Eco-Friendly Coal for China – Value for the Environment and Value for the Power Generator

by
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INTRODUCTION

Objective

Increasingly, over recent years the relative availability of low ash, low sulphur bituminous coal has decreased and the availability of high ash and/or low rank bituminous and sub-bituminous coals has increased. The impact of this transition, as coal demand increases, highlights the requirement for additional sources of better quality coal but more importantly, more environmentally friendly coal.

Power generation in China is often fuelled with low rank, high ash coal in plant that sometimes lacks equipment to clean-up the effluent resulting from the combustion of this coal.

The purpose of this paper is to investigate the extent to which new sources of Australian higher rank, low ash (~10%) coal for power generation can contribute to a reduction in severe atmospheric pollution whilst adding value to power generation economics. It was prompted by a recent episode of extreme particulate pollution in Beijing. The replacement of China's high ash (~25%), low rank domestic coal with high rank, low ash imported coal may contribute to a reduction in such extreme environmental episodes.

Environmental Issues in China

While China's rapid industrial expansion steams on, the fallout from the need for massively increased energy requirements is posing serious environmental problems. The recent *smog* event in Beijing early this year (January, 2013) produced PM2.5 (particles less than 2.5 micron diameter) levels 35 times higher than the safe level recommended by the World Health Organisation.

The pollution is derived from four main sources; vehicle exhaust, industry, natural dust and coal-fired power plants that burn the local, low grade coal. The proportions were reported by the Chinese Government Environment Authority, in the Chinese press, as being 22% vehicle emissions, 16% industry, 16% natural dust and 17% coal burning; leaving 29% unaccounted. The coal that is burnt is generally low rank, with high ash and moisture contents. This exacerbates the problem as the high ash content emits more particulate

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matter into the atmosphere and the high moisture content causes electricity to be produced at low power station efficiency.

China's economy will continue to grow, implying rapid growth in power demand and increasing environmental pressure. To counter the environmental issues, China's 12th Five Year Plan provides for a limit on coal production, capping it at 3.9 billion tonnes per annum from 2015. Predicted forward coal demands to 2030 are shown in Figure 1, with three forward estimates for coal demand in China. In the most extreme case (Wood Mackenzie), the production limit would be exceeded in about 2014. Based on the probability that some production is not included in the official statistics, some would say it has already been exceeded so the exact timing for exceedance is problematic. The point to note is that the limit of 3.9 billion t/a will be exceeded if China's rapid industrial expansion continues.

Options to supplement coal production beyond 2014 include increased use of gas, switching to non-coal generation technologies (e.g. hydro, renewables nuclear) or increasing coal imports. In reality the first two options are not capable of filling the gap as gas supply is limited and it is unlikely that sufficient non-coal generating capacity would be available. This leaves imported coal and presents an opportunity for power stations to capitalise on the significantly better coal quality available from this source.

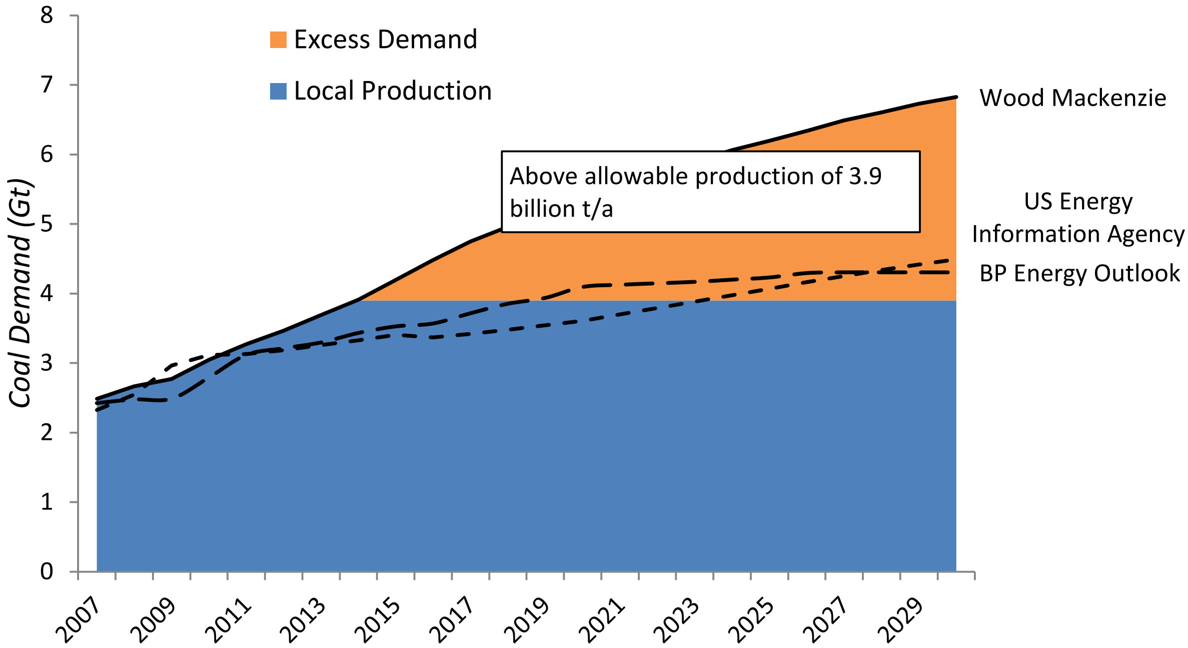

Figure 1: Predicted future coal demand

In addition to the above, a draft proposal is being considered to limit coal quality by three measures; a minimum limit on calorific value (CV) of 4,544 kcal/kg NAR (although at the time of writing, a revision to 3,941 kcal/kg was under consideration), maximum ash content of 25% (as for CV, a revision to 20% was being considered) and maximum sulphur content of 1%. Again, this provides a strong lever towards high quality imported coal. Note also that power station coal demand will compete with industrial uses such as 'coal to liquids' and 'coal to gas' projects.

Sources of Clean Coal

All countries with significant coal resources have coals of varying qualities. The best quality and most readily accessible coals tend to be mined first. As coal reserves continue to be mined, the quality tends to deteriorate and production costs increase, as is occurring in the more mature coal mining regions of Australia, as well as in Indonesia for example.

The development of new, high grade and in a number of cases, large volume, coal deposits in Australia has, for the last decade, been focussed on the Surat and Galilee Basins in Queensland, Australia. These huge resources have come into prominence as the reserves in the Bowen Basin in Queensland and the Hunter Valley in New South Wales move into more difficult mining regimes.

There are some 6.5 billion tonnes of measured and indicated resources in these basins but their development has been hampered by lack of infrastructure and/or distance from the coast. There are several proposals for mines in excess of 20 Mt/a in the Galilee Basin including Alpha, Carmichael, South Galilee and Kevin's Corner. In the Surat Basin a development decision on the long awaited Wandoan mine (> 20 Mt/a) has not been forthcoming to date and many other proposed developments are dependent on the development of the associated rail and port infrastructure.

COAL QUALITY

Assuming the inevitability of increasing demand globally but especially in Asia, and particularly China, it should ideally be satisfied by the best quality coals available from an environmental perspective. There is also a financial aspect that needs to be balanced; is the cheapest coal the best from a value as well as an environmental perspective?

In Australia, new coal mining areas are being planned as existing mining areas are maturing and quality is deteriorating. The Surat and Galilee basins in Queensland are ready made solutions (subject to infrastructure provision) as other new sources of fuel with poor utilisation characteristics, such as low rank Indonesian coals are exacerbating environmental problems rather than solving them.

Boiler Efficiency

Coal quality impacts on boiler efficiency. Moisture content causes energy losses from coal due to the latent heat of evaporation required to dry the coal prior to combustion. Poor combustion efficiency increases unburnt carbon-in-ash, which, if high enough, renders the ash unacceptable for other applications e.g. as an additive in cement manufacture.

Figure 2 shows the calculated boiler efficiency for a selection of Australian, Indonesian and Chinese export quality coals and clearly indicates the impact of total moisture content on the boiler efficiency. The higher the efficiency, the less coal will need to be consumed to achieve the required electrical output from the plant. Furthermore, the less coal consumed the less impact on the environment; at the mine, during transportation, during utilisation and in disposal of the by-products of combustion.

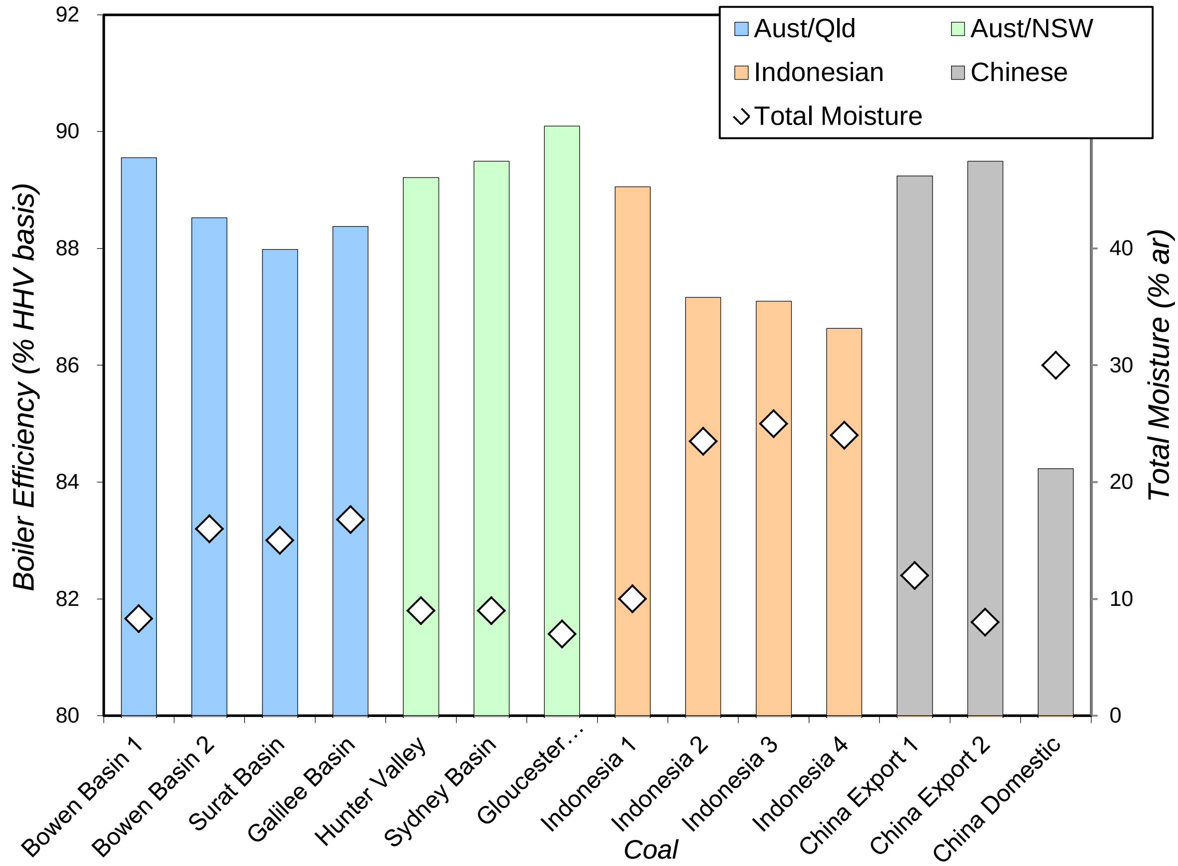

Figure 2: Calculated boiler efficiency for selected coals[2]

Low ash, low moisture coal would have a boiler efficiency of around 89% compared to a low rank, high moisture (30%), high ash (25%) Chinese domestic coal at around 84%.

Ash Content

High ash coal (~20% - 25%) has developed a significant niche in the seaborne market in recent times. Value-in-Use studies, using simulations of a modern super-critical power plant burning an Australian low ash (10%) coal from the Galilee Basin show that this would produce up to 75% (depending on the actual ash content) less particulate emissions than the Chinese domestic coal – the impact on the environment is obvious!

In addition to lower particulate emissions to the atmosphere, low ash coals will require significantly less ash to be disposed of.

Trace Elements

Deleterious trace elements in coal are of considerable concern if they are released to the environment, especially in particulates released to the atmosphere. They are arsenic, boron cadmium, fluorine, lead, mercury, molybdenum and selenium.

[2] Source: Author's calculations from Value-in-Use modeling.

In general, Australian coals, including Galilee and Surat Basin Coals, contain lower concentrations of trace elements that most other coals around the world as illustrated in Figure 3, which shows the average concentrations of a selection of elements of greatest concern.

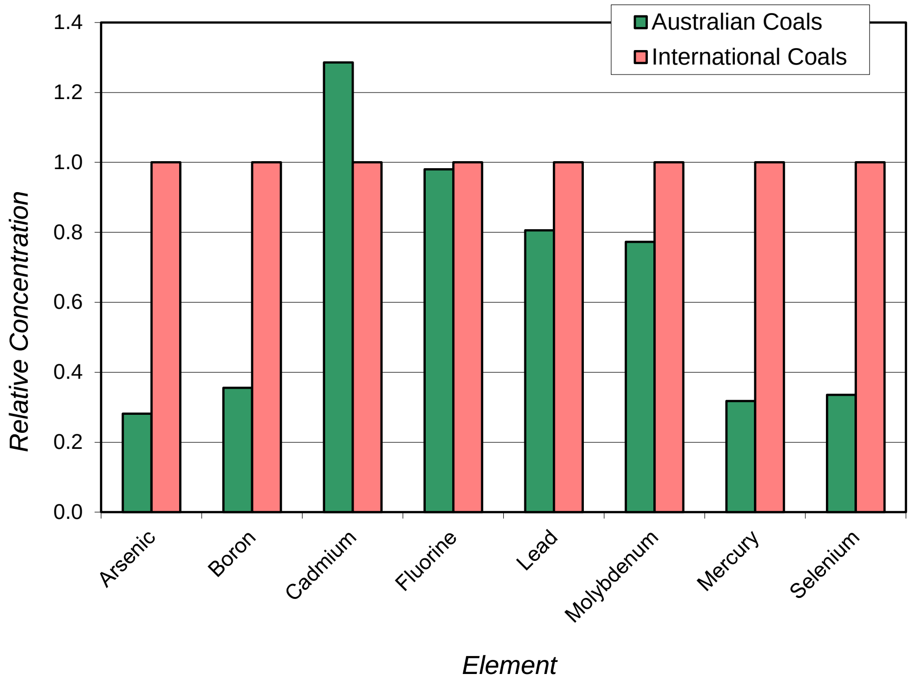

Figure 3: Trace element concentrations in Australian and international coals[3]

Concentrations of arsenic, boron, mercury and selenium found in Australian coals are around 30%, on average, of that for other world coals, indicating a 70% reduction in emissions of these elements from power generating plants.

GASEOUS EMISSIONS

Sulphur Dioxide

Australian export quality coals generally have low sulphur contents in the range 0.25% – 0.75%, with an average of 0.45%. This is higher than some of the low ash, low sulphur Indonesian coals, but well below the proposed Chinese limit of 1%.

[3] Source: Les Dale. *Monograph on Trace Elements in Coal.* ACARP Project C17003, End of Grant Report, June 2009.

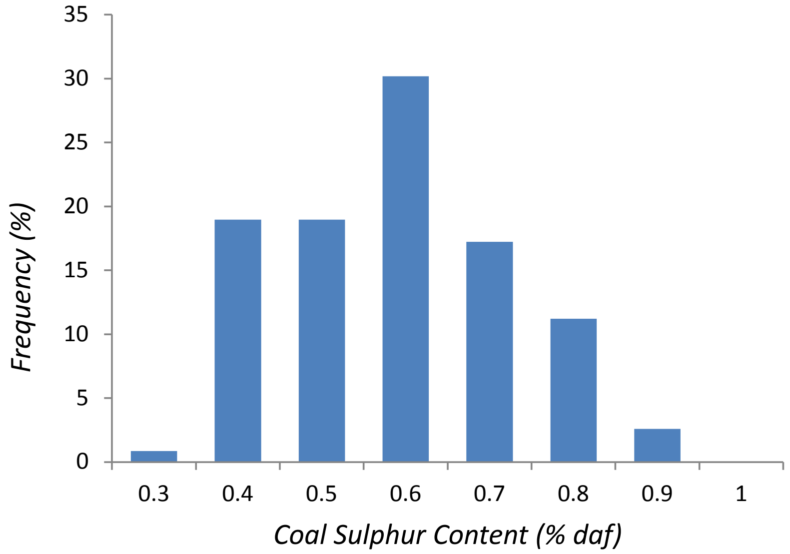

Figure 4: Sulphur content of Australian export coals[4]

These sulphur levels are equivalent to 200 - 500 ppm of SO_2 emission, allowing for 5 – 10% absorption of sulphur in the ash. This compares with a coal with 1.5% sulphur at over 1,000 ppm.

Carbon Dioxide

Emissions of CO_2 (kg/MWh generated) from a power station are mainly dependent on two parameters; the specific CO_2 emissions (kg CO_2/GJ energy in coal) resulting from coal combustion and power plant efficiency. Specific CO_2 emissions are coal specific and are controlled by the hydrogen to carbon ratio in the coal as well as the coal rank; the higher the ratio and rank, the lower the emissions. Plant efficiency is impacted by coal moisture content, among others and the higher the efficiency, the lower are the CO_2 emissions.

By increasing the proportion of high moisture, low rank coals as power station fuels, CO_2 emissions will proportionally increase. By increasing the proportion of lower moisture, higher rank coals in the market, CO_2 emissions will proportionally decrease.

Some Australian coals (coals from the Surat Basin being an example) have unusually high hydrogen to carbon ratios compared with most other coals, leading to generally lower CO_2 emissions (by up to 15%). For a 500 MW plant burning such a coal, the reduction in CO_2 emissions would be around 320,000 tonnes CO_2/year, compared to a Chinese low rank, high ash domestic coal.

[4] Source: Data from Lindsay Juniper & Dick Sanders. *Quality of Australian Black Coals.* ACARP Project C17053, January 2010.

VALUE-IN-USE

CHANGE TO LOW ASH IMPORTED COAL

Ten years ago the breadth of coal qualities available in the seaborne market was quite narrow. Since then sub-bituminous and lower rank coals and high ash coals have been introduced into the market in increasing quantities. Pricing and more importantly valuing this range of coals is no longer a simple process of adjusting the dollars on a pro rata energy content basis. Price and value are now more accurately calculated by considering the cost of producing a unit of electricity. This is achieved by modelling the coal's Value-in-Use, carried out by simulating the performance of a modern super-critical power plant.

Such modelling measures the impact of coal properties on the utilisation performance of the coal and the subsequent impact on costs within the power station. These can be compared with the costs incurred by simulating the burning of other coals to estimate their values relative to each other. Here, we compared a medium rank, export quality bituminous coal, such as that from the Galilee Basin with a domestically produced low rank, high ash, high moisture coal that might be used in a Chinese power plant.

The break-even coal prices shown in Figure 5 are the delivered (to the plant stockpile) prices at which the generator is economically indifferent between the low ash imported coal and Chinese high ash (25%) coal.

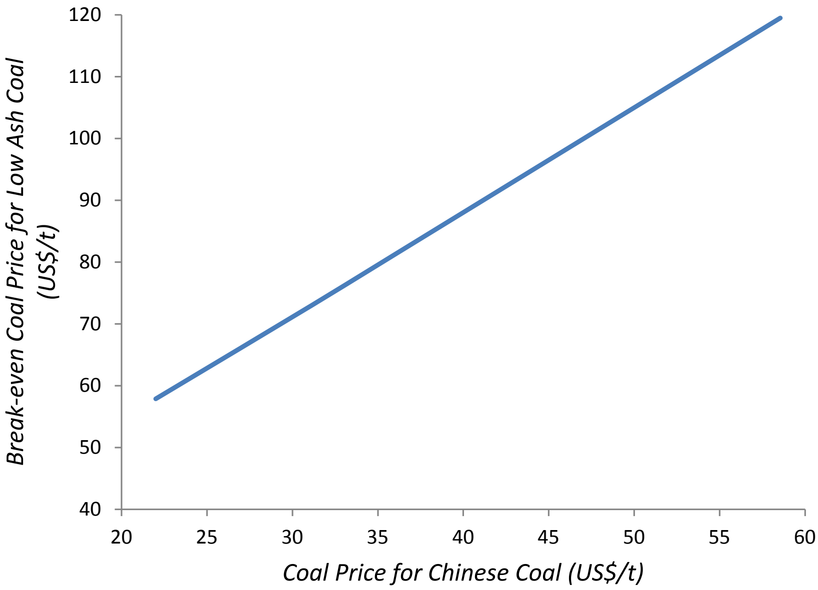

Figure 5: Break-even coal prices for low ash coal[5]

Thus, if the cost of Chinese coal delivered to the plant stockpile was US$40/t (say), then the electricity generator could afford to pay up to US$88/t for the high rank, low ash coal without exceeding his current cost of electricity production with the Chinese coal. When

5 Source: Author's calculations from Value-in-Use modeling.

comparing the costs of electricity generation using a low rank coal with that of a high rank, low ash coal, the value-in-use price difference is greater than the pro rata difference in price based solely on energy content, meaning the poorer quality coal is generally being over-priced.

Other advantages would accrue through the significant reduction in environmental impacts. Environmental issues would contribute to the higher value of the better quality coal resulting from:

- A reduction in potentially deleterious trace element containing particulate material released to the atmosphere;
- A reduction in ash disposal requirements;
- A reduction in CO_2 emissions.

Plant Operations And Blending

The capability of a plant to switch from a poor quality low rank, high ash coal to a better quality high rank, low ash coal will depend on the design of the generating plant and it may be that the design will not allow the high grade coal to be successfully burnt as a single feed. In this case, a blend of high and low grade coals may be appropriate to optimise the performance of the plant. There will also be a range of plant modifications and/or modes of operation of the plant that will mitigate against emissions to the environment. This subject is not covered in this paper.

In a number of countries, it has become the practice to blend cheap low grade coal with more expensive high grade coal to provide an economical feed to the boiler.

If a blending strategy is implemented, then the benefits of importing low ash coal will be reduced and be dependent on the blend ratio. This paper does not calculate the cost of improved environmental conditions from using low ash coals; however, there is obviously scope for an optimisation study to be done between the cost of importing Australian coal and the cost of cleaning up the environment in China and other regions in Asia.

CONCLUSIONS

It can be proven conclusively that improving coal quality contributes to an improvement in a power station's environmental performance. Boiler efficiency and ash content have a significant impact on environmental emissions, both gaseous and particulate. In addition, the lower the particulate emissions, the lower the concentration of trace elements released to the atmosphere with Australian coals performing much better, on average, than their international competitors.

High ash, low rank coals need to be assessed based on the value they provide to a power station via the cost of production of electricity rather than on the simplistic basis of their cost per unit of contained energy. Environment costs need to be part of these value considerations.

ABOUT THE AUTHOR

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Lindsay has had over 50 years' experience in the coal and power industries. In this time he has developed technologies and expertise in the use of coal and other fuels for power generation, specialising in the impact of coal properties on power plant performance and costs. Also including power plant feasibility studies; combustion research and evaluation and specialised testing of a range of different fuels. Lindsay was awarded an Order of Australia Medal (OAM) in 2011 in recognition of these services. He is the author of numerous publications in the technical press.

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