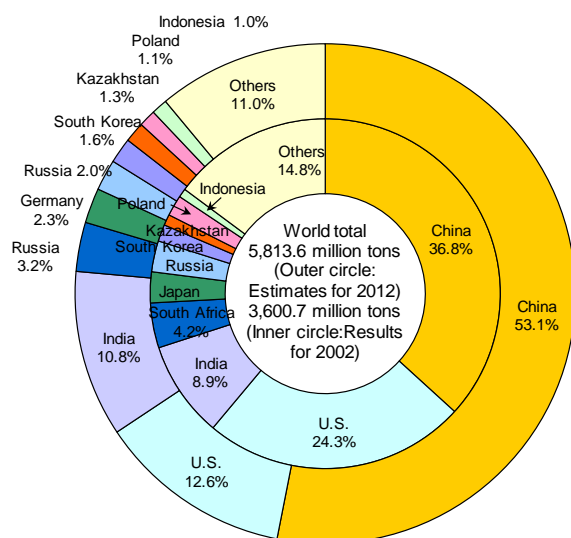
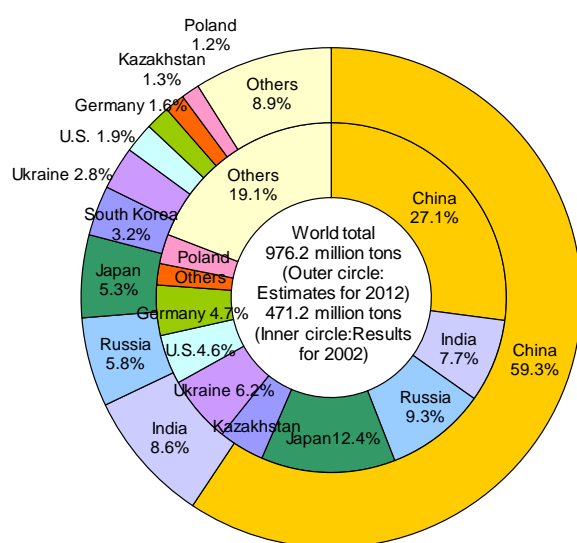|	1992	2002	2012 estimates	2002-2012 growth
				(Million tons)
China	962.8	1,324.1	3,086.5	1,762.5
U.S.	706.9	875.4	730.7	▲ 144.7
India	192.6	321.1	625.9	304.8
South Africa	117.6	149.5	185.0	35.5
Japan	60.2	102.9	131.6	28.7
Russia	150.1	103.3	116.9	13.6
South Korea	25.4	56.0	95.7	39.7
Kazakhstan	60.0	36.3	76.3	40.0
Poland	94.2	69.4	64.1	▲ 5.3
Indonesia	6.9	29.2	60.2	31.0
Others	546.5	533.7	640.8	107.1
World total	2,923.2	3,600.7	5,813.6	2,212.9
Asia total	1,328.7	1,954.0	4,194.5	2,240.5
(Share in world total)	(45.5%)	(54.3%)	(72.1%)	

Note: Data for 2012 are estimates. Anthracite is included.

Source: IEA[3]

Figure 2-4. Steam Coal Consumption (10 largest steam coal consuming countries)

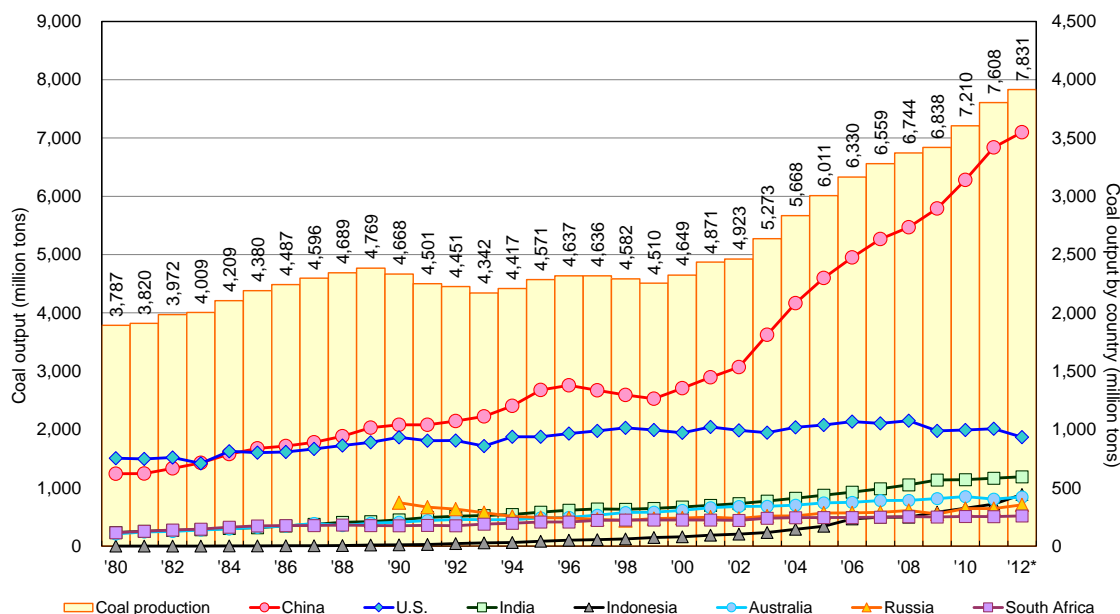|	1992	2002	2012 estimates	2002-2012 growth
				(Million tons)
China	85.3	127.7	579.4	451.7
India	42.7	36.3	83.8	47.5
Russia	41.0	43.8	56.3	12.6
Japan	57.9	58.4	52.2	▲ 6.2
South Korea	14.4	20.0	31.6	11.6
Ukraine	42.6	29.2	27.1	▲ 2.0
U.S.	29.4	21.6	19.0	▲ 2.6
Germany	36.2	21.9	15.3	▲ 6.6
Kazakhstan	24.2	9.3	12.6	3.3
Poland	15.0	12.9	11.6	▲ 1.3
Others	112.0	90.1	87.3	▲ 2.9
World total	500.7	471.2	976.2	505.0
Asia total	208.1	248.8	755.7	506.9
(Share in world total)	(41.6%)	(52.8%)	(77.4%)	

Note: Data for 2012 are estimates.

Source: IEA[3]

Figure 2-5. Coking Coal Consumption (10 largest coking coal consuming countries)

5

2.2 Production

Global coal production plunged on a demand decline mainly in the former Soviet Union in the early 1990s and on a demand fall in China and Europe in the second half of the 1990s before turning upward in response to robust demand growth after 2000. In 2012, coal production totaled 7,831 million tons (Figure 2-6).

A country-by-country breakdown shows that China's production growth since 2003 is remarkable. While annual global coal production increased by 2,908 million tons from 2002 to 2012, China accounted for some 70% or 2,013 million tons of the increase (Figure 2-7). The United States, the second largest coal producer after China, kept annual coal output almost unchanged from around 1.0 billion tons in 1997 before posting a decline in 2012 due to a domestic coal demand drop attributable mainly to shale gas output. India, Australia and Indonesia have steadily expanded coal output.

Note: Data for 2012 are estimates.

Source: IEA[3]

Figure 2-6. Global Coal Production

6

|	1992	2002	2012 estimates	2002-2012 growth
				(Million tons)
China	1,072.8	1,535.7	3,549.1	2,013.4
U.S.	905.0	992.7	934.9	▲ 57.8
India	255.2	363.9	595.0	231.1
Indonesia	22.0	102.1	442.8	340.7
Australia	228.3	339.9	420.7	80.8
Russia	316.4	237.6	353.9	116.4
South Africa	174.4	220.2	259.3	39.1
Germany	314.0	211.0	197.0	▲ 14.0
Poland	198.5	161.9	144.1	▲ 17.8
Kazakhstan	126.5	74.0	126.0	52.0
Others	838.0	683.5	807.9	124.3
World total	4,451.1	4,922.6	7,830.8	2,908.2
Asia total (Share in world total)	1,440.6 (32.4%)	2,081.8 (42.3%)	4,740.0 (60.5%)	2,658.2

Note: Data for 2012 are estimates.

Source: IEA[3]

Figure 2-7. Coal Production (10 largest coal producing countries)

2.3 Trade

The ratio of coal trade (this study assumes trade as equal to exports) to global production was limited to 16.0% in 2012, which is lower compared with other fossil fuels (Figure 2-8). But coal trade has been expanding in line with an increase in demand for steam coal used mainly for power generation. The trade ratio stands at 29.5% for coking coal, 16.2% for steam coal (including anthracite) and 0.3% for lignite.

Coal producing countries are divided according to the production-export ratio into three groups -- domestic consumption-oriented, export-oriented and intermediate countries. China and India with respective small coal trade ratios of 0.3% and 0.2% are domestic consumption-oriented countries, while Indonesia and Australia with respective high trade ratios of 86.4% and 71.7% are export-oriented countries (Figure 2-9). In countries with high coal trade ratios, coal is positioned as both an energy source for domestic consumption and a key export product.
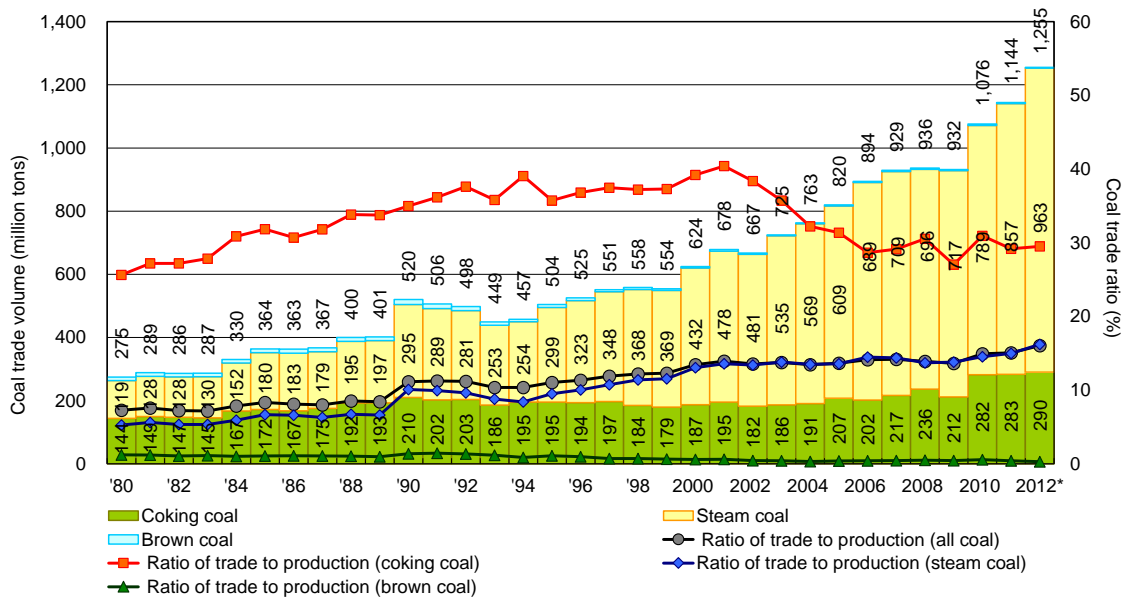
Note: Data for 2012 are estimates. Exports are deemed to be trade volume, with anthracite included in steam coal.
Trade within the former Soviet Union before 1990 is not counted. The coal trade ratio is computed according to the following equation: Coal trade ratio (%) = Coal export ÷ Coal production

Source: IEA[3]

Figure 2-8. Trends in World Coal Trade
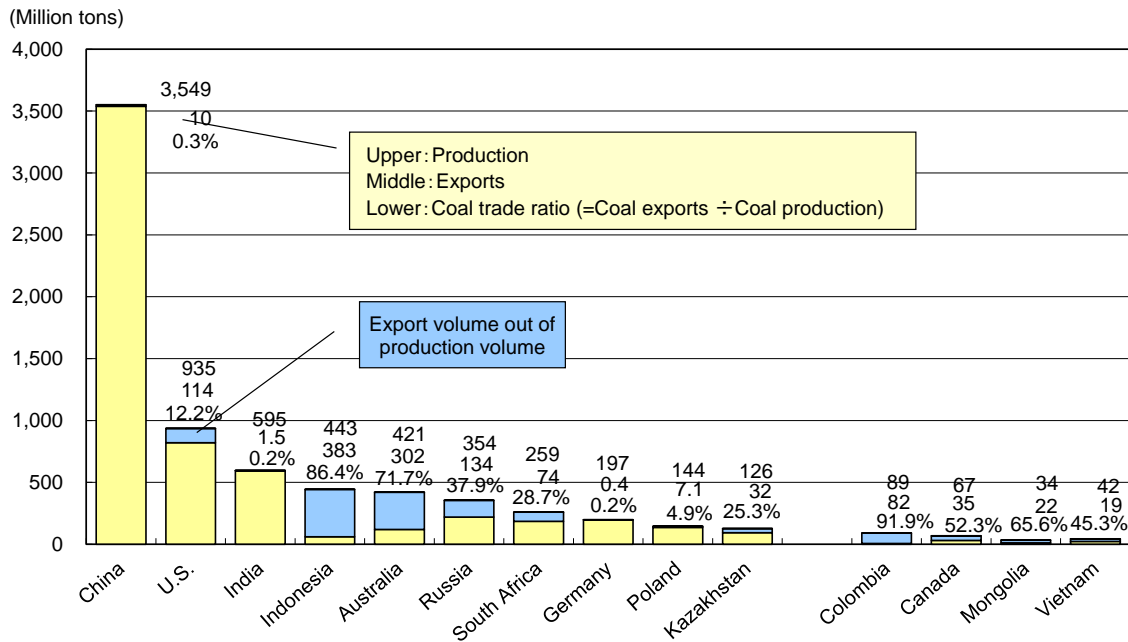
Source: IEA[3]

Figure 2-9. Major Coal Producing Countries (top 10 countries) and Major Coal Exporting Countries' Output and Exports (estimates for 2012)

Coal export trends

Coal exports in the world in 2012 totaled 1,255 million tons. Indonesia was the largest coal exporter with exports at 383 million tons, followed by 302 million tons for Australia. The two countries accounted for 54.5% of total exports in the world. Following Australia were Russia, the United States, Colombia and South Africa. The six countries captured 86.7% of world total exports (Figure 2-10).
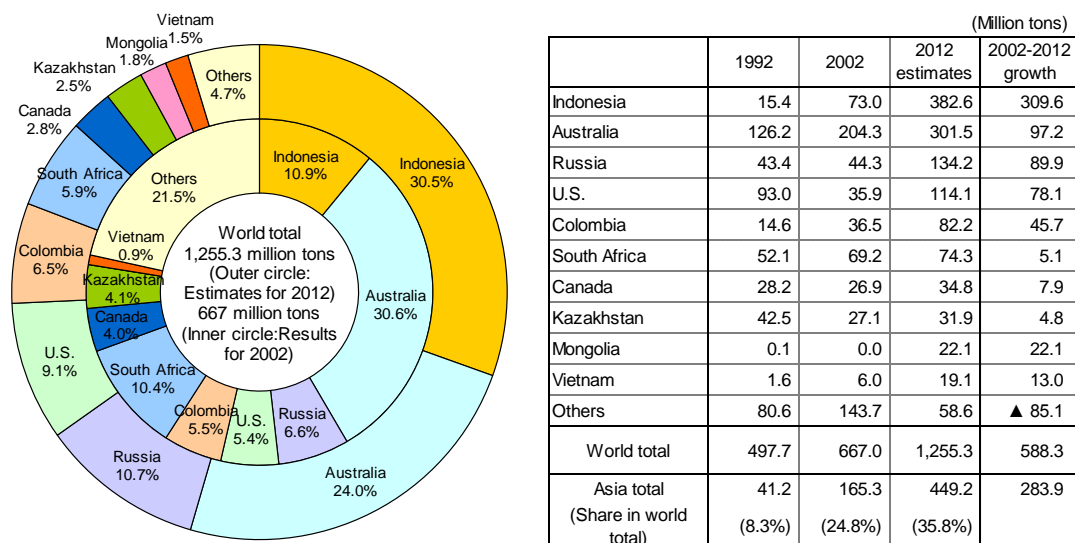
Among major coal exporting countries, Australia was dominant until the first half of the 2000s. But Indonesia expanded coal exports remarkably from the early 2000s and replaced Australia as the largest exporter in 2011 (Figure 2-11). Russia has steadily boosted coal exports since 1999. The United States has increased coal exports since 2010 as domestic coal consumption has declined due to a gas price fall amid a shale gas output expansion. China expanded exports sharply from 2000, remaining the world's second largest coal exporter between 2001 and 2003. Since 2004, however, China has substantially reduced coal exports due to domestic demand growth. In 2012, China was the 12th largest coal exporter with exports totaling 10.5 million tons (Figure 2-11).

(Million tons)

|	1992	2002	2012 estimates	2002-2012 growth
Indonesia	15.4	73.0	382.6	309.6
Australia	126.2	204.3	301.5	97.2
Russia	43.4	44.3	134.2	89.9
U.S.	93.0	35.9	114.1	78.1
Colombia	14.6	36.5	82.2	45.7
South Africa	52.1	69.2	74.3	5.1
Canada	28.2	26.9	34.8	7.9
Kazakhstan	42.5	27.1	31.9	4.8
Mongolia	0.1	0.0	22.1	22.1
Vietnam	1.6	6.0	19.1	13.0
Others	80.6	143.7	58.6	▲ 85.1
World total	497.7	667.0	1,255.3	588.3
Asia total (Share in world total)	41.2 (8.3%)	165.3 (24.8%)	449.2 (35.8%)	283.9

Note: Data for 2012 are estimates.

Exports from Kazakhstan mostly go to Russia. Most of Mongolian exports are destined for China.

Source: IEA[3]

Figure 2-10. Coal Exports (10 largest coal exporting countries)
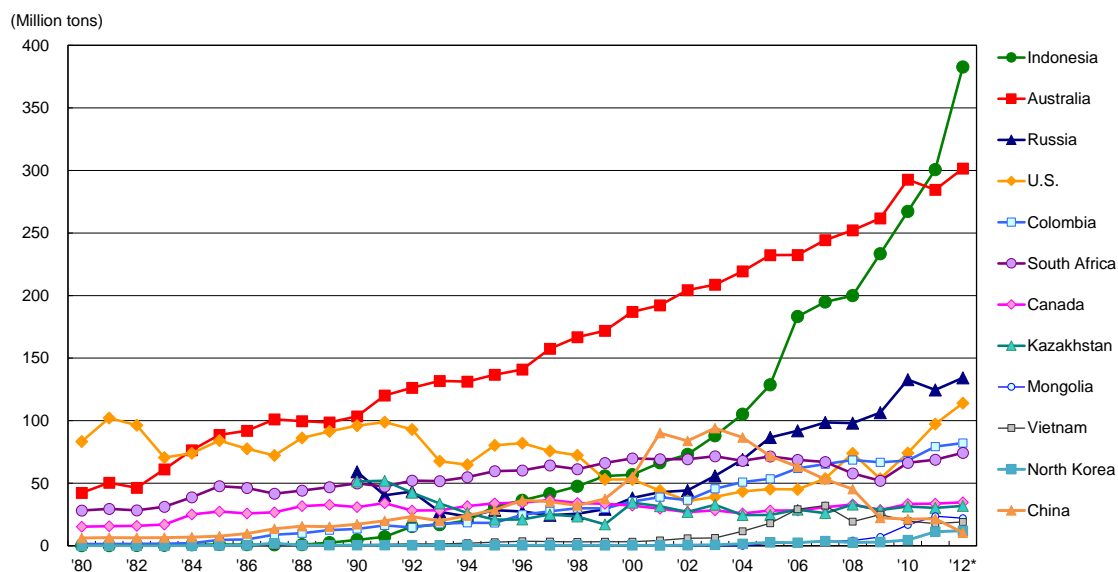
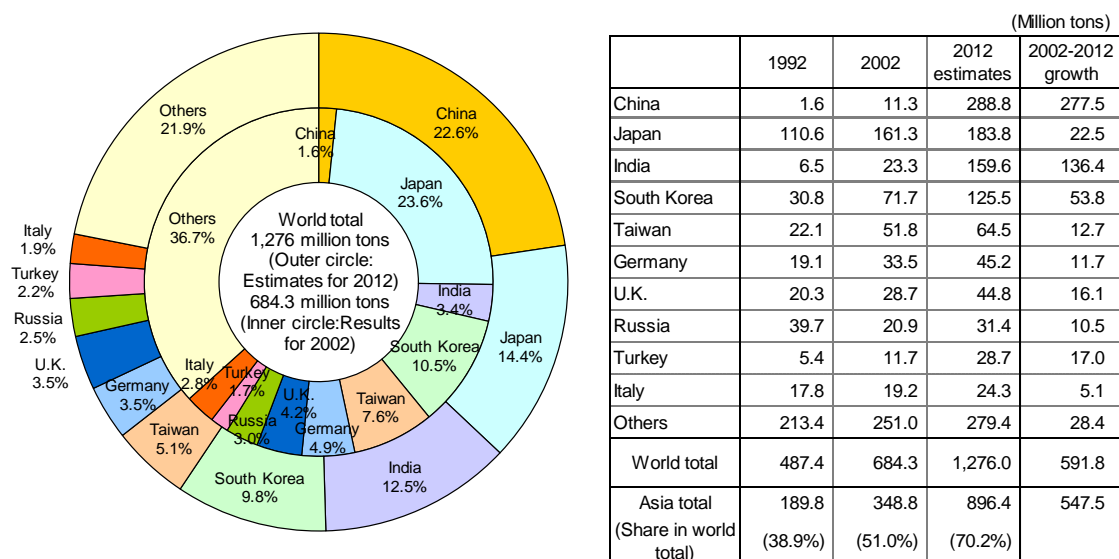(Million tons)

Note: Data for 2012 are estimates.

Source: IEA[3]

Figure 2-11. 12 Largest Coal Exporting Countries' Export Volume Trends

Coal import trends

The largest coal importer in the world in 2012 was China with imports totaling 289 million tons (accounting for 22.6% of total imports) (Figure 2-12), followed by Japan's 184 million tons (14.4%), India's 160 million tons (12.5%), South Korea's 126 million tons (9.8%) and Taiwan's 65 million tons (5.1%). The four major Asian coal importers accounted for 662.6 million tons or 51.9% of world total coal imports.

Among major coal importing countries, Japan had remained the world's largest importer for a long time. But China, which has seen rapid domestic coal demand growth since around 2004, boosted imports mainly for its Southeastern coast region far away from coal production sites from 2009 and replaced Japan as the largest coal importer in the world in 2011 (Figure 2-13). Meanwhile, Japan reduced coal imports due to a recession in 2009 and due to the Great East Japan Earthquake in 2011. In India, domestic coal production growth has failed to catch up with domestic demand growth. India's domestic coal features high ash content and is usually mixed with imported coal for burning. Furthermore, India has begun to operate thermal power plants fueled only by imported coal. As a result, India has expanded coal imports rapidly since 2008. South Korea's coal imports have been increasing as coal power generation and steelmaking capacity have been expanded.

10

(Million tons)	1992	2002	2012 estimates	2002-2012 growth
China	1.6	11.3	288.8	277.5
Japan	110.6	161.3	183.8	22.5
India	6.5	23.3	159.6	136.4
South Korea	30.8	71.7	125.5	53.8
Taiwan	22.1	51.8	64.5	12.7
Germany	19.1	33.5	45.2	11.7
U.K.	20.3	28.7	44.8	16.1
Russia	39.7	20.9	31.4	10.5
Turkey	5.4	11.7	28.7	17.0
Italy	17.8	19.2	24.3	5.1
Others	213.4	251.0	279.4	28.4
World total	487.4	684.3	1,276.0	591.8
Asia total	189.8	348.8	896.4	547.5
(Share in world total)	(38.9%)	(51.0%)	(70.2%)	

Note: Data for 2012 are estimates.

Source: IEA[3]

Figure 2-12 Coal Imports (10 largest coal importing countries)
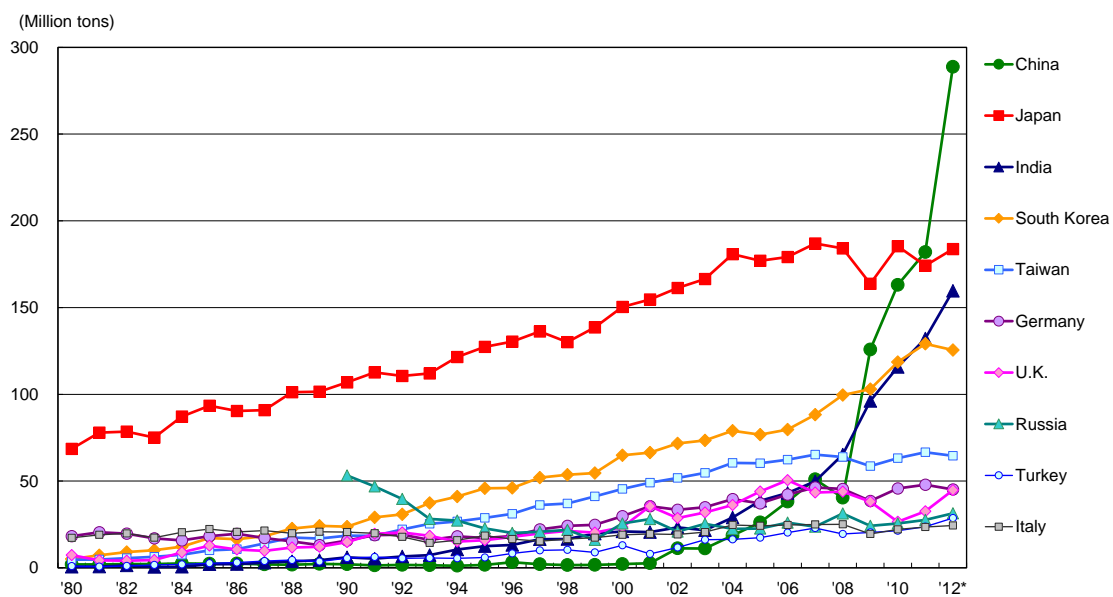

Note: Data for 2012 are estimates.

Source: IEA[3]

Figure 2-13. 10 Largest Coal Importers' Import Trends

11

Coal trade flows

The world coal market is divided into two markets -- the Asia-Pacific market and the Europe-Atlantic market. While the Europe-Atlantic market has leveled off, the Asia-Pacific market including China and India has been expanding. In 2012, the Asia-Pacific market was four times as large as the Europe-Atlantic market.

Figure 2-14 indicates coal trade flows. Generally, Indonesia and Australia provide massive coal for the Asia-Pacific market. Major suppliers for the Europe-Atlantic market are Colombia, Russia and the United States. South Africa has been shifting from the Europe-Atlantic coal market to the Asia-Pacific market due to growing Russian, Colombian and U.S. supply in the Europe-Atlantic market and India's coal import expansion.

Figure 2-15 indicates steam coal trade flows and Figure 2-16 coking coal trade flows. Since steam coal trade accounts for nearly 80% of total coal trade (Figure 2-8), the steam coal trade flows are not so different from the overall coal trade flows. China is the largest importer of both steam and coking coal, importing 218 million tons in steam coal and 71 million tons in coking coal in 2012.
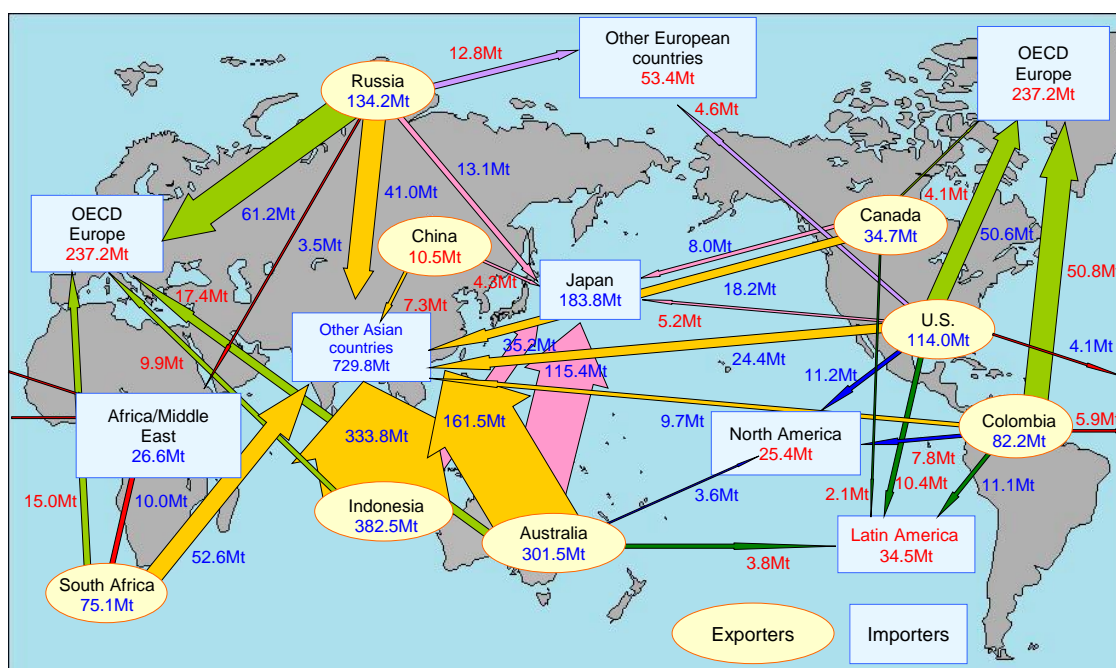
Note: The figure covers flows of more than 2 milllion tons. North America includes Mexico in accordance with a definition in IEA[3]. Blue or red numbers indicate that the figure increased or decreased from the previous year, respectively.

Source: IEA[3]

Figure 2-14 World Coal Trade Flows (estimated for 2012)
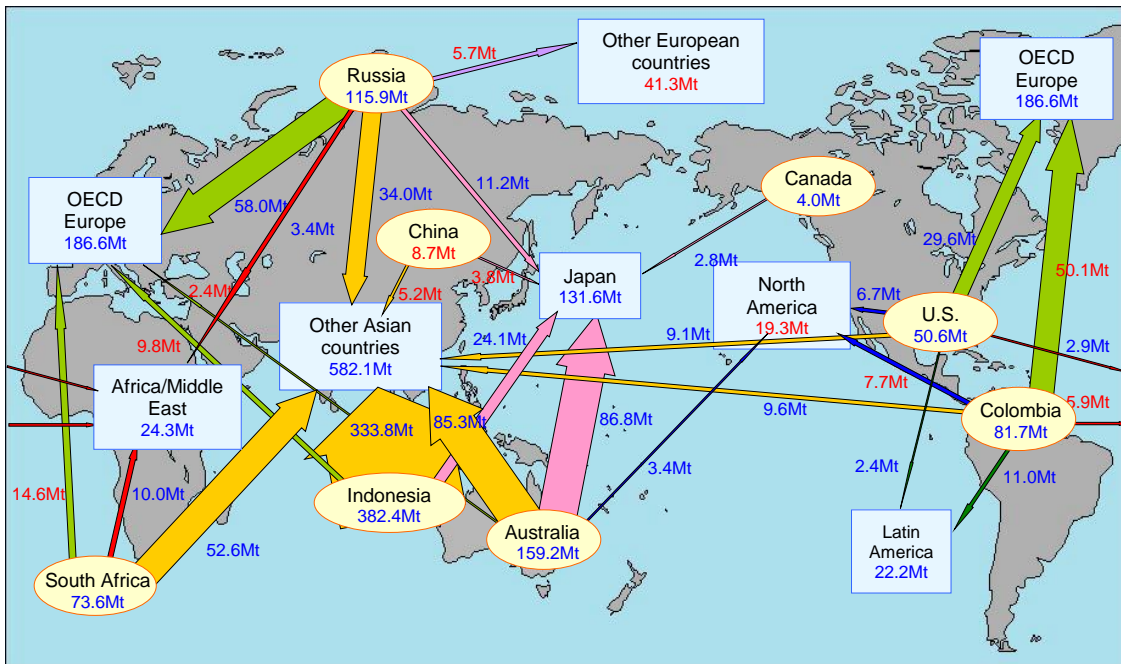
Note: Same as for Figure 2-14

Source: IEA[3)]

Figure 2-15 World Steam Coal Trade Flows (estimated for 2012)

Note: Same as for Figure 2-14

Source: IEA[3)]

Figure 2-16 World Coking Coal Trade Flows (estimated for 2012)

3. Future Global Coal Supply/Demand Outlook

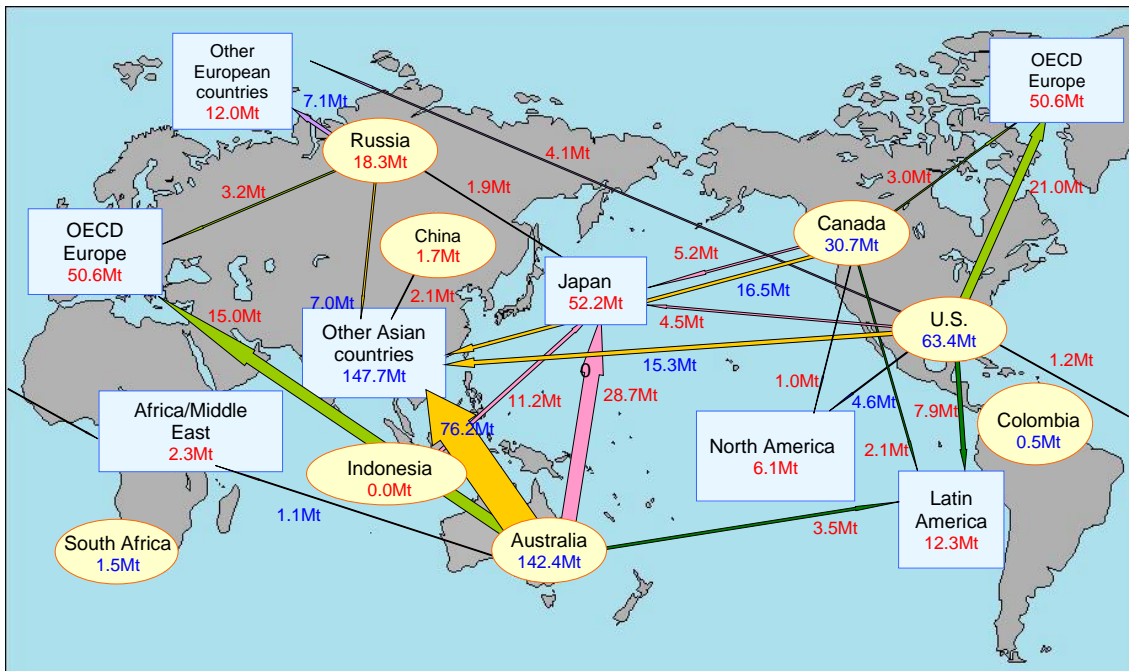### 3.1 Estimation method and assumptions

Figure 3-1 indicates a framework for estimating coal supply/demand and trade flows for this study. For forecasting industrial activities, energy prices and other social and economic indicators that influence energy demand, we use a macroeconomic model that covers gross domestic product, crude oil prices, materials output and other variables. Based on the forecast, we project coal demand within an energy demand model. We divide coal into the three types of steam coal, coking coal and lignite and take into account relevant indicators for these types in projecting demand. On the other hand, we use various statistics and coal mine development projects for forecasting coal supply. We project coal trade flows meeting supply and demand estimates by building and operating a linear programming model.
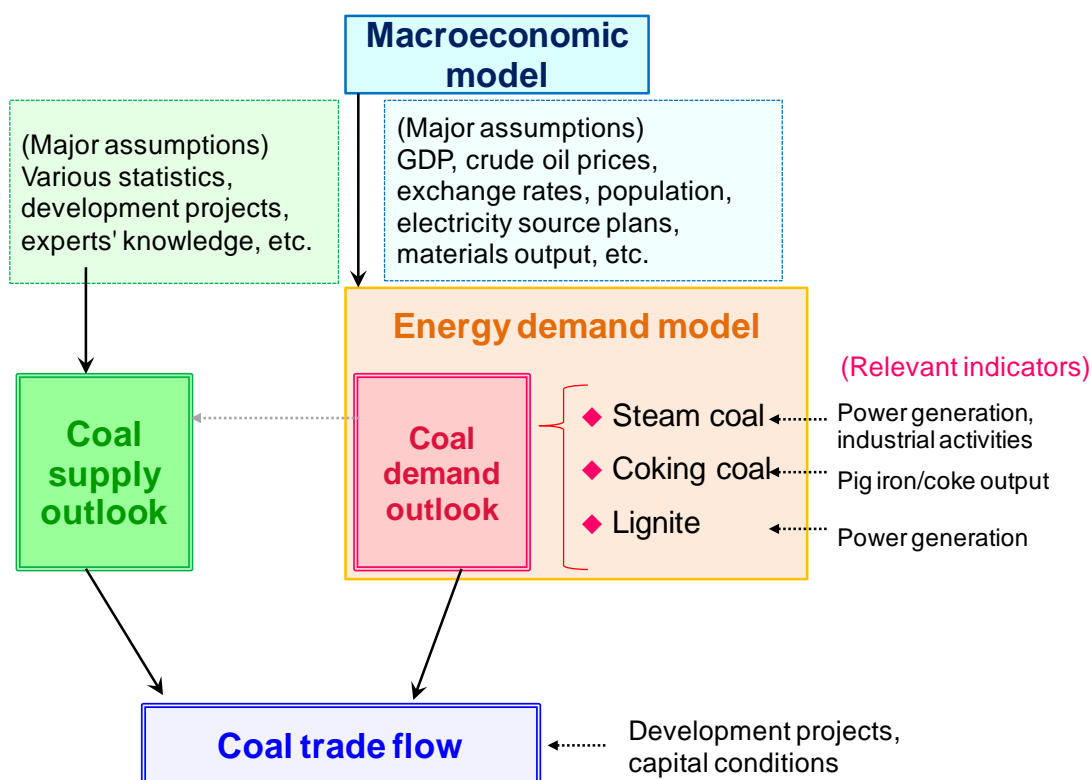
Figure 3-1. Flow for Calculating Future Global Coal Supply/Demand

14

3.1.1 Coal supply/demand forecasts

We estimated future coal supply and demand while reflecting and reconsidering up-to-date coal information, based on "Asia/World Energy Outlook 2013[6]" published in October 2013 by the Institute of Energy Economics, Japan. Unlike the outlook, we estimated supply and demand each for steam coal, coking coal and lignite. See the outlook for major assumptions for the macroeconomic model and energy supply and demand forecasts other than coal.

3.1.2 Coal trade flow estimation

We built a linear programming (LP) model to develop coal trade flows that minimize coal trade costs in the world while meeting projected coal supply and demand.

The LP model is a static model to divide the world into 26 countries and regions and estimate coking and steam coal trade flows between regions (Figure 3-2). We treat coal trade costs as an objective function and minimized them under a linear constraints system. We must note that the LP model views the entire world as an agent and minimizes the total cost for computation. Attention should be paid to the point that trade decisions based on partial optimization cannot be made in this model.

Figure 3-2. Regions Subjected to LP Model

The total cost as the objective function consist of the coal terminal construction costs, the coal production costs (represented by market prices) and the costs for transportation between terminals.

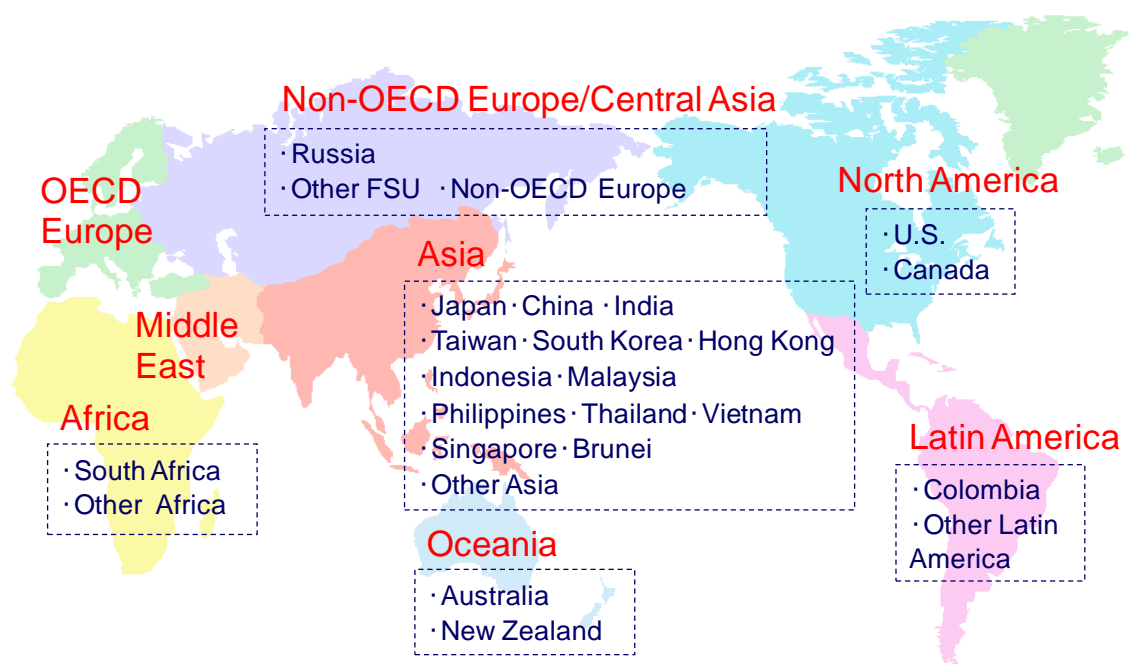We set the representative coal terminal construction cost at $915,000 per 10,000 tons ($1,830 million for a terminal with annual capacity at 20 million tons). For each country and region, we computed the cost while taking into account the regional average price and wage levels along with the representative cost. We assumed the same unit cost for steam coal and coking coal. We put the payback period at 15 years.

As for the coal production cost (represented by market prices), we set the standard price at $110/ton for coking coal and $80/ton for steam coal (2012 prices). For each country and region, we computed the coal production cost while taking into account the regional average price and wage levels along with the standard price. We used a steam coal price hike assumed for "Asia/World Energy Outlook 2013" to set the standard price for 2025 and 2040.

We used Worldscale[7] to compute the cost of transportation between countries/regions. Each country or region was represented by one terminal. We quoted distances between terminals from Worldscale. But North America, Russia and other countries and regions where large distances exist between eastern and western terminals were each represented by multiple terminals.

3.2 Results and discussion

3.2.1 Coal demand outlook

Coal demand will continue to increase in line with the economic growth of developing countries. It will rise from 7,527 million tons in 2011 to 8,671 million tons in 2025 and 10,020 million tons in 2040. The annual average growth rate through 2040 will be 1.0% (Figure 3-3).

By coal type, steam coal demand growth will be overwhelming. The growth will be attributable to growing electricity demand, as detailed later. Steam coal demand will expand from 5,677 million tons in 2011 to 6,723 million tons in 2025 and 8,095 million tons in 2040. In contrast, coking coal demand, though rising from 936 million tons in 2011 to 1,035 million tons in 2020, will turn down later in line with a drop in China's steel production. So far, China's crude steel production has rapidly expanded in an overheated manner (Figure 3-4). But it may peak around 2020 and turn down later. As a result, global coking coal demand in 2040 will slightly increase from 2011. This means that steam coal will account for almost all of the 2,494 million ton increase in coal demand from 2011 to 2040 (Figure 3-5 (a)).

Demand for coal for power generation will expand rapidly as electricity demand increases in line with the economic growth in non-OECD countries including Asian countries. Power generation coal demand will increase from 4,774 million tons in 2011 to 6,984 million tons in 2040 (with the annual average growth rate at 1.3%). Industrial coal demand will rise from 961 million tons in 2011 to 1,139 million tons in 2040. Power generation and industrial coal demand will thus account for 96% of the overall coal demand increase (Figure 3-5 (b)).

Million tons

	Results			Forecasts		

12,000

10,000

8,000

6,000

4,000

2,000

0

4,664   4,762   7,527   8,280   8,671   10,020

1990   2000   2011   2020   2025   2040
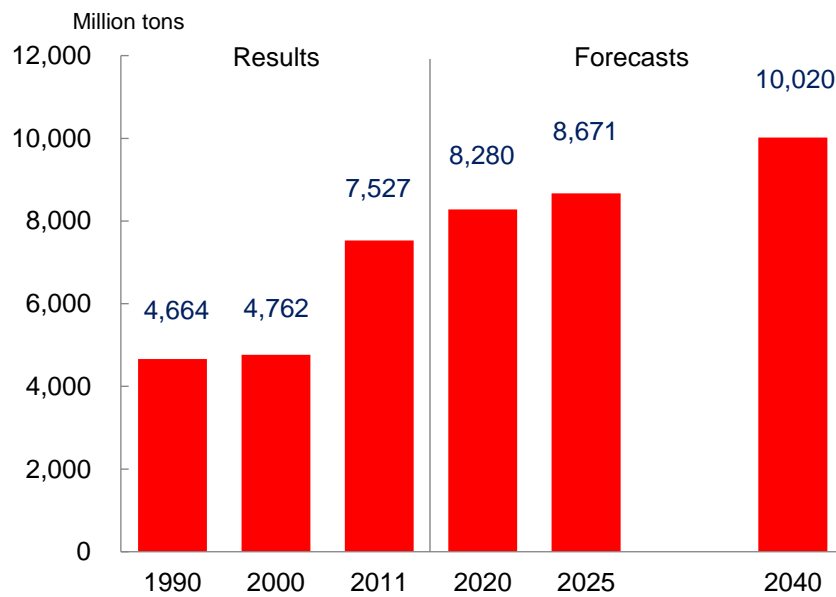
Sources: Past results are from IEA[1), 2)] , with forecasts based on the IEEJ outlook[6)].

Figure 3-3. Global Coal Demand

Million tons

1,000

800

600

400

200

0

Results   Forecasts

65   129   356   702   840   819   687

1990   2000   2005   2011   2020   2025   2040
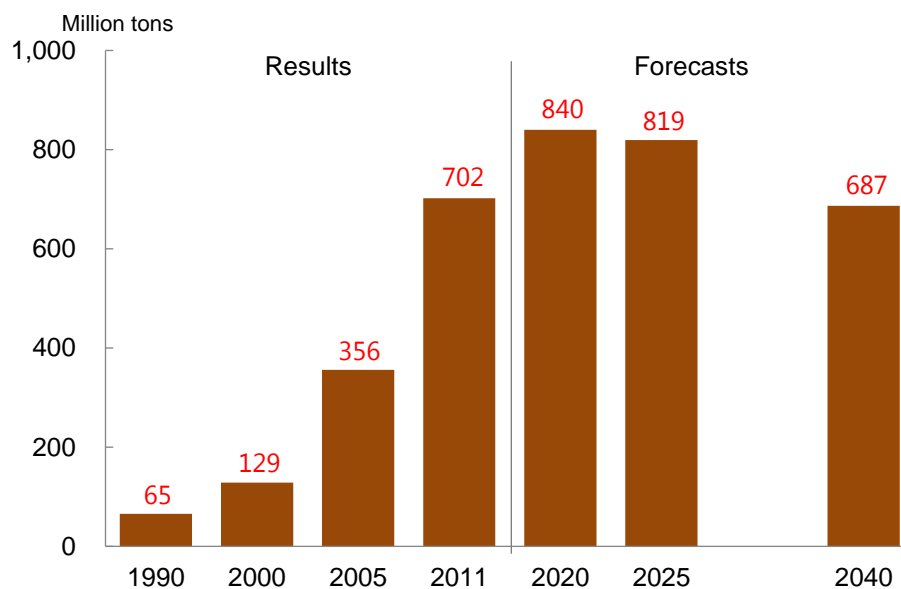
Sources: Results are from the Iron & Steel Statistics Handbook[8)] , with forecasts based on the IEEJ outlook[6)].

Figure 3-4. China's Crude Steel Production

17

| (a). By coal type | (b). By use |
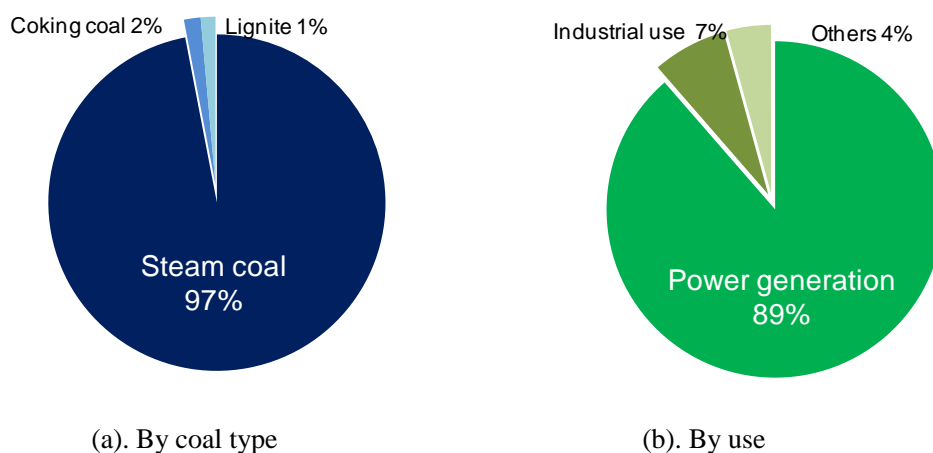
Figure 3-5. Breakdown of Coal Demand Growth (2011-2040)

Region-by-region coal demand is given in Table 3-1.

In Asia where coal demand has expanded rapidly since 2000, demand will continue increasing. Asian coal demand will rise from 4,810 million tons in 2011 to 5,974 million tons in 2025 and 7,273 million tons in 2040. Asia's share of global demand will rise from 63.9% in 2011 to 72.6% in 2040. Among Asian countries, India and ASEAN members will continue boosting coal demand. On the other hand, China will moderate coal demand growth after a rapid expansion during the 2000s and reach a demand peak before 2040.

In North America and OECD Europe, coal demand will decrease as gas and renewable energy power generation expands in response to environmental concerns including air pollution and carbon dioxide emissions. North American coal demand will fall from 963 million tons in 2011 to 832 million tons in 2025 and 740 million tons in 2040. Its share of global demand will decline from 12.8% in 2011 to 7.7% in 2040. Coal demand in OECD Europe will drop from 793 million tons in 2011 to 687 million tons in 2040, with its share of global demand shrinking from 10.5% to 6.9%.

In non-OECD Europe (including former Soviet Union), coal demand plunged in the early 1990s before increasing again in line with an economic recovery from the late 1990s. While Russian coal demand will decline from around 2025, power generation coal demand will increase in Kazakhstan and some other countries. As a result, coal demand in the entire non-OECD Europe will post firm growth through 2040.

In Africa and the Middle East as well, coal demand will expand with coal-fired thermal power plants being constructed.

Regions' shares of global coal demand growth indicate that Asia will account for almost all of the global demand increase between 2011 and 2040 (Figure 3-6).

18

Table 3-1. Projected Coal Demand by Region

|	1980	1990	2000	2011	2020	2025	…	2040	11/00	25/11	40/25	40/11
							(Million tons)		Annual average growth (%)			
World total	3,756	4,664	4,762	7,527	8,280	8,671	…	10,020	4.3%	1.0%	1.0%	1.0%
North America	687	865	1,029	963	859	832	…	775	-0.6%	-1.0%	-0.5%	-0.7%
U.S.	650	816	966	920	815	793	…	740	-0.4%	-1.1%	-0.5%	-0.7%
Latin America	19	33	44	63	96	115	…	180	3.3%	4.5%	3.0%	3.7%
Asia	913	1,544	2,077	4,810	5,597	5,974	…	7,273	7.9%	1.6%	1.3%	1.4%
China	626	1,050	1,338	3,501	3,928	4,011	…	4,173	9.1%	1.0%	0.3%	0.6%
India	108	221	357	710	963	1,189	…	2,068	6.5%	3.7%	3.8%	3.8%
Japan	88	115	153	174	168	165	…	150	1.2%	-0.4%	-0.7%	-0.5%
South Korea	28	45	72	131	139	146	…	150	5.6%	0.8%	0.2%	0.5%
Middle East	2	5	13	16	23	28	…	49	2.0%	3.9%	3.9%	3.9%
OECD Europe	1,158	1,182	831	793	743	726	…	687	-0.4%	-0.6%	-0.4%	-0.5%
Non-OECD Europe	814	800	467	545	587	606	…	625	1.4%	0.8%	0.2%	0.5%
Russia	-	374	230	225	236	233	…	213	-0.2%	0.3%	-0.6%	-0.2%
Kazakhstan	-	56	31	66	81	91	…	109	7.0%	2.4%	1.2%	1.8%
Africa	93	136	170	200	232	250	…	312	1.5%	1.6%	1.5%	1.6%
Oceania	69	98	130	137	143	141	…	119	0.4%	0.2%	-1.1%	-0.5%

Sources: Past results are from IEA[1,2], with forecasts based on the IEEJ outlook[6].
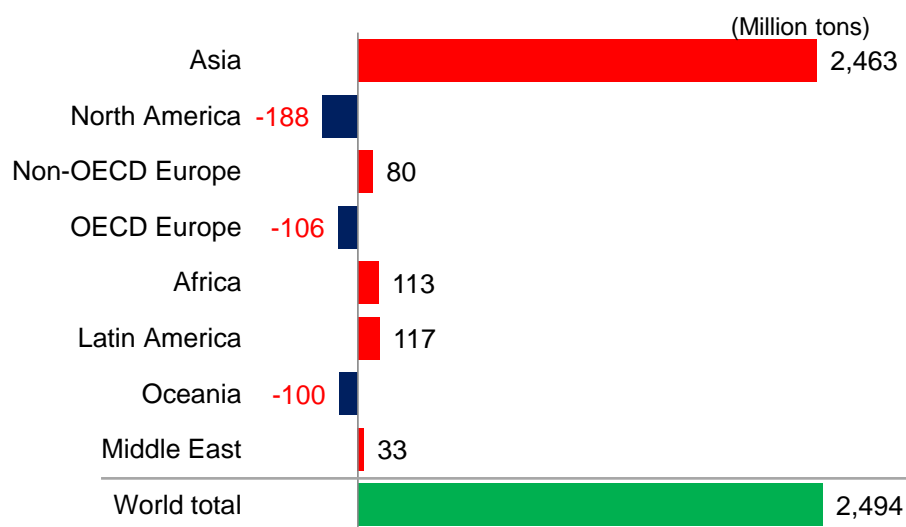
Figure 3-6. Coal Demand Increase by Region (2011-2040)

3.2.2 Coal production outlook

Major coal producing countries are planning to develop coal mines and transportation infrastructure (shipment ports and railways). But actual production depends on demand (domestic demand and international markets), with demand affecting progress in production plans. In estimating production, therefore, we took into account domestic (or regional) demand and coal industry conditions, and for coal exporting countries international market conditions (export demand) and coal development plans.

Tables 3-2, 3-3 and 3-4 indicate region-by-region (country-by-country) coal production by coal type. Future coal production trends in North America and OECD Europe will be far different from those in Asia and non-OECD countries where coal demand will increase.

In North America, Canada will expand coal production as a coal exporting country. But the United States will reduce coal production due mainly to a decline in domestic demand, an increase in production costs and coal mining operations' adverse effects on the environment. As a result, North American coal production will decrease at an annual average rate of 0.6% from 2011 to 2040. Major coal producing regions in the United States include Appalachia, the Powder River Basin and Illinois. Production is expected to decline in Appalachia plagued with low productivity and to keep the present level in the Power River Basin featuring higher productivity and lower costs. In OECD Europe, coal production will fall at an annual average rate of 0.6% due primarily to a demand decline, a production cost hike and the abolition of coal industry subsidies in several countries.

Unlike North America and OECD Europe where production will decline, Asian coal producing countries will expand production in line with their own demand growth. Asian coal production will rise at an annual average rate of 1.3% between 2011 and 2040.

Indonesia has substantially increased its coal production in response to the expansion of the Asian market. Its production will steadily rise from 360 million tons in 2011 to 650 million tons in 2040, with the annual average growth rate standing at 2.0%. But the Indonesian government has adopted a policy to sustainably and efficiently use domestic coal resources for national interests, adjusting the coal production expansion to domestic demand growth. As a result, Indonesia's coal exports will level off from around 2020 and begin to decline around 2025. India will boost its coal production at an annual average rate of 3.7% from 2011 and 2040 in line with growing domestic demand. Its coal output in 2040 will reach 1,633 million tons. But its domestic output may fall short of covering all domestic demand. India will depend on imports to meet the domestic production-demand gap. China is the world's largest coal consumer, producer and importer. China's coal output will increase through the mid-2030s to meet growing domestic demand and will later decrease in line with a demand drop. Other Asian countries will expand coal output according to their own demand growth. Among them, Mongolia will increase coal output in accordance with exports to China.

Other non-OECD countries will expand coal production in response to domestic and regional demand growth. In Africa, South Africa's steam coal production and Mozambique's coking coal output will increase in line with the expansion of the Asian coal market. (Mozambique will boost steam coal output as well as coking coal production.) Colombia will boost steam coal output to meet demand growth in other Latin American countries, although the European market as its largest market will shrink, with U.S. imports decreasing.

Australia's coal production in 2040 will more than double from 2011 to respond to the expansion of the international coal market. Particularly, its steam coal output will more than triple from 2011 due to a sharp market expansion.

Table 3-2. Projected Coal Production by Region

								(Million tons)		Annual average growth (%)		
	1980	1990	2000	2011	2020	2025	...	2040	11/00	25/11	40/25	40/11
World total	3,781	4,624	4,598	7,452	8,280	8,671	...	10,020	4.5%	1.1%	1.0%	1.0%
North America	790	1,002	1,041	1,060	973	954	...	896	0.2%	-0.7%	-0.4%	-0.6%
U.S.	753	934	972	992	903	886	...	824	0.2%	-0.8%	-0.5%	-0.6%
Canada	37	68	69	67	70	69	...	72	-0.3%	0.2%	0.4%	0.3%
Latin America	20	48	75	122	118	126	...	155	4.5%	0.2%	1.4%	0.8%
Colombia	4	21	38	86	86	90	...	112	7.6%	0.3%	1.5%	0.9%
Asia	827	1,325	1,791	4,373	5,101	5,401	...	6,402	8.5%	1.5%	1.1%	1.3%
China	620	995	1,301	3,280	3,665	3,733	...	3,900	8.8%	0.9%	0.3%	0.6%
India	110	219	329	575	750	929	...	1,633	5.2%	3.5%	3.8%	3.7%
Indonesia	0	10	79	360	531	559	...	647	14.7%	3.2%	1.0%	2.0%
Middle East	1	1	2	1	1	1	...	1	-0.5%	-1.6%	-0.2%	-0.9%
OECD Europe	1,093	1,045	652	581	541	525	...	492	-1.0%	-0.7%	-0.4%	-0.6%
Non-OECD Europe	824	813	496	649	716	739	...	764	2.5%	0.9%	0.2%	0.6%
Russia	-	372	240	322	362	363	...	348	2.7%	0.9%	-0.3%	0.3%
Africa	120	182	230	258	334	364	...	442	1.0%	2.5%	1.3%	1.9%
South Africa	115	175	224	253	292	311	...	373	1.1%	1.5%	1.2%	1.4%
Oceania	107	207	310	407	496	560	...	869	2.5%	2.3%	3.0%	2.6%
Australia	105	205	307	402	491	555	...	863	2.5%	2.3%	3.0%	2.7%

Sources: Past results are from IEA[3], with forecasts based on the IEEJ outlook[6].

Table 3-3. Projected Steam Coal Production by Region

								(Million tons)		Annual average growth (%)		
	1980	1990	2000	2011	2020	2025	...	2040	11/00	25/11	40/25	40/11
World total	2,258	2,874	3,254	5,559	6,331	6,723	...	8,095	5.0%	1.4%	1.2%	1.3%
North America	609	792	869	865	785	774	...	730	0.0%	-0.8%	-0.4%	-0.6%
U.S.	592	760	840	837	757	747	...	704	0.0%	-0.8%	-0.4%	-0.6%
Canada	17	31	30	28	29	27	...	26	-0.6%	-0.3%	-0.2%	-0.2%
Latin America	7	30	58	102	106	113	...	140	5.2%	0.7%	1.5%	1.1%
Colombia	3	20	36	82	82	87	...	108	7.6%	0.4%	1.5%	1.0%
Asia	719	1,167	1,597	3,721	4,409	4,713	...	5,709	8.0%	1.7%	1.3%	1.5%
China	552	909	1,178	2,771	3,114	3,219	...	3,491	8.1%	1.1%	0.5%	0.8%
India	87	169	283	488	639	797	...	1,401	5.1%	3.6%	3.8%	3.7%
Indonesia	0	10	79	358	525	551	...	633	14.7%	3.1%	0.9%	2.0%
Middle East	0	0	0	0	0	0	...	0	-6.8%	0.0%	0.0%	0.0%
OECD Europe	365	279	161	103	91	82	...	72	-4.0%	-1.6%	-0.8%	-1.2%
Non-OECD Europe	416	337	204	324	368	383	...	414	4.3%	1.2%	0.5%	0.9%
Russia	-	152	102	180	197	195	...	185	5.3%	0.6%	-0.4%	0.1%
Africa	108	172	226	256	308	335	...	406	1.1%	1.9%	1.3%	1.6%
South Africa	105	165	221	251	290	309	...	371	1.2%	1.5%	1.2%	1.4%
Oceania	33	96	138	187	264	322	...	623	2.8%	4.0%	4.5%	4.2%
Australia	32	94	136	185	262	320	...	620	2.8%	4.0%	4.5%	4.3%

Sources: Past results are from IEA[3], with forecasts based on the IEEJ outlook[6].

Table 3-4. Projected Coking Coal Production by Region

									(Million tons)	Annual average growth (%)		
	1980	*1990*	*2000*	*2011*	*2020*	*2025*	...	*2040*	*11/00*	*25/11*	*40/25*	*40/11*
World total	567	610	488	982	1,035	1,027	...	976	6.6%	0.3%	-0.3%	0.0%
North America	132	121	82	111	106	103	...	94	2.7%	-0.5%	-0.6%	-0.6%
U.S.	118	93	54	82	77	72	...	60	3.8%	-0.9%	-1.2%	-1.0%
Canada	14	28	28	29	29	30	...	34	0.4%	0.1%	0.8%	0.5%
Latin America	12	16	15	18	5	6	...	7	2.0%	-7.9%	1.1%	-3.4%
Colombia	1	2	2	4	3	3	...	4	7.4%	-1.0%	1.1%	0.1%
Asia	97	124	146	578	619	601	...	534	13.3%	0.3%	-0.8%	-0.3%
China	68	86	123	509	541	514	...	409	13.8%	0.1%	-1.5%	-0.8%
India	18	36	22	44	51	59	...	86	6.5%	2.1%	2.5%	2.3%
Indonesia	0	0	1	3	6	8	...	14	14.9%	7.9%	3.7%	5.7%
Middle East	1	1	1	1	1	1	...	1	0.0%	0.6%	-0.2%	0.2%
OECD Europe	128	93	45	25	18	14	...	3	-5.1%	-4.3%	-9.7%	-7.1%
Non-OECD Europe	145	180	90	98	109	115	...	126	0.8%	1.2%	0.6%	0.9%
Russia	-	85	51	65	80	86	...	98	2.3%	2.0%	0.9%	1.4%
Africa	12	10	4	2	21	24	...	30	-4.9%	18.2%	1.5%	9.3%
South Africa	11	9	3	2	2	2	...	2	-5.9%	1.1%	1.0%	1.0%
Oceania	40	65	105	149	157	164	...	181	3.2%	0.7%	0.7%	0.7%
Australia	40	65	104	147	155	162	...	179	3.2%	0.7%	0.7%	0.7%

Sources: Past results are from IEA[3], with forecasts based on the IEEJ outlook[6].

3.2.3 Coal trade flows

We used the LP model to estimate steam and coking coal trade flows in 2025 and 2040. In forecasting trade flows, we took into account planned production deals and capital injection conditions as well as projected coal demand and production.
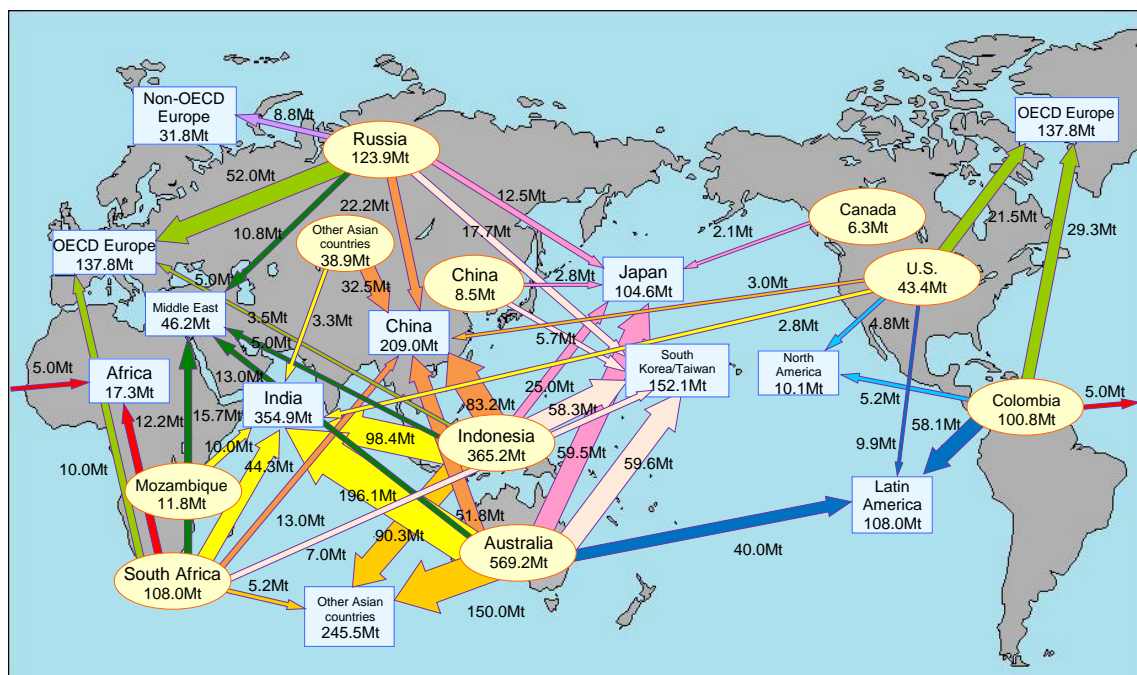
Steam coal

Steam coal trade volume and flows are given in Tables 3-5 and 3-6 and Figures 3-7 and 3-8. Steam coal trade will expand from 857 million tons in 2011 to 1,108 million tons in 2025 and 1,417 million tons in 2040. For OECD Europe where steam coal demand will decline due to environmental concerns and other issues, major coal exporters have so far included Russia, Colombia, the United States and South Africa. Of them, Colombia will reduce coal exports to Europe. This does not necessarily mean any relative decline in Colombia's competitiveness in the market for Europe. But this does indicate that Colombia's exports to other Latin American countries with growing coal demand would cost less than those to Europe. South Africa and Mozambique will expand exports to other African countries, India and the Middle East where demand will increase. While Russian coal exports will level off from 2025 to 2040, Russia will reduce exports to Europe while expanding those to Asia.

In the Asian market, Indonesia's exports will peak around 2025 and gradually decline later due to its domestic demand growth and its policy of making effective use of coal resources. As a result, Australia will greatly expand exports to meet growing Asian demand. Australia's exports in 2025 will expand 1.5-fold from 2011. Those in 2040 will score a more than 2.5-fold increase from 2011. In fact, India and China have invested in new coal mine development projects in Australia and will expand imports from mines subject to these projects.

22

Table 3-5. Steam Coal Trade (2025)

(Million tons)		North America	Latin America	OECD Europe	Africa	Middle East	Non-OECD Europe	Japan	China	India	South Korea · Taiwan	Other Asian countries	
							To						
From	U.S.	5.3	2.4	30.9				0.6	3.1	1.8	0.8		45.0
	Canada			1.2				2.1	0.3		1.4		5.0
	Colombia	5.0	40.3	32.8				0.7	1.5		1.0		81.3
	Russia			60.7		5.5	7.2	14.5	20.2		14.2		122.3
	South Africa			13.6	10.2	3.0		0.6	13.0	39.7	7.0	2.2	89.3
	Mozambique				0.1					12.7			12.8
	China							2.6			5.7		8.3
	Indonesia			5.0		14.0		27.6	100.2	106.9	68.0	83.9	405.7
	Australia	1.9	15.0			3.0		61.3	31.7	42.5	57.6	45.9	258.9
	Other Asian countries			0.0		0.0	0.8	1.1	39.0	3.5	1.5	0.1	46.0
	Others	0.8		7.2			25.6						33.7
		13.0	57.7	151.5	10.3	25.5	33.6	111.1	209.0	207.1	157.2	132.1	1,108

Note: "Others" includes Latin American countries other than Colombia, and non-OECD European countries other than Russia. "Other Asian countries" on the export side includes Mongolia and Vietnam.

Note: The figure covers flows of more than 2 million tons. The legend in the figure is the same as in Figure 2-14. Mexico is included in Latin America.

Figure 3-7. Steam Coal Trade Flows (2025)

23

Table 3-6. Steam Coal Trade (2040)

(Million tons)		North America	Latin America	OECD Europe	Africa	Middle East	Non-OECD Europe	Japan	China	India	South Korea·Taiwan	Other Asian countries	
From	U.S.	4.8	9.9	21.5				0.6	3.0	2.8	0.8		43.4
	Canada			2.5				2.1	0.3		1.4		6.3
	Colombia	5.2	58.1	29.3	5.0			0.6	1.5		1.0		100.8
	Russia			52.0		10.8	8.8	12.5	22.2		17.7		123.9
	South Africa			10.0	12.2	15.7		0.6	13.0	44.3	7.0	5.2	108.0
	Mozambique				0.1	1.7				10.0			11.8
	China							2.8			5.7		8.5
	Indonesia			3.5		5.0		25.0	84.7	98.4	58.3	90.3	365.2
	Australia		40.0			13.0		59.5	51.8	196.1	58.8	150.0	569.2
	Other Asian countries						0.8	0.9	32.5	3.3	1.4		38.9
	Others			19.0			22.2						41.2
		10.1	108.0	137.8	17.3	46.2	31.8	104.6	209.0	354.9	152.1	245.5	1,417

Note: "Others" includes Latin American countries other than Colombia, and non-OECD European countries other than Russia. "Other Asian countries" on the export side includes Mongolia and Vietnam.

Note: Same as for Figure 3-7.

Figure 3-8. Steam Coal Trade Flows (2040)

24

Coking coal

Coking coal trade volume and flows are given in Tables 3-7 and 3-8 and Figures 3-9 and 3-10. Coking coal trade volume will increase from 283 million tons in 2011 to 325 million tons in 2025 and 357 million tons in 2040.

From 2011 to 2025, China and India will expand coking coal imports due to their growing demand. In response, Russia, Mozambique and Australia will expand output. Russia and Australia will increase coking coal exports to China, while Mozambique will expand those to India. Mozambique, a new coking coal exporter, will export to Latin America (Brazil) and Japan as well as India. Indonesia will develop coking coal in Central Kalimantan for exports to other Asian countries including Japan.

From 2025 to 2040, China will reduce coking coal imports in line with a fall in demand. But India will continue increasing imports. Given an increase in Mongolian exports to China and a decline in Japanese demand, Australia's exports to China and Japan will decrease. As a result, Australia's exports to India will expand remarkably.

Table 3-7. Coking Coal Trade (2025)

(Million tons)		North America	Latin America	OECD Europe	Africa	Middle East	Non-OECD Europe	Japan	China	India	South Korea · Taiwan	Other Asian countries	Total
							To						
From	U.S.	3.6	5.3	27.0				4.0	6.0	5.0	6.0		56.8
	Canada	1.0		4.8				6.6	9.5		8.0		30.0
	Colombia		0.6										0.6
	Russia			3.0			11.1	2.0	6.0		3.0		25.1
	South Africa				0.3								0.3
	Mozambique		3.0	2.0	2.1	1.0	1.9	2.0	1.3	7.0	2.0		22.3
	China							0.5		1.0			1.5
	Indonesia							2.0	0.5	2.0	1.0	1.9	7.3
	Australia		5.3	15.0	2.9			37.0	33.4	38.8	23.5	3.2	159.0
	Mongolia								20.4				20.4
	Others						1.5						1.5
		4.6	14.3	51.8	5.2	1.0	14.5	54.1	77.0	52.8	44.5	5.1	324.8

Note: "Others" includes Latin American countries other than Colombia, and non-OECD European countries other than Russia.
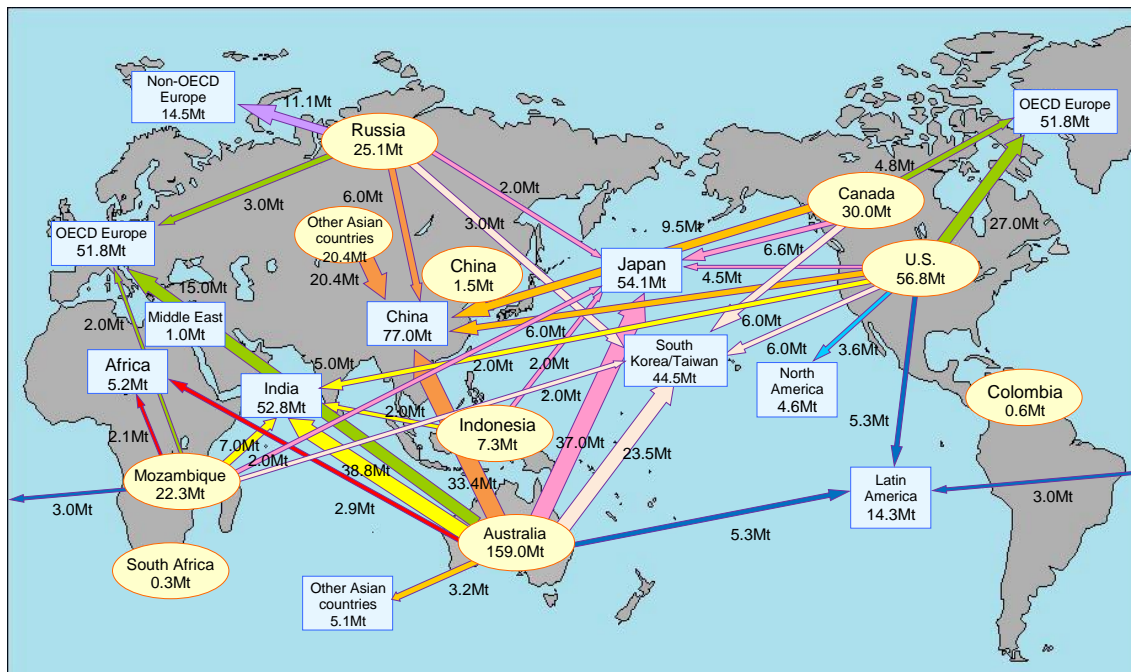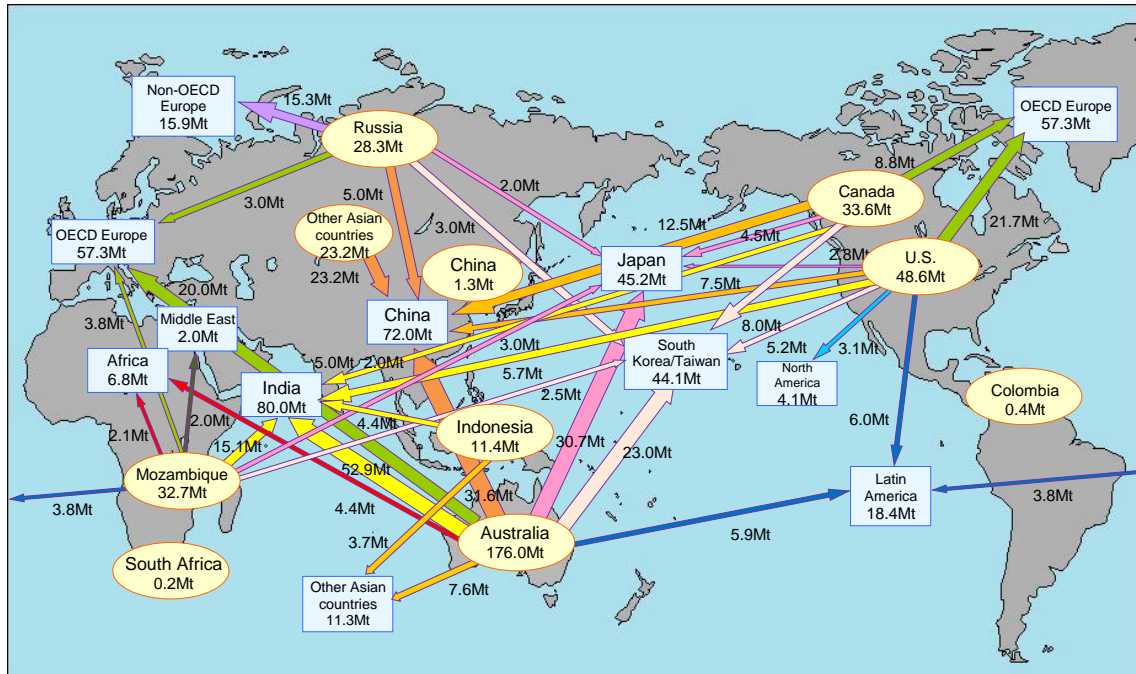
Figure 3-9. Coking Coal Trade Flows (2025)

Note: Same as for Figure 3-7

Table 3-8. Coking Coal Trade (2040)

(Million tons)		North America	Latin America	OECD Europe	Africa	Middle East	Non-OECD Europe	Japan	China	India	South Korea · Taiwan	Other Asian countries	
From	U.S.	3.1	6.0	21.7				2.8	4.2	5.7	5.2		48.6
	Canada	1.0	1.8	8.8				4.5	7.5	2.0	8.0		33.6
	Colombia		0.4										0.4
	Russia			3.0			15.3	2.0	5.0		3.0		28.3
	South Africa				0.2								0.2
	Mozambique		3.8	3.8	2.1	2.0	0.0	3.0	0.5	15.1	2.5		32.8
	China							0.4		0.9			1.3
	Indonesia							1.8		4.4	1.5	3.7	11.4
	Australia		5.9	20.0	4.4	0.0	0.0	30.7	31.6	52.9	23.0	7.6	176.0
	Mongolia								23.2				23.2
	Others		0.5				0.6						1.1
		4.1	18.4	57.3	6.8	2.0	16.0	45.2	72.0	80.0	44.1	11.3	356.9

Note: "Others" includes Latin American countries other than Colombia, and non-OECD European countries other than Russia.

26

Note: Same as for Figure 3-7

Figure 3-10. Coking Coal Trade Flows (2040)

4. Conclusion

In this paper, we detailed past coal supply and demand results by coal type and by region and forecast coal supply and demand through 2040. Furthermore, we built a coal trade model using the linear programming method, forecasting coal trade flows in 2025 and 2040.

In contrast to growing concerns about climate change, global coal consumption has continued expanding. Particularly from 2002 to 2012, global coal demand grew at a very high annual average rate of 4.6% centering on steam coal for power generation, driven by Asia. This trend will continue through 2040, with the demand growth center shifting from China to India. Many OECD countries will reduce coal demand, while China's demand will peak out. As a result, global coal demand's annual average growth through 2040 will slow down to 1.0%. But power generation steam coal demand will continue expanding. The coal demand increase projected through 2040 will rival the rise in the decade between 2002 and 2012.

It will be difficult for most of countries to cover demand growth with domestic production alone. As a result, international coal trade will expand. Total trade will grow by 65% between 2011 and 2040. Given that demand changes differ from region to region, future trade flows will be

27

different from the present ones. New major coal flows will emerge, including those from Mozambique to India, from Russia to Asia, and from Colombia to other Latin American countries. Meanwhile, Indonesia, now one of the major coal exporters, will refrain from expanding exports so much due to domestic demand growth and its policy of protecting coal resources for their effective use.

The coal trade model we have developed in this study separates steam coal from coking coal and uses the linear programming method to estimate trade flows that can minimize the total global trade cost. Therefore, we cannot take into account partial optimization for certain countries or regions, or selection based on quality differences. Nevertheless, the model indicates a picture of quantitative world coal trade while securing trade flows' consistency with supply and demand. This is one of this study's features.

Projected trade flows indicate that demand growth in China and India and policy shifts in coal producing countries may bring about a decline in coal imports into Japan from Australia (steam coal), Indonesia (coking coal) and other major traditional coal exporters for Japan as well as a decline in these countries' shares of total coal imports into Japan, while new exporters (including Mozambique with coking coal) for Japan may emerge. We hope that this study will help trigger efforts to reaffirm the potential strong impacts of other countries' supply and demand trends on trade flows for Japan and other importing countries, or to consider how best to secure stable coal supply for the future.

Reference

1) IEA, "Energy Balances of OECD Countries 2013" (2013)

2) IEA, "Energy Balances of Non-OECD Countries 2013" (2013)

3) IEA, "Coal Information 2013" (2013)

4) IEA, "Energy Statistics of OECD countries 2013" (2013)

5) IEA, "Energy Statistics of Non-OECD countries 2013" (2013)

6) Institute of Energy Economics, Japan, "Asia/World Energy Outlook 2013" (2013)

7) Worldscale Association, "NEW WORLDWIDE TANKER NOMINAL FREIGHT SCALE "WORLDSCALE" (2013)

8) Japan Iron and Steel Federation, "Iron & Steel Statistics Handbook"