

# Australian LV Coal Producers: Proven Performance, But Where to Next ?

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## Introduction

This paper looks at the rapid growth in exports of Queensland Low Volatile (LV) coals for the PCI market. For this paper we loosely define LV coals as coals with a volatile matter of less than 18 % dry basis.

Coal consumers have increasingly benefited from a strong, growing and competitive Australian coal industry with the infrastructure, technology and proven track record of providing economic and environmentally acceptable coals for global markets. The Australian coal industry continues to invest in new mines and infrastructure. Also, the following programs help to ensure the sustainable future of coal:

- **COAL21**, a National Action Plan to identify actions for reducing or eliminating greenhouse gas emissions from the use of coal, and
- **Australian Coal Association Research Program**, which co-ordinates research, development and demonstration of technologies that lead to the safe, sustainable production and utilisation of coal.

Queensland has a long history of exporting coals to the world steel industry with the first trial shipment of Kianga coal leaving Gladstone for testing by Japanese steel mills in 1959. Development of PCI exports first started in the early 1990's and Queensland producers quickly established a reputation for supplying high quality LV PCI coals that meet the changing needs of consumers.

Blast furnace technology is central to the world steel industry and is continually undergoing refinements to improve productivity and reduce operating costs. The BF route to hot metal production will be preferred wherever the production scale is large, scrap is limited, iron ore and coal are available and electric power is expensive. Continuous improvements in productivity, coke consumption and fuel use within the steelworks have been driven by competition in world steel markets.

Early injection of coal was initially a response to high oil prices but now increased use of PCI is driven by the need to reduce raw material costs, pollution and also by the need to extend the life of ageing coke ovens. A typical PCI installation is shown in Figure 1.

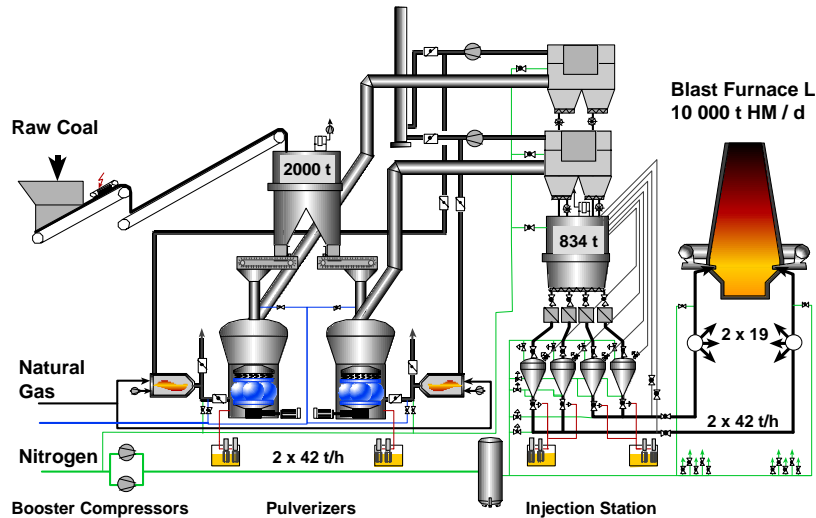


Figure 1: Flow Sheet of the PCI Plant Bethlehem Steel, USA (Source: Claudius Peters Technologies GmbH)

The injection of coal into the blast furnace has been shown to:

- Increase the productivity of the blast furnace, i.e. the amount of hot metal produced per day by the blast furnace,
- Reduce the consumption of the more expensive coking coals by replacing coke with cheaper coals,
- Assist in maintaining furnace stability, and
- Improve the consistency of the quality of the hot metal and reduce the silicon content of the pig iron.

In addition to the benefits mentioned above, coal injection has proved to be a powerful tool to enable the furnace operator to adjust the thermal condition of the furnace much faster than would be possible by adjusting the burden charge from the top.

## Merits of Using LV Coals for Injection

The relative importance of different aspects of PCI coal quality has varied as the technology for injection has improved and the rate of injection increased. In the late 1970's, triggered by the oil crisis, interest in PCI was renewed and coal was considered as an economic replacement fuel for oil. As combustibility was considered to be of importance, the coals used for PCI were typical thermal coals. At that time, thermal coals were readily available and had a much lower cost than Hard Coking and Semi-Soft Coking coals. As understanding of the impact of coal quality on BF performance increased, the demand for lower volatile coals has increased over the last 5 years.

Today, there are many criteria used to measure the performance of coals for injection, both technical and economic. Two key factors are *coke replacement ratio* and *milling capacity*.

### Coke Replacement Ratio

The replacement ratio is the factor, other than coal price, that has the largest impact on the economics of coal injection. It has been shown by modelling and BF performance data that the replacement ratio increases with the carbon content of the injected coal, as shown in Figure 2.

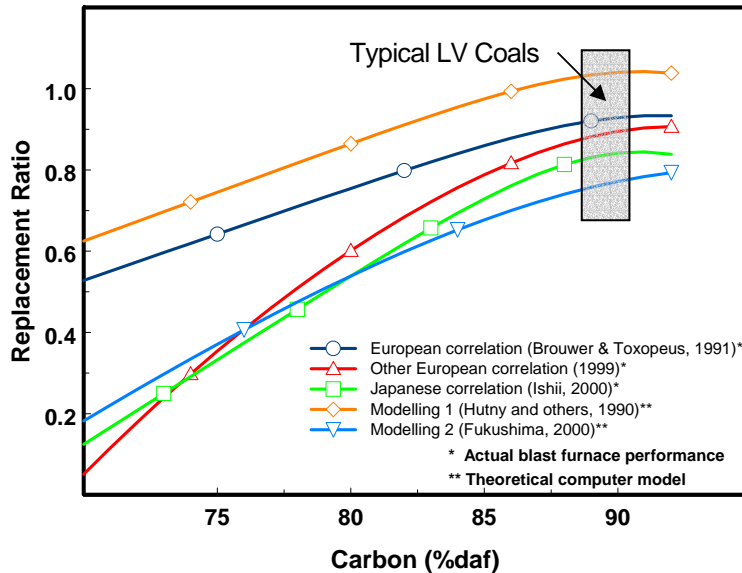


Figure 2: Influence of Rank on Replacement Ratio (Source: CoalTech, 2004)

### Milling

The Hardgrove Grindability Index (HGI) is a good indicator of the expected milling behaviour of a coal. The high HGI of a soft coal allows a mill to be operated at a higher mill throughput with the same or lower mill power requirement. HGI increases as the rank of the coal goes from sub-bituminous to low volatile bituminous coals, then it decreases as the rank further increases to anthracites.

Mills in some injection systems are being operated at rates close to or greater than the design rate; the use of softer coals in these mills provides an increase in injection capacity.

## Issues at High Injection Rates

At injection rates greater than around 160 kg/tHM, it was observed that changes were occurring in the operation of the blast furnace. Some of these changes included:

- The size of the raceway,
- Reduction of permeability of the coke surrounding the raceway,
- Changes in temperature distribution in the raceway,
- Mechanical degradation of coke in the raceway, and

- Decrease in deadman temperature.

All these changes are interdependent and are influenced by the properties and amount of the injected coal and blast conditions. The stable operation of the blast furnace depends on the even distribution of the gas flow upwards and the unheeded flow of slag and hot metal to the hearth. Therefore, maintaining good permeability in the lower zone of the blast furnace is vital to stable blast furnace operation.

### Permeability

As PCI rate increases the permeability decreases, mostly due to the increasing ore/coke ratio in the burden. Permeability is also affected by a large number of other factors such as coke size, coke CSR, sinter degradation and unburnt carbon and ash from the injected coal.

The principal causes<sup>1</sup> of reduced permeability in the deadman zone due to injection of coal is the formation of -1mm fines from highly viscous slag at the deadman surface, and -3mm fines originating from high Ca/SiO<sub>2</sub> dripping slag in the deadman.

### Combustibility

The entry of unburnt char into the burden is inevitable at high injection rates. The level of this unburnt char that can enter the shaft of the furnace is limited by the amount that can be consumed by the solution loss reaction, as seen in Figure 3.

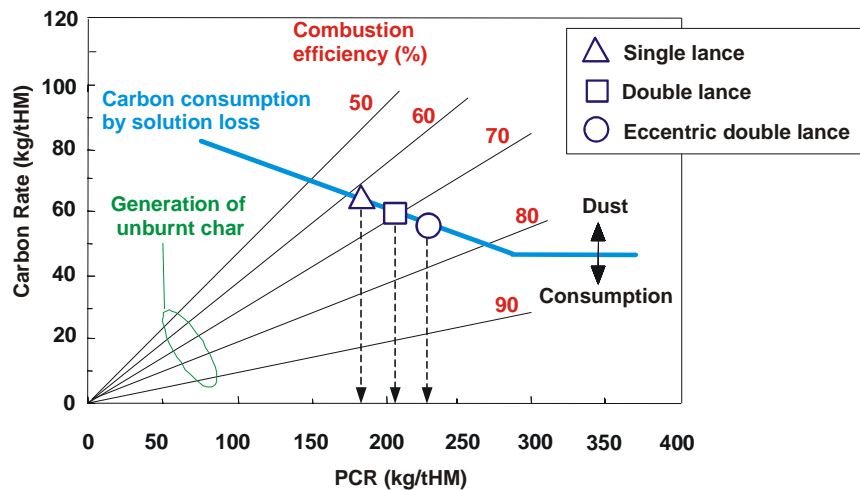


Figure 3: Impact of Combustion Efficiency on Furnace Dust Rate (after Goto and others<sup>2</sup>, 2002)

It is clear from this figure that injection rates of below 150 kg/tHM combustibility is not an issue. At higher injection rates combustibility depends upon several factors including lance design and other BF operating conditions.

Increasing the intensity of combustion by increasing oxygen, increasing blast temperature or improving mixing within the tuyere improves the burnout. Increasing

<sup>1</sup> Ichida, M., Orimoto, T., Tanaku, T., Sakatani, M., Ueno, H., 2002, "Behaviour of pulverized coal ash and physical property of dripping slag under high pulverized coal injection operation", International Blast Furnace Lower Zone Symposium, Wollongong, Australia, 25-27 November 2002.

<sup>2</sup> K. Goto, R. Murai, A. Murao, M. Sato, M. Asanuma, T. Ariyama, 2001, "Massive combustion technology of Solid Fuels Injected Into Blast Furnace", International Blast Furnace Lower Zone Symposium, Wollongong, Australia, 25-27 November 2002.

the intensity of combustion not only increases the reaction rates but also greatly enhances the volatile matter yield. Fragmentation of the char is also increased, reducing the char diameter and therefore significantly speeding the diffusion limited kinetics.

Increasing the oxygen content either in the blast or via the lance is beneficial to the coal combustion. Oxygen is also used to control the raceway temperature when injecting coal. The amount of oxygen required for a constant raceway temperature increases as the volatile content of the coal increases due to the cooling effect of the decomposition of the volatiles.

The use of additional oxygen in the blast will decrease the volume of shaft gas, minimizing the impact of decreasing permeability at higher injection rates, and increase CO and H<sub>2</sub> content, giving improved reduction in the central shaft. Oxygen enrichment of the blast also improves the heat value of BF top gas. With regard to the heat balance within the furnace, the upper limit of oxygen enrichment is dependent on maintaining a sufficient top gas temperature. As oxygen is increased, the gas mass flow within the furnace decreases which decreases the heat flow to the upper region of the blast furnace.

While oxygen enrichment enhances combustibility, it does not directly speed the ignition of the coal particle. The residence time of the coal/air/oxygen plume, prior to the turbulent mixing of the raceway diluting the oxygen concentration surrounding the coal/char particle, is very short. Therefore, the rapid ignition of the coal is vital to achieving high burnout of the char.

Ignition is dependent only on the heating rate of the particle. For the normal range of blast temperatures, the temperature of the gas surrounding the coal particle is mainly a function of the combustion of the volatiles from the coal and to a lesser degree the combustion of very fine coal particles. As the gas temperature increases, volatile yield from the coal increases which will further assist in the shortening of the particle ignition time. The increase in volatile yield with temperature is much greater for LV coals than for HV coals.

It is likely, under the very intense combustion conditions at the tuyere and raceway, differences in the combustibility of coals would be greatly reduced. This has been observed for coals fired in a pressurised entrained flow gasifier.

Blending can also improve combustibility of LV coals, as the addition of high volatile components, such as high volatile coal or plastics, has been shown to greatly improve combustion of the char.

## Market Trends

### Future Demand

Worldwide consumption of PCI coal is a function of the number of furnaces fitted with coal injection, the productivity of these furnaces and the specific injection rate. The recent growth in steel demand triggered by the rapid expansion of the Chinese economy has resulted in increases in hot metal production for most of the regions shown in Figure 4.

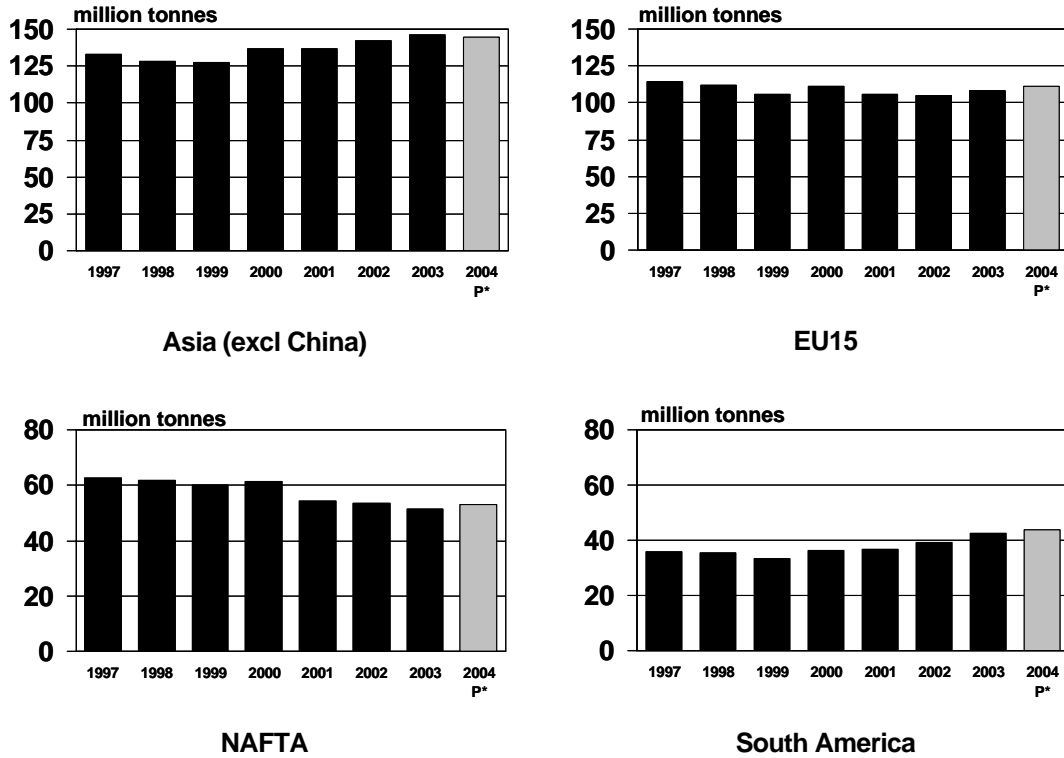


Figure 4: Pig Iron Production by Calendar Year (Source: IISI) [\* P = YTD June x 2]

Continued growth in steel production will depend on world economic growth outcomes, particularly in China. Recently, BHP Billiton's Chief Executive Chip Goodyear, commenting on raw material prices on Australian national television<sup>3</sup>, stated –

"We say that over a long time, raw material prices fall in real terms. But. . . we can go for multi-decade periods where they actually increase. The question is, is China the next multi-decade increase in prices? I think there is certainly a case to be made."

Commentators believe that "India is next in line" for economic expansion indicating a possible long-term growth in the demand for steel.

This demand will be met by new blast furnaces and relining of older furnaces thereby increasing their production capacity. Nippon Steel Corporation recently announced that they had achieved an 8 % increase in blast furnace volume overall through relining. PCI capability is almost universally fitted to new blast furnaces.

### Japanese Market

In recent years there has been a steady decrease in the average fuel rate (coke and injectants) recorded for the Japanese Steel Mills (JSM). The primary driver for this decrease is the need for improved productivity in times of high steel demand and high raw material costs. Another emerging driver is for JSM to lower CO<sub>2</sub> emissions. This will become more important if the Japanese government put into place in the next couple of years a planned Carbon Tax.

<sup>3</sup> Channel 9, Business Sunday, 22 August 2004.

Reviewing<sup>4</sup> the JSM statistical data it is evident that several factors have contributed to the decrease in fuel rate. These factors include increased oxygen enrichment, decreased RAFT temperature, reduced bosh gas rate and improved gas permeability due to better burden distribution and quality. The decrease in coke and PCI rates can also be partly attributed to the increased use of LV PCI coals.

PCI systems in Japan are often limited in capacity to below 150 kg/tHM, with two notable exceptions. This is a factor in explaining why the PCI Rate has reduced slightly over the last year or so. If this injection system is capacity constrained, then any increase in hot metal output results in a reduced PCI rate.

## PCI Coal Supply

The seaborne PCI coal trade is currently around 30 million tonnes per annum which is small compared with the total world coal trade of around 550 million tonnes per annum, comprising less than 200 million tonnes of metallurgical coals. The major regions that supply this market are shown in Figure 5.

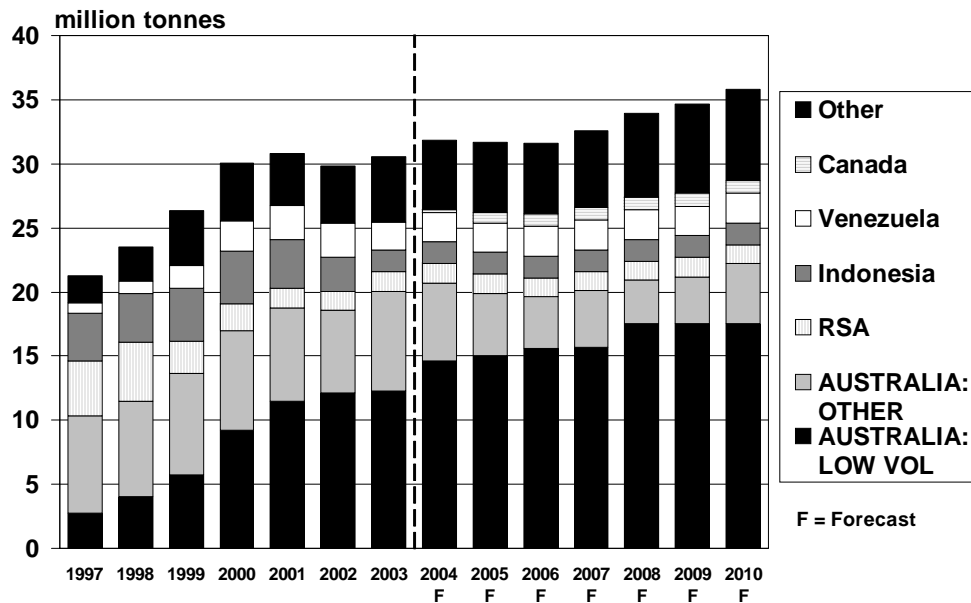


Figure 5: PCI Coal Supply - Major Supplier Regions/Countries (Source: Barlow Jonker – Aug 04)

As shown above the growth in the PCI coal trade has been reflected in a strong increase in the exports of low volatile coals from Queensland, Australia. Queensland low volatile coals currently account for around one half of the seaborne traded PCI coals.

This preference for low volatile coals for injection and the increased overall demand for PCI coals has led some market analysts to predict a significant growth in the export of semi-anthracites from Queensland. Some of this growth in Queensland's low volatile coal exports will offset the decline in exports from New South Wales as these coals move back into their traditional thermal coal market.

<sup>4</sup> T. Fukushima (F-TeCon Pty Ltd), private communication 2004

Another factor that will strongly influence the demand for LV PCI coal is the relative difference in the price of Hard Coking, Semi-Soft Coking and Steaming coals. As shown in Figure 6 there has recently been a very significant price increase in all coals with some spot sales of Steaming coals gaining a price higher than that obtained for SSCC/PCI coals. Other factors impacting upon coal selection are the price and availability of Chinese coke and the forecast lift in coking coal prices expected for fiscal 2005.

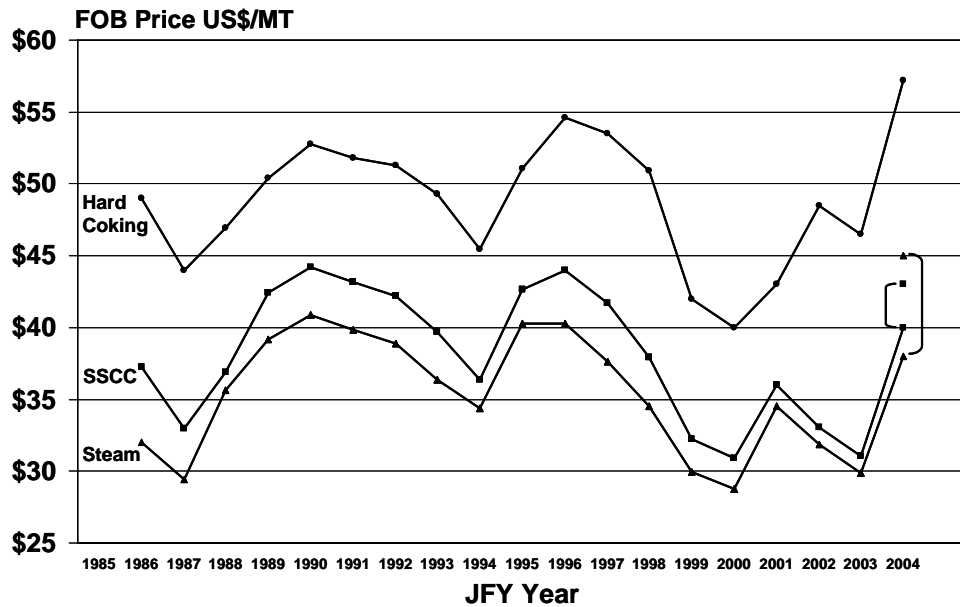


Figure 6: Trends of Coking and Steam Coal Prices - Japanese Reference Price

## Queensland LV Coal Producers

### Reserves

Proven coal resources of bituminous and sub-bituminous coal in Queensland are very large, exceeding 36 billion tonnes in the *Measured* and *Indicated* categories. All the low volatile coals that are exported from Queensland come from the Bowen Basin which has reserves of 26 billion tonnes with 6 billion tonnes of this coal accessible by opencut mining. The mining operations of central Queensland and the rail and port infrastructure are shown in Figure 7.



Figure 7: Coal Resources (LV Coal Producers highlighted) and Infrastructure of Central Queensland (Source: Queensland Coals 14<sup>th</sup> Edition 2003)

## Infrastructure

An extensive rail network links Queensland's coal mines to six coal export terminals at four ports on the State's eastern seaboard, as well as to domestic coal users. The coal rail network in Queensland is owned and operated by QR (formerly Queensland Rail), a Queensland Government-owned corporation. Although QR is presently the sole service provider, using the network to service the coal industry, it is possible for other operators to access the network through third party access agreements that came into force in 2002.

QR transports about 135 million tonnes of coal per year. Driven primarily by the growth in the Queensland coal industry, QR in the past ten years has implemented new initiatives combined with major capital investment in additional rollingstock and rail infrastructure. This has resulted in substantial increases in coal railings and improvement in productivity as shown in Figure 8. As a measure of this, average system train cycle times (turnaround times) have decreased by 15 %, and average system train payloads have increased by 20 % over recent years.

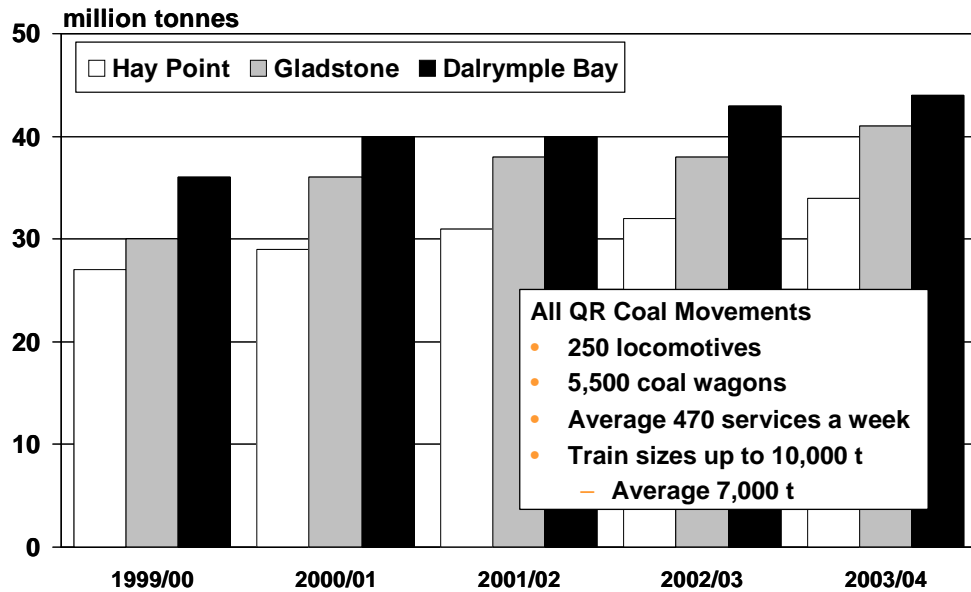


Figure 8: QR Coal Railings by Port (Source: QR)

Queensland LV coals are hauled on Gooyella and Blackwater rail systems. Both of these rail systems are fully electrified.

Coal destined for the export market is handled through six coal terminals at four deepwater ports located along the Queensland coast. The Dalrymple Bay, Hay Point and Gladstone ports collectively handle approximately 85 % of Queensland's coal exports. All LV coals are currently shipped through these three ports. Total handling capacity of the ports continues to increase, with expansions at Dalrymple Bay and RG Tanna terminals completed during 2003. These expansions will result in a total annual loading capacity of all the coal terminals to approximately 150 Mt. The current capacity and exports for these ports are given in Figure 9.

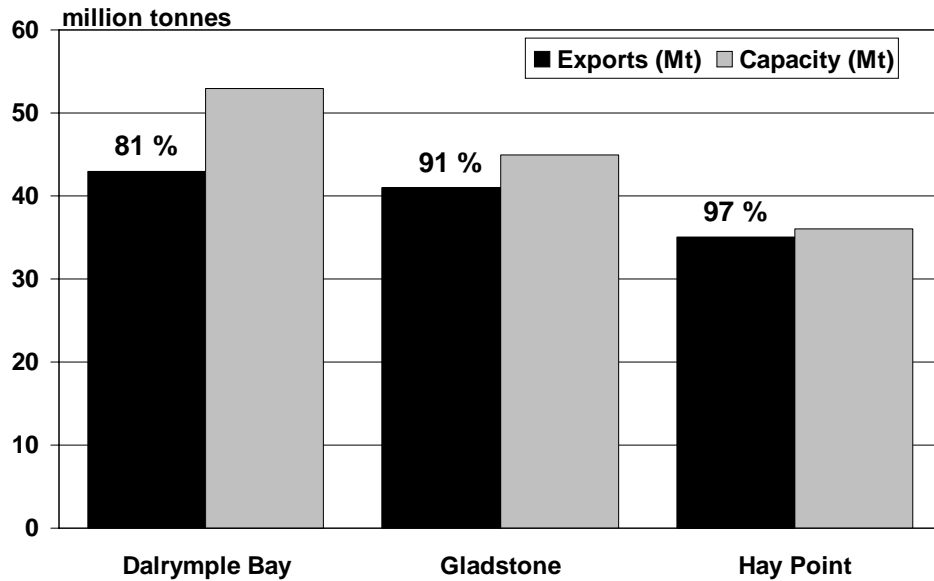


Figure 9: Current Capacity and Exports for Queensland Coal Ports (Source: Barlow Jonker - Aug 04)

### Industrial Relations

Since the introduction of the Workplace Relations Act in 1996, there has been significant improvement in the industrial relations climate in the Queensland coal sector. For example there were over 7000 working days lost in 1996 compared with around 350 in 2003 (5 % of the 1996 level).

### Queensland LV PCI Exporters

The five Queensland LV producers competing for the PCI exports are shown in Table 1. Figure 10 shows the influence of the PCI market on the growth of exports from these mines, from a small start in 1995 to currently where around 80 % of sales from these mines are for PCI. These producers ship through the ports of Gladstone, Hay Point and Dalrymple Bay using two rail systems. This minimises the risk of supply disruptions. The ports are major coking coal supply ports and thus the ability of steel mills to pick up parcels of PCI coal from the same port provides a logistics advantage. Blending is also possible particularly at Gladstone Port where approximately half of all coal loaded is a blend.

Due to the properties of these coals they are not generally suited to the steaming or coking coal market. This ensures the producers remain focused on the needs of the ironmaking sector. Under certain conditions mills have used some of these LV coals in the coke blend, yielding an economic advantage to the coke plant and providing an alternative outlet for the suppliers.

<b>Mine Name</b>	<b>YARRABEE</b>	<b>JELLINBAH</b>	<b>SOUTH WALKER</b>	<b>COPPABELLA / MOORVALE</b>	<b>FOXLEIGH</b>
<b>Mine Operator</b>	Yarrabee Coal Company	Jellinbah Resources	BHP Billiton	Australian Premium Coals	CAML Resources
<b>Rail System</b>	Blackwater	Blackwater	Goonyella	Goonyella	Goonyella
<b>Port</b>	Gladstone	Gladstone	Hay Point	Dalrymple Bay	Dalrymple Bay
<b>Export Sales 2003/2004</b>	1.6 Mt	4.0 Mt	3.7 Mt	5.2 Mt	1.9 Mt
<b>Coal Quality</b>					
<b>Ash % ad</b>	10.5	9.5	8.5	8.5	7.5
<b>Volatile Matter % ad</b>	10.5	15.3	12.5	12 - 16	12.5
<b>SE kcal/kg gad</b>	7450	7550	7750	7800	7850

Table 1: Queensland LV PCI Producers

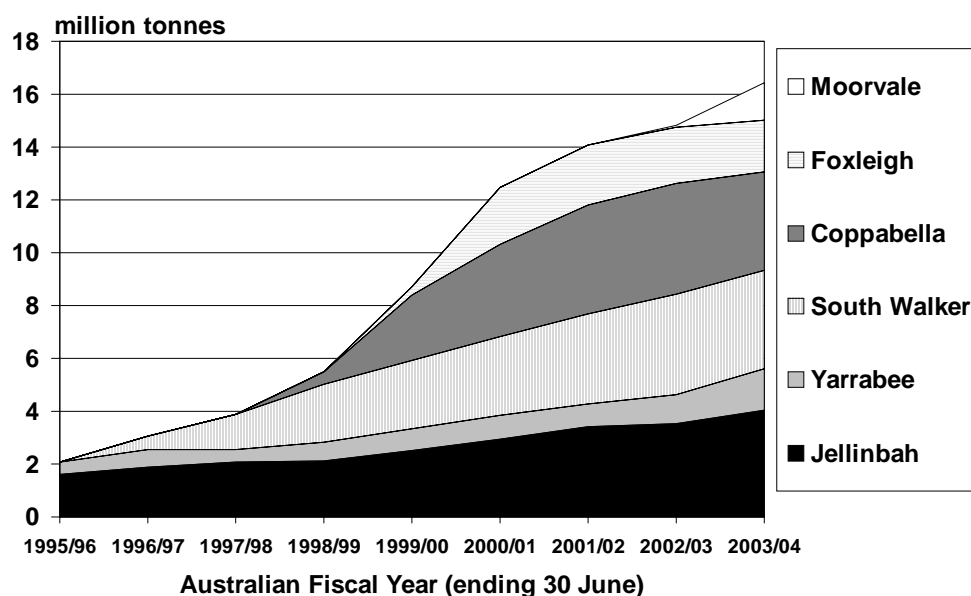


Figure 10: Queensland Low Volatile Coal Exports (Source: Department of Natural Resources & Mines)

### New Prospects

In the Bowen Basin several new coking coal mines are planned, within the Rangal coal measures. In washing to meet coking coal specification a secondary product may be produced, this can be either a Steaming or a PCI product. Typically, the PCI product will be 9-10 % ash and 18-22 % volatile matter. This will generate additional high energy PCI coal should the market require.