Anthony Williams

Market evaluation of Bowen Basin thermal coals for the Indian and Chinese markets

China and India imported 218Mt and 123Mt tonnes of thermal coal respectively in 2012 and this number is expected to increase over the next 5 years. Both countries have a domestic supply of coal available but, due to shortfalls in supply of domestic coals, both countries import significant quantities of coal. There is significant potential for growing the volume of Bowen Basin thermal coals sold into these markets. It is highly beneficial to coal producers of Bowen Basin coals to understand how the coal quality, utilisation performance, and value-in-use of Bowen Basin coals would be perceived in these markets. Blending of coals is also a common procedure in many power plants with Indian and Chinese plants have the options of blending imported coals with domestic coals as well as with other imported coals.

The paper will explore the market potential of Bowen Basin coals for the Indian and Chinese markets. The paper will discuss coal quality of Bowen Basin coals, expected utilisation performance in coal fired power plants and the value-in-use of Bowen Basin coals from the point of view of a Chinese and Indian Power Plant.

Keywords: Value-in-use, Thermal Coal Market, Thermal Coal Utilisation,

INTRODUCTION

There is a significant opportunity for producers in the Bowen Basin to develop their technical marketing strategy to focus on China and India for future growth in coal exports. Figure 1 shows historical and forecast thermal coal imports of China, India, Europe, Japan, Taiwan, and South Korea as sourced from the Australian Department of Industry and Science, 2015. China and India standout as significant coal importers over the next 5 years as seen by the predicted growth in coal imports. India is predicted to increase coal imports by 50 percent, a significant increase. Although there are efforts in India to boost domestic coal supply, it is unlikely that the growth in coal production can match the growth in demand for coal-fired electricity. Japan, Taiwan and South Korea used to be primary targets for the exports of Bowen Basin and other Australian coal but the predicted imports volumes indicates a slowly growing market in Taiwan and South Korea, and a decreasing market in Japan over the next five years. The Europe market is expected to stay relatively constant over the next five years. India currently imports 3 times as much Indonesian coal as Australian coal (IEA coal statistics, 2014) and there is consequently significant potential for Bowen Basin and Australia producers to grow market share in India.

Figure 1 also shows the predicted coal exports from the major producing countries including Indonesia, Australia, Russia, Colombia, South Africa and the United States. Indonesia is the largest exporter of coal which is expected to continue over the next five years. However, exports from Indonesia are expected to decrease by approximately 5 percent over this time period, most likely due to the increasing demand for domestic coal fired electricity within Indonesia. Coal exports from Australia and South Africa are expected to increase by 20 percent and exports from Colombia are expected to increase by an impressive 60 percent. The United States is currently a minor exporter of thermal coal which is expected to reduce over the next 5 years.

POWER PLANTS IN CHINA AND INDIA

China and India are significant users of coal-fired power. Coal generates approximately 81% of China's electricity and 71% of India's electricity (IEA coal statistics, 2014). Figure 2 shows the location of power plants throughout India and China. India has power plants scattered throughout the country, and China also has plants that are scattered, but these are primarily located on the eastern side of the country. The purple dots indicate power plants that are greater than 200kms from the coastline. It is unlikely that these power plants would import coal unless a domestic supply of coal was unavailable. China and India have domestic supply of coal available and consequently the majority of power plants are designed to utilise domestic coal, although a small percentage have been designed to utilise imported coal.

A significant cost for coal-importing power plants is shipping. Shipping costs can fluctuate significantly depending on market conditions. Average shipping costs from different coal exporting ports in Indonesia, Australia, Russia, Colombia, South Africa and the United States were determined from Coalspot (2005). An average cost per distance was calculated from published shipping costs for Capesize ships in cost-per-tonne for difference routes to China and India. Average distances were determined between the coal exporting ports of the major coal exporting countries and the ports of China and India. Shipping distances were determined using BP Marine tables and considered main shipping lanes that circumvent travelling around coastlines. Average shipping costs in $/t were calculated considering the average $/distance and the actual shipping distances between the export and import ports.

Figure 3 shows the costs of shipping a tonne of coal to India and China from Australia vs. other exporting countries.

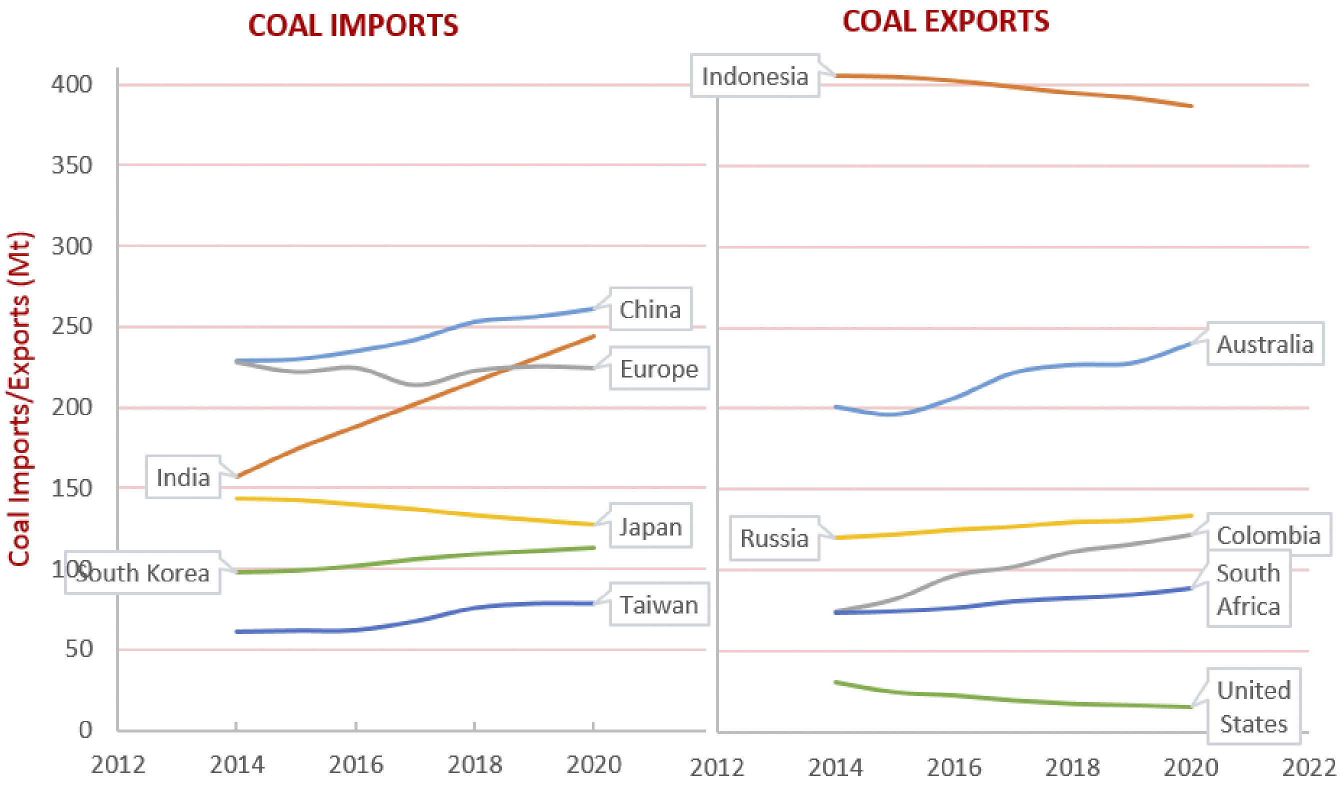

Figure 1: Historical and forecast thermal coal imports and exports for major importing and exporting countries (Australian Department of Industry and Science, 2015).

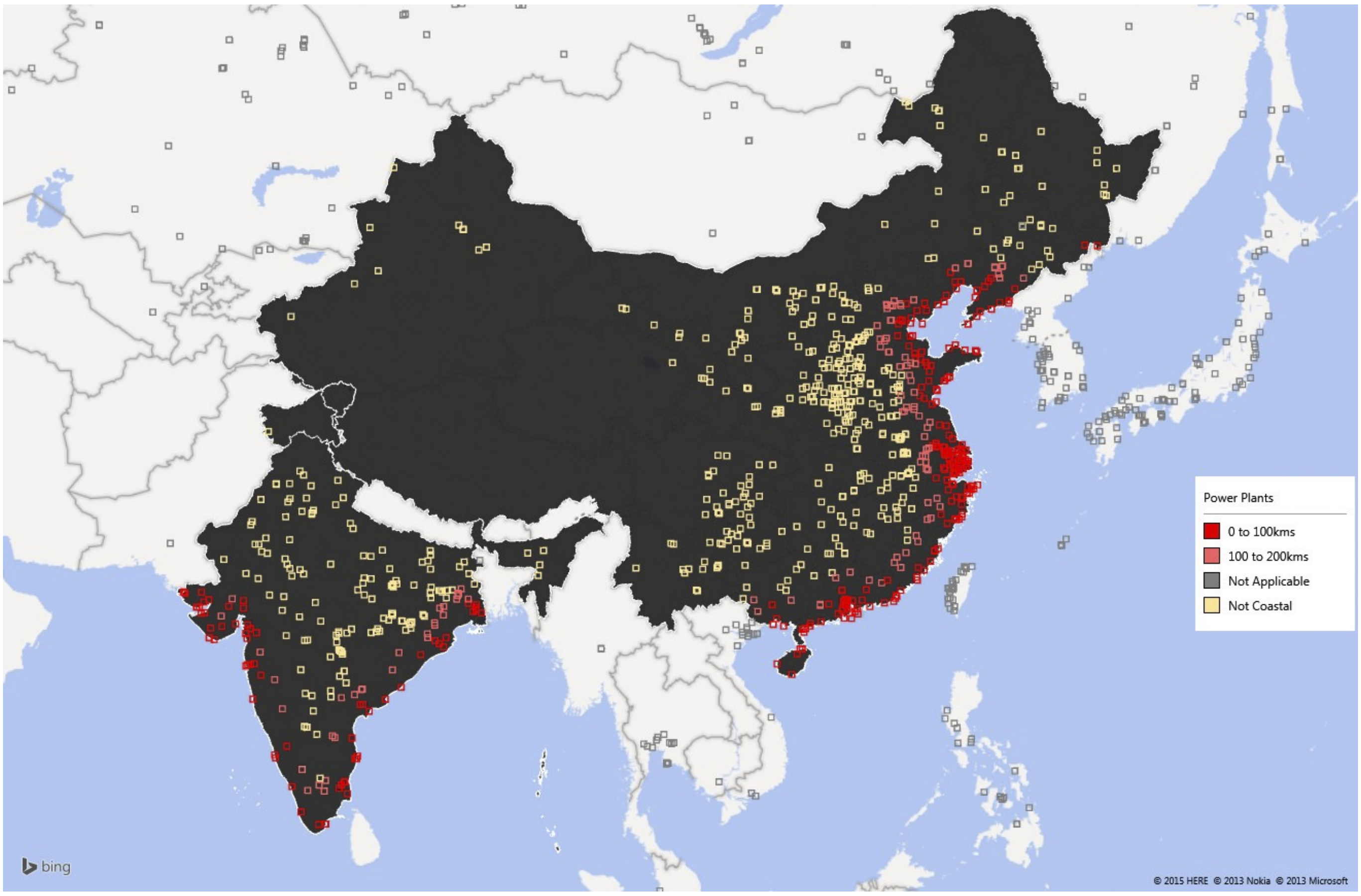

Figure 2: Location of operating coal fired power plants in China and India (A&B Mylec power plant database).

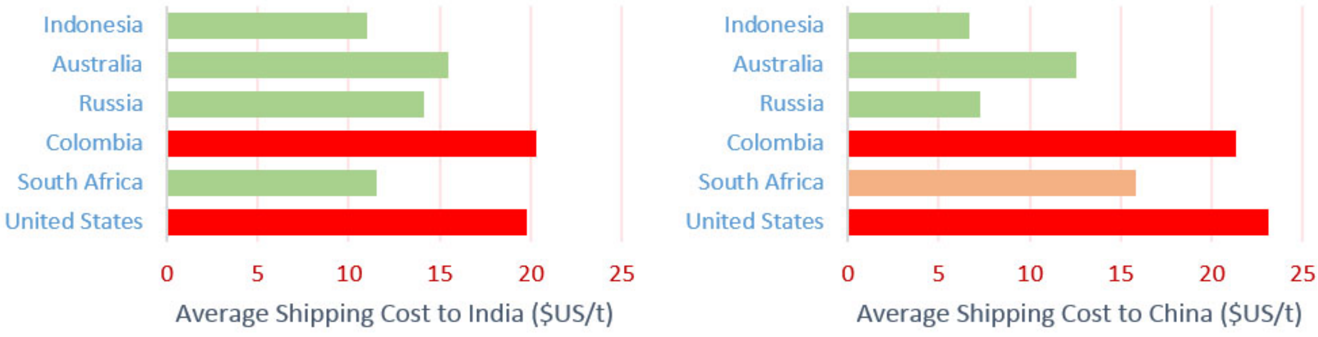

Figure 3: Average shipping costs to India and China from major coal exporting countries.

Based on shipping rates alone, for Indian power plants, coal sourced from Indonesia, South Africa, Australia and Russia are preferred over coal from Colombia and the United States. Chinese power plants prefer coal from Indonesia, Russia and Australia and not necessarily from Colombia and the United States. Coal imports from South Africa may be acceptable. Shipping rates have decreased significantly from 2014 due to the collapse in the oil price and, consequently, coal can be transported further than it can at the previously higher oil prices. Consequently, because of lower fuel costs, coal from sources such as the United States or Russia may be able to compete in the Indian market. However,coal from the United States and Colombia typically flow into the European market. Considering this market is expected to stagnant over the next five years and with the expected rapid growth in coal from Colombia, some of this coal may end up being transported to the South-East Asia region. The evaluation in this paper will focus on coal exports from the Bowen Basin and other regions in Australia, Indonesia, Russia and South Africa to power plants in China and India.

Power plants are designed to a coal specification which could be a domestic coal or possibly an imported one e.g. Japanese power plants are designed for imported coal. Key coal quality specifications for power plant design include calorific value, ash content and moisture content. These parameters are also extremely important in the pricing of coal as shown in Figure 4 which compares the HBB marker published by the Indonesian government, adjusted for coal energy with calorific value, moisture and ash content. Figure 4 shows coals with a wide range of calorific values, moisture contents and ash contents. The benchmark price per energy unit increases as the calorific value of coal increases and moisture content decreases. This means the lower energy content coals are cheaper on an energy basis and this gives credence to the massive growth in coal exports from Indonesia. The data is scattered for variation in ash contents. An equation was developed to estimate the price of a coal from calorific value, ash content and moisture content. Sulfur content is also an important parameter with respects to the pricing of coal, but its importance to pricing is reliant on the local SO_2 emissions regulations of the power plant that's purchasing the coal. Coal prices are used to determine the value-in-use metrics of different coals in a Chinese power plant and an Indian power plant.

The physical tests conducted in a proximate analysis are ash content, moisture content and volatile matter content while fixed carbon is calculated by difference.. A correlation was developed between normalised fixed carbon and calorific value. The normalised fixed carbon was calculated from the as-received ash and moisture contents such that:

$$100 = \text{Ash Content } (\%ar) + \text{Moisture Content } (\%ar) + \text{Fixed Carbon } (\%ar)$$

The developed correlation has a R^2 value of 0.893 indicating a strong correlation exists between calorific value and normalised Fixed Carbon. The relationship allows the plotting

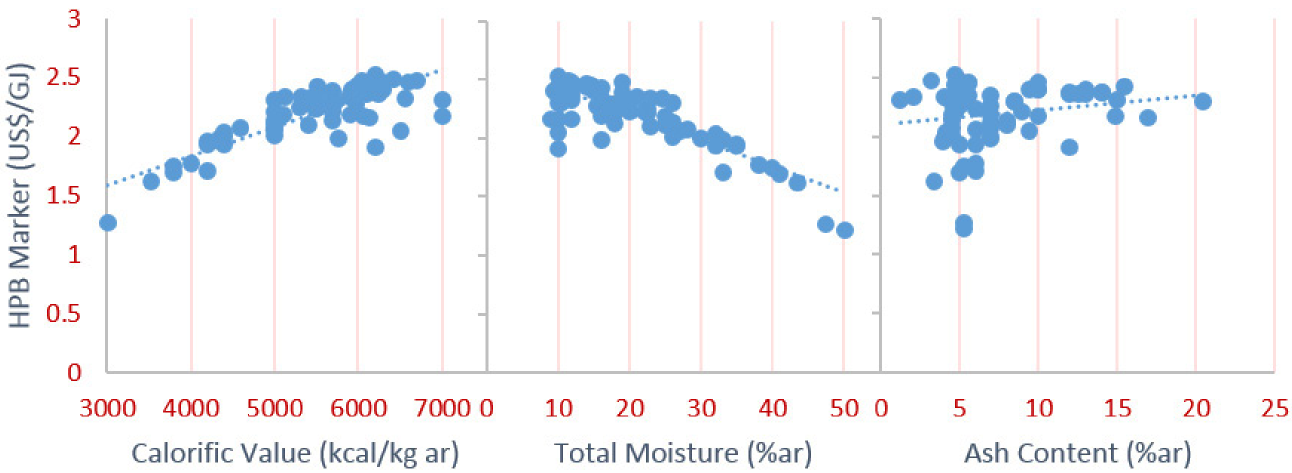

Figure 4: Comparison of HBB marker (April 2015) with calorific value, moisture and ash content.

of coals on a ternary diagram (Figure 5) with the axes of ash content, moisture and fixed carbon/calorific value. Instead of using the fixed carbon determined from the proximate analysis in the chart, the normalised fixed carbon used for the chart was calculated from the calorific value which ensures the parameter is independent of ash and moisture. A&B Mylec's coal quality database is plotted in Figure 5. The data are filtered for export thermal coals and grouped by location – Indonesia, South Africa, Russia, Other countries, Bowen Basin and other Australia. Considering that pricing is heavily dependent on energy, moisture and ash, pricing contours are also included in Figure 5.

Figure 5 shows that all coals tend to be localised within the lower right corner of the ternary diagram and have high energy, an ash content less than 50% and moisture levels less than 50%. Most exported coals have superior properties than coals used domestically (the exception being Indonesia. Most of the Bowen Basin coals are priced above $50/t with ash contents less than 20%, moisture less than 15% and calorific values greater than 6000 kcal/kg. The Indonesian coals are grouped along the base of the diagram and have low ash content and a high variation in moisture content that results in a large variation in calorific values and price. Coals from other countries are scattered around the bottom right corner.

A database of coal-fired power plants around the world has been compiled by A&B Mylec and contains a range of plant information, including design specifications for some plants. The information was sourced from commercial work, library sources and other publically available sources. While th information in the database is currently under review, the power plant data for India and China has already been reviewed and validated against data from multiple sources.

Included in Figure 5 are the ranges of plant specifications for Chinese and Indian power plants. The design ranges include coals that have lower coal quality characteristics than that of exported coals because the plant has been designed to use local, domestic coals without any form of washing or upgrading process. Indian coals are known to have very high ash and the specifications indicate that the power utilities can utilise ash contents up around 45%. India does also have high moisture content coal resources which explains why the plant specifications have high moisture limits.

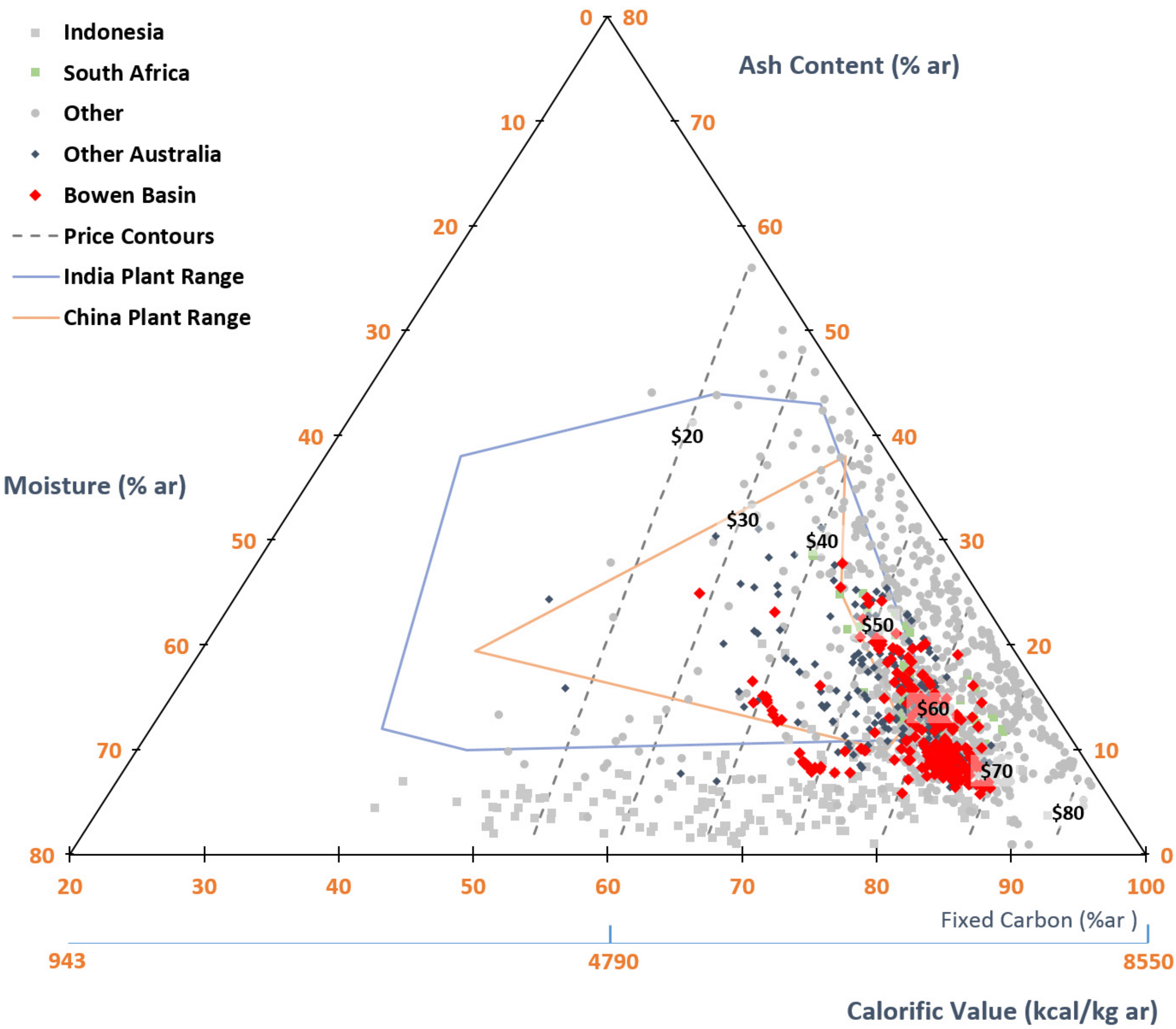

Figure 5: Comparison of calorific value, ash content, and moisture for Bowen Basin coals with other Australian and International coals.

A small selection of Indian coals are included in Figure 5 under the 'Other' category. However these coals do not reflect how low the quality of product coal can be in India. Coal of India, the major coal producing company in India, sells domestic coal with energy contents down to 2200kcal/kg (Coal of India website, 2015)

Even though the product specifications for Bowen Basin coals and other traded coals exceed the typical plant specification of Chinese and Indian plants, they may still be used by the power plants in a blend or utilised as 100% feedstock, assuming that some validation testwork is performed to ensure the plant can safely use the coal.

IMPACT-THERMAL VALUE-IN-USE MODEL

The research in this paper will use a value-in-use model called IMPACT-Thermal to predict utilisation performance and value-in-use metrics of a coal fired power station in China and India. There have been numerous publications describing and utilising the model and further details of IMPACT-Thermal can be found in these publications (Juniper, L 1996 and Juniper & Pohl, 1999).The outputs from IMPACT-Thermal were reviewed and evaluated using MarketMastor™, a tool created to facilitate the evaluation of market data and information by utilising value-in-use models, correlations and data from coal quality specifications, power plants, cement plants, steelworks and shipping ports.

The assumptions are that the coal will be delivered to a modern super-critical 300 MWe, pulverised coal-fired power plant located:

1. on the Eastern coast of India; and
2. in Hong Kong, China.

The general power plant operating conditions assumed are set out in Table 1.

The evaluation of the impact of coal properties on plant performance assesses whether a particular coal will, or will not, suffer any extraordinary cost penalties due to any of the following issues:

- Load limitations caused by exceeding operating limits, such as:
    - o Exceeding dust or pollutant emissions;
    - o Exceeding pulveriser or boiler operating limits;
    - o Not attaining required steam conditions;Boiler shutdown or loss of availability caused by excessive ash deposition; and
- High carbon-in-ash levels, which would prevent sale of fly ash to the cement industry.

IMPACT-Thermal accounts for all of the above limitations with the exception of steam temperature attainment. The mass and energy calculations required to estimate this aspect are very complex and not available in IMPACT-Thermal.

Power Station Costs and Fuel Costs

The performance and costs for individual components in the power station's coal chain can be estimated by using indices and/or correlations between coal properties and plant performance, which have been developed over the past few years. Costs of operating the various components can then be evaluated by assigning relative costs to the variations in performance for a range of coals of interest. This procedure provides an evaluation of the overall cost benefit of using a particular coal in pulverised-coal-fired (PF) plant, and a relative value of the coal of interest, compared to a range of competing coals.

Fuel costs include the net cost of the coal as delivered to the power station stockyard. The price to the stockyard includes the freight cost and a discharge handling cost.

Table 1: Assumed Power Plant Parameters for Chinese and Indian plants.

Parameter	Units	Chinese Plant	Indian Plant
Location		Hong Kong	East Coast
Capacity	MWe	350MWe	300MWe
Annual Capacity Factor		90	85
Turbine Heat Rate	MJ/MWh	8300	9000
Boiler			
Loading Profile		Base	Base
Excess Air	%	20.0	20.0
Flue gas exit temperature	°C	130	130
Mill type		Verticle spindle	Verticle spindle
Number of pulverisers		6	6
Pulveriser capacity		30	30
Design HGI		50	50
Design PF fineness	%<75mm	70	70
Environment			
Dust Collection		Electrostatic Precipitators	Electrostatic Precipitators
Flue Gas Desulphurisation		No	No
Fly ash utilisation		Yes	Yes

UTILISATION PERFORMANCE OF BOWEN BASIN COALS

Four parameters were evaluated for utilisation performance including: power consumption, mill wear, ash deposition potential and carbon-in-ash. Various statistics are used to assess the utilisation performance and allow comparison between different countries. The statistics include the median, 1st quartile, 3rd quartile, 5 percentile and 95 percentile which are described in Figure 6. Figure 7 shows the statistics for the expected utilisation performance for the major thermal coal exporting countries, major thermal coal importing countries that also have a domestic supply of thermal coal available, and coal exporting regions within Australia. The top exporting countries include Indonesia, Australia, Russia, Colombia, South Africa, and the United States of America. The major importing countries include India and China. The coal exporting regions in Australia include the Bowen Basin, other QLD, Hunter Valley and other NSW.

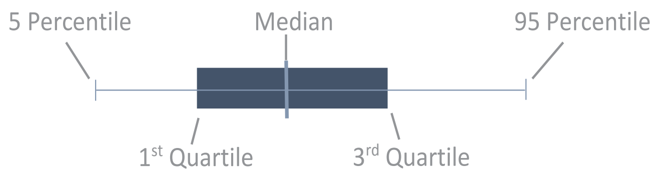

Figure 6: Description of bars used in figures.

Mill power consumption

The coal property most commonly used for evaluation of grinding performance by utilities is HGI. The consequence of low HGI values on the grinding performance of coals is: a) a coarser product which may result in poor burnout, and b) higher power consumption to produce a product of the required fineness. Mills are designed to handle the coal throughput necessary for a given boiler size and the energy content of the coal. A plant fired on low-energy content coals would be expected to have a higher pulverising capacity than a power plant designed to handle a high-nergy coal. For example, an Indian power plant using low-energy domestic coal would be expected to have a higher pulverising capacity than a Japanese plant utilising a high-energy Newcastle coal. Consequently, the Indian plants and some of the Chinese plants would be expected to have spare mill capacity when utilising higher energy coal.

Figure 7 shows expected power consumption (adjusted for coal energy). Bowen Basin coals require very low power consumption when compared to coals from other Australian regions and low consumption when compared to other countries. This is due to the relatively high HGI and calorific value of Bowen Basin coals. However, as well as between Bowen Basin coals and other Australian coals, there is a wide range of variation in these coal quality parametersbetween Bowen Basin Coals themselves, This indicates that individual Bowen Basin coals should be evaluated independently.

The Bowen Basin coals are expected to require lower power consumption in their utilstation than coals from key competing countries like Indonesia, South Africa and Russia.

Mill wear

A factor that significantly contributes to the cost of pulverising is the wear of mill components. Wear is generally governed by the combined influence of coal properties, mill operating conditions and the materials that make up the grinding components. Coals with a high concentration of hard minerals (mainly quartz), are likely to cause higher mill wear rates. Quartz content can be estimated from the silica and alumina contents of the coal ash. Coals that have quartz content in their entrained mineralsof less than about 3–4% are unlikely to cause unacceptable wear of mill components.

Figure 7 shows that Bowen Basin coals have low levels of quartz (which should result in low levels of mill wear). Their mill wear levels are lower than coals from other Australian regions and similar to coals from South Africa and the United States. As a result of their low ash contents, Indonesian coalshave quartz levels significantly less than Bowen Basin coals. The quartz levels in Bowen Basin coals are significantly less than that found in domestic Indian coals and, consequently, Indian power plants will achieve reduced pulverising costs when using Bowen Basin coals. The quartz levels in Bowen Basin coals are are similar to Chinese coals and, consequently, Chinese power plants should notice little variation in mill wear behaviour when utilising Bowen Basin coals.

Boiler tube erosion is also affected by quartz levels in coal and, therefore, coals with a high concentration of hard minerals are likely to cause high rates of boiler tube erosion. Erosion is governed by the combined influence of coal properties, boiler flue gas conditions and tube materials. It is important to appreciate that the size of the quartz particles is a key factor and no assessment of the quartz particle size has been performed in this study. Work by Raask (1985) and Bauver and others (1984) has shown that quartz particles above a certain particle size are very influential in the erosion process. Concentrations of quartz above 6 percent in coal have been shown to cause erosion problems in boilers. The levels of quartz in Bowen Basin coals are less than 6 percent and consequently should cause minimal erosion problems.

Slagging

Ash deposition (slagging and fouling) causes problems in boilers by impeding the heat transfer to the water and steam tubes in the boiler. Operating cost penalties can arise for several reasons, including reductions in heat transfer resulting in reduced load, shutdown of the boiler to remove deposits, and removal of deposits by soot blowers requires the use of non-recoverable steam. Shutting down a boiler to remove slagging deposits can result in loss of revenue in the order of millions of dollars. The propensity of a coal to cause slagging problems in full-scale boiler plant is also affected by the

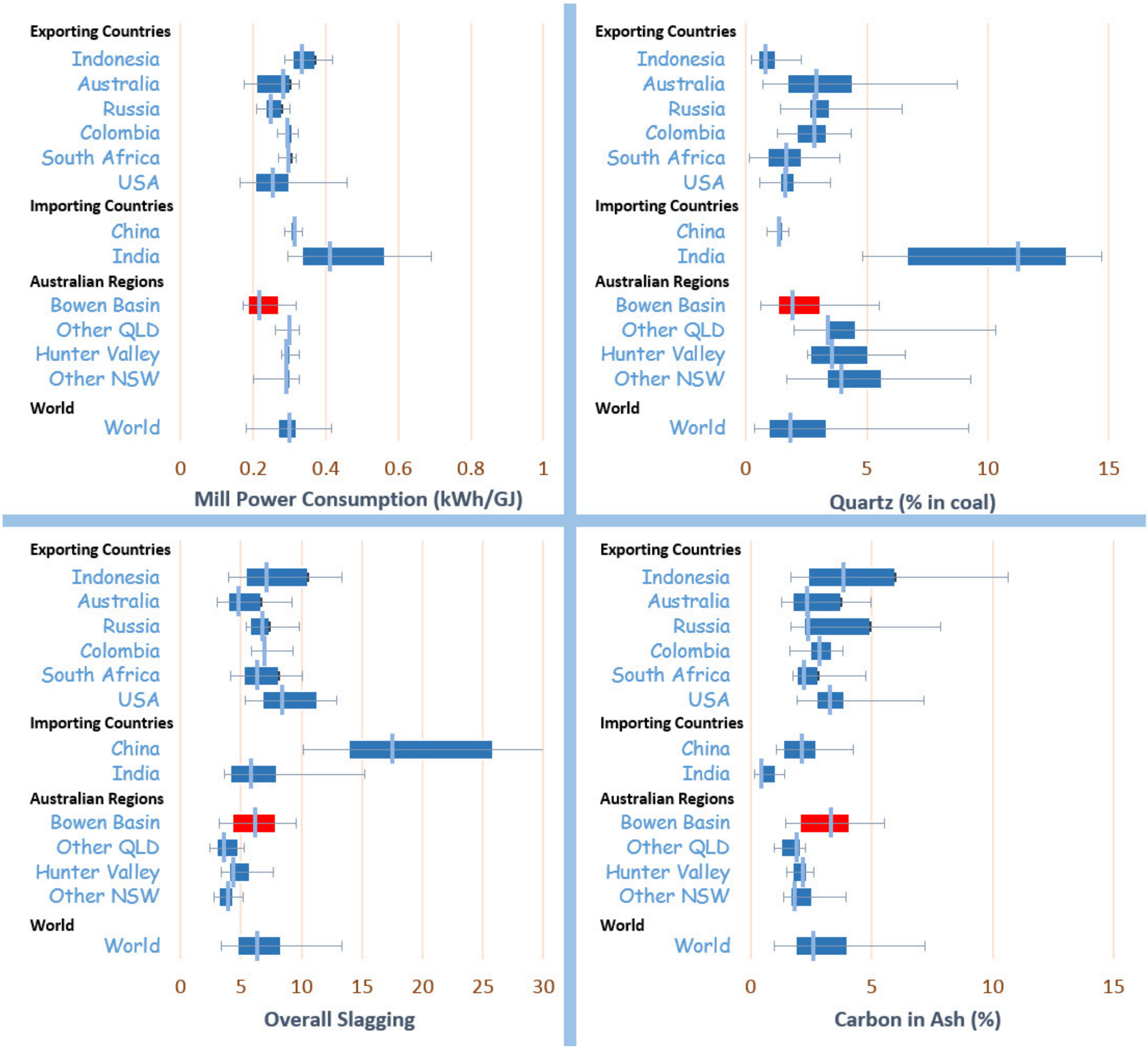

Figure 7: Utilisation performance metrics for Mill Power Consumption, Quartz in coal (mill wear), Overall slagging assessment and Carbon in Ash for Bowen Basin coals and other countries and regions.

boiler design, operating conditions and coal properties. Ash fusion temperatures and ash deposition indices based on ash chemistry are often used for evaluating the ash deposition characteristics of coals. Figure 7 shows an overall rating for ash deposition propensity for Bowen Basin coals and other traded coals. The overall rating is based on a weighted average of the individual indices, with the weighting decreasing from top to bottom of the table. Overall slagging numbers greater than 10 indicate severe slagging potential, numbers greater than 5 and less than 10 indicate moderate potential, and numbers less than 5 indicate low potential.

Bowen Basin coals are expected to have moderate propensity for ash deposition. This propensity is both higher than coals from other regions in Australia and higher than coals from Indonesian, United States and China. Their propensity is similar to competitor coals from Russia, Colombia, and South Africa. The results indicate Bowen Basin coals should behave similar to domestic Indian coals, which should make the coals acceptable to Indian power plants. Bowen Basin coals are significantly superior (have lower propoesnity for slagging) to Chinese coals and consequently Chinese power plants will find these characteristic appealing.

Carbon in ash

The main impact on performance and cost due to combustion characteristics comes from the burnout efficiency of coal. This not only affects boiler efficiency, but it also aids the potential for fly ash to be sold as a by-product to the cement industry. Fly ash can be sold to the cement industry to be used as an additive to cement, provided that the residual carbon-in-ash content is less than 5% (depending on location) and the colour of the ash is acceptable. Ash with high carbon-in-ash values will cause problems with the cement product. However, the actual limit may vary at different plants.

Estimates of pulverised coal burnout can be made from correlations, including adjustments for the effect of pulverised coal size distribution. Fly ash utilisation rates are estimated

at approximately 67 percent for China and 14 percent for India in 2010 (Heidrich & others, 2013). The primary factors that indicate whether a power plant can sell fly ash or not depends on whether the fly ash satisfies the customer's plant requirements and the plant's proximity to its supplier. MarketMastor™ has a database of worldwide cement plants and, considering the distance to the closest cement plant can be determined for every power plant in the world, a good approximation can be made whether these plants are likely to utilise fly ash or not. Chinese and Indian power plants both have accessible cement plants available to use the fly ash, albeit with a sale price of $0/t. Giving away fly ash is still economically appealing for power plants as it avoids fly ash disposal costs.

Figure 7 shows that the expected carbon-in-ash for most Bowen Basin coals is above 5 percent, which is similar to the world average and similar to coal from other coal exporting countries. The carbon-in-ash content is slightly higher for coals from NSW and significantly higher than coals from other Queensland basins. This includes some of the high volatile, reactive coals from the Surat Basin.

There is a broad range of results indicating the analysis should be performed on individual coals. Domestic Chinese coals typically have slightly lower carbon-in-ash than Bowen Basin coals. The carbon-in-ash content is higher for Bowen Basin coals than that typically found in for domestic Indian coals which have low carbon-in-ash due to their high ash contents.

ENVIRONMENTAL PERFORMANCE OF BOWEN BASIN COALS

In Figure 8, emissions of dust and SO_2 are compared for coals from the Bowen Basin, other Australian and coals from other countries.

Dust Emissions

The emissions of dust from coal-fired power plants affects human health and causes smog. The author is unaware of any power plant in the world without some form of dust collection system installed. Modern dust collection units such as electrostatic precipitators (ESPs) and fabric filters remove the majority of dust but the emission of fine dust can especially cause health problems.

The predicted dust emissions from a typical ESP installation are shown in Figure 8. Typical industry limits on dust emissions vary from country to country and from plant to plant. Typically, if dust emissions were to exceed statutory limits, then the output from the plant would need to be reduced. This would have a significant on costs because of the resultant reduction in power sold into the commercial market. In addition, there may be cause to actually import power (usually at higher cost) to fulfil contracts for power supply. Note that, where FGD plant is installed, the ESP performance becomes less critical as a large percentage of the dust is removed by the FGD sprays.

Dust emissions are low for Bowen Basin coals as compared to other Australian coals and to South African coals. The emissions are similar to Russian coals and higher than coals from Indonesia, Colombia and the United States. The emissions are expected to be significantly less than domestic

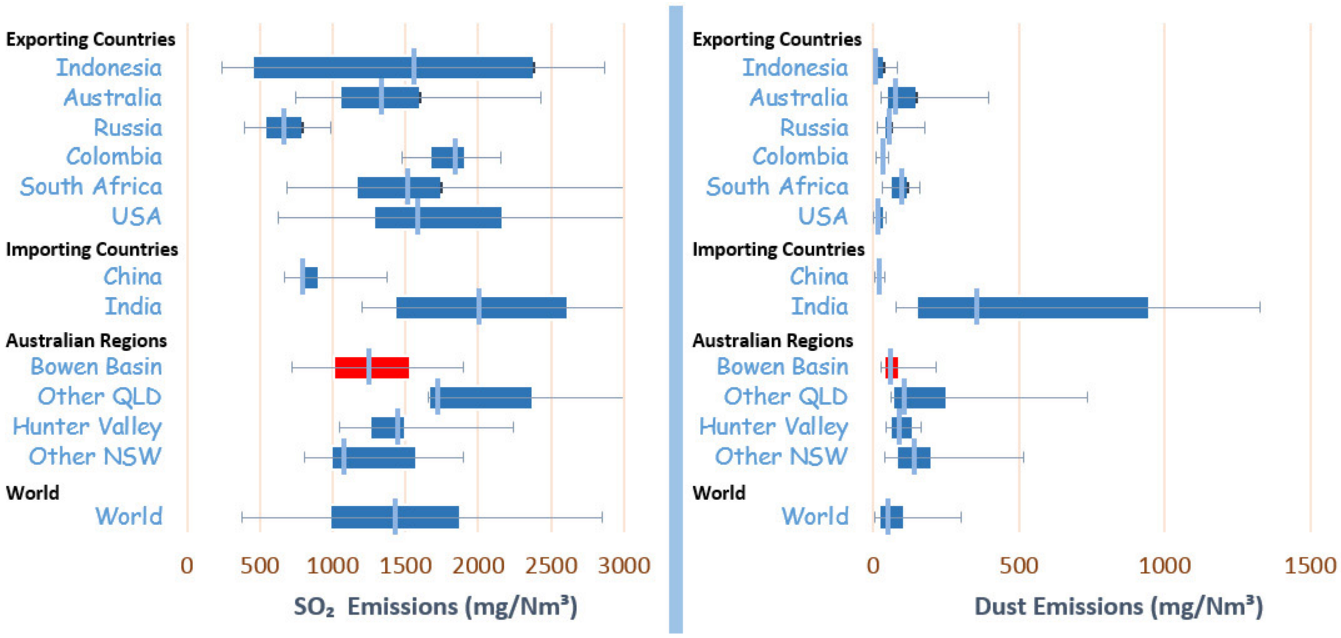

Figure 8: Predicted environmental metrics for SO_2 emissions and dust emissions for Bowen Basin coals and other countries and regions.

Indian coals which have high emissions due to their high ash contents.

SO_2 Emissions

The emissions of SO_2 are regulated by countries around the world due to its effect on human health and influence on the formation of acid rain. During combustion, coal sulfur can either be converted to SO_2 and a small amount of SO_3 or the sulphur can be absorbed into the fly ash. The extent to which the sulfur is absorbed into the fly ash is dependent on the chemical reactions between sulfur and the elements in the ash, particularly calcium. The SO_2 emissions relate very strongly to the sulfur content of the coal.

Figure 8 shows that Bowen Basin coals have lower SO_2 emissions than other coals from QLD, and that they have similar SO_2 emissions to coals from NSW. The emissions for Bowen Basin coals are lower than those from typical coals from Indonesia, Colombia, South Africa and the United States and higher than coals from Russia. Their emissions are significantly higher than those of domestic Chinese coals, which might be seen as problematic in some Chinese power plants, especially as the Chinese government reduces the emissions limits for air pollutants. The SO_2 emissions for Bowen Basin coals are significantly less than domestic Indian coals which will be an important characteristic as India reduces limits for SO_2 emission.

VALUE IN USE OF BOWEN BASIN COALS

The cost of electricity generation at a power plant in China and India was calculated using Bowen Basin coals, coals from other regions in Australia and coals from competitor countries. The cost of utilising coal for pulverised coal fired power generation is dependent on coal properties to the extent that they impact on operating and maintenance costs, net power generated, fuel costs and waste disposal costs. The total generation costs for all the coals included the following parameters:

- Base FOB coal prices were calculated for each coal from a correlation requiring calorific value, ash content, moisture and sulfur content as derived from HBB benchmark data for April 2015.
- Ocean freight rates and discharge costs.
- Penalties due to high carbon-in-ash values, lost income due to low load operation from limits on pulveriser capacity, and reduction in capacity factor due to ash deposition.

Figure 9 compares power plant costs with fuel costs for Bowen Basin coals and other traded coals. The fuel costs for Bowen Basin coals includes the coal cost and their transport costs normalised to the electricity generated from the plant per year. To simplify the charts, coals are categorized into 5 groups; Indonesia, South Africa, Other Countries, Other Australia and Bowen Basin. Plant costs includes capital costs, operating and maintenance costs and lost revenue costs. The plant and fuel costs are normalised to the standard output from the power plant. Preferred coals(i.e. coals with the

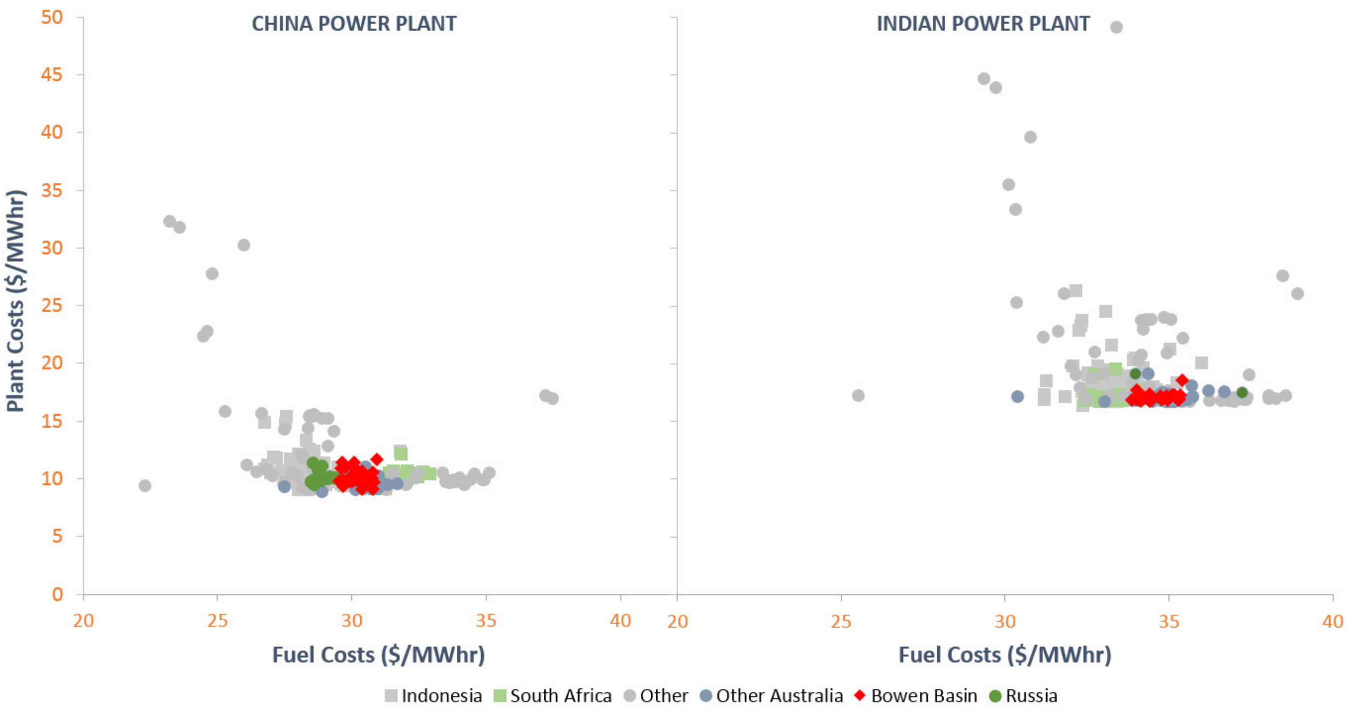

Figure 9: Comparison of plant costs with fuel costs for a Chinese and Indian power plant for Bowen Basin coals and other traded coals.

lowest costs) are those located in the bottom left hand regions of the graphs in Figure 9.

The fuel costs for Bowen Basin coal range around $30/MWhr for the Chinese plant and $35/MWhr for the Indian plant. These costs are in the middle of the cost range for reference coals and similar to the costs for other coals from Australia. The Chinese plant is located slightly further away from Bowen Basin ports than the Indian coal port. The plant costs are low and are similar to competing coal exports. There are a significant number of competing products that have lower fuel costs but have similar plant costs. There are several products with plant costs greater than $15/MWhr that perform significantly worse than other coals. Typically, these coals result in a lower fuel cost than the other coals, but they cause some form of capacity limitation or lost revenue scenario for the power plant. The results indicate Bowen Basin have average fuel costs, but provide low plant costs which should be attractive from a Chinese and Indian power plant point of view.

A comparison of total generation cost versus the delivered cost of coal for Bowen Basin coals and competitor coals is given in Figure 10. The delivered costs refers to the coal price plus shipping price. Other costs such as port and handling costs are not included. The delivery cost of Bowen Basin coals to the Chinese plant or Indian plant varies between approximately $60/t to $90/t. This is a significant cost variation and it is due to the varying properties of the coal products. The delivery costs are higher than for Indonesian coals and they are similar to South African and other Australian coals. Indonesian coals are popular in the market due to the low price and proximity to the major markets in South-East Asia. It could be expected that the cheaper coal price of Indonesian coals would result in lower generation costs.Yet, Figure 10 shows generation costs remain relatively constant, with the majority of coal lying within a narrowly-defined band.

The expected generation costs for the different Bowen Basin coals is similar for both the Chinese and the Indian plant, with the generation costs approximately $10/MWh higher for the Indian plant. The bulk of the coals lie in defined bands for both of these plants. Although the difference in generation costs between the top and bottom of these bands may only be approximately $10/MWhr, this difference equates to $26 million per year for the Chinese plant and $28 million for the Indian plant. Consequently, these plants will experience a significant reduction in costs if a coal is selected fromk the bottom of the range. The Bowen Basin coals lie in the middle of this range and, consequently, power plants in China and India can purchase better performing coals from other countries.

If delivered costs are evaluated considering the electrical output from a plant, a different relationship is observed between Generation Cost and delivered cost ($/MWh) as shown in Figure 11. A clear relationship is observed where increased generation cost results in a an increased delivered cost per electrical output increases. Although Bowen Basin coals are not located at the lower end of generation cost, they are positioned around the average of the dataset. The Bowen Basin coals have a lower delivered cost than South African coals into the Chinese market. However, the South African coals tended to be slightly better than Bowen Basin coals for the Indian power plant. The Bowen Basin coals performed similarly to other Australian coals. Indonesian coals tend to have low generation and delivered cost.

The complexity of coal selection is magnified when coal blending is considered. Domestic Chinese and Indian coals

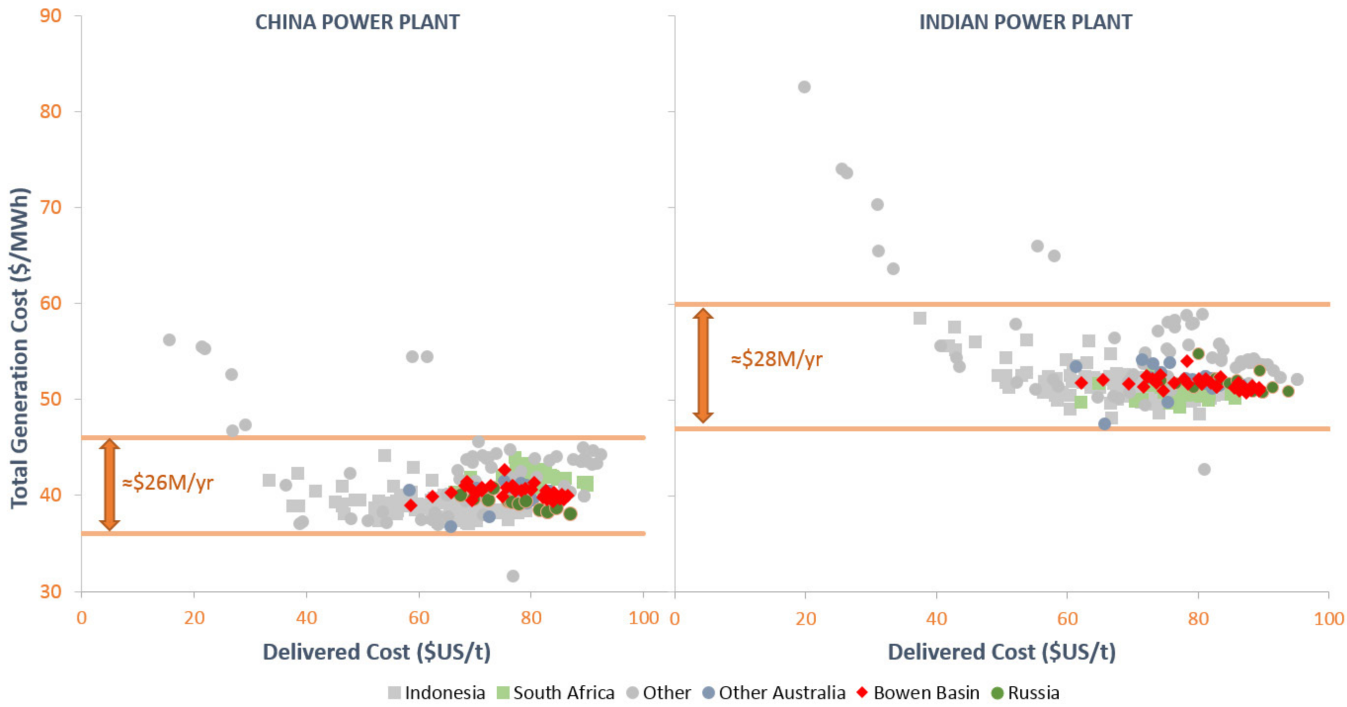

Figure 10 Comparison of total generation costs with delivered cost of coal (coal price + shipping costs) for a Chinese and Indian power plant for Bowen Basin coals and other traded coals.

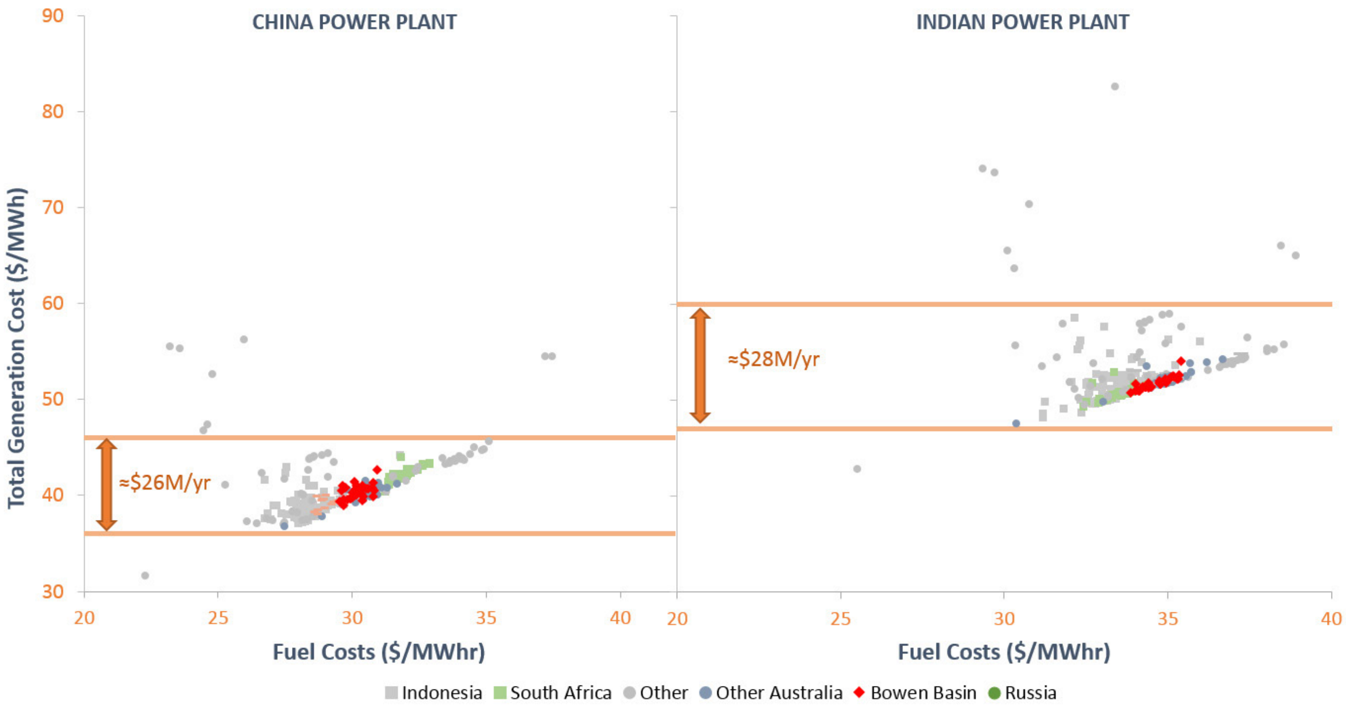

Figure 11: Comparison of generation costs and delivered fuel costs in $/MWh for Bowen Basin coals and other traded coals.

may be blended with imported coals with the objective of optimising generation and maintaining stable production.

CONCLUSIONS

Selection of coal by a power plant is a complex process. Although some coals may have lower delivered prices than other coals, this may not translate to lower overall generation costs. Coals with the same delivered cost can have widely different effects on generation costs and millions of dollars can be wasted utilising poorly performing coals. The research in this study has identified that Bowen Basin coals have:

- Low mill power consumption as compared with other Australian coals and key competitor countries (Indonesia, Russia and South Africa) for the Chinese and Indian markets.
- Low potential for mill wear and erosion as compared with other Australia coals and Russian coals, they are similar potential to South Africa coals and higher potenmtial for mill wear than Indonesian coals (due to low ash content).
- Moderate propensity for ash deposition (which is higher than that for other Australian coals), similar depositon propensity to South Africana and Russian coals and less slagging propensity than Indonesian coals.
- Slightly higher carbon-in-ash than NSW coals but similar carbon-in-ash to coals from competing countries.
- Low dust emissions as compared to other Australian coal and South African coals, similar to Russian coals and higher dust emissions than coals from Indonesia.
- Similar SO_2 emissions to NSW and lower emissions than coals from Indonesia, South Africa, but SO_2 higher emission than coals from Russia.

Bowen Basin coals are an acceptable source of coal for power plants in China and India. However, they are not the cheapest coals available and their delivered costs were around the median price of reference coals. Cheaper coals are available that can also achieve lower generation cost, but these coals can only supply so much of these rapidly growing markets.

Some of the results for Bowen Basin coals were broadly spread and, consequently, further evaluation should be performed on individual coals. Blending is also performed at a growing number of power plants and, consequently, more in-depth evaluations are required into the blending of individual Bowen Basin products with domestic coals and other coals from other countries.

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Anthony Williams
A&B Mylec Pty Ltd, 146 Leichhardt St, Spring Hill, QLD 4000, Anthony.williams@abmylec.com.au,
Ph +61 7 4931 0980, +61 427 910 049