Impacts of seaborne trade on coal importing countries – Pacific market

Paul Baruya

CCC/202 ISBN 978-92-9029-522-8

August 2012

Abstract

In recent years, there has been a convergence of international trade with traditional domestic markets. As imports continue to increase in many coal producing regions, the influence of trade on domestic markets has been twofold. Firstly, imported coal displaces domestic production and, secondly, international price trends may drive prices of what remains of the indigenous market for coal.

While international trade does not provide any additional benefits in terms of reduced CO_2 at coal-fired power stations, importing coal provides many benefits, such as cost savings, improved coal quality, enhanced supply diversity, and often fills a gap which domestic supply is unable to fulfil. This report examines how coal markets have evolved over the decades with utilities and heavy industry moving away from their seemingly secure yet captive markets of domestic coal to procuring more supplies from the international market to satisfy the need of cost reduction and better and consistent quality of fuel product. The various factors that have led to a rise in popularity of seaborne traded coal, and the future of domestically produced coal in the Pacific market are discussed.

This is in one of three reports which examine the changing trends in coal imports over the long term in three geographical regions: a global perspective, the Atlantic market and the Pacific market.

Acronyms and abbreviations

API2	coal price indices for northwest Europe
AR	as received
ARA	Amsterdam, Rotterdam, and Antwerp
AUS	Australia
BAFA	German domestic pricing system
BAT	best available technology
Ca	Calcium
CAA	Clean Air Act (USA)
CAPP	Central Appalachia
CCGT	combined cycle gas turbine
CFBC	circulating fluidised bed combustion
CIF	cost, insurance and freight (coal price at destination port prior to unloading)
CIL	Coal India Limited
Cl	chlorine
CNCIEC	China National Coal Import Export Commission
COL	Colombia
COP	Conference of the Parties
Crore	10 million
DB	Deutsche Bahn
DES	delivered ex-ship
DGTREN	Directorate General of Transport and Energy (EU)
dwt	dead weight (freight capacity, typically the maximum cargo capacity)
EC	European Commission
EIA	Energy Information Administration (US Department of Energy)
ELV	emission limit values
EUETS	European Union Emissions Trading System
FGD	flue gas desulphurisation
FOB	free on board (coal price at export port)
GDP	gross domestic product
GJ/t	gigajoule per metric tonne
Gt	gigatonne (1000 Mt)
GWe	gigawatt electrical generating capacity (= 1000 MWe, one watt = 1 joule per second)
ha	hectare
HCl	hydrogen chloride
HEPCO	Hokkaido Electric Power Company
HGI	Hardgrove Grindability Index
IDT	Fusibility of Ash
IEA	International Energy Agency
IEA CCC	International Energy Agency Clean Coal Centre
IED	Industrial Emissions Directive
IGCC	integrated gasification in combined cycle
INDO	Indonesia
INR	Indian rupees
IPP	independent power producer/production
kcal/kg	kilocalorie per kilogramme (typically net), referring to the heating value of steam coal
km	kilometre
KRW	Korean Won (currency)
Lakh	100 units, 10^2
LCPD	Large Combustion Plant Directive (EU)

LHV	lower heating value
MCIS	McCloskey Coal Information Services
METI	Ministry of Economy, Trade, and Industry
Mg	magnesium
mg/m^3	milligrammes per cubic metre
MJ/kg	megajoules per kilogramme
MoU	memorandum of understanding
MPa	mega Pascal
Mt	million tonnes
Mtce	million tonnes of coal equivalent (multiply by 0.7 to obtain Mtoe)
Mtoe	million tonnes of oil equivalent (divide by 0.7 to obtain Mtce)
MWe	megawatt electric
MWth	megawatt thermal
NAPP	Northern Appalachia
NAR	net as received, for coal pricing
NCV	net calorific value
NDRC	National Development and Reform Commission
nm	nautical mile
NOx	nitrogen oxide compounds
NWE	northwest Europe
OECD	Organisation for Economic Cooperation and Development (OECD)
POL	Poland
PRB	Powder River Basin
R&D	Research and development
R/P	reserves to production ratio
RB	Richard's Bay (same as RBCT)
RBCT	Richard's Bay Coal Terminal (Republic of South Africa)
RMB	Chinese renminbi (currency)
RUSS	Russia
ScoTa	Standard Coal Trading Agreement
SCR	selective catalytic reduction
SOx	sulphur oxide compounds
SSY	Simpson, Spence, and Young
t	metric tonne
TEPCO	Tokyo Electric Power Company
TPES	Total primary energy supply (net balance of production, trade, storage and losses)
TWh	terawatt hour (equal to 1000 GWh; 1,000,000 MWh)
UMPP	ultra mega power project
WTO	World Trade Organisation

Contents

1 Introduction

Internationally traded coal has matured over the last 30–40 years with immense potential for further growth. Yet for some time, international trade has accounted for some 15–20% of world supply, which means locally produced coal still accounts for more than 80% of all the coal consumed in the world.

In recent years, there has been a convergence of international trade with traditional domestic markets, with imports increasing into many coal producing regions. The influence of trade on domestic markets has been twofold. Firstly, imported coal displaces domestic production; secondly, international price trends may drive prices of what remains of the indigenous market for coal if imports are significant enough.

In many regions, where transport allows, imported coal has displaced locally produced coal for one reason or another. Key questions that arises are: to what extent imports displace domestically produced coal; and what have been the key drivers of this displacement. There is no one reason for the decline of coal production in many OECD countries. This makes the assessment of domestic coal production, based on the effects of imported coal alone, a less than straightforward exercise.

This report covers the Pacific markets of Japan, Korea, India and China. This country selection includes some of the largest importers of steam coal in the world; India and China are covered extensively by many analysts worldwide, not least by the IEA CCC, and these countries are considered the future leading coal importers. Under various scenarios, past editions of the IEA World Energy Outlook place China and India as the two nations that are foremost to push coal demand higher into the future. China's coal demand alone accounts for half of global demand; the Chinese market will therefore be the linchpin for the global market for some years. India is also set to play an increasing role and, over the next few decades, could displace the USA as the second largest coal market in the world.

However, it is easy to ignore the importance of countries like Japan and Korea which remain the largest importers of hard coal in the world. Both countries are in the top three coal importing countries with China, while Chinese Taipei (formerly Taiwan) is the fourth largest importer.

For both industrialised and industrialising Asia, imported coal offers a source of coal under circumstances where domestic producers are less able to supply. In the case of China and India which are rich in coal reserves, this is purely a function of inadequate transportation infrastructure. Japan and Korea on the other hand have low coal reserves that suffer from high costs of extraction.

Non-OECD nations will account for all the growth in coal demand in coming years, regardless of which scenario in the WEO is considered. Even when taking into account a reduction in OECD demand, world demand could increase by between 1000 Mtce and 3000 Mtce in the period 2009 to 2035 under the New Policies and Current Policies scenarios respectively.

While it is straightforward to identify the various factors that influence coal switching to imported supplies, it is less straightforward to quantify the degree of these influences. This report on the Pacific market provides an understanding of some of the rudimentary concepts that determine the penetration of coal into coal importing markets:

- coal's role in primary energy supply;
- coal supply trends and the increasing role of international trade;
- the demand for steam coal in the power generating sector;
- cost advantages of coal importing;
- coal import logistics.

The analysis includes the mapping and location of power stations that might use foreign imported coal, along with the mode of inland transport, possible routes, and the likely ports of entry. There is also discussion on the structure of the coal mining industry, the comparative cost of mining hard coal within each country with imported coals, and where applicable the financial aid that might be awarded to the hard coal industries.

2 Japan

Japan is a country roughly the same land area as Germany and has a population of 127 million. Population growth has seen a decline and Japan is considered an ageing country, although this is more an indication of life expectancy which is better than in most OECD nations. The labour market is often criticised for being less flexible than that in Europe or the USA, but generally highly educated. The Japanese economy remains a global leader in high tech design and manufacturing and personal wealth is high with spending based more on savings than debt, although national debt is high. Japan's economy relies on manufacturing exports, but the recent global economic troubles and natural disasters in Japan have dented prospects in the near term.

In past decades, Japan's annual economic growth has been spectacular, averaging 10%/y in the 1960s, 5%/y in the 1970s, 4%/y 1980s, but then by the 1990s, growth slowed to 1.7%/y following the Tokyo stock market crash of 1990. Despite this economic downturn, Japan was still the second largest economy in the world behind the USA, but the situation changed with the emergence of new superpowers. In 2001 Japan was overtaken by the China in terms of economic size, making Japan the third largest economy in the world which it remains today. Government debt is double that of GDP, with GDP estimated at US$ 4.3 trillion. Japan suffers from deflation; the value of goods in the economy appears to be shrinking, and so perhaps are overvalued.

Of course Japan's most recent recession has been due to the global downturn and reduced demand for export goods, but interestingly, Japan was less exposed to subprime mortgages or their derivative instruments, and so the economy weathered some of the mistakes made by western lending practices. In early 2011, the natural disaster and resulting incident at the Fukushima Daiichai power plant affected homes, industry, and manufacturing which compounded the problems already experienced by the global economic downturn.

Currency rates have been a blessing and a curse for Japan. Between 2000 and 2008, the US$ was trading at 110–120 yen, but in 2009 the dollar dropped below 100 yen. By 2011, the dollar had dropped to 80 yen. The devaluation of the US dollar has been harmful in terms of making Japanese domestic currency revenues from export trade much worse than five years ago. Yet, the currency movement would also go some way to soften the blow of the rising price of fossil fuel imports, on which the country is dependent.

2.1 Primary energy

At almost 710 Mtce (500 Mtoe), the entire Japanese energy market is almost twice that of Korea. Coal provided 20–30% of the total primary energy supply (TPES) in 2010, while gas was around 15–17%, and oil was 38–41%. According to IEA (2010) data, Japan imported 86% of its primary energy. In June 2010, the Ministry of Economy, Trade, Industry (METI) announced the intention to increase energy self sufficiency to 70% by 2030. Energy security and cutting CO_2 emissions however were the priorities, forging stronger relationships with energy producing countries (notably the Australian coal industry) and, at the time, increasing the role played by nuclear power.

Almost all of the country's coal supply is imported and used within the country; the same applies to natural gas (LNG) supplies. Oil imports (120 Mtoe of crude and 33 Mtoe of products) are re-exported as products. Some 60% of oil is used within the economy but 40% is re-exported as oil products (45 Mtoe) or consumed in international bunkers (13 Mtoe). Renewables are a small percentage of the total energy supply, but energy policy in Japan is gearing up renewable-based generation and energy efficiency development in the light of the possible demise of nuclear and coal-fired power within the country for environmental reasons.

Under the 15th Conference of the Parties (COP15) of United Nations Framework Convention on Climate (Copenhagen, December 2009), Japan registered a 25% reduction of greenhouse gas emissions as a target for 2020, compared to a 1990 base year. Amongst a suite of aims and objectives, Japan had planned to replace fossil fuelled stations with nuclear, but this objective may face greater opposition in favour of renewable energies, biomass, hydroelectricity, geothermal, and smart grids. Japan's history of R&D is impressive, but energy costs are already high, many business run efficiently, and the development of renewables has been slow for cost reasons.

Coal is considered a secure and established fuel for power generation. In some parts of the world, coal is considered a depleting resource but, internationally, coal is far from scarce. For Japan, coal-fired power is an essential and relatively stable component of the power station fleet, as electricity accounts for more than 50% of household energy consumption, compared with just 27% in Korea; this is a high proportion, similar to countries such as the USA.

Current energy policy is in a state of uncertainty in the aftermath of the Fukushima incident. While it is likely that the building of nuclear plants may be shelved, it is possible that within 10–20 years the government will need to come to terms with cutting CO_2 emissions, and nuclear power expansion may well resume. Despite the recent negative events, Japan remains an enviable world leader in R&D, industrial production, and in terms of coal-fired power stations it achieves some of the highest efficiency and cleanest power plants of their kind in the world.

2.2 Coal demand and supply

In 2008, primary coal consumption increased by 3.6% from the previous year, reflecting the increased demand for electricity. Coal accounted for 23% of the total primary energy supply and 27% of total power generation. Japan consumed 177 Mtce (123.7 Mtoe) of coal in 2010, more than double the consumption in the 1980s, during the period of Japan's highest economic growth. Domestic coal production only accounts for 0.4% of the country's needs; Japan therefore is almost wholly reliant on imported coal (*see* Figure 1).

Coal will continue to play a role in Japan's energy sector, mainly for power generation, and certain industrial sectors such as iron and steel manufacture, cement, and paper and pulp. In 2008, the Japanese power sector had 44 GWe of coal-fired generating capacity in operation (a range of estimates put capacity at 42–46 GWe). Coal accounted for 16% of the total power generating capacity in the country which was 280.5 GWe in 2008. The coal fleet emitted 414 Mt of CO_2 and produced 288 TWh of electricity in 2008, a fall of 5% on 2007. In 2009, production continued to drop by 3%, but recovered in 2010 to levels of generation last seen in 2008.

The structure of Japan's power market is divided into ten geographical regions or prefectures, each dominated by one privately owned monopoly which controls generation, transmission, and distribution. The largest utility is the Tokyo Electric Power Company (TEPCO). All power utilities account for 75% of the country's public generating capacity; the remainder consists of two major organisations, the Japan Atomic Power Company (JAPC) which operates three nuclear plants, and J-Power which operates 16 GWe of thermal and hydroelectric capacity.

In the north is the large island of Hokkaido where coal-fired and nuclear power plants provide a significant proportion of the prefecture's power supply. Hokkaido's climate is such that the winters can be severe and nuclear and coal-fired power account for a bulk of the baseload generation. Domestic coal features prominently, ahead of oil and renewables for this region. Seven coal mines are located in Hokkaido prefecture, producing coal for local power generation plants. In 2006, coal was produced mainly by an underground mine operated by Kushiro Coal Mine Co Ltd, and six other small-scale open pit mines. The Kushiro mine, which was a centre for transferring Japanese coal technology to other countries in Asia, produces about 800,000 t; the remaining six mining companies produce a total of about 540,000 t.

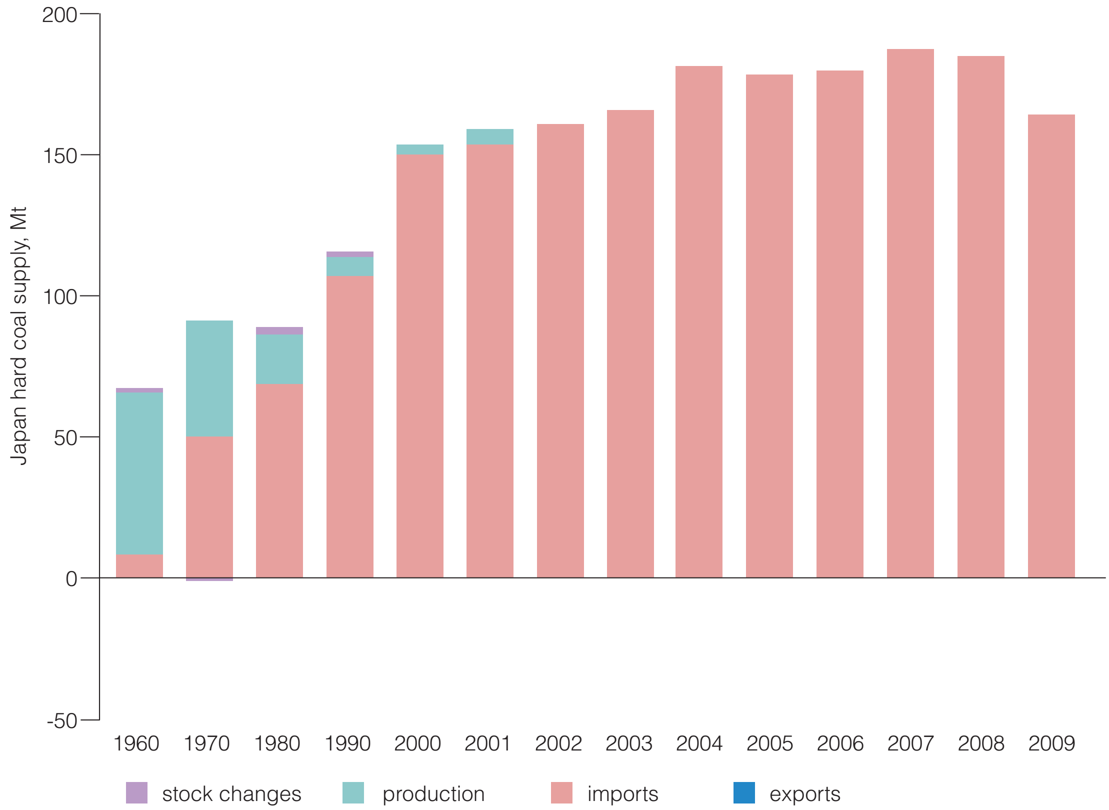

Figure 1 Japanese hard coal supply (IEA, 2010)

As mentioned earlier, Japan is the biggest coal importer in the world, accounting for more than 20% of total global coal imports and one of the most influential participants in the seaborne market. Japan develops coal mines abroad, and imports from these facilities are mainly bituminous coal, with coking coal and anthracites imported for metallurgical purposes. Australia is the single largest supplier of coal to Japan with Indonesia gradually expanding its presence since 2000. Japan's other main steam coal suppliers are China, Russia, USA, South Africa, and Canada. Coking coal is imported from Canada, China, Russia, USA, and South Africa.

Despite a dip in 2009, coal imports appear to be gradually recovering despite the tsunami that devastated the Port of Sendai and caused the closure of more than 16 GWe of nuclear and coal-fired generating capacity. The rise of exports from Indonesia (to Japan) compared with other coal exporters is partly due to the price and the ocean freight advantage that Indonesia has over competitor suppliers, such as Australia. Indonesian producers and export facilities are also able to meet the rapid demand growth seen across Asia, thus outpacing the export capabilities of almost all other world exporters of steam coal. The advantages of Indonesian coals include low sulphur and ash content, leading to lower emissions of SOx and lower loads on FGD systems, and in some cases Indonesian coals have helped lower NOx emissions.

Japanese utilities have long been world price setters based on annual coal price negotiations with Australian export producers, but with the emergence of China and India as major importers, the influence is becoming diluted. Before 2000, the price paid for steam coal by Japanese utilities and industries was observed closely, and other major importers such as Kepco (Korea) and Taipower (Taiwan) followed the Japanese price negotiations in settling their own contracts but at a discount to the Japanese settlements.

In recent years, the 'benchmarking' of Japanese price and volume negotiations continues, but China tends to be influenced by domestic market factors. The higher prices paid by Japanese buyers reflects the value placed on locking in production and investment to ensure security of supply from preferred coal companies. During the price slump of 2009, the steam coal business would have been worth US$9.4 billion, while coking coal imports would have been worth approximately US$6.5 billion, making the Japanese coal import market worth US$16 billion.

Japan's role as a leading importer of hard coal is set to decline, although it will remain significant. Uchiyama (2009) carried out research at the Institute of Energy Economics of Japan (IEEJ) and concluded that coal imports to Japan could see a fall in future decades, while most major economies elsewhere in Asia will see growth. This pattern of coal trade is consistent with projections by other world analytical groups such as the IEA, with non-OECD nations accounting for an increasing proportion of imports.

2.3 Domestic coal production

According to APEC (2010), Japan has a small reserve of bituminous coal at just 355 Mt; at current production rates Japan's reserves could last more than 370 years. However, Japan's reserves are so small they could not meet the country's needs. With steam coal demand at 125 Mt in 2010, this would have exhausted Japan's reserves in less than three years.

In the 1990s, the coal industry in Japan underwent major restructuring due to its low competitiveness, and domestic production decreased by over 60% to 3 Mt in 2001. By 2002, the industry produced just 0.7 Mt after the closure of the Ikeshima mine and reorganisation of Taiheyo mine in 2001. In 2010, the BP Statistical Review of World Energy put Japanese coal production at 0.9 Mt, even though the IEA (2010) shows all production ending in 2002. In the past Japan had a large coal mining industry, but as working seams became increasingly deep and more remote the cost of domestically mined coal rose to approximately three times that of imported coal. The government subsidised the domestic coal mining industry in order to maintain its viability; however, through structural adjustments, subsidies were reduced and coal production gradually decreased.

The IEA Japan 2008 Review stated that Japan had eight remaining mines in 2008, so therefore recently recognised the existence of these mines. While production was negligible, one underground and seven opencast mines were in operation. In 2002, subsidies were eliminated. NEDO (2011) confirms the operation of eight coal mines operating with production data for 2009. In the early 1950s, Japan had almost 950 mines producing 47 Mt of coal per year. Interestingly, the country underwent a massive cut in mine numbers with a minimal cut in production in the 1960s. By 1992, Japan had less than 20 operating mines which produced just over 8 Mt/y.

One of the last of Japan's coal mines is the Kushiro mine which has been mining coal under the sea for more than 7 km. The seam is gently dipping at 5–6 degrees and spreads 2.2 km east to west, and 4 km north to south. The calorific value of the coal is 6100 kcal/kg, with 0.2–0.3% sulphur content, making Japan's coal an enviable product by world standards. With these average coal qualities, clearly the demand for imports is based on economics and cost. Every coal-fired power station in Japan is equipped with FGD to meet strict air quality, but this does not have any bearing on any switch to imported coal. If it were economic or practical to do so, theoretically Japan could be an exporter of steam coal based on quality alone.

Coal at the Kushiro mine is extracted using a longwall system operating over a 320 metre face. Continuous mining is also being exploited. Production was some 0.5 Mt/y at the Kushiro mine, the only underground mine in Japan. At Kushiro coal mine, about 2.5 million m^3/y of methane gas is recovered from mined-out areas and is utilised as fuel for a utility boiler at the mine. The remaining seven opencast mines accounted for 0.8 Mt/y production in 2008. Government policy now only supports clean coal technologies and upstream coal resource development in other countries such as

Vietnam. The mining companies now have responsibility for mining liabilities such as subsidence and mining pollution.

Japan today offers extensive training and exploration expertise for other countries, not least to China, Vietnam, and the world's (current) leading steam coal exporter, Indonesia. Mining engineering services in mechanised mining systems, safety, and management are all provided. The organisation JCoal (Japan Coal Energy Center) was commissioned by NEDO to carry out coal exploration to target coal resources in other countries. Japan's expertise in coal resource assessment and mine operations is therefore as essential now as when the Japanese domestic industry was at its peak. In addition to mining expertise, Japan is world renowned for developing various aspects of clean coal technology for power generation from eliminating airborne pollutants and fly ash from flue gases to work on CO_2 storage.

METI plans to begin construction of CCS test facilities in Hokkaido with the aim to bring this technology into operation in April 2016 (JT, 2012). The plan calls for CO_2 emitted from oil refineries in Tomakomai and Muroran, in Hokkaido, to be captured and shipped via tankers and pipelines to two sandstone beds under the sea. One of the sandstone beds is 1.1 to 1.2 km below the ocean floor, and the other is 2.4 to 3 km below the seabed. Both zones have deep layers of mudstone to help prevent any CO_2 release. METI experimented between 2003 and 2005 in storing about 10 kt of CO_2 under the ground in Nagaoka, Niigata Prefecture, and concluded the gas could be contained safely for at least ten centuries.

While some domestic mines exists, Japan takes a great deal of interest in where imported coals originate, and therefore owns many coal assets abroad. Some of these assets are shared with Korean and other foreign companies. In Australia for example, both Japanese and Korean corporations own a number of coal assets as part of a strategic security of supply measure. The range of Japanese and Korean Corporations that are involved in Australia include Mitsubishi, J-Power, Idemitsu, Mitsui, and Kores. Table 1 shows a list of such coal mining interests. Although not exhaustive, the table shows Japanese and Korean ownership or control of least 35 mine operations in the five-year period between 2003 and 2008. Some of the operations are large, including Blackwater, Goonyella, and Ensham Resources. Japanese corporations owned assets that had a productive output of 159 Mt.

Elsewhere, the Governments of Japan and Indonesia jointly inaugurated the upgraded brown coal project at the Satui coal mine in South Kalimantan Province in Indonesia. Low-rank coal with high moisture and low heating value was dewatered in oil so that it could be transformed into high-rank coal with a higher heating value of at least 6500 kcal/kg of coal. In the future, operation data analysis and product evaluation tests using boilers will be performed prior to commercialisation. Japan was considering importing this upgraded brown coal for its power sector (METI, 2008).

Japan and Vietnam have strengthened ties in the field of mineral resources, including bituminous coals and anthracite used by Japanese steel companies and rare earth metal manufacture used in high-tech devices. A ministerial-level meeting was held in Vietnam in January 2009. Three projects were announced: technology co-operation in coal between the Japan Coal Energy Center and Vietnam National Coal Mineral Industries (Vinacomin) Group; joint coal exploration between new Energy and Industrial Technology Development Corp and Vinacomin; and business co-operation in resource development between the Japan Bank for International Co-operation and Vinacomin. In addition, support for an infrastructure feasibility study project around rare-earth mines was also announced (METI, 2009).

2.4 Price advantages of imported coal

Coal trade is fully liberalised in Japan and there is no price control. Coal imports have been free from government intervention since 1992 and coal supply sources and contracts are negotiated by

Table 1 Ownership of selected Australian mines in 2005-08 (Author's estimates)

Mine operation name	Mine type	Japanese or Korean Ownership	Partners	Production/ capacity	Coal type
Ashton	OC	Itochu (10%)	Felix Resources (60%), IMC (30%)	3.9	Coking
Baal Bone	OC	Sumitomo Coal (5%)	Coalex Holdings (95%)	1.8	Steam/PCI/semi - coking
Bengalla	OC	Mitsui Bengalla Holdings (10%)	Taipower (10%) CNA (40%) Wesfarmers (40%)	6.0	steam
Blackwater	OC	BMA* (100%)		14.0	Coking and steam
Boggabri	OC/UG	Idemitsu† Australian Resources 100%		1.0	Steam
Broadmeadow	UG	BMA* (100%)		3.0	Coking
Bulga/ Beltana	OC/UG	Nippon Steel (12.5%)	Saxonvale Coal (87.5%)	10.0	Coking/steam
Camberwell	OC	Toyota Tsusho Aus. (28%)	Vale (61.2%), others 10.8%	5.4	PCI
Carborough Downs	UG	Nippon Steel (5%), Posco (5%), Tata (5%), JFE Shoji (2.5%)	Vale (80%)	3.8	Coking
Dawson	OC	Mitsui Coal Holdings (49%)	Anglo Coal (51%)	7.0	Coking and steam
Drayton	OC	Mitsui Mining Aus Ltd (3%), Mitsui Drayton Inv Pty (3.83%), Hyundai (2.5%) Daesung (2.5%)	Anglo Coal (88%)	4.0	Steam
Ensham Resources	OC	Idemitsu† (100%)		9.0	Steam/semi-soft coking
Foxleigh Mining	OC	Itochu (20.6%)	CAML (63%), Indigenous Business Aus (16.4%)	3.0	Coking

Table 1 Ownership of selected Australian mines in 2005-08 (Author's estimates)

Mine operation name	Mine type	Japanese or Korean Ownership	Partners	Production/ capacity	Coal type
Glennies Creek	UG	Toyota Tsusho (28%)	Vale (61.2%), others 10.8%	1.3	Semi-soft coking
Goonyella Riverside	OC	BMA* (100%)		14.0	Coking
Gregory Crinum	UG/OC	BMA* (100%)			
Hunter Valley	OC	Coal and Allied (Mitsubishi 10.2%, Sojitz Corp 5.69%)	Rio Rinto (75.71%), Others (8.4%)	11.0	Steam
Liddell	OC	Mitsui Matsushima (32.5%)	Enex (35%) Gabune (32.5%)	3.0	Semi-soft coking
Minerva	OC	Sojitz Corp (45%), Kores (Korea Resource Corp 4%)	Felix Resources (51%)	2.5	Steam
Moolarben	OC/UG	Sojitz Corp (10%), Kores/Kepco/Hanwha Corp (10%)	Felix Resources (80%)	10.0	Steam
Mt Thorley	OC	Posco (20%), Coal & Allied‡ (80%)			
Muswellbrook	OC	Idemitsu† (100%)		1.0	Steam
Norwich Park	OC	BMA* (100%)		5.5	Coking
Peak Downs	OC	BMA* (100%)		9.0	Coking
Poitrel	OC	BMA* (80%), Mitsui (20%)		3.0	
Sandy Creek	UG	Idemitsu† (100%)		0.5	Steam
Saraji	OC	BMA* (100%)		8.0	Coking

Table 1 Ownership of selected Australian mines in 2005-08 (Author's estimates)

Mine operation name	Mine type	Japanese or Korean Ownership	Partners	Production/ capacity	Coal type
South Walker Creek	OC	BMA* (80%), Mitsui (20%)		3.2	PCI
Lamberts Gully	OC	Springvale SK Kores (50%)	Centennial Springvale (50%)	0.2	Steam
Springvale	UG	Springvale SK Kores (50%)	Centennial Springvale (50%)	3.4	Steam
Ulan	OC	Mitsubishi Dev (10%)	Jonsha Pty (90%)	5.0	Steam
Wambo	OC/UG	Sumitomo Coal (25%)	Hunter Coal (75%)	4.0	Steam
Angus Place	UG	Kores (25%)	Centennial (50%), SK Corp (25%)	2.6	Steam
Warkworth	OC	Mitsubishi Development (29%)	CNA Warkworth (55.5%), other 15.5%		
Whitehaven	OC	Idemitsu† Australian Resources 30%			
Subtotal				159.1	

* BMA BHP Billiton and Mitsubishi Alliance (comprising Mitsubishi)
† Idemitsu Australian Resource (comprising 85% J-Power/LG International combined 15% others)
‡ Coal and Allied (comprising Mitsubishi Development 10.2%, Sojitz 5.69%)

individual power utilities and steel companies with their respective suppliers. Traditionally, at least 50% of steam coal imports are based on contracts of 3–5 years, 30% on one-year contracts, and 20% on the spot market. In the coking coal market, 80% are one-year contracts, and 20% are on a longer term basis. Price negotiations are undergoing a period of uncertainty in 2012 with some major producers looking to increase the frequency of negotiations or consider an index linked style pricing system based on an agreed standardised coal quality.

Japanese coals are high in quality and fall within the specification of internationally traded coals. However, the increasingly difficult geology and extraction costs mean costs remain high. Historically, Japan maintained a heavily subsidised coal industry, partly on the grounds of security of supply. Throughout the 1990s, producer subsidies provided at least 105–139 US$/t of aid to keep Japanese coal competitive with imported coal; around 90% of the subsidy was a price support, while the rest was for restructuring, safety upgrades, and modernisation of coal pits (IEA, 1999).

According to the 1999 edition of the IEA Japan review, historical subsidies averaged roughly 13,000 yen/t of coal. By 1997, the subsidy regime was nearing an end and the subsidy was some 12,496 yen/t. In the final year of the subsidy regime, the subsidy was still a considerable 12,110 yen/t (IEA, 2003). By the end of the regime, the subsidy was equivalent to just over 110 US$/t, which is used as the premium over the Japanese import cost for formulating the Japanese domestic coal price (*see* Figure 2). The main form of Japanese coal subsidy was directed at coal consumption by the power companies which agreed domestic contracts. Japanese coal producers received subsidies to pay for the difference between high priced contracts and the international price of coal, a system similar to that seen in the subsidised sectors of Europe.

Transporting coals to the southern islands to the markets in Tokyo and Chubu and elsewhere in central and southern Japan makes the cost of delivering domestic coal higher than that of imported coal. In 1999-2000, this cost premium was paid by all of Japan's utilities even though only three utilities used domestic coal, one of which was the Hokkaido Electric Power Company (HEPCO). The Japan Coal Energy Centre and the Government-funded training and technology transfer project at the Kushiro coal mine, also in Hokkaido, were extended to fiscal year 2009 (ending 31 March 2010).

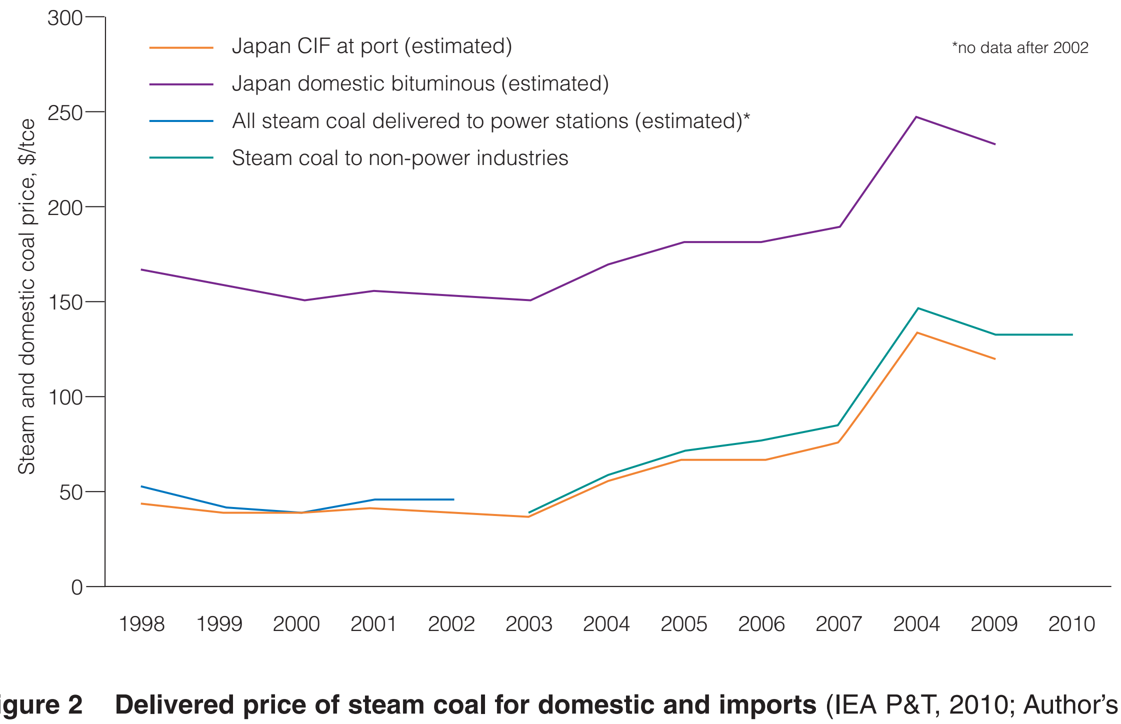

Figure 2 Delivered price of steam coal for domestic and imports (IEA P&T, 2010; Author's estimates)

After 2002, the Japanese coal industry continued to produce, but free of subsidy. The power utility Hokkaido Electric, continued to pay the price of coal to keep operations going. However, whether the price of coal is benchmarked against international prices is not clear. In theory, the industry could feasibly continue at its historical pre-2002 price of approximately 150 US$/t, but in reality it would struggle in the steam coal market, although the PCI market could be considered. However, elements of the operational costs (such as diesel, electricity, steel products, maintenance, tyres) will have undergone inflation, although Japan has also suffered from deflation and the softening of domestic prices.

2.5 Coal logistics and ports

As well as estimating differences in the cost between domestic and imported coal, Figure 2 also provides information that enables an estimate of inland logistics. The figure shows the price of coal delivered to a typical power station in Japan as published by the IEA Prices and Taxes (IEA P&T, 2010), however, this price reporting ended in 2002. The only indication of steam coal prices paid by large users in Japan after 2002-03 is that paid by the industrial sector.

Using the delivered cost of coal to the consumer and deducting the CIF price of coal at the import terminal, a representative inland infrastructure cost can be estimated. This margin would cover the costs of coal unloading, storage, and onward transport to the power station stockpile. As Figure 2 shows, the difference between the average CIF cost of steam coal and the delivered cost to power stations and industry varied yearly between the late 1990s and 2009. However, over this time the cost of inland infrastructure averaged 8–10 US$/t. It is possible the costs have risen in recent years but this range seems plausible.

Figure 3 illustrates the distribution of coal-fired power stations in Japan, and demonstrates that most if not all stations are sited on the coast, a feature common with many power stations in Asia.

The map shows around 38 of Japan's larger coal-fired stations (including three stations on the island of Okinawa off the southern coast of Japan that are not shown). Japan has around 62 coal-fired stations (comprising of 126 units), which access coal supplies via various import terminals and 'coal centres'. Many of the smaller stations are onsite autoproduction plants owned and operated by heavy industrial corporations, such as Nippon Paper and Kobe Steel.

There are at least 14 ports and coal centres where hard coal is stored and blended for consumers all around the coast. All power stations have their own jetty facilities, or are close to storage sites many of which are deep water, in addition to the nine or so dedicated coal terminals. Covered conveyor belts are the normal methods of transferring coal a short distance from the ship to the station stockpiles, and onwards to milling facilities. As such, rail infrastructure is either not required for inland coal transportation, or is at best limited to a few stations.

In Hokkaido, some plants that use domestic coal might receive the coal by truck, which adds to the already high cost of production for the 1 Mt or so of steam coal that is produced every year. Figure 3 is partly based on current knowledge of operating power stations, but also on maps created by the IEA in the 2003 edition of Coal Information, which was based on information published in 1999-2000. In this latter source are 'coal centres', which are described as warehouse and storage facilities, but are likely to also be storage facilities for product blending and storage.

The IEA (2007) reported on a recently-built power plant commissioned by J-Power, called the Isogo I in Yokohama, which was designed to use international coals as well as domestic Japanese coals. Like many coal-fired stations in Japan, the location is close to densely populated urban locations. Consequently, the use of high efficiency technology and very low emission technology is important. The design efficiency is 42% (net LHV) necessary to minimise the coal throughput and otherwise reduce the need for burning, transporting, and storing coal.

Figure 3 Map of coal-fired power stations and ports and handling terminals in Japan

Under local Yokohama emissions regulations, emissions of pollutants are limited to 20 mg/m^3 of NOx, 6 mg/m^3 of SOx, and 1 mg/m^3 of particulates. These emission levels are lower than those specified for BAT performance under the European Large Combustion Plant Directives for gas-fired power plants.

SOx control is done using a dry FGD system using regenerable activated coke, which produces sulphuric acid as a by-product. The station is costly, but designed with efficiency in mind. Imported coal is unloaded at port facilities at Sodegaura, on the other side of the bay to where Isogo is situated, as well as Ougishima. The coal is then transferred in small 5000–6000 dwt self unloading ships. Coal is then conveyed by belt to four silos, each with a capacity of 25,000 t, which are filled and unloaded using enclosed conveyors that use compressed air to support the conveyor belt. The coal is then conveyed from silos to bunkers above four vertical spindle roller mills incorporating rotary classifiers. The whole transportation system is aimed at minimising dust emissions and noise.

3 Korea

The Republic of Korea is a peninsular in the Sea of Japan bordered only by North Korea. It has a population of 49 million. More than 80% of the country is mountainous and two thirds is forested so major centres of population and commerce are located on the coast. The country is the world's largest shipbuilder, the top three companies being Hyundai, Samsung and Daewoo. Other heavy industries such as Doosan Power are world players in the design and manufacture of thermal power stations, while Samsung and LG are leading high-tech electronic manufacturers. Korea is the sixth largest steel producer in the world, with coking coal imports of 26 Mt/y and iron ore imports of 64 Mt. Korea's heavy industry is the largest consumer of steel per capita in the world.

Korea also has an impressive track record of long-term economic growth. In the 1970s, Korea's per capita GDP was comparable with poorer countries in Africa and Asia. The country was under military rule until the late 1980s. Today, Korea is a democracy and has a GDP of 1.4–1.5 trillion US$ and is ranked within the top 20 economies in the world. In 2009 economic growth slowed to 0.2%, which is still stronger than the negative growth seen in parts of OECD Europe. The US dollar has fluctuated against the Korean Won, ranging from 900 to 1400 Won between 2000 and 2011, with the highest rate seen in 2001 and the lowest in 2007. In 2011, the rate averaged 1100 Won, roughly the average for the previous ten years.

3.1 Primary energy

In 2010, Korean TPES reached 352 Mtce (247 Mtoe) roughly half that of Japan, of which 29.4% was provided by coal. Oil and oil products command a large share of the TPES which is similar to many other countries. Hydroelectricity and renewables are small, with less than 1.5% of the TPES being provided from these sources.

3.2 Coal in electricity generation

The electricity market is dominated by the Korean Electric Power Company (Kepco). The Korean government owns a majority share of Kepco which operates 65 GWe of electrical generating capacity. Kepco comprises of six generating companies as well as other engineering subsidiaries. The six generating companies include five regional monopolies that operate thermal fossil-fuelled plants, and a single national hydro and nuclear company. Each regional monopoly operates roughly 9–10 GWe of thermal capacity. Coal is incredibly important to the Korean economy, with 44% of the nation's electricity generation coming from coal (218 TWh out of 478 TWh in 2010). Nuclear power accounts for 30% while natural gas CCGT is just 21%. The balance is provided by oil, hydro and renewables.

All Korea's coal-fired fleet, operated by these five regional companies, is located on the coast and so almost always uses imported steam coal. Some of Korea's projects within the last decade include the Younghung thermal power plant. According to IEA (2007) the Younghung plant comprises of 800 MWe units capable 43% net efficiency (LHV). The steam parameters are 24.7 MPa/566°C/566°C. The Younghung stations, operated by the Korean Southern Electricity Power Company, came online in 2004, with two units, and two more in 2008 and 2009.

With 44% of Korean power coming from coal, and with coal accounting for 29% of the primary energy consumption, Korea is likely to maintain a massive market for coal within its own country for the foreseeable future. Korean-based Doosan Power, a coal-fired boiler manufacturer, is one example of the importance of coal to Korea. Throughout the 1980s and 1990s, Korea adopted the practice of modular construction for their coal-fired fleet, manufacturing power units of identical size and specification. This approach to building stations reduced capital expenditure costs, and made planning easier. A typical unit to be commissioned using this modular system was a 500 MWe capacity with supercritical steam conditions, many using ABB boilers and GE steam turbines, with Doosan Power being a key supplier of later boilers. All of the major stations were also equipped with FGD either from new or retrofitted.

Power plants burning indigenous coal have a role to play despite the apparent higher cost of the fuel (*see below*). Kepco operational data for plants show how the plant utilisation for anthracite-burning stations averages 84–86% in 2010, generating a total of 7.7 TWh (net) from just 1125 MWe of anthracite capacity. By global standards this is an extremely high load factor, normally reserved for nuclear power stations. The plants that burn imported bituminous coals are achieving an even higher load factor of 91.1%. At these load factors the stations are probably running at optimum efficiency and are without a doubt essential baseload generators for the Korean market. In 2010, this bituminous import-coal fleet generated 181 TWh (net) from 23 GWe of capacity, eclipsing the domestic coal capacity.

3.3 Coal supply

The steady rise in coal-fired power over time increased the demand for steam coal in Korea. The country's coal market has trebled from 28 Mt/y in 1980 to 106 Mt/y in 2009. Roughly 80% of the country's coal supply is steam coal, and 20% is for the steel industry as coking coal (*see* Figure 5). The supply of coal looks very different now than it did in the 1980s, with almost all the coal supply being met by imported products. In the 1980s, half of the country's supply came from domestically produced coal, which would have been mainly anthracite. The 1990s saw a dramatic change in supply patterns. Not only did the market for bituminous coal expand rapidly in this time, domestic coal demand shrank from 19 Mt/y to just 2.5 Mt/y (*see* Figure 4). Roughly 0.6 Mt ended up in stocks in

Figure 4 Korean hard coal supply, Mt (IEA, 2010)

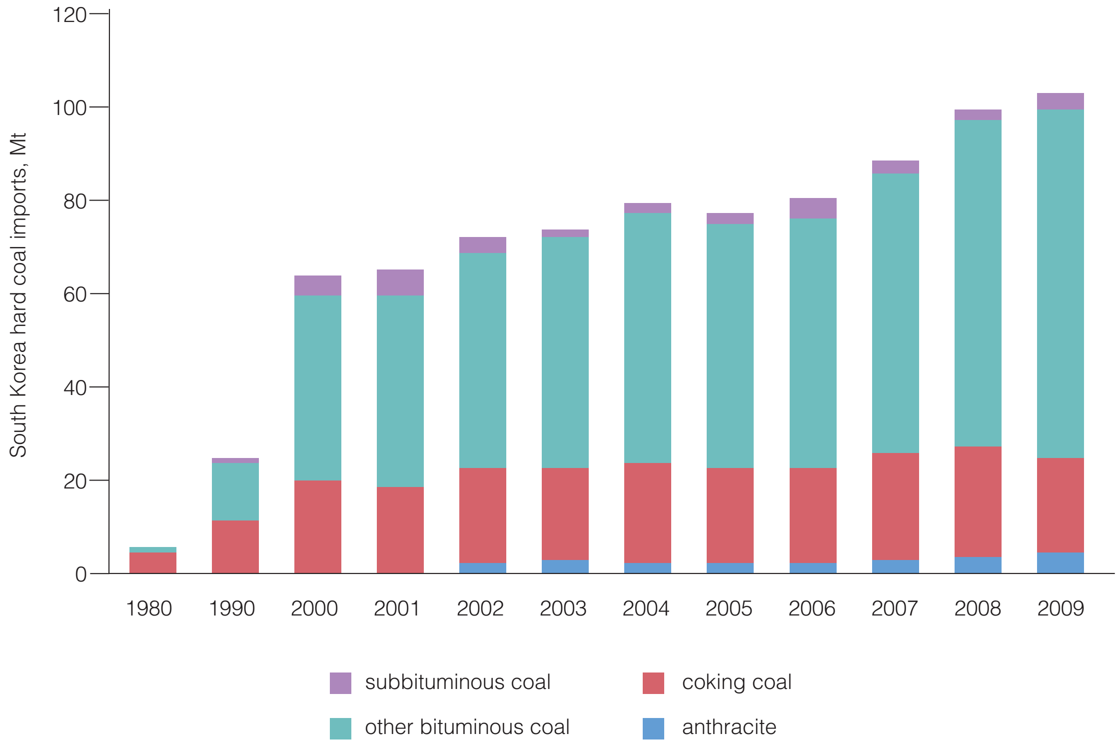

Figure 5 Korean hard coal imports, Mt (IEA, 2010)

2009. In the past, stock building seemed important to Korea, possibly to avert supply problems in time of shortage. Today, stock replenishing is a small proportion of total supply and supplies can be supplemented easily from the seaborne spot market.

All of the country's steam and coking coal supply is imported, while anthracite supply is imported or produced from domestic mines. Bituminous steam coal imports are necessary to complement domestic anthracite production which alone cannot fulfil the country's demand for coal, much like Japan. According to the IEA (2010), Korea imported 3.5 Mt of anthracite in 2009 (*see* Figure 5), although a figure nearer to 6–7 Mt/y is more likely (MCIS, 2011), increasing to 7.4 Mt/y in 2010. With domestic production at around 2.5 Mt/y, the total anthracite market in South Korea could be close to 10 Mt/y. In 2002, imports overtook domestic production indicating a considerable displacement of domestic mining.

3.4 Coal production and resources

Korea has about 1.4 Gt of coal resources, all of which is anthracite hard coal. Korea currently has seven producing domestic coal mines, three of which are operated by the state-owned Korea Coal Corporation (formerly the Dai Han Coal Corporation). This represents a significant decrease from the 347 mines that were in operation in 1988, a result of the government's policy of rationalising domestic coal production. Between 1988 and 2005, annual production fell from a high of over 24 Mt to below 3 Mt (*see* Figure 6). About two-thirds of production comes from the four private mines; the remainder comes from the government-owned mines. Currently there is no plan to privatise any of the state-owned coal mine operations.

The government has been rationalising the industry, and still plans to close one or two more mines, but currently does not plan to fully phase out domestic production. Coal production is uneconomic in Korea – anthracite production costs are higher than the cost of imports and the industry relies on

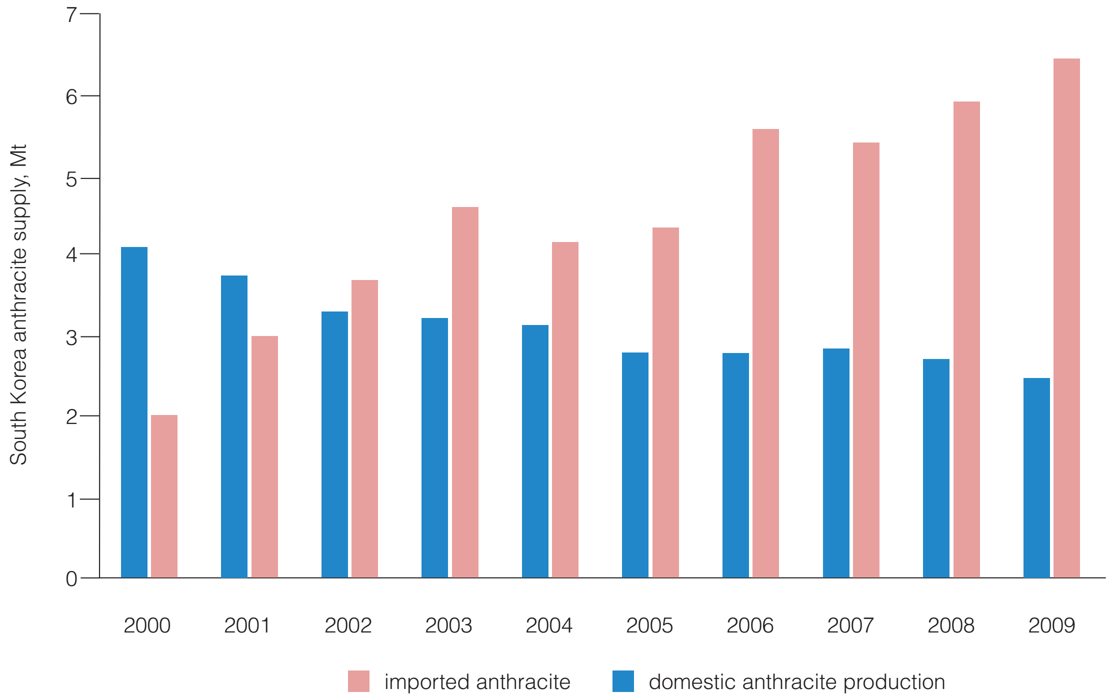

Figure 6 Korean anthracite supply, Mt (IEA, 2010)

subsidies. Nevertheless, the government intends to stabilise supply and demand of anthracite, maintaining a minimum annual production volume, given that it is the country's only abundant energy resource. The level of the minimum annual production volume has not yet been set. In addition, closing mines is politically painful, as rationalisation of the industry remains unpopular. As part of its mine closure activities, the government provides financial support to affected regions.

3.5 Quality advantages of coal imports

The quality of Korean anthracite is mixed, unlike those anthracites that might be traded internationally. The sulphur content of Korean coal is very good, averaging 0.6–0.9 %, which is well within the specification of internationally traded coals. However, domestic products are afflicted by a low calorific value, typically in the range 4600–4800 kcal/kg. The world's leading exporter of anthracite, Vietnam, trades coals with heating values of around 7000 kcal/kg. Like most anthracites, the volatile content is low, but ash is high at 35–47% (Kim, 2007).

Baruya (2009) discusses the technology used to burn low volatile anthracite. Where the coal is used for power generation and not metallurgical applications, special boiler systems are deployed in the form of down-shot boilers, which increase the residence time of anthracite. Domestic coal is therefore particularly difficult to burn in normal power stations designed for bituminous coals. Some of the Korean anthracite is used in briquetting for household cooking and heating. Interestingly, the high ash content proves very useful for this application. If Korean anthracite is blended with 15% bituminous coal, the low ash content of imported coal means the briquette cannot retain its shape during combustion.

Anthracite is still burnt in power stations as part of government policy to support domestic coal mines. Power stations that use domestic coal are fairly small units by Korean standards, they are the Seocheon (400 MWe), Yongdong (325 MWe), Pusan (120 MWe), and Yongwol (100 MWe) plants. The Donghae power station burns domestic anthracite in a circulating fluidised bed combustion system (CFBC) that was built in 1998-99. This station comprises of 2 x 200 MWe units built by ABB Combustion Engineering. According to Kepco (2011), the thermal efficiency of the anthracite plants in 2010 was 31.75 % (net), compared with 37.41% for plants burning bituminous coals. This is probably because of the low calorific values and the high ash content of the fuel.

Plants that source their coal from the world market use coal with heating values within the range 5400–5700 kcal/kg, which would suggest Indonesia is a major supplier of steam coal, notably of the bituminous and subbituminous variety. However, Australia, China and Canada are also major suppliers of steam coal (as well as coking coal). In the past, the Samchompo plant has used a coal feed with a heating value as low as 4970 kcal/kg where domestic coals are blended in some units, in this case units 4 and 5 (Kepco, 2011). The blending is probably done with imported anthracites from China and Vietnam.

3.6 Cost advantages of imported coal

There are no price controls or import duties on bituminous coal into Korea, although annual price settlements between Japanese utilities and Australian coal exporters can influence Korean negotiations with export producers.

The major utilities in Korea each enter negotiations, and import coal from the world market directly or through intermediaries, mostly under medium- or long-term contracts. Each of the electricity generating companies operates its own ports and storage terminals. Most customers buy coal on long-term contracts; on a volume basis 20% of coal is bought on the spot market and the rest is bought on long-term contracts. In light of the rapid price rise for bituminous coal, Korean power and steel companies are increasing the weight of their long-term contracts to ensure stable supply. In particular, Posco relies heavily on advance contracting, purchasing all its coal requirements with five- to ten-year contracts. Part of these contractual commitments could be explained by the ownership of foreign coal production assets in Table 1 (*see* pages 12-14). The Korean companies Kores, Kepco, and Posco own shares in at least 15 Mt/y of coal producing operations in Australia.

According to the WTO (2007), Korean investment in overseas coal ventures was widespread. The state-owned Korean Resources Corporation participated directly providing loans for 42 projects in eight countries in 2007.

Domestic coal subsidies amounted to more than 200 billion KRW in the mid-1990s, but had dropped to 78 billion KRW in 2004 (*see* Table 2). Production dropped 36% between 1996 and 2004, while subsidies dropped 65%, reducing the burden of the subsidy from around 44$/t to just 23.8 US$/t. Anthracite pricing is different to that of steam coal due to the coal quality differences.

Anthracite has its own supply and demand market internationally, and is produced and imported by specific producers and consumers. Figure 7 shows the price of Korean domestic anthracite versus the delivered cost of coal to power stations, compared with other Asian prices such as Japanese domestic bituminous coal and the CIF price at Japanese ports. In 2004, the subsidy awarded to Korean anthracite added a premium of 20–25 $/tce to the cost of unsubsidised imported coal. In 2007, the WTO reported that the total subsidy was around 75 billion Won, which when converted to US dollars and using the 2005-07 average production of 28–29 Mt, meant that while subsidies had fallen in total , the decline in production increased the per tonne subsidy.

The IEA Prices and Taxes publication does not publish delivered cost to Korean power stations prior to 2004. For years where the data are unavailable, the delivered price of steam coal to Korean power stations can be estimated by adding the subsidy (*see* Table 2) to the Japan CIF price, which is a reasonable proxy. As Figure 7 shows, between 1998 and 2004 the subsidy burden fell considerably from 65 US$/tce to around 34 US$/tce, but then rose to 41 US$/tce (28 $/t).The subsidy includes

Table 2 Domestic production subsidies, 1996 to 2004 (IEA, 2006)									
	1996	1997	1998	1999	2000	2001	2002	2003	2004
Production subsidy, billion KRW	225	212	197	205	144	122	102	91	78
Production, Mt	4.95	4.51	4.36	4.2	4.15	3.82	3.32	3.30	3.19
Production subsidy per unit, KRW/t	45,506	46854	45127	48868	34771	32015	30741	27643	24350
Production subsidy per unit, US$/t	44.44	45.76	44.07	47.72	33.96	31.26	30.02	27.01	23.78

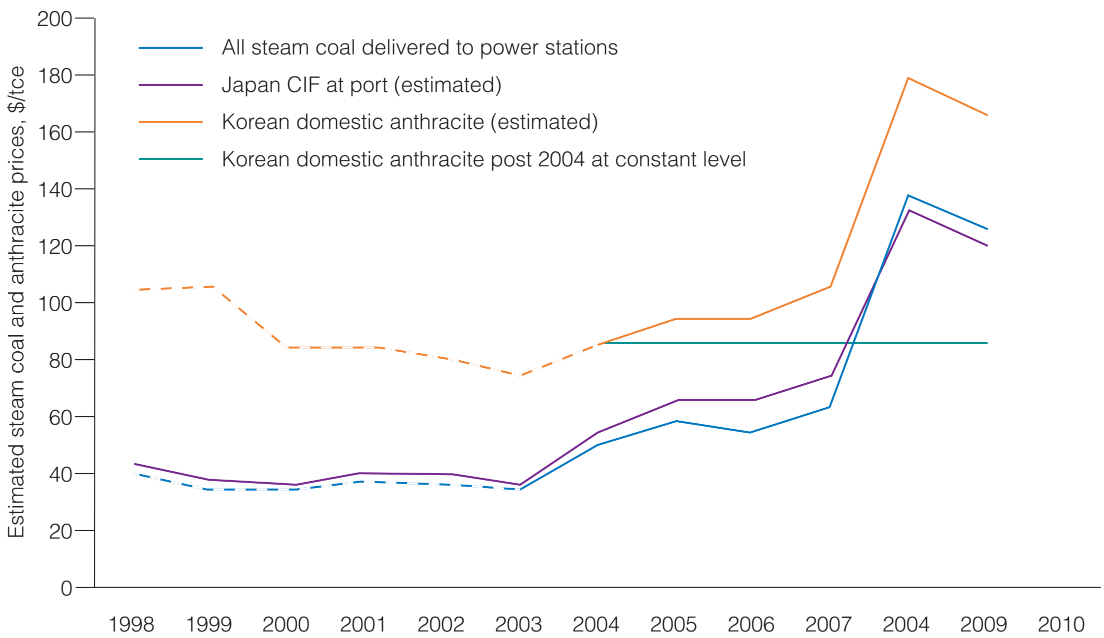

Figure 7 Estimated steam coal prices and anthracite prices in Korea, $/tce (IEA P&T, 2010; Author's estimates)

insurance benefits, support for restructuring, social benefits, and health benefits. Consumption subsidies are also provided to low income users of briquettes for residential and commercial users such as heating and cooking. The price of briquettes and anthracite coal is expected to increase as subsidies are withdrawn.

Coal imports are generally free of duty, but 10% VAT is levied on imported coal while anthracite is exempt. In reality, domestic anthracite should be priced against imported anthracite, but there is a dearth of price data relating to seaborne traded anthracite and so delivered steam coal to Korean power stations is a reasonable proxy. Based on this assumption, the cost of domestic anthracite might have started to rise in 2006, from around 90 US$/tce to a level of 170 US$/tce in 2008, and remained thereabouts since. The cost of the subsidy in the 1990s could have accounted for more than 60% of the price of coal to power stations based on the author's estimates. By 2004, subsidies would have accounted for 40% of the cost of coal, but with an estimated cost of 41 US$/tce, the subsidy burden

Figure 8 Coal-fired power plants in Korea
(Author's estimates)

increased to around 60% again. No doubt as the price of domestic anthracite is increased, subsidies can decrease but while there is a policy to keep burning local coals, the utilities will have to raise tariffs to accommodate the higher cost coal. If domestic coal prices followed a cost plus trajectory, and were delinked from world prices, it is possible, although unlikely, that the cost of anthracite today is cheaper than the cost of imported coal as seen in Figure 7 by the flat line for Korean domestic anthracite held at 2007 levels. If that were the case, the price of anthracite could become more economic if the price of steam coal were to remain above 100 US$/tce.

4 China

China's economic growth has been in double digits for almost ten years, although recent estimates suggest that growth in 2011-12 might have dropped to around 8–9%/y. China is a $7 trillion economy, with some provinces the size of some small OECD countries. China's modern history began in 1979 when the communist party adopted a market economy approach, and manufacturing and intellectual property expanded. The population of 1.35 billion means China is the most populous country. Per capita electricity consumption is 2741 kWh/head (2008), four times that of India, but less than half that of OECD Europe.

China has considerable coal and hydroelectric resources, and has exploited both sources of primary energy to drive the economy. In 2010, China overtook the USA as the largest energy market and the largest emitter of CO_2 in the world. Despite the size of the energy market, per capita CO_2 emissions are a quarter of those of the USA. According to IEA World Energy Outlook (WEO, 2011), China could account for a third of the future growth in global primary energy demand (an additional 1564 Mtoe between 2009 and 2035). Despite some of the vast coal and hydro projects that have been developed over the last twenty years, the government is aware of energy efficiency, sustainability and environmental issues. China now has some of the largest wind turbine manufacturers in the world, and is the world's top investor in renewable energy having committed US$120–160 billion between 2007 and 2010.

4.1 Coal in power generation

Coal-fired power generation is discussed at length in a number of reports published by IEA CCC such as *Coal use in the new economies of China, India and South Africa* (Mills, 2010), *Developments in China's coal-fired power sector* (Minchener, 2010), *CCS challenges and opportunities for China* (Minchener, 2011), and so this Section will briefly describe the current status of coal-fired power at the time of writing, while the significance of imported coal is discussed later.

According to the WEO (2011), in 2008 China had 792 GWe of total generating capacity; by 2009, this had grown to 874 GWe while thermal generating capacity in 2009 increased 8% to 652 GWe. The largest growth occurred in wind power where it almost doubled to 16 GWe, reaching the amount of wind power capacity that the USA and Spain had in 2007. China is fast becoming one of the most dynamic of global wind markets, therefore partly answering the critics of coal-fired power in China. In 2010, China produced more hydroelectric output (196 GWe) than the whole of South and Central America combined.

The IEA projected a possible doubling of total generating capacity to 2378 GWe by 2035 (WEO, 2011). Coal-fired capacity will rise but it will decline as a share of total capacity – 650 GWe (70%) to 1159 GWe (49%) – under the new policies scenario. Coal-fired power could still account for 50–60% of the total generation. Domestic coal production will still form a large proportion of the country's supplies, but it is possible that imports may grow if China's production is unable to keep pace with demand.

4.2 Coal supply

Steam or coking coal is consumed in every region of China, but mass production occurs in just a few. The coal industry in China has undergone a massive transformation since the 1970s. Moves to consolidate the industry through the formation of supermines means the supply chain should be simplified in the future. Chinese coal production has grown from less than 0.5 Gt in the 1970s to

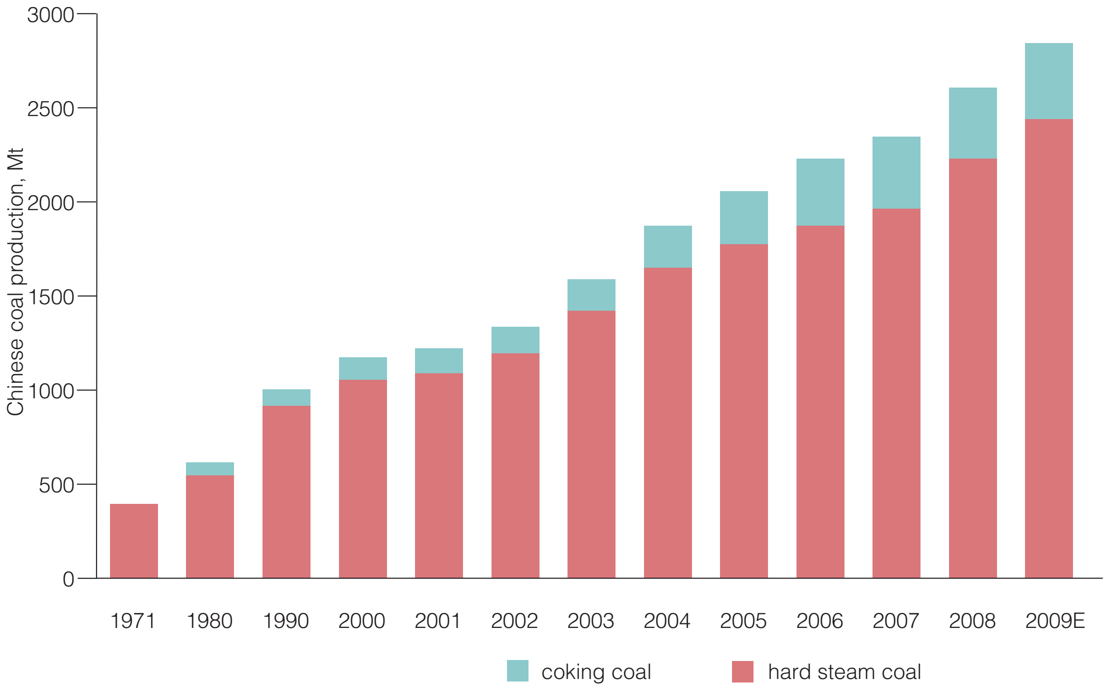

Figure 9 Chinese coal production, Mt (IEA, 2010)

almost 2.9 Gt in 2009 (*see* Figure 9); of this, 0.4 Gt was coking coal. By 2010, coal production reached 3.2 Gt accounting for 45% of the world's production (BP, 2011). While coking coal accounts for just 15% of total production, at 0.4 Gt, coking coal production in China is as high as total hard coal production in Australia, and higher than in Indonesia. The 2.8 Gt of steam coal production in China is therefore a vast amount.

Before 2009, China was a major steam coal exporter, chiefly to Asian importing countries. Chinese coal is bituminous in rank, and a proportion of it is good enough for exporting to power stations in Japan, South Korea and Taiwan (now Chinese Taipei), the three largest steam coal importers until 2009. Today, China is one of the largest importers of steam coal in the world. Figure 10 shows how China's hard coal imports increased from roughly 0.4 Mt in 2000 to 50 Mt in 2007. The most astonishing change occurred in 2009 when hard coal imports jumped to 146 Mt, with bituminous coal and anthracite exceeding a combined 100 Mt. Imports appear to remain strong as China readjusts its coal and power markets, with the closure of small inefficient coal mines, and development of larger-scale mines, while coal-fired power capacity seems to increase apace despite the closure of smaller units (less than 300 MWe). It appears that China remains in flux, and little is certain.

There appears to be more confidence in the country's coal reserves, where some figures could underestimate the amount of coal China has. The country's coal reserves amount to some 114 Gt, almost 14% of world total with a R/P production of just 38 years. Optimistic estimates put China's reserves at a trillion metric tonnes, but assessing reserves is not straightforward. H L Consulting (2006) publishes a databook derived from official coal statistics and from which much of the data for this chapter are drawn. These official figures put recoverable reserves at 1018 Gt, and a further 4552 Gt in what are termed predicted reserves. This would suggest that China has the potential for recoverable reserves of more than 400 years or 2735 years if the larger resource figure is used.

IEA (2006b) quote the German Federal Institute for Geosciences and Natural Resources (BGR) which suggest that the figure could be lower at 95.9 Gt. With the continuing rise in production, the R/P ratio is shortening year by year. Consequently, resource depletion and effective extraction are being taken

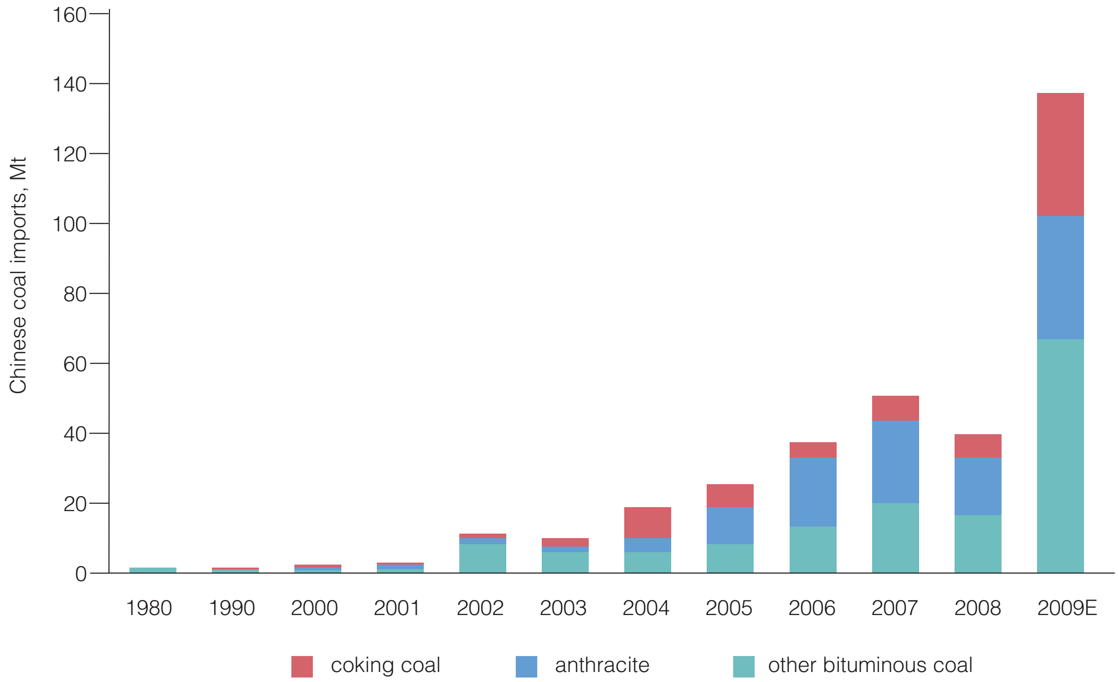

Figure 10 Chinese coal imports (IEA, 2010)

seriously by the Chinese administration and drastic steps to manage the country's reserves are being implemented along with ongoing surveys of the country's coal deposits.

China's coal resources are unevenly spread. Coal reserves are located inland in deep resources in the landlocked provinces of Shanxi, Shaanxi and Inner Mongolia, while coal export terminals, power stations, and industrial facilities are located in the coastal regions. The renowned Qinhuangdao export terminal is east of Beijing, while the most economically important provinces are located in both the eastern and the southeastern coastal areas such as Guangdong, Jiangsu, and Shandong.

Coal imports are overseen by the major state-owned organisations that produce coal within China. Production and trade in China are regulated by the National Development and Reform Commission (NDRC) while the China Coal Group (formerly the China National Coal Import Export Commission – CNCIEC) determines export shipments and quotas from authorised producers. These companies include the coal giants Shenhua Group, China Coal, and Shanxi Coal. These companies started importing coal when it became cheaper to buy coal from the international market than it was to produce and transport coal from their mines to the demand centres in the Southern and Eastern coast of China. These three companies along with China Minmetals Corp are the only firms which have been granted licences by the government to export Chinese coal. Minmetals Corp was founded in 1950 and is the country's largest supplier of iron ore and coking coal for the steel industry, but trading in thermal coal, (as well as copper, aluminium, steel and other metals) is part of the business. Two other companies, Sinosteel and Baosteel, are also purchasers or iron ore, steel, coking coal and steam coal.

Private enterprises that import coal include Qinfa Group which trades 10 Mt/y, most of which is imported from Australia, Indonesia and Vietnam. Guangdong Fuels Co Ltd is a commodity trading company supplying large and medium size firms in the economically powerful Guangdong province, selling 3 Mt/y of steam coal to power plants and cement manufacturers every year, of which 2 Mt comes from Indonesia and Australia. RGL Group is a private steel and iron ore trader which also trades steam coal. The company imports 3–5 Mt/t, and Sino-trust which ships 2 Mt/y.

Table 3 **Chinese steam coal qualities** (CCR, 2011)					
	Ash%	Vol, %	S, %	kcal/kg	US$/t at 6000 kcal/kg
Minimum	7.00	11.00	0.20	3500	32.2
Maximum	33.00	46.00	3.00	6500	198.3
Average	19.94	28.86	1.05	5365	105

Table 4 **Chinese coal qualities by region** (CCR, 2011)					
Region/Province/ Municipality	Ash, %	Vol, %	S, %	kcal/kg	US$/t at 6000 kcal/kg (Jan-Feb 2011)
Anhui	20.43	22.33	0.98	4900	124
Changzhi	22.25	13.60	2.00	5580	106
Datong	14.90	32.89	1.00	5750	102
Gansu	17.50	37.00	0.70	6500	75
Guangdong	13.67	29.00	0.80	5667	167
Guizhou	16.00	16.67	1.47	6000	90
Hebei	22.44	30.49	0.93	4833	101
Helongjiang	29.00	35.75	0.43	5500	103
Henan	22.00	38.70	1.00	4750	111
Hunan	19.33	18.23	1.70	5333	121
Inner Mongolia	16.43	33.86	0.59	5414	84
Jiangsu	21.40	30.00	0.74	5400	136
Jinzhong	19.43	18.57	1.66	5400	100
Liaoning	24.33	37.67	0.67	4500	106
Linfen	21.75	24.25	1.05	5250	101
Lvliang	20.67	27.33	1.63	5433	98
Qinghai	19.00	25.00	0.50	5500	69
Shaanxi	17.57	33.54	0.82	5643	97
Shandong	21.08	32.00	0.88	5425	128
Shuozhou	25.00	34.67	1.07	5150	95
Sichuan	22.25	31.25	1.05	4750	94
Taiyuan	20.00	18.50	1.60	5500	103
Xinjiang	18.50	33.33	1.37	5633	97
Yangquan	20.50	11.50	1.20	5500	105
Yuncheng	25.00	18.00	1.50	5000	97
Zhejiang	14.00	23.00	1.00	6000	145

4.3 Coal quality advantages of imported coal

The bulk of Chinese coal is bituminous in rank, probably accounting for 85% of the reserves; a further 5% is lignite, and 10% is anthracite. A quarter of the bituminous coal is suitable for coking purposes. A large proportion of Chinese coals are of low to medium ash content, and the overall sulphur content is little more than 2% by mass, with the majority less than 1%. Chinese coal is therefore relatively good quality that may be exported, or may be blended with imported coal with few problems.

The *China Coal Resource* publishes price and volume statistics for every region of China. As well as price information, coal qualities are also provided. For the period Jan-Feb 2011, price data for 26 provinces were published and the data showed the following coal quality ranges. Tables 3 and 4 show the quality of hard coals, but given that the highest heating value is 6500 kcal/kg, these are likely to refer to hard steam coal products. The average heating value of Chinese coals across the entire range is 5365 kcal/kg, which is close to the 5500 kcal/kg coals that are sometimes quoted in the industry press for price indices purposes. The sulphur content averages 1.05%, while ash contents are roughly 20% and with a modest heating value of 5365 kcal/kg, the overall coal quality for China's coal supply is on par with lower quality internationally traded coal. Some high sulphur products are sold in a number of regions, and so in these regions it is desirable that sulphur reduction technologies are deployed at power stations.

The average ash content of around 20% is higher than the ideal international coal, which would be around 10%. Australian and Russian coal imports range from 6300 to 6700 kcal/kg, and so supplement the lower heating value Chinese coals. All imports are low in sulphur and ash so the blending of coals, especially Indonesian, can decrease the environmental impact of burning Chinese coal alone.

4.4 Cost advantage of imports

Morse and He (2010) carried out research on the interaction between coal imports and domestic production depending on coal prices at certain delivery points around China's key economic zones. China's import behaviour is in some ways typical of many countries, but the transparency of the Chinese market prices is such that it is easier to see arbitrage in more frequent time periods.

Morse and He (2010) describe how China's role as the world's largest arbitrageur has a significant implication for the global market: it links international coal prices to China's domestic price (at least in the Pacific market). In other words, what happens in mines in Shanxi could affect the price of coal in North West Europe. Morse and He (2010) discuss the fact that China is a cost minimising market, and that it sees the purchase of coal fluctuate between imported and domestic coal as the price of each changes in relation to the other. This fluctuation is greater than is seen in countries such as India. There is some regulation in the shipment of exports outside China, which remains under the guidance of the NDRC that determines the volume quotas for coal trade. The NDRC is also responsible for gearing up domestic production and oversees any closure programmes of wasteful or inefficient mine operations.

Analysis was carried out comparing the cost of Chinese and internationally traded coal shipped to a location in the southern most regions of China, in the province of Guangdong. Transporting Chinese coal from the north to the south can constitute 50–60% of the delivered price to Guangzhou. This cost is comprised of rail transport to the export ports of Qinhuangdao, Rizhao, or Lianyungang, plus the cost of shipping to the southern port of Guangzhou. The coastal city of Guangzhou was deemed a suitable location, not far from Hong Kong and considered a hub for Chinese steam coal imports. Guangdong province is heavily industrialised, but geographically far from the coal producing provinces in the north of the country. In 2009, Guangdong was the largest importer of coal of all the major coastal provinces (34 Mt/y out of a total 126 Mt/y), although other zones nearby exhibit similar trade and price relationships (which Morse and He analysed). Much of the coal that is consumed in China is negotiated on contract. For marginal spot purchasing, buyers might compare the CIF cost of coal landed in Guangzhou for both Chinese coal and internationally traded material, and the cheapest coal will be preferred.

China suffers from two seasonal problems – the dry period in China's summer, and the severe winters suffered in the colder months. Therefore, seasonal coal price fluctuations occur with regularity, but occasionally markets can be taken by surprise. Prolonged drought can lead to poor hydroelectric availability, and therefore put pressure on coal-fired power output, deplete coal stockpiles, and increase demand. Other economic influences such as the exchange rate relaxation of the Yuan in June 2010, making the cost of exports less attractive but imports more attractive, might have had some impact on the increase of imported coal. The FOB price at Qinhuangdao versus the FOB price at Newcastle (Australia), Kalimantan (Indonesia), and Vostochny (Russia) in recent years has favoured coal imported into China.

The relative effect of the global recession hit China less hard than other coal importing regions of the world, and so energy demand within China remained stronger creating a demand pull effect on domestic prices, while elsewhere energy demand was much softer and so prices dipped more severely, albeit to recover later. While demand for international coal reduced globally, and domestic Chinese coal was in shorter supply due to infrastructure constraints, imports became more freely available at lower cost.

Evidence of this is provided in Morse and He (2009), where the price advantage of imported coal at Guangzhou improved in the period Feb 2009 to Feb 2010. In this period, imports were 10–40 $/t cheaper than Chinese coal delivered to this same port. Volumes of coal being shipped to China from Australia, Russia and Indonesia in the same period increased by 8–12 Mt/y per month. While the FOB cost of coal was higher for Chinese coal (at Qinghuangdao), freight rates to ship coal from the northern Chinese ports to the southern Chinese ports of Shanghai and Guangzhou also played a part in this arbitrage.

At the same time, the international shipping industry went into a major oversupply situation for dry bulk, and freight rates for internationally traded coal to the Port of Shanghai fell sharply in 2008, by as much as 80%. China's domestic maritime rates fell by 50% of the 2007-08 levels. Both drops are staggering, but the difference might go some way to explain the deeper cuts faced by foreign suppliers. China's maritime freight is measured by the Shanghai Shipping Index comprising relatively small vessels of around 40–50,000 dwt, while foreign coal may arrive in international capesize vessels of 100,000 dwt or more which have a lower per tonne rate (albeit at higher daily charter rate). International freight rates therefore seemed more attractive, further softening international prices compared with China's suppliers. By 2011, freight rates barely recovered, and export FOB prices globally returned to the 2007-08 levels, thus making imported coal more expensive, and possibly creating a switch back to Chinese coal.

Since the market is dominated by coal, there is almost no alternative (for example natural gas) for utilities to switch to in times of excessive coal prices. Utilities' costs of operation are therefore bound by the costs of the price of coal. Inflation in electricity tariffs is heavily regulated, while coal prices are more fluid. This therefore affects the profitability of coal-fired generation in China, if coal price inflation is high. Since the cost of coal is more market-based, it is heavily affected by winter weather, infrastructure disruptions, and occasionally hydroelectric performance.

Utilities are more free to switch to imported coals than previously, and so small aberrations in the market can lead to a flurry of speculation and interest in import levels and prices. However, this is not always the case. China's import tax was phased out in 2007, and had little discernible impact on the import surge that occurred in 2009 (*see* Figure 10). Other additional charges include VAT which is charged on all coals (on a CIF basis) and transaction costs for Chinese coals that are around 3 $/t.

These additional charges are not negligible, but nonetheless have less of an impact than overall market drivers. As long as the zones for economic development remain in the regions located close to the south and south eastern coast of China, the arbitrage between domestic and international coal will still be an important dynamic in China. Even the massive coalfields of Mongolia are located too far inland to make a major impact as yet, but the situation may change in the future.

4.5 Coal importing power stations

In 2010, China imported an estimated 166 Mt of hard coal, of which 92 Mt was steam coal (MCIS, 2011). Coking coal imports were 47 Mt in 2010, and anthracite was 27 Mt. In terms of steam coal, Indonesia was the chief supplier at around 28 Mt, Australia accounted for 17 Mt, South Africa 7 Mt, and Russia 6 Mt. Vietnam was the chief anthracite supplier, while Mongolia and Australia were the top coking coal suppliers. While most of these countries will maintain an export industry, Vietnam is one case where the country is shifting its market to serve domestic industry and power generation and could feasibly withdraw from the export market.

Establishing a map of coal-fired power stations in China is problematic given the rapid build rate of plants, and the extensive closure programme for smaller plants. The map therefore only captures the main stations that are likely to burn imported coal, or have access to ports by rail or river. Figure 11 shows a multitude of coal-fired stations that are located across the entire coastline of China from the southernmost province of Guangxi to the northernmost province of Liaoning. There are nine provinces that have coastlines, and several others which are within 500 km rail distance of the ports. While coal logistics and price are often quoted as the reason for arbitrage between domestic and imported coal, what is mentioned less often is the regulation on sulphur emissions which restricts emissions from many newer power stations to 400 mg/m^3 and particulates to 50 mg/m^3. Tighter emission regulations will have reinforced the effect of supply availability and price arbitrage in China in recent years and helped the drive to increase imported coal.

Prior to 2004, China had undemanding coal-fired power plant emissions compared with OECD countries (Minchener, 2004), but MEP and the State Bureau of Technical Supervision, Inspection and Quarantine jointly formulated new standards. In 2003, The Emissions Standards of Air Pollutants for Thermal Power Plants (GB 13223-2003) was issued, becoming effective from 1 January 2004 (Wang and Zeng, 2008). These standards apply as national emission standards, but in large metropolitan areas such as Beijing, Shanghai, Guanghzou, Hangzhou and Guilin, local EPA can issue stricter emissions standards. However, in 2011 the Chinese authorities adopted a new set of emission standards (Emission standards of air pollution for thermal power plants GB 13223-2011) which could make Chinese power stations subject to standards that would exceed those in the EU and USA, but perhaps not as stringent as some local standards in Japan.

The standards were introduced in January 2012, and provide existing plants with a 2.5-year period of grace before they need to comply with the new standards, while new plants will be affected immediately. Even tighter rules will apply to gas-fired plants in accordance to the cleaner nature of the fuel. A full text of the standards is available at:
http://www.zhb.gov.cn/gkml/hbb/qt/201109/t20110921_217526.htm

Table 5 shows the emission standards that could apply to coal-fired stations, based on stack or flues.

The implication for coal imports is that power plants built after 1 January 2012 that are not fitted with FGD to achieve emissions of less than 200 mg/m^3 cannot burn coal containing more than 0.3–0.4% sulphur, a level which can be achieved with few internationally traded coals. All coal-fired stations will therefore have to be fitted with FGD, and for existing plants retrofits will need to be installed by 2015. Compliance could be rewarded, as plants fitted with FGD can charge an additional 0.015 RMB/kWh. An emissions tax has also been levied at a rate of 0.65 RMB/kg on SO_2 and NOx.

Figure 11 Map of Chinese power stations capable of importing coal

Table 5 Thermal power boiler air pollutants emission concentration limits, mg/m^3 (Sloss, 2011)

Type of energy conversion facility and fuel	Pollutant	Condidtions	Limits
Coal-fired boilers	Soot (pariculates)	All	30
	SO_2	New boiler	100 200*
		Existing boiler	200 400*
	NO_2	All	100 200†
	Hg and Hg compounds	All	0.03

* To be located in Guangxi Zhuang Autonomous Region, Chongqing Municipality, Sichuan Province and Guizhou Province, where the limits will be implemented with coal-fired boilers.
† Implementing limits on W-type thermal power generation boilers or furnace chamber flame boilers, circulating fluidized bed (CFB) boilers, and boilers put into operation as of 31 December 2003 or through the construction project's environmental impact report's approval of coal-fired power boilers

By the end of 2008, there were at least 29 FGD suppliers manufacturing mainly limestone scrubbers possibly accounting for 75% of global FGD installations every year and fitted at a price 50% below that of the international price (PEI, 2009). In 2009, some 365 GWe of Chinese power stations had FGD fitted; by 2020, China could have 723 GWe.

Table 6 shows a list of power stations within the key importing region of Guangdong where the port of Guangzhou is located. In this province there are at least 27 power stations operating or under construction with a total generating capacity of 54.5 GWe. If developments continue, Guangdong Province will have more coal-fired capacity than Japan or Germany within a few years. Around the Port of Guangzhou, there is a cluster of nine power stations around the mouth of the Pearl River which opens up to Hong Kong where three of the power stations are located.

Petrocom is a Hong Kong based company that is building a coal blending facility in the Port of Lianyungang on the eastern coast of China. Coal blending can vary in sophistication, from using bulldozers to mix coarse grades of coal, to using stockpiling methods such as stacking different layers of different quality coals on top of another, and then accessing the coal vertically. Petrocom are building a series of silos each of which will contain a different quality of coal. Large conveyor belts and weighing scales are mounted beneath the silos, and coal from each silo is weighed within the silo and sprayed onto the conveyor belt before onward transport by rail or conveyor to the power station. The silos can process 10 Mt/y. According to Petrocom, the cost of blending coal in such a precise system is around 5 $/t, which at current import costs is perhaps 5% of the cost of coal.

4.6 Coal import logistics

Given China's GDP of $6–7 trillion and a current account balance of $300 billion, most of the country's ports are geared towards exporting goods. Historically, these ports exported coal to the international seaborne market, but for now China is a massive net importer. The export ports in the north of China now serve as a transfer point before coal is shipped southwards to the Chinese coal importing ports. Instead, the coal is railed along rail lines such as the Da-Qin and Shuo-Huang rail links to the coastal ports of Qinhuangdao, Jingtan and Caofeidian, Tianjin, and Huanghua. Central

Table 6 Coal importing power stations in Guangdong (CoalPower, 2011; Author's estimates)	
Plant name	Operational or under construction, MWe
Haimen	4000
Sanbaimen	3200
Shantou	1200
Huilai	3200
Dapu	1200
Shanwei	2520
Heyuan	1200
Pinghai	2000
Huizhou	660
Mawan	1800
Shajiao	3880
Yunfu	1120
Zhujiang	1200
Huangpu	2670
Guangzhou Huaran	660
Hengyun	1120
Zhuhai	4600
Taishan	5000
Yangxi	2400
Qiaoyuan	1200
Shaoguan	3200
Yuelian	520
Maoming	1100
Zhanjiang	2400
Hengmen	250
Nanhai I	1000
Hangyi	1200

coalfields and southern Shanxi coalfields rail coal along lines which are exported through Qingdao, Rizhao and Lianyungang. According to the NDRC, in 2006 the rail capacity in coal producing provinces was 690 Mt, but the capacity was oversubscribed by 14%, suggesting that coal producing provinces need access to at least 790 Mt of rail capacity to adequately meet domestic demand (Shenhua, 2007). This percentage is expected to improve to around 11% despite a forecast rise in demand due to the planned investment in rail capacity.

Apart from dedicated rail links, rail distances for coal transport in China average 550 km, similar to distances between South African coal mines (Witbank) and the Richard's Bay Coal Terminal. In China, the rail to port distance can range from 50 km to 1400 km for some provinces. For example, the distance from Shanxi to Qinhuangdao port is between 500 km and 800 km depending on location of the coalfield.

Based on author's estimates, around 100 coal power stations are located on the coast, or close to the river outlets which exit into the South and East China Seas. The greatest concentration of power stations occurs along the massive Yangtze River between Jiujiang and the Eastern China Sea where there are at least 20 coal-fired stations. These coal plants are however much closer to the Chinese coalfields by rail.

The cost of transporting coal by rail ranges from 6.0 to 9.9 US$/t. The system for regulating freight prices is set by the State Planning Commission based on a rate per tonne-km in nine basic categories of freight. Rail fees are further determined by negotiation between the Ministry of Railways, the larger coal mines and provincial governments. Fees tend to be highest on more technically advanced lines, such as those with the latest infrastructure developments which are electrified and double tracked. Fees on short haul journeys are as low as 0.07 yuan/t km (0.8 US cents/t km) or can be as high as 8 US cents for longer journeys (Ball and others, 2003). Ball and others (2003) also published average figures for rail fees on four major west-east coal trunklines at 1.85 US cents/t km. For a 500 km rail journey, the cost of transit would be around 9–10 US$/t. While this is costly, it is still half the costs of transporting some Russian coals from their mines to Baltic export ports.

Transport links are vital to maintaining coal supplies to power plants: these links account for 60–70%

of rail freight operations (Melanie and Austin, 2006). The pressure on rail infrastructure continues to mount, but spare capacity has been achieved with little expense. Such increases have been achieved through improving the existing services for both passengers and freight. For example, since 1997, China has raised its train speeds, boosting passenger train speeds to 120 km/h on 22,100 km of tracks, 160 km/h on 14,000 km of tracks, and 200 km/h on 5370 km of track. The increased passenger efficiency also frees up capacity for freight movements on certain routes. The speed of freight trains on the above-mentioned tracks has been raised to 120 km/h. Previously, China's trains used to travel at just 60 km/h. Despite the vast improvements to the rail system, transport bottlenecks still exist.

Infrastructure is a major issues that determines the flow of coal within China, and the supply chain linking China's coalfields to the demand centres in the south via the export ports and coastal shipping means competition between imported coal and domestic coal may well be intense. There will probably be no clear winner as the rise in demand will increase business for both domestic and seaborne markets for some years as the country locks into coal-fired power as a preferred form of electricity generation.

5 India

India enjoyed a GDP growth almost equal to that of China, estimated at just under 9%/y for 2011 and 2012, during a period when OECD economies were experiencing extremely cautious growth, especially in Europe. Yet, much of India's population remains impoverished in energy terms and consumer inflation in 2010 was almost 14%. Per capita electricity consumption ranged from 600 to 700 kWh/head (2008), while the rest of the world consumed 3240 kWh/head, and OECD nations consumed between 6200 and 10,500 kWh/head. It is unlikely India and China will reach such high consumption levels (per head) for the foreseeable future, given the vast population such levels would probably be unsustainable. Yet even modest increases will lead to vast increases in the total demand for electricity, which in India is chiefly coal-fired power.

In terms of demand, China exerts a considerable force in world coal markets and India is reinforcing China's 'pull' on the seaborne hard coal markets. India is altering trade flows in the seaborne market and driving demand in a way that may not have been considered seriously 15 or 20 years ago, although analysts may have alluded to it briefly. For instance, Europe's diminishing market would have caused concern for South African exporters, which previously relied on the Atlantic market for its main customers. India now buys South African coal, and could draw more coal from the fledgling industries growing in the rest of Southern Africa, such as Mozambique, Botswana, and Zimbabwe. Richard's Bay Coal Terminal is perfectly situated to deliver coal to India being within 3800 miles of the western coast (avoiding the waters affected by Somali piracy activity). The east coast of India is even closer to Indonesia, being 2000 miles from South Sumatra and 2600 miles from South Kalimantan (www.netpas.com). These trade relationships with major exporters are important as India faces pressing challenges, which include a number of issues, from environmental performance of its generating fleet to the internal shortage of coal at the nation's power stations. Coal production keeps growing, but not at a pace that can yet keep up with demand.

India is currently the second largest non-OECD hard coal producer, and third largest producer of coal in the world. In 2009, production reached 490 Mt according to IEA data, an almost threefold increase on 1990. Given that production is always chasing a burgeoning demand, this threefold increase in output almost certainly indicates a threefold increase in demand, since India does not export coal.

Imports have also grown; India was described by the Australian Bureau of Agriculture and Resource Economics (ABARE) as the fastest growing importer of thermal coal (O'Connell, 2010). While India's coal supply remains dominated by domestic production, energy security is a key component of the nation's energy policy. Crude oil and natural gas are almost entirely obtained from the international market, and therefore subject to the volatility of world prices. Only coal, hydroelectricity, waste and biomass, and renewable energy are available in India as indigenous sources of primary energy at present. Whether India finds new oil and gas reserves is not certain, but the possibility exists. In the absence of indigenous reserves of oil and gas, India is securing such fossil fuel supplies by buying foreign assets that produce these necessary fuels.

5.1 Coal-fired power

Coal-fired power generation is discussed at length in a number of reports published by IEA CCC such as *Coal use in the new economies of China, India and South Africa* (Mills, 2010) and *Prospects for coal and clean coal technologies in India* (Mills, 2007). This Section is a brief overview of the state of coal-fired power in general in the country; the significance of imported coal is discussed later.

Coal is currently supplied to state-owned generators and seven of the largest IPPs that include Tata Power, Reliance Energy, and the Calcutta Electric Supply Corporation (Jha, 2005). Other important

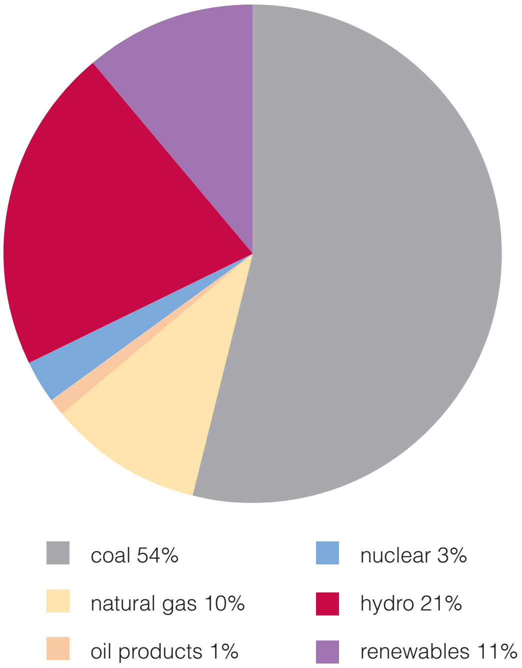

Figure 12 Total power generating capacity

companies active in importing coal include Swiss Singapore, Bhatia, Adani, and Agarawal. For this reason, coal infrastructure is essential for the operation of the country's power generation.

In 2006, India had 146 GWe of installed electricity generating capacity, with 56% being coal-fired (Mills, 2006). Five years on and little has changed in terms of market share, except for an increase in the total generating fleet. By April 2011, India had 174 GWe of generating capacity, of which 54% was coal fired (*see* Figure 12). High coal demand in India is partly explained by the low efficiencies being achieved in subcritical (typically pulverised) coal-fired plants operating at high load factors. A massive investment in better plant maintenance, station upgrades, and ultimately a shift to supercritical (SC) and ultra-supercritical (USC) power stations could yield massive fuel savings as well as enhanced power station performance. In India, overall efficiency is improving slowly compared with China, owing to the faster pace of new coal-fired capacity additions, coupled with the closure programme that has led to some 70 GWe of old inefficient plants being shut in China.

With poor coal quality and high ambient temperatures, the average efficiency for the coal-fired fleet in India was 27.6% (LHV basis) in 2006, compared to the OECD average of 36.7% (Ricketts, 2006). More recent efficiency estimates for the Indian fleet are closer to ~30% (Smouse, 2009). The ongoing programme to develop supercritical and ultra-supercritical stations could raise this, provided these stations are maintained to optimum performance levels.

It is no surprise that India's demand for electricity outpaces the capacity to supply both the electricity and the coal to fuel the power stations. This dilemma is partly due to fast economic and population growth, but the pressure is not helped by the massive loss experienced by the transmission and distribution network. Much of the loss is due to poor infrastructure, and so would naturally represent perhaps 5–10% of the generated electricity. However, the bulk of the loss arises from the large amount of unmetered consumption and/or theft. System losses for the Indian electricity market in 2009 amounted to 24% of the electricity supply – this is one of the highest levels of loss (in percentage terms) seen anywhere in the world. The OECD average is closer to 6%, while the rest of Asia averages 5–10%.

Where electricity is metered and billed, tariffs to households are a third of those in OECD countries, and this is in part due to the low cost of coal. The inability to recover costs through a more robust tariff system means that new capital investment is slow to develop, and there is greater incentive to operate existing coal-fired power plants beyond their design lifetimes. For many years, the country has maintained a rolling renovation and modernisation (R&M) programme, focused mainly on 200–210 MWe units that are 20 years old or more (Mills, 2007). Many coal-fired units have operated without modernisation for far longer periods than their counterparts in OECD countries.

Historically, India has fairly lax standards with regard to airborne pollution from coal-fired stations. Emission standards on particulates are not stringent, and there are no emission limits for SO_2 or NOx (Mills, 2010). Until some indication that these basic pollutants are under much stricter control, there is little or no impetus to embark on a CO_2 reduction programme of the power station fleet.

5.2 Coal supply

Coal exists in at least 14 of the 28 states in India and coal resources total 277 Gt, although only 106 Gt are proven and recoverable. Based on production today, the R/P ratio exceeds 200 years, close to that of the USA and perhaps five times that of China (CIL, 2011).

India is a strong-coal based economy and, being self-sufficient in coal, the only security of supply issue it faces is transporting coal from the coalfields in the central regions of the country to power stations across the whole country. Energy security nevertheless remains high on the political agenda and in 2005 the Indian President set 2030 as a target year to achieve energy independence from imports. The President highlighted the need to minimise fossil fuel imports, which are demonstrated by the large oil and oil products import figures. While the country is expected to wean itself off oil, India is expected to maximise hydro and nuclear potential, and to increase power generation from renewable energy technologies to 25% (currently ~5%).

Energy security is currently being achieved most effectively with coal. Coal mining in India is relatively low cost by world standards, but the coal is generally low in quality. Imported coal provides added quality and security of supply advantages to indigenous supplies. Also, domestic coal supply problems, whether mine or transport infrastructure related, tend to cause more disruption and concern for Indian power utilities than imported supplies, although minemouth power stations will still have a secure, if not captive, indigenous supply. Even for non-minemouth stations, domestic coal has long been the keystone in the development of coal-fired power in India.

During the 12th Five-year plan, the state utility National Thermal Power Company planned to build 15 GWe of extra capacity by 2018. This would be mainly supplied by domestic coal, much of which would come from new mines. However, on environmental grounds, the government cancelled five coal blocks that were allocated to power utilities for development into dedicated coal mines to their power stations (Steelguru, 2011). Until the dichotomy created by the desperate need for more domestic coal supplies and the need to satisfy environmental standards and practice is overcome, the government should recognise the importance of coal imports for some years to come.

Despite these problems, Indian coal production has increased fivefold since 1980 (*see* Figure 13). All of the growth was from hard steam coal, while lignite and coking coal production have remained a small proportion of total supply and barely increased in decades. India imports almost all of its coking coal, making Indian steel mills major players in the metallurgical market.

Domestic coal production therefore consists of mainly steam-type products. Coal India Ltd (CIL) is the largest producer of coal in India, with production at over 431 Mt in the 2010 financial year (Jha, 2011). CIL is also the largest coal producer in the world. CIL is 90% owned by the Government of India, and 10% by other institutions. However in 2010, CIL cut production targets three times. In the financial year 2010, coal-fired power also reduced target output by 4%. Coal stocks were also just a few days, compared with a normal stockpile of 21 days and many stations were at a 'critical' status with seven days of stock remaining. To fill the coal supply gap, steam coal imports have therefore been necessary, and expected to exceed 100 Mt by 2012, of which 60–80 Mt might be steam coal.

CIL have identified 142 new coal mining projects with an ultimate capacity of 380 Mt/y (Jha, 2011). Some 107 of these projects are opencast and 35 are underground. The total capital expenditure could be as much as US$7.7 billion. A further 20 washeries with a capacity of 111.1 Mt/y costing US$510 million are planned. Expansion of CIL's operations under the provisional 12th Five-year plan could see production rising by 87–186 Mt by 2016-17.

The Singareni Collieries Company Ltd (SCCL) is the second largest coal producer which is a joint venture between the Government of Andhra Pradesh and the Government of India with each owning roughly half of the company. The official government target production for 2009-10 shows that CIL

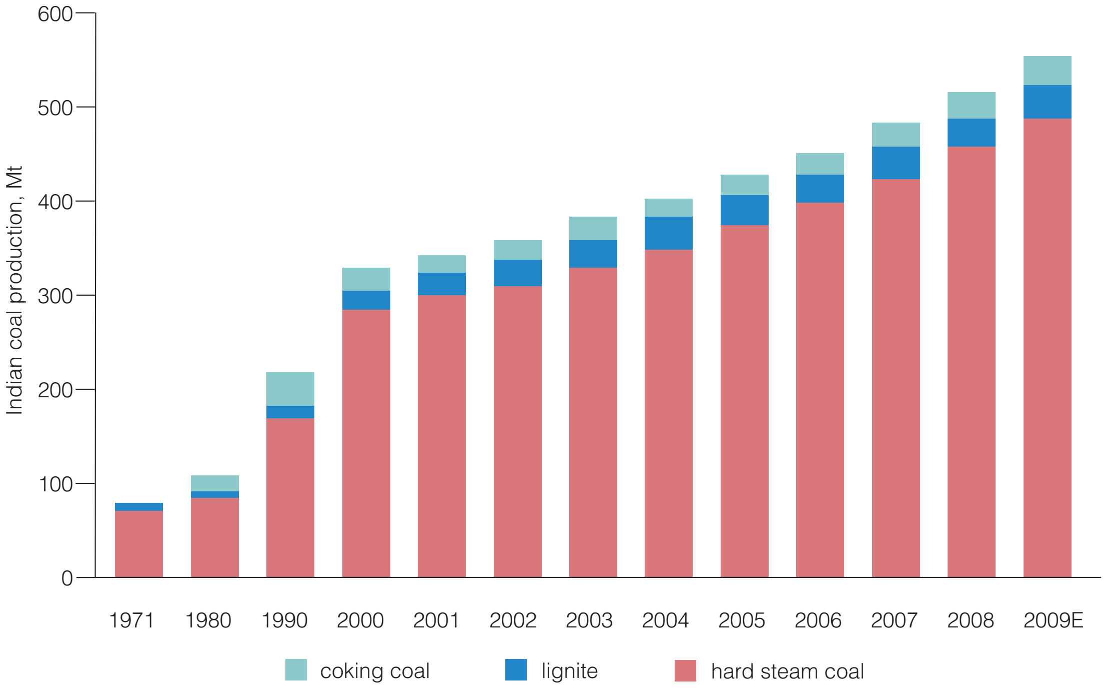

Figure 13 Indian coal production, Mt (IEA, 2010)

would account for 82% of Indian production. SCCL would produce 8% and the remaining 10% would be produced by a variety of producers (*see* Table 7), many of which would be captive producers mining coal for their own use or short haul transport.

Under the Coal Mines (Nationalisation) Act 1973, coal mining was reserved for the public sector. An Amendment to the act in 1976 enabled two exceptions to the policy permitting captive mining associated with iron and steel production, or private companies operating in local markets, provided they did not transport coal using the rail network. Captive consumption includes a number of methods of coal exploitation where the Government can permit coal production for captive power generation, iron and steel facilities, cement production, syngas production, coal gasification, and coal liquefaction. The allocation of coal blocks is done through inter-governmental and departmental bodies called the Screening Committee. The Committee is represented by the Ministries of Steel, Power, Industry and Commerce, Environment and Forests, Railways, and CIL, amongst other smaller parties. As such, the exploitation of all coal reserves remains largely within the confines of Indian based organisations.

Table 7 Structure of Indian coal production 2007-10, Mt (MoC, 2010)

Company	Target production, 2009-10	Actual production to January 2010	Achievement, %	Actual production, January 2007-March 2008	Growth, %
CIL	437.4	338.42	77.37	316.44	6.95
SCCL	45.00	41.03	91.17	36.75	11.65
Others	52.83	37.02	70.07	31.83	16.31
Total	535.23	416.47	78.16	385.02	8.17

5.3 Coal import trends

While imports are a growing feature of hard steam coal supplies, it remains a small proportion of overall supplies (*see* Figure 14). Imported coal serves two criteria; one is a blend coal for lowering the ash content of coals to coal-fired power stations, which is discussed later. The second criterion is that imported supplies bridge the gap created by local supply problems. The plant load factor of thermal power stations in Madhya Pradesh fell from 63% in 2010 to 61.1% in 2011, due to a lack of coal supplies. In response, the Madhya Pradesh government urged the Madhya Pradesh Power Generating Company Limited (MPPGCL) to import 0.8 Mt of coal in 2011 (SP, 2011).

Imported hard coal in the 1980s and 1990s consisted mainly of coking coal (approximately 10 Mt/y in the latter decade) By 2000, steam coal imports accelerated to 9.9 Mt/y, almost matching coking coal trade. By 2005, India was importing 21.7 Mt/y of steam coal, overtaking coking coal for the first time. Steam coal trade has since grown year-on-year.

By 2009, Bloomberg reported that thermal coal imports rose to 60 Mt, although a figure of 75 Mt/y is probably more realistic. Table 8 shows the target coal imports for 2009-10. The largest importer appears to be the National Thermal Power Company, which could double its coal-fired capacity to 75 GWe by 2017, making it potentially one of the largest importers in the country. There are plans to import 14.5 Mt of steam coal in 2011-12.

According to MCIS (2012), steam coal imports reached 92.5 Mt/y (plus 32.9 Mt of coking coal) in 2011. With the new coal-fired capacity coming online, steam coal imports were envisaged to rise to 200 Mt in 2012 (Sharples, 2010). This equates roughly to 50–60 GWe of new coal-fired capacity, which is not unrealistic, but delays in commissioning this capacity are possible. Hence, with 200 Mt/y of thermal coal becoming the norm in coming years, the timing of such import levels is uncertain, as of 2012.

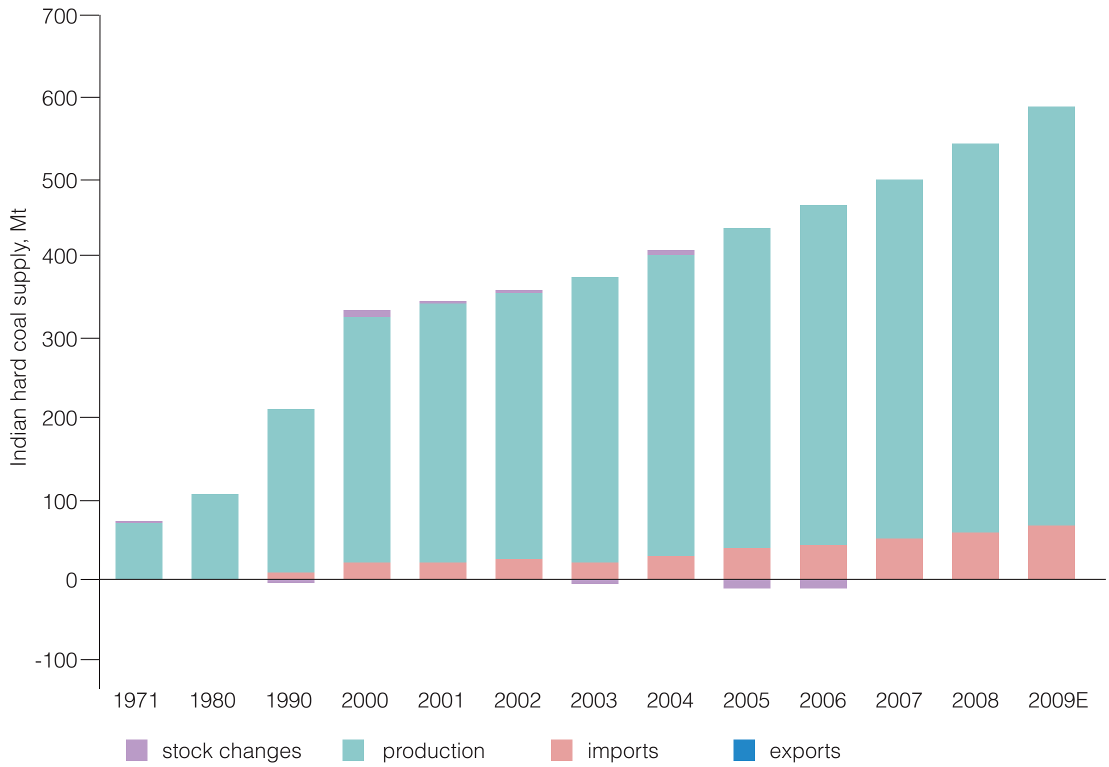

Figure 14 Indian hard coal supply, Mt (IEA, 2010)

Table 8 Utilities with coal import targets (CEA, 2009)

Utility	Annual target of imported coal, Mt (2009-10)
Haryana Power	0.6
Punjab SEB	0.6
Rajasthan RV Utpandam Nigam	0.8
UPRVUNL	0.4
Madyha Pradesh GENCO	0.6
Torrent AEC	0.5
Gujurat SEB	1.48
Maharashta SEB	2.2
Reliance	0.5
Andhra Pradesh Genco	0.8
Tamil Nadu EB	1.8
KPCL	0.8
OPGC	0.02
DVC	0.8
CESC	0.5
West Bengal Power Dev. Co	0.8
NTPC	12.5
TROMBAY	3
TOTAL	**28.7**

Given the problems that are experienced with short-term stocks at Indian power stations, limited port capacity and rail availability issues, large step increases in imports could be delayed, but not indefinitely. Yet, domestic supplies struggle to keep pace with demand, partly due to rail services that are unable to move the coal from mine stockpiles to the power stations. More long- to medium-term issues include the poor productivity of domestic mines and the difficulty of gaining permission to expand operations on environmental grounds, often determined by the Ministry of Environment and Forests. If the obstacles to growth are overcome, coal imports to India could double in the coming years to 250–300 Mt/y.

Indonesian coal currently dominates the Indian import market as a result of its geographical advantage and its rapid production growth in recent years. South Africa has shifted business away from the European region to Asia, not least India, thus preserving its important export potential of almost 100 Mt/y.

In the future, several new market entrants could change the situation. Within a few years, Bangladesh in particular could have between 5 Mt/y and 15 Mt/y of coal available for export. This is likely to be more expensive than Indonesian coal, but cheaper than India's other current suppliers.

5.4 Quality advantages of coal imports

While Indian coals are generally considered poor quality, they are often low in both sulphur and trace elements. Ash contents are high (25–55%), but the ash forming mineral matter is bound within the coal matrix making ash removal using standard coal cleaning processes difficult (Venkataraman, 2006). Indian coals are high in silica and highly abrasive. Such coal properties can increase wear on coal and ash handling equipment, coal milling equipment, and flue gas particulate control. The effect on milling equipment could mean achieving the correct particle size is more difficult in the pulveriser, thus reducing the efficiency of particle burn-out. Typical coal qualities of Indian coal are as follows:

- Ash content is 25–55%, although most probably averages 41% (often 11% higher than most boiler designs). Other impurities might include shale, stones and iron.
- Moisture content is low, typically 4–7%, and so derating from drying moisture is minimal.
- Sulphur content ranges from 0.2% to 7.0%.
- Gross CV varies from 3100 to 5100 kcal/kg, averaging 4200 kcal/kg.

In one example, the Suratgarh power station was built by BHEL and designed to use domestic coals of 45% ash supplied by CIL, some of which comes from the Northern Coalfield Ltd (NCL). Imported coals are blended with domestic supplies to reduce the ash content to 30%, which is still high, but complies with the government imposed limits of 34% above which coal is not permitted to be railed over long distances (*see below*). Even coking coals are blended to achieve the desired ash qualities. For example, SAIL uses up to 12 different sources of coal for coke production (Mills, 2006).

Blending techniques adopted by power plants are often rudimentary and there may be little in the way of formalised procedures, so coal properties within a single consignment can vary greatly (Couch, 2007). In a few cases, there has been some movement towards the adoption of more advanced blending systems. At Reliance Energy's Dahanu power plant, the fuel management system is now used to control the blending of high ash indigenous coal with low ash Indonesian imports. This is claimed to be the first such application in India (Mills, 2006).

Table 9 shows three examples of how altering the coal feed can benefit power station operation. Three stations analysed by Dua (2003) switched to lower ash coals, and in doing so managed to increase plant availability, load factors, boiler efficiency, reduce mill power consumption, reduce auxiliary power consumption, and reduce oil back-up consumption. Clearly, importing coal can provide benefits to some power utilities in these respects, as well as improving the health prospects of citizens, especially those that are already subject to poor living standards, and are residing close to power generating plants with inadequate control equipment to reduce stack emissions.

Similar experiences elsewhere were shown by Chandra and Chandra (2004) who analysed the impact of importing Australian coal at the Bardarpur power station located in New Delhi. This is an unusual example as the power station is far inland, but perhaps proves that coal imports are possible in all of India's power stations if the infrastructure is in place. The Indian coals had an ash content of 21–40%, moisture content of 1.9–7.8%, and heating values at a low 3910–4300 kcal/kg. If it were not for the low moisture content, such heating values are normally seen in lower ranks coals such as lignites and subbituminous coals.

While much is said of the low quality of Indian domestic coals, much of the indigenous supplies to

Table 9 Examples of power plants switching to lower ash coals (Dua, 2003)

	Satpura TPS	Dadri TPS	Dahanu TPS
PLF, %	Increased from 73% to 96%	Increased by 4%	Increased from 76.6% to 88.7%
Coal consumption	Reduced from 0.77 to 0.55 kcal/kWh (28.5% reduction)	Reduced by 0.05 kg/kWh	
Boiler efficiency	Increased by 3%	Increased by 1.2%	
Availability			Increased from 92% to 98%
Mill power consumption, kWh	48% reduction		
Auxiliary power consumption			Reduced by 5.4%
Support oil	None now required	Reduced by 0.35 ml/kWh	Reduced by 0.31 ml/kWh
Operating hours		Increased by 10%	
Daily generation		Increased by 2.4 MU	Increased by 1.48 MU

power plants suffer from contamination. As opencast mining dominates Indian coal mining practice, and extractions often crude, coal quality is often compromised by the inclusion of soil and other material from the overburden. To counter these effects, in 2002, the long distance transport of coal with an ash content of more than 34% was prohibited. Of the country's 81 major thermal power plants, 39 are now required to use cleaned coal with ash below this prescribed level.

Since the prohibition of transporting 34% ash coals was introduced, rail costs per tonne have reduced, along with reductions in the amount of bottom ash, flyash, and CO_2 emitted (Pandey and Tyagi, 2007). The Maharashta State Power Generation Co (Mahagenco) is reported to require coal with a gross heating value of no less than 6300 kcal/kg, although some coal imports can be as low as 5500 kcal/kg (TOI, 2010). However, at the time imports were considerably more expensive than domestic coal, some six times the cost, but given the lack of environmental controls on Indian power stations, that statement probably did not account for the environmental benefits and the improved performance of the power plant, in some ways justifying the cost of the coal (Chaudhary and Sethuram, 2010).

5.5 Cost advantage of imported coal

This Section examines the cost advantages offered by imported coal compared with domestic coals. Almost 88% of the country's production comes from opencast mines, while 12% comes from underground deep mines. Geological conditions for the underground mines are difficult, while the opencast seams are generally thick and close to the surface. CIL has a planned capital outlay of Rps 18,000 crore (approximately US$ 400 million), part of which will go towards larger payload trucks (240 Mt) and larger shovels supplied by US equipment suppliers Caterpillar and Bucyrus International Inc. This investment is the first step in the direction for higher productivity, but there is still a great deal of modernisation yet to be achieved.

With 397,000 employees and a total production of 431 Mt, labour productivity in the Indian coal industry remains low. In 2009-10, mine productivity was roughly 1100 tonnes per man year. This is probably comparable with many mines in China. The next largest producer Singareni Collieries Company Ltd, had a lower level of productivity in 2011 estimated at 770 tonnes/man year. When compared with other major producing countries, Australia productivity is in the range 8,000–12,000 t/man year for both opencast and underground mines. So with abundant coal reserves and the potential to improve productivity, India could be a world class producer of coal; however this potential seems a long way off.

The most important factor that keeps Indian coal competitive with imported coals is the cost of production per tonne. Figure 15 shows the US$ cost of producing coal in India, the most important number being that for opencast mines. The cost of opencast mining has risen in recent years, probably due to increasing diesel costs, explosives, and labour on a per tonne basis; cost inflation is being experienced in mine operations worldwide.

According to Jha (2011), the cost of coal in 2009-10 was just 11.5 US$/t. Given this is for a low heating value and high ash coal, then it is not directly comparable with internationally traded coal, but adjusting for a 6000 kcal/kg South African coal could put Indian coal at a cost equivalent to 15–20 US$/t, still placing Indian coal some way below the cost of export mines across the world. Consequently, India is similar to some other non-OECD nations where coal imports have offered little or no cost advantage (on an equivalent heating value and per tonne basis).

The price trend of steam coal destined for power generators is published by the IEA in the Prices and Taxes databook and shows that the delivered cost of coal is on average low. Coal is subject to a Stowing Excise Duty (SED), which was at a rate of 3.5 INR/t prior to 2003, and raised to 10 INR/t from June 2003. Royalties have increased in steps, presumably as the demand for coal has risen. The

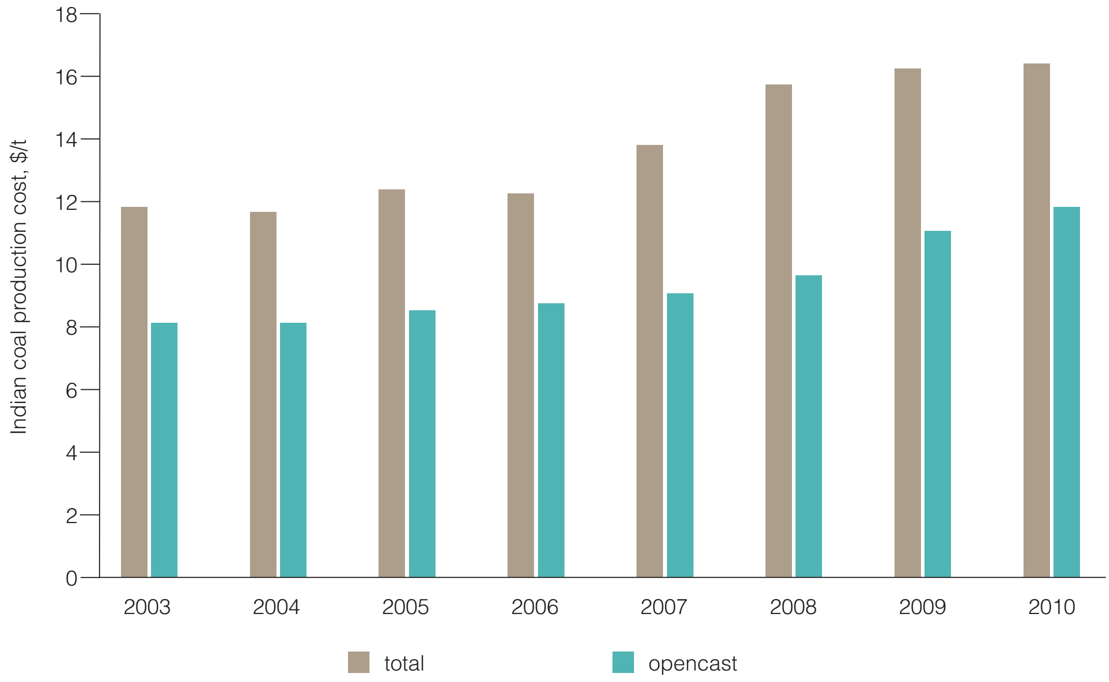

Figure 15 Cost of Indian coal production

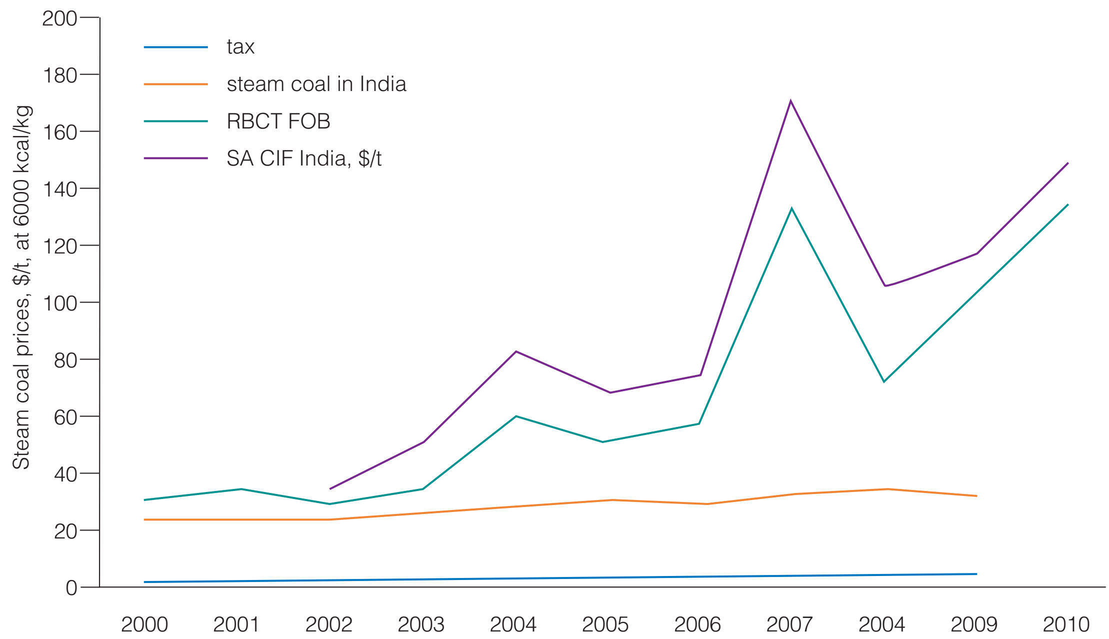

Figure 16 Steam coal prices for power generation in India

current rate of 124.5 INR/t was introduced in August 2007, from 85 INR/t previously. The prices published by the IEA are based on non-coking coal Grade E (ROM, non-long flame) from the Rajmahal Area of Eastern Coal Ltd (ECL) a subsidiary of CIL. The net heating value is estimated to be 4560 kcal/kg.

It is difficult to standardise steam coal prices in India since the regional differences in prices must be wide. The rail costs alone are difficult to establish as the distances can vary widely, but reports suggest that rail costs may be as little as 1.7 $/t or 2.3 $/t on a 6000 kcal/kg basis (DB, 2008). However, according to ICC (2009) coal costs at the power station are often double, due to the cost of inland freight. Much of this is attributed to artificially elevated freight rates due to the cross-subsidisation to aid lower passenger fares. This would suggest that the cost of rail could be in the range 7–16 $/t assuming the figures in Figure 16 are used for comparison. This might be a more sensible figure as coal sent by rail is often sidelined in favour of passenger traffic sharing the same railway lines, along with congestion and demurrage charges due to delays which will worsen as production capacity increases.

In the past, CIL operated a Domestic Price Fixation system for certain coal grades (grades E to G) until January 2000, with a clause to update prices every six months to reflect a cost index based on an escalation formula that was contained in the 1987 report of the Bureau of Industrial Cost & Prices. After January 2000, CIL was free to fix prices of any grade in relation to market prices.

5.6 Infrastructure and logistics

Coal reserves are concentrated in the east and south of the country, while consumption is spread across the country. Getting the coal to the west and northern states is therefore done using inland transportation. The major mode of inland transport for coal in India is rail, although small quantities are transported by road.

Coal is moved in a variety of ways, rail, sea, road, MGR (merry-go-round) closed loop for minemouth plants, belt conveyor, or even ropeway. Rail infrastructure is by far the largest system, and coal is the largest single commodity being carried around India. Rail carries 53% of the coal in the country. MGR moves 23%, road is 21%, belts 2% and ropeways 1.5%. However in the 1980s, as much as 70% of coal was moved by rail. Likewise for the railways, coal is an important commodity accounting for 46% of freight loading and 38% of total freight earnings (Mills, 2006). Short haul transport includes conveyor systems and ropeways.

Delays in the development of the Indian rail system in terms of freight capacity expansion through rail line capacity and wagon/rolling stock could pose an obstacle to growth in indigenous coal production. New freight lines are being considered, and one proposal is a dedicated freight corridor (DFC) from Howrah to Delhi which could relieve some of the congestion for coal movements.

A 43 km rail link in the Ib Valley has been approved while other proposals might see a tripling of the freight line between Bhubaneswar to Vishakhapatnam, double and triple lines between Rajatgarh to Khurda, and a link between Talcher and Paradip (ICC, 2009). In North Karanpura, a double rail link of 93 km has been proposed for which the company is seeking forest clearance from the Environment Ministry as of May 2011. The new coalfield Mand-Raigarh is being linked to Korba coalfield, which will be eventually linked to the Pendra Road-Amritpur line.

In 2010, while rail lines were available, a lack of rolling stock was cited as a problem for some regions. Orissa state has seen coal imports being affected by this problem seeing less steam and coking coal being transported to Indian consumers due to few wagons being supplied by the rail companies (Singh, 2010). Part of this is rail shortage is due to the recent ban on iron ore export in July 2010 which means fewer rail cars are available to return (backhaul) with coal imports or higher charges to move the stockpiled imports. The ban applies to ore mined in Karnataka in India’s south west as a last ditch attempt by the government to reduce illegal mining that avoided tax.

Coal importers loaded stock onto wagons that arrived at export ports with iron ore for backhaul journeys. The worst affected ports included Gangavaram, Krishnapatnam, Chennai, Vizag, and Paradip. Vessel congestion increased and even CIL has had problems acquiring empty backhaul trains to take coal from its own stockpiles to power stations. This manifested itself as a shortage of coal at power stations, and hence a reduction in available capacity. Some of the reduced capacity was helped

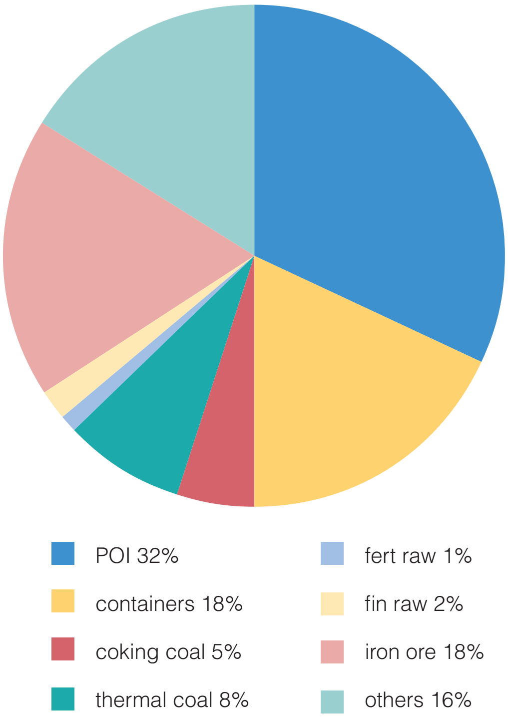

Figure 17 Commodities handled at Indian ports in 2007-08

by the reduction in industrial demand ahead of the monsoon season when industrial facilities overproduce cement and metals to carry them through the monsoon period. Ganagavaram (or Visakhpatnam) is capable of taking capesize vessels and is considered the deepest port in India. West coast ports have been less affected, and the western coast ports of Mundra, Pipavav, Navlakhi, and Kandla generally handle South African imports. East coast ports tend to handle Indonesian coal imports.

A shortage of line and wagon availability forced CIL to store a large quantity of the fuel itself, with stocks as high as 63 Mt in March 2010 (WSJ, 2011). CIL may invest heavily in coming years on railway infrastructure, which could be dedicated to coal transport and so could provide a greater security of supply to India's domestic supply. Three new rail links could be built totalling 350 km, requiring in excess of Rs 2000 crore (US$45 million). The rail lines would link Ib Valley, North Karanpura, and the Mand-Raigarh coalfields.

According to official railway policy, companies wanting dedicated services, like CIL, will have to fund the construction of the rail link, along with land acquisition costs. Ownership, operation, and maintenance of the services and assets will be the responsibility of Indian Railways. Investing firms such as CIL can recover their costs through the levy of 'surcharge' on the freight rates, over a 10–25-year period. Companies can recover the costs through development charges from various users of the line, or can also be compensated by the surcharge – but the Railway Ministry is yet to finalise the model concession agreement for implementing the policy. New routes that could boost imports have been proposed to connect New Mangalore, Kandla, Tuticonrin, and Diamond Harbore to main lines and cities.

Hard coal is imported through a number of ports, according to the ICC (2009), India has 12 major ports and about 180 minor ports. The cargo handling capacity of major Indian ports was 530 Mt in 2008. Many ports still lack vessel traffic management systems (VTMS) used for berthing ships although most ports have adequate tugs and launches to assist individual vessels.

Figure 17 shows the distribution of commodities handled at Indian ports. Major ports in India handle more than 70% of the cargo volume but the share of cargo handled by minor ports has been increasing over the last twenty years. The biggest tonnages are handled by the ports of Paradip (the biggest), Ennore, Tuticorin, Haldia, Visakhapatnam and Chennai. However, not all major ports (for instance, Calcutta) are engaged in coal traffic (Indian Ports Association, 2006). Various means of coal discharge are deployed. These include shore crane/grab-conveyor systems used at Haldia (8000 t/d), Paradip (9000 t/d) and Chennai, and ship crane/grab transfers from jetty to stockyards at Haldia, Paradip and Vizag. Recently, three state-owned power plants (one each in Maharashtra,West Bengal and Bihar) have begun importing coal through eastern ports.

The Maharashtra State Electricity Board is importing coal via Visakhapatnam to supply its Koradih power station, NTPC is importing through Haldia for its Kahalgaon plant, and West Bengal Power Development Corporation is bringing in coal through Haldia for its Kolaghat plant. To date, NTPC has been the major importer of coal through all three east coast ports, also bringing in supplies for its Farakka, Simadri and Talcher stations.

Equipment at ports breaks down frequently due to poor (and lack of ongoing) maintenance. Long response times and a lack of spares means longer periods of downtime while carrying out remedial repairs. Port facilities are expected to rise sharply due to the rise in the number of ultramega power projects. The abolition of the steam coal import tax (equivalent to 5% of the price) may well help importers shoulder some increase in costs needed to build capacity for the inland rail system. The abolition expires in 2014, after which the tax could be reinstated.

India's prospects for coal imports are as dynamic as they are for China, except for major constraints on domestic supply and import infrastructure. While China has a market that has been able to swing from export to import, and could swing back again in years to come, India appears to have no such capability at present. India is therefore a more predictable market than China. The main issues for India are that the development of domestic coal production faces obstacles that are common in many OECD economies. In the case of India, the domestic industry may be criticised for not developing mine capacity to keep up with demand, but developments can be delayed if the Environment Ministry is not satisfied with the submission of environmental impact assessments and/or relevant permit applications. Despite the apparent slowness in developing Indian coal production, productivity could be improved at existing mine facilities. Nevertheless, while steam coal production continues to increase, albeit not enough to meet the rising demand, the supply of coking coal may not improve.

5.7 Coal importing power stations

Figure 18 is a map of coal-fired power stations in India, and while coal production is concentrated in the eastern and southern states, coal-fired power is spread widely across the entire country. Almost every major utility in India imports coal. Imports are also known to have supplied inland power stations such Chandrapur and Torenagella, but many stations that import coal are located coastally, some within a few km of the coastal ports.

In June 2009, the target imports for 2009-10 amounted to 28.7 Mt, imported by eighteen utilities. Out of 43 GWe of power capacity that had been awarded through competitive bidding, 13 GWe are dependent on imports. This roughly equates to a maximum 26 Mt of coal if all the capacity was burning imports.

Table 10 lists a number of power stations that use imported coal, mostly in blend with domestic coal, but few rely on imported coal. The list is not exhaustive and only shows those stations where there is knowledge of coal imports, either through IEA CCC internal databases or from evidence from the Indian Central Electricity Authority (CEA). Where the coal quality of the power station is known, many show that the main fuel is domestic, given that the ash contents are 34% or above, and the heating values are low at less than 20 MJ/kg (typically net). The list has 42 stations either importing, or earmarked to import coal. This list is likely to lengthen as time goes on. Figure 19 shows how diverse the companies are that are either building dedicated coal-fired capacity for imported coal, or are increasingly blending domestic with imported coal.

Every month, the CEA (2010) lists power stations which are undergoing emergency stock levels of less than seven days. This problem has become worse in recent years, and confusingly, these stations are called *critical* and *supercritical* power stations (supercritical where stocks are less than four days). Therefore, these terms do not refer to those commonly applied to the steam conditions employed for high efficiency thermal power generation. This stock level list includes reasons for supply shortfalls due to mine disruption, transport failures, a shortfall in imported sources, or port delivery problems. Estimates for the generating plants with access to imported coal are around 48 GWe, this means a potential 100 Mt/y of coal could be imported for these stations if they switched to imported coal

Figure 18 Power station map of India

completely. There are nineteen companies shown here, with some companies having more capacity that can burn imported coal than others, some of which include privately owned corporations such as Reliance and Tata Power Company (*see* Figure 19). Other companies that import coal include the

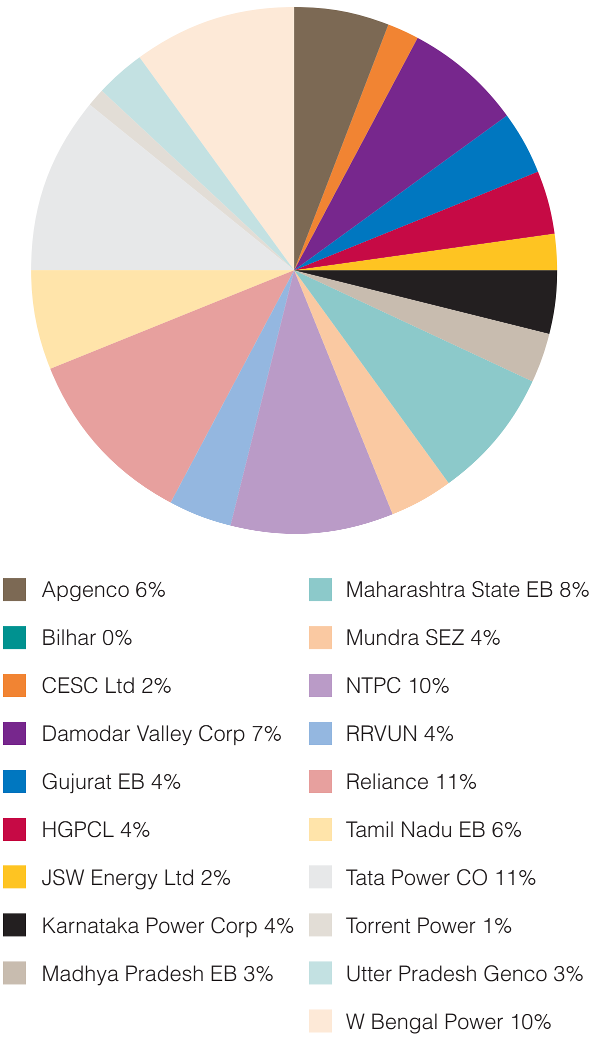

Figure 19 Coal capacity that imports coal by utility share, %

public utilities such as NTPC, West Bengal Power, and Maharashtra State Power.

Under the 12th Five-year Plan (2012-17) a further 80 GWe could be built, much of which could come from IPPs seeking imported coal as a major source of fuel supply. According to O'Connell (2010), India is planning to expand its generating capacity by a massive 14%/y between 2010 and 2012. Generating capacity could rise to 220 GWe although not all of this would be coal fired. The demand for imported coal could range between 24 to 164 Mt/y in 2015 Mt depending on the growth scenario for steam coal in power generation and coking coal for iron and steel production. Whichever scenario is considered accurate, imports appear to be on the rise in the future.

At least, 500 kt of coal imports will be used in the Satpura Thermal Power Station at Sarni in Betul, while any remaining stock will be used in the Sanjay Gandhi Thermal Power Station at Birsinghpur in Umaria. Interestingly, the Satpura power station demonstrated the benefits of switching to low ash coals in the early 2000s (*see above*), and so Madhya Pradesh state is not unaccustomed to importing coal. Coal imports are expanding nationwide as more coastal power stations are being built, especially with demand from the ultra mega power projects (*see below*). However, the existing power stations that typically buy domestically mined coal and experience supply shortfalls do not always find importing coal a straightforward process (Bihar, 2011). The tendering process for purchasing coal imports can take a long time in order for due diligence to be completed.

5.8 Role of the UMPP and overseas mining investments

Additional investment is taken in the form of transmission grid capacity, and in terms of coal-fired capacity nine ultra mega power projects (UMPP). These are all supercritical stations of at least 4000 MW capacity. These are all being built on coastal sites to exploit imported coal as well as minemouth stations that will use domestic coals. Only four UMPP have progressed. The first is a sea water reverse osmosis plant built at Mundra in the Kutch district of Gujurat. It is also the country's first IPP that uses supercritical technology at a cost of $4.2 billion. Mundra is owned by Coastal Gujurat Power Ltd (CGPL) formed by Tata Power, the largest IPP in India.

Coal will be imported from Indonesian coal mines, also part owned by Tata. Contracts for three other UMPP are also in place for Sasan (minemouth power station); Tilaiyya (minemouth); Krishnapatnam (coastal); these have been awarded to Reliance Power. Reliance Power Ltd, a subsidiary of the Reliance Infrastructure group, in 2008 announced an investment of US$1 billion in acquiring and developing a coal mine in the Indonesian province of South Sumatra. The subbituminous coal was

Table 10 Sample list of coal-fired stations known to import coal (CoalPower, 2011; CEA, 2010)

Plant name	Ownership	MWe	Status	Net CV	Ash, %	Total annual consumption (Domestic + Imports) Mt/y
Dr N Tata Rao/Vijayaweda	Andhra Pradesh Generating Co (APGENCO)	1760	OPR			
Rayalaseema	Andhra Pradesh Generating Co (APGENCO)	1050	OPR			
Muzaffarpur	Bihar SEB	220	OPR			
Budge Budge	CESC Ltd	750	OPR	17.0		2.2
Titagarh	CESC Ltd	240	OPR	18.0		1.2
Chandrapura	Damodar Valley Corp	1750	OPR		40.0	1.5
Mejia	Damodar Valley Corp	1340	OPR			3.7
Ukai	Gujurat EB	850	OPR	13.5	34.6	3.6
Gandhinagar	Gujurat EB	870	OPR	12.9	35.0	3.2
Panipat	Haryana Power Generating Co Ltd (HGPCL)	1360	OPR			5.8
Yamuna Nagar	Haryana Power Generating Co Ltd (HGPCL)	600	OPR			
Toranagallu	JSW Energy Ltd	860	OPR	25.1	11.0	0.6
Raichur	Karnataka Power Corp	1720	OPR		34.0	6.0
Sanjay Gandhi	Madhya Pradesh EB	1340	OPR			3.7
Deepnagar/Bhusawal	Maharashtra State EB	478	OPR			2.4
Nasik	Maharashtra State EB	910	OPR			
Parli	Maharashtra State EB	1170	OPR		38.0	3.8
Paras	Maharashtra State EB	558	OPR	18.0	34.0	0.3
Khaparkheda II	Maharashtra State EB	840	OPR			
Mundra	Mundra SEZ	1980	OPR			

Table 10 Sample list of coal-fired stations known to import coal (CoalPower, 2011; CEA, 2010)

Kahalgaon	NTPC	2340	OPR	10.8	40.0	5.8
Bhilai	NTPC	574	OPR			
Simhadri	NTPC	1500	OPR			5.9
Talcher	NTPC	460	OPR			2.8
Chhabra	Rajasthan Rajya Vidyut Utpandan Nijam	500	CON			
Suratgarh	Rajasthan Rajya Vidyut Utpandan Nijam	1500	OPR			6.0
Rosa	Reliance	600	OPR			
Dahanu	Reliance	500	OPR		34.0	2.3
Krishnapatnam	Reliance	3960	CON	Indonesian		
Ennore	Tamil Nadu EB	450	OPR			0.6
Mettur	Tamil Nadu EB	840	OPR			4.0
North Chennai	Tamil Nadu EB	630	OPR			2.5
Tuticorin	Tamil Nadu EB	1050	OPR			5.7
Mundra	Tata Power CO	4000	PLN	Indonesian		
Trombay	Tata Power CO	1400	OPR	Imported		
Sabermati	Torrent Power	400	OPR			2.0
Obra	Utter Pradesh Genco	1550	OPR			4.8
Bandel	W Bengal Power	530	OPR			1.3
Kolaghat	W Bengal Power	1260	OPR			5.0
Sagardighi	W Bengal Power	600	OPR			
Santaldih	W Bengal Power	980	OPR			
Kolaghat	W Bengal Power	1260	OPR			5.0
Total		47530				91.7

destined for the 4000 MWe UMPP at Krishnapatnam and Andhra Pradesh, which is due online in 2013. Coal would also supply the 4000 MWe Shahapur project in Mahrashtra.

By 2011, two Memoranda of Understanding (MoU) had been planned for the total project investment of $5 billion, to involve a 2 Mt/y coal mine, 200 km railway, port and a 2000 MWe project costing total of US$3.5 billion. A further project in Indonesia, the Jambi project, consisted of another coal mine and transport and export infrastructure costing $1.5 billion. It was expected that the project in Sumatra would be completed by 2016. In 2010, Reliance acquired three coal mines, in Sumatra from PT Sriwijaya Tiga Energi and PT Brayan Bintang Tiga energy. The three mines cover an area of 125,000 ha and contain 2 Gt of coal. All this coal was destined for Krishnapatnam.

IPPs sought government intervention in anticipation of the rise in imported coal, which entailed a rise in delivered coal prices. The 14 member Association of Power Producers (APP) set up an expert committee to deal with the issue of imported prices. Reliance, Tata, Essar Power, Adani Power, GMR Energy and Jindal Power could face changes in law in Indonesia under the new benchmark pricing which means that coal exporters, many dealing with India, cannot underprice coal, but will need to adhere to a price indexation system based on past prices. In addition, Australian exporters may be subject to export taxes on excessive profits, as well as imposing carbon taxes. The estimated hike in prices could be 20–25 US$/t. Some 50% of coal imports come from Indonesia and 5% from Australia. The APP Committee wanted to pass coal price hikes through to the tariffs in a way that was agreeable to the government.

6 Conclusions

In recent years, there has been a convergence of international trade with traditional domestic markets, with imports increasing in many coal producing regions. The influence of trade on domestic markets has been twofold. Firstly, imported coal displaces domestic production; secondly, international price trends may drive prices of what remains of the indigenous market for coal if imports are significant.

Where transport infrastructure is adequate, imported coal has displaced locally produced coal for one reason or another. The Pacific market is interesting as there are large importing countries from both an OECD and a non-OECD perspective. All are vying for secure coal supplies from the international seaborne market, but some are operating under tight emission standards such as Japan and Korea. Countries like India are readily importing coal to maintain steady supplies, while operating power generating plants under less stringent emission standards. Interestingly, China is bridging these two tier markets, having newly adopted emission standards to rival those of OECD Europe. All countries have one thing in common which is the continued demand for imported coal.

China and India are rich in coal reserves, and despite the potential for economic slowdown in the short to medium term, long-term growth in electricity demand in these two economies could push coal demand higher. However, it is easy to ignore the importance of countries such as Japan and Korea which remain among the largest importers of hard coal in the world. Both countries are in the top three coal importing countries, along with China, but India is catching up.

In the past, Japan and Korea had flourishing coal industries, but migration of working coal faces into difficult geological conditions and ensuing rising costs has meant that they have become almost entirely dependent on imported coal. This is a pattern that may be reflected in some European hard coal industries in the near future, such as Germany.

In the early 1950s, Japan had almost 950 mines producing 47 Mt of coal per year. Interestingly, the country underwent a massive cut in mine numbers in the 1960s. By 1992, Japan had less than 20 mines operating and produced just over 8 Mt/y of high quality bituminous coal. Today, Japan imports some 165 Mt of hard coal, accounting for 20% of the world seaborne market. Two thirds of its imports are bituminous steam quality and the rest is coking coal. Coal-fired power stations are almost all sited on the coast, so the logistics of importing coal are straightforward.

There is little difference in quality between domestically produced coal and imported products. Indigenous coal qualities are similar to equivalently ranked coals that are traded internationally. Domestic coal mines cannot operate at the scale needed to meet demand. In some ways there are similarities with India, where imported coal is bridging the gap between higher demand and lower local supply. Demand for steam coal alone is 150 Mt/y.

The cost of coal delivered to all power stations in Japan is determined by the price of internationally traded coal. In turn, Japanese utilities are some of the most important price negotiators in the world, and have long been world price setters, based on its annual negotiations with Australian export producers. With the emergence of China and India as major importers, this influence could diminish somewhat.

In 2002, subsidies to the Japanese coal industry were eliminated. In Europe, Spain continues to support its domestic hard coal industry, but in the absence of market support, the industry could follow a similar path to Japan (and Germany). As well as operating a few small mines in the north of the country, Japan now offers extensive training and exploration expertise for other countries, not least to China, Vietnam, and the world's (current) leading steam coal exporter, Indonesia. Mining engineering services in mechanised mining systems, safety, and management are all provided.

Korea has had a similar history to Japan. Domestic coal consists entirely of anthracite, while imports comprise 70–80% bituminous steam coal, with 20% coking coal, and small amounts of anthracite.

Domestic production is around 2.5 Mt/y. In the 1980s, domestic coal accounted for 50% of Korean supplies; by the 1990s, domestic production provided 30% of the nation's supply. Today, the demand for coal is met by imports, although a third of anthracite supplies still comes from domestic mines. Korea imports more than 100 Mt of hard coal every year, and has been one of the top three hard coal importers for some years. The cost of all coal delivered to power stations in Korea is dependent on the price of internationally traded coal.

In China and India, imported coal plays a marginal role in terms of volume, providing perhaps 5% and 10% of these countries' respective supply. China once produced more coal than it needed and, until recently, was a regular net-exporter to the international market. Between 2007 and 2009, China became a massive net-importer of hard coal, switching its role in the world market.

In China, coal imports account for such a small proportion of the market yet command a significant influence over coal price negotiations between domestic producers and power utilities. China produces almost half the world's supply of coal. Its domestic mines' activities determine the degree to which imports are needed, and the volumes can be sizeable. As such, the draw on imports can affect international coal prices, and China's markets can affect the price of coal in Europe.

The demand centres in China are located in the southern and eastern regions, along the coast of China, the most significant being Guangdong. Logistically, these regions are located a considerable distance from the domestic mining regions which are located inland in Shanxi, Shaanxi and Inner Mongolia. Rail infrastructure is still oversubscribed for freight routes although great strides have been made to speed up traffic and modernise freight lines. Coal from the mining regions still requires rail transport to the northern ports before being shipped by sea down the Chinese east coast.

Seaborne traded foreign coal and seaborne domestic coal converge at various import points along the Chinese coastline, competing on a delivered price at the ports. The quality of Chinese coal is generally very good, and in the past has been cheap enough to export, which explains why domestic and imported coal is easily interchangeable. The Chinese coal market is to some degree 'micromanaged' by central authorities which determine the closure and restructuring of coal mines (often due to safety reasons), and also influence trade export quotas. However at the same time, coal products are competing on price and tonnage, a new market based approach to coal negotiations, and changes in the exchange rate, making imported coal increasingly attractive. Negotiations between utilities and coal suppliers within China are influenced by international prices, despite the relatively small role imports play in volume terms. This is in contrast to the USA, which imports small amounts, but these have almost no obvious influence on US domestic prices.

The influence of China may well increase in the future, and become the primary driver of world prices. If power developments continue apace in China, the Guangdong Province alone could have more coal-fired capacity than Japan or Germany within a few years, and much of this will be seeking coal from the internationally traded seaborne market.

In India, imported coal serves two criteria: one is a blend coal for lowering the ash content of coals to coal-fired power stations; the second is that imported supplies bridge the gap created by local supply problems. India also has the potential for coal imports to penetrate local markets which are already doing so in more than 40 GWe of coal-fired generating capacity. However, there seems less, if any, arbitrage between imports and domestic supplies compared to the Chinese market. Import demand tends to even out fluctuations in demand and power station stock levels resulting from disruptions from local suppliers, but there seems less reported evidence of price competition. A few projects however are contractually bound to coal sourced from Indonesia, especially among the new ultra mega power projects.

Indian coal is generally low in production and transportation costs, but imports offer better availability and quality. Coal quality in India is good in some respects, such as heating value, but ash content is very high and the coal is difficult to clean using conventional coal preparation methods – ash removal therefore becomes an issue for the power generator.

There has been a threefold rise in coal production since 1990 (fivefold since the 1980s) and the country produces almost 500 Mt/y, making it the third largest producers in the world behind China and the USA. This is a considerable effort, yet pressure remains on domestic producers to develop new mine capacity. Coal mines in India are located in the north of the country and inland. Many operations are overmanned and unproductive by world export standards, using small-scale mechanisation. A few mines are starting to adopt large scale mechanisation, which could spread across the country but this will require considerably more investment. Regardless of these issues, coal mining is a low cost industry. Most mines are opencast, and many serve power stations both minemouth and in other regions.

The high demand however is also a function of the excessive fuel requirements of less efficient coal-fired plants. China on the other hand has a programme to shut smaller and inefficient units of less than 300 MWe, and so the efficiency of the fleet is progressing quickly. India has no such programme and so the fleet is progressing rather more slowly.

New so-called ultra mega power projects are garnering the opportunity to provide bulk power to local public utilities using larger generating units with up-to-date technology; almost all are located on the coast and can exploit the international coal market.

In summary, with a lack of significant oil and gas reserves all the countries featured in this report rely on coal to play a role as a secure form of power generation. However, security of supply of coal can be marred if there is complete dependence on domestic sources, which often proves inadequate where there are limited coal reserves or the infrastructure is inadequate to transport the coal from mine to power station (except for minemouth stations). With more power stations located closer to demand centres, and away from mines, supplies today are always supplemented with imported coal supplies. Coal qualities can be improved through coal blending, but imports can then expose domestic markets to the fluctuations in international prices and market dynamics outside the influence of these individual markets. Prices are driven in part by Japanese and Korean price negotiations, and domestic circumstances in China. Indian domestic mining is less influenced by import coal prices.

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