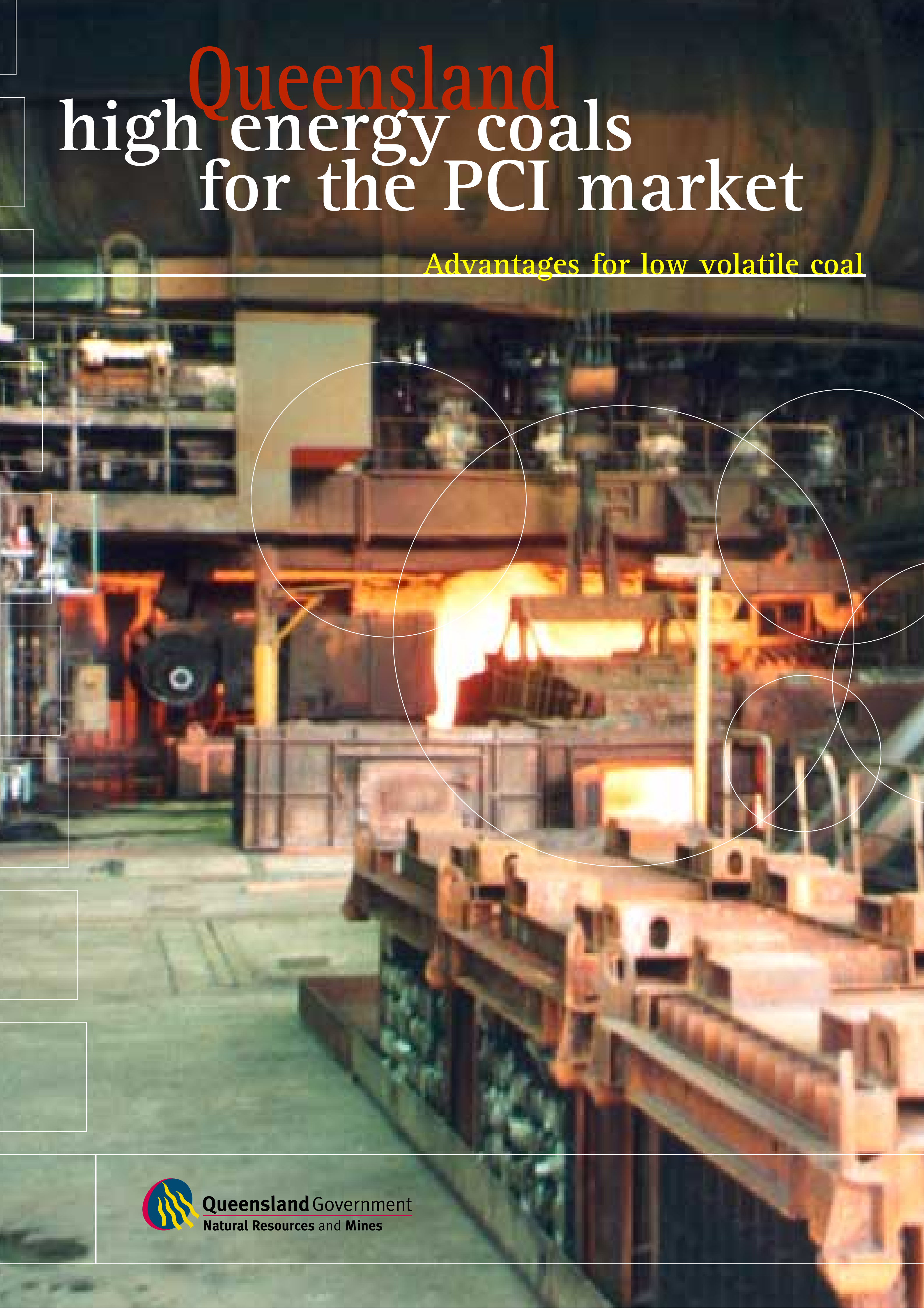
# Queensland high energy coals for the PCI market

## Advantages for low volatile coal



Queensland Government
Natural Resources and Mines

## Queensland PCI Coals

Pulverised coal injection (PCI) has become a standard practice in many of the worlds major steelworks. Finely ground coal is injected with the hot blast directly into the raceway of the furnace to provide energy and reductant in addition to that from the coke bed, thus replacing some of the coke with cheaper non-coking or weakly coking coal. Hence the PCI process increases the economic efficiency of steel-making by using lower cost coals to reduce consumption of higher cost prime coking coals. In addition the PCI coal is not subject to a coke-making or other process stage, other than grinding, prior to its introduction to the blast furnace. PCI rates must be such that stable blast furnace operation is maintained while the permeability of the coke bed is not affected.

Central Queensland hard coking coals are recognised by steelworks as prime coking coals which produce high strength and low reactivity cokes that provide a permeable burden support in the blast furnace. As the proportion of PCI increases, these coke properties are of increasing importance.

Coal deposits in the Bowen Basin of central Queensland (Figure 1) include extensive resources of low and medium volatile semi-soft coking and thermal coals that are well-suited to the PCI market. These coals give high coke replacement ratios, assist in maintaining blast furnace productivity and exhibit good grinding characteristics.

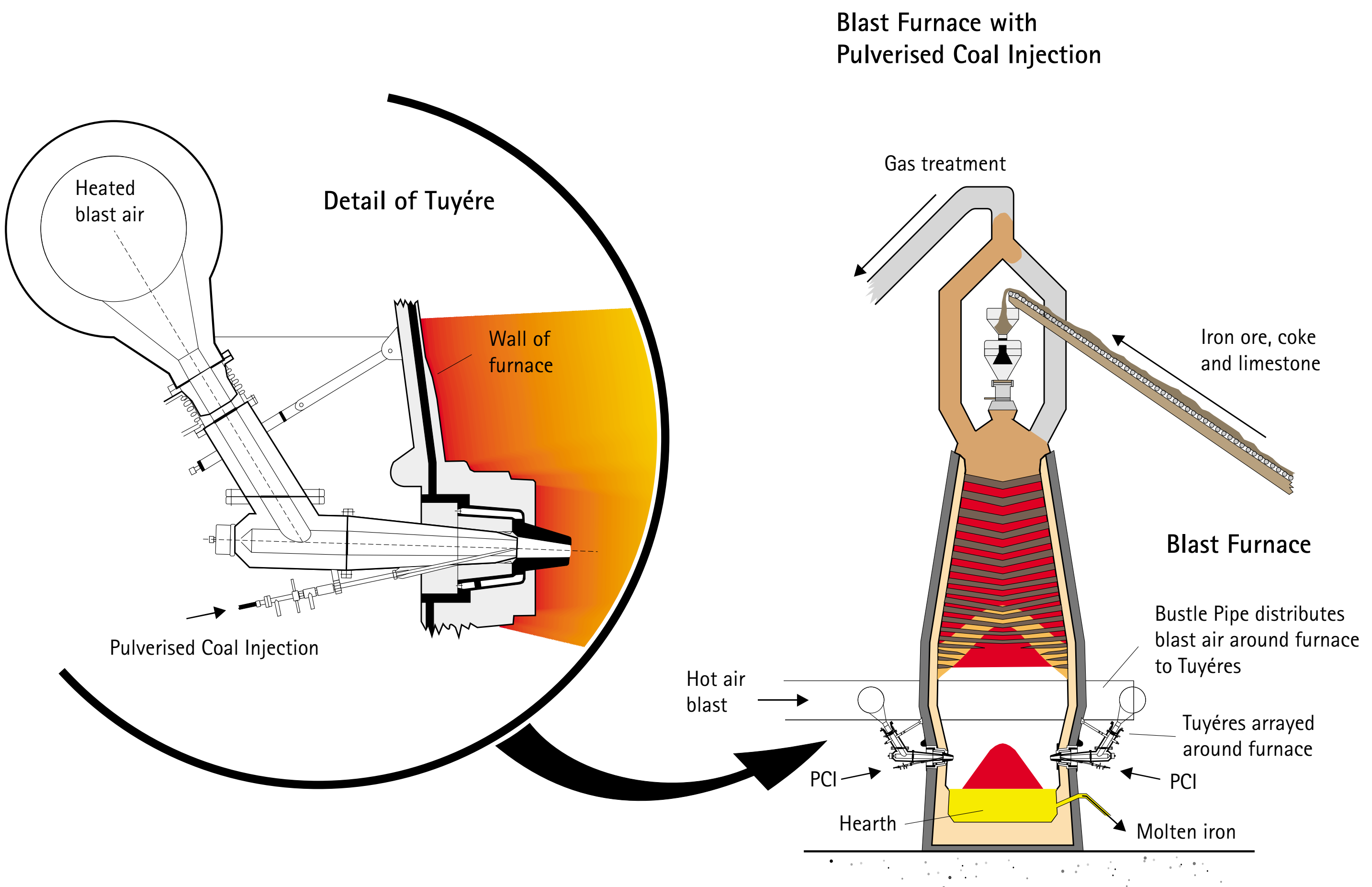
## Market—World Steel Production

The International Iron and Steel Institute (IISI) reported world steel production in 2001 was 839.9 Mt, down 7.3 Mt on the 847.2 Mt produced in 2000 but still substantially higher than the 788.3 Mt produced in 1999. IISI estimated world apparent steel consumption in 2001 at 773 Mt and optimistically expects further growth (averaging 2.6%) in 2002 with consumption reaching 799 Mt.

Much of this growth is attributed to mainland China where consumption is forecast to reach 170Mt in 2002, up from 160 Mt in 2001 and 141 Mt in 2000. (http://www.worldsteel.org/article/2001101).

Operators of integrated steel plant will continue to strive to minimise operating costs to increase competitiveness. One important avenue is to minimise the cost of raw materials and especially prime coking coals which command a price premium over most other coals. PCI is playing an increasingly important role in this area by allowing the utilisation of cheaper coals.

Growth in world steel production will create further demand for PCI coals and higher prices for coking coals will also drive higher injection rates that will range up to about 200 kilograms per tonne of hot metal (kg/tHM).




Details courtesy of BMH Claudius Peters AG.

**PCI Furnace and Tuyére diagram**

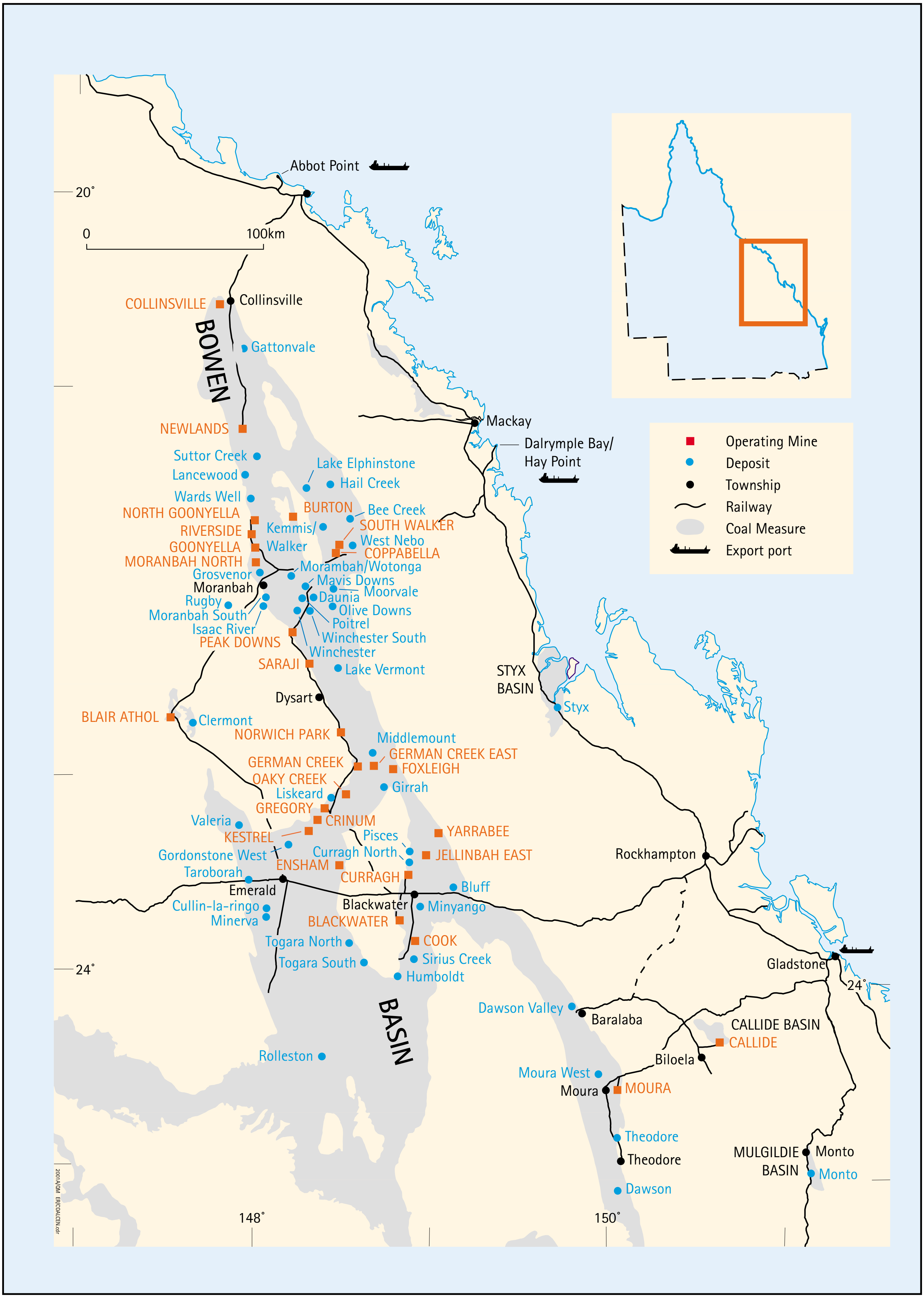



**Figure 1: Central Queensland Coal Mines and Deposits**

## Queensland Coal Resources

Queensland has some 23 billion tonnes of thermal coal resources (raw coal *in situ*) already proved to indicated status. These include 3.75 billion tonnes with volatile matter less than 25% and of this, in excess of 1.5 billion tonnes are amenable to opencut mining. Further exploration will no doubt increase the amount of known resources. Given the relatively small level of current production of this type of coal, Queensland is able to boost production to supply large tonnages of these high quality lower volatile coals into the world market for many years. Figure 2 shows estimates of the known tonnages of Queensland's thermal coals according to the volatile matter content of the product coal on an air-dried basis (adb).

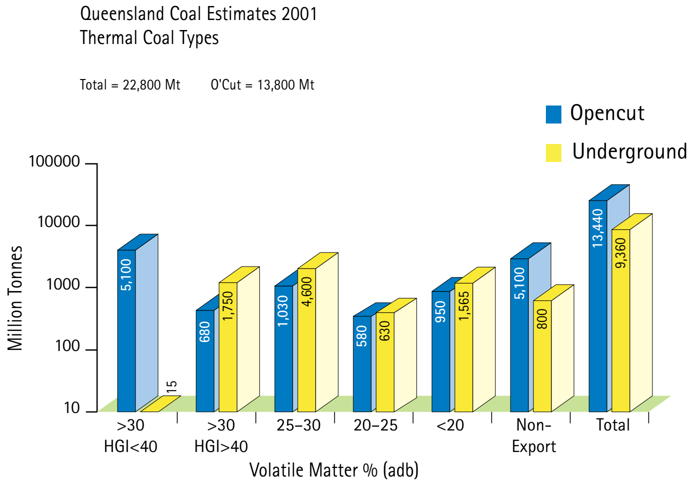



**Figure 2: Queensland Thermal Coal Estimates 2001**

New developments in the Bowen Basin, including expansions, have the potential to increase Queensland coal exports by over 20 million tonnes per year over the next 5 years. Table 1 summarises the deposits of high energy medium to low volatile coals that are being actively explored whilst a list of undeveloped higher volatile coal deposits is presented in Table 2. Export thermal coals currently produced in Queensland are listed in Table 3.

## Replacement Ratio

The choice of coal for use as the injected fuel impacts significantly on the cost benefit that can be obtained by pulverised coal injection. The primary factor that influences the cost benefit of PCI is the amount of coke that can be replaced by the injected coal. The replacement ratio normally quoted in the literature is the metallurgical corrected coke rate where the coke rate is corrected for furnace parameters. The theoretical coke replacement ratio is between 0.8 and 1.0 kg coke/kg coal depending on the energy and carbon content of the coal. Actual replacement ratios achieved in blast furnace operations with low to moderate injection rates tend to be slightly higher while at higher rates replacement ratios can be lower than theoretical. Hutny & others (1990) have reported that replacement ratio increases with the rank of the coal.

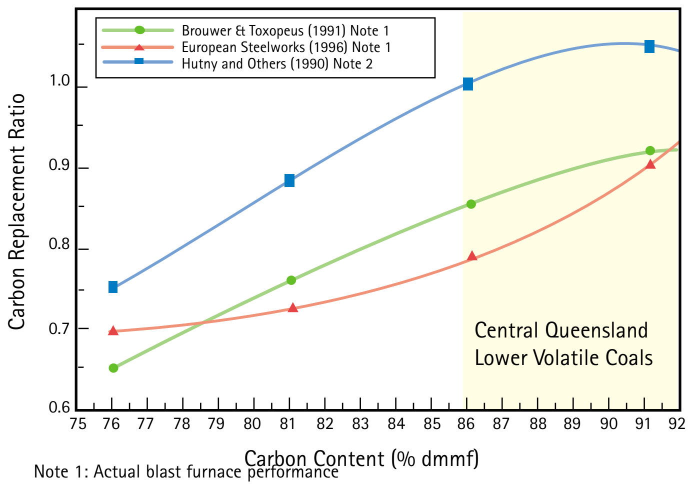
## Advantages of High Energy Coals

A major factor limiting PCI rates, while maintaining stable blast furnace operation, is the permeability of the coke bed surrounding the raceway. As injection rates increase the level of unburnt char entering the raceway and the blast momentum both increase, leading to:

- changes in the size of the raceway,
- mechanical degradation of coke in the raceway,
- reduction of permeability of the coke surrounding the raceway, and
- changes in temperature distribution in the raceway.

All of these influence raceway stability and the distribution of gas flow through the lower sections of the blast furnace, both of which impact on furnace stability and therefore blast furnace productivity.

The main economic benefit of coal injection is the replacement of high cost coking coals. The coke replacement ratio of a coal can be shown to be dependent on the energy or carbon content of that coal, with low volatile coals having the highest coke replacement ratio (Figure 3).

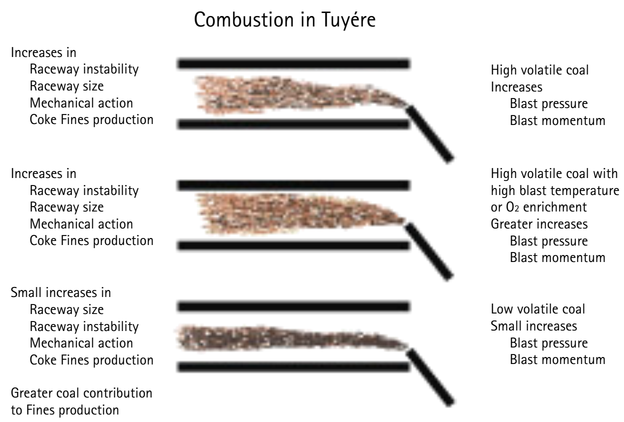



Note 1: Actual blast furnace performance

Note 2: Theoretical based on computer model

**Figure 3: Variation in replacement ratio with the rank of injected coals**

The volatile content of the injected coals can impact on char formation, blast momentum and generation of coke fines in the raceway (Figure 4).




Source; Lüngen H.B. & Poos A., 'Injection of Coal into Blast Furnaces—ECSC Synthesis Report' Cokemaking International, Volume 3, No. 3 1996

**Figure 4: Effects of coal volatile content on combustion in blast furnace tuyére**

The main influences coal properties can have on blast furnace performance are:

- Coke replacement ratio increases with the dry ash-free carbon content of the coal up to approximately dry ash free carbon content of 91% where the replacement ratio seems to level out.
- The blast momentum decreases with increasing carbon content of the coal when the dry ash-free carbon content is greater than 85% (Figure 5); the blast momentum directly influences the raceway depth and coke degradation within the raceway.
- Blast oxygen enrichment requirements to maintain raceway gas temperatures decrease as the dry ash-free carbon content of the injected coal increases.

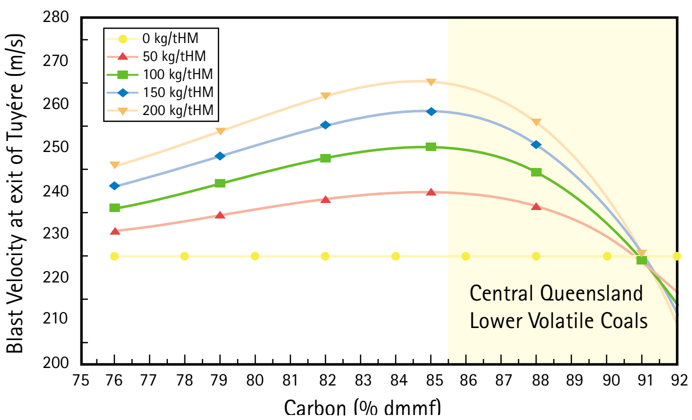



**Figure 5: Variation of blast velocity with the rank of injected coal**

At high injection rates and injecting a coal with carbon content less than 85% daf, any fluctuations in the coal rate delivered to a tuyère will result in fluctuations in the raceway depth and the generation of coke fines. Fluctuations in raceway depth and the generation rate of fines will reduce blast furnace stability and therefore productivity. By choosing a coal with a dry ash-free carbon content greater than say 88%, the impact of variations in coal feed rate on blast furnace stability will be reduced and furnace productivity will be maintained.

Low volatile coals are generally softer coals with Hardgrove Grindability Index around 80. As these coals are very easy to mill, there will be savings from reduced mill power consumption for a given coal throughput. Low volatile coal also allows the mill capacity to be increased up to 40% above that of a 50 Hardgrove Grindability Index coal, thus allowing the steelworks to increase injection rates without further capital expenditure on additional milling capacity.

Semi soft coking, low and medium volatile thermal coals from Central Queensland are well suited to the PCI market giving high coke replacement ratios, assisting in maintaining blast furnace productivity and having good milling characteristics.

The economic benefit of the coke replacement ratio can be illustrated in the following simplified example using Brouwer & Toxopeus (1991) data to calculate replacement ratio and assuming:

- a CIF coking coal price of US$63/t,
- a CIF PCI coal price of US$50/t,
- 1.43 tonnes of coking coal is required for each tonne of coke, and
- the total fuel rate is 490 kg/tHM.

Then the coal cost savings can be calculated as shown in Figure 6. This figure shows that up to US$6.50/tHM can be saved at high injection rates by using a low volatile coal.

## Suitability of Central Queensland Coals for the PCI Market

Semi-soft coking, low and medium volatile thermal coals from Central Queensland are very competitive in the PCI market both in terms of price and operational advantages.

These advantages are:

- high coke replacement ratio due to their high energy content;
- relatively low ash content; and
- combustion characteristics that will assist in maintaining blast furnace stability at high injection rates, and therefore improving the productivity of the blast furnace.

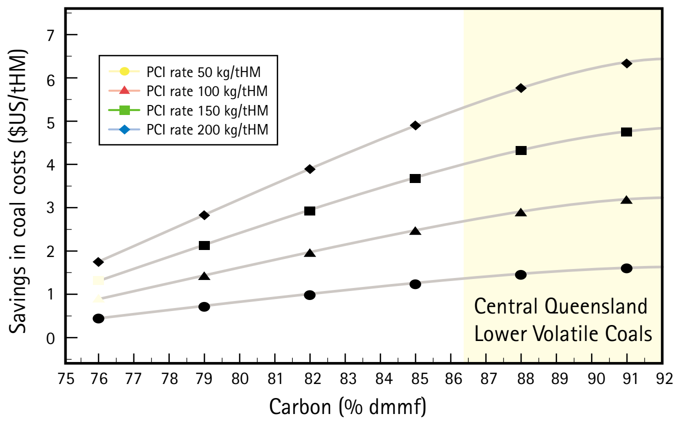



**Figure 6: Saving in total costs from the replacement of coking coals**

These coals from Central Queensland have potential to become the benchmark coals in the PCI market just as the hard coking coals from Queensland have gained world recognition in the coking coal market.

## References


Bennett, P.A., (1997): Advantages of Low Volatile Coals for PCI. *A report prepared for the QTHERM Program of the Queensland Department of Mines and Energy.*

Brouwer, R.C., & Toxopeus, H.L., (1991): Massive coal injection at Hoogovens Ijmuiden BFs, Revue de Metallurgie. *Cahiers d'Informations Techniques*, V88, N4, Apr 1991.

Hutny, W.P., Price, J.T., & Gransden, J.F., (1990): Evaluation of coals for blast furnace injection using a computer model, *Ironmaking Conf. Proc., 1990.*


This article is a modified extract from a technical report prepared by Energy Tactics for the *QTHERM* Program in the (then) Queensland Department of Mines and Energy.

## Table 1: Some Potential New Developments of Lower Volatile Thermal and PCI Coal Deposits in the Bowen Basin, Queensland

| Project and Operator | Type | Volatile Matter (% daf) | Production | Status—2002 |
|---|---|---|---|---|
| **Bee Creek** BHP Coal Pty Ltd | opencut thermal | 17 | not yet determined | Uncommitted, if market accepts the low volatile product, mining could quickly proceed. |
| **Daunia** BHP Billiton Mitsubishi Alliance | opencut thermal and coking | 23 | not yet determined | Advanced project, mine development could quickly proceed subject to market demand. |
| **Dawson Valley** Republic Coal Pty Ltd | opencut thermal (semi-anthracite) | 13 | not yet determined | Plans to recommence mining are advanced, awaiting suitable marketing opportunities. |
| **Hail Creek** Pacific Coal Pty Ltd | opencut coking | 22 | 5 Mtpy coking initially thermal coal later | Under construction. |
| **Girrah** (previously Lake Lindsay) Curragh Queensland Coal Pty Ltd | opencut thermal and coking | about 21 | not yet determined | Assessment advanced, early development is possible to augment production from Curragh Mine. |
| **Kemmis Creek** BHP Mitsui Coal Pty Ltd | opencut thermal | 21 | not yet determined | Uncommitted, if market accepts the lower volatile product, mining could quickly proceed. |
| **Lake Vermont**—Queensland Coal Mine Management Pty Ltd | opencut thermal and coking | 23 | 0.5 Mtpa increasing to >1.0 Mtpa | Exploration, feasibility and marketing studies continuing, start-up will depend on suitable market conditions. |
| **Moorvale** C & S Exploration Joint Venture | opencut thermal | 19 | 1.6 Mtpa | Feasibility and marketing studies in progress, development likely in 2003. |
| **Olive Downs** C & S Exploration Joint Venture | opencut and underground thermal and coking | 21 | not yet determined | Exploration advanced, pre-feasibility and marketing studies are progressing. |
| **West Nebo** BHP Coal Pty Ltd | opencut thermal (anthracite) | 7 to 9 | not yet determined | Awaiting market opportunities. |
| **Winchester South** Pacific Coal Pty Ltd | opencut thermal coal | 25 | not yet determined | Awaiting market opportunities. |

## Table 2: Some Potential New Developments of Higher Volatile Thermal and PCI Coal Deposits in the Bowen Basin, Queensland

| Project and Operator | Type | Volatile Matter (% daf) | Production | Status—2002 |
|---|---|---|---|---|
| **Clermont** Pacific Coal Pty Ltd | opencut thermal | 32 | ramping up to >10 Mtpa | Will be phased in to replace Blair Athol Mine as reserves are depleted. |
| **Cullin-la-ringo** Queensland Government | underground thermal | 36 | not yet determined | Exploration area held by the Queensland Government for future release. |
| **Gordonstone West** Pacific Coal Pty Ltd | underground thermal | 35 | 4.0 Mtpa | Uncommitted, awaiting favourable market conditions. |
| **Humboldt** BHP Billiton Mitsubishi Alliance | underground thermal | 33 | not yet determined | Development may occur in conjunction with future operations of the expanded Blackwater Mine. |
| **Minerva** New Hope Coal Australia | opencut thermal | 36 | 1.0 Mtpa | Mining Lease granted, development to proceed according to market demand for this coal. |
| **Poitrel / Winchester** BHP Coal Pty Ltd | opencut thermal and coking | 26 | not yet determined | Uncommitted, development likely to occur in conjunction with the Daunia deposit. |
| **Rolleston** Mount Isa Mines Limited | opencut thermal | 36 | 6 Mtba | Stage 2 feasibility, advanced and full scale mine development is expected in 2004. |
| **Suttor Creek** Mount Isa Mines Limited | opencut and underground thermal | 32 | not yet determined | Plans in place, production will supplement/replace output from Newlands, an opencut mine will be developed prior to underground operations. |
| **Theodore** Anglo Coal Australia Pty Ltd | opencut and underground thermal | 38 | 3.5 Mtpa and potential to expand | Not yet committed, initially an opencut mine will be developed, later to be followed by underground operations subject to market conditions. |
| **Togara North** Togara North Joint Venture | underground and opencut thermal | 34 | 3.0 Mtpa expanding to 7 Mtpa | Feasibility completed, development will proceed following grant of Mining Lease and adequate sales contracts. |
| **Togara South** Coal Mines Australia Ltd | underground thermal | about 34 | 4 Mtpa expanding to 8 Mtpa | Prefeasibility study completed, development delayed but mining may commence by 2005, subject to market conditions. |
| **Valeria** Pacific Coal Pty Ltd | opencut thermal | 39 | About 5.0 Mtpa | Awaiting suitable market opportunities. |

## Table 3: Export Thermal & PCI Coals Produced in Queensland

| Mine and Operator | Type of Operation | Volatile Matter (% daf) | Coal Exports 2001–2002 (Million tonnes) |
|---|---|---|---|
| Blackwater Mine – BHP Billiton Mitsubishi Alliance<br>GPO Box 1389 Brisbane Qld 4001<br>Telephone: 61 7 3226 0600; Facsimile: 61 7 3229 2575 | opencut | 29-30 | 11.5* |
| Blair Athol Mine – Pacific Coal Pty Ltd<br>GPO Box 391 Brisbane Qld 4001<br>Telephone: 61 7 3361 4200; Facsimile: 61 7 3229 5087 | opencut | 32 | 10.11 |
| Burton Mine – Burton Coal Pty Ltd<br>PO Box 108 Glenden Qld 4743<br>Telephone: 61 7 4940 5555; Facsimile: 61 7 4940 5561 | opencut | 24 | 3.96* |
| Collinsville Mine – Collinsville Coal Co Pty Ltd<br>GPO Box 1433 Brisbane Qld 4001<br>Telephone: 61 7 3833 8000; Facsimile: 61 7 3832 2430 | opencut | 25 | 4.07* |
| Cook Mine – Cook Resource Mining Pty Ltd<br>PO Box 119, Blackwater Qld 4717<br>Telephone: 61 7 4982 0311; Facsimile: 61 7 4986 0302 | underground | 28 | 0.18* |
| Coppabella Mine – Australian Premium Coals Pty Ltd<br>PO Box 7075 Riverside Centre Qld 4001<br>Telephone: 61 7 3239 7666; Facsimile: 61 7 3239 7699 | opencut | 14 | 4.12* |
| Curragh Mine – Curragh Queensland Mining Pty Ltd<br>GPO Box 51 Brisbane Qld 4001<br>Telephone: 61 7 3031 7777; Facsimile: 61 7 3211 7908 | opencut | 23 | 3.38* |
| Ensham Mine—Ensham Resources Pty Ltd<br>GPO Box 814 Brisbane Qld 4001<br>Telephone: 61 7 3221 1201; Facsimile: 61 7 3221 1225 | opencut | 31 | 4.86* |
| Foxleigh Mine—Foxleigh Mining Pty Ltd<br>GPO Box 843 Brisbane Qld 4001<br>Telephone: 61 7 3220 0800; Facsimile: 61 7 3220 0449 | opencut | 14 | 2.29* |
| Gregory Mine—BHP Billiton Mitsubishi Alliance<br>GPO Box 1389 Brisbane Qld 4001<br>Telephone: 61 7 3226 0600; Facsimile: 61 7 3229 2575 | opencut | 36 | 4.78* |
| Acland/Jeeprobilly/New Oakleigh Mines—<br>New Hope Coal Australia<br>PO Box 47 Ipswich Qld 4305<br>Telephone: 61 7 3810 0500; Facsimile: 61 7 3202 4315 | opencut | 49 | 1.40 |
| Jellinbah East Mine—Jellinbah Resources Pty Ltd<br>GPO Box 374 Brisbane Qld 4001<br>Telephone: 61 7 3877 6700; Facsimile: 61 7 3221 7119 | opencut | 16 | 3.40* |
| Kestrel Mine—Pacific Coal Pty Ltd<br>GPO Box 391 Brisbane Qld 4001<br>Telephone: 61 7 3361 4200; Facsimile: 61 7 3229 5087 | underground | 36 | 3.72* |
| Moura Mine—Moura Coal Mining Pty Ltd<br>PO Box 225 Moura Qld 4718<br>Telephone: 61 7 4990 9700; Facsimile: 61 7 4990 9800 | opencut | 36 | 5.07* |
| Newlands Mine—Newlands Coal Pty Ltd<br>GPO Box 1443 Brisbane Qld 4001<br>Telephone: 61 7 3833 8000; Facsimile: 61 7 3832 2430 | opencut<br>and underground | 32 | 7.81 |
| Norwich Park Mine—BHP Billiton Mitsubishi Alliance<br>GPO Box 1389 Brisbane Qld 4001<br>Telephone: 61 7 3226 0600; Facsimile: 61 7 3229 2575 | opencut | 19 | 4.24* |
| South Walker Creek Mine—BHP Mitsui Coal Pty Ltd<br>GPO Box 1389 Brisbane Qld 4001<br>Telephone: 61 7 3226 0600; Facsimile: 61 7 3229 2575 | opencut | 14 | 3.41* |
| Wilkie Creek Mine—Peabody Wilkie Creek Pty Ltd<br>PO Box 260 Dalby Qld 4405<br>Telephone: 61 7 4663 5555; Facsimile: 61 7 4663 5549 | opencut | 51 | 0.68 |
| Yarrabee Mine—Yarrabee Coal Company Pty Ltd<br>PO Box 174 Blackwater Qld 4717<br>Telephone: 61 7 4982 7730; Facsimile: 61 7 4982 5793 | opencut | 11 | 0.86* |

* Figures also include metallurgical coal exports