SUPPLY CHAIN OPTIMISATION WITH BENEFICIATION IS THE KEY TO MINIMISING GENERATION COSTS

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ABSTRACT

Numerous coals can be purchased in the international market for a wide variety of costs on a per tonne and per energy basis. Fuel costs account for a high proportion of the overall generation cost of coal fired power plants especially those using traded coals (as opposed to mine-mouth power plants). There are consequently efforts to minimise fuel costs by incorporating higher proportions of lower cost coals. The real cost and value of a coal can often be hidden, especially when coal procurement departments do not interact with plant operations and do not appreciate the impact of coal quality on plant operations which can result, in the worst case scenario, in plant outages and loss of revenue in the millions of dollars.

Work has been completed using a value-in-use model developed for coal-fired power plants to identify the potential reduction in generation costs for beneficiated coals. The model is currently in use by a power plant in Australia to assist in coal selection and blend optimisation. The paper evaluates and discusses the utilisation performance and financial benefits of using coals using beneficiation processes as compared to other coals in the marketplace. The model was configured for a power plant in Japan and included a wide variety of coals from Australia, Colombia, Indonesia, Russia, South Africa and the United States. The paper will present the results from the modelling research and discuss the effect of beneficiation on coal value and its effect on power plant generation costs.

INTRODUCTION

Coal beneficiation is performed to reduce ash, moisture and other impurities in coal for a variety of reasons including

- Improve operational performance of power plant,
- Achieve higher contract prices for coal producer,
- Enable coal to compete in different markets (e.g. beneficiated coal might be classified as PCI coal whereas raw coal may only be sold as thermal coal),
- Satisfy regulatory limits (e.g. dust emissions could be reduced by reducing ash in coal, reduce SO_2 emissions by reducing pyrolytic sulfur), and
- Reduce freight and other costs on a $/t basis by transporting higher energy product.

The objective and benefits of beneficiation can be different depending on whether a coal producer or power plant is evaluating the benefits. A coal producer will focus on maximising coal pricing and minimising mining and beneficiation costs. A secondary consideration and for some, no consideration is given to the operational performance in the customer's power plant. A power plant however will have a higher weighting on the operational performance of the coal as poorly performing coals can have significant financial impact on power plants.

IMPACT MODEL

This research used a value-in-use model called IMPACT-Thermal to predict utilisation performance and value-in-use metrics of beneficiated and non-beneficiated coals used in a power plant in Japan for 4 export coals and a power plant in Australia for a power plant with a captive mine. 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, Juniper & Pohl, 1999, Williams, A, 2015). 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 databases of coal quality specifications, power plants, cement plants, steelworks and shipping ports.

MarketMastor is a data analysis and visualisation tool that is utilised to perform various market evaluation of coals. MarketMastor can be used to evaluate how coal products:

- Compare in the marketplace,
- Compare with other coals in various value-in-use studies,
- Perform in blending studies with international and domestic coals,
- Could deliver higher revenue through optimising product specifications, and
- Improve efficiencies and lower $/GWhr through better source coal and blend selection.

IMPACT-Thermal estimates the performance of plant components through a range of correlations and indices to predict the impact of coal quality on power plant performance. The model can also determine the economic costs of a power plant, how coal quality affects these costs and the value-in-use of coal. The model can be calibrated to a power plant by updating correlations with ones developed with actual power plant data. This process significantly improves the accuracy of predictions for the different process parameters. The model is regularly used to model power plants around the world. Under these scenarios, the model results provide an excellent platform for comparing plant performance between difference coals in different power plants. This means, for example, that predicted boiler efficiency may not be exactly the same as the actual plant boiler efficiency, but the prediction that coal A has higher boiler efficiency than coal B is expected to hold true.

It was assumed that the export coals (2 raw and 2 beneficiated) will be delivered to a sub-critical 350 MWe, pulverised coal fired power plant located in Japan. The domestic Australian coal (one raw and one beneficiated) will be delivered to a modern super-critical 350MWe in Australia. The general operating conditions assumed are set out in Table 1.

Power Station Costs and Fuel Costs

The performance and costs for individual components in the power station coal chain can be estimated by using indices and/or correlations between coal properties and plant performance, which have been developed and improved over time. 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 can provide an evaluation of the overall cost benefit of using a particular coal in a pulverised coal fired 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, delivered to the power station stockyard. The price to the stockyard includes the shipping cost, domestic freight cost, taxes, port charges plus any other miscellaneous charges.

Table 1: Assumed Power Plant Parameters for the Japanese and Australian plants

Parameter	Units	Plant 1	Plant 2
Location		Japan	Australia
Capacity	MWe	350	350
Annual Capacity Factor	%	90	86.2
Turbine Heat Rate	MJ/MWh	9817	8650
Boiler			
Excess Air	%	20.0	18
Flue gas exit temperature	°C	110	140
Mill type		Vertical spindle	Vertical spindle
Number of pulverisers		6	6
Pulveriser capacity	t/hr	37	36
Design HGI		50	50
Design PF fineness	%<75µm	80	70
Environment			
Dust Collection		ESPs	ESPs
Flue Gas Desulfurisation		Yes	No
Fly ash utilisation		Yes	Yes

COALS

Beneficiation of 2 Australian export coals and 1 domestic coal was evaluated. Table 2 shows coal quality data for the evaluated coals and beneficiated coals. One Australia coal (Australia 1) underwent a dry beneficiation process that reduced the ash content by about 5.5%, increased the energy content by 8.5% and costs approximately $2/t. The moisture content remained the same. The second Australia coal underwent a typical washing process that reduced the ash content by 7%, moisture content remained the same and increased the energy content by 9%. This process costs approximately $5/t. The domestic coal underwent a washing process that reduced the ash content by about 6% with moisture remaining relatively constant. The domestic washing process costs approximately $4/t.

Table 2: Coal quality of raw coals and beneficiated coals

Coal Quality	Units	Basis	Export 1, Raw	Export 1, Dry Ben	Export 2, Raw	Export 2, Ben	Domestic, Raw	Domestic, Ben
Total Moisture	%	ar	15.0	15.0	18.5	18.5	8.0	10.0
Proximate Analysis								
Moisture	%	ad	7.5	7.5	9.5	9.5	2.4	2.2
Ash	%	ad	17.8	12.3	15.0	8.0	31.5	25.6
Volatiles	%	ad	32.1	34.3	27.0	31.0	28.2	30.1
Fixed carbon	%	ad	42.6	45.9	48.5	51.5	37.9	42.1
Calorific Value								
Calorific Value	MJ/kg	ad	24.0	26.0	24.6	26.8	20.5	24.0

UTILISATION PERFORMANCE OF BENEFICIATED 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, whether the coal was beneficiated or not, different ash content level and different moisture level. The statistics include the median, 1st quartile, 3rd quartile, 5th percentile and 95th percentiles in a box and whisker type chart. Figure 1 shows the statistics for the expected utilisation performance for the major thermal coal exporting countries, whether the coal was

beneficiated or not, ash content level, and moisture level. The top exporting countries include Indonesia, Australia, Russia, Colombia, South Africa, and the United States of America (USA).

Mill Power Consumption

The coal property most commonly used for evaluation of grinding performance by utilities is hardgrove grindability index (HGI). The consequences of low HGI values on the grinding performance of coals is a coarser product which may result in poor burnout and higher power consumption to produce a product of the required fineness. Mills are designed to handle the coal throughput necessary given the boiler size and energy content of the coal. A plant firing low energy content coals would be expected to have a higher pulverising capacity than a power plant designed to handle a high energy coal e.g. 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 Australian coal.

Figure 1A shows expected mill power consumption adjusted for coal energy for the evaluated coals and other traded coals for the Japanese plant. The Export 1 coal shows a slight improvement in mill power consumption for the beneficiated coal whereas the Export 2 coals shows a negligible change in mill power consumption. The increase in energy content for the beneficiated coals tends to reduce the mill power consumption on an energy basis as shown by Export 1 coal. Export 2 shows a decrease in HGI, which counteracted the energy content increase resulting in a negligible change in mill power consumption. The domestic coal shows a significant reduction in mill power consumption which is attributed to the higher energy content of the beneficiated coal.

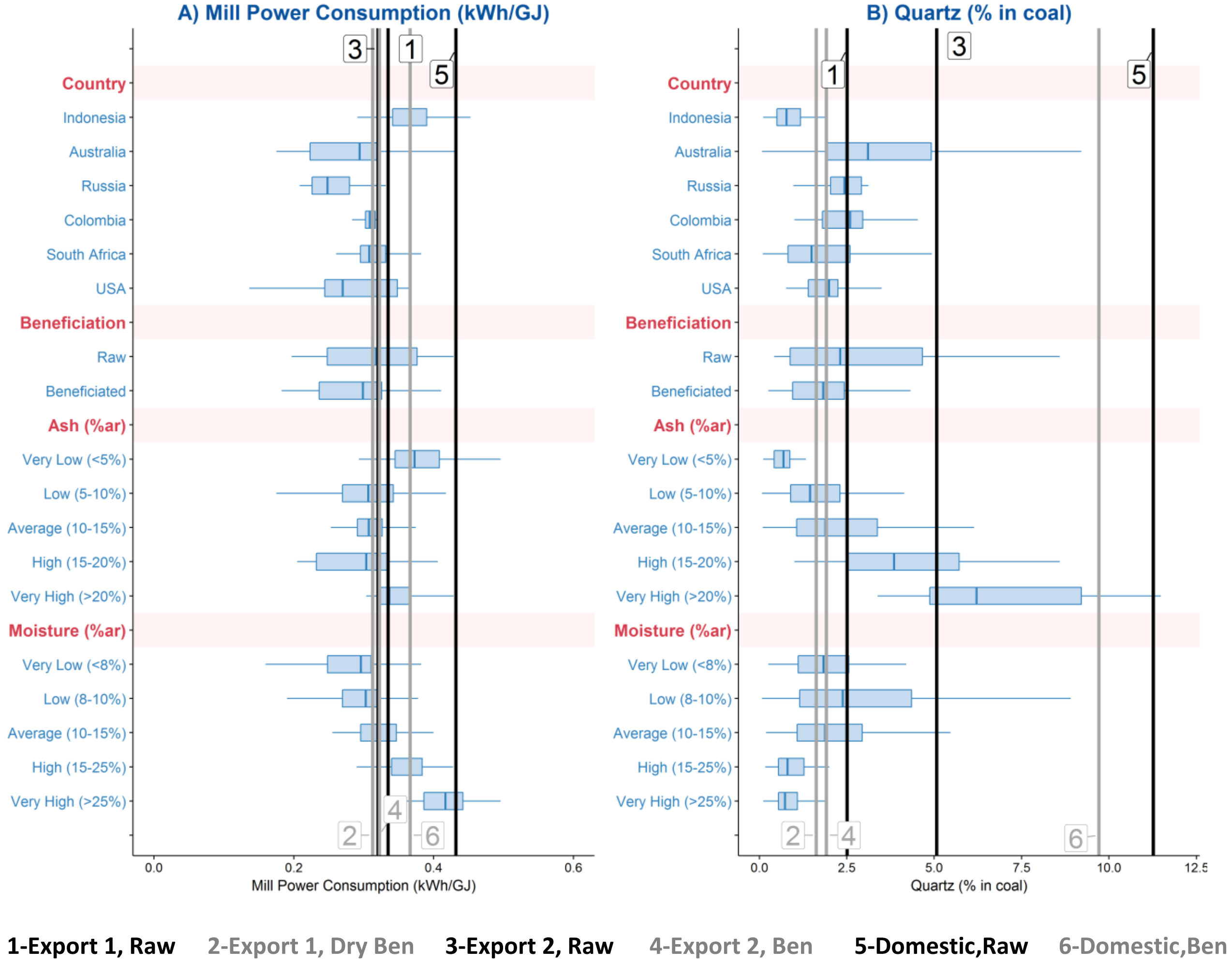


Figure 1: Comparison of raw and beneficiated coals with different countries, beneficiation, ash levels and moisture levels for specific mill power consumption and Quartz in coal level.

A wide range of results is shown in Figure 1A for the different coal exporting countries. Indonesia tended to have the highest mill power consumption compared to the other countries which is influenced by the lower calorific value of Indonesia coal and also lower HGI. Australian and United States coals have a large range of possible mill power consumptions with the median Australia coal having slightly higher mill power consumption than the median United States coal. Colombia and South African coal tended to have slightly higher mill power consumptions than the Australian and United States coals. Russian coals offered the lowest mill power consumption compared to the other major coal exporting countries.

The beneficiated coals tend to have slightly lower mill power consumption which is caused by the increased energy content of the beneficiated coal rather than a higher HGI. The range of power consumption values for beneficiated coals, especially the quartiles, decreased, indicating a decrease in mill power consumption with beneficiated coals compared with raw coals. Increasing the ash level initially decreased the mill power consumption, but then the consumption levelled and was not readily predictable. Increasing the moisture content level tended to increase the power consumption as the energy content decreased for higher moisture coals.

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 the coal less than about 3 – 4% are unlikely to cause additional wear of mill components.

Figure 1B compares quartz in coal for the evaluated coals and other traded coals for the Japanese plant. The quartz in coal content for all of the beneficiated coals are less than the raw coal. A significant reduction in quartz in coal is shown by export 2 coal such that the beneficiated coal is not expected to cause mill wear problems whereas as the raw coal might. The domestic raw and beneficiated coals are expected to cause mill wear problems, with the beneficiated coal wearing the mills less than the raw coal.

Figure 1B shows Indonesian coals have the lowest mill wear problems, followed by South African and United States coals. Australian coals tended to have the highest mill wear problems followed by Colombian and Russian coals. Australia coals also have a significantly wider range of quartz in coal values compared to coals from the other countries.

The raw coals have a wider range of quartz in coal values than the beneficiated ones, but had similar median values indicating some improvement in mill wear potential for beneficiated coals. As ash levels increase, quartz in coal increases indicating mill wear problems increase for higher ash coals. There is a wide range of quartz values in most ash bands and consequently coals within a higher ash band may have quartz in coal similar to a lower ash band. Higher moisture bands (>15%ar) had lower quartz in coal than the lower bands.

Boiler tube erosion is also affected by quartz levels in coal and 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. The size of the quartz particles is also very important and no assessment of the quartz particle size has been performed. 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% in coal have been shown to cause erosion problems in boilers. The levels of quartz in beneficiated coals are less than 6 percent and consequently should cause minimal erosion problems. Some raw coals however, had quartz levels greater than 6% and are expected to cause some erosion problems.

Ash Deposition

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, removal of deposits by soot blowers requires the use of non-recoverable steam. Shutting down a boiler to remove slagging deposits can result in lost revenue in the order of millions of dollars. The propensity of a coal to cause problems in full-scale boiler plant is affected by the 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 2A shows an overall rating for ash deposition propensity for coals from top exporting countries and various groups of 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. Figure 2A compares ash deposition potential for the evaluated coals and other traded coals for the Japanese plant. The export 1 coals and domestic coal showed negligible difference between the beneficiated coal and raw coal for ash deposition potential. The export 2 coals showed an increase in ash deposition potential for the beneficiated coal. The increase can be attributed to the beneficiation process concentrating the ash deposition contributing components (e.g. alkalis) and removing inactive components (e.g. quartz).

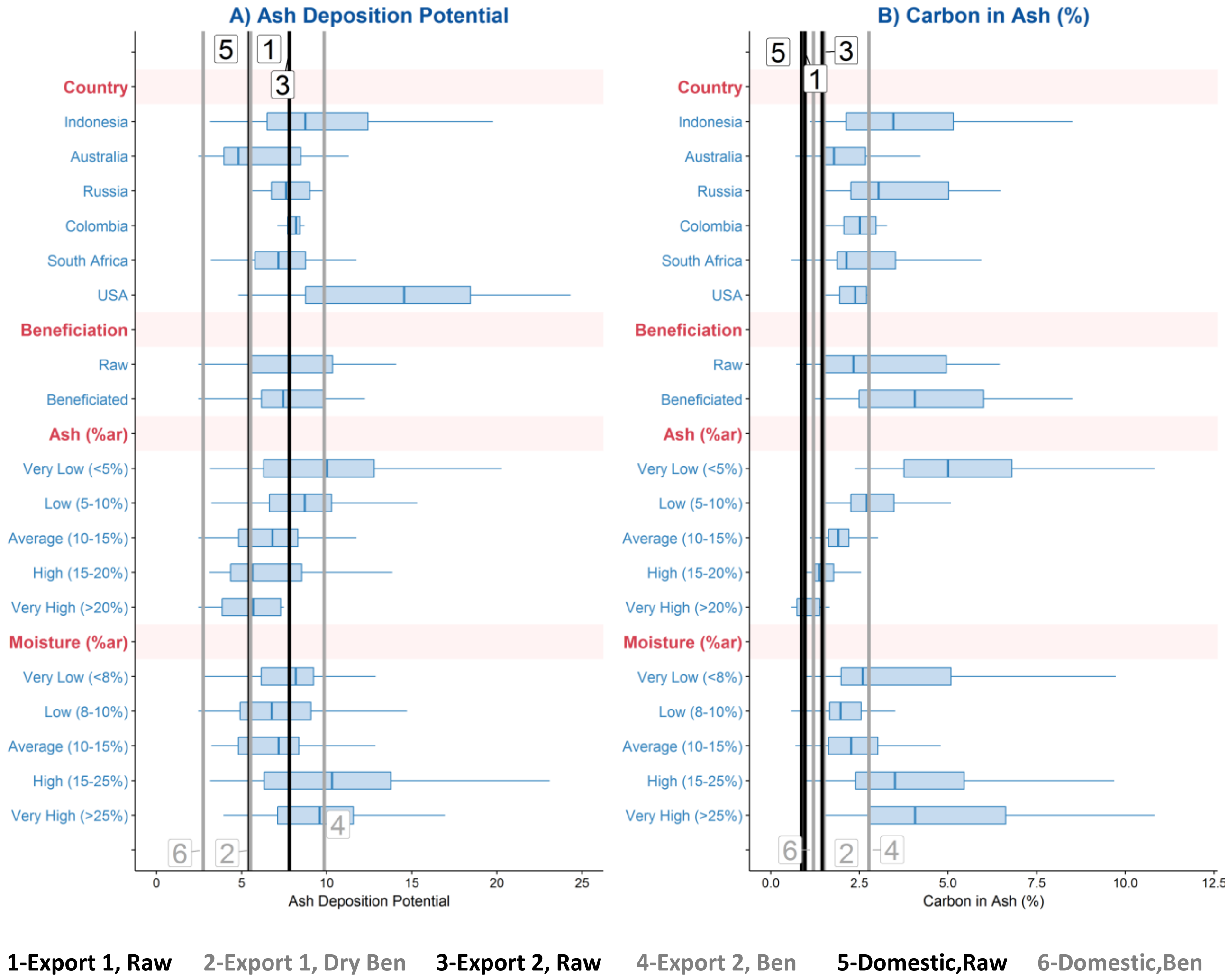


Figure 2: Comparison of raw and beneficiated coals with different countries, beneficiation, ash levels and moisture levels for ash deposition potential and carbon-in-ash.

The beneficiated coals are expected to improve ash deposition characteristics slightly as shown by the lower median value, lower 75% quartile and 95% percentile than the corresponding raw coal value. As ash increases with the different bands, the ash deposition characteristics tend to decrease. This is likely due to the higher proportion of SiO_2 in the higher ash bands, which is inactive (if present as quartz) in the boiler. Many low ash coals (<10%ar) have a high propensity to cause ash deposition. Coals with moisture levels between 8 and 15% tend to have lower ash deposition potential than the other coals. Coals with moisture levels between 15 and 25% tended to have the highest ash deposition potential.

Carbon-in-Ash

The main impact on performance and costs due to combustion characteristics comes from the burnout efficiency of coal, which affects boiler efficiency, but also 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. Countries such as Japan have a carbon-in-ash limit of around 3%. 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 96.4 percent for Japan in 2010 (Heidrich and others, 2013). The primary deciding factors on whether a power plant can sell fly ash or not is whether the fly ash satisfies the plant requirements and whether a cement plant or other end user is located close by.

Figure 2B compares carbon-in-ash for the evaluated coals and other traded coals for the Japanese plant. Carbon-in-ash increased for all of the beneficiated coals, but remained below the 3% carbon-in-ash limit. Burnout efficiency is consistent between the beneficiated and raw coals and consequently the increase in carbon-in-ash is attributed to the lower ash in the beneficiated products.

Most coals from Australia, Colombia, South Africa and the United States have carbon-in-ash values less than 3% and are suitable for use in a Japanese power plant. Indonesia and Russia coals have higher carbon-in-ash with median values above 3% and a wide spread of possible values up to over 6%.

Figure 2B shows that the expected carbon-in-ash for beneficiated coals is higher than for the raw coal. This is caused by, for the coals where the beneficiation process has reduced the ash, the raw coal having higher ash. Higher ash coals produce lower carbon-in-ash as the higher levels of ash dilute any remaining carbonaceous residue. The lower moisture coals (<15% ar) tended to have lower carbon-in-ash than the higher moisture coals.

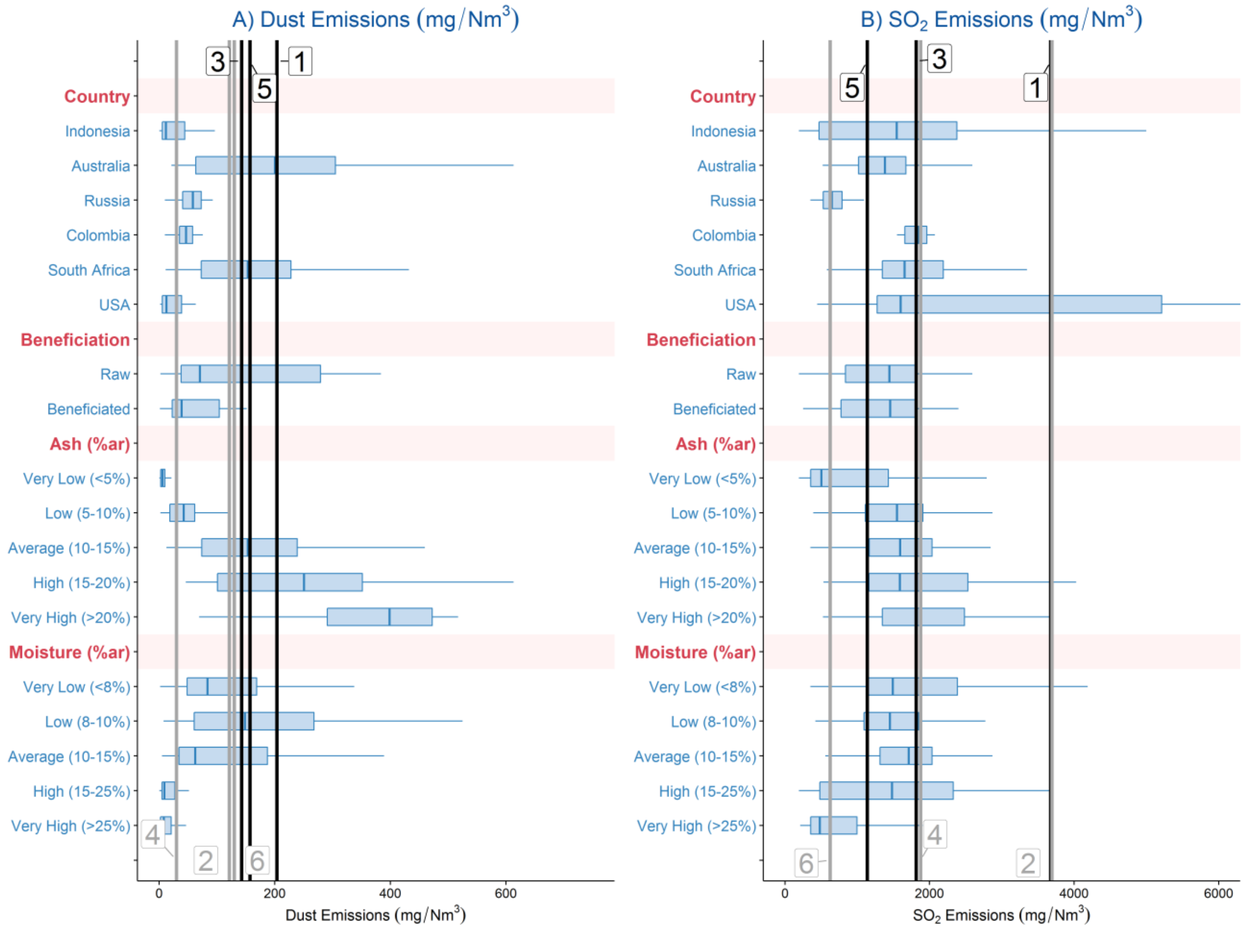
Although carbon-in-ash increased for the beneficiated Australian coals, the results are still less than the 3% limit for Japanese power plants. The Indonesian raw and beneficiated coals both have carbon-in-ash values above the 3 % and 5% limits. This result is caused by the low ash content of these coals. Consequently, the Indonesia coals can be blended with a higher ash coal to reduce the carbon-in-ash to an acceptable value.

ENVIRONMENTAL PERFORMANCE OF BENEFICIATED COALS

Emissions of dust and SO_2 are compared for the raw and beneficiated coals with other traded coals and coals categorisation by beneficiation, ash content and moisture content in Figure 3.

Dust Emissions

The emissions of dust from coal-fired power plants affects human health and contributes to smog formation. 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 pass through collections systems and cause health problems to the local community.



1-Export 1, Raw 2-Export 1, Dry Ben **3-Export 2, Raw** 4-Export 2, Ben **5-Domestic,Raw** 6-Domestic,Ben

Figure 3: Comparison of raw and beneficiated coals with different countries, beneficiation, ash levels and moisture levels for dust emissions and SO_2 emissions.

The predicted dust emissions from the ESP installation in the Japanese power plant is shown in Figure 3A. Typical industry limits on dust emissions vary from country to country and from plant to plant. If dust emissions were to exceed statutory limits, then the output from the plant would need to be reduced. This would cause significant costs because there would be less power sent out to the commercial market. In addition, there may be justification to actually import power, at higher cost, to fulfil contracts for power supply. Note that where a flue gas desulfurisation (FGD) plant is installed, the ESP performance becomes less critical as a large percentage of the dust is removed by the FGD sprays.

The dust emissions from the beneficiated coals are less than that of the raw coals as expected from the low ash loading of the beneficiated coals. The reduction in dust emissions for the beneficiated Export 2 coal is significantly greater than the reduction achieved by the other beneficiated coals with dust emissions reducing by approximately 80 percent. The reduction is greater than that expected by the reduction in ash loading and consequently the beneficiation has improved the migration velocity and resistivity for the fly ash particles.

The expected dust emissions from coals from Indonesia, Colombia, Russia and the United States are expected to be low as compared to coals from Australia and South Africa. There is a wide range of dust emissions for coals from Australian and South Africa. Beneficiated coals are expected to emit lower dust emissions than raw coals as shown by lower median dust emissions, lower 75th percentile and lower 95th percentile. Coals with increasing ash content are expected to emit higher dust emissions although the quartiles indicate a wide degree of scatter and that coals with very different ash content can emit similar

dust emissions. The median values for dust emissions however, increase as ash content increases. There is a wide variety of dust emissions at moisture levels less than 10%. At higher moisture levels, dust emissions decrease, which is caused by low ash, high moisture Indonesian coals.

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 3B shows a negligible variation in SO_2 emissions between the raw and beneficiated export coals. The domestic coal however shows a 45 percent reduction in SO_2 emissions for the beneficiated coal. The large reduction in SO_2 emissions for the beneficiated domestic coal is attributed to a high level of pyrolytic sulfur in the raw coal, which is removed in the washing process.

Coals from Russia show the lowest SO_2 emissions. Although some Indonesian coals emit low SO_2 emissions, there is a large range of SO_2 emissions for other coals from Indonesia. Coals from the United States also show a wide range of possible SO_2 emissions. The median SO_2 emissions from United States coals is similar to other traded coals, but a significant number of high SO_2 emission coals lifts the 75th percentile and 95th percentile to very high SO_2 emissions levels. Coals from Australia and South Africa have similar SO_2 emission levels. The median SO_2 emissions for Colombian coals is higher than coals from all of the other countries. The beneficiated coals shown in Figure 3B the same SO_2 emissions as the raw coals although this is expected to vary on a case by case basis. Lower ash coals (<5% ar) emit lower SO_2 emissions whereas the higher ash coals emit higher SO_2 emissions (>20% ar). Some of the higher ash coals are expected to have higher levels of pyrolytic sulfur which will account for the higher SO_2 emissions. The SO_2 emissions for the other ash categories are approximately the same. The SO_2 emissions are approximately the same for moisture contents less than 15%. At higher moisture levels, the SO_2 emissions reduce.

VALUE-IN-USE METRICS

The cost of electricity generation at a power plant in Japan was calculated using the evaluated raw and beneficiated coals, other coals from Australia and coals from competitor countries. Considering the domestic coal will never be exported, the value-in-use metrics for the raw and beneficiated domestic are calculated for the actual Australian power plant that utilises the coal. Consequently, the value-in-use metrics for the domestic coals should only be compared with each other, and not with the export coals or other traded coals. 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 base FOB coal prices, shipping and discharge costs, and penalties (e.g. high carbon-in-ash values).

Total generation cost and break even Free On Board (FOB) coal price are compared for the raw and beneficiated coals with other traded coals and coals categorised by beneficiation, ash content and moisture content in Figure 4.

Generation Cost

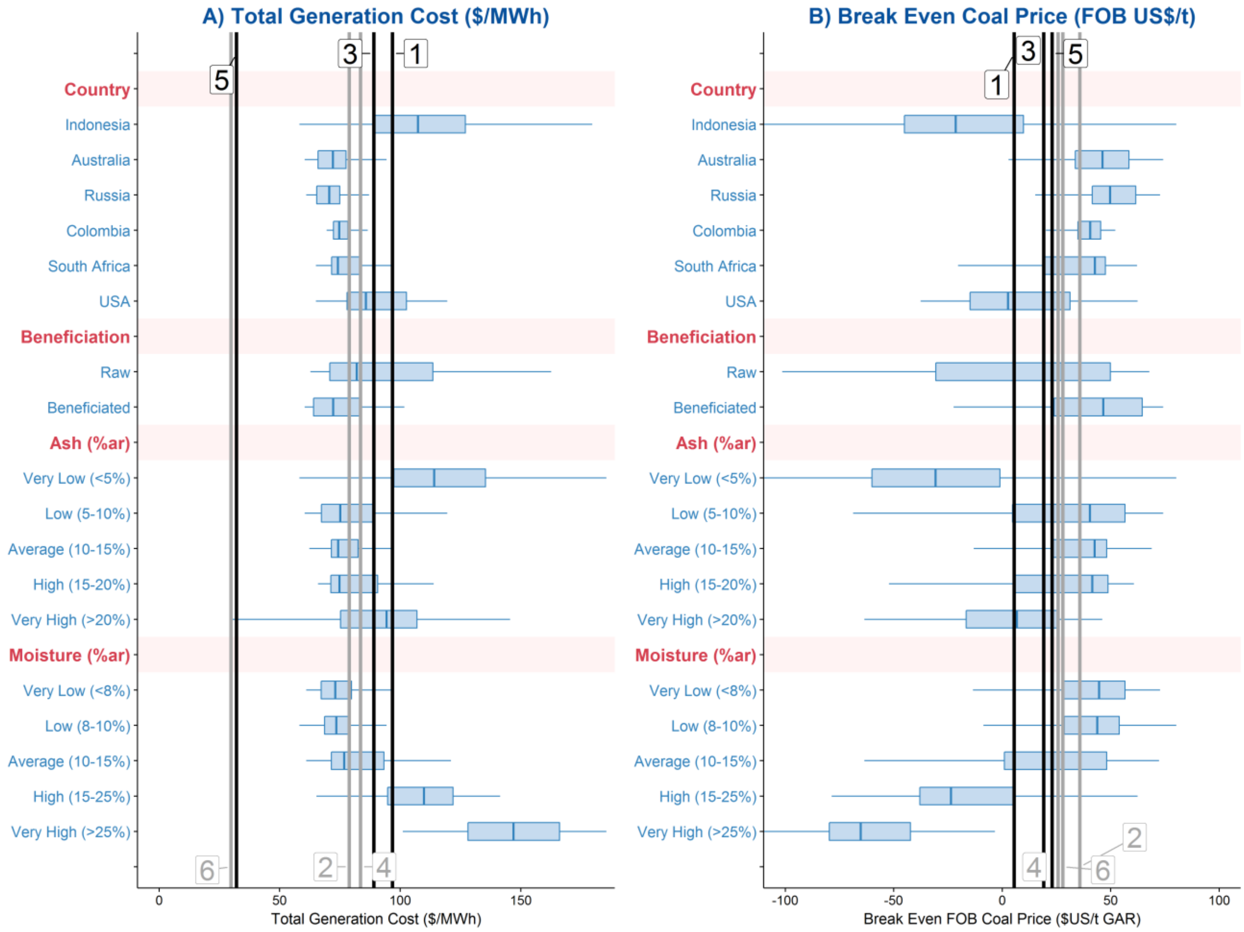
The total generation cost for the beneficiated coals is significantly less than that of the raw coals. The export 1 beneficiated coal shows a reduction in generation costs of approximately $18/MWhr. The high generation cost for the raw export 1 coal indicates the coal isn't suitable for the Japanese power plant, but is suitable, if the coal is beneficiated. The domestic coals have very low generation costs as compared to the other coals which is due to the costs not including shipping costs and the lower fuel cost due to the coal coming from a captive mine. The power plant also has lower operating and maintenance costs.

Russian coals have the lowest generation costs, followed by Australian, Colombia, and South African coals. Indonesian coals have the highest generation costs for the Japanese plant which is caused by load reductions due to the mill capacity being exceeded.

The beneficiated coals show a significant reduction in generation costs. The median generation cost is slightly lower for beneficiated, but the 75th percentile and 95th percentile decreases significantly. The low ash (<5% ar) and higher ash (>20% ar) coals tended to have higher generation costs than the other coals. The median generation costs for coal with ash contents between 5 and 20% ar is similar. Increasing the moisture content from 10% increases the generation costs significantly. Coals with moisture contents greater than 25% may lead to mill capacity issues in the Japanese power plant and are consequently not suitable.

Break Even FOB Coal Price

The breakeven coal price was determined assuming the generation costs for all coals equals the reference coal. The coal price was calculated by back calculating the price considering each coals operating and maintenance costs, capital costs, transport costs and lost revenue. A negative break even coal price indicates the coal has excessive transport costs as compared to the reference coal, excessive operating and maintenance costs, or excessive lost revenue costs. A negative price indicates the coal is not suitable for use in the Japanese power plant.



1-Export 1, Raw 2-Export 1, Dry Ben **3-Export 2, Raw** 4-Export 2, Ben **5-Domestic,Raw** 6-Domestic,Ben

Figure 4: Comparison of raw and beneficiated coals with different countries, beneficiation, ash levels and moisture levels for total generation cost and break even FOB coal price.

The expected coal price for the Export 1 beneficiated coal, Export 2 beneficiated coal and Domestic beneficiated coal are approximately $30/t, $6.60/t and $5/t respectively greater than the corresponding

raw coal price. These price increases account for the increased processing costs of the beneficiation process. The expected price for the export 1 raw coal is approximately $0/t and hence the dry beneficiation created a valuable product that can be utilised and compete in the global marketplace.

The Russian and Australian coals are estimated to attract the highest prices followed by Colombian and South African coals. A significant proportion of Indonesian coals are not suitable for 100% use in the Japanese power plant as shown by over half of the Indonesian coals having a negative coal price. Indonesian coals however, offer significant value when blended with other coals. United States coals are expected to achieve lower prices than Australian, Colombia, Russian, and South African coals, but higher than Indonesian coals.

The beneficiated coals achieved significantly higher prices than the raw coals as shown by the higher median, quartiles and percentiles. Very low ash (<5% ar) and very high ash (>20% ar) coals achieved significantly lower prices than the other ash levels. As the moisture levels increased above 10%ar, the coal prices decreased steadily. The increasing moisture would have exceeded the mill capacity in increasing levels thus causing a reduction in the plant capacity.

VALUE-IN-USE BREAKDOWN

A comparison of the value-in-use breakdown of the discount from the reference coal to the raw or beneficiated coal is given in Figure 5. Negative values indicate a pricing discount from the reference coal for that particular parameter and can be caused by the coal instigating poorer performance in the area compared to the reference coal (e.g. a higher negative discount for pulverising will probably be caused by a lower HGI coal). Positive discounts are attributes for the coal and indicates superior performance. Summing the discounts with the reference coal price will equate to the evaluated coal price. For the domestic coal scenario, the raw coal was the reference coal for the Australian plant and consequently the discount values are zero.

The Export 1 beneficiated coal shows significantly lower discount for lost revenue. Lost revenue is assigned when the plant cannot meet its expected electricity output due to problems like severe ash deposition, mill capacity limitations, and dust emissions problems. The reduced output also affects capital costs. Higher electricity output reduces the capital costs on a $/MWhr basis and consequently the beneficiated coal shows a smaller discount for capital costs. A smaller discount for tonnage was also determined and caused by the higher energy content of the beneficiated coal. The energy content of the coals is less than that of the reference coal, hence the discount.

The export 2 beneficiated coal shows improved discounts for pulverising, ash disposal, and tonnage. The beneficiated coal does however, increase the lost revenue discount over the raw coal. The lost revenue is caused by the poorer ash deposition characteristics of the beneficiated coal. Although the beneficiated coal might cause ash deposition problem for the customer, the coal producer may not focus on fine tuning the washing strategy to reduce ash deposition potential as the current product achieves a better price than the raw coal.

The domestic coal shows positive discounts for all of the parameters indicating superior performance to the raw coal. The increase in energy content of the beneficiated coal accounts for most of the positive discount although ash disposal, lost revenue and capital cost also contribute significantly. The ash disposal positive discount is expected and due to the lower ash in the beneficiated coal. The lost revenue for the raw coal was caused by a mill capacity limitation, with the mills have insufficient capacity to pulverised the low energy raw coal. The beneficiated coal resolves this problem and consequently the lost revenue is a positive discount for the beneficiated coal.

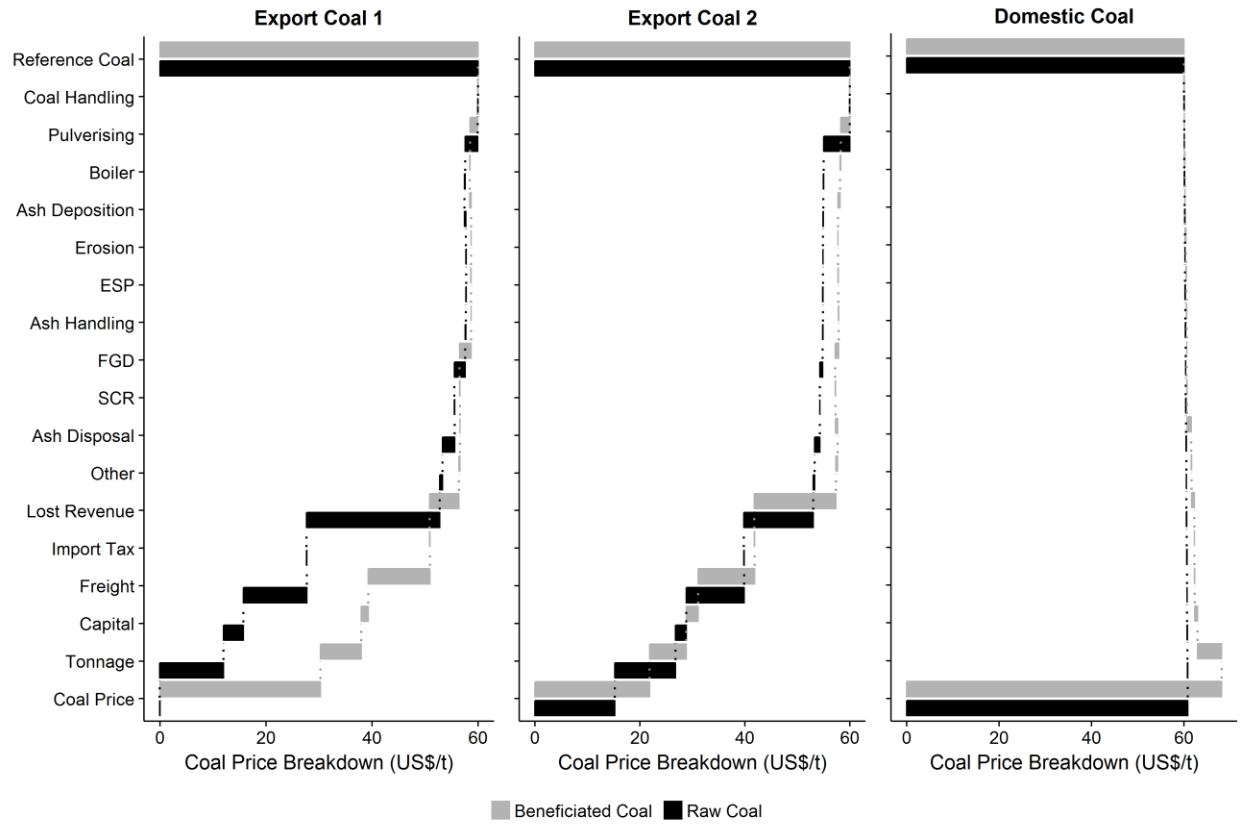


Figure 5: Value-in-use breakdown of the coal price discount from the reference coal and the raw or beneficiated coals (SCR – selective catalytic reduction (NO_x reduction technology)).

CONCLUSIONS

Three scenarios were evaluated for the effects of beneficiation on coal value and effect on power plant operations. Beneficiation mostly had positive impacts on operational performance in areas such as mill wear, and dust emissions but could also have negative impacts. This is especially apparent for carbon-in-ash where the lower ash of beneficiated coals will tend to increase the carbon-in-ash. Ash deposition potential may also be affected by beneficiation processes.

Beneficiated coals with lower ash will reduce ash disposal costs and can improve deficiencies in coals that result in a reduction in electricity output (reduce lost revenue costs). Consequently, higher electricity output can be made with beneficiated coals. The beneficiated coals can also reduce other cost areas such as pulverising costs, erosion, and freight, but to a lesser degree.

The decision on whether to beneficiated coals or not will come down to the financial metrics, and the beneficiated coals reduced generation costs for the Japanese and Australian power plants, as well as achieved higher prices for the coal producers.

Coal beneficiation has significant potential to improve plant operations, lower generation costs for the power plant and increase contract prices for a coal producer. Each coal producer or power plant should perform their own assessment on whether coal beneficiation will have significant positive financial metric for their situation.

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