Impacts of seaborne trade on coal importing countries – global summary

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Abstract

In recent years, there has been a convergence of international trade with traditional domestic markets, with import increasing into many coal producing regions, the influence of trade on domestic markets has been twofold. Firstly, imported coal displaces domestic production, and in doing so, 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 a 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 is left where domestic supply is unable to fulfil. This report examines the various factors that have led to rise in popularity of seaborne-traded coal, and seeks to discuss the future of domestically produced coal in some of the major coal markets of the world.

This report provides a global perspective of the changing trends in coal imports. Two separate reports provide more detail of the Atlantic and Pacific markets.

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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 wong (currency)
Lakh	100 units, 10^2
LCPD	Large Combustion Plant Directive (EU)

LHV	lower heating value
MCIS (NWE)	McCloskey Coal Information Services (North West Europe)
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 metric 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 (1000 kWe)
MWth	megawatt capacity (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

The international trade of coal has matured over the last 30–40 years to become a 1 Gt global market with immense potential for further growth. The world seaborne market is dominated by steam coal, at least in terms of volume traded. In 2009, international steam coal trade was worth US$71 billion (versus $84 billion in 2008 and $51 billion in 2007). The seaborne-traded market for metallurgical (mainly coking) coal is roughly half that of steam coal in tonnage terms, albeit traded at a considerable price premium. The focus of this report however is mainly on steam coal for power generation and heat raising but some discussion on other hard coals is made.

For many years, international trade has accounted for some 15–20% of world steam coal supplies, which means locally-produced coal accounts for more than 80% of all the coal consumed in the world. Where transport allows, in many OECD and non-OECD regions, imported coal has displaced locally-produced coal for one reason or another. A key question that arises is, to what extent do coal imports displace domestically-produced fuel, 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.

International trade provides power stations with fuel where there are few or no coal resources to be exploited. Yet, where coal does exist, imported coal provides many useful benefits notably lower cost and better environmental performance. Some domestic coal industries however are affected by a shrinking market for their product, particularly in OECD Europe and in parts of OECD America. Most of this reduction in demand is due to the closure of ageing coal-fired plants, and the replacement of this older generating capacity with cleaner natural gas fired plants.

This report constructs a picture of how the international trade in steam coal developed over time, and highlights the drivers that improved the conditions for coal imports to penetrate markets that once dominated by domestic production. The report covers some of the rudimentary issues that have led to the above trends and are examined as follows:

- **World coal production trends** and the increasing role of international trade, the development of the Atlantic and Pacific markets and the role of dry bulk shipping.
- Coal supply trends in importing countries and **structural changes** in the demand for steam coal, in the power generating sector.
- The role of **environmental regulation** and issues pertaining to switching coal of different quality.
- Trends in **international prices** for hard steam coal and the influence on prices in importing countries, and **the role of state aid** in selected OECD coal importing countries.

Separate reports look at long-term trends in steam coal demand and supply, environmental regulations, and crucially the relative cost advantage of imported coal over domestic supplies in the Atlantic and Pacific markets. Analyses in these reports include mapping and locating coal-fired power stations across the world that might use foreign imported coal, along with identifying the mode of inland transport, the possible routes, and the ports of entry for these imported shipments. There is also important discussion on the domestic mining industries and where applicable, the financial aid that has been awarded to some coal industries to keep them operating over past years, and how this will change in the coming years.

It is relatively straightforward to identify the various factors that influence coal switching to imported coal supplies, but it is considerably more difficult to quantify the degree of these influences. Even so this report attempts to highlight the factors that have affected domestic production in the OECD, and provide evidence of the direction that coal industries in other countries could take.

This global summary examines the fuel switching and coal procurement behaviour of power plant operators in selected OECD countries, and their in response to the regulatory issues that limit sulphur oxide (SOx, chiefly SO_2) and particulate (PM) emissions imposed on coal-fired power stations at both a national and local level. Since the 1990s, the imposition of such regulations led to the rise of both the blending of imported coals with domestic products, or switching completely to imports. In combination with further regulation of nitrogen oxides (NOx, mainly NO_2) and greenhouse gas (chiefly CO_2) emissions there might be an investment decision to switch from coal-fired stations to cleaner natural gas. China and India are likely to maintain their massive coal industries, but some displacement of domestic coal is likely to occur in markets within close proximity of international markets. More displacement of domestic coal could result from increasingly stringent emissions regulations, particularly in China.

Industrialised economies demonstrate a sophisticated structure of emissions monitoring by both utilities and state authorised agencies and have mechanisms in operation to ensure compliance with the relevant emission regulations. Industrialising economies are following this path and, in China especially, emission standards rivalling those of some of the most stringent in Europe (at least for new plants) are being introduced. Emission regulations regarding SOx and particulates are explained later in this report. NOx emissions are generally less affected by switching from domestic to imported coals, although small effects can be experienced.

If lower emissions can be achieved at a lower generating cost, then the power station operator enters a win-win situation, especially where a power station operates in a deregulated competitive market. Relative coal pricing is discussed later in this report. Blending domestic and imported coal is commonplace, wherever two or more coal products are compatible, while a complete switch to imported coals is necessary where the domestic supply for coal has disappeared or become prohibitively expensive to produce without state aid. Walker (2001) covers much of the demise of coal industries across parts of Europe, and the same analogy would apply to the rest of the OECD producers.

A separate report looks at the various steam coal trends in selected countries in the Atlantic market, notably Germany, Spain, UK, and the USA. Historically, imports may have filled a temporary shortfall in domestic supplies, but once the appetite for imported coal exists, shifting towards imports can be done easily, provided the infrastructure is there to receive and transport the coal shipments, and the price and quality of the product are the same or better than those of the domestic product. The European countries all had a flourishing domestic industry, but now competition from imported coal has fundamentally changed the way these countries source their coal. The USA remains a massive producer of coal, but has a relatively small import business. Nationally, foreign imports do not pose a threat to the domestic steam coal industry, but the USA has experienced a massive shift within the country due to interstate trading. This shift in regional production illustrates the shifts seen elsewhere around the world in the international market and hence justifies inclusion in this report.

A third report covers the Pacific markets of China, India, Japan and Korea. These countries represent some of the largest importers of steam coal in the world. For both industrialised and industrialising Asia, imported coal offers a source of coal under circumstances where domestic producers cannot fulfil orders. In the case of China and India, this is purely a function of transport logistics, while for Japan and Korea the inadequate reserves and costs of extraction are prohibitive. Under various scenarios, the IEA place China and India as the two foremost nations that will push coal demand even higher in the future. China's coal demand currently 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 according to the World Energy Outlook (IEA, 2011).

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 see an increase of 1000 Mtce to 3000 Mtce between 2009 and 2035 under the New Policies and Current Policies scenarios. In the non-OECD countries, power stations were traditionally located at mine locations. As population and economic development occurs, many demand centres in India and China are increasingly being located away from the coal producing regions. The demand for coal, and the demands on the transport infrastructure often outstrip the ability to deliver, and this renders a complete reliance on domestic coal supplies as either uneconomic or impractical at current capacities.

2 Production trends in hard (steam and coking) coals

The global economic downturn in 2009 affected economies in many ways, including the largest reduction in oil consumption in 30 years and a fall in global energy demand. As oil production fell in 2009, so did that of natural gas, yet coal production in industrialising economies grew enough to push global production up by 2%, quite the opposite to the markets for oil and gas. Economic growth in industrialising economies seems to have been a result of many factors, such as improved education, domestic and foreign capital investment and better living standards. All of this is made possible by the adequate supply of least-cost electricity (in economic terms), which today happens to be coal-fired power. Some of these projects were financed locally, others may have been co-financed using multinational institutions, but nearly all projects have featured foreign equipment manufacturers or design and consultancy expertise. Therefore, capital investment in the Far East remains an important growth area for many heavy industrial firms around the world today.

By 2010, global coal production reached 7063 Mt consisting of 6200 Mt of hard coal (roughly 85% attributed to steam coal for power generation and heat raising industry and 15% metallurgical coal) and the balance comprising of lignite (IEA CI, 2011). When adjusted to Mtce these figures are much lower, as seen in the figures published in the IEA World Energy Outlook, and so some care must be taken when interpreting coal figures from different documents. Figure 1 shows the extent to which China dominates world hard coal production, producing as much coal as the next nine biggest producers combined. These top ten producers combined account for more than 95% of world production so it is no surprise that China produces almost half the coal in the world today.

Since 2000, hard coal production has increased annually by a substantial 5.7%/y; all the growth is attributed to demand in non-OECD economies, notably China and India. Both bituminous steam and coking coal markets experienced a surge in production of around 6%/y, but it was the small anthracite market that outpaced the market, experiencing a massive 13%/y rise between 2000-09, albeit only accounting for around 1% of the total hard coal production.

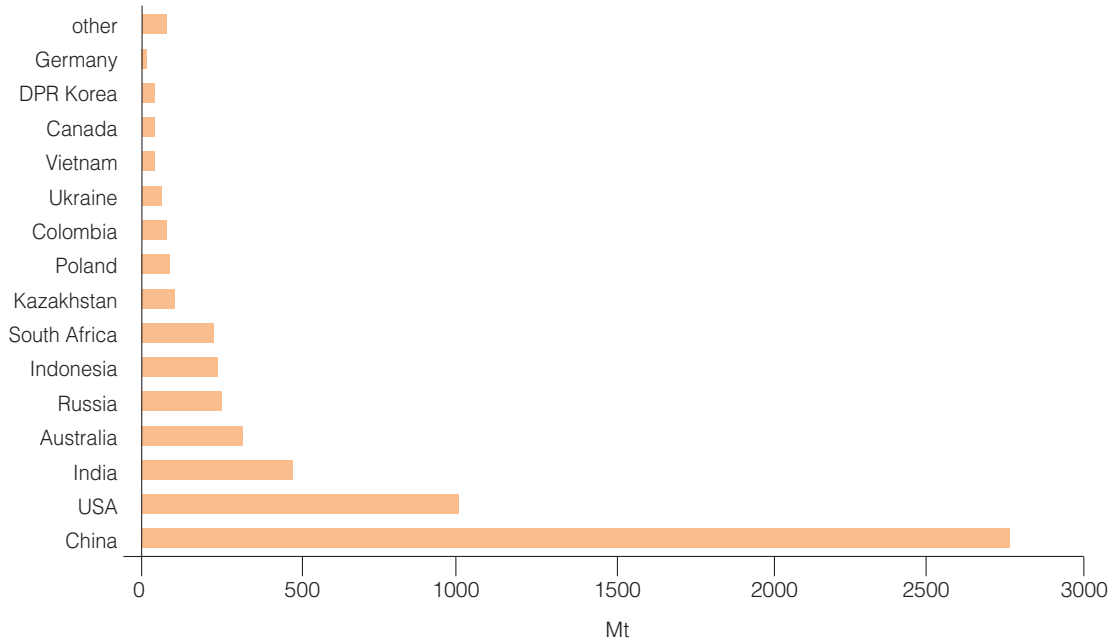

Figure 1 Top 15 hard coal producers in 2008, Mt (IEA, 2010b)

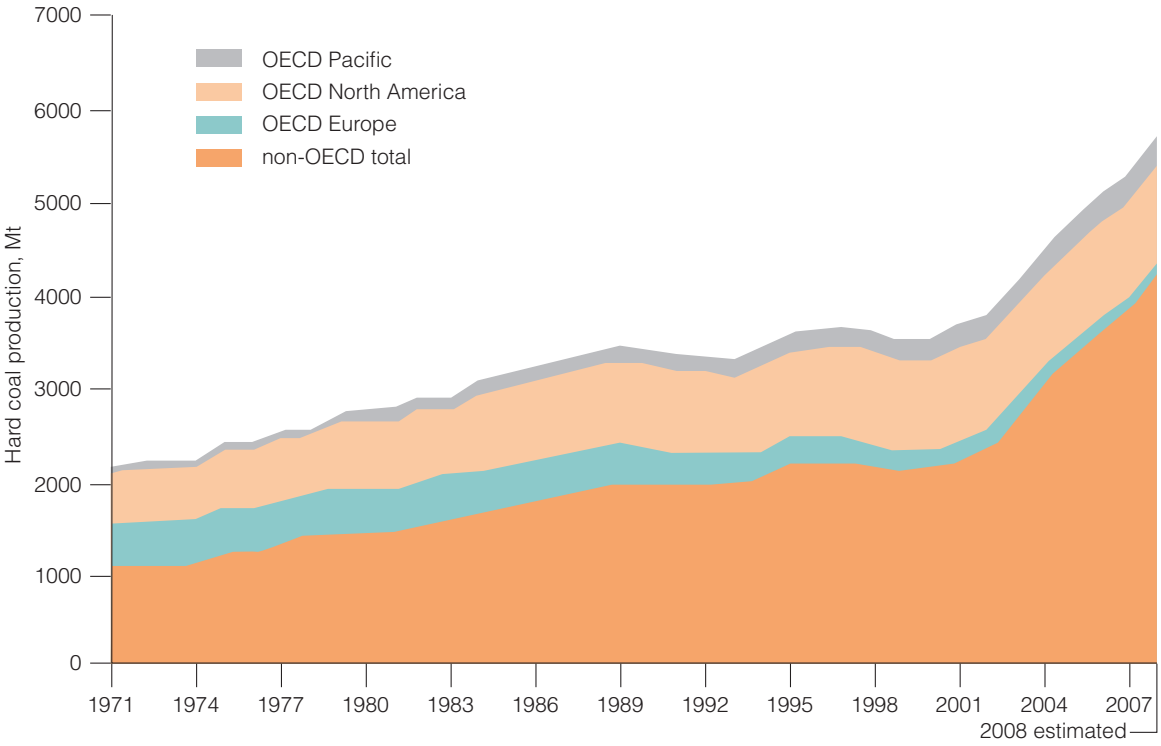

Figure 2 Global hard coal production (steam and coking coal), Mt/y (IEA, 2010b)

In terms of the geographical spread, production has gradually petered away in OECD countries (*see* Figure 2), with the exception of Australia which has the largest hard coal export business in the world. While OECD countries squeeze coal out of their economies, emerging economies in the Far East are taking a competitive advantage by not being as heavily bound by environmental and climate targets. They are using coal as a platform to help fuel economic growth through heavy and light manufacturing, which are activities that were once strong in European and North American countries. Almost every European country in this report has seen a decline or even disappearance of large-scale coal mining, while the USA has seen decline in some states and an increase in others. Amongst the Asian economies, China and India are two nations where imported coal competes with domestic production, at least on a marginal level for now. The price of international coal versus domestic coal in all these countries is discussed in the separate reports on the Atlantic and Pacific markets.

3 Global steam coal trends

Hard coal (bituminous, anthracite and some subbituminous coal) production has been noticeably affected by a number of factors in OECD Europe. By 2008, production in OECD Europe had decreased by a massive 70% over the previous three decades to just 124 Mtce. This was a reduction of roughly 330 Mtce; a considerable contraction in the industry. Estimates for 2010 has seen production fall further to 110 Mtce.

Figure 3 charts the reduction in hard coal production in OECD Europe in ten-year intervals and shows how between 1978 and 2008, the contraction was not uniform across the period. While there was some modest reduction in 1978-88, the period 1988-98 saw the biggest reduction, which was felt by the coal industries in Poland, UK, Czech Republic and Germany. Smaller reductions occurred in Belgium and France, both of which experienced a steady reduction throughout the entire 30-year period, but with a small industry base this led to a near disappearance of their mining industries.

Since 1978, Poland and the UK lost some 85–100 Mtce of production due to restructuring, rationalisation and competition. Germany lost about 60 Mtce of production while the Czech Republic has contracted by 45 Mtce since 1978. By 1998, most of Europe's industry experienced rationalisation, but contraction continued in the UK, Germany, and Poland. Today, Poland remains the largest producer of coal in Europe from its operation in the Silesian Basin. For many parts of OECD Europe, imported steam coal is now the sole source of supply; almost all coking coal is now imported.

Whilst domestic coal production has ceased in a number of OECD European and Asian countries the pattern has been less evident in the USA, although regional shifts within the country have occurred.

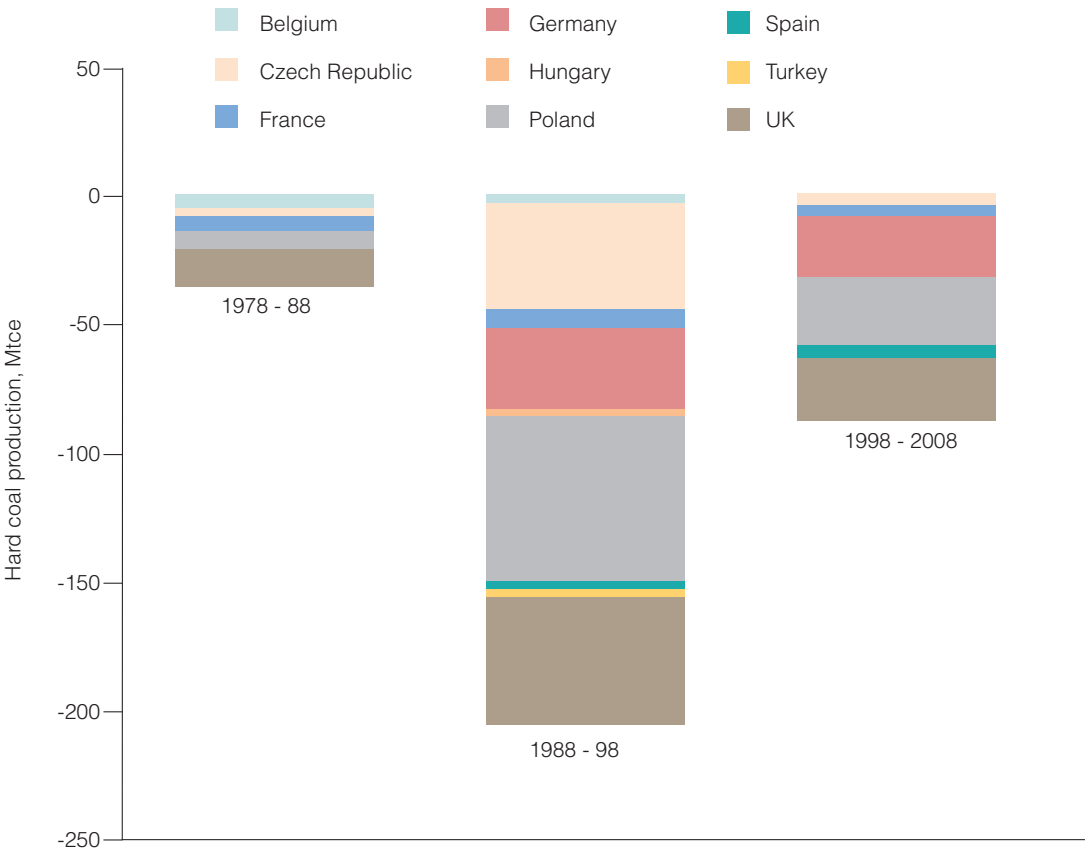

Figure 3 Change in OECD European hard coal production since 1978 (IEA, 2010)

Australia is the major OECD exception where production of hard coal continues to increase to meet the growing seaborne-traded market. Elsewhere, growth in production to meet this export trade has come from non-OECD economies. International trade is therefore a key part of OECD coal procurement strategies, and even amongst non-OECD countries, imports are growing in importance across South East Asia, but most notably in China and India (see the reports covering the Pacific market).

4 The increasing role of international trade

Over the years, the international trade in coal has been studied in a variety of reports, some of the most concise being the *IEA Evolution of Coal Markets* (1997), and more recently the *World Market for Hard Coal* by the German Importers Association, *Verein der Kohlenimporteure* Annual Report 2010 (VdK, 2010). Much of the following section has been drawn from these reports, but adapted to reflect some of the major upheavals that have occurred since the publication of these documents.

When looking at the actual volumes and methods of trade, more than 90% of the 1000 Mt of global hard coal exports is by sea, although this balance could shift slightly as China expands imports from Mongolia by rail. In terms of steam coal, Figure 4 illustrates the evolution of the world export market since 1960. The key developments over the period include a rise from 146 Mt in 1971 to 707 Mt in 2009. During this time, the profile of exporters changed vastly. In the 1970s, almost all trade occurred in the Atlantic market with the USA, Germany and Poland as the chief exporters. By 2007, the world coal market more-or-less settled into its current form (as of 2012). Exports from producers in the Pacific market in (Australia, Indonesia, China, and Vietnam) accounted for some 65% of the global exports in hard coal. The rest is accounted for by Atlantic producers.

One of the chief reasons for the rise in internationally-traded coal remains the fundamental price advantage that seaborne-traded coal has over almost all other energy supplies, with little or no

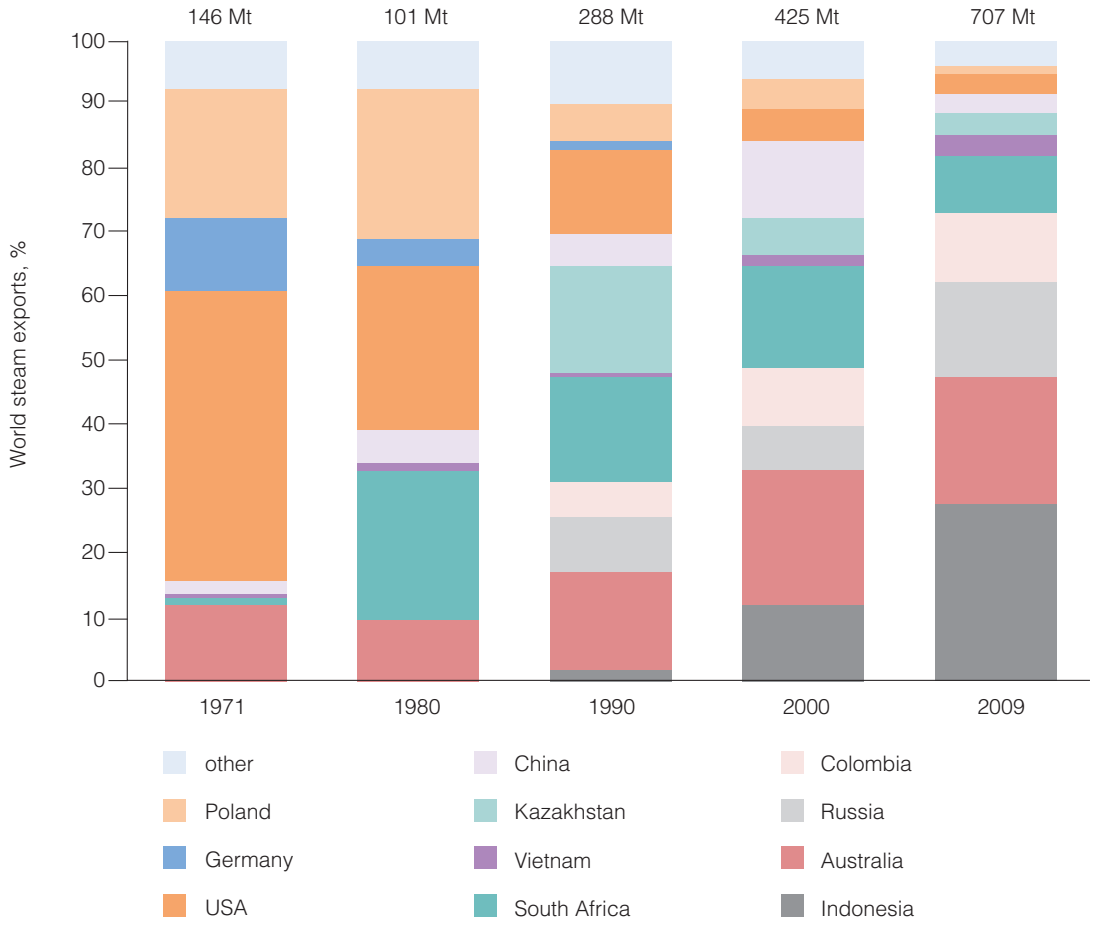

Figure 4 World steam coal exports, % share by exporting country (IEA, 2011)

detriment to coal quality and often an improvement on the quality of domestic coals. The subject of coal pricing is discussed later. Coal exports have also been driven by the world's need to improve the security of supply of primary fuels. Coal users are no longer tied to domestic producers in the way they used to be. If the transport logistics are in place, arbitrage between domestic and imported coal enhances flexibility and security of both supplies and pricing. There are exceptions, such as minemouth power stations that are tied to specific producers and coal qualities that may become prone to operational disruption if the local coal supply stops for any reason.

Imported coal can be obtained by a variety of means; for some countries it is possible to send the coal overland by rail, but a majority of the world's internationally-traded coal is transported by ocean vessels over long distances. According to Euracoal (2008), European cross-border trade in hard coal exceeded 900 Mt, of which 820 Mt was seaborne trade. In terms of seaborne trade, steam coal was

Table 1 Ocean voyage distances and times by export port and destination (Author's estimates based on Netpas Distance, 2010)

Market destin-ation	Export country	Export port/ region	Via	Import country	Port of entry	Distance between ports, nm	Average speed, nm/h	Approx voyage time, days
Pacific	Colombia	Puerto Bolivar	Cape of Good Hope	Japan	Yokohama	14320	13	46
Pacific	South Africa	Richard's Bay		Japan	Yokohama	7555	13	24
Pacific	Indonesia	Kalimantan		Japan	Yokohama	2515	13	8
Pacific	Australia	Newcastle (NSW)		Japan	Yokohama	4275	13	14
Pacific	Australia	Gladstone (QLD)		Japan	Yokohama	3740	13	12
Atlantic	USA	Hampton Roads		Northwest Europe	ARA	3490	13	11
Atlantic	USA	Mobile (Gulf)		Northwest Europe	ARA	4792	13	15
Atlantic	Colombia	Puerto Bolivar		Northwest Europe	ARA	4360	13	14
Atlantic	South Africa	Richard's Bay		Northwest Europe	ARA	7010	13	22
Atlantic	Australia	Newcastle (NSW)	Cape of Good Hope	Northwest Europe	ARA	12200	13	39
Atlantic	Australia	Newcastle (NSW)	Suez Canal	Northwest Europe	ARA	11630	13	37
Atlantic	Australia	Gladstone (QLD)	Suez Canal	Northwest Europe	ARA	11680	13	37
Atlantic	Indonesia	S Kalimantan	Suez Canal	Northwest Europe	ARA	9155	13	29

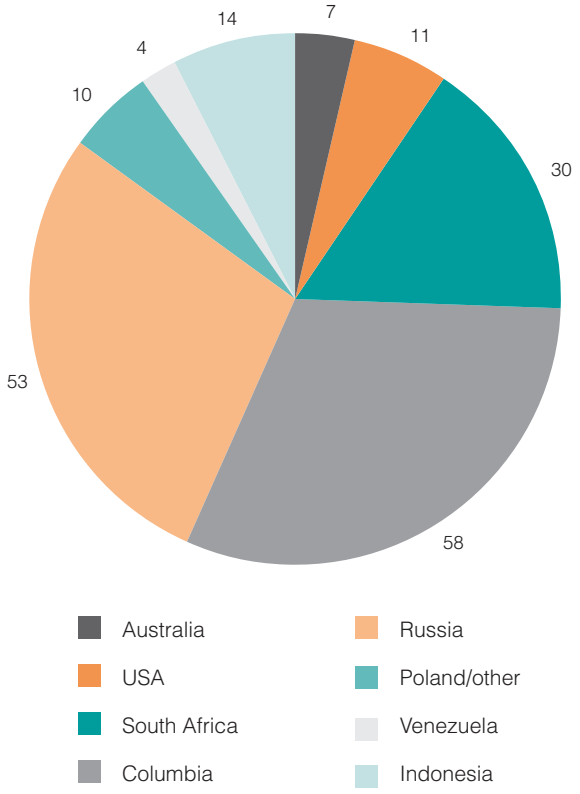

Figure 5 Steam coal exports in the Atlantic market in 2009, Mt (VdK, 2010)

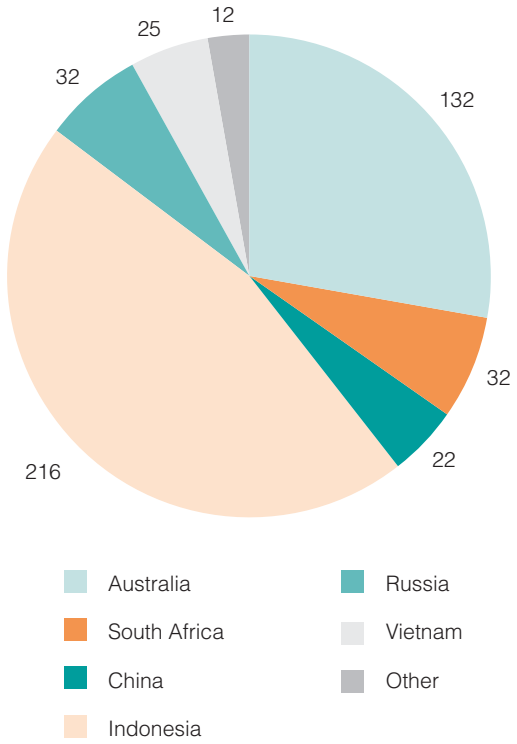

Figure 6 Steam coal exports in the Pacific market in 2009 Mt (VdK, 2010)

destined mainly for the power generation industry (620 Mt), far outstripping the demand for coking coal for the steel sector (200 Mt), although some steam coal is used for steelmaking.

Seaborne trade therefore opens up opportunities to obtain coal from more distant and varied sources. The international market is split into two broad geographical markets, the Atlantic and Pacific, and within these the trade is further split into the various coal products of steam and metallurgical coals.

Focusing on the geographical aspect of the world market, in the Atlantic the key coal exporters are Colombia, Poland, Russia, South Africa, and the USA. Based on an average speed of 13 nm/h, Atlantic voyages range from a few days to several weeks. Coal being exported from Russian coal to Germany (via Latvia) takes three days, while South African coal to the northwest port hub of Amsterdam-Rotterdam-Antwerp (ARA) takes three weeks. For Australian and Indonesian coal imports into Europe, the voyage can last 29-37 days, making this journey costly when freight prices are high (*see* Table 1). This comparison is purely between seaborne shipping port and ignores the additional time for inland transportation.

Figures 5 and 6 show steam coal exports in the Atlantic and Pacific markets. While there is some overlap between each region in terms of suppliers, the regions have some distinctive suppliers which have a geographical advantage.

In the Pacific market, the main exporters are Indonesia, Australia, China, and Vietnam which supply coal to the main importers in Japan, South Korea, and Taiwan, with China as a major trader in both exported and imported coal. The voyage between Qinhuangdao in Northern China and the import port of Yokohama Bay in Japan is as little as four days, offering a much quicker delivery than the 14 days it takes to ship coal from New South Wales in Australia.

The reason for the specific market split between Atlantic and Pacific oceans is due to the distance limits of seaborne freight between these two oceans. Ships sailing from one ocean to the other generally have to compete with the shorter distance

trades within these markets. For this reason, export prices in the two regional markets might run in parallel and influence each other, but can experience different dynamics based on local events.

Shipping coal from the Pacific to the Atlantic market can be problematic where passage through the Suez Canal means passing close to regions patrolled by Somali pirates. While there appears to be little reporting of coal ships being targeted, it remains an increasing risk, despite efforts by government forces to patrol waters in the Indian Ocean. Nevertheless, coal is shipped from the Pacific to the Atlantic on a regular basis, albeit in small quantities. Occasionally, coal from the Atlantic market may be traded to the coal importers in the Pacific. The growth of the markets for imported coal in Asia has led to the unusual possibility that coal supplies from the Atlantic market could be shipped eastward to markets like India which is typically served by South Africa and the Pacific exporters (ICR, 2010).

As mentioned above, international coal trade is split into two product markets and two geographical trading regions. Regarding coal products, the seaborne market for coal is split into steam and coking coal. Other marginal products such as semi-soft coking coal, pulverised coal injection products, and anthracite form a smaller, but growing, share of the seaborne market. Both steam and coking products are traded within the Pacific and the Atlantic markets.

Almost all seaborne traded coal is carried by the world's dry bulk shipping fleet, but some localised shipments can be moved by large barges which are not discussed here. The main seaborne fleet consists of ships that have a deadweight of up to 150,000 tonnes and are suited to carry any dry bulk such as iron ore, steel, grain, aside from any coal, but separate from the tanker fleet where the primary cargo is liquids and chemicals. Dry bulk ships also differ from the container fleet which carry manufactured and value added products.

Deadweight refers to the carrying capacity of the vessel in tonnes, typically including the fuel capacity to propel the vessel (as well as fresh water, ballast water, and personnel) which can be around 5% of the deadweight. The deadweight is the safe carrying capacity of the ship. Coal-carrying ships are categorised in broad terms, with representative tonnages stated as follows:

- 100,000–219,999 dwt are called Capesize (too large for the Panama or Suez Canals, and so must navigate between Oceans around the Cape of Good Hope or Cape Horn);
- 60,000–99,999 dwt : Panamax (a large yet versatile vessel capable of passing through the Panama and Suez canals);
- 40,000–59,999 dwt: Handymax;
- 10,000–39,999 dwt: Handysize.

Very large bulk carriers can carry >220,000 dwt, but are usually reserved for iron ore. Based on SSY Shipping Review, Handysize and Handymax vessels account for 63% of the total vessel numbers. However, in terms of carrying capacity, Handysize and Handymax only account for 35% of the total carrying capacity. Capesize vessels (including very large carriers) account for 40% of the world's carrying capacity with just 14% of the ships. The total world fleet comprises of more than 8000 ships that can carry 545 Mdwt at any one time. Capesize and larger vessels can carry some 216 Mdwt, Panamax can carry 138 Mdwt, and the balance is taken by smaller vessels.

Seaborne freight can have a major influence on the delivered price of steam and coking coal across the world. The coal price is reported in many ways depending on where the pricing point is, whether it is at the export port, the destination port, or on the ship. The three most common terms for pricing coal are:

- FOB: Free-on board;
- CIF: Cost, insurance and freight;
- DES: delivered ex-ship

CIF is the price of coal at the destination port, just prior to offloading. CIF refers to the price of coal where seaborne carriage and insurance are arranged by the seller, where risk and costs are transferred

to the buyer once the cargo passes the ship's rail at the port of destination (ICC, 1999).

FOB is the price of coal at the exporting port, prior to being loaded onto the ship. Seaborne carriage is arranged by the buyer and delivery risk and carriage costs transfer to the buyer when the cargo passes the ship's rail at the export port.

DES is similar to CIF. Seaborne carriage is arranged by the seller and determined by the port of destination. Risk and costs are transferred from the seller to the buyer when the goods are placed at the disposal of the buyer on board the ship. The difference between CIF and the FOB is the cost of seaborne freight and insurance. However, reported FOB and CIF prices for particular trade routes rarely provide an accurate freight figure unless the delivery dates are consistent, and will vary depending on the ships used.

Freight rates are determined by the overall dry bulk market, that includes the transportation of iron ore, steel, and grains to name but a few. Dry bulk commodity rates have risen in the past years leading up to 2008 due to high demand and the slow rate at which new vessels came online, but rates have subsided since these vessels were commissioned. The global freight market was short on capacity, chiefly due to the rise in Chinese demand for commodities, and the tightness in the freight market appeared to worsen more in the Capesize market than in the smaller vessel Panamax market. New additional freight capacity increased very slightly in the period 2001-05. Then new capacity came online *en masse* after the price peaks in 2006-10, causing the market to settle at a new and much lower equilibrium (*see* Figure 7).

Shipping rates are published in various market newsletters and journals and the daily reports often come in the form of the Baltic Freight Index published by the Baltic Exchange which takes a daily consensus of the major shipping brokers. Shipping brokers also publish individual shipping analysis and price data. Freight costs are quoted on a daily charter basis in $/day, and rise with the size of vessel. However, on a per tonne basis, Capesize rates are typically lower due to the economies of scale. Figure 8 shows the trend in shipping rates since 2000, when the average cost of transporting coal was less than 10 $/t, rising to 30–40 $/t by 2007-08. Capesize rates between 2002 and 2009 were at a premium over the Panamax rates.

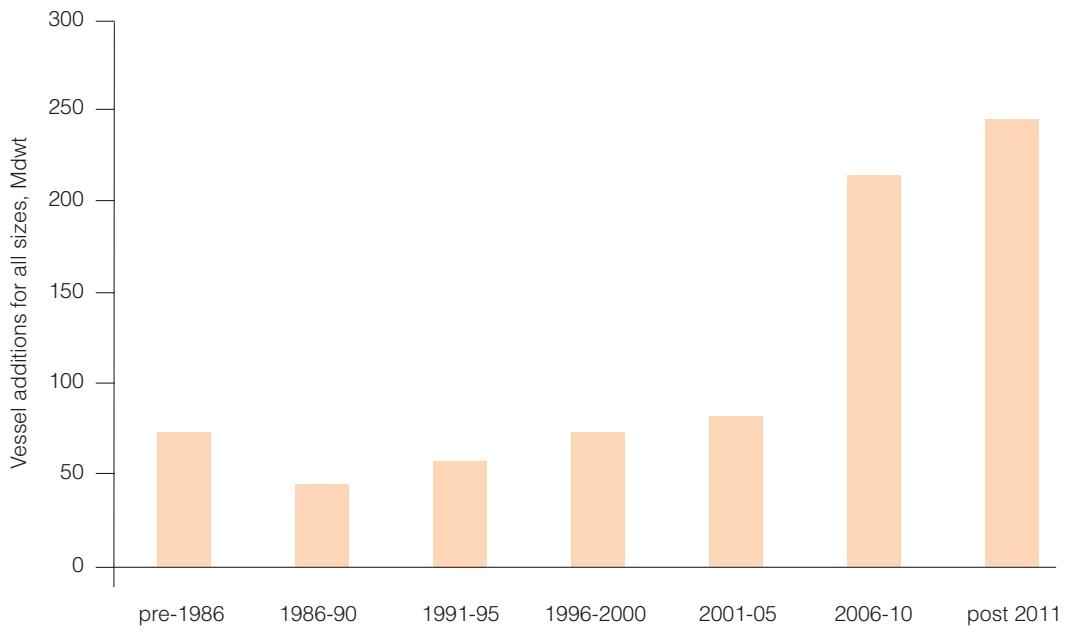

Figure 7 Five year vessel additions for all vessels, Mdwt (SSY, 2010)

A typical long-term freight rate is difficult to assess as there are many factors that determine this. Recent years have masked any form of long-term trend when in 2007-09 the coal exporters saw a significant level of volatility in shipping rates. In this period, daily charter rates climbed to more than 234,000 $/day at the peak of the market in May 2008 for Capesize vessels, to record lows of 2316 $/d in December the same year. The cost of shipping is a function of the demand and supply for the existing fleet of ships, which in turn is influenced by the scrapping of older ships and the addition of new ships as well as the demand for commodities. All these factors determine the world capacity of dry bulk shipping. Older ships however are kept in service in time of high rates as the profits can be substantial, but when the market is tight, shipbuilding firms might bring on vessel capacity to soak up any demand and perpetuate a predictable drop in charter rates. Moreover, short-term volatility is driven by the general commodity dynamics for all dry bulk goods. For example, in early 2008 when the price peaked and then dropped dramatically, iron ore shipments were suspended from ports in Brazil due to a safety incident (SSY, 2008). Port problems such as damage to piers resulting from bad weather means that physical commodities cannot be moved out of a country. This results in an excess availability of ships waiting for cargo loading. If these events occur at the same time, massive changes in shipping rates can occur.

Coal and iron ore exports are the major sensitivities as they are the largest dry bulk commodities. These in turn are determined by weather-related problems, which are often severe, despite the predictability of cyclones in many parts of the world. Therefore, many factors work for and against freight rates, and the dynamics can be different for different sized vessels. Coking coal and iron ore trades affect Capesize and Panamax markets, while the smaller Panamax and Handysize rates are affected by the seaborne demand for other commodities such as grain, other agricultural dry bulk and steel products.

Increased trade over longer distances tends to lead to higher freight rates (on a per tonne basis). Ship charters *between* Pacific and Atlantic markets are limited compared with trade *within* these markets, but are not uncommon and may increase if the price of coal is high and the cost of freight is low. South Africa is perfectly poised to supply both the Atlantic and Pacific markets due to its location,

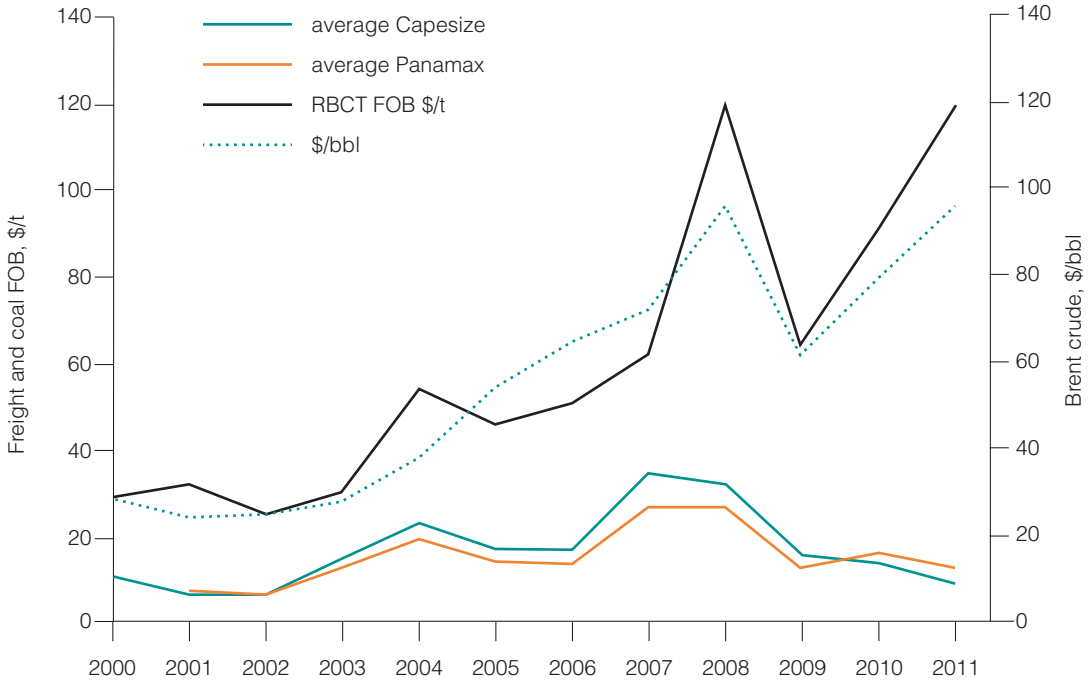

Figure 8 Freight rates, FOB coal and Brent crude trends since 2000 (BP, 2011; MCIS, 2011)

being almost equidistant at 7000–7500 nautical miles from each of the major coal import locations in Japan and ARA Europe. The price of coal in each market naturally determines which market South African exporters will choose to settle their business with; increasingly this appears to be the Pacific for now.

In a global context, China's switch away from being a net exporter of coal to being a net importer has major implications with regard to the direction of trade flow in the Asia-Pacific region, boosting demand for seaborne-traded coal while demand weakens in Europe. This additional demand from China, India, Vietnam, Chinese Taipei, and Korea adds pressure on export countries to develop capacity in both rail and port facilities. Conveniently, Indonesia stepped in to exploit this growth potential, to become the world's leading exporter of steam coal in the world; Australia remains the lead exporter when including coking coal exports.

Force majeure or industrial action occasionally create short-term shortages. Depleting stockpiles due to high demand can add pressure to supplies, trimming the surplus stocks that normally buffer against shortages in deliveries. Coal prices tend to rise during periods when supplies tighten, suggesting the capacity to mine, convey/rail, and export coal is still lagging behind demand in some countries. However, if demand destruction occurs as a result of the high prices, then prices will settle ultimately at a lower level. Port and inland transportation does not always benefit from high coal prices as port and rail rates are priced separately, often inflation linked or similar, but not usually a direct function of the market FOB or CIF cost of coal.

5 Trade trends in major importing countries

While the pattern of coal exports has changed since the 1970s (*see* Figure 4), a similar shift occurred amongst the importers; import demand shifted away from the Atlantic market towards the Pacific market. Figure 9 illustrates the share of major coal importers (by country) since 1971. The dashed line demarcates the regional split between Atlantic importers, which are above the line, and Asia-Pacific importers that are below the line. The key issue that Figure 9 shows is how Atlantic importers in the 1970s accounted for 70% of coal import demand, and how coal trade was once largely amongst the OECD European economies; later, Japan became the single largest steam coal importer, by far.

In the 1990s, Russia became a significant importer for a brief period, partly due to the break-up of the Soviet Union, where the statistics showed former Soviet production in Kazakhstan being reclassified as overland imports. At this time, imports by Asian countries emerged as a growing proportion of world trade – by 2000 Japan was once again the leading importer of steam coal, and the Asian economies of Taiwan and Korea established themselves as influential players. In 2009, the picture was the same, except for an increasing share for these countries and the emergence of China and India as steam coal importers. Thailand and Malaysia also became notable importers of coal, being particularly well positioned to receive steam coal from the rapidly growing export country of Indonesia.

The current picture therefore shows that coal imports into OECD countries are becoming less influential compared to the rise in share of imports to non-OECD economies. From a demand point of

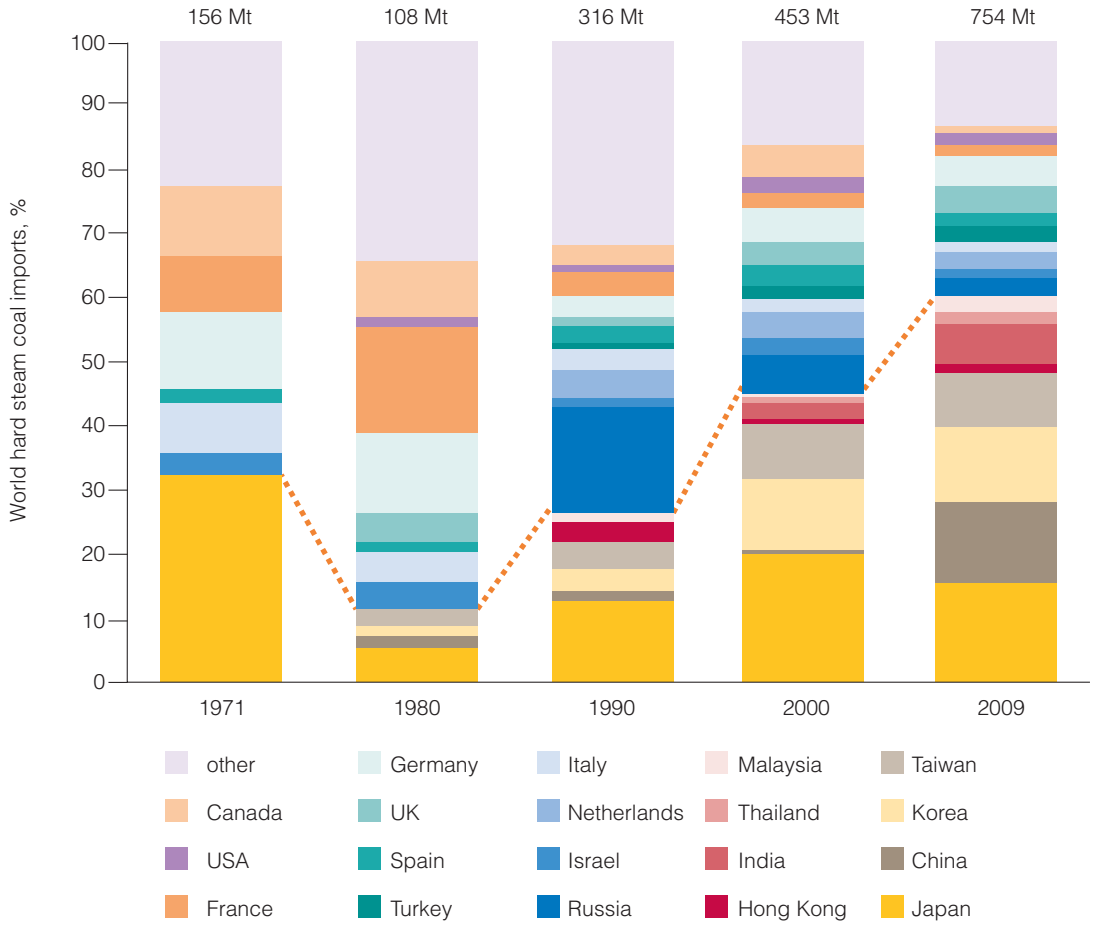

Figure 9 Coal import countries, % (IEA, 2011)

view, prices will be increasingly driven by non-OECD countries, and whilst the influence of OECD demand will still be strong, it will become less.

6 Structural changes in the demand for coal in the power sector in Europe

The previous chapter discussed the broad patterns of demand and supply for international coal, and established the diminishing role of OECD countries in the world market for coal demand. However, in parts of the OECD, the local demand for coal has shrunk, seriously diminishing the only outlet for domestically-produced coal, while simultaneously being displaced by imported supplies.

Two very important changes in the structure of power generation markets affected the demand for coal in many OECD countries: deregulation of the electricity wholesale and retail markets and, at the same time, regulation of emissions from power stations. The former is a complex dismantling of markets that spurred the development of gas-fired power generators, while the greater regulation of environmental performance of power stations created stricter criteria to further squeeze the operation of coal-fired power stations forever. Environmental regulations and penalties add considerable financial and legal risks to the more polluting power stations that use coal. In most cases, this would be coal without the appropriate measures to clean flue gas or other discharges. However, coal benefits more than gas and oil, and can be the least-risky option where the cost or price volatility of the fuel is concerned. Furthermore, coal-fired power offers a level of despatch flexibility that is matched by very few other stations at a similar cost per kWh.

Before embarking on the impact of imports on domestic coal production, it is important to understand the changes that occurred in the market demand for coal in some countries which would prescribe two things:

- the total market demand for all hard coal in a country;
- the preference for domestic coal, or imports, or both.

It is not straightforward to simplify the problem to just two factors, but within these issues are market forces that will be common to both and that resulted in the same outcome, a reduction in the market for domestic coal.

One of the key factors to affect the demand for steam coal is the contraction (or growth) of coal-fired power in the energy economy. This chapter is split into those markets where coal-fired power diminished, and those markets where coal-fired power increased. This provides the overall framework that determines the potential for importing coal. By filtering out the effects of structural change, it is possible to look at how much of the remaining domestic market has been affected by imported coals, and the factors which drove those displacements.

The focus of this chapter is on selected countries in OECD Europe (*see also* the report on the Atlantic market), where coal-fired power once played a major role in power generation, but which has lessened somewhat. Europe serves as an interesting mosaic of different domestic coal industries which have been rationalised; some have been supported with subsidies while others have adapted without state aid.

Elsewhere in the OECD, coal markets have been overhauled, for example in the USA where interregional trade has led to a massive change in coal transport flows across the country, while in Japan and Korea, domestic coal production has almost disappeared altogether. In non-European countries, coal markets have remained strong, or have grown in terms of both domestic production and import (*see* Figure 4 and Figure 9). The prominent countries of China and India are discussed in detail in a separate report on the Pacific market.

Contrary to common perception of coal-fired power in Europe, Figure 10 shows how overall output of coal-fired generation has remained unchanged for decades, although there has been some decline

since 2006. Despite this decline, about the same amount of coal-fired power is being generated today as in the 1980s, a surprising outcome considering the negative image of coal from an environmental point of view. While this trend is consistent for Europe as a region, the data tell a different story on a more local scale where coal-fired power has stagnated. For instance, coal-fired generation has fallen in Belgium, Denmark, France, Germany and the UK.

Output from coal-fired generators peaked in 2003, and again in 2005, just as the EU emission trading scheme for greenhouse gases was being introduced. Even before this, the UK had in place a trial national emission trading scheme which started in 2002 and ended in 2006, similar to the EU *Emissions Trading Scheme* (ETS) but for UK-based organisations only.

The downward trend in coal-fired power output since 2007 is unlikely to recover. The years 2008 and 2009 saw steep declines of 8% and 9% respectively in OECD Europe, and further declines are likely.

Over the period to 2016, a number of coal-fired power stations are due to be retired due to age. As coal-fired stations shut, they will be replaced with gas-fired capacity. The impact of tighter CO_2 legislation and the continuing advance of gas-fired power may well push coal out of the merit order in many countries. Such countries, including the UK, will need to adapt to a different set of uncertainties regarding their electricity supplies. Increasing reliance on imported gas and LNG will need to be carefully managed as the price volatility of gas is far more aggressive than coal; managing both gas supplies and price will create greater demands on utilities and end consumers, especially for Northern European countries in winter months.

Increased renewable power is often considered a threat to stable supplies, notably because of the intermittency of such power sources. No major economy in the world yet relies on wind power for its main source of power although Germany and Scotland have political aspirations to do so. It is unlikely renewables could sustain a large economy without vast storage facilities such as pumped storage hydro.

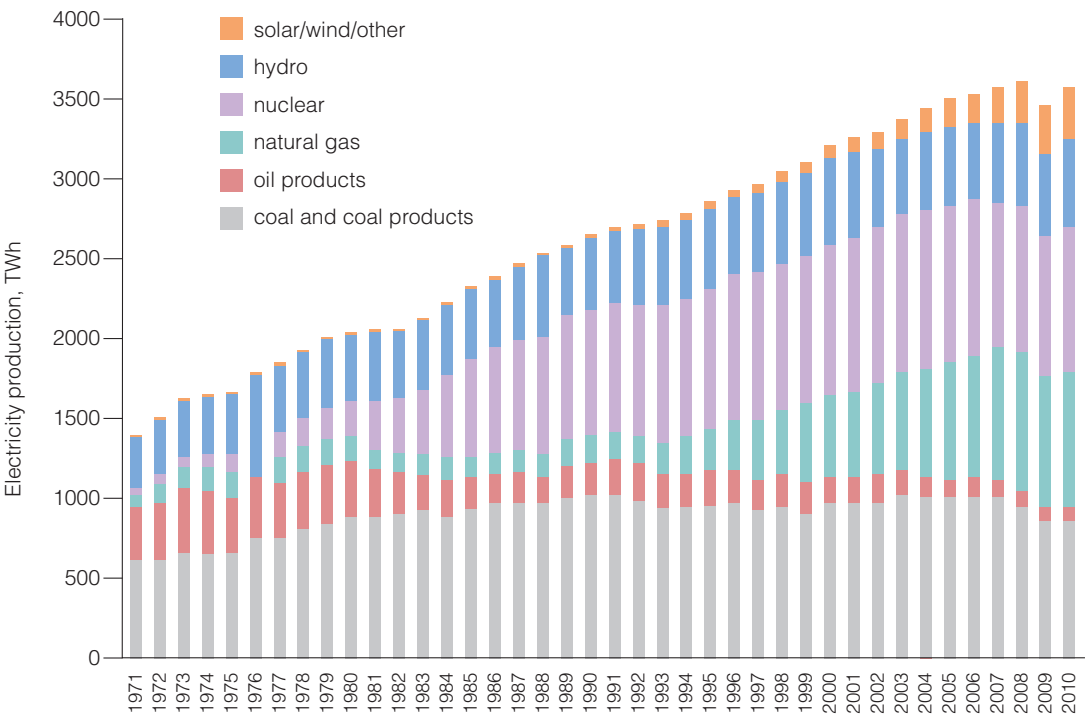

Figure 10 Electricity production in OECD Europe, GWh (IEA, 2011)

Increased developments in gas-fired power in Europe and a slowdown in overall economic activity and electricity demand resulting from a prolonged economic crisis post-2007 may well see a decline in coal supplies to OECD Europe in the medium term. Where the few replacement power plants will be built, new ultra-supercritical power plants will provide a significant efficiency improvement on older plants, perhaps reducing coal demand and CO_2 per MWh by 20–30% from the plant it replaces. However, without a significant ongoing commitment to invest and develop a CCS network, new coal-fired power plants in Europe will be few.

To illustrate this decline, Figure 11 shows the trend in *apparent* consumption of all coal in OECD Europe, defined as production plus net imports. Total coal consumption in OECD Europe dropped 33% between 1980 and 2008. The major decline occurred when coal consumption dropped from 660 Mtce in 1980 to below 500 Mtce in the 1990s (a difference of 160 Mtce). By the late 1990s, coal consumption then averaged around 450–470 Mtce for almost ten years, only to see another sharp drop in 2009 following the global economic downturn and a reduction in electricity demand. By this time, OECD coal consumption had dropped to 400 Mtce.

Therefore, since 1980 the coal market in OECD Europe contracted by a massive 260 Mtce, which is equivalent to 10% of all the primary energy consumed. Throughout this period of decline, imports were making increasing headway into the coal markets; all these trends suggest that domestic coal mining experienced the worst effects. Coal production in OECD Europe fell by a staggering 60% (equivalent to 360 Mtce) in the 28 years between 1980 and 2008, and continues to fall. Curiously, the reduction in coal consumption in OECD Europe's power sector was just 4% (as Figure 10 helps to illustrate). This modest fall is quite unlike the 33% drop in total coal demand. While many commentators talked about the death of coal in Europe, such stories were localised, but on a European level this was clearly not happening in the power generation sector between 1980 and 2009.

In 2010, the TWh output from all coal stations was just below levels in 1980 (–3%), but markedly below the peak levels of 1991 (–17%). Kyoto Protocol measures and carbon trading were being implemented acrosss Europe in 2005. While total coal demand fell 218 Mtce since 1980, coal demand

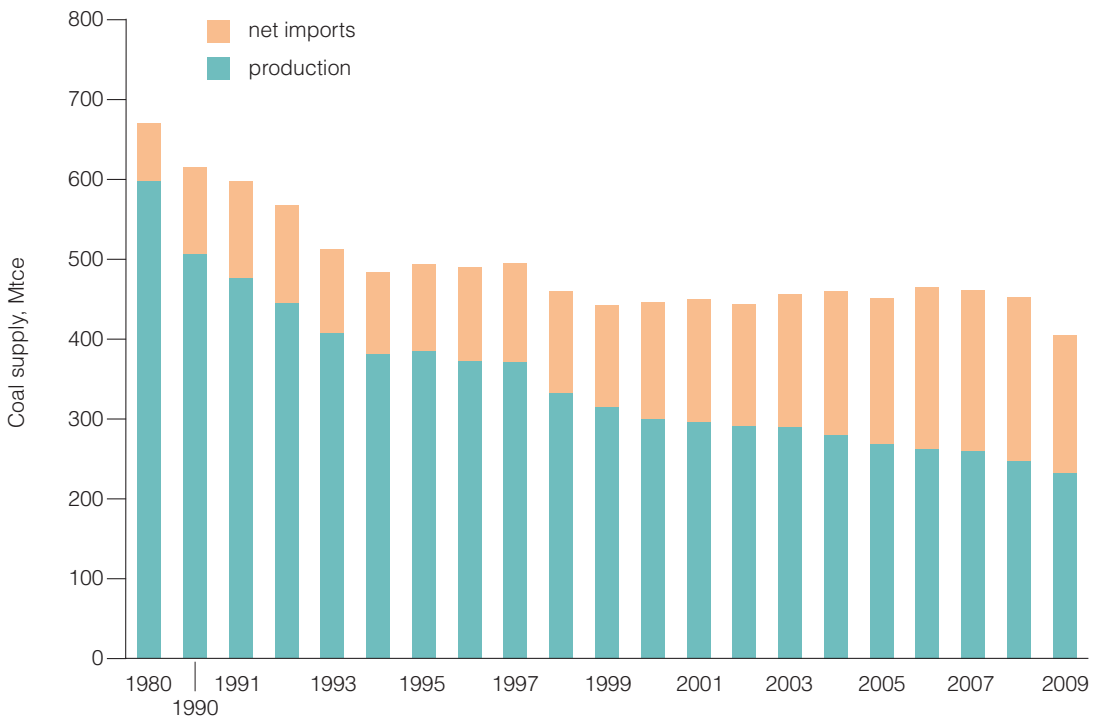

Figure 11 Apparent consumption (production plus net trade) in OECD Europe (IEA, 2010b)

in the power and heat raising sector dropped by just 45 Mtce. This leaves a massive 173 Mtce of coal demand disappearing from the economy over 30 years that was not related to a decline in power generation. Therefore, the trend suggests that declining coal demand in non-power sectors such as industrial, residential, and commercial sectors was the major cause for the coal market to contract in OECD Europe.

Before discussing the nature of the decline in the coal market in Europe, it is worth reviewing what was happening in the power generation sector in this period. Figure 12 shows the age profile of the coal-fired fleet using 1980 as the reference; much of the capacity that exists today was built before 1980. Between 1980 and 2008, many older stations closed as new investments required for emission control equipment could not be justified. In 1980, coal-fired generating capacity stood at 175 GWe. In the 28-year period between 1980 and 2008, 74 GWe of new coal-fired capacity was brought online, but only 54 GWe was decommissioned by 2008. More coal-fired generating capacity existed in 2008 across the whole of OECD Europe than it did in 1980, even if some operated at lower loads.

Since 1980, where new plants were being built, development in boiler designs, emission technologies, and new steel products capable of withstanding high temperatures and pressures continued. This progress raised the average efficiency of the coal fleet over time. By 2008, some 18 GWe of capacity in OECD Europe was operating using supercritical technology (efficiency exceeding 39% net LHV), 75% of which was built before the year 2000. Stations built around this time were probably achieving efficiencies of perhaps 40–42% (net LHV) while later plants were probably closer to 43–44% (net LHV). These coal-fired efficiencies were similar to the early gas-fired CCGT stations that were built in the 1990s. Whilst the new high efficiency stations reduced coal demand in the power sector they were not responsible for all of the reduction.

As mentioned earlier, coal demand in OECD Europe dropped by 218 Mtce since 1980 to 442 Mtce in 2008, and to 400 Mtce in 2009. The demand for steam coal in the power (and heat) sector reduced by 45 Mtce, while non-power sectors dropped by 173 Mtce. Of this, residential and commercial demand dropped by almost 70 Mtce.

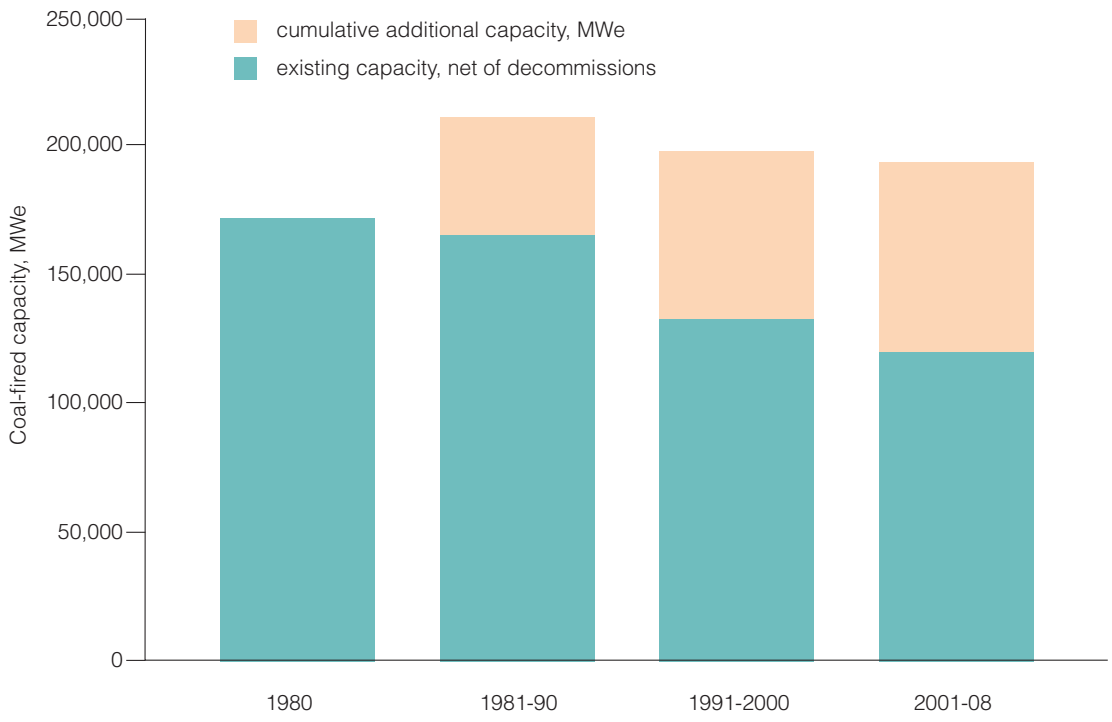

Figure 12 Coal-fired capacity in OECD Europe (IEA CCC, 2010)

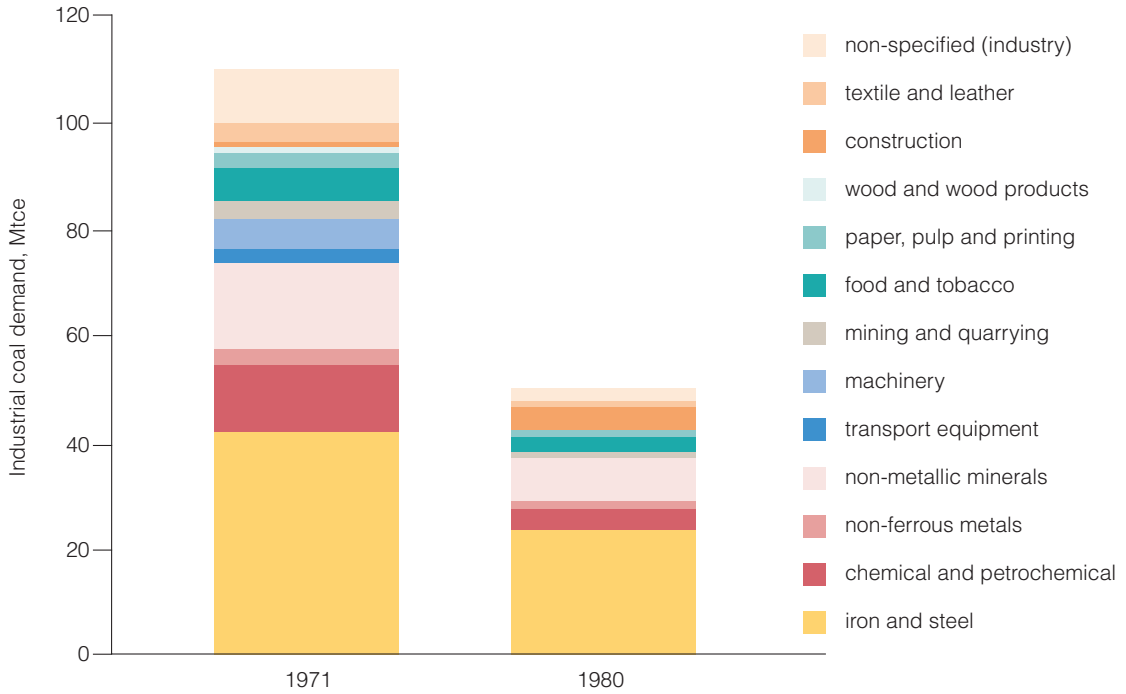

Figure 13 Industrial coal demand in OECD Europe, Mtce (IEA, 2010b)

This would imply that the remainder of the economy decreased demand by some 100 Mtce, mainly in the heavy industrial sectors. The statistics are complicated by coal that is converted into other fuels or products, and losses and non-fuel usage also occur. To simplify matters, the conversions and losses are ignored, but based purely on end user coal consumption; industry saw coal demand fall from 110 Mtce to 50 Mtce, a 55% reduction in 29 years (*see* Figure 13). Based on the rise in coal trade, chiefly imports, it seems logical that international trade increased too and displaced 200 Mtce of indigenous coal production since 1980.

The most striking reduction comes from the iron and steel sector, where demand for coking coal will have been affected by the output of iron from blast furnaces using the carbon-intensive basic oxygen furnace and the disappearance of the least energy efficient manufacturing process – the open hearth furnace. Throughout this period, the steel industry has adopted a number of measures to reduce the use of coking coal, either by the use of imported coke or by using *pulverised coal injection* (PCI) coals, which are low volatile steam coals.

The other major industrial sector which has faced decline, or been forced to switch fuels to natural gas, as well as overall major efficiency drives to reduce coal use, is the non-metallic mineral sector. Non-metallic minerals chiefly refer to cement production, but will also include energy intensive production of construction bricks and tiles, ceramics, and glass. Other industry sectors have either seen a major contraction in coal use, or a major contraction in industrial output with production being transferred to other countries, notably in the far east. These industries include textiles, food and tobacco, mining, machinery, and transport equipment. While economic factors have shifted heavy industry away from some OECD nations in Europe, more stringent environmental legislation in these countries increased the cost of producing electricity, and forms the basis of the next chapter.

7 Environmental regulatory drivers

The previous chapter highlighted the trends in coal consumption, chiefly in the power generation sector. Within this sector there have been a number of factors that have reduced the overall demand for coal in Europe and indeed elsewhere in the OECD, not least the switch away from coal as a highly polluting fuel if combusted with no emission control measures. The reduction in the role of coal in some regional markets over the long term has been mainly due to legislative requirements to limit SOx, NOx, and particulates, although increasingly the limits to greenhouse gases and in some cases mercury are gaining importance. The first of this list of airborne pollutants, SOx, is the most critical as it has probably led to more coal switching activity amongst power utilities over the years than any other pollutant.

Environmental legislation pertaining to coal-fired power is analysed in depth by a number of IEA Clean Coal Centre Reports (www.iea-coal.org), but the major issues will be discussed briefly. One of the most important factors that predated the legislation on climate change was the elevated levels of acid rain affecting many parts of the world due to unabated coal combustion from the power sector. International and national legislation for the reduction of acid rain dates back to the 1960s, when the USA and Japan introduced a variety of environmental pollution control legislation. In the 1970s, the EU-wide Environmental Action Programme was introduced which set out objectives and principles of national laws. In 1979 the Geneva Convention on Long Range Transboundary Air Pollution became the first international agreement to deal with air pollution and came into force in 1983. A succession of industrialised regions followed. The key legislation for Europe came in 1996 in the form of the Directive on *Integrated Pollution Prevention and Control* or IPPC (96/61/EC).

7.1 Sulphur legislation

In a previous IEA CCC report, Davidson (2000) reported on how coal properties influence emissions and concluded that, despite considerable work on the properties that affect sulphur emissions, for the most part nearly all the sulphur in the coal is converted to SO_2. The only coal properties that greatly affect the emissions of SO_2 are the total sulphur content and the ash. Most of the SO_2 is either emitted or captured by flue gas desulphurisation, little is retained in the ash.

SO_2 is readily dealt with using *flue gas desulphurisation* (FGD) equipment, a technology that has been analysed widely by the IEA CCC for many years. FGD is proven and fitted to almost all new power stations across the world. However, flue gases from the combustion of coals with a high chlorine content can affect the operation of the desulphurisation equipment by reacting with the sorbent more readily than SO_2. Ironically, such high chlorine content coals might be used as they are often low in sulphur in the first place. If such sorbent 'wastage' occurs as a result of blending high chlorine coals, either more sorbent needs to be used or the HCl present must be absorbed before it enters the FGD system (*see* Chapter 8 for more issues regarding interactions of different chemical components).

Legislation on emissions of SO_2 affects the use of coal in a number of ways. Strict emission standards may require the addition of pollution control equipment such as FGD. This requirement increases the cost of coal-fired power in terms of capital cost of installation but also the operational costs due to the extra power drawn from the station to drive the FGD system, as well as the need for sorbent material and maintenance. The impact is borne by the utility and such costs would typically be passed onto the end consumer, but some cost can be recovered if the resulting gypsum by-product can be sold on to the construction industry for plasterboard.

To further reduce the load on the FGD system, SO_2 emissions can be reduced by replacing all or part

of the existing fuel feed with a lower sulphur coal. If the feed coal has a very low sulphur content, occasionally, FGD can be bypassed altogether. This has many advantages. It enables the utility to operate a more flexible fuel buying strategy. Limited financial resources and intense competition from other fuels and renewables force many utilities to adopt the most cost-effective pollution control technology.

Replacing high sulphur coal with low sulphur coal has reduced emissions immensely, and forms a basis for much of the analysis in this series of reports.

7.2 European legislation

The adoption and strengthening of Environmental regulation and the uptake of pollution control equipment has played a part in the importation of coal, especially in the Atlantic market. In 2007, IEA CCC published a report on the effect of European Legislation and the revised LCPD on coal-fired power (Nalbandian, 2007). The revision of the *Large Combustion Plant Directive* (LCPD) 2001/80/EC replacing the 1988 Directive (88/609/EEC) applies to power plants with a capacity of >50 MWth. The purpose of the directive was to reduce a number of airborne pollutants proven to have adverse impacts on health and the environment; these were acidification, ground level ozone, and particulate emissions by controlling emissions of SO_2, NO, NO_2, and particulate matter. This new Directive affected power stations in two ways. From 2001, the Directive affected new plants. Existing plants, however, were given seven years to adapt to new stricter emissions which would not be enforced until 2008. The period of enforcement ends in 2016 when the *Industrial Emissions Directive* (IED – *see below*), agreed in 2010, will take over, subjecting utilities to ever-stringent emission limits. It is potentially responsible for the closure of many coal-fired station across Europe that are not equipped with appropriate FGD and SCR emission control systems.

Environmental regulations are rife with complexity (Tsadari, 2006), for example, permitting procedures for coal-fired plants are lengthy and face many objections and appeals. Such issues also affect the planning and construction of wind turbine arrays and especially nuclear generators for a variety of different reasons. With regards to coal-fired plants, part of the problem lies in the numerous directives that appear to have conflicting demands due to a lack of legislative consistency. The most important interaction is between the IPPC and the aforementioned LCPD directives. The LCPD applies *Emission Limit Values* (ELVs) to power stations on a mg/m^3 basis, which differ depending on the reporting period, but stations must comply with an overall average. The LCPD is a legally-binding document, while the IPPC is not, but rather provides national regulators and industrial emitters with guidance on the methods of best practice, but nevertheless has strict limits to which targets can be set. Either way, the importance of having a competent authority to guide and enforce these regulations on incumbents is essential.

Emission limits are discussed in much greater detail in Nalbandian (2007) but will be reviewed here based on the IEA CCC environmental standards database. NOx and particulate emission reduction are done more by physical control and changes to the power station boiler rather than switching coals. Therefore, displacing domestically-mined coals with imported products may not always achieve the desired effect, but in the case of countries like India where the domestic coals are very high in ash, importing coals has benefits in reducing excessive slag, ash, and particulate production. One of the major benefits of moving to imported coals is that the sulphur content tends to be lower while possessing good heating values and low ash content. Switching to low sulphur coal reduces the burden on the whole power station, whether it be the load on FGD units, FGD residue production, FGD sorbent consumption, ash management and disposal, and so on, all of which help prolong the life of power stations and minimise the cost of operation. As mentioned earlier, minimising operating costs is especially important when considering the installation of FGD and other control equipment to help meet the LCPD and IED regulations which may require utilities to spend large sums on capital equipment.

Coal switching is common in Europe brought about by the IPPC and the LCPD. In 2005, the EC launched a review of legislation to simplify the ambiguities and confusion brought about by having more than one set of legislation to cover industrial emissions, hence the *Industrial Emissions Directive* (IED) was proposed in 21 Dec 2007, combining:

- The *Large Combustion Plant Directive* (LCPD);
- The *Integrated Pollution Prevention and Control Directive* (IPPC);
- The *Water Incineration Directive* (WID);
- The *Solvent emission Directive* (SED);
- The three existing Directives on TiO_2.

On 8 November 2010, the European Council ratified the proposal set out in June the same year, and the Directive (2010/75/EU) came into force on 6 January 2011. The emission standards for the LCPD remain the key driver for plants closing before 2016 as it will not be cost-effective or indeed practical to fit the appropriate FGD equipment. Plants opting into the LCPD will remain open, and have FGD fitted. After 2016, the IED adds further pressure on NOx emissions, forcing the fitting of *selective catalytic reduction* (SCR), or the restriction to 17,500 hours of operation between 2016 and 2023. Details of the Directive are available from the Official Journal of the European Union, at: http://ec.europa.eu/environment/air/pollutants/stationary/ied/legislation.htm.

While it impossible to set out all the nuances of the document, a summary of the impact on existing power stations is explained by Poyry (2010) for large combustion plants only, along with a comparison with previous emission limit values (*see* Table 2). The Directive document contains many derogations, exceptions, and conditions where combustion plants are exempt or can temporarily emit more than the emission limit values permit. There are also details on *emission limit values* (ELV) applying to plant stacks, or for plants with limited operating hours (opted out), and plant extension and so on.

The IED requires the *best available technology* (BAT) which for SO_2 is FGD, and so goes well beyond coal switching. A simple conversion from mg/m^3 emission limits to the equivalent sulphur content as a percentage of the coal shows that probably no coal exists that would meet the criteria set by the IED. There are a number of exceptions, such as power stations that operate at low load, for

Table 2 EU emission limits under the LCPD and IED (Poyry, 2010)

Emission limit values by plant	Previous directive	Equivalent % sulphur content (coal)	Current directive	Equivalent % sulphur content (coal)
SO_2, mg/mg^3	**LCPD**	**LCPD**	**IED**	**IED**
Coal plant, >500 MWth	400	0.192	200	0.096
CCGT	35		35	
NOx, mg/m^3	**LCPD**		**IED**	
Coal plant, >300 MWth	500		200	
CCGT, 50–500 MWth	300		50	
CCGT, >500 MWth	200		50	
Particulates, mg/m^3	**LCPD**		**IED**	
Coal plant, >300 MWth	50		20	
CCGT	5		5	

which emission limit values are more lenient at 800 mg/m^3. Other standards apply regarding NOx and comprise some of the most difficult limits to achieve without costly addition of SCR, hence the decision to close plants has been taken in many cases. All large power stations after 2016 will operate with FGD and SCR, and many may cofire biomass to complement the coal burn and improve CO_2 compliance. However, this means European generators may seek out imported coals, not for low sulphur content but instead for high sulphur coals with better heating values, lower chlorine content, and improved combustion properties to aid the burning of large amounts of biomass. Nevertheless, there seems to be continuing demand for coals with less than 1% sulphur.

8 Impacts of changing the quality of coal due to importing

Switching a coal feed into a power station to a blend that uses more imported products, or products mined from distant sources, often offers economic benefits. Cost savings are often made even after the cost of transportation is taken into account. However, the quality of these non-local coals must be considered carefully through small- and full-scale testing to ensure the performance of the power plant is not impaired. The compatibility of the imported coal must ensure there is no significant cost or performance impact with respect to handling, storage, milling/pulverising, combustion, boiler furnace and heat transfer performance, emission levels, and residues handling and utilisation.

Low cost (low sulphur) subbituminous coals are mined in the US Midwest in the well known *Powder River Basin* (PRB) and transported widely across the continent. For more than 30 years, subbituminous coals have penetrated domestic markets once dominated by bituminous coals. Therefore, US experience of domestic coal switching since 1990 is an interesting model for global seaborne trade where subbituminous coals from countries like Indonesia are being shipped in large quantities to utilities across the world. Typically, internationally-traded coals from major exporters

Table 3 Scota coal criteria (Globalcoal, 2010)

Shipments must conform to the quality specifications shown below

For shipments originating from:	South Africa	Australia	Colombia	Poland	Russia	USA
Calorific value, kcal/kg*	6000	6000	6000	6000	6000	6000
Total moisture, ar	12 % (max)	15 % (max)	14 % (max)	14 % (max)	14 % (max)	12 % (max)
Volatile matter, ar	22% (min)	24–35%	31–37%	25–32%	26–35%	27–35%
Ash, ar	15% (max)	15% (max)	11% (max)	15% (max)	15% (max)	14% (max)
Sulphur, ar	1% (max)	0.75% (max)	0.85% (max)	1% (max)	0.75% (max)	1% (max)
HGI†	45–70	45–70	45–70	45–70	45–70	45–70
Nominal topsize	50mm	50mm	50mm	50mm	50mm	50mm
IDT, °C‡	1250 (min)	1250 (min)	1200 (min)	1150 (min)	1250 (min)	1430 (min)
CaO in ash, dry	12% (max)	7% (max)				
Chlorine, ar						0.15% (max)

* Calorific value: basis 6000 kcal/kg NCV, minimum 5850 NCV
† Hardgrove Grindability Index: typical, and not to be used for determining whether or not a shipment complies with the Specification
‡ Fusibility of ash (DT) [ash fusion temperature - initial deformation]

such as Australia, Russia, South Africa and Colombia are bituminous and meet specific guidelines represented by the qualities stated in the *Standard Coal Trading Agreement* (Scota) trading scheme.

Tables 3 and 4 show the quality specifications for coal traded via the Scota system. The most obvious quality is the calorific value of the coal, with 6000 kcal/kg (25.12 MJ/kg) being typical. Indonesian coal could be considered to be somewhat 'off spec' at a lower heating value of at 5000 kcal/kg (20.94 MJ/kg) with a higher level of moisture, but few utilities seem deterred from using Indonesian coals on quality grounds. Nevertheless, most hard coals that are traded worldwide fall within these parameters. Most coal mines that serve the export market are restricted to meeting these qualities. However, apart from the increasing trade in Indonesian coals, there may well be a shift towards lower calorific value bituminous coals, partly as existing suppliers deplete the high quality deposits and move into lesser quality deposits. Also, some consumers may well be seeking lower cost products in order to compete with low cost local sources such as buyers in India. Some Indian consumers are keen to exploit lower quality coals to feed power stations and according to some traders, will seek qualities below some of the Scota standards.

For now, most consumers seek international quality coals for a number of reasons. Coals that are traded within a recognised trading system are more likely to be supplied with greater consistency and quality than if they were traded 'off market'. This does not mean that non-standard contracts are any more risky. Some 80% of world hard coal is not traded internationally, and so many contracts will be signed with local suppliers with quality parameters well outside the standard world coal criteria. For some decades domestic markets have seen a convergence towards international standards. For instance, according to CMC (2010), German utilities in the 1970s had design coals with calorific values of 7000 kcal/kg NAR (29 MJ/kg). With international coals being traded around 5700–6000 kcal/kg NAR (23.8–25.1 MJ/kg) some coal qualities are below typical specification, but are readily burned in plants such as Indonesian products of 5500 kcal/kg (23.0 MJ/kg) which is rapidly gaining share in the world steam coal market.

Table 4 Scota coal criteria for Indonesian coals (Globalcoal, 2010)

For shipments originating from:	INDO A	INDO B	INDO C
Calorific value, kcal/kg*	6000	5500	5500
Total moisture, ar	15 % (max)	22 % (max)	28 % (max)
Volatile matter	36–45%	36–45%	36–45%
Ash, ad	15% (max)	15% (max)	10% (max)
Sulphur, ad	1% (max)	1% (max)	1% (max)
Selenium, dry	1 ppm (max)	1 ppm (max)	1 ppm (max)
Boron, dry	180 ppm (max)	180 ppm (max)	180 ppm (max)
CaO in ash, dry	7% (max)	7% (max)	20% (max)
Nitrogen, dry ash free	2% max	2% max	2% max
HGI†	40 (min)	40 (min)	40 (min)
Nominal topsize	50 mm	50 mm	50 mm
IDT, °C‡	1200 (min)	1200 (min)	1150 (min)

* Calorific value: basis 6000 kcal/kg NCV, minimum 5850 NCV
† Hardgrove Grindability Index: typical, and not to be used for determining whether or not a shipment complies with the Specification
‡ Fusibility of ash (DT) [ash fusion temperature - initial deformation]

Commercial testing for coal quality and behaviour during combustion continues at power plants as part of daily operations, but results are rarely published. Public research continues but more in the field of understanding the effects of cofiring biomass or waste with coal. Research into the combustion behaviour of coal and fly ash from blending different coals is still published by some groups but the findings are usually for either small-scale furnaces or associated with technologies such as gasification or oxyfuel based environments. These papers are therefore atypical of the current operating fleet of power stations worldwide.

Nevertheless, work has been done since the 1990s when various studies examined the effects of changes in ash deposition, corrosion, moisture, and stack emissions during a period when blending and switching coal was becoming increasingly necessary. The IEA CCC studied the effects of switching to cheaper coals in power stations (Carpenter, 1998) in a literature study on large-scale operating plants. Much of the study by Carpenter (1998) focused on switching to low rank coals such as lignite, which is an unusual measure for most power station operators. However, much of the analysis also discussed the issues of switching from a 100% bituminous coal to a blend of, or complete switch to, subbituminous coals in the USA in the 1990s.

It is relevant to look at the experiences in the 1990s during a time when power stations in the USA were being subjected to stricter regulations on SO_2 emissions, forcing some utilities to consider blending lower sulphur coals. This section draws on the experience of power stations in the USA that tested subbituminous coals from the PRB of Montana and Wyoming. Although some generalisations can be made about the behaviour of introducing new coals, each unique combination of coal and unit design is individually evaluated to confirm the acceptability of the coal and performance of the station. Even if a blended coal product closely resembles the design coal specification, the blend may not burn in the same way. Blending or switching to imported coals of a lower rank, notably subbituminous coals, is more complex than just heating values and moisture, although they are fundamental to the impact assessment on boiler and power station performance. This section of the report examines just a few aspects of introducing new coals that must be considered by power station operators and fuel procurement officers, these include: ash deposition, moisture content, chlorine related corrosion, and sulphur emissions.

8.1 Ash deposition

Ash can affect power station boilers in several ways, the chief one being fly ash accumulation on the boiler and heat transfer surfaces, thus reducing the efficiency of the system. This deposition can also increase the frequency of maintenance outages for removing problem ash that sinters more readily within the boiler furnace. Another aspect of the ash is the mineral content, that can influence deposition characteristics, but can also corrode the boiler tubes as well as other surfaces (*see below*).

A boiler designed for firing a bituminous coal may experience increased slagging and fouling with lower rank coals. For instance, many low rank coals contain high alkali ash which is linked to fouling. A survey was carried out in the USA on 11 power plants firing different blends of PRB coals with eastern bituminous coals in boiler units designed for the latter coals (Gunderson and others, 1994, 1996). In some units, a reflective ash layer accumulated on the furnace walls (McComas and Morris, 1995; PSI Energy, 1996; Rens and others, 1993; Zakis and others, 1996). These deposits reduced the heat transfer performance in the furnace, making the exit flue gas hotter than desired, which promoted excessive fouling in the heat recovery sections further down the stream in sections such as the economiser.

Blending just small amounts of PRB coal led to rapid sintering of highly reflective deposits that adhered rapidly to waterwall tubes. This was due to the presence of large iron or aluminosilicate particles in the bituminous coal reacting with calcium-rich particles in the PRB coal (Johnson and others, 1994). The presence of other iron-rich particles such as pyrite decreased the deposit

reflectivity. So the presence of iron in two different forms had different effects. Regular use of soot blowing and water lances were required to loosen and remove the sintered material although at the time, water lances were considered more effective than conventional sootblowers in cleaning the reflective deposits (Gunderson and others, 1994, 1996). Water lances can be more expensive than soot blowers and were considered a long-term modification. Further measures might be required if calcium in the deposit reacts with sulphur in the flue gas, forming hard deposits that are high in calcium sulphate. Once the deposit sinters, it is virtually impossible to remove while the boiler is operating, and therefore would have required more drastic measures such as careful blasting with explosives (Marcy and Burger, 1994).

Blending subbituminous coals with high sulphur coals (likely to be Illinois coals) and feeding the blend into boilers designed for the latter coal at the Monroe and St Clair power plants in Michigan led to increased slagging and fouling. Again, additional sootblowers and periodic boiler washes were required to remove the build-up of ash. Additional control measures to decrease the rate of ash accumulation included increasing the mill fineness and eliminating the use of higher elevation burners.

In other tests, blending subbituminous and bituminous coals was more beneficial than burning either fuel on its own. At the D H Mitchell coal plant in Indiana, burning 100% (low sulphur) bituminous coals produced resistant slag layers, while 100% PRB coals led to ash pluggage fouling caused by the calcium. However, blending 30% of the low sulphur bituminous coal with 70% of the PRB coal produced a more balanced ash chemistry and balanced out the high and low ash fusion temperatures associated with each of these coals (Barna, 1992).

In a more recent study on internationally-traded coals, increasing the use of low sulphur subbituminous coals did not lead to consistent ash and slag behaviour. Coals from different parts of the world showed different characteristics and so provided an array of outcomes when burned alone and in blends of different proportions. The Israeli Electric Power Corp is a regular participant in the Atlantic coal market, importing all of its steam coal from all the major export countries in the world. In a paper published in 2008, Korytnyi and others (2008) studied the properties of four different coals from Indonesia, one from Colombia, and three different coals from the US PRB. Most coals were of a fairly high slagging nature, but fouling varied widely, even amongst the US coals with coals of similar rank demonstrating an extremely wide variety of characteristics.

Indonesian coals that are commonly exported worldwide are not without issue. When Indonesian subbituminous coals were fired in the Paiton power plant, Indonesia, slagging and fouling problems occurred even though the coals had a low ash content (<3%). However, the Paiton plant was designed for a high ash fusion bituminous coal (Freeman and others, 1997). When burning subbituminous coals, the flue exit gas temperature increased causing fouling to become unmanageable. The problems were a result of the high alkali content. Ash problems are not only confined to subbituminous coals, bituminous coals are also a problem and variations in plant load can worsen this. Some supercritical stations with low NOx burners exhibited problems with >1.5% sulphur content coal. Changing to an imported higher sulphur coal could increase waterwall tube wastage in boilers with low NOx firing systems.

8.2 Moisture content

Coals with higher moisture levels (naturally occurring) are generally lower in rank such as subbituminous or lignite coals. Chars from such lower rank coals can be more reactive than those from bituminous coals, and without any modification to the boiler, the higher moisture content usually results in problems maintaining the boiler temperature or increases the parasitic load onto the power plant (Gunderson and others, 1994, 1996).

One of the most important aspects of moisture content is the effect on NOx production. Research by Ikeda and others (2003) in Japan raised concerns about the impact of the increasing use of Indonesian subbituminous coals in boilers designed with advanced low NOx burners. They found that subbituminous blends with bituminous coals showed evidence of elevated unburnt carbon in the ash and higher NOx production, based on experimentation in a pulverised fuel test furnace with a fuel rate of just 0.1 t/h. The results showed that the blend of coals produced more undesirable effects than when each coal was burned separately; the use of the blend resulted in increased NOx emissions and unburnt carbon in fly ash as the concentration of subbituminous increased. However, adaptation of the secondary air flow angle reduced these effects to enable a higher proportion of subbituminous coal to be burned.

Most bituminous coals that are traded internationally contain some 12–15% moisture (*see* Table 3); moisture levels of some Indonesian coals can be well over 20% (*see* Table 4), similar to levels seen in PRB coals in the USA. Consequently, a switch to these low sulphur, but higher moisture coals require careful blending and testing in the power stations to determine the correct adaptations to ensure there is minimal or no loss in efficiency or availability.

Gunderson and others (1994, 1996) noted that when some US utilities increased the quantity of PRB coals, the subbituminous coals tended to suppress the pulveriser mill outlet temperature. Attempts to attenuate the temperature increased the parasitic load on the plant and resulted in derating of the plant. However, there were no detrimental effects on burner flame stability despite the higher reactivity of the subbituminous coal. Test burns of blends of subbituminous and bituminous coals at the Gibson plant, Illinois, also resulted in a reduction in the mill outlet temperature and a loss in boiler efficiency (Meehan and others, 1995).

8.3 Chlorine content

A literature study carried out by Tillman and others (2009) established the effects of corrosion and ash deposition on a boiler when blending high chlorine solid fuels into the normal coal feed. The analysis relied heavily on papers published throughout the 1990s when much of the material came out. The conclusions highlighted the wealth of knowledge regarding the effects of chlorine content of solid fuels, its sources, and reactions in pulverised fuel firing. Yet, the research over the years was not considered exhaustive with plenty of scope for further work. Chlorine is an increasing problem in pulverised fuel combustion with the rising use of different rank coals, but also with the increasing importance of cofiring (sustainable) fuels such as biomass.

Mechanisms for corrosion due to chlorine focused on the release of chlorine during pyrolysis with alkali metals (for example KCl, NaCl) and how they affected steel-based superheater tubes and other surfaces with these chlorides while in a molten state. High temperature corrosion also involves oxidation, but the alkali chloride mechanism can be reduced by the presence of sulphur based compounds such as K_2SO_4 and Na_2SO_4. Tillman and others (2009) observed that high chlorine fuels such as biomass posed a higher risk, but the findings suggested that the main body of published evidence could be overstating the risks of high chlorine levels, but the authors admitted more work needed to be done.

Work has also been published studying other aspects of elevated chlorine in the solid fuel, especially if the coal is being burned in conjunction with the use of FGD, a piece of equipment that is becoming ever more present amongst the world's modern power station fleet.

High chlorine content can be detrimental to the performance of wet scrubbers (Davidson, 1996). There are various measures that can be implemented, if necessary, to improve the performance of wet scrubbers after a coal change (Scott, 1997). They include:

- selecting a higher reactivity limestone;

- grinding the sorbent more finely; and/or
- adding organic acids to the FGD reagent slurry, such as a dibasic acid which can improve SO_2 removal efficiency.

In the past, spray dry scrubbers were originally suitable for low sulphur coals, but their potential has been improved through experience over the years. Unlike wet scrubbers, where chlorine is detrimental, HCl in the flue gas entering a dry scrubber can improve operations (Hjalmarsson, 1992), but the corrosiveness of chlorine becomes a risk. Born and Seifert (1996) looked at the mechanisms to deal with chlorine in this context. Introducing coals with a high proportion of calcium and magnesium compounds, particularly those with a high acid soluble Ca and Mg contents, can inhibit corrosion in the boiler and heat transfer surfaces.

8.4 Sulphur content

As mentioned throughout this report, sulphur and its associated emissions from combustion is one of the key drivers for coal switching and a major reason behind the importing of coals at the expense of locally mined high sulphur coals. Whenever a change in coal supply is considered, it is important to evaluate its effect on SO_2 emissions, but also how effectively a blend of the new coal can meet the strictest standards when burned in conjunction with an FGD system. Figure 14 illustrates how the amount of sulphur to be removed changes with the coal sulphur content to meet specific emission standards. For example:

- to meet the current European Community standard of 400 mg/m^3, changing to a coal with a 5% sulphur content will require approximately 90% SO_2 removal;
- to meet a standard of 400 mg/m^3, switching to a coal containing 1% sulphur requires around 50% SO_2 removal;
- to meet an emission standard of 200 mg/m^3 limit set by the IED is equivalent to a sulphur content of just 0.1%.

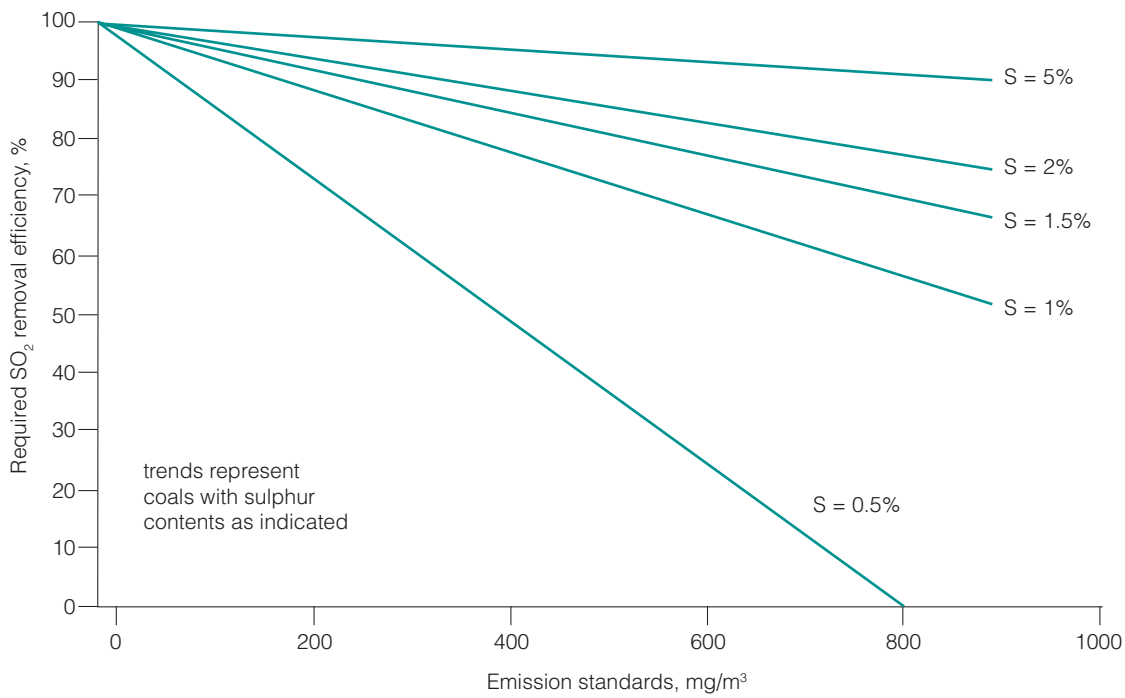

Figure 14 Effect of coal sulphur content on meeting emission standards (Baruya and McConville, 1997)

These simple comparisons demonstrate that internationally-traded coals of <1.0% sulphur become attractive blend fuels that can ease the burden on the FGD system, which in turn could reduce the operating cost and prolong the life of the investment.

According to Carpenter (1998), a lower sulphur coal/blend could lead to small cost savings at power plants fitted with FGD systems since a smaller amount of sorbent would be required to meet the emission limits. However, some countries' emission regulations specify the percentage of sulphur that must be removed relative to uncontrolled emissions. For example in the past, German regulations required existing large coal-fired boilers (>300 MWth) to remove at least 85% of the sulphur, as well as complying with a 400 mg/m^3 limit. For low sulphur coals it can become difficult to achieve the required sulphur removal percentage. In addition, a lower sulphur coal/blend can affect the efficiency of ESPs. For some low rank coals, the fly ash with a high alkalinity entering a wet scrubber can experience a change in its chemistry in ways that influence the effect of the pH and additives on SO_2 sorption and reagent utilisation. Because of wide variation in ash composition, experience is needed to determine the optimum conditions for sulphur removal (Sondreal, 1993).

As mentioned in this section, introducing a low sulphur coal of a lower rank can cause plant derating due to the higher moisture content, a possible increases in NOx, and higher alkalinity in the fly ash. A great deal of experience has developed over the years and adjustments to power station operation and components from milling, maintenance cleaning, fuel blend, or the introduction of SO_3 and SO_4 compounds could be considered. However, each power station will have its own set of unique problems and solutions; testing and investigation will be required to develop the best solution for each plant.

9 World prices and the influence on European domestic coal markets

The previous chapter discussed briefly some of the impacts of power station operation when introducing new coals to power stations, often of differing characteristics resulting in changes in slagging, fouling and ash chemistry. This chapter looks at the more commercial aspects of importing coal and in some cases, its profound impact on domestic pricing. Further analysis is provided in the accompanying reports on the Atlantic and Pacific markets, but a brief summary of the patterns is given here.

Comparing the prices and costs of imported coal against domestic coal provides some indication as to why such a seismic shift occurred away from domestic hard coal production towards internationally-traded coal imports. Figure 15 illustrates the trend in delivered steam coal prices to three European countries and the MCIS market price for northwest Europe (MCIS NWE). Evident from the trend line is that the international price of coal is having a direct influence on the cost of coal to power stations in Europe, even where domestic coal constitutes a large proportion of the supply. Long-term contracts for coal in some of these countries will either have renegotiation clauses to review prices regularly, or track international prices.

The price of steam coal to power stations broadly reflects the price movements shown by the MCIS NWE market for internationally-traded coal. The delivered price to each of the countries in the chart however does not seem to move with the same degree of volatility as that of internationally-traded coal, possibly a reflection of the fact that a proportion of coal supplies in Germany and UK remain domestically sourced with longer-term contracts, or less frequent price settlements. This may well dampen the fluctuation in world price, adding some support to the argument that domestically-produced coal provides a partial buffer to primary energy imported from the world market, yet domestic coal remains benchmarked against imports. Between 2007 and 2008, the MCIS NWE

Figure 15 Delivered steam coal prices for electricity generation, $/tce (IEA P&T, 2010)

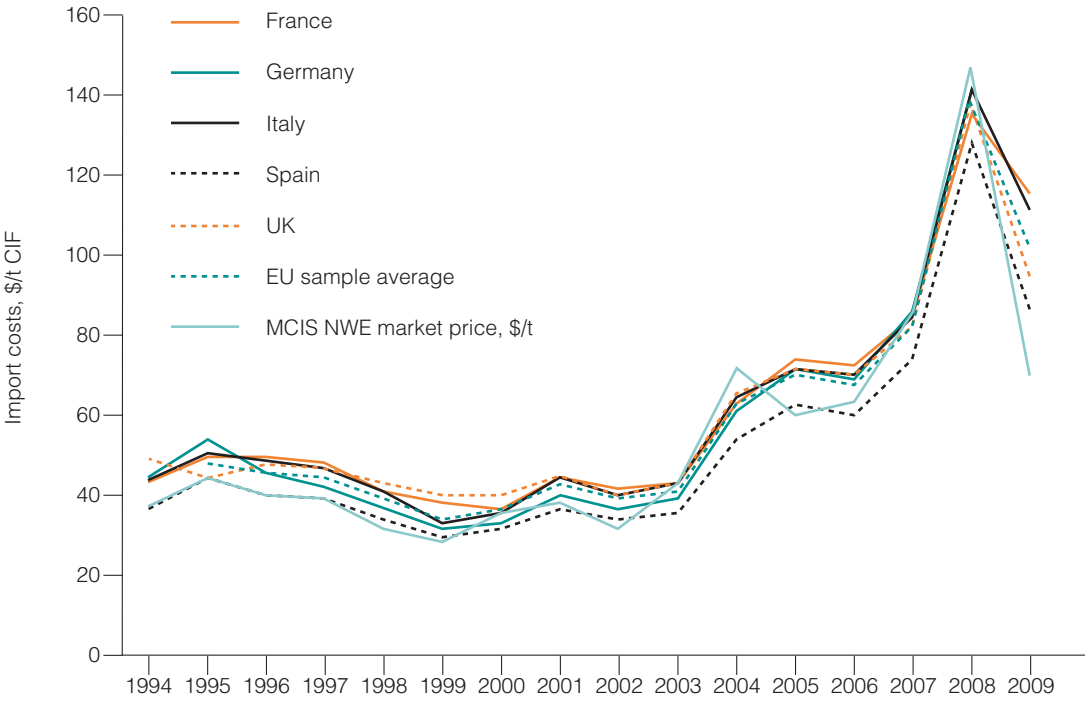

Figure 16 Cost of steam coal imports, $/t CIF (IEA, 2010b; MCIS, 2012)

marker price exceeded the average annual price of coal delivered to UK and Germany, but by 2009 the NWE market had plummeted below the UK price, indicating the direction that continental prices will take.

Figure 16 illustrates the direct relationship that price markers for NWE published by MCIS have with the price of all imported coal going into Europe. Whether the coal is destined for the northern ports in Germany or the Italian and Spanish ports in southern Europe, it is clear that the price trends set in Northwest Europe apply to the whole of OECD Europe. Spain appears to be consistently below all the other European countries. This below-average trend is likely to be associated with the lower calorific coals shipped from countries such as Indonesia. France, Italy and the UK have generally paid a premium over the average CIF price to northwest Europe, while Germany has been on or around the CIF average. France and Italy are small importing countries compared with the UK and Germany, and so import costs are understandably higher. The UK however has paid a slightly higher price than Germany. This is partly logistical as German coal-fired stations can get coal directly from ARA, and are geographically closer to Russia and Poland; transportation could be a factor here. There is clearly a convergence of imported coal prices in Europe, with a few marginal differences based on the onward transports from trading hubs such as ARA. The delivered prices of domestic coal are typically set by the cost of imported coal in one way or another. In the UK, Germany and Spain, imported coal prices have historically traded at a discount to domestically-produced hard coal. In a number of mainland European countries, state or market subsidies have played an essential role in ensuring the survival of domestic industries for some years and are discussed in the next chapter.

10 State aid in Europe

This chapter examines the extent to which subsidies have been permitted to maintain domestic coal industries in parts of Europe in order to compete with coal imports on a price basis. There is further discussion of these issues in the separate report on the Atlantic market European state aid policy is governed by Articles 86 to 89 of the EC Treaty. State aid is analysed in detail by DG TREN (2008) which describes the Treaty's definition of state aid as granted by Member States.

Aid can be provided under certain circumstances, notably to promote economic development in deprived regions or where there is chronic underemployment. In 2000, the Commission's Green Paper *Towards a European Strategy for the security of energy supply* drew scrutiny on the obscure nature of state aid granted by Member States to energy products in the EU. Council *Regulation No 1407/2002* was adopted, and was to mark a retreat from state aid to the coal industry. However, between 2002 and 2005, under the new regulation some €21 billion of state aid to the coal sector was approved. Further to this aid planned for 2010 had already been approved. State aid is set to fall, however the aid per tonne is considered to be high as production has declined considerably.

Table 5 was published by DG TREN and summarises the level of coal production in EU countries that fall under state aid and those not captured by the regulation for aid. According to the report, out of thirteen coal-producing countries, six did not receive official state aid. Estonia and Greece produced only ortho-lignite or oil shale and so were not eligible to be covered by the Coal Regulation. Italy has one small operation in Sardinia which receives no state aid. The UK and the Czech Republic have restructured their coal industries making the remaining industry fully competitive, although there is some provision for liabilities inherited by the pre-restructuring days.

The remaining seven countries have coal production that is covered in part or fully by the Coal Regulation. The countries receiving state aid for coal are: Germany, Hungary, Poland, Romania, Slovakia, Slovenia, and Spain. Slovenia provides state aid to closed mines, while the remaining six provide funds for active mines. Hard coal production in Romania, Hungary, Slovakia and Bulgaria was reported to amount to some 4–6 Mt/y. Lignite production however was 20–23 Mt/y almost all of which was not under the state aid regulations. This leaves Germany and Spain as the major producers of subsidised hard coal in the group of seven state aid coal industries. In those countries where state aid is granted, the aid is split into three broad categories:

- Aid for accessing coal reserves – ongoing aid for operating mines with ongoing activity (Art 5-3: applicable to Germany, Hungary, Romania and Spain), and aid for initial investment (Art 5-2: applicable to Poland and Slovakia); the level of investment throughout each EU member state varies widely, and so a direct comparison is not straightforward. However, when calculated on a per tonne basis, it provides a more useful comparison for determining the amount of publicly funded aid that is provided.
- Aid for reducing mining activity – operational aid for those planned for closure (Article 4).
- Aid to cover exceptional costs – to cover the cost of restructuring and decommissioning, as well as inherited social and environmental liabilities associated with mine closure (Article 7). Each mining corporation may have a combination of state aid packages to cater for a number of mines, some closing and others maintaining operations.

Table 6 and Figure 17 show the major producers in the EU that receive state aid for hard coal production. In many of these countries, lignite is produced without the need for state aid; however clearly hard coal production is assisted to varying degrees. In 2007, some 99 Mtce of coal was produced in these seven EU member states under the regulation that qualifies for state aid. The largest producer was Poland, which accounted for almost 70% of all the coal produced with state aid, in one form or another. However, Poland's state aid comes mainly under Article 7, which covers exceptional costs for restructuring the industry.

Table 5 Coal priduction falling under the scope of the EU Coal Regulation (Rademaekers and others, 2008)

Coal-production, Member State		Year	Production of coal		
			falling under regulation, tce	amount of subsidised coal, tce	**not** captured by the Regulation, tce
Bulgaria	hard coal	2007	1,278,900	Competitive. Only aid under article 7	0
	ortho-lignite	2007	0	0	9,750,800
Czech Republic	hard coal	2007	12,142,000	Competitive. No more subsidies since 1993	0
	ortho-lignite	2007	0	0	18,734,000
Germany	hard coal	2007	17,600,000	17,600,000	0
	ortho-lignite	2007	0	0	68,552,000
Hungary	hard coal	2007	935,550	935,550	0
Italy	hard coal	2007	312,000	Aid from region to capital. EC not notified	0
Poland	hard coal	2007	69,920,000	No production aid. Only aid under Article 5-2 and Article 7	0
	ortho-lignite	2007	0	0	21.812,000
Romania	hard coal	2007	2,100,000	2,100,000	0
	ortho-lignite	2007	0	0	12,500,000
Slovakia	hard coal	2007	819,850	No production aid. Only aid under Article 5-2 and Article 7	0
	ortho-lignite	2007	0	0	7,136
Slovenia	ortho-lignite	2007	0	Competitive. Only aid under Article 7	1.786,0000
Spain	hard coal	2007	6,446,000	6,446,000	0
	ortho-lignite	2007	0	0	1,673,885
UK	hard coal	2007	13,600,000	Competitive. Subsidies stopped in 1994	0

Table 6 State aid to coal (Rademaekers and others, 2008)

Country/ EU Member state	Coal type	Year	Subsidised coal, Mtce	Article 5-3 production subsidy, €	Article 5-2 initial investment aid, €	Article 4 Aid for reducing mining activity, €	Article 7 Aid to cover exceptional costs, €	Total aid under Article 4, 5-2, 5-3 & 7, €	Average Total aid per tce, €/tce	Operational aid and initial investment ex decomm and other exceptional losses, €\/tce	Operation aid and initial investment of total aid, %
Bulgaria	hard	2007	1.3				4.86	4.86	3.8	0.00	0
Germany	hard	2007	17.6	1880		424	560	2864	162.7	106.82	66
Hungary	Hard	2007	0.9	39				39	41.7	41.69	100
Poland	hard	2007	69.9		51.47		1810	1861	26.6	0.74	3
Romania	hard	2007	2.1	92.8			4.0	96.8	46.1	44.19	96
Slovakia	hard	2007	0.8		3.2		2.5	5.7	7.0	3.90	56
Spain	hard	2007	6.4	450.2		35	663.121	1148.3	178.1	69.84	39
TOTAL			99.1	2462	54.67	459	3045	6020.2	60.7	25.4	42

State aid in its various forms however is most controversial when it is applied to help ongoing production of mines that would otherwise be uneconomic. It is worth mentioning that subsidised mining across Europe is facing a bleak future due to economic constraints, and the decline in coal demand. However, the relatively volatile pricing and security concerns of other fossil fuels and raw material commodities means that domestically available coal is increasingly attractive, even against the backdrop of increasing imported coal. It is possible that coal state aid could experience a renaissance if the EU deem such coal supplies as essential to provide a platform for secure domestic energy supplies alongside renewable energies and to some degree, nuclear.

Table 6 and Figure 17 show some €6 billion was issued across these countries. Funding is dominated by just three countries, Germany, Poland, and Spain. The remaining producer subsidies are insignificant in terms of total fund. It can be argued that under Article 7, the funding for exceptional costs could be deemed as a contribution to redevelopment and actively financing a reduction in uneconomic mining. Almost all of Poland's state aid falls under this. Germany has a large proportion of production subsidy, amounting to €1.9 billion in 2007. This production subsidy accounts for two thirds of the total funding to the hard coal industry, the remainder is split to cover coal restructuring and exceptional costs under Articles 7 and 4 respectively.

In Spain, there is a similar situation where producer subsidies account for a large proportion of the total fund, in this case, almost 40%. While the total state aid is considerably smaller in Hungary and Romania, operational subsidies account for 100% of the allocation of funding. So, the distribution of state aid shows a varying level of fund allocation in different member states. If this state aid was interpreted in terms of per unit of coal produced, the picture shows a proportionally similar picture. When looking at state aid on a per tce basis, a similar picture emerges except

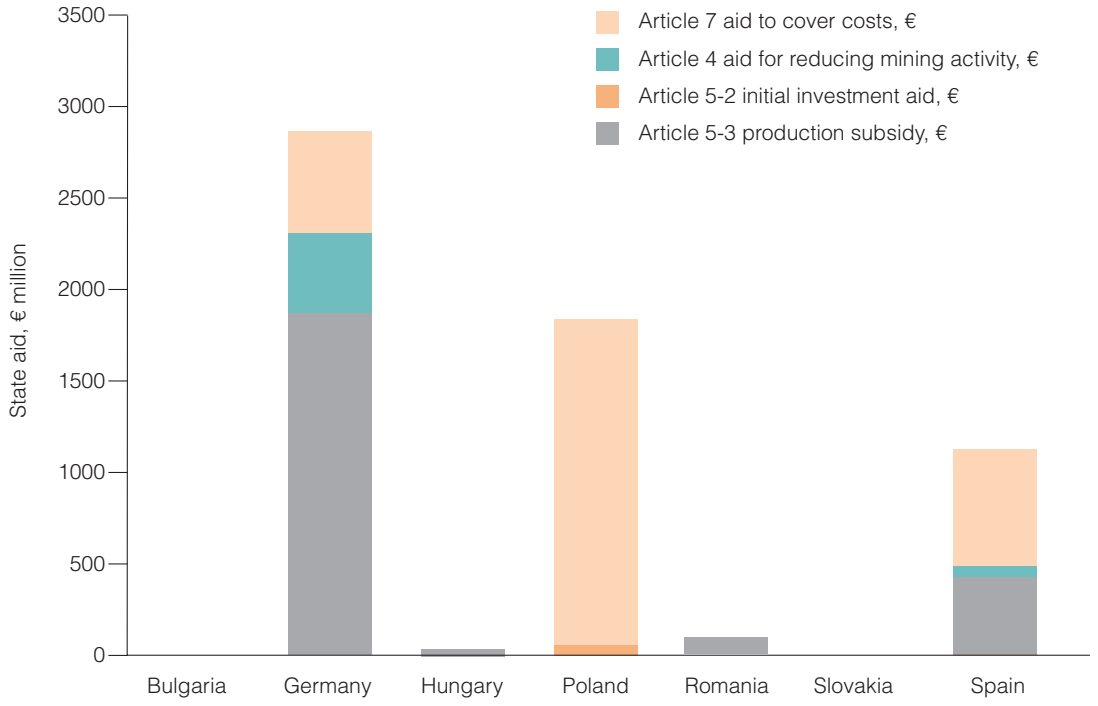

Figure 17 Components of state aid in 2007 by EU Member States (Rademaekers and others, 2008)

for Poland. Since Poland is the largest producer of hard coal in the EU at some 70 Mtce/y, the €/tce level of state aid drops significantly to below that of Hungary and Romania. The interesting cost spikes occur in Germany and Spain, where production has been in decline but state funds have remained more or less constant in past years.

Spain appears to provide the most aid to its industry financing a total of almost 180 €/tce (*see* Figure 18). However. the bulk of the funding is for the decommissioning of the industry as well as financing social and environmental liabilities. The inclusion of these are logical since the mining industry leaves a legacy of health, social and environmental issues that if not properly accounted for, must be paid for by the state or passed through by appropriate pricing. This issue is discussed later, but is a very important one since the pass through of costs may appear transparent as subsidies, but may be a component of coal pricing that is omitted by some major coal exporters. Regarding the inclusion of decommissioning and legacy costs, this is an area which is debated vigorously amongst stakeholders and opponents of nuclear power.

It is important to understand the full costs of closing a mining industry even if the sector is in receipt of state aid. This is because when industry is in decline or contracting, society pays for the social welfare of the incumbents either through regeneration schemes or simply welfare costs to provide incomes to those affected. In one way or another, the state and private industry have to provide some form of extra assistance to these regions. There is a danger that such aid is wrongly stated as assistance to the coal *industry* as opposed to assistance to coal *communities*.

If operational subsidies were considered in isolation, Spain state aid accounts for 70 €/tce. German state aid is equivalent to a considerable 110–115 €/tce. Typically, the operational subsidies allow the true (and high) cost of coal production to be deflated to levels equivalent to the delivered price of coal from imported sources. The extra fund therefore allows domestic production to be competitive.

Subsidised coal is almost exclusively used for the purposes of electricity generation. However whether coal produced in many EU Member States is capable of being competitive in the future is

questionable. In Hungary, operating aid is expected to end in 2014; Germany intends to cease operational aid in 2018. Most Member States are undertaking measures to reduce subsidies. DG TREN (2008) considered the reduction in output and employment in Member State coal industries. This is summarised as follows, and in further detail on the Atlantic and Pacific markets.

Germany: under the Hard Coal Financing Act 2007, sales aid and decommissioning funds between 2009 and 2019 will add up to €19.5 million. North-Rhine Westphalia will contribute €4 billion. Saarland Federal State will refuse any further payments. After 2018, a further €2 billion will be provided to those workers who are unemployed after closure of the last pit. Any remaining employees will be deployed in the decommissioning process until 2022. Surface mine workers aged 57, and underground mine workers aged 52 will receive transitional benefits for five years until they reach the age of early retirement. The measures to secure the wellbeing of German miners are impressive, albeit costly to the German state.

France: the coal industry stopped producing in 2004, but was still eligible for aid in order to restructure the industry. The Ministry of Industry estimated that public spending on mine closure could amount to €820 million between 2003 and 2013 under Articles 4 and 7 of the EU Regulation. This funding is aimed primarily at securing mining sites, pit surveillance, and monitoring of subsidence and gas leakage, pollution cleaning, hydrogeological and hydraulic issues, and the dismantling of infrastructure. Charbonnage de France is the main recipient of state aid, the only main coal production entity in France. In 2005 the EC Commission permitted €94 million to ensure the clean and safe shut-down of coal-fired power stations; €11.6 million was earmarked for addressing direct environmental damage caused at the mining sites; €300 million was spent during 1997-2007 on post mining security and environmental management.

UK: is not in receipt of any operational aid, although the country did receive €5.2 billion of EU-authorised aid between 1994 and 2005. State aid is not being sought for future production, although there is rigorous support for state aid in clean coal power to help ensure a clean and sustainable

Figure 18 State aid in 2007 on a $/tce basis for selected EU Member states (Rademaekers and others, 2008)

market for coal in the UK power sector that will aid both domestic production and imported coals.

Spain: In 2010, Spain was granted approval to double its coal aid until the end of 2014 (Tait, 2011). The subsidy will operate as a guaranteed takeoff agreement for coal-fired power that runs on domestic coal. The agreement is still under a legal review and being opposed by some groups in the gas industry as well as regional authorities.

11 Conclusions

Coal imports provide a useful buffer for supplies when domestic supplies are disrupted, and also act as a suitable complement to traditional sources, but imports are the first to suffer when there is a downturn in the market for coal.

It is difficult to draw conclusions on a global scale as the world's coal industry is a patchwork of different markets, each incurring different sets of environmental regulations, market deregulation, and competition from other fuels. This report is one of three reports covering general global aspects of international trade and its role in displacing domestically-produced coal in certain regions in the world. Separate reports look in more detail at selected Atlantic (Germany, Spain, UK, and USA) and Pacific (China, India, Japan, and Korea) coal importers that have experienced a rise in trade.

Internationally-traded coal is almost entirely moved by sea in dry bulk vessels, sometimes over vast distances. However distance is still sometimes a limiting factor and two key regions have developed in two distinct ways, the Atlantic and the Pacific market. Each can interact with the other, and the price trends tend to be the same.

Over the years, the seaborne trade in hard coal has developed into a 1 Gt market. This report focuses on the steam coal market, which has seen seaborne trade rise to 700 Mt/y. World trade in coal was initially driven by Europe in the 1970s, but has since been dominated by Asia. Australia and Indonesia are the leading exporters of steam coal, however their role is mainly in the Pacific market. The Atlantic is served chiefly by Russia, Colombia and South Africa, although there is increasing crosstrade with Asia.

The USA has a much smaller role as an importer, the country is better known for its export potential. Its inclusion in this report is due to the way the trade in international coal imitates the US domestic market. Since the 1990s, the USA saw cheaper subbituminous coals from the Midwest displace locally-mined bituminous coal in the Eastern and Northern states due to the superior sulphur qualities of the Midwest coals. Utilities adapted their power stations to take the low sulphur product in order to meet stricter emission standards. For the same reasons today, Indonesian subbituminous coal exports are carving the same niche in many local markets worldwide, in both Asia and Europe.

Internationally-traded coal provides coal in a fairly tight specification band, that is typically high in heating value, low in sulphur, moisture and ash. However, the rise in lower rank coals in the international market with coals from Indonesia shows how power utilities across the world will readily blend coals of differing qualities and characteristics to ensure certain criteria such as sulphur content is met.

As far as the future is concerned, OECD Europe serves as a model that other countries could follow as Europe has some of the strictest emission regulations in conjunction with greenhouse gas reduction targets. This combination makes the European market particularly challenging for coal industries. Structural changes in the power generation sector and a massive shift away from coal in the residential and industrial sectors has led to a massive reduction in the demand for coal. Europe also has logistics in place to import coal, and as such, the threat to domestic coal industries comes from two directions, structural change and foreign suppliers. Other countries may well look to Europe to see what could happen to their domestic industries if they adopt greenhouse gas emission targets alongside stricter airborne pollution standards.

The future of domestic production is different for different markets. The threat of closure is acute in parts of Europe, but until subsidies are withdrawn, it is difficult to see how industries will adapt. Production in OECD Europe has undergone restructuring and a withdrawal of state aid that kept these

industries successful for decades (40–100 €/tce). However, unsubsidised coal production remains in some European countries such as the UK, while Spain and Germany face an uncertain futures beyond 2018. Price competition with internationally-traded hard coal is now impossible in some countries, and unsustainable. However, clearly the cost of imported coal is influencing and driving the price of domestic coals, subsidised or not.

Internationally-traded coal offers a great deal more supply security at lower cost, and changes in quality are readily dealt with. As already mentioned, the experience in the USA with regards to coal switching is considerable. Careful testing over the years shows these coals cause changes in boilers designed for bituminous coals regarding ash behaviour. Also, the alkalinity of the fly ash composition can affect corrosion in various parts of the station. However, adapting to lower rank coals seems to be done readily given the massive rise in demand for these products despite the higher moisture and lower heating values. It is clear that in today's more competitive power markets, power station operators are now no longer tied to local coal mines the way they once were.

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