Energy
for
Minerals Development
in the
South West Coast Region
of
Western Australia

Study Report

December 2004

Prepared by

Sleeman Consulting

In alliance with

GBRM

Australian Government
Department of Industry Tourism and Resources

Department of Industry and Resources

Office of Energy
Government of Western Australia

ALCOA

ARC Energy

AVIVA

GORGON Australian Gas

GRIFFIN energy

ILUKA

Millennium Chemicals

Premier Coal

TIWEST JOINT VENTURE

Western Power

WOODSIDE

Copyright

Disclaimer

The statements made and views expressed in this Report are those of the authors and do not necessarily represent the views or position of, or have the endorsement of, any individual member organisation of the Management Committee or its officers or employees.

The authors have used all reasonable endeavours to ensure that material contained in this report is correct but it is, nonetheless, general in nature and does not take into account the particular circumstances of any individual or company. No representation is made with regard to the completeness or accuracy of the data or information contained herein, and the authors disclaim any or all liability for loss or damage whatsoever suffered or incurred resulting from the use or reliance on data or information contained herein.

Readers should make and rely upon their own enquiries, research and judgements in making decisions touching their own or any other person's interest.

Contents

This page left blank intentionally

1 EXECUTIVE SUMMARY

1.1 Background

This Study was commissioned by the Western Australian Department of Industry and Resources and has been undertaken within the framework of the Australian Government's *Regional Minerals Program*, administered by the Department of Industry, Tourism and Resources.

The ultimate objective of the Study is to provide information to attract private sector investment into Western Australia to stimulate development of the State's mineral and petroleum resources for the benefit of investors, the State and Australia. The focus of the Study was the south west coast region of Western Australia which extended from Port Gregory (north of Geraldton) to Albany, as depicted in Figure 1.1. The study region comprised the regional areas of the Mid West, Perth Metro, Peel, South West and part of the Great Southern Region and had a total area of the order of 175,000 square kilometres, which is just over half the size of Italy. The region represents about 5% of the Western Australian land mass and is home to 90% of the state's population.

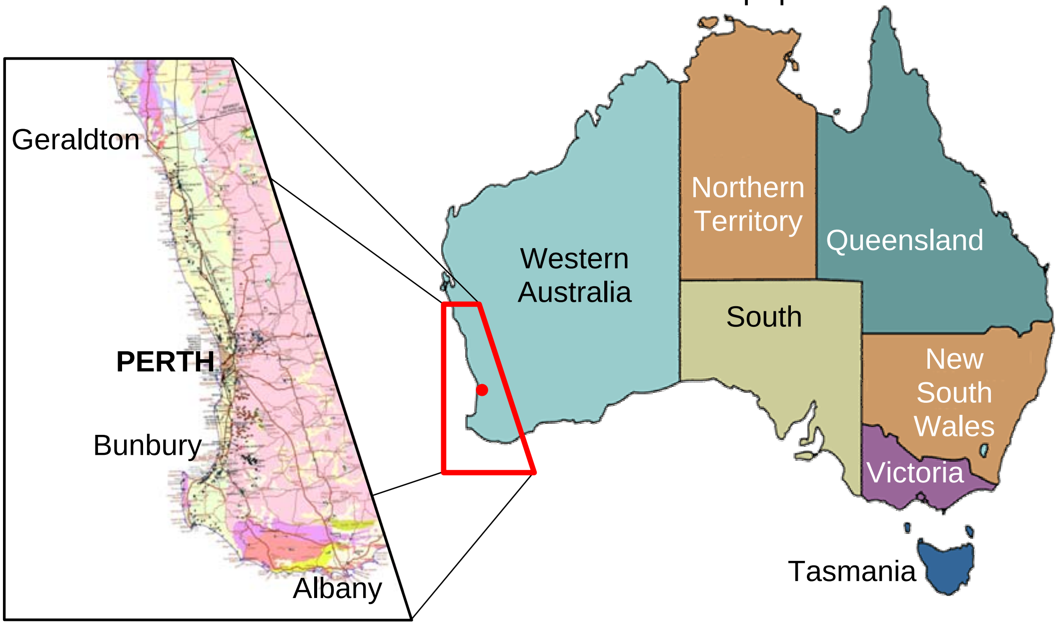

Figure 1.1: South West Coast Study Region

The Study was thematic in nature. It investigated material and information of relevance to energy and minerals development in the south west coast region of Western Australia in order to identify the most significant issues and priorities for ongoing attention. In particular, the following activities were completed.

- The mineral resources of the south west coast region were reviewed, with regard for quality, size and production costs to identify development opportunities and target prices of energy required to achieve project viability. The mineral resources of the study region represent approximately 10% of the state's mineral wealth and have a combined value, estimated by the Geological Survey Division of the Department of Industry and Resources, in excess of $660 billion.

- Prospects for supply of additional energy and/or electricity to the south west coast region were reviewed and estimates of the availability and price of energy were developed.

- The projected energy requirements were compared to the predicted availability and cost of energy in order to identify likely integrated development scenarios. The economic impacts of the identified scenarios were investigated using computable general equilibrium modelling techniques.

- Issues related to the development of minerals opportunities or to the supply of energy to them were reviewed and, where appropriate, recommended actions were formulated.

1.2 Review of Minerals Sector

1.2.1 Bauxite, Alumina and Aluminium

a) Alumina Production

The south west coast region was the world's largest single producer of alumina during 2003. As international demand for alumina grows, it is anticipated the production capacity of the region's low cost refineries will be progressively expanded. By 2010, the alumina production capacity of the south west coast region is projected to reach 15.7 Mtpa, giving rise to a requirement for 143 TJ/d of additional energy.

Known reserves of bauxite are sufficient to support operations at current and planned production rates for over thirty years.

b) Fused Alumina

A small quantity of locally produced alumina is used in the value-added production of 21,000 tpa of high-quality, white fused alumina for high performance abrasive and refractory uses. Australian Fused Materials Pty Ltd ('AFM') uses around 4.7 MW of electricity in this process.

The fused alumina market is extremely competitive with Chinese producers dominant during the late 1990's and early 2000's. Recent power shortages in China have lead to reduced international availability of fused alumina and potential may exist for expansion of AFM's operation. An expansion decision will be largely market driven.

c) Aluminium

Over the period 2003 to 2007 world demand for aluminium is projected to increase on average by more than 1.0 Mt each year. To satisfy this demand growth it is expected that some 2 Mtpa of capacity, equivalent to the development of 1.5 new aluminium production pot-lines per annum, will need to be developed outside of China.

Over the past seven years, the average cost of electricity to new aluminium smelters has been estimated to be US$13.20/MWh (1.9 c/kWh Australian). However, the availability of low-cost electricity from traditional sources is declining.

For a smelter development to be attractive in the south west coast region it will need to be capable of producing aluminium at a cost level that is in the bottom quartile of aluminium production costs. To achieve this, labour, capital costs and electricity prices will need to be competitive with alternative locations. The target electricity price to achieve international competitiveness is reported to be of the order of 2.6 c/kWh.

Modern Aluminium smelters have a production rate of 350,000 tpa per pot-line with two pot-lines being required in order to achieve internationally competitive production costs. The energy requirement per pot-line is around 500 MW which, in turn, requires some 60 TJ/d of gas if high levels of efficiency are achieved through electricity cogeneration. Alcoa World Alumina Australia (‘Alcoa’) is reportedly able to achieve this level of efficiency.

1.2.2 Iron Ore

Western Australia is a major supplier of iron ore to international markets, with the majority of production being from the Pilbara region. However, strong demand for seaborne iron ore has created opportunities for development of a number of iron ore deposits within the study region.

As depicted in Table 1.1, there are a number of iron ore deposits in or just outside the boundaries of the study region. Several companies are working to develop these deposits and the first shipment of iron ore through Geraldton for thirty years was made in February 2004 when 38,000 tonnes was shipped to China from Mt Gibson Iron Limited’s Tallering Peak hematite mine. Exports of hematite by Mt Gibson and Midwest Corporation Limited are projected to reach 5.2 Mtpa by 2006.

Further iron ore related expansion opportunities in the study region are based around the large magnetite deposits of the Mid West Region and Great Southern regions. These deposits can be developed for export either as a magnetite concentrate or in beneficiated form (as pellets).

Company and Deposit	Reserves		Measured and indicated	
	Mt	Grade %Fe	Mt	Grade %Fe
Mt Gibson Iron Limited				
Tallering Peak T4 & T5			20.5	63.68
Extension Hill			10.7	63.8 – 58.2
Iron Hill			20.7	63.8 – 58.2
Midwest Corporation Limited				
Koolanooka	405	34.9	430	35
Blue Hills	0.7	60.4	1.2	60.3
Weld Range	129	55.6	152	56.03
Grange Resources Limited				
Southdown			53.6	30.3

Table 1.1: Iron Ore Resources in the Study Region

Due to the complexity of processing required, the capital cost of magnetite processing facilities is significantly higher than for hematite production. Feasibility studies are underway for production of magnetite concentrate in 2.5 Mtpa modules and for 5 Mtpa concentrator and pellet plants. The electricity demand for a 2.5 Mtpa magnetite concentrate plant is estimated at 20 MW. At current export prices, electricity is not a major cost component and magnetite production would be feasible at electricity prices of 6 to 7 c/kWh.

The total capital cost of a 5 Mtpa magnetite mine, concentrator and pellet plant is estimated at $540 million. The energy requirement for such a facility is estimated to be up to 1.0 GJ per tonne of pellets. On the basis of current pellet pricing, indications are that a project of this nature would be viable with a gas price of $3.00/GJ to $3.50/GJ.

The potential also exists for production of metallurgical pig-iron from hematite, magnetite and/or iron-rich synthetic rutile tailings. Both gas and coal based technologies are available. To be internationally competitive, it is estimated that an operating cost below US$110 per tonne of pig-iron is necessary. In turn, it is estimated a power price in the range of 4 c/kWh would be required for pig-iron production in the south west coast region to be viable. Energy would need to be available at prices of not more than $1.50/GJ for coal or $2.80/GJ for gas in order for a pig-iron development in the south west coast region to be viable.

The HIsmelt metallurgical pig-iron plant at Kwinana is scheduled to commence operation early in 2005 and will produce a premium grade hot metal from iron ore fines and non-coking coals. The first stage of the HIsmelt plant will have a production capacity of 0.8 Mtpa. The intention is to increase this to 1.5 to 1.6 Mtpa after the process has been operated for two to three years and any initial problems have been addressed. To meet process requirements coal is to be imported from Queensland. The prospect may exist for Collie coal to be upgraded to meet HIsmelt requirements and to displace imported coal. HIsmelt also uses an average of around 4.95 TJ/d of gas and will export a small amount of electricity to the grid.

1.2.3 Silicon

Simcoa Operations Pty Ltd produces 32,000 tpa of high grade silicon metal at its Kemerton facility, 17 kilometres north of Bunbury. Quartz reserves are sufficient for twenty years of operation, and there are significant additional resources that have not been drilled. Electricity demand is estimated at 11 MWh/tonne with a total site demand of 45MW.

World demand for silicon metal is increasing at an estimated rate of 45,000 tpa of which 55% is in the high end chemical sector of the market serviced by Simcoa. There is reasonable scope for expansion by Simcoa, with the key factors in an expansion decision being the availability of electricity at a price of the order of 4.0 c/kWh, and the ability to market silicon product.

Expansion could be either one or two furnaces with potential capacity of 20,000 tpa per furnace. This would result in an increase in power demand to 75 to 80 MW to bring total production to 72,000 tpa of silicon metal.

1.2.4 Mineral Sands

a) Mineral Sand Production

The mineral sands industry of the south west coast region comprises a small number of producers with operations as set out in Table 1.2.

Company	Major Mine	Dry Plant	Synthetic Rutile	Titanium Pigment
Iluka Resources Limited	Eneabba, Capel & Geraldton	Capel	Capel, Geraldton	-
TiWest Joint Venture	Cooljarloo	Chandala (Muchea)	Chandala (Muchea)	Kwinana
Cable Sands (WA) Pty Ltd	Jangardup	Bunbury	-	-
Doral Mineral Sands Pty Ltd	Dardanup	Bunbury	-	-
Millennium Inorganic Chemicals Inc	-	-	-	Bunbury

Table 1.2: Location of Major Mines and Processing Facilities

The major mineral sands ore bodies at Capel, Eneabba and Cooljarloo have been mined for 48, 32 and 15 years respectively and are significantly depleted.

While new projects may commence in the next 10 years, in view of reserves limitations, it is unlikely that this will result in major expansions of mineral sands production levels from the study region.

b) Synthetic Rutile Production

Synthetic rutile ('SR') is produced using the modified Becher process by both Iluka Resources Limited ('Iluka'), at Capel and Geraldton, and the TiWest Joint Venture ('TiWest') at Chandala. The process uses coal as both a reductant and a heat source. Iluka's Capel plant recovers excess heat to generate 7.5 MW of electricity, which is just over half of its requirement.

Production of 691 kt for 2002/03 was comprised as shown in Table 1.3.

Company	Location	Production (kt)
Iluka	Geraldton	215
	Capel	256
TiWest	Chandala	220
Total		691

Table 1.3: Synthetic Rutile Production 2002/03

Over the next 10 years, as the availability of ilmenite suitable for use in the Becher process declines, it may be necessary to import ilmenite as feed to maintain the SR operations at capacity. In the near term it is anticipated that any production increases will be due to process changes or debottlenecking of existing facilities. The potential may exist for a more significant (up to 20%) increase in production capacity through the use of briquettes or coal char manufactured from Collie coal. Present coal consumption is around 0.65 tonnes per tonne of SR.

Iluka is currently carrying out studies to determine the location for a new generation SR process based on gas rather than coal. While sites in the study region are under consideration, locations close to the Murray Basin mineral sands deposits or in other countries offering significant tax benefits, may be favoured

c) Titanium Pigment

TiWest and Millennium Inorganic Chemicals Inc both operate chloride route pigment plants within the south west coast region. In these plants, synthetic rutile is combined with petroleum coke and chlorine to produce titanium tetrachloride that is purified and oxidised to produce titanium dioxide. Based on an average price for Australian pigment exports to Asia in 2003 of US$1,730 ($2,470), the value of pigment produced within the study region is $494 million.

Major costs in the process are the synthetic rutile feed, wages and salaries, other chemicals and maintenance. Energy, in the form of natural gas (at 5 GJ/t) and electricity (at 0.5 MWh/t), represents less than 10% of operating costs. Consequently, expansions will take place at prevailing levels of energy price.

d) Zirconia Based Opportunities

Zircon flour, zirconia and fused zirconia are all produced in Western Australia. These are all energy intensive processes and expansion decisions are dependent on competitive power and gas costs. However, current overall power consumption (less than 10 MW) is relatively small compared to major industrial projects.

e) Titanium Metal

Some 70,000 to 80,000 tpa of titanium sponge is produced world-wide each year using the electricity-intensive Kroll process. While prices in 2003 were US$7.28/kg, which was the lowest level for ten years, with demand growth in aerospace, armour, industrial and consumer markets, opportunities are now emerging for start-up of mothballed, or installation of new, production capacity.

There are several companies currently working on new titanium metal production processes that are significantly less electricity-intensive than the Kroll process. The target of these processes is to halve production costs so that titanium use will be competitive with other light metals. There is the potential to establish a titanium metal pilot plant adjacent to existing titanium pigment operations in the south west coast region over the next two to three years.

1.2.5 Nickel and Cobalt

While there are no operating nickel mines in the south west coast region and no known reserves, nickel refining operations are carried out at Kwinana. WMC Resources Limited’s Kwinana refinery processes nickel matte from the Kalgoorlie Nickel Smelter to produce high quality nickel briquettes and nickel powder, and is one of the world’s lowest cost producers. The refinery currently consumes around 3,300 TJpa of gas (for steam raising and as a reductant) and 15 MW of electricity.

The capacity of the refinery will be increased from 67,000 to 70,000 tpa by the end of 2004, making it the world’s third largest refinery. It is expected that ongoing expansion of the Kwinana refinery will take place, with production reaching 80,000 tpa over the next three to five years, and with potential for further expansion to 100,000 tpa of refined nickel within the next 10 years. These expansions will proceed at present energy prices.

1.2.6 Tantalum, Spodumene and Tin

Sons of Gwalia Ltd ('SOG') operates one of the world's largest sources of tantalum at Greenbushes. Lithium minerals (spodumene) and tin are also produced as a byproduct of tantalum production. Although SOG was placed into administration in August 2004, the Greenbushes project is expected to continue to operate.

There has been recent strong growth of demand for tantalum, driven by requirements in the electronics and turbine markets and prices have returned to previous highs of US$40-50/lb. With SOG supplying over 50% of global demand it is considered likely to expand production in order to stabilise the market and discourage new entrants. However, with production contracted to major US and European consumers it is unlikely that any downstream processing will be carried out in Australia.

While SOG has the major hard rock deposits of lithium in the world, its leadership in the world market was displaced in 1997/98 when Chilean producers reduced prices from $4.50/kg to $2.10/kg for brine based lithium, which is the preferred feed for lithium carbonate production. SOG has suspended production from its lithium carbonate plant and the majority of spodumene produced now goes into the glass and ceramic markets. On this basis the potential for further processing in Western Australia is considered to be low.

1.2.7 Ferro Alloys

Ferro alloys are alloys of iron that contain sufficient concentrations of one or more chemical or metallic elements to modify the properties to which they are added, mainly steel. Ferro-silicon is the only product that is considered to have significant potential for development in the south west coast region.

Chinese production of ferro-silicon, which accounts for over 40% or 5 Mtpa of world production, has declined over the past twelve months owing to power shortages while rapid increases in steel production have led to increased levels of demand and price. The development of a 50,000 tpa ferro-silicon plant would require capital of approximately $80 million and would have an electricity demand of 8 MWh per tonne of product. At an electricity price of less than 4.0 c/kWh a ferro-silicon production cost of approximately $700/t might be achieved. This could make such a development viable.

1.2.8 Other Minerals

While a wide range of other minerals are produced in the study region, they are either minor energy consumers or have little potential for energy based downstream processing.

1.3 Review of Energy Availability and Cost

1.3.1 Coal

a) Industry Overview

There are numerous identified coalfields within the south west coast region of Western Australia, including the state's only producing coalfields in the Collie Basin. Collie Basin mining activities are carried out by the Griffin Coal Mining Company Pty Limited ('Griffin') and by Wesfarmers Premier Coal Limited ('Premier'). Mining is by means of open-cut, truck and shovel methods.

Griffin and Premier have roughly equal shares of the present market for Collie Basin coal, although Griffin supplies a greater portion of the smaller (non-Western Power Corporation) customers. Indications are that, at present production levels, prevailing run-of-mine coal prices average around $45/t ($2.25/GJ).

b) Northern Perth Basin Development

The coal resource of the northern Perth Basin represents a significant prospective energy source. Development of the northern Perth Basin coal reserves could be particularly attractive as an energy source for coal-based minerals developments to the north of Perth. Freight costs from the existing coal mining operations of Collie to locations north of Perth would otherwise add of the order of $1.00/GJ to $2.00/GJ to the delivered cost of coal.

Aviva Corporation Ltd is promoting development of its 'Central West' coal resource, which lies within existing mining lease areas at Eneabba. The unconsolidated nature of the overburden in the Eneabba area means that a dozer-trap operation (whereby overburden is pushed by bulldozer into a truck loading facility) may have application. Coal production costs as low as $23/t ($1.35/GJ) might be achievable. The cost and availability of Eneabba coal are illustrated in Figure 1.2. The cross-hatched area in Figure 1.2 represents possible production, dependent upon the realised capacity of the dozer-trap.

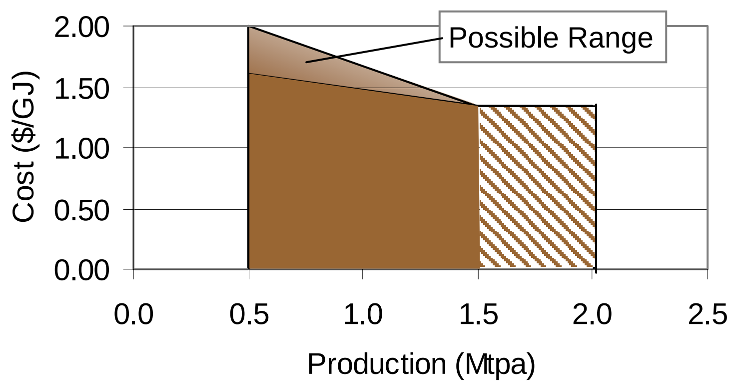

Figure 1.2: Cost and Availability of Eneabba Coal

c) Collie Basin Expansion

The potential exists for Griffin and Premier to achieve lower average coal production costs with increased coal production.

The overburden handling capability of Premier's existing equipment fleet could allow the production of some 5 Mtpa of coal. On the basis of Australian coal industry indicative information, there would appear to be scope, through increased production, for Premier to produce coal at a cost of the order of $30/t ($1.50/GJ).

With an increase in coal production quantities the potential could exist for use of a dragline as the primary means of overburden removal at Griffin's Ewington operation. The introduction of draglines has not been possible historically owing to a combination of factors including low coal tonnages and, in particular, the depth, moisture content and geometry of the Muja open-cut. The introduction of a dragline would reduce the cost of overburden removal and, on the basis of Australian coal industry indicative information, Griffin should also be able to produce coal at or below a cost of the order of $30/t ($1.50/GJ).

Recognising the magnitude of benefits that are estimated to be achievable through increase in the production of coal, initiatives that might contribute to the achievement of scale economies (for example, integration of operations, possibly using a joint venture model) need to be pursued.

Premier is investigating prospects for production of coal char and has committed to the development of a 50,000 tpa demonstration plant to prove the commerciality of the product. If successful, 1.6 Mtpa of Collie coal might be used to displace imported coal from the HIsmelt operation. Griffin is currently piloting a process for briquette production with a key, initial target market being the synthetic rutile operations where, through use of briquettes, there may be scope to achieve increased synthetic rutile production.

Overall, the estimated cost and availability of additional coal from the Collie Basin is as illustrated in Figure 1.3.

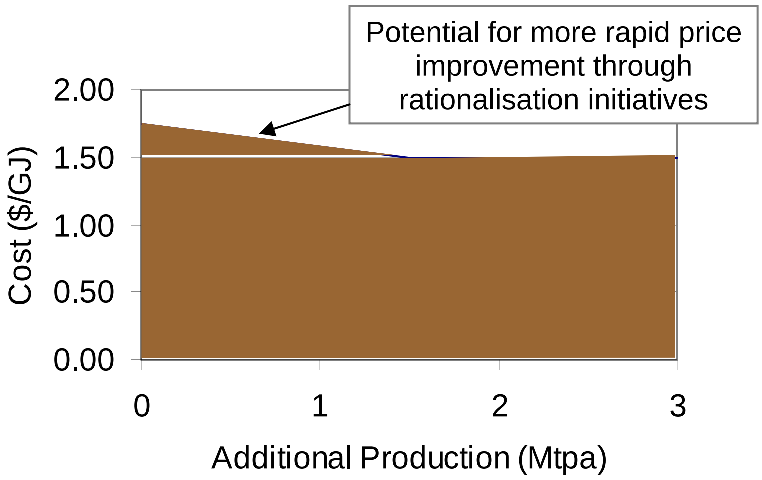

Figure 1.3: Availability and Cost of Additional Collie Basin Coal

Where customers are located away from the mine it is necessary to add freight costs to the depicted values to determine delivered coal costs.

1.3.2 Gas

Western Australia is well endowed with natural gas, with in excess of 70% of Australia's commercial gas reserves being located within sedimentary basins off the northwest coast of the state. The availability of gas at internationally competitive prices has stimulated growth of the Western Australian gas market, particularly though use of gas in minerals projects. At the same time, development of remote gas production and pipeline infrastructure has been underpinned through the foundation gas purchase commitments of large minerals projects.

Ongoing development of gas reserves will need to take place in a timely manner to ensure that gas continues to be available in quantities to meet existing and expanded domestic market requirements. The most likely sources of gas for future supply are located in the Perth and Carnarvon Basins. Carnarvon Basin sources include ongoing development of the North West Shelf and Varanus Island projects, as well as new developments (eg, Gorgon).

Perth Basin

While all available gas reserves of the Perth Basin are presently contractually committed, prospects for further discoveries of gas within the Basin are good. Based upon the extent of various Perth Basin prospects, backed by experience to date, it would appear that new discoveries of gas in the Perth Basin may be in the 10 to 15 PJ size range. Even though a number of new discoveries could be made, the size and proximity to existing infrastructure and markets means that this gas will inevitably be used to compete on a price-taking basis in the south west gas market, rather than to stimulate new developments requiring lower gas prices. For example, Figure 1.4 shows that a large portion of the forecast south west coast gas market is not presently contracted for supply in the longer term. To illustrate the extent of the uncontracted market the shaded area in the figure represents a gas quantity of approximately 1 exajoule ('EJ', roughly equivalent to 1 TCF), which is double the initial reserves of the Dongara gasfield (to date the biggest commercial discovery in the Perth Basin). The large change that occurs in 2020 reflects the expiry of Alcoa's and Alinta Limited's gas purchase contracts.

From a practical commercial perspective, marketing of Perth Basin gas on a price setting basis would probably only be considered if the availability of gas is materially in excess of that which might be readily sold into the existing market. In order of magnitude terms, this would require several exajoules of gas to be proven. Although the probability that discoveries of this size might be made is considered to be low, it is not to be ignored. For example, several exajoules of gas are presently known to exist in tight formations within the Perth Basin and technological developments may allow their commercialisation.

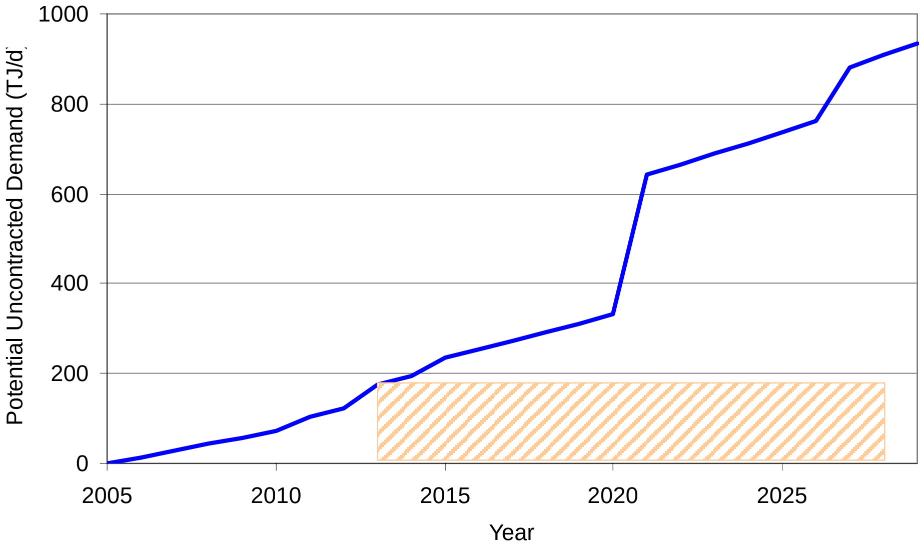

Figure 1.4: Estimated Uncontracted South West Coast Gas Market

The potential may also exist for production of coal seam methane from the Vasse Shelf coal resource, which extends from Busselton to Augusta and which has a rank and depth consistent with the requirements for coal seam methane.

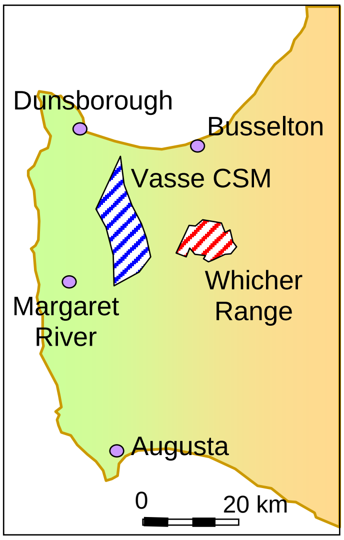

Figure 1.5: Whicher Range Gas and Vasse CSM Prospects

It is desirable that further exploration in the Perth Basin, and continued pursuit of the Whicher Range natural gas and Vasse coal seam methane initiatives, be encouraged.

North West Shelf Project

The North West Shelf ('NWS') project is the state's largest supplier of gas. It produces gas from reservoirs located around 130 kilometres off the coast of WA, to the northwest of Karratha, and routinely supplies up to 600 TJ/d of gas for domestic market use throughout the State.

Subject to ongoing development of gas reserves, gas should be available from the NWS Project for supply to existing markets or to new minerals developments in the south west coast region. The extent to which gas is available for new minerals developments in the south west coast region may however be dependent upon the value of gas in domestic markets relative to its value in export markets (although near-term domestic sales are likely to be attractive in comparison with longer-term LNG sales).

If significant alternative sources of gas supply are not developed a tightening of gas supply to domestic markets could result, leading to upward pressure on gas prices.

Gasfields Surrounding Varanus Island

Processing and compression of gas from the Harriet, East Spar, John Brookes and a number of smaller fields takes place on Varanus Island. Gas is presently available from these sources for supply under new or extended gas sales arrangements. However, it is unlikely that it will be offered at prices that would facilitate new minerals developments in the south west coast region since increased water depths and/or distances from Varanus Island are expected to lead to increased reservoir development costs and, in the short to medium term, there will be numerous opportunities to contract for supply of gas to existing users, as depicted in Figure 1.4.

It is estimated gas prices tending towards $2.50/GJ could be sought in the medium term as development of more remote reserves of gas becomes necessary.

Gorgon Project

The Gorgon gasfield is one of the largest discovered in Australia. The Gorgon and surrounding gasfields contain probable resources in excess of 55 EJ. Development of the gasfields is dependent upon commitments being secured for the sale of LNG in quantities to achieve commerciality. There are reasonable prospects that a sufficient level of LNG sales commitments will be achieved and that the Gorgon project may commence production around 2010.

A go-ahead of the Gorgon project will pave the way for supply of gas for domestic purposes, and 2,000 PJ (ie, 2 EJ) of gas has been earmarked for this purpose. The Gorgon project proponents are required (under the terms of the State Agreement) to actively seek domestic markets. Expansion of LNG sales will not be allowed until domestic sales are established (or their lack of viability demonstrated).

Subject to a sufficient quantity of gas being contracted for sale, it is estimated there may be an opportunity for a large, base-load customer to procure gas at a price of the order of $1.85/GJ. This is not a price that would be generally available (ie, to the wider gas market).

Other Carnarvon Basin Sources

Although there are numerous, other prospective sources of gas within the Carnarvon Basin it is unlikely, for the following reasons, that gas would be available from them at prices below present market levels (estimated to be of the order of $2.10/GJ to $2.30/GJ, excluding transmission costs).

- Unlike Gorgon, other major gas resources of the Carnarvon Basin may not have the level of gas reserves that would justify complementary sales of gas to domestic markets.
- The prospective use of floating production, storage and offtake ('FPSO') techniques may contribute to project economics, but would mean gas is not available for onshore use.
- Development of gas resources for delivery through existing infrastructure, such as that of the North West Shelf project, may in some cases be an option but it is not envisaged this will allow delivery of gas at prices below prevailing levels.

There are no development prospects that presently afford the opportunity to procure gas at less than prevailing or predicted price levels.

Browse and Bonaparte Basins

The gas reserves of the Browse and Bonaparte Basins may be sufficient to support further development of LNG export markets or might in some cases be developable to supply onshore markets (eg, development of Blacktip to supply gas to Gove Alumina in the Northern Territory). However, owing to the remote location of these resources, gas is unlikely to be available from them at prices that are competitive with gas from Carnarvon Basin sources.

d) Gas Transmission

The major prospective near-term source of gas for use in mineral related developments in the south west coast region is the Carnarvon Basin. To deliver gas from Carnarvon Basin projects to the south west coast region expansion of the capacity of the Dampier to Bunbury gas pipeline ('DBNGP'), or bypass of it, will be required. The economics of expanding the capacity of the pipeline are attractive and it is important that the benefits of expansion economies flow through to tariffs for use of the pipeline.

e) Potential Delivered Gas Costs

The forecast availability and price of gas for use in the south west coast region are illustrated in Figure 1.6.

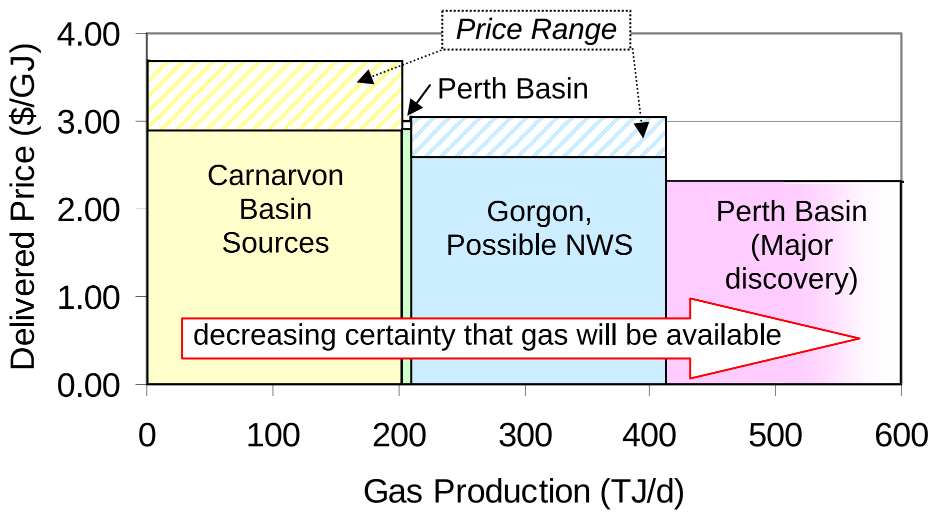

Figure 1.6: Availability and Delivered Cost of Additional Gas

1.3.3 Electricity

The south west coast region is serviced by an interconnected electricity system, referred to as the South West Interconnected System ('SWIS'). All large users of electricity have open-access to the SWIS, allowing them to purchase their requirements from electricity generators of their choice.

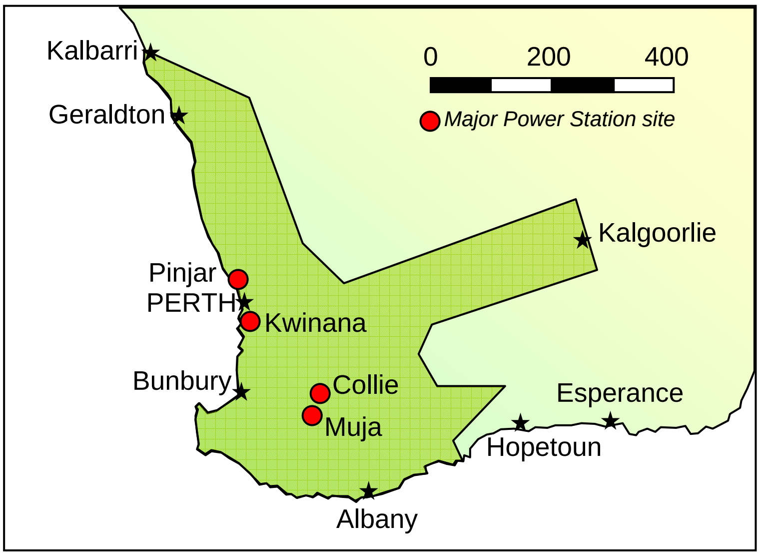

Figure 1.7 South West Interconnected Electricity System

a) Opportunities for Expansion

Generation of electricity as part of Western Power Corporation's integrated system has potential advantages in that the overall capacity factor of the system will be improved and a whole-of-system approach can be adopted to determine optimal power station expansion and dispatch arrangements.

The estimated cost of generating additional electricity to meet small to medium load increments is around 3.6 c/kWh, excluding transmission costs and margin. Significantly, if the incremental load to be supplied is interruptible this figure might then fall to around 2.8 c/kWh.

Alternatively, stand-alone electricity generation facilities could be developed on, or adjacent to, the site of the electrical load to be supplied or could be developed at a separate location, in which case electricity transmission costs will also be incurred. In either case, if the electrical load is not interruptible there is also a need to take back-up generation requirements into account.

On the basis of potential coal and gas price levels, electricity costs of around 4.0 c/kWh, +/- 0.3 c/kWh, would appear to be achievable using conventional (coal based steam or gas combined cycle) technologies to generate electricity for large, base loads. This figure does not include transmission costs or back-up/spinning reserve charges, if applicable.

The potential also exists for cogeneration of electricity, particularly at Alcoa's alumina refineries in the southwest of the state. It is estimated that Alcoa may be able to generate electricity at a marginal cost of around 3.0 c/kWh, or potentially less if favourable gas price, efficiency and capital and operating cost outcomes are achievable.

b) Electricity Transmission

Electricity transmission costs represent a potentially significant portion of the delivered cost of electricity, particularly toward the extremities of the SWIS.

c) Delivered Electricity Costs

Subject to fuel availability and cost, the preferred location for new power generation facilities to supply a mining or mineral processing development will be on the site of the development. This is illustrated in Table 1.4 for selected generation locations.

Power Station Location and Type	Delivered Electricity Cost c/kWh
On-site at Kemerton - gas	**4.05**
Collie - coal	4.55
Eneabba - coal (with -15.8% loss factor) (no loss factor)	3.78 4.42
Eneabba - gas (with -15.8% loss factor) (no loss factor)	3.78 4.42
Kwinana - gas	4.36

Table 1.4: Predicted Costs of Electricity at Kemerton

On-site generation of electricity avoids uncontrollable risks associated with the level of electricity transmission system charges and loss factors. For large loads, on-site generation of electricity is therefore likely to yield the lowest electricity cost for new or expanded electricity-intensive minerals developments. For smaller loads, supply of electricity via the interconnected system will usually be appropriate. Determination of the appropriate supply arrangement will need to be made on a case by case basis.

1.3.4 Alternative Energy Sources

Environmental considerations, to the extent they are reinforced by the Australian Government's Mandatory Renewable Energy Targets ('MRETs') scheme, make the use of renewable energy forms increasingly attractive. However, as illustrated in Figure 1.8, for the foreseeable future the use of gas and coal offers the most reliable source of competitively priced electricity.

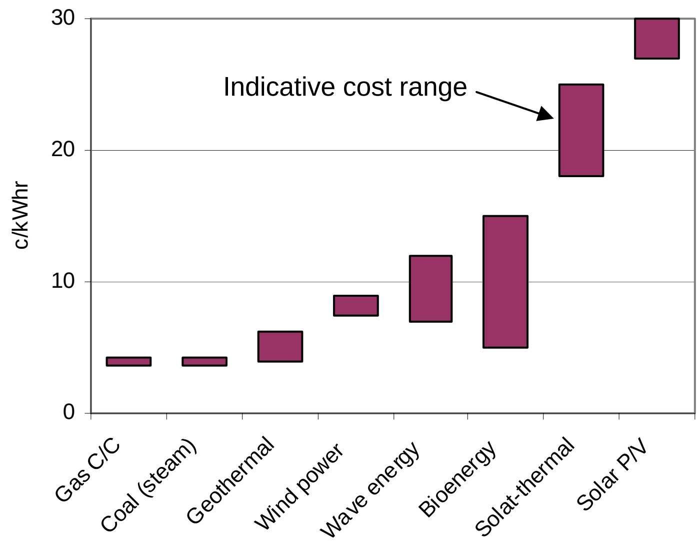

Figure 1.8: Comparison of Predicted Electricity Cost

Geothermal energy has a distinct advantage over other renewable energy sources in terms of reliability and cost. The other energy sources suffer in that significant additional expense must be incurred in provision of back-up generation.

1.4 Achieving Target Energy Prices

1.4.1 Comparison of Energy Requirements and Availability

The fuel requirements of the identified minerals sector development opportunities are depicted in Figure 1.9. In determining the fuel requirements consideration has been given to the costs and efficiencies of electricity generation. Gas based electricity generation has been assumed to be by means of combined cycle plant except in the case of the aluminium smelter, where cogeneration has been assumed. In addition, where a project can use either coal or gas (or electricity derived from either coal or gas) the requisite value for both fuels is depicted. The target (maximum) coal price is represented by the top of the khaki shaded area while the target (maximum) gas price is represented by the top of the turquoise area.

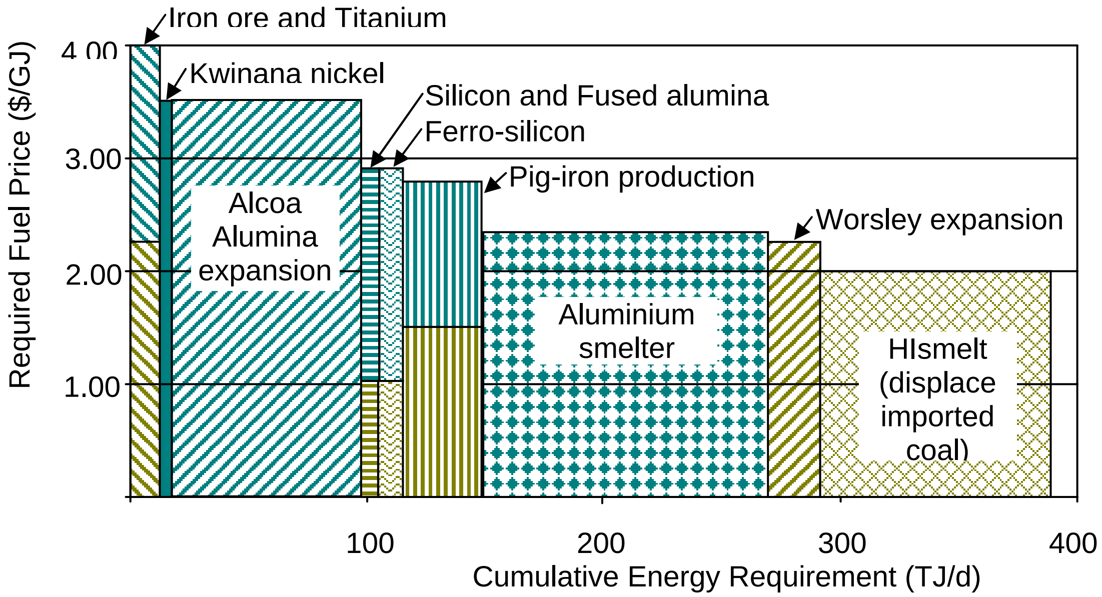

Figure 1.9: Requisite Fuel Prices and Quantities

On the basis of forecast availabilities and prices of coal, gas and electricity it can be seen that the potential exists for many of the identified minerals development opportunities to achieve target energy prices. In the case of an aluminium smelter a number of favourable outcomes will need to be realised, including the achievement of:

- high levels of electricity generation efficiency through the use of cogeneration; and
- a delivered gas price of not more than $2.50/GJ.

The potential exists for these outcomes to be achieved. Simultaneously, development of an aluminium smelter could provide a foundation load to facilitate development of a new source of domestic gas supply for the state.

It is essential to note that, regardless of the level of energy prices that may be achievable, there are numerous other factors that affect the viability of project development opportunities in the south west coast region. Therefore, even if the identified target levels of energy price are achieved there is no certainty that a particular opportunity will proceed.

1.4.2 Economic Modelling

The economic impacts that might be expected to flow from achievement of the identified project developments have been analysed by the Centre of Policy Studies ('CoPS') at Monash University using the MMRF-Green, multi-sector dynamic model of Australia's six States and two Territories.

For modelling purposes three scenarios, as described below and summarised in Table 1.5, were formulated.

Base Case: For reference purposes, a projection of the Australian and State economies, incorporating business-as-usual assumptions for minerals development, was adopted as a Base Case. The Base Case specifically included projects that are already committed or highly likely to proceed at current energy prices.

Development Scenario 1: In addition to the Base Case developments, Scenario 1 included projects of a brownfields nature.

Development Scenario 2: In addition to the Scenario 1 developments, Scenario 2 included projects of a greenfields nature. Scenario 2 also included a general, modest lowering of delivered gas prices, reflecting a flow-through of the benefits of projected pipeline expansion economies.

The economic effects of Scenarios 1 and 2 were assessed by comparison of the values of variables for those scenarios with their value in the Base Case scenario. The results of this comparison are outlined in Table 1.5. Realisation of the identified development opportunities will deliver significant economic benefit to the state.

<table>
<tr><th rowspan="2"></th><th rowspan="2">Projects Included</th><th colspan="3">Present Value of Increase
($ million 2001 basis, @ 5%)</th><th rowspan="2">Long-term, Full-time Employment Increase</th></tr>
<tr><th>GDP</th><th>GSP</th><th>Real Cons.</th></tr>
<tr><td rowspan="4">Scenario 1</td><td>Synthetic rutile exp.</td><td>339</td><td>594</td><td>368</td><td>100</td></tr>
<tr><td>HIsmelt - Collie coal use</td><td>147</td><td>813</td><td>520</td><td>200</td></tr>
<tr><td>Silicon smelter exp.</td><td>632</td><td>1,264</td><td>659</td><td>500</td></tr>
<tr><td>Subtotal*</td><td>1,121</td><td>2,673</td><td>1,548</td><td>900</td></tr>
<tr><td rowspan="4">Scenario 2</td><td>Mid West pig-iron</td><td>773</td><td>2,934</td><td>1,951</td><td>1,600</td></tr>
<tr><td>Aluminium smelter</td><td>4,563</td><td>10,440</td><td>5,598</td><td>4,900</td></tr>
<tr><td>Ferro-silicon</td><td>128</td><td>711</td><td>516</td><td>600</td></tr>
<tr><td>Total*</td><td>6,764</td><td>17,676</td><td>10,503</td><td>9,100</td></tr>
</table>

Table 1.5: Modelling Scenarios and Results

(totals are subject to rounding errors; totals for Scenario 2 include impact of gas price change)*

1.5 Conclusions and Recommendations

1.5.1 Key Observations

The south west coast region of Western Australia derives significant economic benefit from a diverse mix of mining and mineral processing projects. However, opportunities exist for more rapid expansion or for the development of new mining and processing initiatives. For a number of these opportunities a key determinant of project viability is the availability and cost of energy.

Prospects appear to exist for energy to be sourced at prices that will meet the threshold requirements of these development opportunities, although this cannot be taken to imply that any particular project will proceed. All prospective developments are sensitive to a range of factors other than energy prices including:

- capital costs;
- market factors;
- the availability and cost of other raw materials;
- the availability of, and access to, infrastructure;
- successful development of facilitating technologies, such as the use of coal char to displace imported coal; and
- extraneous factors over which Western Australian project proponents have no influence, such as the provision of incentives for development in other, competing locations, and the considerable time required for State approvals processes.

If all the identified minerals development opportunities go ahead within the south west coast region, significant benefits will accrue to Western Australia. The gross state product could be increased by more than $2 billion per annum, real consumption over the period to 2020 increased by more than $16 billion and 16,200 new jobs created.

1.5.2 Issues Requiring Attention

In the course of this Study a number of issues have been identified that require attention. The issues are summarised in Table 1.7. For ease of reference the issues are grouped by subject area.

These identified issues need to be addressed in order that minerals development opportunities, and the significant financial and employment benefits flowing from them, are not lost.

Issue	Description
Availability and Price of Energy	
1	Development of the coal reserves of the northern Perth Basin will be required for coal-based pig-iron production in the Geraldton region.
2	Opportunities for rationalisation or expansion of Collie coal production activities should be pursued.
3	Successful development of briquette and coal-char production (using Collie coal) will allow significant benefits to be realised.
4	Capacity constraints in the DBNGP need to be addressed and transportation economies realised need to flow through to delivered gas prices.
5	Perth Basin exploration activities should be promoted, and a range of technical issues addressed.
6	Ongoing development of Carnarvon Basin gas reserves will be important to ensure the continued, competitive availability of gas to meet domestic requirements.
7	It is desirable there be increased competition for electricity supply.
8	Aluminium smelter viability is dependent upon low cost electricity.
9	Geothermal (hot dry rock) technologies show promise and there may be merit in investigating opportunities for application of the technology in the south west coast region.
Environmental Considerations	
10	Policy in relation to greenhouse gas emissions must be clear and non-discriminatory.
11	Government policy in relation to greenhouse and emissions matters must not inappropriately disadvantage Western Australian industry.
12	Initiatives that may reduce possible future costs of compliance with greenhouse constraints or imposts, including potential sequestration opportunities, need to be pursued.
Non-Energy Issues	
13	Ongoing attention must be paid to the level of all costs of operating mining and mineral processing projects within the south west coast region.
14	For iron-ore based developments in the Mid West region to proceed a range of infrastructure constraints must be addressed. Immediate upgrading of rail systems is necessary.
15	Infrastructure issues in the South West and Great Southern regions will need to be addressed.
16	To realise the potential for development of an aluminium smelter in the south west coast region will require a number of energy related and other outcomes to be achieved.
17	The south west coast region must be promoted as the preferred location for development of a titanium metal pilot plant.
18	Considerable time and expense is required to secure State Government project approvals.
19	There may be a future requirement for development of mines in areas that are socially and environmentally sensitive.

Table 1.7: Identified Issues

1.5.3 Recommendations

Table 1.8 sets out recommendations for dealing with or addressing the issues identified during the course of this Study. Implementation of these recommendations will remove impediments and open up the potential to facilitate further development of the minerals opportunities of the south west coast region, resulting in significant employment and financial benefits for the region, the State and Australia.

	Recommendation	Issues Addressed	Responsibility	Due
Recommendations Relating to Availability and Price of Energy				
1	Development of a northern Perth Basin coal mine as a source of energy supply to facilitate iron-ore processing initiatives should be promoted. The Department of Industry and Resources ('DoIR') should provide active facilitation and support for industry participants.	1, 13	Industry DoIR	ongoing ongoing
2	Cooperative initiatives (eg, joint venture approach) that may allow improved economies of coal production should be investigated.	2	Industry	2005
3	The Collie coal companies should complete their programmes of research into and commercialisation of coal briquette and coal char production. Gasification related technological developments should be monitored.	2, 3	Industry	ongoing
4	The capacity of the Dampier to Bunbury Natural Gas Pipeline should be expanded and any resulting economy of scale benefits that are realised should flow through to gas transportation tariffs.	4, 8	Industry	ongoing
5	Perth Basin exploration prospects should be further promoted.	5	DoIR	ongoing
6	To assist in promotion of Perth Basin exploration, the Geological Survey Division of DoIR should undertake research that will allow a better understanding of exploration prospects or that will contribute to identification and commercialisation of techniques for production of gas from tight formations.	5	DoIR	ongoing
7	Mechanisms to avoid stranding or flaring of small or associated gas resources should be actively pursued. This could include, for example, the use of CNG technologies.	5	Industry	ongoing
8	An audit of technical regulatory requirements (relating to gas production activities) should be undertaken, with input from industry stakeholders, to ensure Western Australian requirements are not unnecessarily onerous.	5	DoIR with Industry	2005

Table 1.8: Recommendations, Including Responsibilities and Timing

	Recommendation	Issues Addressed	Responsibility	Due
9	Ongoing development of the gas resources of the Carnarvon Basin, including for supply of gas for domestic purposes, should be promoted.	6, 8	DoIR Industry	ongoing
10	Development of gas reserves to ensure there is competition for supply of gas to meet present and future domestic market requirements should be actively encouraged. This could involve working with industry stakeholders to identify foundation loads that will allow timely development of new gas projects.	6, 8, 13, 16	DoIR and Office of Energy	ongoing
11	DoIR, in conjunction with the Department of Treasury and Finance ('DTF'), should establish a working group with industry stakeholders to identify and remove barriers to development of an aluminium smelter within the south west coast region.	6, 8, 16	DoIR DTF	2005
12	Development of the Western Australian electricity market, to facilitate and promote competition between generators of electricity, should be continued	7	Office of Energy	ongoing
13	Potential sites in the south west coast region, if any, that are suited for use of hot dry rock electricity generation technologies should be identified by the Geological Survey Division and data made available for consideration by prospective project developers.	9	DoIR	2005
Recommendations Relating to Environmental Considerations				
14	A clear statement of policy regarding carbon dioxide emissions should be developed and promulgated by the Western Australian State Government and applied in a consistent manner.	10, 11	DoIR Office of Energy	asap
15	A consistent Australian and international approach to greenhouse gas issues and imposts is required.	11	Office of Energy Australian Greenhouse Office	ongoing
16	Prospective geosequestration sites within the south west coast region should be identified by the Geological Survey Division of DoIR.	12	DoIR	2005

Table 1.8: Recommendations, Including Responsibilities and Timing (continued)

	Recommendation	Issues Addressed	Responsibility	Due
17	The technical and commercial viability of establishing a 'common-user' carbon dioxide sequestration facility to service the needs of industry in the south west coast region should be investigated.	12	DoIR	2005
18	Opportunities for low emissions research (including geosequestration) should be identified and research programmes involving industry or other stakeholders developed to take advantage, if possible, of the Australian Government's low emissions research program.	12	DoIR and Industry	2005, then ongoing
Recommendations Relating to Non-Energy Issues				
19	Opportunities for ongoing productivity improvement need to be identified and pursued to ensure the international competitiveness of industry in the south west coast region is maintained.	13	Industry	Ongoing
20	Consideration should be given to assisting industry by identifying issues of general concern and, as appropriate, promoting research through Cooperative Research initiatives (such as the A J Parker Centre for Hydrometallurgy, the WA Energy Research Alliance or the Australian Resources Research Centre).	13	DoIR	Ongoing
21	Consideration should be given to carrying out a 'skills inventory' to identify skills requirements and availability in the medium to longer term and to promote training and education programmes to meet identified shortfalls. DoIR should facilitate this process with input from relevant Departments and industry.	13	DoIR	2005
22	A solution for the Mid West infrastructure constraints needs to be identified and implemented immediately in order to ensure proposed iron ore developments in the region are not further impeded. In order to achieve this, a working group including DoIR, the Department for Planning and Infrastructure ('DPI'), industry and the major infrastructure providers needs to be established to facilitate necessary solutions.	13, 14	DPI, DoIR	2005

Table 1.8: Recommendations, Including Responsibilities and Timing (continued)

	Recommendation	Issues Addressed	Responsibility	Due
23	DoIR and DPI, in conjunction with the Mid West Development Commission should undertake a focussed review of medium and long-term infrastructure requirements with input from industry stakeholders to develop plans and strategies to ensure infrastructure is developed in line with industry requirements. The review should address transportation and port infrastructure as well as water, electricity, the availability of industrial land, and social infrastructure requirements and should include input from industry stakeholders.	13, 14	DPI, DoIR and Mid West Development Commission	2005-2006
24	Consideration should be given, if necessary, to the use of innovative infrastructure financing arrangements.	14	DoIR and State Treasury	as required
25	DoIR, with the Department of Planning and Infrastructure and with input from key stakeholders in the minerals and other industries, should carry out a comprehensive study to identify long term infrastructure requirements in the Southwest and Great Southern regions. Coordinated strategies should be developed to ensure infrastructure is in place as required to support regional development.	15	DoIR	2005
26	DoIR in conjunction with the Great Southern Development Commission should carry out a study to determine the region's competitive position in regard to industrial and commercial development and determine how this potential should be promoted.	15	DoIR, Great Southern Development Commission	2005
27	The benefits that may be realised through development of an aluminium smelter are significant and, accordingly, appropriate project facilitation should be provided.	16	DoIR State Treasury	as required
28	DoIR should promote the development of a pilot plant to demonstrate new titanium metal production technologies. DoIR should be aware of companies involved in this avenue of pursuit in order to successfully promote the south west coast region.	17	DoIR	near term

Table 1.8: Recommendations, Including Responsibilities and Timing (continued)

	Recommendation	Issues Addressed	Responsibility	Due
29	A more rigorous, fully resourced and empowered approach is required to implement the recommendations of the Keating Report to ensure Government approvals processes are not an obstacle to project developments or expansions. The State Government must clearly understand industries' concerns in regard to the approvals processes and implement an integrated approvals system consistent with "world best practice".	18	DoIR, CME	2005
30	DoIR should coordinate matters relating to development of mines in sensitive areas. This will involve working with industry and communities to identify and address issues at an early stage so that there can be a logical and timely progression of mine development.	19	DoIR	ongoing

Table 1.8: Recommendations, Including Responsibilities and Timing (continued)

2 INTRODUCTION, BACKGROUND AND METHODOLOGY

2.1 Regional Minerals Program

The Regional Minerals Program was established by the Australian Government in 1996 as a key element of its strategy to encourage a coordinated approach by industry and governments to facilitating regional development of mining and processing activities (including oil and gas) and to promoting regional employment opportunities.

The program funds regional studies, carried out in partnership between industry and governments, to:

- provide an overview of the mineral resources and processing potential of selected regions;
- assess the infrastructure and government services of a region and develop proposals to overcome impediments to development; and
- identify and explore wider policy issues that warrant further attention, such as specific research and development needs, land access and environmental issues.

Twenty two studies and projects covering regions across Australia have been facilitated.

Information about these can be found at www.industry.gov.au/rmp.

2.2 Study Objective

The ultimate objective of this Study, which was carried out under the auspices of the Regional Minerals Program, is to provide information to attract private sector investment into Western Australia to stimulate development of the State's mineral and petroleum resources for the benefit of investors, the State and Australia.

The Terms of Reference for the Study are provided in Appendix 2.

2.3 Study Region

The study region, referred to for this Study as the 'south west coast region', extended from Port Gregory (north of Geraldton) to Albany, as shown in Figure 2.1 and comprised all or part of the regional areas of the Mid West, Perth Metro, Peel, South West and part of the Great Southern. The boundaries of the study region were somewhat arbitrary in that they did not align with particular geographic formations or Local Government boundaries.

The study region covers an area of the order of 175,000 square kilometres, which is just over half the size of Italy. The region comprises about five percent of the Western Australian land mass and is home to almost 90% of the state's population. It was selected for investigation in consideration of the following factors.

i) Although the minerals and mineral processing sector of the south west coast region is well established and is a major contributor to the regional economy, opportunities for further resource development or for value-adding downstream processing, particularly in the light metals area, were perceived to exist. The Geological Survey Division of Department of Industry and Resources ('DoIR') estimates that, at current price levels, the identified mineral resources of the study region have a value exceeding $660 billion.

ii) If the perceived development opportunities are not commercialised or are stranded (because their development is not viable) significant benefits in terms of income and employment will be lost.

iii) The commercial viability of many of the perceived development opportunities is likely to be sensitive to the price of energy. Although the region has adequate supplies of coal and gas, the scope for sourcing energy at prices that will stimulate further minerals development needed to be investigated.

2.4 Study Management

2.4.1 Study Coordination and Management

The Study was coordinated by DoIR on behalf of the organisations listed in Appendix 3, all of which provided funding and guidance for the Study.

The Study was managed by a Management Committee that comprised representatives of the participating agencies and organisations.

2.4.2 Study Timeframe

The Study commenced with the appointment of Sleeman Consulting on 3 June 2004 and concluded with publication of this report in December 2004. Sleeman Consulting undertook the Study in alliance with Goodall Business and Resources Management.

In the course of the Study the Management Committee met at four-week intervals. Progress meetings involving the Project Manager and the Consultants were convened as necessary.

2.5 Study Methodology

The Study was thematic in nature. It investigated material and information of relevance to energy and minerals development in the south west coast region of

Western Australia in order to identify the most significant issues and priorities for ongoing attention.

In particular, the mineral resources of the study region and the energy resources available to the study region were reviewed in order to determine the energy requirements, in terms of quantity and price, of prospective minerals developments and to identify possible sources of energy to meet these requirements.

The methodology adopted in carrying out the Study is illustrated in Figure 2.1.

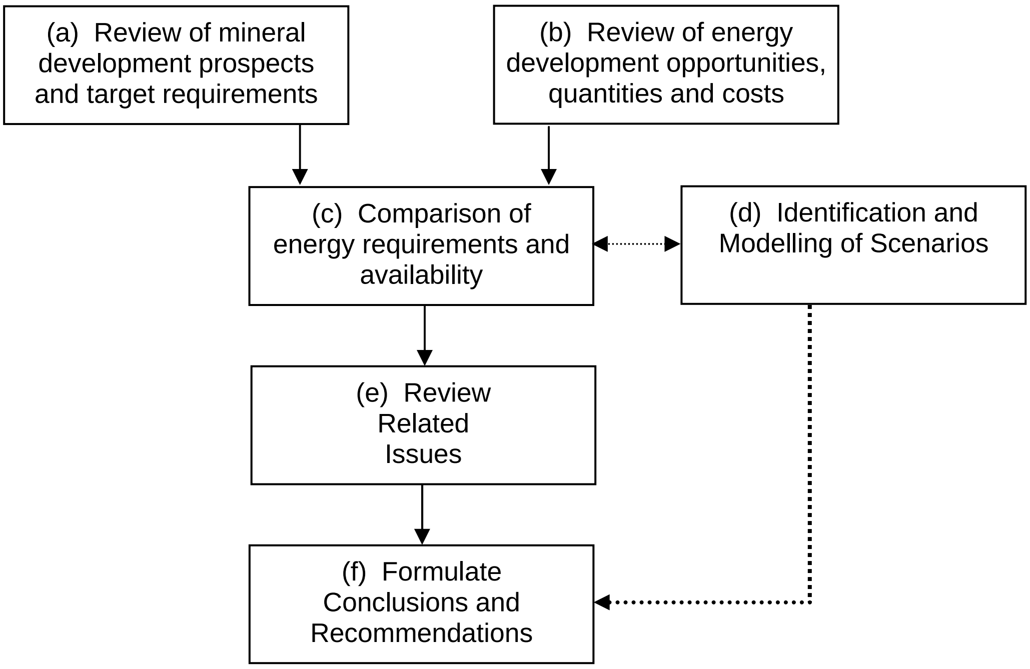

Figure 2.1: Study Methodology

a) Review of mineral development prospects

The mineral resources of the south west coast region were reviewed, with regard for location, quality and size, to identify development opportunities. Interviews were held with all major producers and for each opportunity, the quantities and target prices of energy required to achieve project viability, having regard for market expectations and other development costs, were identified.

b) Review of energy development opportunities

Interviews were held with all key energy suppliers and prospects for supply of additional energy and/or electricity to the south west coast region were reviewed, having regard for competing opportunities and, as appropriate, transportation and processing costs. Estimates of the availability and price of energy were developed.

c) Comparison of energy requirements and availability

Comparison of the energy requirements for minerals development and the predicted availability and cost of energy allowed identification of strategies to stimulate private sector investment.

d) Identification and modelling of development scenarios

Prospective development scenarios were identified and their economic impacts investigated using computable general equilibrium modelling techniques. This component of the Study was carried out on behalf of Sleeman Consulting by the Monash University, Centre of Policy Studies using a multi-region version of the Monash Computable General Equilibrium Model.

e) Review of related issues

Issues related to the development of minerals opportunities or to the supply of energy to them were reviewed. For example, this included infrastructure requirements and other constraints, greenhouse gas issues and carbon sequestration.

f) Formulate conclusions, recommendations and actions

Observations, conclusions and recommended actions, as identified during the course of the Study, were consolidated during preparation of this Report.

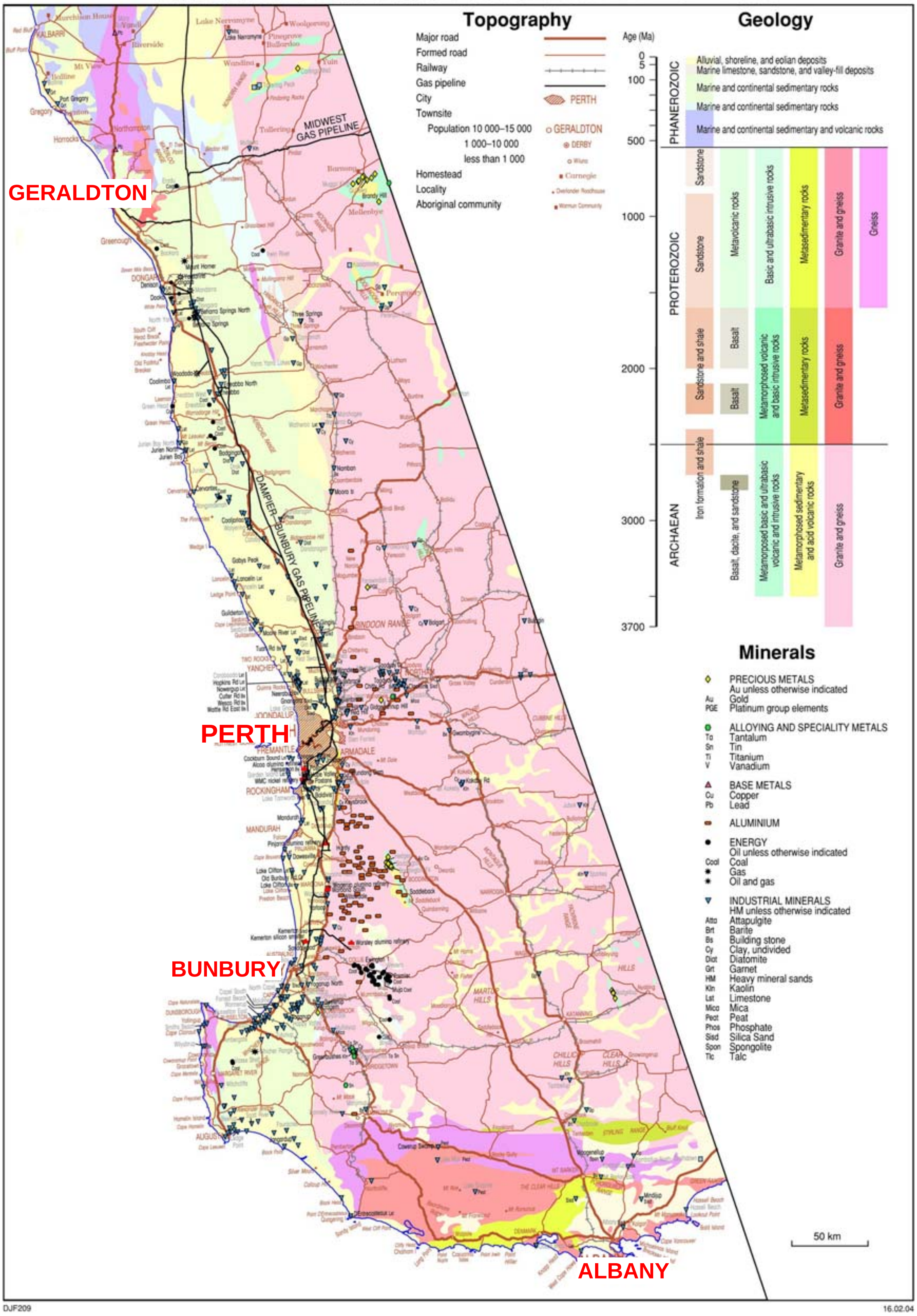

Figure 2.2: South West Coast Study Region

This page left blank intentionally

3 MINERALS

3.1 Introduction

a) Background

The south west coast region is one of the world's major mineral provinces. It contains identified mineral resources that have a value, estimated by the Geological Survey Division of DoIR on the basis of current market prices, in excess of $660 billion. The value estimate is presented in Table 3.1.

The mineral resources of the study region represent approximately 10% of the State's known mineral wealth. In comparison, the study region accounts for 5% of the area of the state and is home to around 90% of the state's population.

The major mineral resources of the study region are bauxite and coal. The region's bauxite reserves are world class. They contain in excess of 1,250 billion tonnes of alumina and support current levels of production in excess of 11 Mt per annum.

The coal reserves of the study region are estimated at 5.8 billion tonnes and, although not considered to be suitable for export, provide a secure long term energy source for industry and for electricity generation.

Mineral sands are another key resource of the study region and have supported world scale production of ilmenite, zircon and rutile for over 40 years.

World class deposits of tantalum and spodumene are also being mined, and gold and iron ore resources are under development. There are also substantial deposits of minor minerals, such as talc, limestone, clay, garnet and silica-sand, mined in the region or being assessed for production potential.

b) History and Regional Significance

The south west coast region first came to international prominence as a major mineral province in the 1960's with the development of the regions' massive bauxite resources. Processing of bauxite to produce alumina was carried out by Alcoa World Alumina Australia ('Alcoa') at its Kwinana refinery, which commenced operation in 1963. The Kwinana industrial precinct was, at that time, also home to a BHP steel bar plant, which opened in 1954, and the BP Kwinana Refinery, which commenced operation in 1955.

The Western Australian minerals sands industry was established in a similar timeframe. In 1956, Cable Sands (WA) Pty Ltd ('Cable Sands') commenced mining of ilmenite at Koombana Bay, near Bunbury. By 1966, four more deposits had been brought into production, including Westralian Sands' (now Iluka Resources Limited) Capel operation (1959). Laporte (now Millennium Inorganic Chemicals Inc) opened a pigment plant at Australind, near Bunbury, in 1963. In the early 1970's, a synthetic rutile plant using the Becher Process (developed by the Western Australian Government Chemistry Centre) commenced operation at Western Titanium's Capel operation.

The expansion of the minerals potential of the south west coast region continued through the 1970's and 1980's. Western Mining Corporation Limited's nickel refinery, producing nickel briquettes and powder from nickel matte produced at the Kalgoorlie nickel smelter, was commissioned in 1970. Alcoa opened additional alumina refineries at Pinjarra (1972) and Wagerup (1984) and Worsley Alumina Pty Ltd ('Worsley') commenced alumina refinery operations near Collie in 1984. Westralian Sands commenced synthetic rutile production at Capel in 1982, and Jennings Mining, Allied Eneabba and Western Titanium commenced production of mineral sands from deposits around Eneabba in 1974.

Subsequently, further greenfields developments (such as the commencement of silicon metal production in 1989) and progressive expansions of existing operations have occurred.

The annual value of minerals and upgraded mineral products from the study region is currently estimated to be $5 billion with direct employment in excess of 10,000 personnel and contributing wages and salaries of over $500 million.

Both product value and employment are projected to increase with the development of new projects such as HIsmelt, iron ore production, and expansion of alumina, silicon metal and titanium pigment output.

Large employers in the area include Alcoa, Worsley, Iluka Resources Limited ('Iluka'), TiWest Joint Venture ('TiWest'), Millennium Inorganic Chemicals Inc ('Millennium'), Wesfarmers Limited, Griffin Coal, Cable Sands (WA) Pty Ltd, Mt Gibson Iron Ltd ('Mt Gibson') and Luzenac Australia Pty Ltd. Many of these companies are the major employers in regional towns such as Collie, Capel, Greenbushes, Bridgetown, Pinjarra, Boddington, Eneabba, and Three Springs and are large employers in the major centres of Geraldton, Mandurah, Bunbury and Perth.

c) Prospect for Further Development

The availability of this wide range of minerals from world class resources together with access to competitive sources of gas and coal offers the potential for further resource expansion and development of downstream processing options to meet buoyant market demand.

This section of the report considers each of the current non energy mineral operations in the study region and investigates the potential for expansion or downstream processing.

Commodity Group	Mineral or Commodity	Contained Commodity	Unit	2003 Unit Value	Unit	Total Value ($M)	Total Value ($M)
Bauxite	Alumina	1,250	Mt	280	$/t	348,000	348,000
Coal	Coal	5,800	Mt	44	$/t	256,000	256,000
	Ilmenite	140,000	kt	125	$/t	18,000	
	Garnet	9,000	kt	100*	$/t	1,000	
Heavy Minerals	Leucoxene	4,600	kt	370	$/t	1,700	32,000
	Rutile	5,500	kt	650	$/t	3,500	
	Zircon	14,000	kt	5,790	$/t	8,100	
Gold & Copper	Gold	614,000	kg	17,900	$/kg	11,000	12,800
	Copper	790	kt	2,370	$/t	1,800	
	Ta_2O_5	56,000	t	180,000*	$/t	10,100	
Tin-Tantalum-Lithium	Li_2O_5	480,000	t	20	$/t	10	10,100
	Kaolin	690,000	t	80	$/t	60	
Iron Ore	Iron ore	256	Mt	26	$/t	6,700	6,700
Silica Sand	Silica sand	302,000	kt	10	$/t	3,000	3,000
Talc	Talc	1,100	kt	90	$/t	100	100
						Total	**666,000**

Table 3.1: Mineral Resources in the South West Study Region July 2004 [a,b]

a. Mineral resources extracted from MINEDEX in July 2004; excludes construction materials

b. Unit values from DoIR's Statistics Digest 2003; but 2001 data used for selected* commodities. Data are rounded and values are approximate.

3.2 Bauxite/Alumina and Aluminium

3.2.1 Key Observations

i) Current alumina production is 11.2 Mtpa, 90% of which is exported, with China at 22% the largest destination.

ii) The alumina industry is expanding to meet increased market demand. Current expansions will increase capacity from 11.2 Mtpa to 12.2 Mtpa by 2006.

iii) If Alcoa and Worsley expand in line with market demand, production is expected to increase to 14.5 Mtpa by 2010. This will require an estimated 91 TJ/d of additional energy.

iv) If planned increases all proceed production will reach 15.7 Mtpa by 2010, requiring an estimated 124 TJ/d of additional energy.

v) Modern aluminium smelters have a production rate of 350,000 tpa per pot-line, and require 2 pot-lines to be internationally efficient.

vi) Electricity price to be internationally competitive must be at, or below, US1.8 c/kWh. If prices below this level cannot be achieved a smelter development in the south west coast region is unlikely.

vii) If gas is used to co-generate electricity for an aluminium smelter, around 60 TJ/d will be required per pot line. The gas price will need to be below $2.50/GJ.

viii) While energy/electricity price is important, capital and other operating costs will also influence the international competitiveness of the project.

3.2.2 Industry Overview

The Western Australian alumina industry started production in 1963 when Alcoa commenced development of the extensive reserves of bauxite situated in the Darling Range within the south west coast region. The initial mine was located at Jarradale to supply a refinery at Kwinana.

Since then, the industry has developed to the point where Western Australia, with Alcoa mines at Huntley and Willowdale and refineries at Kwinana, Pinjarra and Wagerup and Worsley's Boddington operation, is now the biggest single source of alumina in the world. Annual production of aluminium from the study region is 11.2 Mt. The location of key reserves, mines and processing sites are depicted in Figure 3.1.

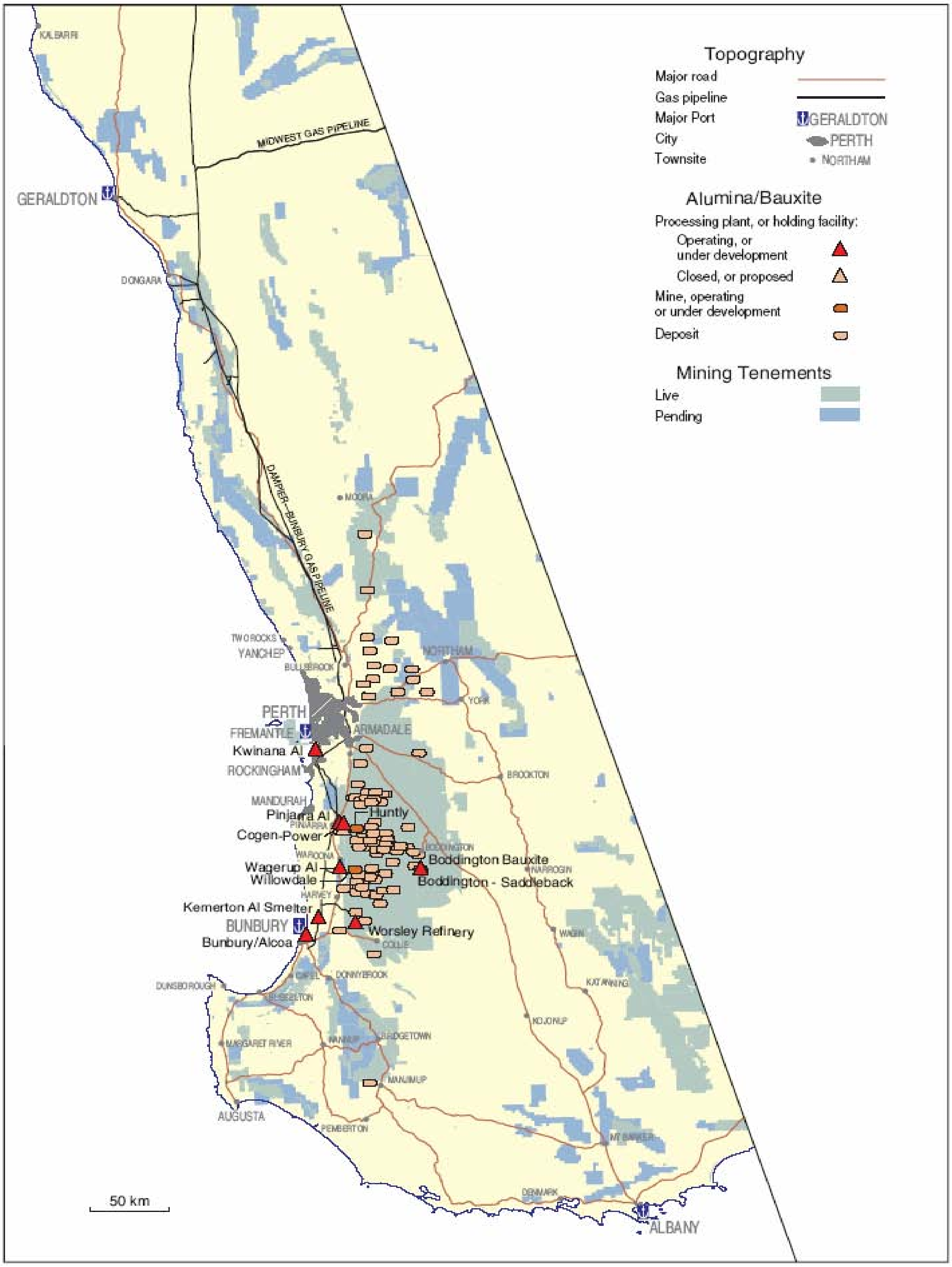

Figure 3.1: The Alumina Industry in the Study Region.

Expansions are underway that will increase alumina production capacity to 12.2 Mtpa by 2006. In addition, the feasibility of further expansions is being investigated or environmental approvals are being progressed.

In 2003, 11.2 Mt of alumina were produced in Western Australia representing 19% of world capacity. As shown in figure 3.2, over 90% of this production was exported with China comprising the largest destination at 22% followed by the US and Canada combined at 25%, South Africa 14%, United Arab Emirates 11%, Bahrain 10%, and Mozambique 8%.

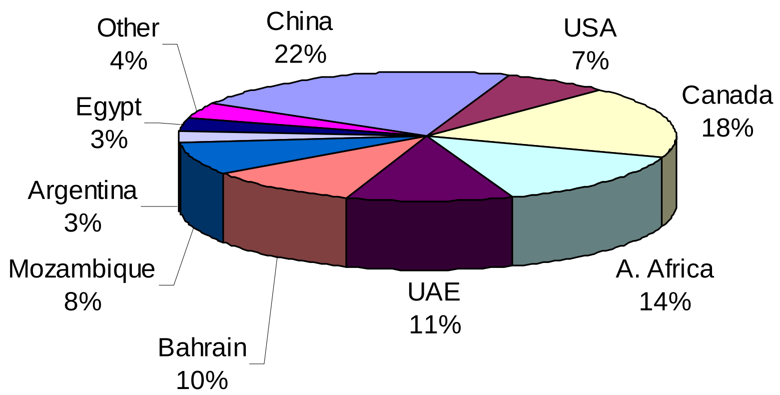

Figure 3.2: Western Australian Alumina Exports[1]

The major port for export is Bunbury which handled 8.25 Mt in 2003 with the remaining tonnage being exported via Kwinana.

Production from Alcoa's Kwinana refinery is used to produce Alumina Chemicals and also to feed AFM's fused alumina plant located on the Kwinana Industrial strip.

3.2.3 Extent of Resources/Quality/Location

There are extensive reserves of bauxite in the south west coast region. As detailed in Table 3.2, known reserves are sufficient to support operations at current and planned production rates for over thirty years. However, as reserves are consumed the distances from the reserves to the refineries will increase, resulting in a higher transport cost for the raw material.

[1] Source: DoIR publication

Company	Resources[2] Mt	Production Mt/annum		Mine Life Years
		Alumina	Bauxite	
Alcoa Huntley Willowdale	 1,000 1,000	 5.8 4.8	 22 18	 40+ 56[3]
Worsley Mt Saddleback	 400	 3.2	 12.0	 33
Other (Chittering)	100			

Table 3.2: Bauxite Resources of the South West Coast Region

3.2.4 Production Costs

The three modern refineries at Worsley, Pinjarra and Wagerup are among the world's lowest cost producers of alumina. In 2002 they were rated by AME Minerals Economics ('AME') to be in the world's leading operations on a cost basis. However the strengthening of the Australian dollar has resulted in the Western Australian producers dropping back against world competition.

Figure 3.3 shows the production cost (excluding capital charges) for the world's twenty lowest cost refineries. Together, these refineries produce approximately 50% of the world's alumina and as such represent the lowest and second lowest cost quartiles.

While Wagerup, Pinjarra and Worsley are still in the lowest cost quartile of producers, several Chinese and one Indian plant now have lower production costs. Alcoa's older Kwinana refinery is in the middle of the second quartile of costs.

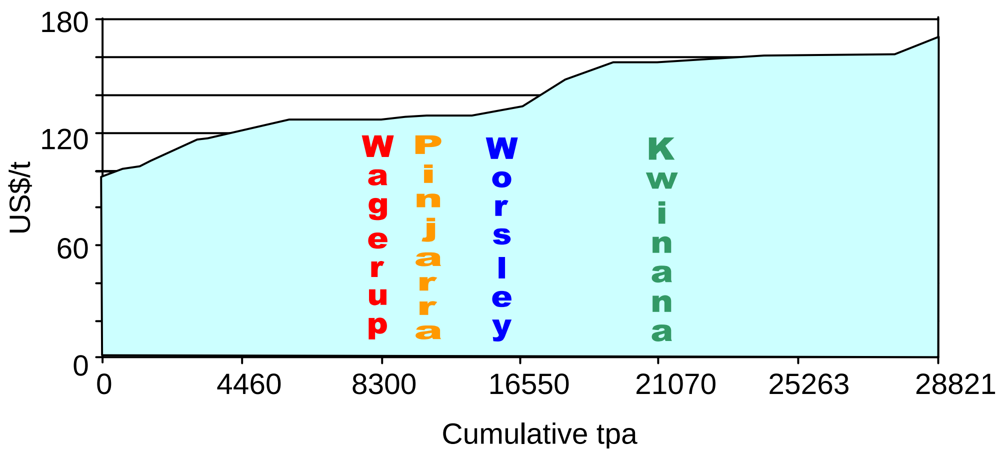

Figure 3.3: Refinery Production Cost[4]

---

[2] Measured and indicated resources.
[3] Assumes expansion occurs at Wagerup Refinery.

Major cost drivers associated with alumina production are bauxite feedstock, energy, caustic soda and labour. As depicted in Figure 3.4, these costs are estimated by AME to represent 85% of production costs of Australia's modern refineries.

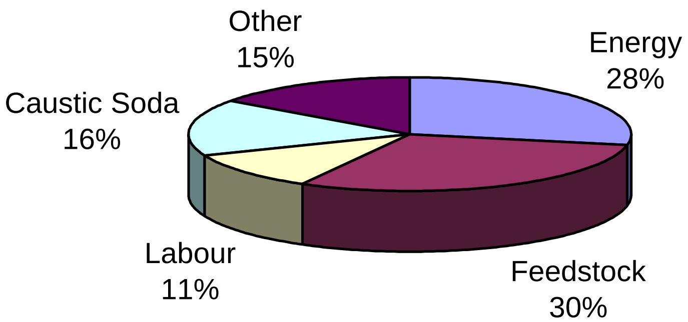

Figure 3.4: Operating Costs for Alumina Production[5]

In Western Australia the large efficient mining operations result in feedstock costs being significantly lower than 30% with other costs increasing proportionately, as shown in Figure 3.5.

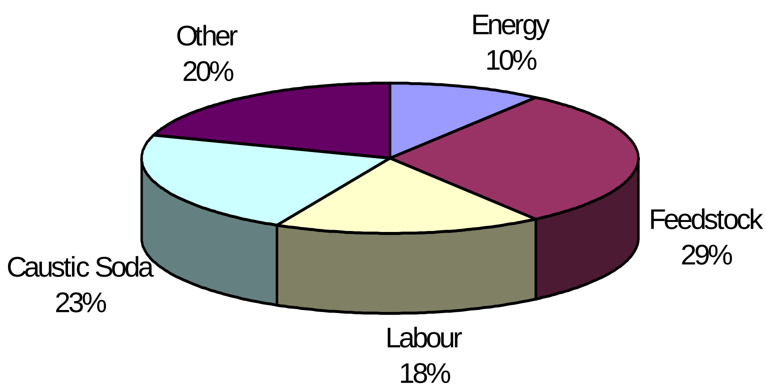

Figure 3.5: Western Australian Cost Estimates for Alumina Production[6]

The real costs of alumina refinery production have been gradually falling as the producers have achieved efficiency improvements. This is expected to continue, with Alcoa targeting cost reductions of 3% per annum.

[4] Source: John F King Alumina and Bauxite Report May 2004
[5] Source: AME
[6] Source: Alumina companies

3.2.5 Energy Consumption

a) Alcoa

Based on data published by the International Aluminium Institute, the average energy consumption for alumina mining and refining in Australia is 11,375 MJ per tonne of alumina produced.

With annual production capacity of 8.7 Mt, Alcoa's energy consumption is approximately 240 TJ/d, indicating its refineries are energy efficient. While Alcoa has the capacity to burn other fuels, it generally operates using 100% gas.

b) Worsley

Worsley operates three coal fired boilers and currently consumes 800,000 tpa of coal. It also purchases power and waste heat from the South West Co-generation facility and currently sells excess power via the grid.

Gas consumption of the co-generation facility is 35 TJ/d and Worsley also consumes an additional 35 TJ/d in its process.

Worsley is located in close proximity to the Collie coalfields and has a clear preference for use of coal for steam generation. It is however concerned that the Environmental Protection Authority ('EPA') has indicated a policy for coal use in electrical generation that has no regard for economic factors and therefore has the potential to adversely impact the viability of the State as a low cost location for mineral processing.[7]

3.2.6 Expansion Potential

Since 90% of the world's alumina is consumed in the production of aluminium, its growth pattern can be expected to follow that of aluminium.

World aluminium production in 2003 was 27.3 Mt, which is equivalent to 80% of the installed capacity of 31.1 Mt. This was an increase in production of 5.4% over the 25.9 Mt produced in 2002. At the end of September 2003 stocks were estimated at 3 Mt of which 1.37 Mt was in London Metal Exchange ('LME') inventories.

As depicted in Figure 3.6, world aluminium metal demand is projected to grow by 7% in 2004, and 4.9% in 2005, before gradually returning to its long-term growth profile of 2.5%, to reach a total demand of 35 Mt by 2010.

[7] The Western Australian EPA has taken a position that to be environmentally acceptable carbon dioxide from coal fired power generation must be equivalent, or lower than, emissions from a similar sized power generation facility based on combined cycle gas.

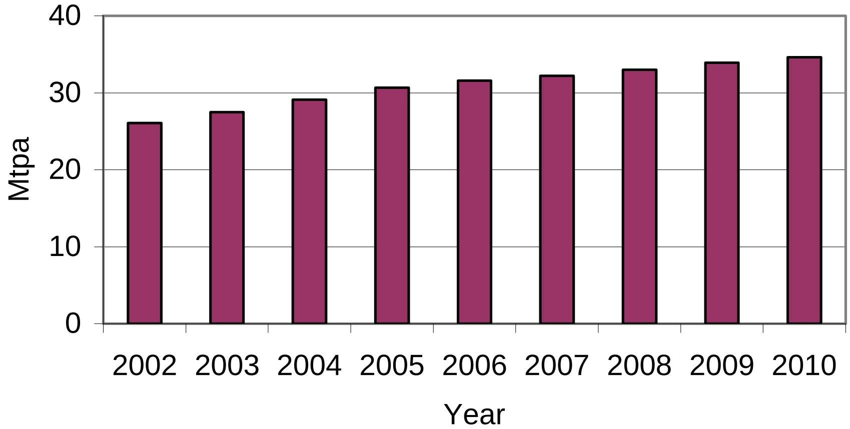

Figure 3.6: World Aluminium Production Forecasts 2002–2010[8]

As Western Australia is currently a low cost producer of alumina with a relatively modern asset base it has significant potential for expansion to meet increased alumina demand. This is projected to be through brownfield expansion based on a large low cost resource base, supported by secure and reasonable energy prices. The local industry is already the major supplier to the key growth market, China, which is projected to have an alumina shortfall of 7 Mtpa by 2006.

Both Alcoa and Worsley are expected to at least extend capacity in line with demand growth. On this basis the current production rate of 11.2 Mtpa (2003) would be expected to increase to 14.5 Mtpa by 2010.

Current planned incremental increases and future expansions of production capacity for Alcoa and Worsley are detailed in Table 3.3. If these all proceed capacity will reach 12.2 Mtpa by 2006 and 15.7 Mtpa by 2010.

However there is a wide range of countries with large bauxite reserves where major producers are looking to develop new or expand current capacity. These include Guinea, Suriname, Vietnam, Brazil, Venezuela, Jamaica, India, China and Russia. Consequently it will be important for Western Australian producers to maintain their status as low cost producers.

[8] Source: James F King Aluminium Report May 2004

Refinery	Capacity Status	Capacity (ktpa)	Timing of Expansion
Worsley	Current Capacity	3,200	
	Incremental Announced	500	2006
	Under Consideration	600	2008
	Under Consideration	600-1,300	2010 plus
Wagerup	Current Capacity	2,400	
	Planned Expansion	1,100-1,600 [9]	2007
Pinjarra	Current Capacity	3,400	
	Announced Expansion	600	2005
Kwinana	Current Capacity	2,100	
	Expansion Plans	Nil	
Totals	Current	11,100	
	Announced	1,100	
	Planned/Under Construction	2,300 – 3,500	

Table 3.3: Alcoa and Worsley Production Capacity and Expansions[10]

3.2.7 Capital Cost of Expansion

Capital costs for current greenfield and brownfield expansions recently announced in Australia are as set out in Table 3.4.

Company	Date	Type	Tonnages Mtpa	Capital $M	Capital Cost $/t
Comalco	current	greenfield	1.4	1,000	0.71
Pinjarra	current	brownfield	0.5	500	1.00
Worsley	current	brownfield	0.250 – 0.300	270	1.08-0.90
Worsley	2005-2008	brownfield	1.1-1.6	NA	
Worsley	2000	brownfield	1.5-3.1	850	0.53

Table 3.4: Capital Cost of Expansion[11]

[9] Alcoa is presently addressing environmental/community concerns regarding expansion of the Wagerup operation.
[10] Source: Company data
[11] Source: Published company information.

3.2.8 Downstream Processing

a) Aluminium

Over the past thirty years several companies have carried out feasibility studies for development of an aluminium smelter in Western Australia.

Modern aluminium smelters have a production rate of 350,000 tpa per pot-line but require two pot-lines to be internationally competitive. Over the past seven years, the average cost of electricity to new aluminium smelters has been estimated to be US$13.20/MWh (1.9 c/kWh). However, the availability of low-cost electricity from traditional sources is declining. The target electricity price to be internationally competitive is stated to be below 1.5 to 1.8 USc/kWh (2.1 to 2.6 c/kWh). The electricity requirement per pot-line is in excess of 500 MW which, in turn, would give rise to a gas requirement, based on cogeneration, of approximately 60 TJ/d or a coal requirement of 2.0 Mtpa.

Aluminium demand is continuing to strengthen and, as illustrated in Figure 3.7, is projected to increase to 32.5 Mtpa by 2007. This represents an increase of 7.4 Mtpa over the period 2000-2007 (an average of 1.06 Mtpa). Production is projected to increase in line with demand, keeping the market in balance throughout the next three to four years.

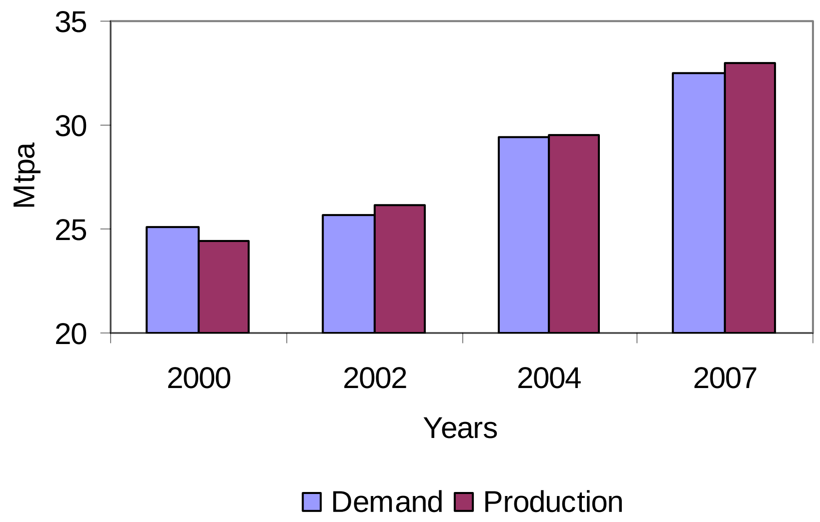

Figure 3.7: Aluminium Production and Demand 2000-2007[12]

During the period 2000-2004 significant cuts in aluminium production occurred in US Pacific North West, due to electricity shortages, and in Ghana, due to water shortages. These were offset by commissioning of new plants in Mozambique, South Africa and India and major expansions in China associated with modernisation of smelter capacity at a number of plants.

[12] Source: James F King Aluminium Report May 2004

Over the period 2004-2008 it is expected that smelter capacity will increase by 4.3 Mtpa. As depicted in Figure 3.8, 20% of the capacity increase will be incremental expansion, 33% will be expansion of Chinese capacity and the remaining 47% will be new capacity elsewhere in the world. The requirement for new production capacity outside China totals 2 Mtpa, which is equivalent to the construction of 1.5 pot lines/annum.

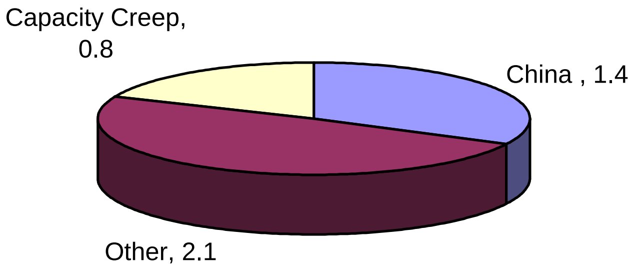

Figure 3.8: Projected Increases in Primary Aluminium Production 2004-2008[13]

Key countries where major plant capacity increases or new plants are projected over this period are China, Canada, Venezuela, Iceland, Russia, Bahrain, Iran, UAE, India and Australia. Other projects are also under consideration in China, Trinidad, Russia, Qatar, Saudi Arabia, Malaysia and Australia.

Consequently, prospects for development of a smelter in the south west coast region must be weighed against competing projects in a significant number of possible locations that may have advantages in terms of power, labour or capital costs. This is demonstrated in Table 3.5.

[13] Source: Industry Data

Country	Alumina Source	Cost Structure		
		Power	Labour	Capital Cost
China	local/import	concerns	very low	very low
Trinidad	local	low	low	low
Russia	local	low	low	low
Qatar	import	low	medium	med/high
Saudi Arabia	import	low	medium	med/high
Malaysia	import	low	low	medium
W. Australia	local	medium	medium	medium

Table 3.5: Cost Basis for Prospective Aluminium Plants

Average production costs for operating smelters are estimated at US$1,269/tonne[14]. As illustrated in Figure 3.9, this is made up of alumina 34%, energy 28%, labour and admin 15%, other raw materials 14% and other costs 10%.

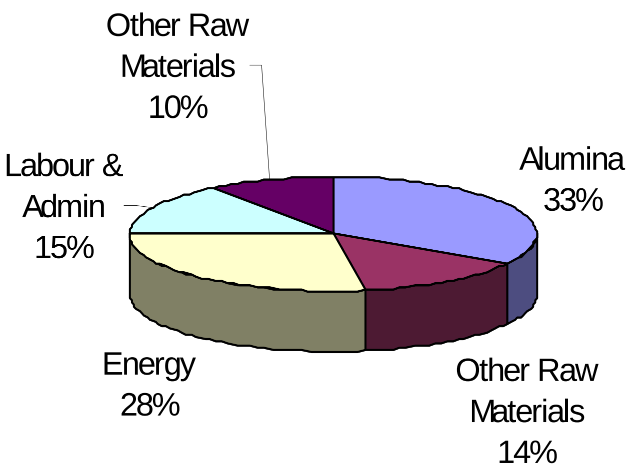

Figure 3.9: Price vs. Production Cost[15]

When capital charges and profits are included total costs increase to US$1,727/tonne.

A comparison of total costs with LME aluminium prices over the period 2004-2007 is presented in Figure 3.10. It is clear that a smelter with average operating costs did not register an acceptable return on investment in 2003 and if price projections are accurate this situation will recur in 2006/07.

[14] James F King World Capacity and Market Report Primary Aluminium May 2004
[15] Source: Industry Data

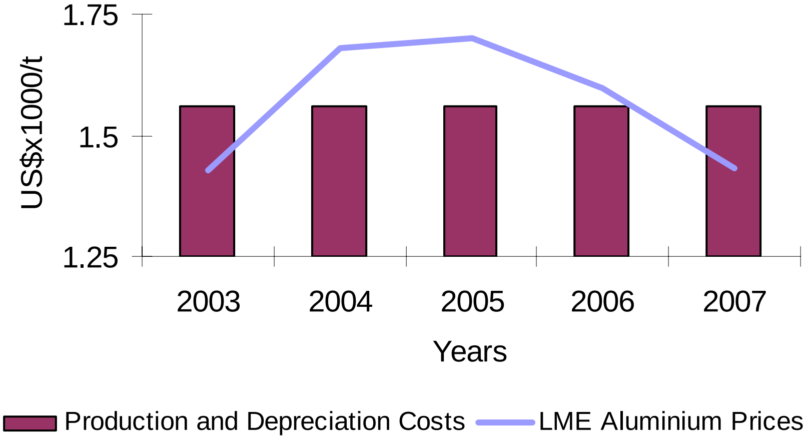

Figure 3.10: Price Vs Production Cost

For a smelter to be profitable throughout the price cycle it will need to be in the bottom quartile of production costs. CRU information suggests that the first quartile (i.e. lowest costs) is US$1,240/tonne.

With labour and capital costs for the study region both being in the medium range, it is essential that power pricing is world competitive, matching prices available in the Middle East and Trinidad.

Another major factor, with alumina currently being in strong demand, is to ensure that alumina is available on a contract that reflects long-term world prices. Smelters that need to import alumina may be impacted by higher short-term alumina prices, as is currently the case in some Chinese smelters. This should not be a problem for a smelter in the south west coast region.

If both competitive electricity (below 2.6 c/kWh) and construction costs can be achieved there is real potential for a smelter development within the study region. If this cannot be achieved, it is unlikely that development of an aluminium smelter would proceed.

b) Fused Alumina

Australian Fused Materials Pty Ltd ('AFM')[16] produces 21,000 tpa of high quality white fused alumina, a high performance abrasive and refractory material, at a plant established in Kwinana in 1990. AFM produces over thirty size ranges targeted at specific markets.

It has two alumina furnaces consuming approximately 4.7 MW of power, which equates to approximately 14% of manufacturing costs.

[16] owned by Iwatani International and St Gobain.

The fused alumina market is extremely competitive with Chinese producers dominating the market during the late 1990's and early 2000's and causing a large number of western producers to place plants on a care and maintenance basis. However recent power shortages in China have resulted in many of the Chinese producers dropping out of the export market, resulting in supply shortages.

While the potential exists for AFM to expand, this decision will be market driven although competitive power pricing is clearly an important factor in ensuring the plant is world competitive.

c) Gallium

Rhodia Pinjarra (formerly Rhone Poulenc) established a $50M Gallium plant at Pinjarra in 1989. The plant operated for only a short period, with an over-supply of gallium into a depressed market forcing its closure. Gallium for the plant was sourced from liquor pumped from Alcoa's Pinjarra refinery. Production capacity was 30 tpa although, during its short period of operation, the plant demonstrated a capability of producing at greater rates.

In March 2001 Geo Speciality Chemicals Inc of the USA announced plans to spend $75M on developing a 100 tpa 4N[17] metal production facility on the Rhodium site. Although this project did not proceed, the potential exists for developed of a gallium facility. However, such a facility will not be a major consumer of energy.

[17] 4N grade gallium is 99.9% pure.

3.3 Iron Ore

3.3.1 Key Observations

Iron Ore

i) There are significant reserves of iron ore particularly magnetite in the study region.

ii) Production has commenced based on hematite and is projected to reach 5 Mtpa by 2006.

iii) Expansion potential is based around magnetite with a capacity base of 2.5 Mtpa per project.

iv) Initially magnetite is expected to be exported as a concentrate with pellets not produced until the 2010-20 period.

v) Energy for concentrate production is 20 MW per 4-5 Mtpa plant and between 0.5 to 1 GJ/t for pellets.

Downstream Processing - DRI/HBI/Metallurgical Pig Iron

vi) HIsmelt will use 0.5 Mtpa of coal and 4.95 TJ/d of gas in stage 1 production of 0.8 Mtpa. The production capacity of HIsmelt is expected to be doubled in 2009/10. There is some potential for the use of Collie coal to displace imported coal through modifications to the front end of the plant or through use of coal char.

vii) Potential exists for DRI/HBI/Pig Iron production based on magnetite and / or synthetic rutile iron rich tailings. Both gas and coal supplies are readily available to feed plants based on a range of technologies.

viii) Coal based projects also produce excess gas, which can be used to produce electricity. This could be consumed by hematite producers for a Mid West location.

ix) Technologies exist for a plant to produce between 0.5-2.5 Mtpa. To be internationally competitive, it is estimated that an operating cost of US$110/t is required. It is estimated that energy prices of around $2.80/GJ for gas and $1.50/GJ for coal would be required to make such a facility internationally competitive within the study region.

3.3.2 Industry Overview

Western Australia is a major source of iron ore. In 2002 exports were 172 Mt, 98% of which was produced by BHP Billiton Ltd, Hamersley Iron Pty Ltd and Robe River Iron Associates from deposits in the Pilbara.

Major markets for Western Australia iron ore in 2002 were in Asia. As depicted in Figure 3.11, Japan accounted for 43% of exports, China 28%, Korea 15% and Taiwan 7%.

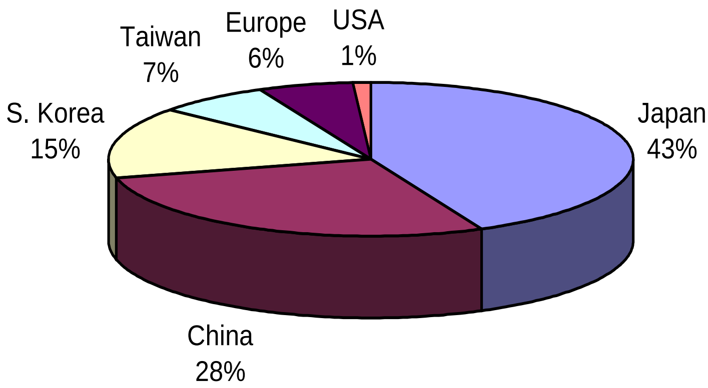

Figure 3.11 Major Markets for Western Australian Iron Ore 2002[18]

Since 2002, Chinese demand has grown rapidly with projected growth rates in 2004 and 2005 of 25% and 20% respectively, taking Chinese total imports to 220 Mtpa, as demonstrated in Table 3.5.

Year	2003	2004	2005
China Imports (Mt)	148	185	220

Table 3.5 China Imports of Iron Ore[19]

Other Asian countries such as Japan, Taiwan and South Korea are also experiencing strong demand based on growth in steel production mainly to service China.

As the major supplier to Asia and particularly China this significant growth in demand for seaborne iron ore has resulted in expansion by all Western Australian producers and has also led to the study and development of a number of deposits in the study region specifically in the Mid West and Great Southern regions.

The first shipment of iron ore from Geraldton for thirty years was made in February 2004 when 38,000 tonnes was shipped to China from Mt Gibson's Tallering Peak hematite mine. Significant expansion in export from the region is projected over the next 10 years.

[18] Source: DoIR
[19] Source: AME

3.3.3 Extent of Resources/Quality and Location

As may be seen in Figure 3.12, there are a number of iron ore deposits in or just outside the boundaries of the study region. Reserves figures published by DoIR as at the end of 2002 are detailed in Table 3.6.

Company	Reserves		Measured and indicated		Ore Type
	Mt	Grade %Fe	Mt	Grade %Fe	
Mt Gibson Iron Ltd					
Tallering Peak T4 & T5			20.5	63.68	GGT
Mt Gibson – Extension Hill			10.7	63.8 – 58.2	GGT
Mt Gibson – Iron Hill			20.7	63.8 – 58.2	GGT
Midwest Corporation Limited					
Koolanooka	405	34.9	430	35	BIF in GGT
Blue Hills	0.7	60.4	1.2	60.3	BIF
Weld Range	129	55.6	152	56.03	BIF
Grange Resources					
Southdown			53.6	30.3	BIF in GGT

BIF – BANDED IRON FORMATION GGT– IRON IN GRANITE-GREENSTONES TERRAINS

Table 3.6: Iron Ore Resources in the Study Region[20]

a) Mt Gibson Iron Limited

Mt Gibson has resources of 35 Mt of hematite and 250 Mt of magnetite across the Tallering Peak, Mt Gibson and Koolanooka South deposits. It has also recently applied for leases over a significant magnetic anomaly at Wolla Wolla east of Pinjar.

[20] Source: DoIR Iron Ore Industry 2003

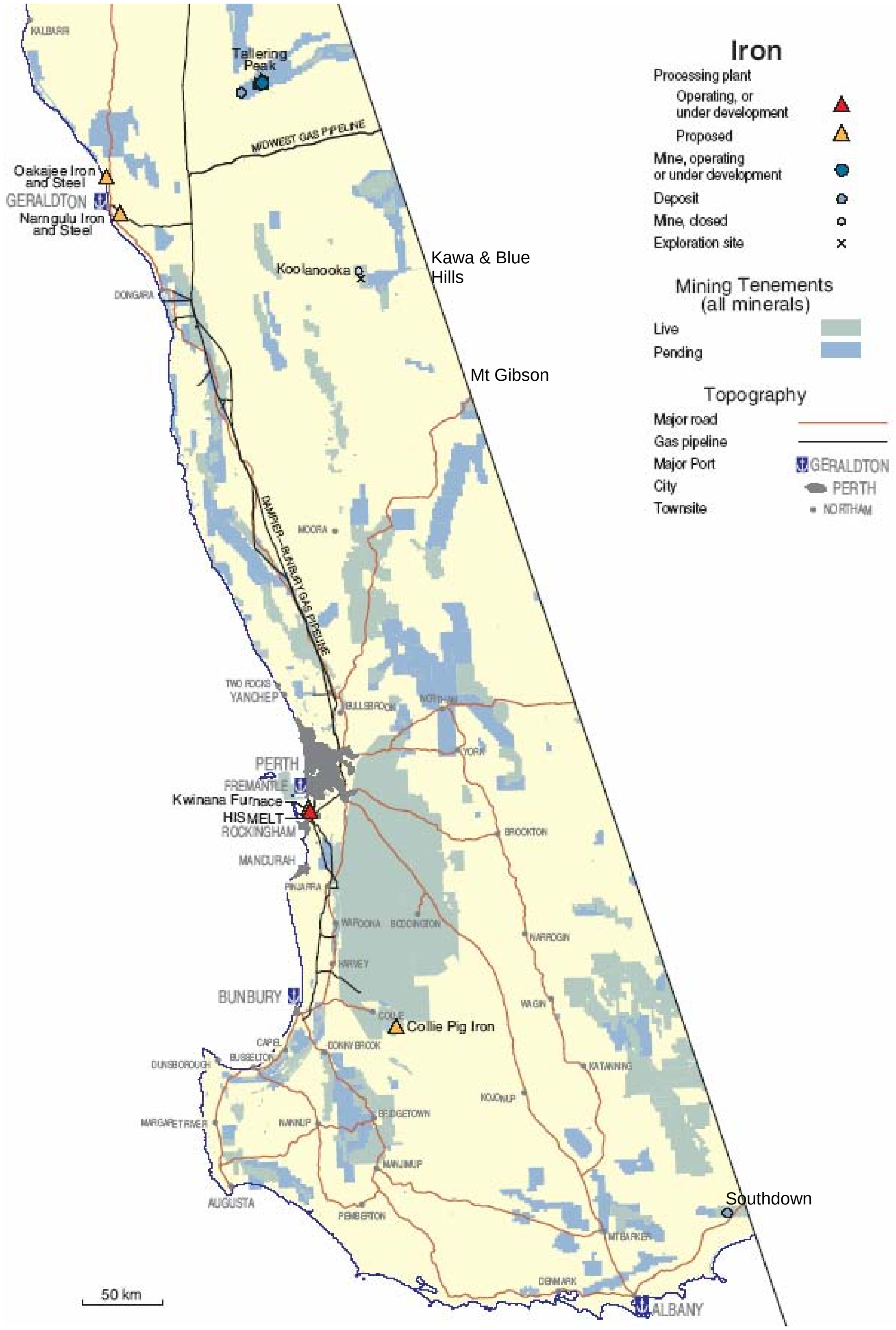

Figure 3.12: The Iron Ore Industry in the Study Region

b) Midwest Corporation Limited

Midwest Corporation Limited ('Midwest') has some 6 Mt of hematite at the Koolanooka and Blue Hills deposits and 430 Mt of magnetite at Koolanooka. In addition the company has substantial hematite and magnetite reserves at Weld Range which, while outside the study region, will be exported via Geraldton. However as this will require export in Cape sized vessels a new deep water port development will be required.

c) Grange Resources

Grange Resources Limited's Southdown Magnetite Project had ore reserves estimated for a small section of the deposit in 1987. These ranged from 45.4 Mt at a cut-off grade of 35% Fe to 75.8 Mt at 15% Fe cut-off. Metallurgical tests indicated a concentrate grade of between 69.6% and 68.5% Fe. The company is targeting further drilling to increase resources to 300 Mt of ore containing 37.5% magnetite.

d) Gindalbie Metals Ltd

Gindalbie Metals Ltd ('Gindalbie') has leases in the Blue Hills area that are prospective for both hematite and magnetite.

Previous drilling by WMC Resources Limited ('WMC') has shown a deposit outcropping over 4 kilometres with an estimated in-situ tonnage of 200 Mt of ore in the Mt Kara deposit. Gindalbie has named the area "The Minjar Iron Ore Project" and believe that it has the potential for an in-situ tonnage of 400 Mt when the full 10 kilometre Branded Iron Formation ('BIF') horizon is assessed.

Gindalbie is currently carrying out a first stage feasibility program at Mt Kara. This involved repeating WMC's laboratory test work on the magnetite core samples and further drilling. This is scheduled for completion in December 2004 at which point Gindalbie will determine whether to enter into a full feasibility study.

3.3.4 Production and Costs

a) Mt Gibson – Tallering Peak

Mt Gibson commenced mining, crushing and screening operations at Tallering Peak, north of Mullewa in the second half of 2003, with the initial shipment via Geraldton in February 2004.

Mt Gibson's current production rate is 1.65 Mtpa. This is scheduled to be increased to 1.85 Mtpa in the third quarter 2004 once the 25 kilometre unsealed section of road between the mine and railway has been bitumised with further increase to 2.2 Mtpa under consideration. Mine life is estimated at 8 to 10 years.

Production and administration costs for mining of hematite and export from Tallering Peak are estimated at $25/t. As shown in Figure 3.13, the major cost components are mining, processing and transport of the iron ore 172 kilometres by road and rail to the Geraldton Port.

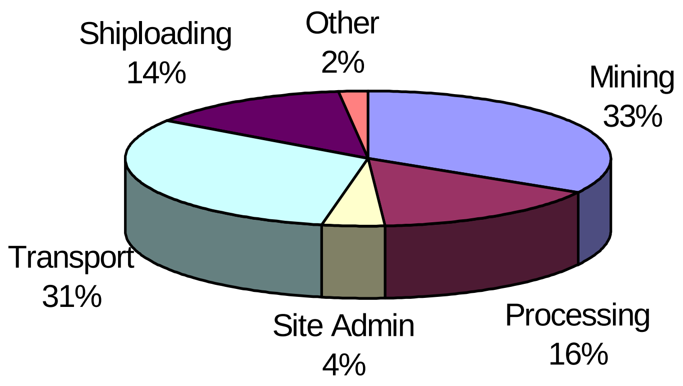

Figure 3.13: Costs for Mining of Hematite - Midwest[21]

The power demand associated with crushing and screening of the ore prior to transport to the port is 4 MW.

b) Mt Gibson – Mt Gibson Deposit

Development of this deposit will commence in January 2005 with the initial shipment of ore in June 2005. The production rate will commence at 1.5 Mtpa increasing to 2.0 Mtpa by mid 2006.

Costs are expected to be similar to Tallering Peak with lower mining costs due to less overburden being offset by increased transport costs for the 325 kilometre trip to Geraldton. On this basis other costs will remain at similar percentages.

c) Midwest – Koolanooka

Midwest is currently re-establishing the on-site facilities at the old Koolanooka mine, with the objective of commencing operations in the last quarter 2004.

The initial operation will be based on recovery from the fines stockpile, hence on site costs will be very low. This material will last for 19 months at 1 Mtpa before the operation will move to mining the remaining hematite deposit at Koolanooka and Blue Hills.

Mine life for this stage of the operation will be five to six years based on current resources, but Midwest expects this to extend to 10 years or more at 1.5 to 2.0

[21] Source: GBRM Pty Ltd records.

Mtpa due to the scope for exploration success in the Koolanooka – Blue Hills area.

As the mine is 19 kilometres from the railway and a further 200 kilometres to Geraldton transport costs will be slightly lower than that for the Mt Gibson deposit.

d) Other

None of the other deposits are currently in production. Potential for these have been addressed in expansion potential.

e) Production Rate

Iron ore (hematite) export from Geraldton is expected to reach 5.2 Mtpa by June 2006, as shown in Table 3.7.

Company	June 2004 Mtpa	June 2005 Mtpa	June 2006 Mtpa
Mt Gibson			
Tallering Peak	1.6	1.5	2.2
Mt Gibson	nil	1.5	2.0
Midwest			
Koolanooka	nil	1.0	1.0
Total	1.6	4.35	5.2

Table 3.7: Iron Ore Production and Export via Geraldton 2004/2005[22]

It will require further upgrading of railway capacity from Morawa to Geraldton and materials handling facilities at Geraldton port to be able to handle this tonnage.

3.3.5 Energy Consumption

Direct energy consumption (electricity and gas) for mine, crush, screen and transport of iron ore is estimated at 2.6 MW/Mtpa of production each year.

3.3.6 Expansion Potential

The major expansion potential in regards to iron ore in the region is based around the large magnetite deposits, as set out in Table 3.8, that are owned by Mt Gibson, Midwest and Gindalbie in the Mid West Region and Grange Resources in the Great Southern. These deposits can be developed for export as a magnetite concentrate or can be beneficiated into pellets.

[22] Source: Company announcements

While all companies are determining the feasibility of both options at this stage, Mt Gibson and Grange initially favour export of concentrates, while Midwest proposes to export pellets.

Magnetite deposits in the Mid West region need to be ground to approximately 80% -38µm prior to magnetic separation, resulting in a magnetic product containing 66.6% iron. This is suitable for Blast Furnace feed but will require further flotation treatment to produce a DRI grade feed.

It is not expected that development of the magnetite deposits will happen immediately as the more complex processing results in a higher capital cost. The final product from this processing is a wet concentrate, which can be transported to the port either via pipeline or road/rail transport. However due to the significant capital involved in a long distance pipeline it is estimated that production levels would need to reach 5 Mtpa before such capital investment would be warranted.

In addition as the product generally is fed to a pellet plant either on site or at the export destination, production rates of 2.5 Mtpa are the initial base for such operations.

Company and Deposit	Production Mtpa	Timing	Distance to Port km	Concentrate Grade % Fe		Reserves Mt @ %Fe
				DRI	Blast Furnace	
Mt Gibson Iron Limited						
Mt Gibson	2.5	2006-07	300	71	68.8	200 (500 -1,000)
Koolanooka South	2.5	2006	260		67	25 – 30
Midwest Corporation Limited						
Koolanooka	5.0	2007	219	70	68	400 @ 34.9%
Weld Range	5.0	2010 onwards	360			TBD
Grange Resources Limited						
Southdown	4.0	2009 onwards				53.6 @ 30.3%

Table 3.8: Potential Magnetite Developments in the Study Region[23]

[23] Source: Company data

3.3.7 Cost Estimates

a) Concentrate Production

The process for production of magnetite is mine, crush and grind, prior to magnetic separation and possibly flotation.

The capital cost for a plant with capacity to produce 2.5 Mtpa of magnetic concentrate at 67% Fe is estimated at $85-150 million depending on the nature of the magnetite involved.

Based on an export price of $35/t, cost of production, transport and shipping would need to be $29/t in order to earn a return of 14% before tax on a capital cost of $85m.

Based on production of 2.5 Mtpa the major on site cost components are:

Mine, crush, grind	6.5-7.5 Mt
Power requirements	20 MW
Personnel	150
Water	2 GL/annum

The relativity of the production cost components is presented in Figure 3.14.

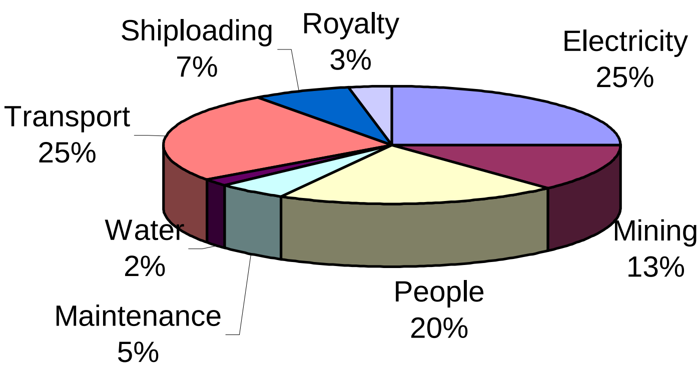

Figure 3.14: Cost breakdown for Magnetite Concentrate Production

b) Pellet Plant

The capital cost of a 5 Mtpa magnetite mine, concentrator and pellet plant is estimated at $540 million. Pellet pricing for Savage River Blast Furnace pellets is $59/t. Hence in order to earn a rate of return of 14% before tax, the operating cost would need to be less than $37/t.

As depicted in Figure 3.15, the major production costs for all of the deposits located in the study region will be power, mining, wages and salaries, other raw materials and transport to the port.

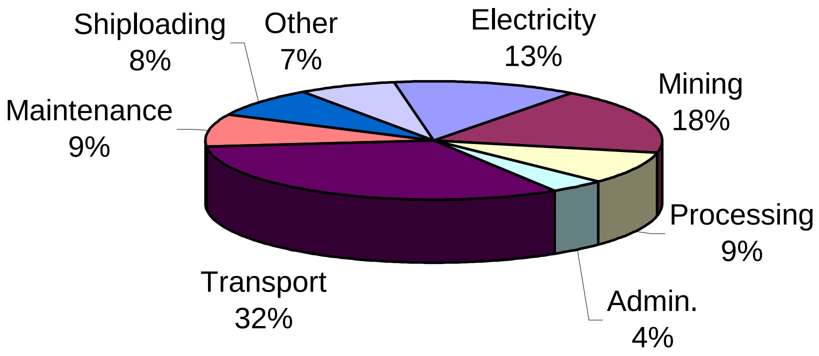

Figure 3.15: Cost breakdowns for a Magnetite Pellet Plant.

The energy consumption of a pellet plant is generally quoted as being 400 to 500 MJ per tonne of pellets. However discussions with prospective producers in the Mid West indicate that the energy consumption could be as high as 1GJ/t.

Coal can also be used to augment the process[24] being charged directly on the hearth at a rate of approximately 9 kg/t of pellets.

3.3.8 Downstream Processing

a) HIsmelt

- Overview

The HIsmelt plant currently being constructed at Kwinana produces a premium grade hot metal from iron ore fines and non-coking coals.

The HIsmelt Kwinana Joint Venture Companies are as follows:

Rio Tinto Limited	60%
NuCor Corporation	25%
Mitsubishi Corporation	10%
Shougang Corporation	5%

[24] Coal would be used in addition to gas to enhance the reduction process. The coal does not displace gas.

- Process

The HIsmelt process can use a wide range of raw materials including iron ore fines, steel plant wastes and varying feed qualities, including medium to high levels of phosphorous, without detrimental impacts on the process or product quality.

This ability to treat varying quality feed stocks will allow the development of deposits that are currently not considered viable.

Of the three major iron ore producers in the world Rio Tinto have by far the largest reserves of high phosphorous ore. Hence it has a significant incentive to develop and market HIsmelt technology, with the modernisation of the Chinese industry as a key target.

- Production

The first stage of the commercial plant is scheduled to commence commissioning in the 4th quarter 2004. It has a production capacity of 800,000 tpa. The intention is to increase this to 1.5 to 1.6 Mtpa once the process has been operated for two to three years, and any problems have been addressed.

- Energy

The major sources of energy are coal, electricity and gas.

Coal is the primary energy source, being used in the process as a reductant to remove oxygen and also to produce electricity from the hot off gases. Coal consumption is 0.5 Mtpa (0.625 t/t metal) and this is being sourced from Queensland anthracite with volatiles of 10-12%. Coal costs represent some 25% of total operational costs.

Electricity consumption is 0.75 to 1.0 MW. This is produced from the hot off-gases and approximately 0.5 MW is sold into the grid.

Collie coal has the necessary reductant capacity but its high level of volatiles would result in HIsmelt having to produce a significant excess of power which is not considered to be economical.

Gas consumption averages 4.95 TJ/d with steady state operational requirements of 4.6 TJ/d. The balance of 100 TJ per annum is consumed during plant start ups. On this basis gas would be approximately 10% of the operating costs.

- Expansion Potential

HIsmelt plans to double production to 1.6 Mtpa after the current plant has been in operation for 2 to 3 years. This will take the plant to a production level where it is considered to be economically viable. Timescale for this expansion to be operational is 2009-10.

Expansion can be achieved either by doubling the current plant or by introducing a new front end to the process, which preheats the coal and iron ore together as solids.

This process is currently undergoing pilot testing in Germany. Should it be successful it will have several benefits including:

- ability to use volatiles from coal as part of the reduction process, hence making it feasible to use Collie coal, and
- significantly reduce the emissions of $C0_2$ per tonne of iron.

This would result in the HIsmelt process having better performance than any blast furnace in the world.

- Costs

Capital cost for the initial 0.8 Mtpa plant is $400 million. The major operating costs for the plant will be iron ore, coal, and gas which, as shown in Figure 3.16, represent 75% of total operating costs.

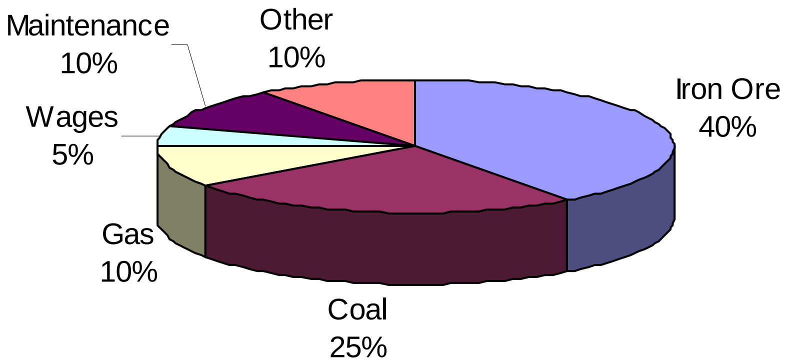

Figure 3.16: HIsmelt Operating Costs[25]

The price for Merchant Grade Pig Iron ('MPI') has fluctuated significantly over the past fifteen years from a high of US$178/t to a low of US $110/t, as shown in Figure 3.17. Consequently a modern plant must be able to survive at the bottom of this price cycle (ie, at a product price of US$110/t). While HIsmelt costs are in this region, as discussed earlier, HIsmelt believes that the plant needs to expand to 1.5 Mtpa before maximum efficiency is achieved.

[25] Source: Company Data

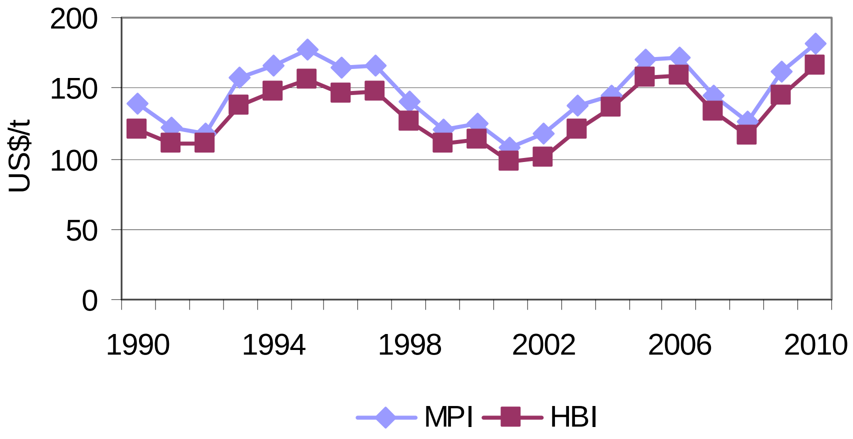

Figure 3.17: Merchant Pig Iron Prices US$/t 1990 – 2010[26]

b) DRI/HBI/Metallurgical Pig Iron

In 2003 a total of 49.45 Mt of DRI was produced world-wide and 90% of this was gas based processes. Some 12.80 Mt DRI/HBI was produced in the Asia/Oceania region, of this 60% is produced in India, with 1.9 Mt in Australia from the BHP Billiton plant in Port Headland, which is currently closed pending findings from an accident enquiry.

<u>Gas Based DRI/HBI Plants</u>

A nominal size of DRI/HBI plant based on current gas based technology is between 0.5 – 2.3 Mtpa.

Consumption figures for the Midrex process, on which 67% of DRI/HBI plants are based, are set out in Table 3.9 and a breakdown of operating costs is set out in Figure 3.18.

The construction time for a Midrex plant is 30 months from commencement of engineering. Consequently on the basis that magnetite production in the region is unlikely to commence before 2007-2008, such a plant would not be expected to be developed in the study region before 2010.

The capital cost for a 1.3 Mtpa Midrex facility is estimated at $1.5 billion.

[26] Source: GBRM Data

	Unit	DRI	HBI
Iron Oxide	T	1.42	1.45
Natural Gas	Net GJ	9.42	9.84
Electricity	kWh	95	115
Oxygen	nm^3	12	12
Water	m^3	1.2	1.5
Labour/Administration	man hours/t	0.1-0.2	0.1-0.25
Maintenance and Supplies	US$	4.0	6.0

Table.3.9: Consumption figures for the Midrex process[27]

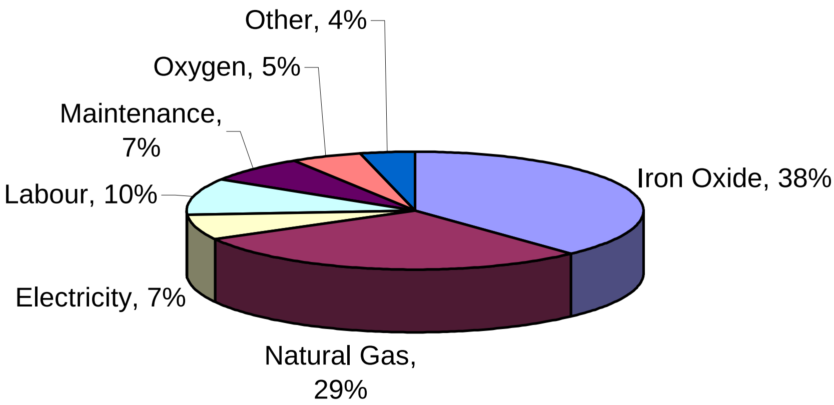

Figure 3.18: Midrex Plant Operating Costs[28]

The price for DRI/HBI has fluctuated in line with MPI over the past decade from a high of $156 to a low of $98/t, as shown in Figure 3.17. Consequently a modern plant would need to have operating costs that ensure its continued viability at the bottom of the market.

<u>Coal Based Plants</u>

- FASTMET/FASTMELT/ITmk3.

Midrex FASTMET, FASTMELT and ITmk3 technologies are being considered by Aviva for development of a 500,000 tpa plant producing pig iron from Mid West Magnetite and Eneabba coal. The potential also exists for such a plant to use synthetic rutile waste streams as an iron source.

[27] Source: Midrex published data
[28] Source: Midrex published data

Key cost figures for the FASTMELT and ITmk3 technologies are quoted as shown in Table 3.10.

	FASTMELT	ITmk3
Plant size ktpa	100-1,500	500
Capital cost US$/t PI	200-300	180-230
Operating Costs US$/t PI	80-120	85-90

Table 3.10: FASTMELT and ITmk3 Size and Cost

On this basis, development of a 0.5 Mtpa FASTMELT or ITmk3 plant would require a capital investment of between $130 and $210 million. Coal consumption would be estimated at 0.4 Mtpa and magnetite 0.7 Mtpa. The potential also exists to use excess heat to produce 50 MW of power which could be used by magnetite producers in the Mid West.

- Corex

Corex is an industrially proven smelting-reduction process developed by Voest Alpine Group which produces hot metal of blast furnace quality suitable for steel applications.

Corex plants are available in three sizes as shown in Table 3.11.

Plant	Mtpa DRI	Combined Cycle MW
C1000	0.3 – 0.4	
C2000	1.0	178
C3000	1.4	224

Table 3.11: Corex Plant sizes

Consumption figures for the Corex technology are set out in Table 3.12. Non-coking coal is used as the reducing agent and the iron charge comprises lump ore and/or pellets. The plant's export gas is a valuable bi-product which can be used in a combined cycle plant to produce electrical power.

Item	Requirement (per t HBI)	Price ($)	Operating Cost ($/t)
Coal (T)	0.5-0.65	40	24
Ore (T)	1.45-1.50	60[29]	90
Electrical energy (kW)	60-70	95	5
Maintenance ($)		12	8.50
Refractories (kb)	1.3	2.50	3.30
Steam (kg)	15	bi product	-
Operating man hours	0.14		6.50
Water ($m^{3)}$)	2.0	0.40	0.80
Other (0_2, N_2, etc)			10.00
Export Gas (*credit*)	13GJ	2.50	(32.50)

Table 3.12: Corex Plant Key Operating Costs

On this basis if a Corex plant is located close to Collie coal, it would be effectively cost neutral on power, with export gas value covering the cost of coal and electricity.

- Collie Pig Iron Facility

Westralian Iron and Steel Corporation ('WISCOR') is evaluating the feasibility of construction a $700 million pig iron facility at Collie, in the south west of Western Australia.

The pig iron facility would be constructed adjacent to the Muja Power Station on unused land owned by Western Power. It is estimated that around 2 Mtpa of iron ore fines would be required for the project, which would be railed to the site and stockpiled. Several iron ore mines are being considered as sources of this iron ore. The iron ore would be mixed with pulverised coal and the Midrex FASTMELT process would most likely be used to produce around 2 Mtpa of merchant pig iron. The pig iron would be shipped through the port of Bunbury for export to electric arc furnace steelmakers. Markets in East or South-East Asia are likely to be potential buyers.

Test work on the suitability of using Collie coal and iron ore fines is being undertaken in the United States. The results from these tests will provide support for desktop modelling completed to date, and permit firmer estimates for raw materials, quantities, product quality, product and

[29] Includes transport Mid West to Collie

recycling factors, levels of emissions and slag composition, to be determined.

The principal reasons for the development of the pig iron project at Collie are:

- Agreement in principal has been reached with Western Power to allow construction and operation of the plant adjacent to the Muja Power Station;
- An MOU has been signed with Western Power to purchase around 130 MW of power from the nearby Muja Power Station;
- Around 1.5 Mtpa of coal will be purchased from Collie coal suppliers;
- Water is readily available at the site location;
- Availability of sophisticated infrastructure such as rail, road, Port of Bunbury and a technically skilled workforce; and
- The plant would require 130 MW of power, but waste heat will have the capacity to produce 150 MW. The company is seeking funding to complete its feasibility study.

3.4 Silicon Metal

3.4.1 Key Observations

i) Annual production is 32,000 tpa with the majority targeted at the high quality end of the market.

ii) Simcoa is in the lowest priced 30% of world producers.

iii) World demand is increasing by 45,000 tpa. Over half of the increase is for chemical grade product.

iv) Power represents 34% of operating costs and is a key consideration in any expansion decision.

v) Simcoa has indicated it has received several competitive power supply proposals.

vi) The addition of one or two furnaces each with 20,000 tpa capacity is expected to be announced in 2005. Two additional furnaces will increase overall power demand to 75 to 80 MW.

vii) Further expansion could follow in 2009-2010

3.4.2 Overview

Simcoa Operations Pty Ltd, a fully owned subsidiary of Shin Etsu, produces 32,000 tpa of high grade silicon metal from its plant located at Kemerton, 17 kilometres north of Bunbury. Production is mainly targeted at the high end of the market but, as set out in Table 3.13, Simcoa produces a full range of grades and silica fume as a bi-product.

Grade	tpa	Target Market
Primary	17	Primary Aluminium
Chemical & Semi Conductor	13	Chemical, Silicones, Semi Conductors
Secondary	3	Secondary Aluminium
Fines	1.5	Refractory
Silica Fume	8	Concrete, refractory

Table 3.13: Simcoa Production

Approximately 80% of the production is exported to Japan, Europe, USA, NZ and the Middle East, with the remainder servicing domestic customers mainly in the eastern states.

3.4.3 Extent of Resources/Quality/Location

Major raw materials used in the production of silicon are rock quartz from Moora and wood, predominantly Jarrah, for production of charcoal reductant.

a) Quartz

Rock quartz is mined at Moora, transported to Bunbury by rail and then carted to the Kemerton site by road.

Simcoa has proven reserves to feed the plant for twenty years and there are significant additional resources that have not been drilled.

b) Charcoal/Reductants

The main reductant used in the process is Jarrah charcoal with a small tonnage (12,000 tpa) of coal with 40% low ash coal mainly from New Zealand being used to blend with 60% Collie coal.

When Simcoa commenced operation it sourced the majority of its Jarrah from the Forest Products Commission which provided both fallen logs from the forest floor and thinnings. Simcoa passes this through a saw mill and then converts it to charcoal in two retorts. Recently Simcoa have entered into an agreement with Alcoa to take Jarrah logs that are removed as part of the Bauxite mining process. Recent test work has shown that Simcoa can make good quality charcoal from pine and blue gum. Simcoa also uses mill ends from saw mills

The annual consumption and use of logs sourced from Alcoa is expected to be:

100,000 tpa

- block 50-60,000 tpa to produce 15,000 tpa of high grade charcoal.
- Chip 20,000 t – used directly in furnace
- remainder mulched for garden centres

Charcoal fines from Simcoa are sold to Auschar for production of charcoal briquettes, which are exported to Asia and Europe.

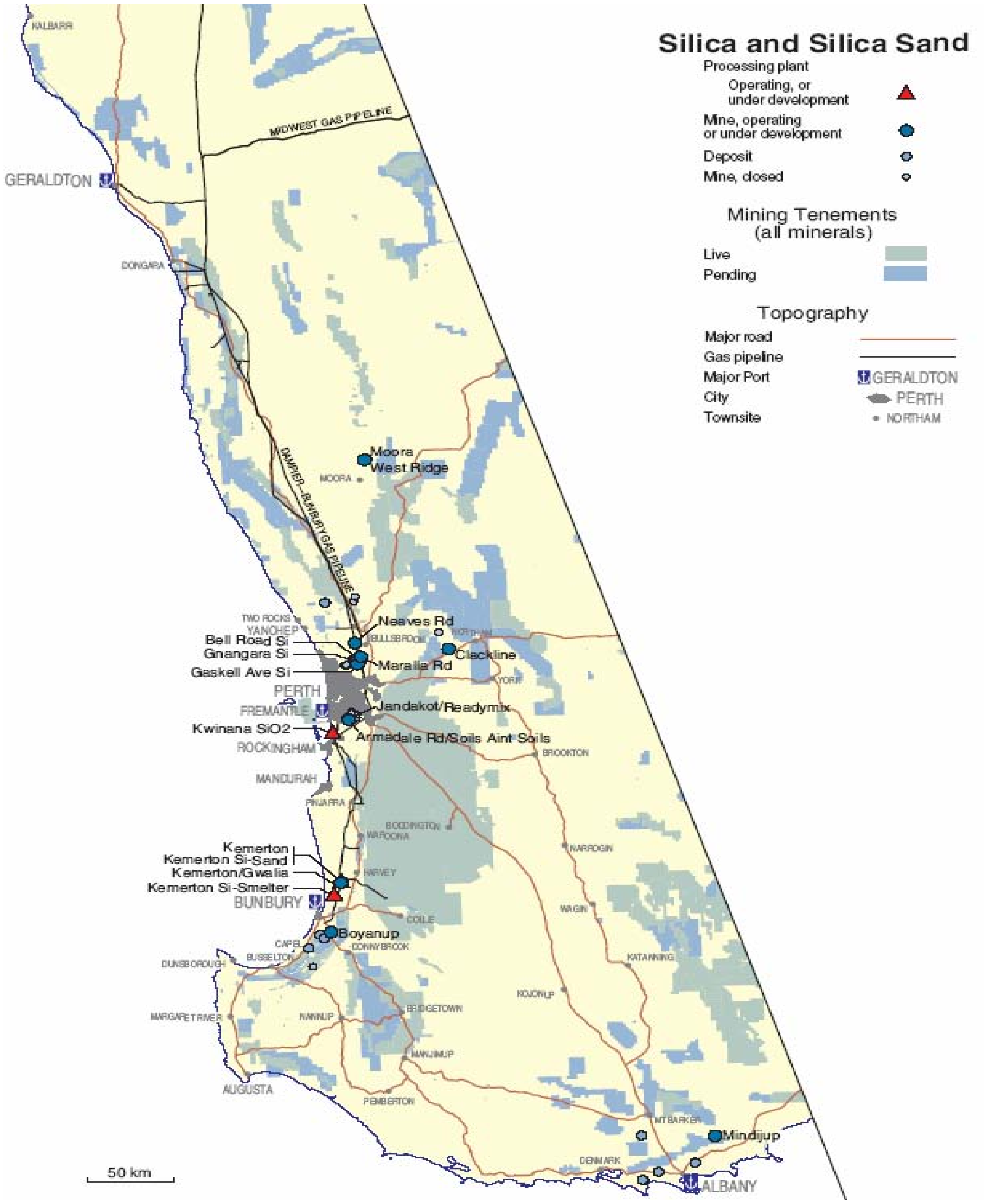

Figure 3.19: The Silica and Silica Sand Industry in the Study Region

3.4.4 Production and Costs

Simcoa is currently producing 32,000 tpa of silicon, which is the full capacity of its two furnaces.

In order to be competitive in the world's markets, it is necessary for Simcoa to produce both high quality material and maintain operating costs in the lowest quartile. Simcoa's key operating cost components are set out in Figure 3.20.

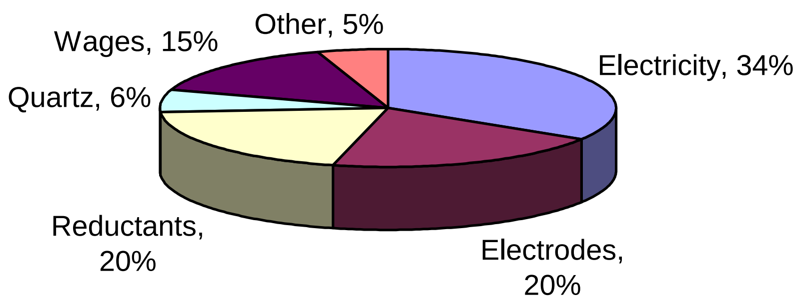

Figure 3.20: Simcoa Operating Costs

As depicted in Figure 3.21, the major competition in the premium end of the silicon market is from Brazil and South Africa, both of which have plants with lower or similar production costs than Simcoa. China is also rapidly increasing its supply to this market, albeit from a low base, using a low price marketing strategy.

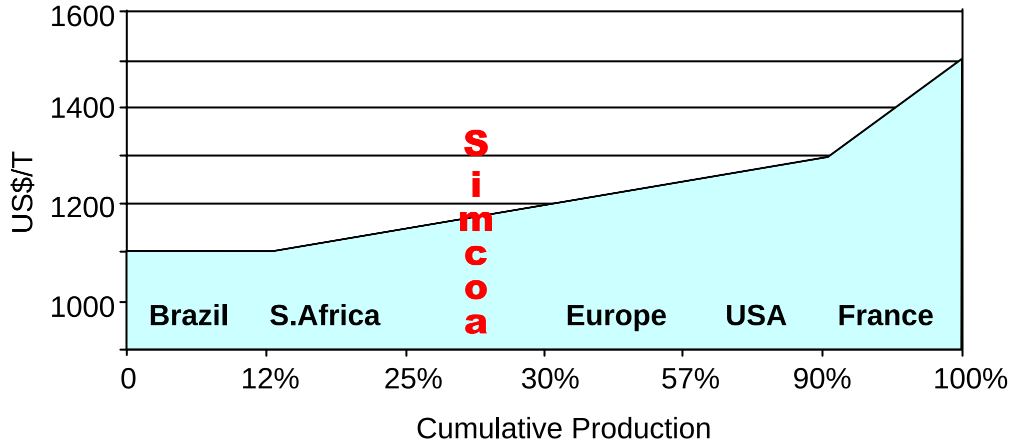

Figure 3.21: Premium Grade Silicon Production Costs by Country

In addition the Chinese have a large number of plants capable of producing extremely cheap silicon and these operations are the price setters at the lower quality end of the market. In 2003, 36.4% of western silicon demand was met by China (95%) and the CIS (5%) This is projected to increase to 42% in 2008 with China exporting in excess of 550,000 Tonnes.

As shown in Figure 3.22, the spot price for silicon metal has fluctuated significantly over the period 2000-2004 from US$1,100/t to its current level in excess of US$1,500/t.

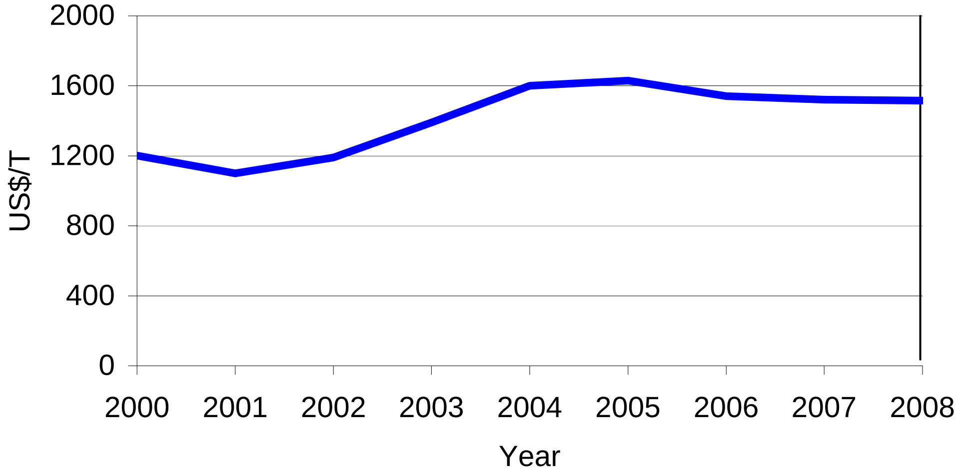

Figure 3.22: Silicon Metal – Spot Price 2002-2008[30]

To be world competitive it is important that a plant is profitable at the lowest point of the price cycle.

3.4.5 Power Consumption

Power consumption is estimated at 11 MWh/tonne with a total site demand of 45MW.

This is currently being supplied by Western Power on an interruptible basis.

3.4.6 Expansion Potential

World demand for silicon metal is increasing at an estimated rate of 45,000 tpa of which 55% is in the high end chemical sector of the market. This demand may be further increased by the prospective closure of some high cost operations in France and the USA.

While the major expansions in the top end of the market are expected to be in Brazil, Norway and South Africa there is substantial prospect for expansion by Simcoa. The key factor in the expansion decision will be the ability to market the silicon. This is dependent upon product quality and production cost.

[30] Source: CRU

Electricity costs represent more than 30% of total production costs and need to be maintained at levels that ensure Simcoa's plant is world competitive.

Simcoa is currently sourcing bids for power supply and is confident of achieving prices at levels that will maintain its world competitive position.

Other factors that would reduce Simcoa's costs include:

- the development of a rail spur into Kemerton allowing direct delivery of quartz by rail, and
- facilities to allow container shipments out of Bunbury.

Expansion could be either one or two furnaces with potential capacity of 20,000 tpa per furnace. This would result in an increase in power demand to 75 to 80 MW for installation of two furnaces to bring total production to 72,000 tpa. An additional 20 to 25 personnel would be required.

3.4.7 Downstream Processing

The potential to develop a silicones plant adjacent to Simcoa has been considered previously, however such a plant is normally located close to its markets and in an area with a critical mass of supporting industry.

3.5 Mineral Sands

3.5.1 Key Observations

Mineral Sands

i) The mineral sands industry has operated in Western Australia since 1956.

ii) While major companies have reserves to support mining for 15-20 years, it is considered unlikely that production capacity will be expanded significantly.

Synthetic Rutile

iii) The Becher process for synthetic rutile production uses coal as both a reductant and heat source. Consumption is 0.65 t/t of synthetic rutile.

iv) Production of coal briquettes with significantly reduced moisture levels can potentially increase kiln production by 20% without major capital investment.

v) Iluka has developed a gas based synthetic rutile process. The company is assessing potential sites, which include Trinidad, Portland (Victoria), South Australia and Western Australia.

vi) The potential exists for synthetic rutile producers to import ilmenite from either the eastern states or overseas to meet synthetic rutile feed requirements as reserves of processable ilmenite diminish over the next decade.

Titanium Pigment

vii) Power cost (at 7%) is not a key cost in titanium pigment production.

viii) Both W.A. producers have environmental approval to expand production by a total of 190,000 tpa.

ix) It is expected capacity will be increased by at least 100,000 tpa in the period 2004-2010.

Downstream Processing

x) Zircon flour, zirconia and fused zirconia are all produced in Western Australia. These are all energy intensive processes, and expansion decisions are dependent on competitive power and gas costs. Currently overall power consumption (less than 10 MW) is relatively small compared to major industrial projects.

xi) Titanium Metal – several companies are working on development of new, energy efficient processes for producing titanium metal. Potential exists for a pilot plant to be established at Kemerton over the next two to three years.

3.5.2 Industry Overview

Western Australia has been a major source of the world's mineral sands supply since the first mine was commissioned at Bunbury in 1956.

The industry currently comprises a small number of producers in Iluka, TiWest Joint Venture, Cable Sands, Doral Mineral Sands Pty Ltd ('Doral') and Millennium all of which are located in the Mid West or South West regions of the state, as shown in Figure 3.24

The locations of the major processing facilities for each of these companies are set out in Table 3.14.

Company	Major Mine	Dry Plant	Synthetic Rutile	Titanium Pigment
Iluka	Eneabba, Capel & Geraldton	Capel	Capel, Geraldton	-
TiWest	Cooljarloo	Chandala (Muchea)	Chandala (Muchea)	Kwinana
Cable Sands	Tutunup & Ludlow	Bunbury	-	-
Doral	Dardanup	Bunbury	-	-
Millennium	-	-	-	Bunbury

Table 3.14: Location of Major Mines and Processing Facilities

The total value of minerals sands exports in 2002/2003 was $746 million. The major countries to which they were exported were USA, Netherlands, Japan, UK and China, as shown in Figure 3.23.

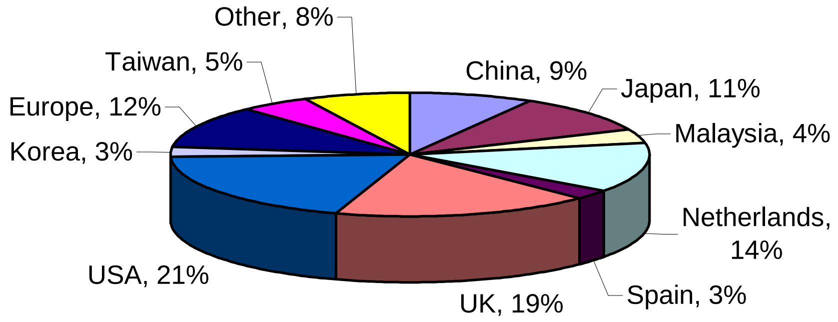

Figure 3.23: Western Australian Mineral Sands Exports 2002/2003[31]

3.5.3 Extent of Resources/Quality/Location

The major mineral sands ore bodies at Capel, Eneabba and Cooljarloo have been mined for 48, 32 and 15 years respectively. Consequently, reserves have been significantly diminished and the companies are starting to develop smaller deposits to augment production.

a) Iluka Resources Limited

Iluka has 30 to 40 ore bodies between Dunsborough and Geraldton that are estimated to have an average of 3 to 5 years life. Six concentrators and six mines will be operated at any time with a new mine being developed on average each year, giving a total reserve life of 15 to 20 years. Major mines currently being operated or planned for mining in the next five years are as detailed in Table 3.14.

Location	Notes
South West	
Yoganup extended	Close 2004/05
Yoganup West	5 years estimate
North Capel	5 years estimate
South Capel	10 years (previously mined)
Eneabba	2 mines operating
Mid West	
Gingin	2005-2010
Cataby	Large, low grade

Table 3.14: Location of Iluka's Major Deposits

[31] Source: DoIR

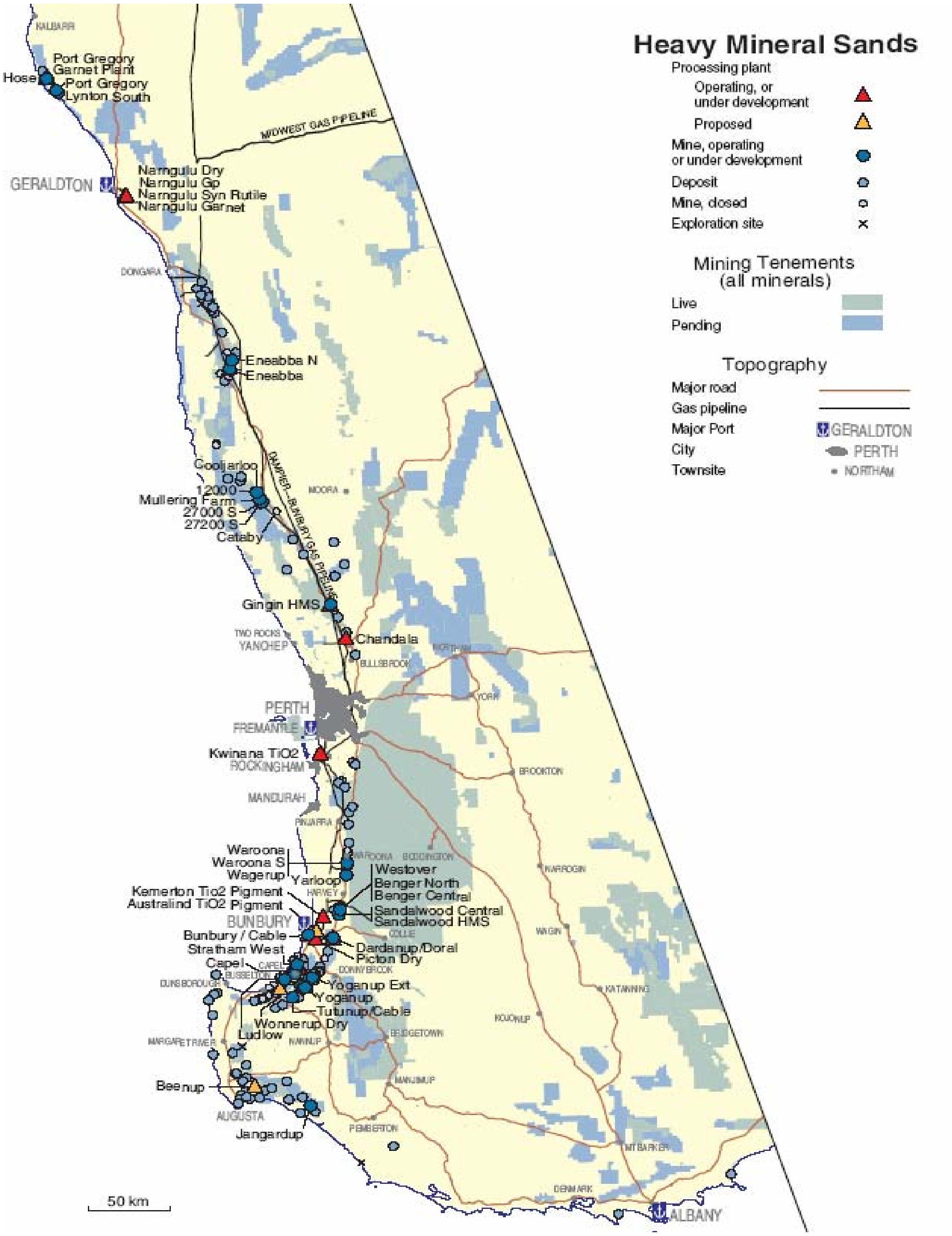

Figure 3.24: The Heavy Mineral Sands Industry in the Study Region

b) TiWest Joint Venture

TiWest's Cooljarloo operation is estimated by the company to have in excess of 15 years mine life remaining. The company also has three other leases:

- a new lease at Cooljarloo
- Jurien Bay leases (2 to 3 years life)
- Magnetic Minerals leases at Dongara (owned by TiCor Limited)

These leases will be developed to supplement production from Cooljarloo as required.

c) Cable Sands (WA) Pty Ltd

Cable Sands has recently become part of an integration with BeMaX Resources NL and Sons of Gwalia Ltd's mineral sands operations.

Cable Sands does not release specific resource information. A review of published information indicates that the company has a number of potential mining areas in the South West region including: Tutunup, Rowindinup, Happy Valley and Ludlow. Reserves are estimated at 6-8Mt, giving the company a projected mine life of up to ten years at current production rates.

d) Doral Mineral Sands Pty Ltd

Doral has a stated 10 years of reserves based on current production levels, although recent exploration is understood to have extended operating life a further 4 to 5 years.

3.5.4 Production and Costs

a) Mining and Mineral Processing

The ore is recovered either by wet (dredge) or dry (scraper) mining and the heavy mineral is separated from the sand by gravity to produce a concentrate containing 96% heavy mineral.

The concentrate is then separated into the individual minerals by magnetic, electrostatic and gravity separation. As shown in Table 3.15, some 1.8Mt of ilmenite was produced in 2002/2003, the majority of which is used as feed for the synthetic rutile process. Other major products are rutile and zircon.

Company	Product				
	Ilmenite	Rutile	Zircon	HiTi Leucoxene	Staurolite
Iluka - Mid west	397,861	69,992	245,492	-	-
Iluka - South West	635,177	-	55,639	13,702	-
TiWest	420,000	25,000	70,000	15,000	2,000
Cable Sands	307,650	3,926	19,133	3,200	
Doral - Dardanup[32]	110,000	-	10,000	10,000	-
Totals	**1,870696**	**98,848**	**400,264**	**41,902**	**2,000**

Table 3.15: Mineral Sands Production 2002-2003

Costs vary from operation to operation depending on mining methods (dredge or dry mining) and the distance between the mine and the dry plant. The major mining and processing costs are wages, mining, transport, power and maintenance, as shown in Figure 3.25.

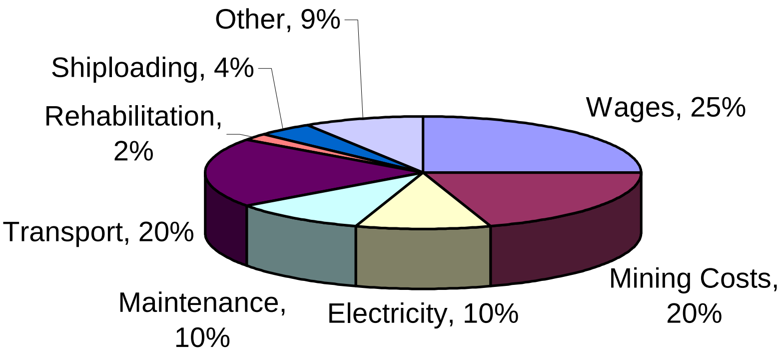

Figure 3.25: Mineral Sands Production Operating Cost Components[33]

b) Synthetic Rutile

Synthetic rutile is produced using the modified Becher process by both Iluka at Capel and Geraldton, and TiWest at Chandala.

Ilmenite is processed through a synthetic rutile plant in three stages, reduction, aeration, and acid leaching. The process uses coal as both the reductant and source of heat. Iluka's Capel plant recovers excess heat to generate 7.5 MW of power, which is just over half of its requirements.

[32] Projected capacity
[33] Source: GBRM data-base

Synthetic rutile production in 2002/03 was 691kt from, comprised as shown in Table 3.16.

Company	Location	Production (kt)
Iluka	Geraldton	215
	Capel	256
TiWest	Chandala	220
Total	691	

Table 3.16: Synthetic Rutile Production 2002/03

Of this 30% feeds directly to the local titanium pigment plants and the remainder is exported. The synthetic rutile ('SR') process takes the ilmenite valued at $120/t to a value of $530/t. As 1.60 tonnes of ilmenite is consumed per tonne of SR the value upgrade ratio is 2.75 times.

The principal cost components of synthetic rutile production are, as illustrated in Figure 3.26, associated with ilmenite, coal, labour and maintenance. An estimated 450 people are employed in Synthetic Rutile production across the three sites.

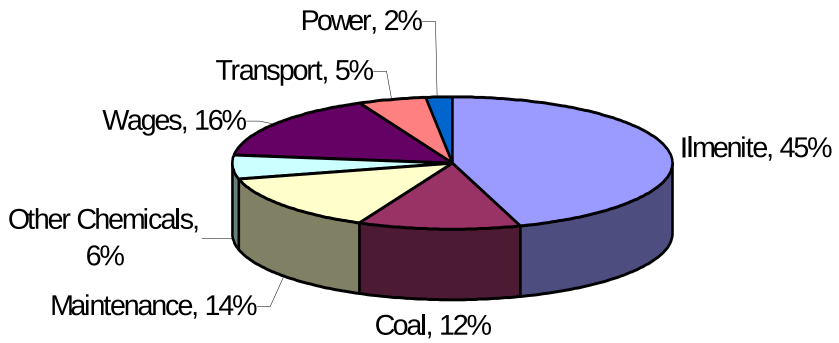

Figure 3.26: Synthetic Rutile Production Operating Cost Components[34]

Coal usage is approximately 0.65 T per tonne of synthetic rutile. Iluka at Capel uses slightly more coal (0.75 t/t) as it generates its own electricity. Power consumption is 0.06 MWh/t.

c) Titanium Pigment

There are two titanium pigment plants in the study region, details of which are set out in Table 3.17. TiWest operates a plant at Kwinana, while Millennium

[34] Source: GBRM data-base

has a facility that is spread across two sites at Kemerton and Australind near Bunbury. Both plants use the chloride route process which combines synthetic rutile with petroleum coke and chlorine to produce titanium tetrachloride. This is then purified and oxidised to titanium dioxide which passes through the finishing process prior to shipping. Some 90% of the 200,000 tpa of pigment produced is exported, mainly to Asia.

Company	Location	Production tpa	Employment
Millennium	Kemerton, Australind	95,000	300+
TiWest	Kwinana	106,000	300+

Table 3.17: Western Australian Titanium Pigment Production

Based on an average price for Australian pigment exports to Asia in 2003 of US$1,730/t ($2,470/t), the value of pigment produced is $494 million.

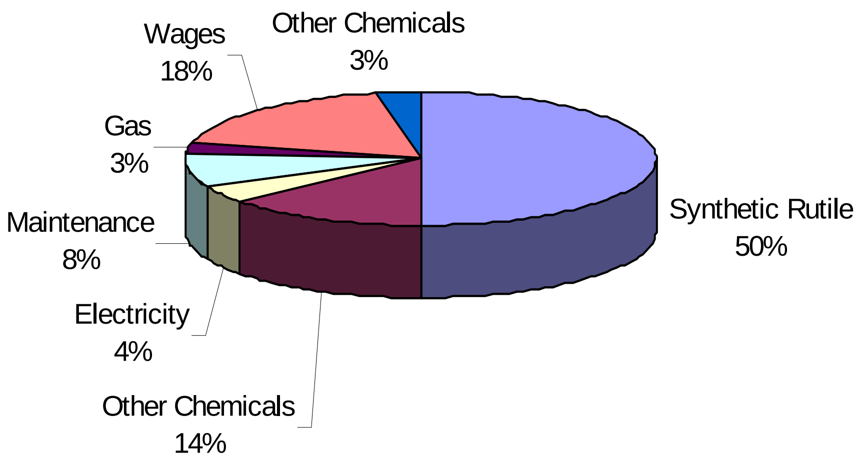

Figure 3.27: Pigment Production Operating Cost Components[35]

As shown in Figure 3.27, the major costs in the pigment production process are the synthetic rutile feed, wages and salaries, other chemicals and maintenance. The costs of natural gas (5 GJ/t) and electricity (0.5 MWh/t), while important in ensuring the plants are at the low end of the cost scale, represent less than 10% of operating costs.

Capital cost is estimated at $250 million per 100,000 tonnes of production capacity and based on consumption of 1.06 tonnes of SR per tonne of pigment, the value upgrade ratio is 3.5 times.

Western Power has developed a co-generation plant adjacent to the TiWest pigment plant. TiWest uses steam produced from the power plants waste heat.

[35] Source: Published data

The plant produces TiWest's entire power requirement and the agreement isolates the pigment plant from potential grid shutdowns.

3.5.5 Energy Consumption

Energy consumption is a significant but not major cost in each step of the processing of a mineral sands deposit to titanium pigment.

Mine & Dry Plant	Electricity }	10%
	Gas drying }	
	↓ 4.5%	
Synthetic Rutile	Coal }	12%
	Electricity }	2%
	↓ 9.25%	
Titanium Pigment	Gas }	2%
	Electricity }	4%

While direct power cost in the titanium pigment process is approximately 6% the overall power requirement to produce a tonne of titanium pigment is closer to 15% of total costs when allowance is made for the input into ilmenite and synthetic rutile. This would be further increased to close to 20% when the power consumed in producing chlorine, oxygen and nitrogen feedstocks is included.

3.5.6 Expansion Potential

a) Mineral Sands

Mineral sands mining has been in operation in Western Australia for almost 50 years and as a result the major deposits have been mined to the point where reserves are now limited.[36] While these are sufficient to maintain the current operations at capacity, it is considered unlikely that significant expansion will take place, and in the next 10 years it may be necessary to import ilmenite as feed to maintain the synthetic rutile operations at capacity.

b) Synthetic Rutile

Iluka is currently working on a new synthetic rutile process which uses hydrogen rather than coal as the reductant in the process. It is projected that this process will be initially commercialised in South Australia or Trinidad treating ilmenite from the Murray Basin. As this process can treat any grade of ilmenite and can

[36] See section 3.4.2 for more details.

also remove chrome, there is a potential that a plant could be built in Western Australia. However Iluka states that this would not be for several years and would probably replace current capacity.

Over the next five to six years it is anticipated that any production increases will be due to process changes/debottlenecking within current plants. A major 20% increase could be possible from all kilns if the briquetting process for Collie coal is successful as the moisture reduction will significantly improve heat transfer in the early part of the kiln.

Such an expansion would take SR production to over 800 ktpa. However this would be achieved with only marginal increase in power consumption.

c) Monazite

Monazite is also found in mineral sands and was, until the early 1990's separated out and sold for processing into the individual rare earth [37] components. Following a rapid expansion of Chinese rare earths production in the late 1980's and early 1990's, the market for monazite evaporated and the product is now returned to the mine with the other gangue materials from the mineral sands process.

With Chinese production now moving downstream to include rare earth products, it is becoming difficult for processors in other countries to secure basic rare earth materials. Consequently the potential exists for monazite to be produced by mineral sands producers and possibly, though less likely, to be processed into individual rare earths. These processes are not energy dependent.

d) Titanium Pigment

The titanium pigment industry has been impacted by several factors which have resulted in a flat market over the past five years. Strong growth in Chinese imports over the past six years from 82 ktpa in 1999 to 261 ktpa in 2003 has been the one major positive for the market. This makes China the world's largest importer of TiO_2 pigment and as the majority of pigment trade is inter regional, places Western Australia in a strong position to increase production to service China's growth.

Both companies have environmental approvals in place to expand, as set out in Table 3.18.

[37] The rare earths are the elements of the lanthanide series of the periodic table. The rare earth metals share many common properties, including high electrical conductivity, that makes them difficult to distinguish and separate.

Company	Current capacity tpa	Approved capacity tpa
Millennium	95,000	195,000
TiWest	106,000	180-200,000

Table 3.18: Approved Scope for Titanium Pigment Expansions

While the tight markets and pricing do not support current expansion, the pigment supply/demand curve is in balance, as illustrated in Figure 3.28. Continue rapid growth in China supported by the predicted upswing in the world's economy could result in the need to expand plant capacity rather than meeting increased demand through debottlenecking as has been the recent trend.

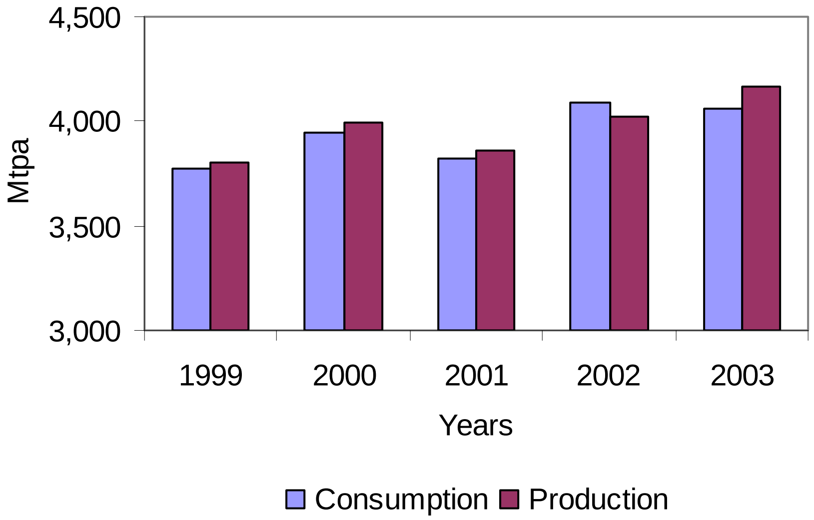

Figure 3.28: World Pigment Production and Consumption 1999-2003[38]

Consequently it will be important to ensure that the operating costs of the Western Australian plants are cost competitive with expansion potential elsewhere. To ensure this it is important to keep all major cost areas including natural gas and power cost competitive on an international basis.

3.5.7 Downstream Processing

Several Areas of downstream processing have been developed in the area of mineral sands, in addition to synthetic rutile and titanium pigment. These include production of zircon flour, zirconia and zirconium chemicals, fused zirconia and titanium metal.

[38] Source: AME

a) Zirconia Flour

Some 10,000 tpa of zircon is ground for Western Australian mineral sands companies in Western Australia and further tonnages are ground in Europe.

b) Zirconia and Zirconium Chemicals

Millennium's zirconia plant at Kwinana has recently been purchased by Doral. This plant produces 600 tpa of zirconia and zirconium chemicals. Raw material for the plant is zirconium oxychloride sourced from China.

While both zircon flour and zirconia production are reasonably energy intensive, power consumption is relative small compared to major industrial plants and as such they have not been included in forward projections.

c) Fused Zirconia

AFM produces 4,200 tpa of fused zirconia from its Kwinana plant.

Zircon is heated to over 2,800^{o}C in an electric arc furnace and disassociates to molten zirconia and silica. Power demand for this process is approximately 2.5 MW. The zirconia is cooled to room temperature before crushing to meet customer's size requirements.

The company currently has no plans to increase fused zirconia production in the next two to three years, but there is some long-term potential particularly if the ownership of the company is rationalised from its current two major shareholders.

d) Titanium Metal

Some 70,000 to 80,000 tpa of titanium sponge is produced world-wide each year using the Kroll Process. World capacity is over 100,000 tpa with production being tailored to meet demand.

Prices in 2003 were US$7.28/kg, which was the lowest level for ten years.

Opportunities are emerging with growth in aerospace, armour, industrial and consumer markets result in mothballed plants being re-commissioned and new capacity being installed. There are several companies currently working on new titanium metal production processes that are less electricity intensive. The target of these processes is to halve the production costs so that titanium can compete against other light metals.

There is the potential to establish a titanium metal pilot plant at Kemerton over the next two to three years. A commercial scale-up decision will depend on internationally competitive electricity to service a demand of up to 20 MW demand.

3.6 Nickel/Cobalt

3.6.1 Key Observations

i) WMC Resources Ltd has a nickel refinery at Kwinana with a capacity of 67,000 tpa.

ii) WMC Resources Ltd is one of the world's low cost producers.

iii) Refinery capacity will increase to 70,000 tpa by the end of 2004, 80,000 tpa by 2007-2008 and 100,000 tpa by 2010-2015.

iv) While power consumption at 15 MW and gas consumption at 9 TJ/d represent significant process costs, the expansions will take place at current energy price levels.

3.6.2 Industry Overview

While there are no operating nickel mines in the study region and no known reserves, WMC Resources Limited ('WMC') has a nickel refinery at Kwinana.

The Kwinana Nickel Refinery ('KNR') commenced operations in 1970. The nickel produced at the refinery originates from nickel sulphide ores mined at Kambalda, Leinster and Mt Keith, located as shown in Figure 3.29. The refinery receives nickel matte from the Kalgoorlie Nickel Smelter ('KNS') and produces high quality nickel briquettes and nickel powder with a purity of >99.8% Ni. Recovery at the plant is 97.8%.

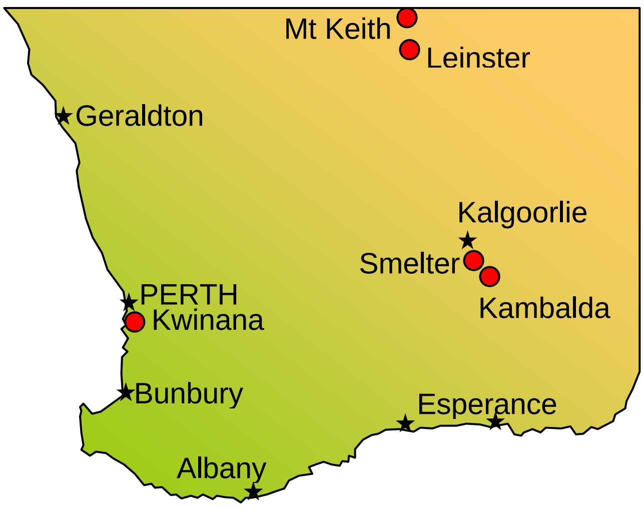

Figure 3.29: Location of Western Mining Operations

The capacity of the Kwinana refinery will be increased from 67,000 tpa to 70,000 tpa by the end of 2004, making it the world's third largest refinery. This follows previous capacity increases from 60,000 tpa, that have been achieved in 2000 by continual debottlenecking of the production circuit

3.6.3 Reserves

While there are no nickel reserves in the study region, there are substantial reserves in the North East Goldfields, development of which could result in shipment through the port of Geraldton.

3.6.4 Production Costing

WMC is the world's third largest nickel producer and its highly efficient integrated mine, smelter and refinery facilities have operating costs that place it close to the bottom of the cost curve. This is illustrated in Figure 3.30.

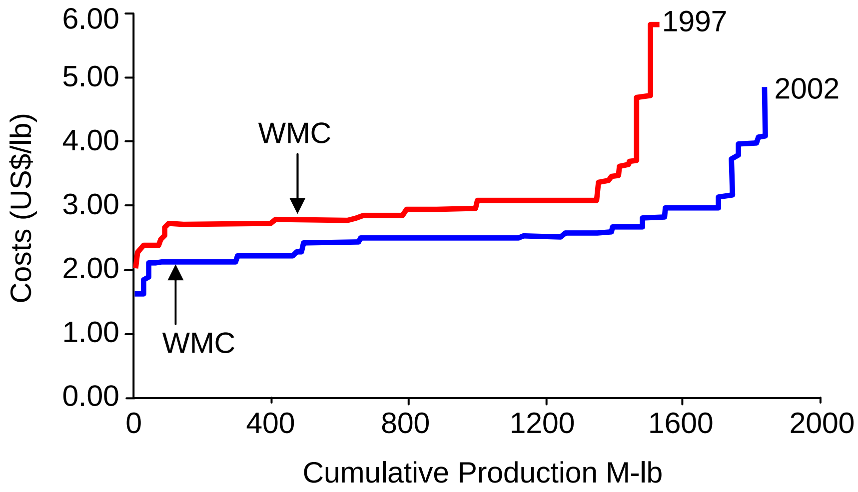

Figure 3.30: Nickel Smelter Cost Curve

With strong growth predicted in nickel demand over the next five years, WMC is well placed to increase production and maintain market share.

3.6.5 Energy Consumption

WMC has long term power purchase contracts with Trans Alta that were established as part of the sale of the power generating capacity at WMC's mines[39].

e) Electricity

The refinery currently consumes 15 MW of electricity. This has the potential to increase to 20 to 25 MW over the next five years.

[39] In 1998, WMC sold its power generating capacity (at Mt Keith, Leinster, Kalgoorlie and Kambalda) and its interest in the Goldfields Gas Pipeline.

f) Gas

Gas is used in the refinery process both as fuel, for steam generation, and as a reductant. Gas consumption is estimated at 3,300 TJpa and is supplied to WMC through the Parmelia pipeline.

The feasibility for co-generation of power and steam was studied in 2000 but it was decided not to proceed at that stage. The option is currently being reassessed.

3.6.6 Expansion Potential

Several expansion scenarios are currently being investigated by WMC and it is considered likely that production will be increased to 80,000 tpa over the next three to five years, with potential for further expansion to 100,000 tpa of refined nickel within the next 10 years.

3.6.7 Downstream Processing

While a significant tonnage of nickel concentrate may be exported via Geraldton over the next decade from mines developed in the NE Goldfields, it is unlikely that the development of a new smelter complex could be supported by the existing reserve base within Western Australia. WMC have capacity to expand their existing smelter at a relatively low capital cost compared to a new "Greenfield's" smelter.

It is more probable that new smaller scale hydrometallurgical concentrate processing facilities will be introduced by either WMC and/or local nickel industry participants. The most probable location for these potential new plants would be in the Goldfields.

Value adding of nickel metal products to stainless steel or other speciality alloys may be expanded beyond the current small scale facility at Welshpool. Development of any large processing facilities could be located at either Kwinana or Kemerton.

3.7 Tantalum/Spodumene/Tin

3.7.1 Key Observations

i) While Sons of Gwalia Ltd is a major producer of tantalum, world consumption is relatively small and processing takes place close to key markets in US, Europe and Asia.

ii) Lithium carbonate and associated chemicals are predominantly produced from brine sourced operations in Chile and China. Rock spodumene feeds the glass and ceramics markets.

3.7.2 Overview

The Sons of Gwalia Ltd ('SOG') Greenbushes operation is one of the world's largest sources of tantalum and also produces lithium minerals (spodumene[40]) and tin. Tin is produced as a bi-product of the tantalum production.

Despite SOG being placed in administration in August 2004, the Greenbushes project is expected to continue to operate.

3.7.3 Extent of Resources/Quality/Location

Reflecting changes in market demand, SOG reduced production at Greenbushes in 2003 with targeted production of 400 tonnes in 2004. The section of the tantalum deposit that is accessible by open cut mining is reducing in grade, with resultant increase in production costs. SOG has carried out a feasibility study to develop the underground section of the mine and has recently announced its intent to restart this section of the operation. This has been reconfirmed since SOG was placed in administration.

The spodumene deposit has an estimated mine life of over thirty years at current production rates.

3.7.4 Production and Costs

Production from Greenbushes operation in 2002/03 was as set out in Table 3.19.

[40] Spodumene is Lithium Aluminium Silicate

Product	Production (tonnes)	Value ($ million)
Tantalite	909	0.8
Spodumene	102,573 (6,162 Li_20)	4.5
Tin	763	0.13

Table 3.19: Greenbushes Production 2002/03

3.7.5 Energy Consumption

SOG sources electricity from Western Power. There is no gas pipeline servicing Greenbushes. Energy is not a key factor in the company's operating costs.

3.7.6 Expansion Potential - Tantalum

The tantalum market is again enjoying increased demand with prices returning to previous highs of US$40/lb to US$50/lb. Strong growth is being experienced in both the electronics and turbine markets and demand is close to the record levels achieved at the peak of the I.T. boom in 2000. With SOG supplying over half of global demand it is considered likely to expand production in order to stabilise the market and discourage new entrants.

3.7.7 Downstream Processing

a) Tantalum

As the world's largest producer of tantalum, SOG has an off-take agreement for in excess of 85% of its production with the world largest tantalum consumers Cabot Corporation of the USA and HC Stark a division of the Bayer Group in Germany. These companies manufacture a variety of chemicals, powder ingots and alloy from plants that are located close to major markets in USA and Europe.

Consequently it is considered unlikely that any downstream processing will be carried out in Australia.

b) Spodumene/Lithium

While SOG has the world's major hard rock deposits of lithium, its leadership in the world market was displaced in 1997/98 when the Chilean producers reduced prices from $4.50/kg to $2.10/kg for their brine based production[41]. Brine based production of lithium carbonate now supplies over 85% of the market, and SOG has suspended production from its Lithium Carbonate plant.

[41] Chilean and Chinese brine containing 6%Li

Lithium carbonate is the feedstock for other lithium chemicals including lithium chloride (the raw material in producing lithium metal). Lithium carbonate is also used in the production of aluminium

The majority of international spodumene production goes into glass and ceramic markets. On this basis the potential for further processing in Western Australia is considered to be low.

3.8 Ferro Alloys

3.8.1 Key Observations

i) The potential exists to produce ferro-silicon in the study region.

ii) For the past decade, the ferro-silicon market, particularly in S.E.Asia, has been dominated by the Chinese.

iii) Power shortages in China have resulted in supply shortfalls.

iv) A power price in the 4c/kWh range plus competitively priced reductants would be required for ferro-silicon production in the south west cost region to be world competitive.

3.8.2 Industry Overview

Ferro alloys are alloys of iron that contain sufficient concentrations of one or more chemical or metallic elements to modify the properties of materials to which they are added, mainly steel.

Ferro alloys are considered in two groups:

- Bulk alloys – ferro-chrome, ferro-manganese, ferro-silicon, silico-manganese
- Noble alloys – ferro-cobalt, ferro-molybdenum, ferro-nickel, ferro-niobium, ferro-titanium, ferro-tungsten ferro-vanadium and ferro-zirconium.

Bulk alloys represent 90% of the world's ferro alloy production while noble alloys are produced in much smaller tonnages but have specialist properties and attract higher prices.

For the production of these alloys to be considered feasible in the study region it would be necessary to have ready access to the key raw materials. For this reason ferro-chrome, ferro-manganese and silico-manganese have not been considered as production would be more likely in the Pilbara where these materials are produced.

In addition several of the noble metals have been discounted as either the raw material is not produced in the region or the market is relatively small. This has discounted ferro-molybdenum, ferro-niobium, ferro-titanium, ferro-tungsten, ferro-zirconium and ferro-cobalt.

It is also considered unlikely that a ferro-nickel plant will be developed unless it is located adjacent to a major nickel producer with appropriate reserves and production process. Consequently ferro-silicon is the only plant that is considered to have a high potential for development in the south west coast region.

3.8.3 Ferro-silicon

a) Overview

Chinese production accounts for over 40% or 5 Mtpa of world production with Norway 12%, USA 11%, and Brazil 10%. India is the other major producer in the S.E.Asian region. There is currently no ferro-silicon production in Western Australia.

During the past twelve months both Chinese and Indian production has been under extreme pressure due to power shortages resulting in significant capacity being placed on care and maintenance.

Ferro-silicon is used primarily as an alloying element in the production of iron and steel. The rapid increase in steel production has led to increased demand for ferro-silicon and the closure of capacity in China and India has resulted in further strengthening of demand and a corresponding increase in price.

b) Extent of Resources, Quality and Location

The major raw materials required for ferro-silicon production are quartz, iron ore, coke and coal.

Quartzite

Quartzite in lump form could be sourced from a number of deposits such as Simcoa's mine at Moora. Reserves are sufficient to meet silicon and ferro-silicon demands for 20 to 30 years.

Iron Ore

Iron ore could be sourced from one of the new Mid West producers as lump hematite. Alternatively the synthetic rutile producers have a waste iron product which could be used if purity levels are acceptable.

Coke/Coal

Metallurgical coke is not presently produced in Western Australia and would need to be imported either from Indonesia or the eastern seaboard. Alternatively a charcoal source similar to that used by Simcoa could be used.

Coal would need to have low ash and sulphur contents. It is likely that NZ coal could be mixed with Collie coal to produce an acceptable mix. The production of char from Collie coal could also enhance its use in such processes.

c) Production Costs

Initial production has been based on a 50,000 tpa plant which would require capital of approximately $80 million to develop. The major cash costs of production are estimated to be as depicted in Figure 3.31.

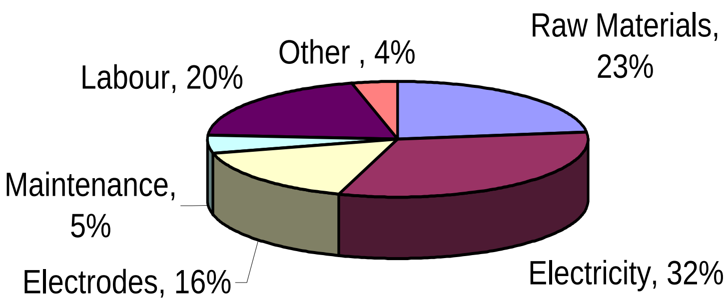

Figure 3.31: Cost estimates associated with Ferro Alloy Production

Raw material requirements[42] for production of 50,000 tpa of ferro-silicon (containing 75% silicon) are as set out in Table 3.20.

Material	Requirement (t per t)	Total Requirement (t)
Quartzite	1.854	92,700
Iron Ore	0.265	13,250
Coke	0.408	20,400
Coal	0.541	27,050

Table 3.20: Raw Material Requirement for Ferro-silicon Production

Based on a power price similar to that set for silicon metal (ie, 3.5 c/kWh) the production cost for ferro-silicon would be approximately $700/t.

During the first half of the 1990's the ferro silicon price hit a low of between US$500 to US$550/t (ie, $700 to $760/t). Price levels over the period 2001 to 2004 are presented in Figure 3.32.

On the basis of historic low prices, a Western Australian plant would require a power price in the range of 3.5c/kWh to be cash neutral at the bottom of the market.

[42] Source: DoIR prefeasibility study on ferro-alloys.

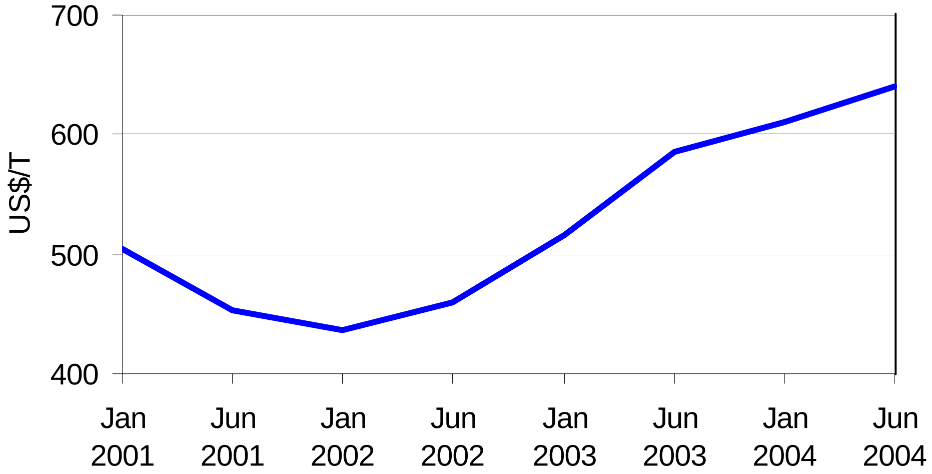

Figure 3.32 Ferro Silicon Price 2001 to 2004

d) Power Consumption

Power consumption for a ferro-silicon plant is approximately 8 MWh/t. Furnace off-gases typically contain 60% to 70% carbon monoxide which can be used for power generation. The Norwegian ferro alloy industry indicates that 20% of the energy used in the production of ferro alloys can be recovered as electrical energy through power cogeneration plants. On this basis there is potential to recover 1,200 to 1,600 kWh of electrical energy per tonne of alloy produced.

3.9 Other Minerals in the Study region

There are several other minerals produced in the study region that are not major consumers of power or have little potential for energy based downstream processing. Accordingly, they have not been reviewed in detail

The following brief comments are provided for completeness of coverage.

3.9.1 Silica Sand

Silica sand is mined from a number of deposits in the study region, including Jandakot and Gnangara in the Metro area, Kemerton near Bunbury and Albany.

Production from Western Australia was stated to be 568 k in 2003, representing some 0.3% of total world production of in excess of 150 Mtpa. Major uses for silicon sand are as follows:

	%
Glass Production	40
Foundry Sand	23
Abrasives	5
Hydraulic Fractioning	5
Recreation	5

The majority of Western Australian silica sand is glass grade and is exported to Japan for use in glass production. Japanese companies are also involved in ownership of the majority of deposits.

Selected silica sand feedstock may be upgrade to a high level of purity as outlined in Table 3.21 or processed to produce other products. Western Australian silica sand is in the low purity end of the tabulated range and is classified as glass grade sand.

Purity	Total Impurity Level	Source	Relative Price
Low	>5,000	Silica sand or quartz as flotation tailings. Subdivided by end use e.g. glass-grade, filter sand, silica flour etc.	1
Medium	300-500	Quartz after complete physical and chemical beneficiation	12-20
Intermediary	300-500	Quartz with high-purity capability through further chemical beneficiation. Quartz double floated, magnetically treated e.g. Quintus Quartz.	30-40
High	2-50	Quartz where impurity levels are strictly restricted to lattice impurities. Natural quartz acid leached, magnetically separated, calcined or hot chlorinated, e.g. Lota quartz, Rock crystals, and Lascas.	250-560
Ultra-high	1-8	Exceptional natural quartz after complete physical and chemical beneficiation e.g. lota 6. Precipitated silica from high purity silicon tetrachloride	600-6,000
Hyper	<1	Excludes natural quartz crystal. Silicon compound glass derived from the oxidation of hyper pure silicon powder.	>40,000

Table 3.21: Classification of Silica by Purity [43]

3.9.2 Fused Silica

Fused silica may be produced from silica sand by one of the following four alternative methods:

- carbon electrode (most common);
- carbon arc;
- plasma arc; or
- gas fired continual extrusion.

In the carbon electrode process, silica is fed into a furnace with two carbon electrode probes achieving temperature at the centre of 2,300^{o}C. After 4 to 5 hours an unmelted outer-shell of silica acts as insulation around an egg-shaped fused centre which on cooling is crushed and sized. On average 1.2 T of quartz silica and 1,500 kWh of electricity is required to produce 1T of fused silica. The

[43] Source: Industrial Minerals

product has a wide range of uses across a number of industrial products and processes.

While the potential exists to produce fused silica in Western Australia, total world demand is estimated at only 150,000 tpa and major producers are located near the major markets in Asia, Europe and the USA. Production from China has also had a significant impact on the market over the past decade.

3.9.3 Silica Carbide

Over 1 Mtpa of silicon carbide is produced each year with the major end uses being abrasives, refractories, ceramics and metallurgical applications.

Production of silicon carbide takes place in an Acheson furnace where the silica and carbon sources are combined at in excess of 2,400^{o}C. High temperature and pure (99.9%) SiO_2 are required to ensure conversion to high quality SiC. Process energy requirements total 4.3 MW/t.

Over the past decade China has become the dominant producer of silicon carbide with other production in Europe, Japan, US and Canada, and South America aimed at meeting local consumption. Production levels for 2003 are set out in Table 3.22.

Country	Production (T) 2003
China	455,000
Norway	80,000
Japan	60,000
USA & Canada	43,000
Mexico	45,000
Brazil	43,000
Germany	36,000
Venezuela	30,000
France	16,000
Other	200,000
Total	**1,010,000**

Table 3.22 World Production of Silicon Carbide

With over 50% of production in the Asian market zone there appears to be limited potential for development of production in the south west coast region, particularly since there is no shortage of raw materials in the major producing/consuming countries.

3.9.4 Glass Production

Over the past decade various studies have been carried out for the establishment of glass cullet and bottle plants in Western Australia.

The dominant costs for this type of production are raw materials and wages/salaries which together represent 85% of total operating costs. Energy, which is usually gas, represents less than 10% of operating costs and as such a low energy price is not considered to be critical for development of this type of plant.

3.9.5 Garnet

Some 128,000 tonnes of Garnet were produced in 2003 by GMA Garnet Pty Ltd from deposits at Port Gregory, north of Geraldton. This represents some 22% of world production.

The garnet is separated from gangue materials through gravity and magnetic methods before sizing into various products for use in abrasives, filtration and gemstones. Production is exported from Geraldton mainly to major importing countries in Asia (Japan, South Korea, Singapore, and Taiwan) and Europe (UK, France and Germany).

There is no apparent potential for a major energy use associated with this product.

3.9.6 Talc

120,000 tonnes of talc were produced in 2003 by Luzenac from its deposits at Three Springs. Luzenac is the world's largest talc producer with operations in Europe, USA, and Asia. Some of the talc is processed and milled at Three Springs to produce material for the high value end of the market while the remainder is exported as lump material to other Luzenac processing plants around the world.

There is no apparent potential for power intensive processing.

3.9.7 Clay

There are a significant number of clay producers in the region, and a number of other deposits are currently under study for development.

While clays may be consumed in energy intensive industries, such as brick works, clay processing is not a major energy consumer and as such this mineral suite has not been considered further.

Several studies are currently being carried out on a number of high-grade kaolin deposits in the study region, and kaolin has previously been recovered and exported from the Greenbushes' deposit. These potential developments will not be major energy consumers. They will however need good transport facilities between the mine and port.

3.9.8 Gold

Studies are currently being finalised on the feasibility to recommence mining of the Wandoo orebody at Boddington. Power demand for this project is projected to be 20 MW. Factors other than energy price are the determinants of viability for this type of project.

There is also potential for future gold mining at Donnybrook, but, as for the Boddington mine, energy costs, will not be the determinant of viability.

3.9.9 Other Minerals

There is some potential for base metal mineralisation to be located at the Balingup and Biranup Metamorphic Complexes. Hampton Hill Mining NL recently announced (Australian Stock Exchange May 11 2004), an intersection of 4.1 metres grading 2.2%Zn, 0.2%Cu, 0.5% Pb, 0.12 g/t Au and 14 g/t Ag at Wheatley associated with semi-massive sulfides. This project is still in the early stages of exploration.

Other minerals found in the study region and worked on a small scale include gypsum, diatomaceous earth, limesand, limestone, spongolite, graphite, kyanite, sillimanite, and barite none of which are significant energy consumers. Although some of these current or potential industries are, or could be, significant users of energy (for example, in the production of lime or cement) in discussions with the Study Sponsors it was agreed that detailed investigation of such projects was not warranted for the purpose of this Study.

3.10 Energy Demand for Minerals Development

3.10.1 Project Requirements

The energy requirements of the identified development opportunities need to be assessed with regard for the type, quantity and price of energy that is required in order to achieve viability[44]. A range of different energy types are required for the identified minerals development opportunities of the study region, including:

- coal - as a reductant in production of synthetic rutile, silicon, DBI/HBI/Pig iron and ferro-alloys;
- gas as a direct heat source, for example, in the calcining of alumina;
- gas or coal as a heat source to produce steam in alumina production; and
- electricity which, in the study region, has typically been produced using either coal and gas.

In some cases there are also specialist requirements (for example, the use of wood as a source of charcoal reductant for use in silicon metal production).

Relevant information on the type, quantity and target price of energy for each of the development opportunities reviewed in Sections 3.2 to 3.9 is set out in Table 3.23. Should all of the identified development opportunities proceed, the total additional requirement for energy in the south west coast region will be as set out in Table 3.24.

Aggregate Energy Requirement		
Gas PJ/a	Coal ktpa	Electricity MW
45 - 50	2,400 - 2,500	1,200 - 1,300

Table 3.24: Aggregate Energy Demand of all Development Opportunities

[44] As noted elsewhere, energy prices are not the only determinants of project viability.

Project		Energy Requirement					
Description	Increase Mtpa	Electricity		Coal		Gas	
		Quantity	Price	Quantity	Price	Quantity	Price
Bauxite/Alumina	3.3			400 ktpa	$2.25/GJ	29.2 PJ/a	$3.50/GJ
Fused Alumina	0.01	2.5 MW	4 c/kWh				
Aluminium Smelter	0.7	1,000 MW	2.6 c/kWh				
HIsmelt – use of Collie coal	no change			1,000 ktpa	$2.00/GJ		
Hematite	5.2	13.5 MW	6 - 7 c/kWh				
DRI/HBI/Pig-iron	1.3						
Coal based		130 MW	4 c/kWh	1,000 ktpa	$1.50/GJ		
Gas based		16 MW	4 c/kWh			13 PJ/a	$2.80/GJ
Magnetite Concentrate	5.0	40 MW	6 - 7 c/kWh				
Magnetite Pellets	5.0			45 ktpa	$1.50/GJ	5 PJ/a	$2.80/GJ
Silica	note		6 - 7 c/kWh				
Silicon metal	0.04	35 - 40 MW	3.5 - 4 c/kWh	5 - 10 ktpa	$2.25/GJ		
Ferro-silicon	0.05	45 MW	3.5 - 4 c/kWh	27 ktpa	$2.25/GJ		
Synthetic Rutile	0.14			Convert to briquettes or char			
Titanium pigment	0.1	6.0 MW	6 - 7 c/kWh			0.5 PJ/a	$3.50/GJ
Zircon/Zircon Flour	note		6 - 7 c/kWh				
Fused Zirconia	note		4 c/kWh				
Zirconia/Zirconium	note		4 c/kWh				
Tantalum	note		6 - 7 c/kWh				
Spodumene	note		6 - 7 c/kWh				
Gold	note		6 - 7 c/kWh				
Nickel Smelter Expansion	0.025	5 - 10 MW	5 - 6 c/kWh			1.2 PJ/a	$3.50/GJ

Table 3.23: Energy Type, Quantity and Price Requirements

Note: These projects are included in Table 3.23 for completeness. They are of limited prospectivity and, hence, project sizes and energy requirements are not identified