Appendix 10

PROJECT
IRON BOOMERANG
east west line parks limited

TATA STEEL

TATA

TATA STEEL CONSULTING

Provision of Technical Assistance To

East West Line Parks Pty Ltd

Brisbane, QLD, Australia

TSC Project Code – PIB2

Project Iron Boomerang – Prefeasibility Report

Tata Steel Consulting
P.O. Box 30
Stephenson Street
Newport
South Wales NP19 0RB
United Kingdom

February 2012

PROJECT IRON BOOMERANG
east west line parks pty ltd

CONTENTS

TATA STEEL

TATA

1. EXECUTIVE SUMMARY

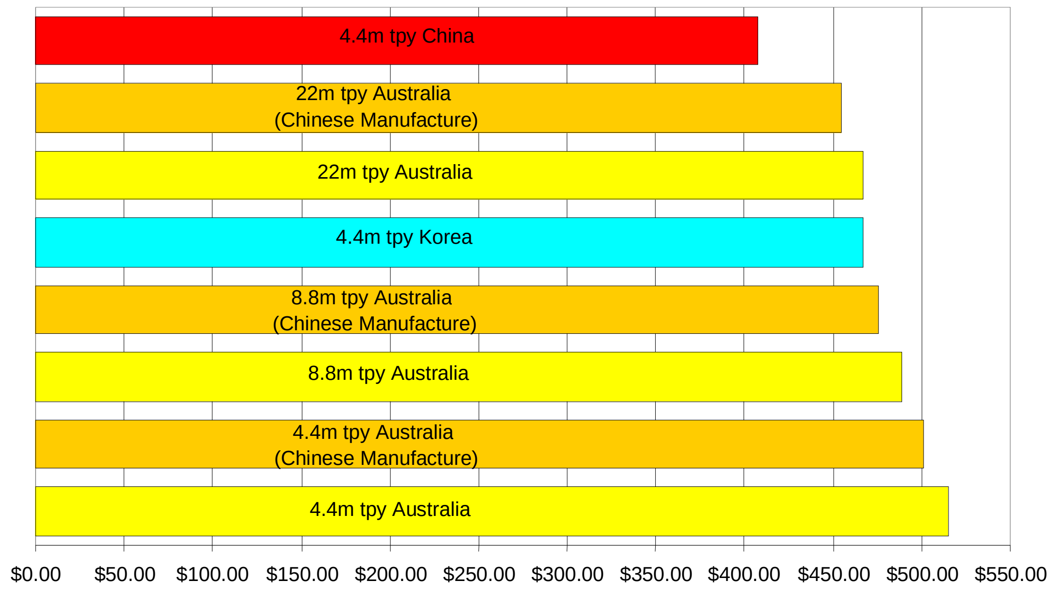
Tata Steel Consulting (TSC) has been commissioned by East West line Parks Limited (EWLP) to carry out a pre-feasibility study into the Project Iron Boomerang (PIB) project in particular developing the estimated breakeven cost of slab for various stages of project development in Queensland, Australia compared to a Base Case plant of the same advanced technology located at a port in Korea. The main findings of this study are as follows.

- Based on the developed case in Australia (22MTPA plant in QLD.) the estimated cost per tonne is some $17.92/tonne of slab cheaper in terms of delivered slab FOB Korea compared with a 4.4MTPA slab plant located in Korea.
- The scale of the fully developed case provides the opportunity for the export of substantial quantities of surplus energy to the surrounding economy. There are various options (considered in section 7 of this report) to utilise the estimated 4.6GJ/tonne surplus of energy in the form of blast furnace, coke oven and BOS gas.
- Energy consumption of the facility is estimated to be approximately 16GJ/tonne of slab, which is the order of 15-20% better than typical world practice.
- A further benefit of the scale of the developed case is that it should allow PIB to approach "world's best" productivity benchmarks for slab production, TSC estimates a productivity figure of 0.25 manhours/tonne of slab produced will be achieved compared to a typical world figure of around 0.5 manhours/tonne.
- There will be substantial savings of green house gas (GHG) emissions mainly due to the supply chain consolidation by only shipping finished slab outside Australia, rather than shipping iron making raw materials (coal and iron ore) as is currently the case. In volume terms this represents a saving of over 50% in the quantities of materials shipped.
- Due to the reduced energy consumption of the developed facility there will be significant savings in GHG emissions during the iron and steelmaking process compared to world steel average. As yet this has not been evaluated.
- On the basis that the proposed Steel Producers will co-operate in terms of process routes, significant savings can be made by standardising on the design of the main iron and steel making processing units, this will generate savings in the following areas:
    - Design costs for repeat designs
    - Economies of scale in ordering & scheduling multiple units through procurement and subsequent erection
    - Savings in spares holding due to the commonality of design
    - Savings in project management and execution
    - Manufacture of equipment in low cost markets such as China
    - Savings associated with the above equate to an estimated US$B3.8 for the developed case as opposed to having 5 stand alone facilities in Korea.
- In evaluating the relative cost of shipping ore and coal from Australia to Korea as opposed to moving the ore and coal within Australia and subsequently shipping the slab to Korea, the original savings identified by EWLP in 2007/8 have been eroded due to the collapse of the bulk freight price.
- Whilst there are substantial savings in productivity levels for the developed scheme compared to the base case and world benchmark levels, due to the relative high level of employment costs in Australia, these benefits are eroded.

PROJECT IRON BOOMERANG
east west line parks pty ltd

TATA STEEL TATA

The financial summary of the various options considered in this report is presented in the chart below in terms of breakeven slab cost.



At this stage some caution is required with regard the Chinese slab cost for the following reasons:

- Obtaining valid capital cost of equipment on an equivalent scale and to an equivalent specification has been difficult particularly to take account of the latest environmental legislation etc. This has been discussed in section 11 of this report.
- Labour costs in China have been very difficult to obtain and compare on a like for like basis with other economies. This element impacts both on the cost of capital, labour and maintenance in the above analysis.

The recommendations for further work are as follows:

- Explore means to increase the OPEX differential between the PIB case and the base case. This might include raw material costs, labour costs, detailed exploration with suppliers of savings in capital costs as scale increases, cost of rail transportation(for example use of additional freight other than ore and coal on the E-W rail line),etc
- Gain a more detailed appreciation of the iron ore and coal chemistries available to this project and evaluate their impact on the blend and production cost of slab, particularly with regard to the magnetite ores that may be available from mines along the proposed E-W rail line.
- Gain a greater understanding of the proposed Steel Producers product mix to further develop the steel complex operational configuration with particular regard to the steel plant layout and logistics.
- This developed facility will “extend the envelope” in terms of the scale of the main processing units. There are currently very few equipment manufacturers with references producing plants of this size it would therefore be prudent to develop high level facility specifications and approach the technological equipment designers and manufacturers to gain latest budget information on operating and capital cost of equipment taking into

account economies of scale, Chinese manufacture etc. Once this is established review the impact on the cost estimates produced to date.

- Investigate further the logistical flow of material from the steel complex to the port and subsequent loading onto the proposed “roll-on-roll-off” facility and the impact on slab cost.
- Look at further shipping options in terms of long term Charter or buying the necessary cargo vessels. In particular reviewing further the effects of the roll-on roll off slab vessel on shipping costs
- Investigate further the effect of green house gas emissions, not just from a transport viewpoint but to include the potential emission savings from the developed facility due to the much improved energy efficiency of this project compared to world steel average.
- Start to develop equivalent proposals for the Newman steel complex in WA, taking into account the particular differences in logistics with regard to slab transfer to the port.

TATA STEEL

TATA

2. OVERVIEW OF PROJECT IRON BOOMERANG

Project Iron Boomerang (PIB) was developed by East West Line Parks Pty Ltd (EWLP) with the aim of establishing semi finished steel production in Australia close to the major sources of raw materials.

This involves the development of an east-west railroad across Australia to link the coal deposits in the Bowen Basin of Queensland with the similarly massive iron ore deposits in the Pilbara Region of Western Australia.

At each end of the railroad, it is proposed to develop semi finished steel production facilities owned by international steelmakers. EWLP would procure, construct and operate a suite of shared services to support the steel making facilities covering such items as power, water, raw materials handling and storage, steel export and site facilities management.

The proposed location of the Pilbara Steel Complex is approximately 55km north of Newman, WA, approximately 400km inland.

The proposed location for the Queensland Steel Complex is a few kilometres from the existing port at Abbot Point.

The steel complexes will be linked by a new heavy gauge inland east - west railway line (40t axle loading) over 3,300 kilometres in length, connected to existing rail line systems. PIB trains will in the majority of cases run inland direct from the mine sites to the steel plants. This will effectively link Australia's vast reserves of iron ore and coal (particularly coking coal), both of which are currently almost exclusively exported, facilitating major steel manufacturing in Australia

PROJECT IRON BOOMERANG
east west line parks pty ltd

3. PURPOSE OF THIS REPORT

Tata Steel Consulting (TSC) has been commissioned by EWLP to carry out a pre-feasibility study into the project including analysis at each stage of development. This report sets out the findings of the study.

The first substantive section of the report (section 4) sets out the assumptions (both technical and commercial) made in the study.

Section 5 and 6 consider the manufacturing process options and logistics available to the project and sets out the reasons for the selection of the preferred processes. A high level review of material flows and supporting logistics is provided together with a brief description/specification of the main steel making equipment (e.g. Raw Material handling, Sinter, Coke ovens, blast furnaces, steel plant).

Sections 7 and 8 describe and estimate energy requirements including usage for electricity, gases and water, whilst section 9, assesses manning requirements.

Sections 10, 11 and 12 assess CAPEX and OPEX requirements and consider these in comparison to the construction of facilities in the Far East, which, as far as possible, are intended to reflect possible alternatives to PIB. A cost model has been developed, which considers the CAPEX and OPEX at each phase of the project and the benefits to steel operators and investors of sharing common services and facilities, particularly as scale increases. Total CAPEX is estimated at each phase together with a fully developed Discounted Cash Flow (DCF) of each option.

Specifically, the cost model for the Steel Complex considers the following cases:

- Base Case originally based on a 3.5MTPA steel plant located at a port in SE Asia, subsequently increased to 4.4MTPA.
- Case 1 originally based on a 3.5MTPA steel plant located at proposed PIB site in QLD Australia, subsequently increased to 4.4MTPA.
- Case 2 originally based on a 7MTPA steel plant located at proposed PIB site in QLD Australia, subsequently increased to 8.8MTPA.
- Case 3 a 22MTPA steel plant located at proposed PIB site in QLD Australia.
- CAPEX for the above will be based on Western Supply taking into account economies of scale associated with multiple units. Sensitivity on Chinese supply will also be provided.

Section 13 and 14 contain the main conclusions and the recommendations for further study work.

4. LIST OF ASSUMPTIONS

In the production of this Pre-Feasibility study report, TSC has had to make a number of assumptions, which would need to be discussed and verified further if a subsequent full Feasibility Study is undertaken.

4.1 TECHNICAL & OPERATIONAL ASSUMPTIONS

4.1.1 Steel Complex Output

It has been assumed that the fully developed project will comprise 22MTPA of steelmaking capacity at each complex as set out in the EWLP Feasibility work.

4.1.2 Indicative Iron Ore Chemistry

In order for TSC to carry out the necessary process modelling work, an assessment of the likely iron ore chemical composition has had to be made. For the purposes of this report the following chemical composition, which is representative of Hematite ores and fines available in Australia, has been assumed

Chemical	Lump Ore %	Fines %
Iron	64.7	63.3
Lime	0.06	0.05
Silica	2.6	3.5
Magnesia	0.1	0.07
Alumina	1.3	1.95
Phosphorus	0.06	0.07
Manganese	0.22	0.17
Sulphur	0.014	0.02
K_2O	0.016	0.014
Na_2O	0.011	0.022
FeO	0.23	0.23
TiO_2	0.047	0.08
V_2O_5	0.003	0.005
ZnO	0.001	0.002
PbO	0.001	0.003
Moisture	2.75	7.9

4.1.3 Indicative Coal Chemistry

Similarly to the Iron ore requirements above, the following coal blend for Coke production has been assumed for the basis of this report.

Item	%
Volatile matter	23.1
Ash	8.82
Phosphorus	0.033
Sulphur	0.056
Moisture	9.7

4.1.4 Iron Making Production Philosophy

Iron making production will be based around the blast furnace process. Within this report a discussion on the various alternative iron making processes that could be considered for PIB has been provided. These are described fully in Section 5.1.

The recommendation for a Blast Furnace route has been made on the basis that at the current time the alternative iron making processes are either:

- Not mature or developed technically to compete with the established Blast Furnace Route, or
- Not developed to the same level of scale that can be produced by the Blast Furnace route commensurate to produce 22 million tonnes of semi finished product.

Work to date carried out by EWLP has been based on the assumption that each Blast Furnace will produce nominally 3.6MTPA of hot metal. This is the equivalent of approximately 10000 tonnes of hot metal per day (355 operating days) and would require a furnace with an inner volume of approximately 4000 to 4600 cubic metres. This was typically the norm for large blast furnaces built circa 20 years ago.

In the last 10 years however, a number of furnaces have been either built or rebuilt with increased inner volume in the range 5000 to 6000 cubic metres, giving a capability of output in the range 11000 to 13000 tonnes per day of hot metal. In the case of PIB this would effectively mean that the number of Blast Furnaces required to give the 22 million tonne per year output from a steel complex would be 5, not 6. On the basis of this, it is recommended that each complex be based on 5 blast furnaces.

Carbon for the iron making reduction processes will be provided by a combination of Coke and Injected Coal. For the purposes of this evaluation a coal injection rate of 150kg/THM has been assumed which is a typical industry figure. TSC is aware of higher injection rates up to 180-200kg/THM being achieved and this is an area for further debate with potential Steel Producers and would have a bearing on both CAPEX and OPEX for the project.

Process Modelling has indicated that, assuming coal injection at 150 kg/thm, the Coke requirement in the blast furnace would be around 338kg/ THM giving a total fuel rate of 488kg/THM.

It has been assumed that the Blast Furnace burden will be approximately 85% Sinter and 15% Lump Ore, based on the good quality Iron Ores available.

This again is an area for further discussion. At present, it is assumed that there are sufficient "sintering" ores available to support PIB, however as time progresses, and finer and less high quality ores are processed it is likely that pelletising will become more prevalent. For stable blast furnace operation, the mix should either be predominantly sinter or predominantly pellet. Experience has shown that issues with blast furnace operation can occur with an approximate equal mix of pellet/sinter in the burden.

Iron ore supply from one of the 'Big Suppliers' (sinter feed and lump) will likely be difficult. BHP Billiton and Rio Tinto, who account for almost 90% of iron ore production in Western Australia, are unlikely to have sufficient spare capacity to meet PIB needs from existing sources, however new mines are being developed.

Therefore, better opportunities are likely to exist for iron supply from the new entrants, however almost all of significant new producers are magnetite based which will mean pellet feed or pellets (magnetite / concentrate can be used in the sinter process route but in relatively low quantities circa 10%). The CAPEX and OPEX using either the sinter or pellet route is similar, therefore at this stage For the purposes of this study it has been decided to assume a predominantly sinter route.

Similar issues will likely occur regarding the supply of coal.

Availability of local fluxes (limestone and/or dolomite) require further research. Currently EWLP assumptions are based on importing Limestone from Papua New Guinea by ship to Abbot Point for the Queensland complex and subsequent transfer to the Steel Complex by conveyor. For the proposed Steel Complex in Western Australia, limestone and dolomite will have to be transported from the port by rail due to the much greater distances involved.

Scrap availability is also likely to be an issue in Australia; as such a steelmaking regime low in scrap charge (60kg/TLS) has been assumed, with works generated scrap being supplemented with iron ore as coolant, however additional scrap will still be required to achieve the required 60kg/TLS .

4.1.5 Indicative Iron Chemistry

It has been assumed that the hot metal chemistry required by the Steel Producers will be similar. The following basic hot metal chemistry has been assumed:

Chemical	%
Carbon	4.84
Manganese	0.3
Silicon	0.3
Phosphorus	0.08
Sulphur	0.035

4.1.6 Steel Making Philosophy

The precise steel chemistries and grades to be produced will depend upon the semi-finished feedstock and final steel requirements needed to supply the Steel Producers down-stream mills and customer base. This could require quite complex Steelmaking logistics and plant designs. At this stage to simplify the current pre-feasibility work, and in the absence of more detailed information, An assumption has been made that that finished steel output will be slab. The design of Steel plant will be around the Basic Oxygen furnace (BOF) process (see section 5.2. for further discussion on this)

Within the Steel plant scheme, made provision has been made for Ladle metallurgy through ladle furnace and Vacuum Degassing stations between the BOF and the continuous slab casters.

Within the modelling work undertaken for this report, typical industry norms for the following have been used

- yields,
- material recipe compositions,
- consumption rates, and
- generation rates

To arrive at values for inputs and outputs in terms of:

- raw materials,
- services and utilities provision and
- By-product gas generation.

4.1.7 Indicative Steel Chemistry

At this stage the finished steel slab chemistry is unknown and will be dependant on the Steel Producers business and marketing plans. Finished steel chemistry has a direct impact on the Steelmaking process route in terms of:

- Layout of plant and equipment
- Secondary steelmaking process requirements
- Alloy additions
- Semi finished product further processing
- Impact of the above on the CAPEX and OPEX of the overall process

For the purposes of this study it has been assumed that the product mix will be predominantly based on typical construction grades of steel, S275 is shown below, values are maximum %:

C	Si	Mn	P	S	N	Cu	Nb	V	Ti
0.21	-	1.5	0.035	0.035	0.012	0.55	0.05	0.13	0.05

4.1.8 Indicative product Mix

In terms of Slab Product mix, for the purposes of this study, the following slab thickness, width and length summary has been assumed:

Slab Dimensions			Weight/Unit		Slab Weight at a given Length (tonne)						
			Length								
Width	x	Thk									
(mm)		(mm)	(kg/m)	TPA	4.5	5.5	6	7	8	9	10.5
1500	x	250	2943.75	660,000	13.25	16.19	17.66	20.61	23.55	26.49	30.91
1600	x	250	3140.00	660,000	14.13	17.27	18.84	21.98	25.12	28.26	32.97
1700	x	250	3336.25	660,000	15.01	18.35	20.02	23.35	26.69	30.03	35.03

1800	x	250	3532.50	660,000	15.90	19.43	21.20	24.73	28.26	31.79	37.09
1900	x	250	3728.75	660,000	16.78	20.51	22.37	26.10	29.83	33.56	39.15
2000	x	250	3925.00	660,000	17.66	21.59	23.55	27.48	31.40	35.33	41.21
2100	x	250	4121.25	660,000	18.55	22.67	24.73	28.85	32.97	37.09	43.27
2200	x	250	4317.50	660,000	19.43	23.75	25.91	30.22	34.54	38.86	45.33
2300	x	250	4513.75	660,000	20.31	24.83	27.08	31.60	36.11	40.62	47.39
2400	x	250	4710.00	660,000	21.20	25.91	28.26	32.97	37.68	42.39	49.46
1500	x	300	3532.50	770,000	15.90	19.43	21.20	24.73	28.26	31.79	37.09
1600	x	300	3768.00	770,000	16.96	20.72	22.61	26.38	30.14	33.91	39.56
1700	x	300	4003.50	770,000	18.02	22.02	24.02	28.02	32.03	36.03	42.04
1800	x	300	4239.00	770,000	19.08	23.31	25.43	29.67	33.91	38.15	44.51
1900	x	300	4474.50	770,000	20.14	24.61	26.85	31.32	35.80	40.27	46.98
2000	x	300	4710.00	770,000	21.20	25.91	28.26	32.97	37.68	42.39	49.46
2100	x	300	4945.50	770,000	22.25	27.20	29.67	34.62	39.56	44.51	51.93
2200	x	300	5181.00	770,000	23.31	28.50	31.09	36.27	41.45	46.63	54.40
2300	x	300	5416.50	770,000	24.37	29.79	32.50	37.92	43.33	48.75	56.87
2400	x	300	5652.00	770,000	25.43	31.09	33.91	39.56	45.22	50.87	59.35
1500	x	350	4121.25	770,000	18.55	22.67	24.73	28.85	32.97	37.09	43.27
1600	x	350	4396.00	770,000	19.78	24.18	26.38	30.77	35.17	39.56	46.16
1700	x	350	4670.75	770,000	21.02	25.69	28.02	32.70	37.37	42.04	49.04
1800	x	350	4945.50	770,000	22.25	27.20	29.67	34.62	39.56	44.51	51.93
1900	x	350	5220.25	770,000	23.49	28.71	31.32	36.54	41.76	46.98	54.81
2000	x	350	5495.00	770,000	24.73	30.22	32.97	38.47	43.96	49.46	57.70
2100	x	350	5769.75	770,000	25.96	31.73	34.62	40.39	46.16	51.93	60.58
2200	x	350	6044.50	770,000	27.20	33.24	36.27	42.31	48.36	54.40	63.47
2300	x	350	6319.25	770,000	28.44	34.76	37.92	44.23	50.55	56.87	66.35
2400	x	350	6594.00	770,000	29.67	36.27	39.56	46.16	52.75	59.35	69.24
				22,000,000							

Average slab length will be nominally 7.5m with an average weight of 33.3 Te. Maximum weight will be 75 Te.

Once the Steel Producer requirements are better understood in terms of finished steel qualities and semi finished product (Slab, Bloom and Billet) this issue should be revisited.

4.2 FINANCIAL ASSUMPTIONS

4.2.1 Capital Expenditure and Phasing

Capital Costs for major plant items have been estimated based on TSC's own database of capital costs; TSC has then applied its industry judgement to arrive at potential CAPEX cost savings to account for economies of scale and repeat designs. This is discussed further in section 11 of this report.

TSC has assumed that the chosen sites for the steel complex will have no special civil works requirements, which might adversely affect the construction cost. . It is assumed there are no major changes in level and gradient within the site nor are there very soft ground conditions or conversely significant bedrock.

The breakeven cost of slab quoted for each case considered in this study represents the FOB price.

For the purposes of this appraisal, in common with normal steel works practice the Steel Complex is assumed to have an economic life of 25 years.

One of the main benefits of this scheme is the reliance on “return full” trains between 2 steel complexes located at Abbot Point in Queensland and Newman in Western Australia. At this stage this study details the Abbot Point Costs, but is based on the assumption that the Newman complex would be constructed in a similar timeframe.

The Costs between the Abbot Point and Newman complexes should be broadly similar; however some differences will occur due to:

- Potential differences in labour rates between QLD and WA
- Water and Utilities cost differences between QLD and WA
- The Newman plant is some 400KM inland compared to the Abbot Point facility, this will have an effect on
    - Capital cost in terms of delivery of equipment to the site
    - Requirements for slab transportation to the docks
    - Import of other materials, particularly limestone and dolomite

In order to arrive at an estimate for project Phasing, the following basic tabular Gantt chart has been produced.

Year	-5	-4	-3	-2	-1	1	2	3
Phase 1 2 Blast Furnaces								
Phase 2 – Additional 2 Blast Furnaces								
Phase 3 – Final Blast Furnace								
% Cumulative CAPEX	5	19	39	65	89	100	100	100
% Production						30	90	100
Output Tonnes						6.6	19.8	22.0

It has been assumed that for Phase 1 based on 2 Blast Furnaces, plant design and construction will be completed within 60 months starting from issue of a “Notice to Proceed” to the EPC contractor.

Phase 2 for each steel complex would provide additional steel slab production facilities based around a further 2 blast furnaces and would Start approximately 18 months after Phase 1 start and be completed in 4 years.

Phase 3 for each steel complex would provide the additional facilities to increase production to the

22,000,000 tonnes of slab and would start some 3 years after Phase 1 start and be completed some 1 year after phase 1 completion.

Commissioning and working up of phase 1 production would take 2 years, with lessons learned reducing commissioning of phases 2 and 3 so that full output from the complex would be achieved after just over 7 years from commencement of phase 1.

Decommissioning and remediation of the land by the end of the steel mill's life is excluded in the cash flow analysis.

4.2.2 Capital Charges

The discounted cash flow analysis is used to evaluate the breakeven price per tonne of slab produced. A discount rate of 10% has been assumed.

All capital requirements will be available according to the schedules of capital expenditure included for each case considered. The capital infusion could be assumed as cash available for the construction of the steel complex based on a combination of equity and debt, however the level of debt is not considered or accounted for in this study.

The Cost of Capital also uses a discount rate of 10%, which represents the weighted average of capital charges (WACC).

No interest during construction is applied but the timing of capital expenditure is taken into account in the discounted cash flow analysis.

4.2.3 Recurring Major Capital Expenditure

In line with normal practice, it is assumed that the refractory relining of the blast furnaces will need to be replaced every 20 years of continuous operation. The study has assumed a relining will be carried out in the 20th year from start up with steel production assumed to maintain at 100% full capacity during this period (it is understood that this is a relatively simplistic approach and in reality Blast Furnace performance will start to tail off towards the end of it's life however the same assumptions have been made in all cases).

4.2.4 Raw Material Costs

TSC has access to a great deal of commercially available sources of information regarding raw material costs and has used this in estimating both the cost of raw materials and freight costs.

In all cases costs for demurrage have been excluded.

4.2.5 Delivery of Slab

In terms of Delivery of slab, this report assumes that in all cases the finished slab is delivered to a port in South Korea. Slab shipments from Queensland have been assumed to be based on Panamax shipping loads using TSC's latest view on freight shipping costs.

In all cases costs for demurrage have been excluded.

EWLP is currently in discussions with an international Shipping company regarding the design of a roll-on-roll-off vessel for transporting slabs which has the potential to reduce the shipping cost of slab to the final destination. At the stage of righting this report, the potential savings have not been evaluated compared to “standard” Panamax shipping costs.

4.2.6 Inflation

Inflation assumptions were not included. No allowance has been made for escalation of fuel, reductant, raw materials, labour or other costs.

4.2.7 Depreciation

Depreciation is assumed to follow a straight line at 4% rate.

4.2.8 Estimate Accuracy

The estimate accuracy is within the range +/- 25%.

5. TRENDS IN IRON AND STEELMAKING TECHNOLOGY

5.1 OPTIONS FOR IRONMAKING

There are a number of ironmaking processes, which could be used for PIB and these are discussed below. These comprise:

- Blast Furnace
- Rotary Hearth Furnace
- Rotary Kiln
- HiSmelt
- Corex/Midrex
- Finex
- Natural Gas Based Zero-Reforming HYL Process
- Coal Based HYL Process
- Electric Ironmaking Furnace
- Submerged Arc Furnace (SAF)
- Hisarna
- Ausmelt

In the next sections we will consider the iron making options beginning with the best known of these – the Blast Furnace.

5.1.1 Blast Furnace

The Blast Furnace – Basic Oxygen steel furnace process route is the most common production route for crude steel production amounting to just under 70% of World Steel production in 2010 (source Steel Statistical Yearbook 2011).

For the first time in 2010, overall iron production by the blast furnace route topped one billion tonnes.

The blast furnace consists of a tall, vertical shaft furnace, which has the purpose of heating and reducing iron oxides (hematite and magnetite) into hot metal which is basically a carbon-saturated silicon and manganese iron alloy with residual amounts of sulphur and phosphorus.

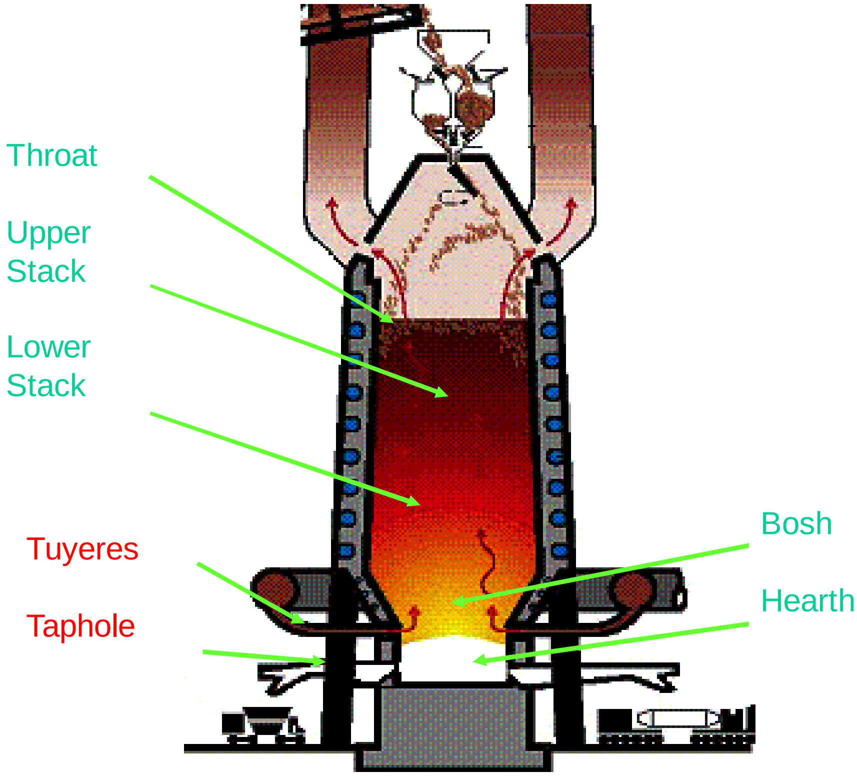
The Blast Furnace can be described as a counter current reactor. Coke, ore and sinter/pellets are charged into the top of the Blast Furnace together with limestone and other fluxes; this charge is known as the Burden. Hot Blast, which is basically preheated air produced by the blast furnace stoves is injected through tuyeres in the base of the furnace fanning the charge and reducing the ore and allowing hot metal to descend into the furnace hearth from where it is tapped.

The Blast Furnace construction is basically a cylindrical steel shell and is divided into 4 main areas.

- Throat – this is at the top of the furnace where the charging equipment is installed and where the blast furnace gas produced during the reduction process is discharged.
- Stack (sometimes called the upper and lower stack) extends from the throat with increased diameter to allow for expansion of solids as their temperature increases.
- Bosh or belly, which is the area between the stack and the hearth. This is where the melting process starts and the burden contracts as liquid iron forms.

- Hearth – This is the area where molten iron (hot metal) and slag accumulate. The tap holes to draw off the iron are located in the hearth. At the top level of the hearth, the tuyeres are located to allow the hot blast to enter the furnaces.

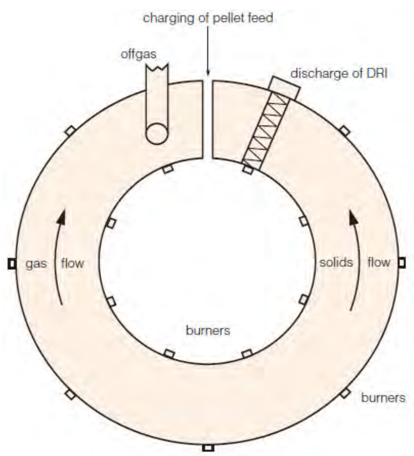
A generic view of a blast furnace is shown below:

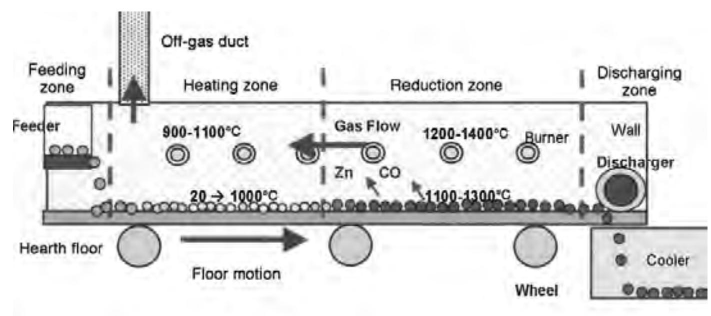


The blast furnace (BF) route is flexible in both operation and output with sizes of BF ranging from 4.5 m hearth diameter (420 m^3 volume) up to 15.5 m hearth diameter (5,500 m^3 volume) with furnaces under construction of 6000 m^3 volume. In terms of daily hot metal output, these range from 700 to 12000 tonnes of hot metal per day.

The raw materials feedstock proposed by PIB will not cause any issues with hot metal production using the Blast Furnace route. In terms of economies of scale, the Blast furnace offers the best method in achieving the required output of 22Mte per annum at each of the proposed steel complexes.

5.1.2 Rotary Hearth Furnace





The rotary hearth furnace (RHF) consists of a flat, refractory-lined hearth rotating inside a high temperature, circular tunnel kiln. The feed typically consists of cold-bonded pellets, made from a mixture of iron ore fines, coal, water and a binder such as bentonite. The pellets are placed evenly on the hearth, usually one to two layers thick to give a fast reaction time. Burners located in the RHF roof and/or sidewalls heat the pellets to the required reduction temperature, typically 1250–1400ºC. The pellets pass first through an oxidising zone and then through the reducing zone.

Heating of the pellet layer is accompanied by drying; and the expulsion and combustion of volatiles from the coal and, when the reduction temperature is reached, the generation of carbon monoxide (CO) from the outer shell towards the pellet centre. Thus, as the iron becomes metallic it is protected both by the CO inside the pellet and by a CO veil surrounding the pellet and the pellet layer as a whole. The maintenance of this CO veil is essential to avoid re-oxidation; particularly in the latter stages of the process when metallisation advances and CO generation weakens. The process is therefore controlled to maintain low oxygen potentials in the local furnace atmosphere.

Additional heat is provided by the injection of excess air to burn the evolved volatiles and carbon monoxide. This combustion provides up to 75% of the total energy to the process. An auxiliary fuel may be burned in the final reduction zone to balance the local energy requirements (Cairns and others, 1998). Thus, the amount of coal used in the pellets depends on its volatile matter (VM) content – more coal is required as the VM increases. However, this decreases the amount of fuel required for the burners, because of the heat supplied by combustion of the volatiles and CO, around 3–5 GJ/t DRI.

The carbon content in the pellet influences the iron metallisation and also the remaining carbon content in the DRI product. The homogeneous mixing of coal with the iron oxide is a key point in reaching the best DRI quality. Like the rotary kiln, the combustion gases from the burners flow counter current to the solids flow. The pellets are fed and discharged continuously and stay on the hearth for only one revolution, typically under 20 minutes, depending on the reactivity of the feed mixture and target product quality. The DRI composition can be varied depending on the RHF operating conditions and the blending ratio of the raw materials. A variable speed hearth drive, for example, controls the retention time of the pellets and hence the desired product quality with regard to metallisation degree and carbon content; longer residence times promote stronger pellets.

The burners are fired with natural gas, fuel oil, waste oil or pulverised coal. Pulverised coal firing increases the capital cost of the plant but provides a more radiant flame than natural gas, however high volatile coals are preferred (>30% VM, >20% ash).

The sensible heat in the off-gas is recovered and used to preheat the RHF burner combustion air and dryer air. The off-gas is then cleaned to remove SO_2 and particulates before being vented to the atmosphere. Compared to coal-based smelting reduction processes, RHF processes produce lower volumes of lower energy off-gases, so there is only a small residual capacity for steam generation.

To avoid disintegration of the pellets and to maximise reduction, the furnace atmosphere, gas velocity and gas composition must be accurately controlled in each zone of the RHF to ensure smooth heating and reduction of the pellets, and to avoid re-oxidation in the final furnace zone. It is important to determine the right furnace parameters such as the ratio of the oxidising-to-reducing gases, residence time, temperature profile and gas velocity in order to optimise productivity and DRI quality (Degel and others, 2000). The raw materials specifications and the pellet preparation recipe also need to be optimised according to how the DRI (and HBI) is to be used. Testing in a pilot plant is required.

Although the coal-based direct reduction concept utilising RHFs is a simple one, commercial implementation of the concept has not been easily achieved. Drawbacks associated with RHF processes include:

- **Excessive gangue.** The reduced DRI pellets are made of an iron matrix in which the residues of the coal and binder are trapped. The carbon excess, 60 to 90% of the coal sulphur, all the coal ash and most of the binder thus remain in the product and become part of the feed to the subsequent steelmaking processes (Borlee and others, 1998).
- **Large equipment** is required for a commercial unit. A 500,000 t/y unit would need a 500 m^2 RHF with an external diameter close to 50 m. On the other hand, the equipment is relatively simple with most of the furnace constructed from carbon steel, with little expensive alloys, and with normal ironmaking refractory.
- **Operational problems**. The RHF operation by Iron Dynamics in Butler, IN (USA) has shown erratic operation since it started production in 1999. Typical problems related to the strength of cold-bonded pellets (fines creation leading to dust and yield losses) and temperature in-homogeneity across the bed.

Currently, the two main commercially available RHF processes are Fastmet and Inmetco and both are currently used to process steel mill wastes. However, there are other RHF's operation – e.g. at Nippon Steel's Kimitsu Works and others are expected to come on line in the near future. Research is being carried out to increase RHF productivity, DRI quality, and fuel efficiency by, for example, increasing the reaction temperature, the height of the bed, the volatile matter content in the carbonaceous reductant and increasing post combustion.

New RHF concepts are being developed (e.g. ITmk3 by Midrex) that produce iron nuggets rather than DRI pellets by melting down the pellets and thus separating the gangue.

Producing a less reduced DRI reduces the need for burner fuel, which is mostly used in the final and hottest section where oxidising conditions (from post combustion) should be avoided.

The low productivity of RHFs can partly be overcome by producing DRI with lower metallisation (75% to 85%, instead of 95%) and completing the final reduction and melting within an Electric Arc Furnace.

In terms of suitability for PIB, the Nominal Operating capacities of the RHF are very low when compared with the Blast Furnace route. Of the handful of plants known in the world, the largest by far is the Hoyt Lake facility in Minnesota, USA. This is a joint venture of Kobe Steel and Steel Dynamics Inc, commissioned in 2010 using the ITmk3 process with a design capacity of 500 KTPA.

Information produced by Steel Dynamics in their quarterly business updates indicate that the plant is only operating at about 40% of it's design capacity after nearly 2 years of operation.

To adopt this process for large scale operation at PIB would require a minimum of 44 units at each site assuming the current design and operational issues can be overcome.

As described above, the quality of off gas to provide supplementary fuel for generation is also much lower than the conventional Blast Furnace / Coke oven route.

In terms of specific consumption figures, Midrex/Kobe for ITmk3 quote Per Ton of Nuggets:

- Iron-bearing Feed (t) 1.5
- Coal (t) 0.5
- Natural Gas Burner Fuel (GJ) 4.6
- Electricity (kWh) 200
- Water (m3) 2.0
- Air (m3) 85
- Nitrogen (m3) 12
- Direct Labour (personnel) 50 total
- Maintenance ($) 5
- Other ($) 15

A List of Known RHF plants is shown on the table below from VDEh Plant facts:

TATA STEEL

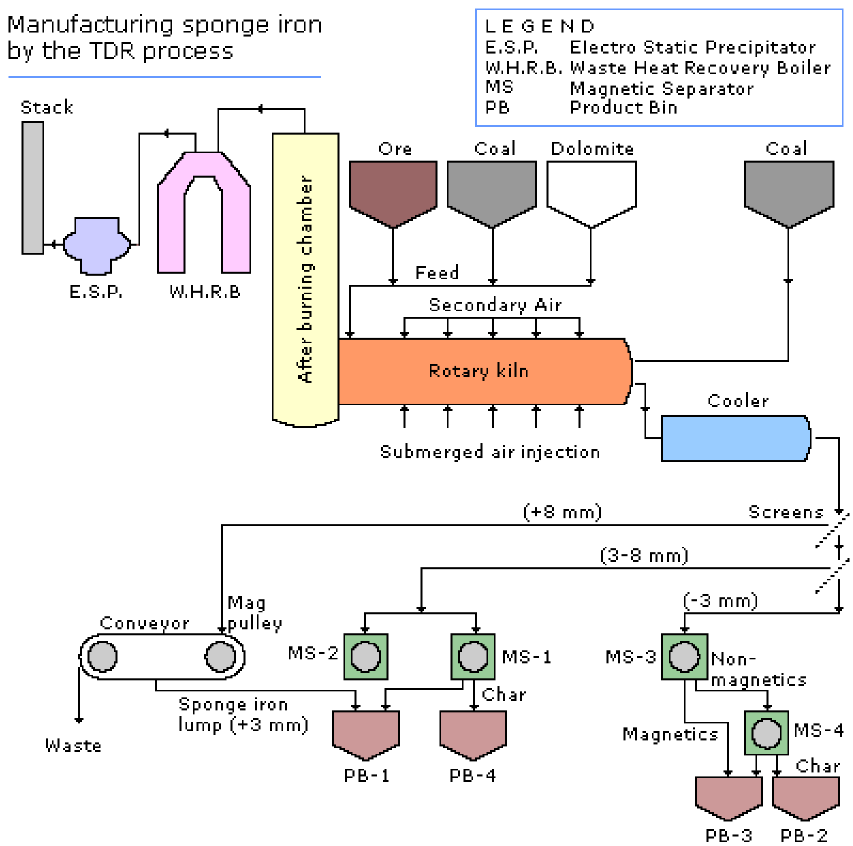
TATA

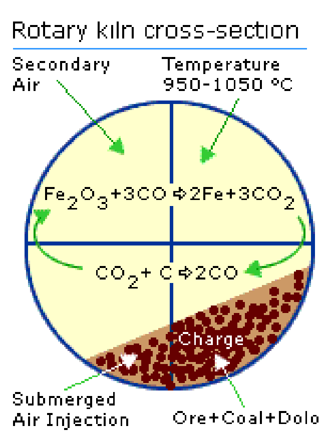
Country	Company	Location/ Works	Plant Status	Manufacturer	Start Up	Process	Type Of Ore	Reduction Medium:	Product: Type	Nominal Capacity
Japan	Aichi Steel Corp	Chita, Nagoya	Operating	NSC Const. Div., Jp	2008	RHF	EAF Dust	Pulverized Coal	Sponge Iron	10
Japan	Kobe Steel	Kakogawa, Hyogo	Operating	Kobe Steel, Jp	2001	Fastmet®	Mill Scale	Fuel Oil Tailings	Sponge Iron	16
Japan	Nippon Metal Ind.	Kinuura	Operating	Nippon Steel, Jp	2008	RHF	BF/BOF Dust	Coal	Sponge Iron	200
Japan	Nippon Steel Corp	Hirohata, Hyogo	Operating	Kobe Steel, Jp	2000	Fastmet®	BF/BOF Dust	Coal	Sponge Iron	190
Japan	Nippon Steel Corp	Hirohata, Hyogo	Operating	Kobe Steel, Jp	2005	Fastmet®	BF/BOF Dust	Coal	Sponge Iron	190
Japan	Nippon Steel Corp	Hirohata, Hyogo	Operating	Kobe Steel, Jp	2008	Fastmet®	BF/BOF Dust	Coal	Sponge Iron	190
Japan	Nippon Steel Corp	Hirohata, Hyogo	Under Const.	Kobe Steel, Jp	2011	Fastmet®	BF/BOF Dust	Coal	Hbi	220
Japan	Nippon Steel Corp	Hikari, Yamaguchi	Operating	NSCConst. Div., Jp	2001	RHF	BF/BOF Dust	Coal	Sponge Iron	28
Japan	Nippon Steel Corp	Kimitsu, Chiba	Operating	Nippon Steel, Jp	2000	RHF	BF/BOF Dust	Coal	Sponge Iron Pellets	300
Japan	Nippon Steel Corp	Kimitsu, Chiba	Operating	NSC Const. Div., Jp	2003	RHF	BF/BOF Dust	Coal	Sponge Iron Pellets	135
Japan	Nippon Steel Corp	Kimitsu, Chiba	Operating	Nippon Steel, Jp	2008	RHF	BF/BOF Dust	Coal	Sponge Iron	300
South Korea	Posco	Pohang	Operating	Nippon Steel, Jp	2009	RHF	BF/BOF Dust	Coal	Sponge Iron Pellets	200
South Korea	Posco	Gwangyang	Operating	Nippon Steel, Jp	2009	RHF	BF/BOF Dust	Coal	Sponge Iron Pellets	200
South Korea	Posco	Gwangyang	Operating	Nippon Steel, Jp	2009	RHF	BF/BOF Dust	Coal	Sponge Iron Pellets	200
Pr China	Maanshan I&S Co	Maanshan-I, Anhui	Operating	Nippon Steel, Jp	2009	RHF	BF/BOF Dust	Coal	Sponge Iron	200
Taiwan	China Steel Corp	Kaohsiung	Operating	Nippon Steel, Jp	2008	RHF	BF/BOF Dust	Coal	Sponge Iron	200
United States	Mesabi Nugget Delaware Llc	Hoyt Lakes, Mn	Operating	Tenova It,US & Kobe Steel	2010	Itmk3®	Fine Ore, Pellets	Pulverized Coal Or Coal	Iron Nuggets	500

PROJECT IRON BOOMERANG
east west line parks pty ltd

5.1.3 Rotary Kiln

A schematic diagram of a rotary kiln process developed by Tata Steel is shown below.





This process and other rotary kiln processes consist of a revolving horizontal cylinder comprising a shell with an internal refractory lining. Seals at each end join the rotating cylinder to the stationary equipment for adding materials and discharging product from the furnace. The furnace is inclined at an angle of 3–4° from the horizontal toward the discharge end so the burden travels through the rotary kiln by rotation and gravity. The overall process requires a duration of approximately 10-12 hours inside the kiln. A metallization of 90-92% should be possible making the product suitable for charging direct to an EAF furnace for steelmaking.

Coal, flux and iron oxide are fed into the high end of the kiln and pass through a heating zone where coal is devolatilized and the charge is heated to the reduction temperature. Iron oxide is reduced in the reduction zone by carbon monoxide.

A portion of the process heat is usually provided by a burner at the solids discharge end of the kiln. The burner operates with a deficiency of air to maintain a reducing atmosphere in the kiln. Additional process heat is supplied by combustion of coal volatiles and the carbon monoxide from the bed. Combustion air is supplied through ports spaced along the length of the kiln. The airflow is controlled to maintain a relatively uniform temperature profile in the reduction zone and a neutral or slightly reducing atmosphere above the bed. The kiln gas flows counter current to the flow of solids.

The iron oxide feed (lump ore or pellets) should fulfil certain requirements regarding chemical composition, size distribution and behaviour under reducing conditions in the kiln. The feed should have high iron content so that costs for further processing in the electric furnace are as low as possible. Sulphur and phosphorus contents should also be low. The minimum size should be controlled at approximately 5 mm. Besides being elutriated from the kiln, fines contribute to accretion build-up (ringing) in the kiln. Reduced fines in the product also re-oxidize more rapidly. Ore reducibility, a measure of the time required to achieve a desired degree of metallization under a standard set of conditions, has a strong influence on the capacity of the kiln. The behaviour of the ore under reducing conditions is important, especially with regard to swelling and subsequent decrepitation.

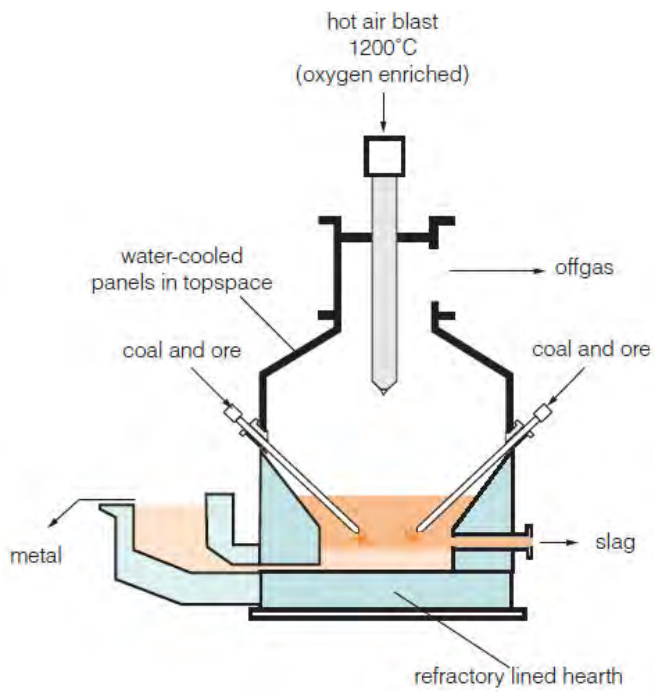
Important factors in the selection of coals are reactivity, volatile matter content, sulphur content, ash content and ash softening temperature. Coal reactivity is indicative of the coal's reduction potential and with increased reactivity; the throughput of the rotary kiln can be expected to increase within certain limits. Consideration should be given to the fact that the volatile content generally increases with reactivity. Because coals with high volatile content generate more gas than can be used in the process for reduction and fuel, the recovery of the sensible and chemical heat contained in the waste gas would have to be considered for overall heat economy. Low-sulphur coals are preferred to minimize sulphur in the DRI product.

The solids discharged from the rotary kiln are cooled, then screened and separated magnetically. DRI fines can be briquetted and used for steelmaking. A carbon char is separated and recycled to the kiln to increase fuel efficiency. The off-gas passes through a gravity separation chamber that can also serve as an afterburner and is then cooled and cleaned before being released to the atmosphere. Dust from the settling chamber is transported to a waste disposal area.

In the SL/RN process the kiln is fed with indurated pellets and/or lump iron ore. Iron sands are used at New Zealand Steel, with design modifications to provide efficient operation. A wide range of fuels and reductants including lignite, char, low temperature coke, coke breeze and anthracite coal have been used satisfactorily. Depending on the fuel used, the proportion of the reductant fed through the inlet of the kiln with the oxide feed and the proportion fired through the burner at the kiln exit will be adjusted. With very low-volatile coal, a supplementary fuel such as natural gas or fuel oil is fed through the central burner or through the air tubes to maintain the proper temperature profile in the kiln. Smooth kiln operation is achieved when operating with a relatively high volatile coal charged together with the iron burden through the kiln feed end.

5.1.4 HIsmelt

A view of the Hismelt Smelting Reduction Vessel (SRV) (Bates and Muir, 2000) is shown below:



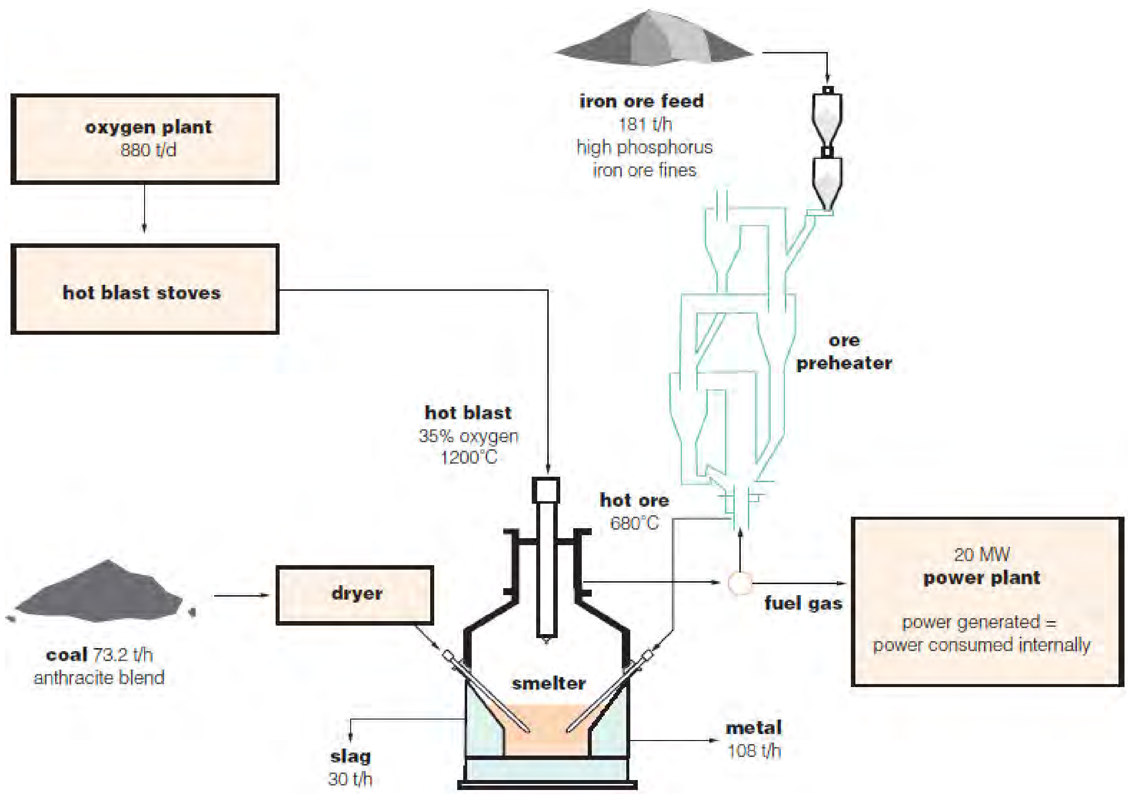
In the HIsmelt process preheated and pre-reduced iron ore fines (typically <6 mm), waste iron oxide materials, ground coal (typically <3 mm) and fine fluxes are injected through side mounted water-cooled lances deep into the metal bath[1]. Rapid dissolution of coal and smelting occurs and the resulting gases (mainly CO and H_2), along with the injected nitrogen carrier gas, propel a highly turbulent fountain of metal and slag droplets into the top-space.

Air preheated at 1200ºC, and enriched with oxygen (35%), is injected through a water-cooled lance into the top-space. Post-combustion occurs and the energy produced is transferred to the metal and slag droplets that provide a large surface area for the heat transfer. Post-combustion in the range 50–75% has been achieved (59% is the assumed level in calculations).

The HIsmelt flow sheet and mass streams (Goldsworthy and Gull, 2002) are shown below:

TATA STEEL

TATA



The SRV operates at a moderate pressure of around 1 bar gauge. The hot metal is continuously tapped through a forehearth (siphon) to maintain a nearly constant metal level within the SRV, whilst the slag is periodically tapped via a conventional water-cooled taphole. The hot metal is then desulphurised to produce hot metal with 4% C and low Si.

Production capabilities were assessed across the full range of ferrous feed reduction levels from hematite, hematite goethite, and goethite ores through to DRI. Normal sinter plant feed and typical pellet feed materials (80% finer than 40 µm) can be directly processed. The process can use coals ranging in volatile matter from 9.8% (anthracite) to 38.5% (high volatile bituminous). The fixed carbon, ash, volatile matter, oxygen and sulphur contents do influence productivity. Best results are achieved using a low volatile (10%) anthracite coal. A commercial plant is estimated to have a coal rate of around 650 kg/thm (in combination with an ore preheating system).

The fountain of metal and slag coats the water-cooled panels in the slag and top-space area. It is reported that this results in low refractory wear rates: as low as <1 kg/thm (refractory wear will occur mainly in the highly turbulent bath area). The hot off-gas from the SRV is cooled via a water-cooled hood, cleaned in a scrubber, and used to

a) fire the stoves to create hot air blast
b) preheat and pre-reduce the iron-bearing materials
c) used to generate steam and/or electricity.

Advantages of the HIsmelt process:

- can use low value iron ore fines and non-coking coals directly (with actual specific consumption of LV coal expected to be similar to a BF route – once process is fully industrialised)

- can process steel plant waste materials
- can process high phosphorus ore fines (0.12% P) that are unsuitable for processing in blast furnaces or DRI.
- most coals can be used. In general, the use of low and medium volatile coals is preferred, but high volatile coals result in a richer off-gas that can be used for power generation
- flexibility of operation: the process can be started, stopped or idled more easily
- is expected to significantly reduce emissions of SO_2, NOx, dioxins and particulates, while some CO_2 reduction will be achieved as well.

Disadvantages of the HIsmelt process:
- not fully industrialised (see Status)
- expected lower availability (~92%) than the BF and higher refractory wear due to aggressive slag (it typically contains 4% FeO);
- iron yield is slightly lower than for blast furnaces as the FeO content in the slag will be around 4% compared to 2% in blast furnace slag.
- uncertain whether the slag is suitable for direct utilisation in cement production due to its FeO content.

Status of the HIsmelt development:
A commercial plant, costing a reported US$208 million, with a capacity of 800 kt/y, based on a 6 m diameter SRV was commissioned in 2005 at Kwinana, Australia. It was a joint venture between Rio Tinto (Australia) 60%, Nucor Corp. (USA) 25%, Mitsubishi Corp. (Japan) 10% and Shougang Corp. (China) 5%. The Kwinana plant was expected to form the platform from which further scale-up (to 8 m hearth diameter) and development of the process and engineering to be made.

The Kwinana plant has been in production for about 4 years. Annual production –

- 2005 - 9,000 tonnes of pig iron.
- 2006 - 89,000 tonnes of pig iron.
- 2007 - 114870 tonnes of pig iron
- 2008 – up to end June 82218 tonnes of pig iron

HIsmelt further optimised the Kwinana Plant operation in the second half of 2008. A major improvement was made by installing two co-injection Giga lances during the July-August shut-down, which contributed to better heat transfer efficiency, lower coal rate, and a record high daily and weekly production rates of 1,834 and 11,000 tonnes respectively. The installation of a full set of Slag Zone Coolers demonstrated that an extended campaign life can be expected under steady operation conditions.

The quality of the metal produced so far has been encouraging with carbon levels consistently around 4.4% ± 0.15. Phosphorus and silicon levels have remained extremely low (0.02% ± 0.01% P, <0.01% Si).

The plant achieved a production rate record of over 80 tonnes hot metal per hour and a sustainable production rate of 75 tonnes hot metal per hour. Numerous other production records have also been broken including highest production in a week, highest production in a month, and lowest coal consumption (810 kg per tonne of hot metal).

However, the reported Hot Blast problems imply that the scaled-up (8m) SRV (~1.5 Mt/y) will be

designed with 4 off-centre lances instead of 1 large centre lance (currently).
In March 2009, HIsmelt advised that the plant had been put on a 12 months "Care and Maintenance" period due to the depressed global market for Pig Iron.

In December 2010 Rio Tinto advised "that the HIsmelt joint venture partners agreed to permanently close the Kwinana site and terminate the joint venture. The majority of closure work is expected to be completed by 2014. The technology business (100 per cent Rio Tinto owned) continues and a number of licensing opportunities are progressing."

In terms of suitability for PIB therefore, HIsmelt technology is not sufficiently mature to suit the large scale production requirements of the project.

5.1.5 Corex/Midrex

The Corex process is the most developed of the smelting reduction technologies using coal and has been in commercial operation since 1989. It combines a melter-gasifier vessel with a reduction shaft to produce a liquid product that is very similar to blast furnace hot metal. Four commercial plants are currently in operation based on the C-2000 module, which has a production capacity of 0.8–1 Mthm/y, namely at Posco's Pohang Works in South Korea, at Saldanha Steel's plant at Saldanha Bay, South Africa,Essar Steel, Hazira, Gujarat steel plant (2 modules) and at Jindal Vijayanagar Steel's steel plant at Torangallu, Karnataka, India (2 modules).

At Saldanha Steel and Essar, the Corex plant has been combined with EAF steelmaking, whilst Jindal and Posco have used the BOF route. Modifications have been introduced as experience with the C-2000 plants is gained. For example, unexpected wear of the refractory lining in the first C-2000 plant at Posco has resulted in changes in the refractory and cooling system design in the melter-gasifier. A C-3000 module with a production capacity of 1.2–1.5 Mthm/y is now available (and used for Finex at Posco). Two C-3000 modules are installed at Shanghai Baosteel Pudong Iron and Steel Co. Ltd. (Baosteel) in Luojing, near Shanghai, China.

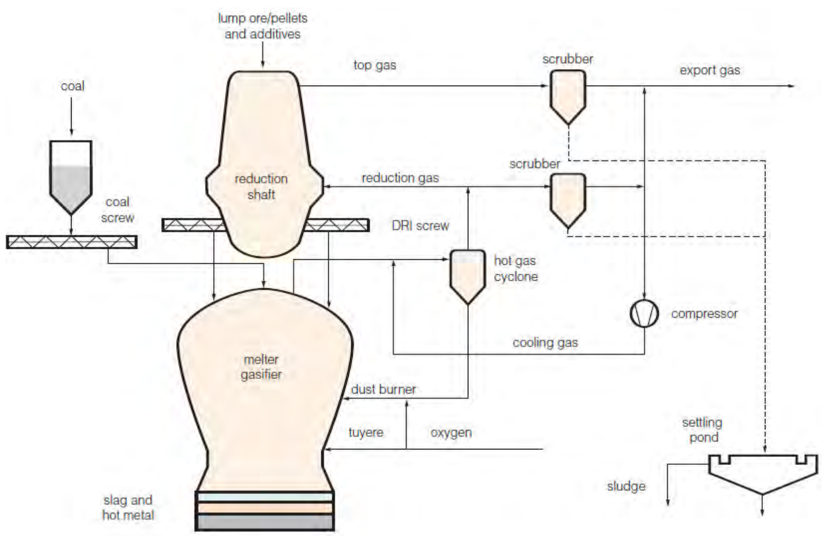


Figure 13 – Corex Schematic

Lump iron ore and/or pellets, and additives (limestone and dolomite) are charged into the top of a reduction shaft. Reducing gas from the melter-gasifier is injected into the lower part to reduce the iron ore to sponge iron (DRI). The additives ensure that adequate slag basicity and sulphur removal from the hot metal in the melter-gasifier is achieved. The hot DRI (metallisation 80–95%) and calcined additives are then transferred into the melter-gasifier by screw conveyors. Lump coal (6–50 mm) is fed in separately through the dome where it falls onto the char bed above the hearth. In the hot, reducing atmosphere (about 1000ºC), the coal is dried and devolatilised to char. The tars and other volatile matter from the coal are cracked and oxidised to mainly carbon monoxide and hydrogen.

Heat for the processes is supplied by the reaction of coal char with the injected oxygen to form carbon monoxide. The DRI passes through the char bed, where it is finally reduced and melted, creating a pool of slag and metal, both are periodically discharged by conventional tapping procedures. The reducing gas, containing about 65% CO and 20% H2 (rest CO2, H2O, N2), exits the melter-gasifier at a temperature of 1000ºC, and is cooled by recycled process gas to 800–850ºC.

After cleaning in a cyclone, the gas is fed into the reduction shaft to reduce the iron ore. The fines captured in the hot cyclone are recycled to the melter-gasifier. The top gas leaving the reduction shaft is cooled and cleaned in a scrubber, when it is now termed the export gas. This gas generally has a net calorific value of about 7,500–8,500 kJ/m3. This corresponds to about half of the energy content of the feed coal. The export gas can be used for a variety of heating, drying, metallurgical, chemical and power generation purposes.

The maximum productivity of Corex plants has been achieved by charging 70% pellets and 30% lump ore to the reduction shaft. Iron ore fines cannot be used without agglomeration in the reduction shaft because of the need to ensure adequate permeability within the bed to permit access and passage of the reductant gas. Instead, the iron ore fines are mixed with the coal and charged directly into the melter-gasifier. Iron ore fines can form up to 15% of the total iron-bearing charge.

Fine steel plant waste products, such as dusts and scales, can also be charged into the melter-gasifier. At the Jindal plant, BOF slag is used as a substitute for limestone, and the Corex sludge is mixed with the pelletising plant feed as a substitute for coal fines. The undersized limestone and dolomite fines (<6.3 mm) that cannot be charged through the reduction shaft can be charged into the melter-gasifier to fine-tune the slag chemistry. At the Saldanha Steel plant, sludge from the wet scrubbers and dust are granulated in a specially designed granulation plant. The granules are sold to a cement producer, but there are plans to recycle some to the melter-gasifier.

The chemical and physical properties of the iron ores and pellets affect the productivity of the plants. The total iron content should be above 60%, and the sum of the SiO2 and Al2O3 contents should be below 6% to keep the slag volume low. Separation of reducing gas generation from the reduction of iron ore allows a wide variety of coals or their blends to be used, although coal composition does affect its consumption, offgas quality and the amount of excess reducing gas.

A small amount of coke is used in the Jindal plant, before and after shutdowns for process corrective measures. The plant also requires about 10–15% coke, it is primarily required to improve char bed permeability within the melter-gasifier.

The overall economics of Corex depend to a large extent on the economic utilisation of the export gas. Both plants at Jindal and Posco were set up within existing integrated steel units where the prevailing gas deficit is met by the Corex export gas. At Posco the export gas is utilised for power generation, and at Jindal for both power generation and pellet production.

A different option was implemented at Saldanha Steel. The export gas, after removal of the CO2, is utilised in an adjacent Midrex direct reduction plant.

The Midrex process was developed by the Surface Combustion Division of Midland-Ross Corporation in the USA in the mid 1960's. In 1983 Midrex was acquired by Kobe Steel.

The Midrex process produces DRI from pellets using a reducing gas. This DRI is then typically used in EAF steelmaking, as a substitute for metal scrap.

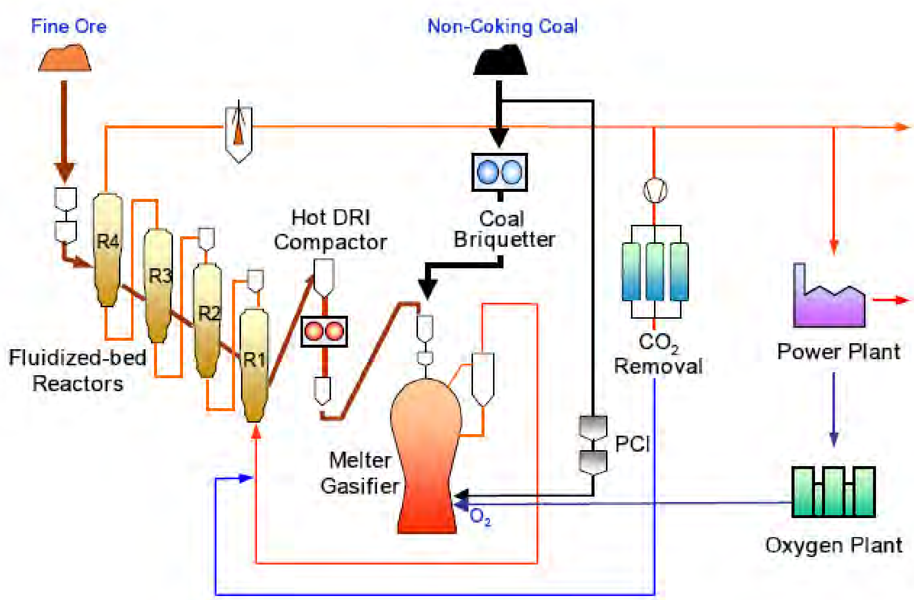
The Midrex process is the most widely used DRI process and typically uses natural gas to produce the reductant gas. When this is not economically available, the required reducing gas can be produced by a coal gasifier (not yet commercially used) or the Corex melter-gasifier. The latter option is operated at Saldahna (SA). This combined Corex-Midrex plant produces around 800,000 t/y of hot metal and 800,000 t/y of DRI.

In terms of the suitability for PIB, the main issue with these processes is again down to scale factor with a typical maximum sized unit producing circa 1,500,000 t/y compared with a Blast furnace producing up to 4,400,000 t/y.

5.1.6 Finex

Finex is an innovative Ironmaking process which has been developed by Siemens VAI and Posco.

A Schematic of the process is shown below:



Molten iron is produced directly using iron ore fines and non-coking coal rather than processing through a sinter plant and coke ovens as the traditional blast furnace route.

In the Finex process, iron ore fines are charged into a series of fluidized-bed reactors. The fines pass in a downward direction where they are heated and reduced to direct-reduced iron (DRI) by means of a reduction gas – derived from the gasification of the coal – that flows in the counter-current direction to the ore.

The DRI fines are then hot-compacted to hot-compacted iron, transferred to a charging bin positioned above a melter gasifier and then charged by gravity into the melter gasifier where smelting takes place.

The tapped product, liquid hot metal, is equivalent in quality to the hot metal produced in a blast furnace or Corex plant.

Because the preliminary processing of raw materials is eliminated, the construction of the Finex plant costs less to build than a blast furnace facility of the same scale. Furthermore, a 10-15% reduction in production costs is expected through cheaper raw materials, reduction of facility cost, pollutant exhaustion, maintenance staff and production time.

The excess gas produced from the process can be further utilised for the generation of Electricity.

In addition, it is eco-friendly in that it produces less pollutant such as SOx, NOx, and carbon dioxide than traditional methods.

Current Status

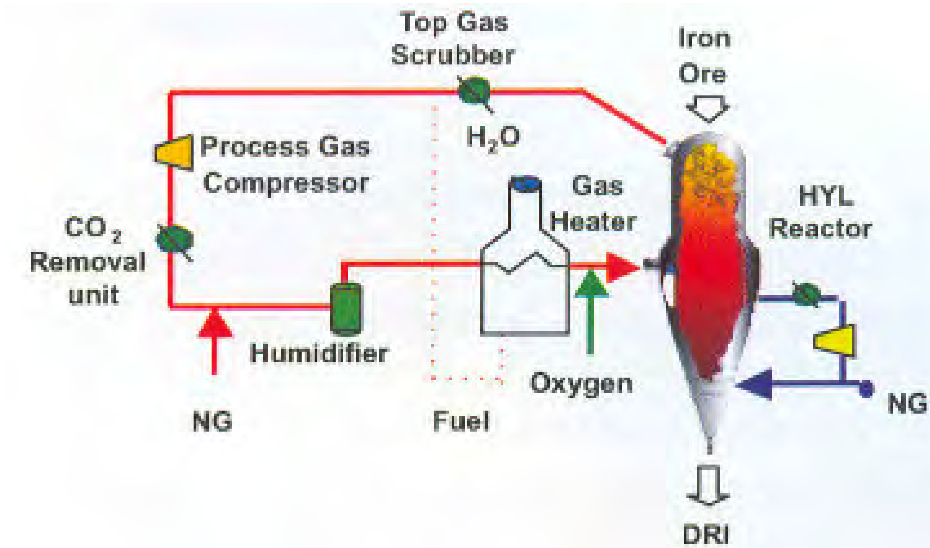
Posco together with Siemens VAI have designed and built the first commercial operational plant in Korea producing 1.5 million tonnes of hot metal per year. Posco are now considering scaling up to 2 million tonnes per annum.

Based on work completed so far, Posco estimate that the Finex equipment costs only 80% of the traditional Blast furnace route costs with operating costs of 85% of the blast furnace route costs.

5.1.7 Natural Gas Based Zero-Reforming HYL Process

The HYL process was developed by Hojalata Y Lamina s.a. (Hylsa) of Monterrey, Mexico with the first commercial unit starting production in 1957.

The Zero Reforming (ZR) HYL process is one of the latest developments by Tenova-HYL. A diagram of the process is shown below:



The HYL furnace is a moving bed shaft type reactor operating at a pressure of approximately 8 bar. Feed material in the form of pellets and/or lump ore is charged through a set of pressurizing and depressurizing bins and sealing valves.

Iron oxide is reduced by a counter current flow of reducing gas which contains mainly H_2 produced by self-reforming of natural gas inside the reactor, where fresh reduced iron plays the role of catalyst.

Due to high content of H_2, reduction reactions are fast and residence times of 2 – 4 hours are achieved. Natural gas is injected into the reducing gas circuit before the humidifier. Reduced material flows down into a transition zone where most of the carburization of DRI takes place.

Depending on the type of product, the material continues to flow down into either a cooling zone where it is cooled by a counter current flow of cooling gas to produce cold DRI, or is hot discharged into briquetting machines to produce HBI, or discharges hot into a HITEMP® pneumatic transport system to be directly charged into EAF (HDRI).

The product discharges through a set of pressurizing and depressurizing bins and seal valves to keep the reactor high pressure isolated from atmosphere. Spent gas is cooled and cleaned of CO_2 and sulphur and re-circulated into a reducing gas circuit. The process has the capability to produce DRI with carbon content in the range between 1.5 to 5 %.

Main Benefits

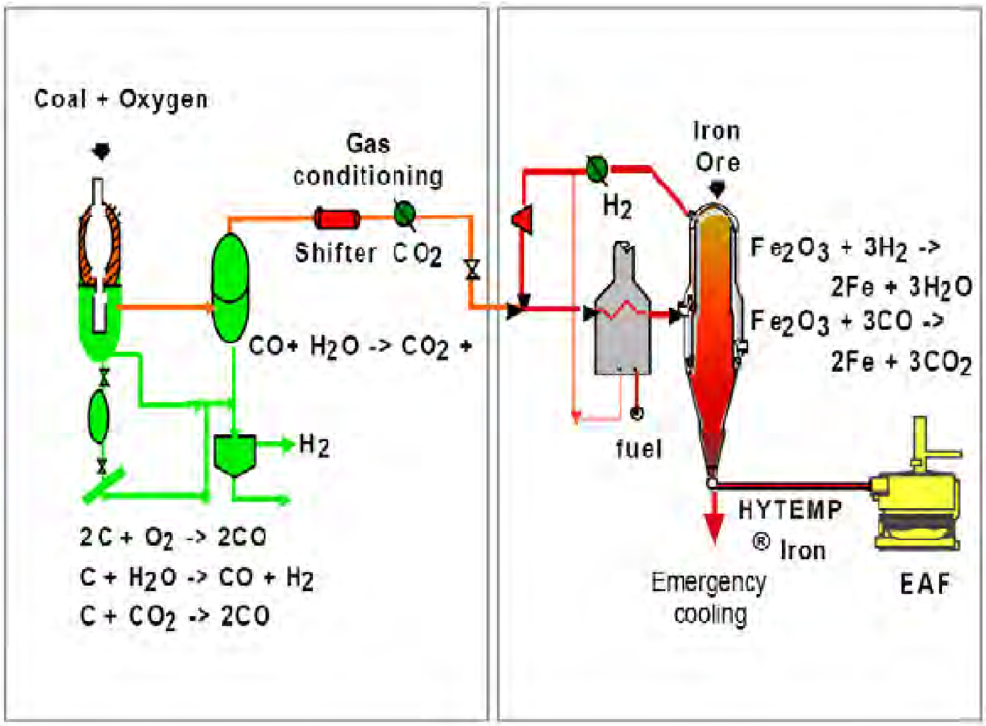
- No need for coking coal and coke
- Lower natural gas consumption compare to reformer based HYL process
- Production of high carbon DRI
- Production of hot DRI that could be charged to an EAF with significant energy savings

Main Disadvantages

- Requires additional electricity and Oxygen over traditional HYL process
- Typically installed capacity is 1MTPA with up to 1.75MTPA under development.

5.1.8 Coal Based HYL Process

The schematic of this process is shown below:



The HYL reactor and its peripheral systems and principles of operation are the same as the gas based HYL process in which oxide material is fed from top and is reduced by a counter current flow of H_2 and CO containing gas.

Since natural gas is not available for the carburization of DRI, lower carbon content of product is expected to be approximately 0.4 %. Similar to gas based HYL process, furnace top gas is cooled and cleaned and its CO_2 is removed and then recycled into the reducing gas circuit.

Reducing gas is produced in a coal gasifier that can process practically any kind of carbon bearing material. Coal and Oxygen are injected into the gasifier and almost all carbon in the coal is gasified. The gas is dust laden and includes CO_2 and H_2O and other impurities. It is cleaned and cooled in a series of cyclones and H_2O, CO_2 and Sulphur are removed.

Since the reactor is designed to work with high H_2 content reducing gas, and the gas from the gasifier contains considerable amounts of CO, a gas shift reactor is required to convert CO into H_2 by the reaction $CO + H_2O > CO_2 + H_2$

The shift reactor is installed before the CO_2 removal system. The temperature and pressure of the gas is then regulated before injection into the reactor.

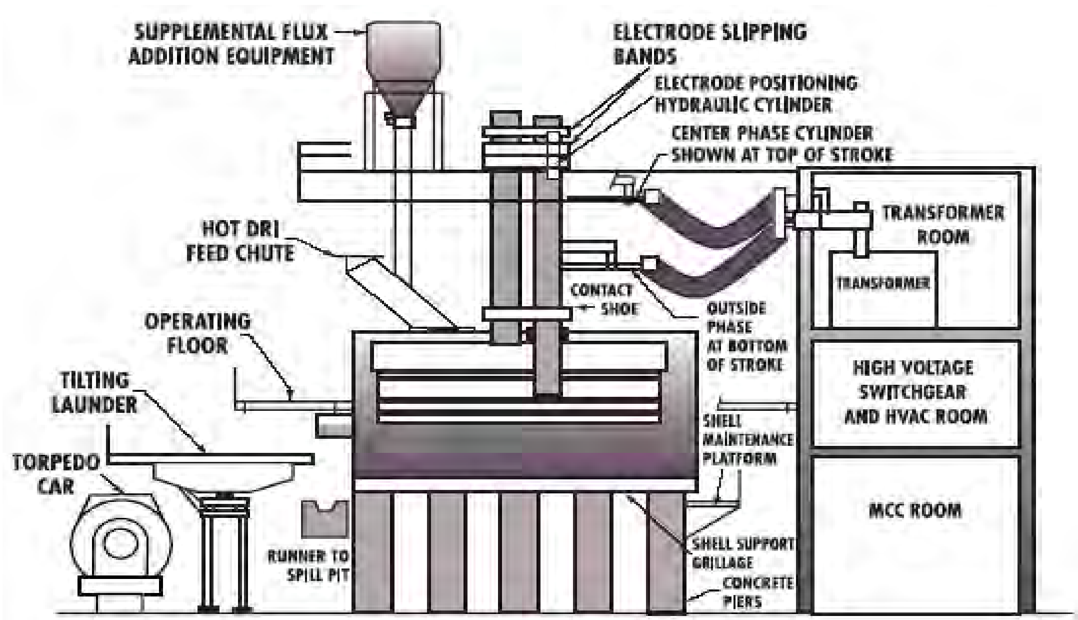
Main Advantages

- No need for coking coal and coke
- No need for natural gas
- Usage of low quality coals
- Production of hot DRI that could be charged to an EAF with significant energy savings

The main disadvantages are as per the Natural Gas HYL process described earlier.

5.1.9 Electric Iron Furnace (EIF)

The Electric Iron Furnace is a fixed position circular refractory lined airtight vessel that utilises direct arc heating via three electrodes. The technology was first developed by in 1995 by Midrex and Kobe Steel using DRI produced from the RHF pilot plant located at the Kakogawa Steel Works, Japan.



The EIF is stationary, has a fixed roof and tapping is carried out by drilling out a tap hole similar to a blast furnace tapping. DRI is continually gravity fed (either hot or cold) from storage bins located above the furnace.

It is a batch process that utilises pre-baked graphite electrodes (similar to an EAF) and a large hot heel practice to allow for variations in DRI chemistry. As the EIF is sealed and maintained under highly reducing conditions sulphur removal is efficient. Typical hot metal analysis produced by the Midrex pilot plant is as follows:

%C	%Si	%Mn	%S	%P	Tap Temp. C
4.5	0.47	0.107	0.013	0.036	1455 - 1510

Status of EIF Technology

As previously mentioned Midrex have a 1.5 ton pilot EIF at their research centre in the USA, however the only industrialised application was installed by Paul Wurth at Differdange, Luxembourg, as a part of their Primus Process. This process was designed to treat EAF red dust and oily sludge produced by the various Arbed (now Arrcelor Mittal) steel plants located in Luxembourg.

EIF Productivity

Limited data is available on EIF productivity, however the Midrex 1.5 tonne pilot plant had production rate of 260 lbs/h with an electrical energy input of 250kVA from a single phase AC transformer.

EIF Unit Size & Capital Costs

The only industrialised reference plant at Differdange, Luxembourg, is reported to now be producing approximately 125 kt/y. Due to the limited published data of EIF's it is not possible to make any sensible comment on the scaling up of units, however Paul Wurth claim they are comfortable with scaling it to 500 kt/y.

Capital Costs

Based on a budget estimate from Midrex it is recommended to use a preliminary capital cost estimate of US$160/thm, hence cost per 125 kt/y unit is US$20M.

Please note that given the very limited public availability of capital data on EIF's we strongly recommend to use supplier capital quotes as part of the detailed project report.

Estimated Consumptions

The unit consumption of the RHF-EIF route was estimated by using the IRMA RHF-EIF model (a steady state heat & mass balance model developed at the Tata RD&T Ironmaking department). Two cases were calculated: DRI with 70% and 85% metallisation.

Input data and assumptions on the EIF

- 30% of arc power is assumed to be lost to the cooling system (current industrial standard)
- Fe-containing dusts from the EIF are ignored.
- The slag contains 5% FeO and is conditioned to 0.9 B4 basicity. Resulting in the following composition:
    - Al_2O_3 14 wt%,
    - CaO 26 wt%,
    - CaS 2.5 wt%,
    - MgO 9.4 wt%,
    - MnO 0.13 wt%,
    - SiO_2 25 wt%,
    - Rest 18 wt%
- The hot metal consists of 4.5% C and 0.3% Si, 0.3% Mn and 0.05% S.
- Electrode consumption is 1.25 kg/GJ.

TATA STEEL TATA

Calculated unit consumption rates

Calculation of unit consumption rates of the RHF + EIF combination

		85% metallisation Hot-link	70% metallisation Hot-link	85% metallisation Cold-link
Ore	kg/thm	1433	1433	1433
Coal	kg/thm	420	419	418
Bentonite	kg/thm	18	18	18
Burnt Lime	kg/thm	51	51	51
Natural gas	Nm^3/thm	62	68	62
EAF electricity	GJ/thm	1.9	2.5	3.1
	kWh/thm	519	701	875
Electrode	kg/thm	2.3	3.2	3.9
Other electricity	kWh/thm	85	85	85
Slag	kg/thm	205	205	205
Export energy	GJ/thm	3.1	3.6	3.1

In terms of suitability for PIB, this process has only currently only one worldwide installation, operating at very low production levels when compared with a conventional blast furnace operation or with Corex/Midrex.

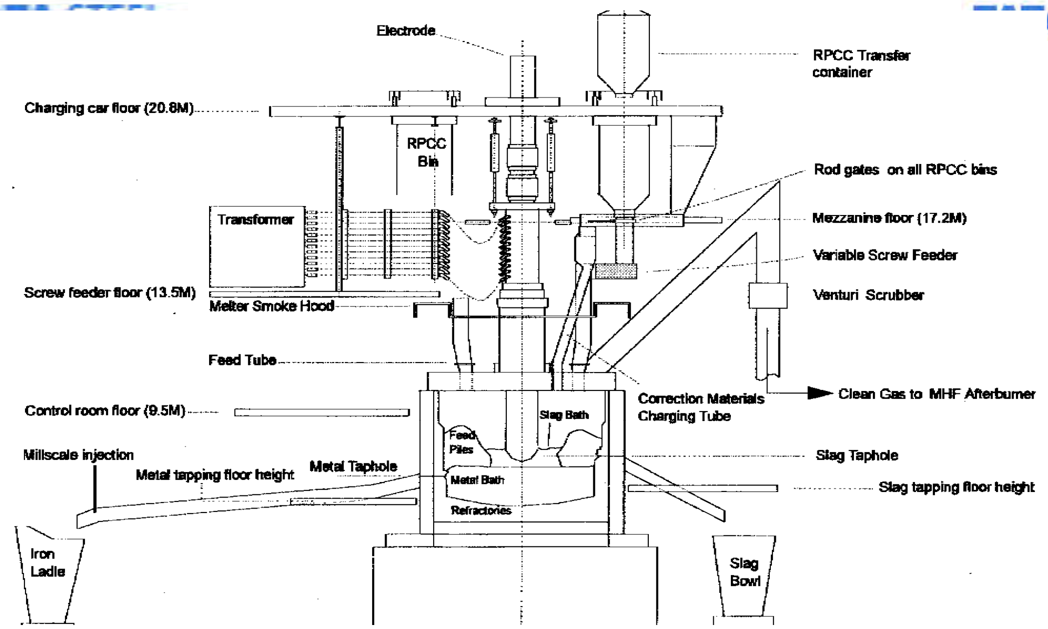
The system relies on a large capacity electricity supply and would require significant power plant input to support this process.

5.1.10 Submerged Arc Furnace (SAF)

The submerged arc furnace consists of either a rectangular or circular refractory lined sealed vessel that utilises resistance heating through a slag layer via a number of electrodes (normally six). The technology has been in use since the early 1900's in a variety of industrial applications including, ferroalloys, pig iron, waste treatment and non-ferrous metals.

DRI is gravity fed (either hot or cold) through the furnace roof from a system of storage bins located above the furnace. Additional fluxing agents i.e. lime or dolomitic lime can also be added in a similar manner, the quantity of which is determined by the analysis of the DRI.

The SAF is stationary and has a fixed roof, refractory sidewalls (MgO Brick) and refractory hearth (carbon block + MgO brick). Campaign lives up to 15 years are achievable with careful furnace operation. The SAF usually has two tap holes, one for slag and one for hot metal, and both are opened up using a dedicated tap hole drill similar to blast furnace tapping.



Off-gas from the SAF, primarily CO, can be recycled to the RHF where it is used as a fuel.

Status of SAF Technology

There are numerous SAF's in production around the world, SMS Demag for example have over 500 reference plants producing over 100 different products, some highlights of which are shown in the table below:

Customer	Country	Transformer Rating MVA	Product
Eramet-SLN	New Caledonia	99	FeNi
CVRD	Brazil	2 x 120	FeCr
SA White Martins	Brazil	49.5	CaC
Namakawa Resources	South Africa	1 x 28, 1 x 30	TiO – slag
Kumba Resources	South Africa	2 x 36	TiO – slag
Xinli	PR China	30	TiO – slag

However reference plants producing hot metal are not as common and research has identified only three furnaces as follows:

Plant	Country	Transformer Rating MVA	Capacity ktpa
New Zealand Steel	New Zealand	No.1 69 No.2 69	No.1 330 No.2 300
Highveld	South Africa	63	N/a
Iron Dynamics	USA	38	N/a

The Highveld furnace is reported as being mothballed following the acquisition of the company by Arrcelor Mittal, whilst the furnace at Iron Dynamics is reported to have had a problematic history, never achieving nameplate capacity. However the two SAF's in operation at New Zealand Steel (NZS) are successfully smelting a DRI produce via four multiple hearth furnaces and two rotary kilns utilising locally available titaniferous ironsand and high volatiles sub-bituminous B coal. The main design parameters of these SAF's are as follows:

Type - Elkem, rectangular AC furnaces each powered by three 23MVA transformers

Electrodes – Six in-line (three pair) 1.3m dia. Soderberg electrodes

Dimensions – 26m long x 7.6m wide x 4.6m high. 900mmm wall thickness

Hearth – Inverted arch (6.2m wide x 11m radius)

Sidewalls – magnesite brick with combination external steel plate (upper) and water-cooled steel panel (lower) shell supported by vertical buck stay held together at the top and bottom by tie rods to keep the hearth under compression and maintain dimensional control. Penetrative copper coolers at located at the slag level.

Roof – refractory design, either alumina castable or magnesite brick

Charging – continuous feed via variable speed screw feeder from 12 bibs located above the furnace, one either side of each electrode.

Tap holes – Separate tap holes for slag and metal. Two metal tap holes located on one side of the furnace above the lowest point of the hearth and two slag tap holes located on the opposite side 500mm above the metal tap holes.

Launders – slag launders are short with a steep gradient, feeding into a slag pot. Metal launders are longer with a shallow gradient and split at the end to allow feeding into two hot metal ladles.

Off-gas – off-gas production varies between 6,000 and 8,500 Nm3/h at 85% to 90% CO. The off-gas is cleaned in a fixed throat wet venture scrubber before being sent to either the rotary kilns or MHF afterburners for co-generation.

Typical hot metal analysis produced by the SAF's at NZS is:

%Fe	%C	%Ti	%Si	%Mn	%V	%S	%P
95.0 – 96.0	3.0 – 3.3	.20 - .35	.15 - .30	.40 - .50	.45 - .50	.025 - .040	0.50 - .090

SAF Productivity

The role of the SAF is to complete the reduction of and melt the DRI to produce liquid iron of a consistent carbon and sulphur content, hence the productivity of the SAF can be expressed in terms of total output (thm/h).

The two SAF's in operation at NZS have a quoted productivity between 35 to 50 thm/h, dependant upon production rate and inventory.

Discussions with a SAF equipment supplier (SMS Demag) have suggested that a rectangular furnace, approximately 26m long x 10m wide, with a 55MW power input would have a productivity of approximately 80 thm/h, which is comparable to the NZS furnaces who have a power input of 43MW and 39MW respectively.

SAF Unit Size & Capital Costs

Unit Size

Given that the SAF is a continuous process an operating time of 8,300 h/y has been assumed and hence a capacity of 660 kt/y has been calculated, which is the maximum unit capacity that SMS Demag have advised.

The SAF's in operation at NZS have quoted capacities of 330 and 300 kt/y, albeit with lower electrical energy inputs.

Capital Cost

At a scale of 660 kt/y it is recommended to use a (preliminary) capital cost estimate of 118 USD/thm. This estimate is based on a single source (SMS Demag).

SMS Demag SAF at 660 kt/y = US$ 78M

Please note that given the very limited public availability of capital data on SAF's we strongly recommend to use supplier capital quotes as part of the Detailed Project Report.

Estimated Unit Consumptions

Unit consumptions quoted by NZS are as follows:

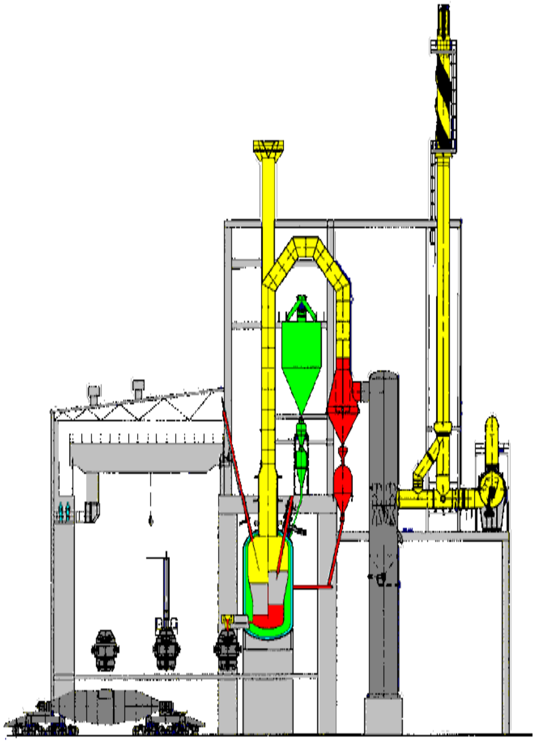
Item	Unit	Quantity
DRI	Kg/thm	1,600
Coal	Kg/thm	1,145
Limestone	Kg/thm	70
Electricity	KWh/thm	900
Electrode	Kg/thm	2.9

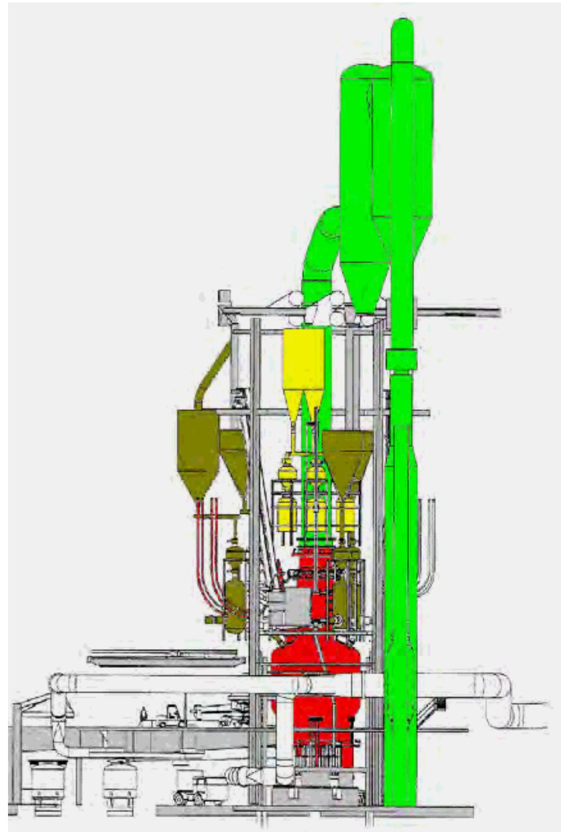
SMS Demag quoted electrical power consumption of 700 – 800 kWh/thm and electrode consumption of 2 kg/thm

TATA STEEL

TATA

5.1.11 HIsarna





HIsarna is a project jointly funded by the ULCOS partners to develop a €26 million pilot project (including an extended trial period). The basic engineering for a 65 kt/y plant at Tata Steel's IJmuiden plant in the Netherlands has been constructed and undergone some initial trials this year with Project management carried out by Tata Steel's RD&T with HiSmelt as a partner.

The process is similar, in many ways, to HISmelt but is expected to be more energy efficient and will generate around 20% less CO_2. It features an iron ore melting cyclone which is sited above, and feeds into, a bath smelting and reduction vessel.

HIsarna make use of ore fines and can use low cost coals and/or biomass as a fuel.
The process has been designed to handle high phosphorus ores, high zinc ores, and waste oxides.

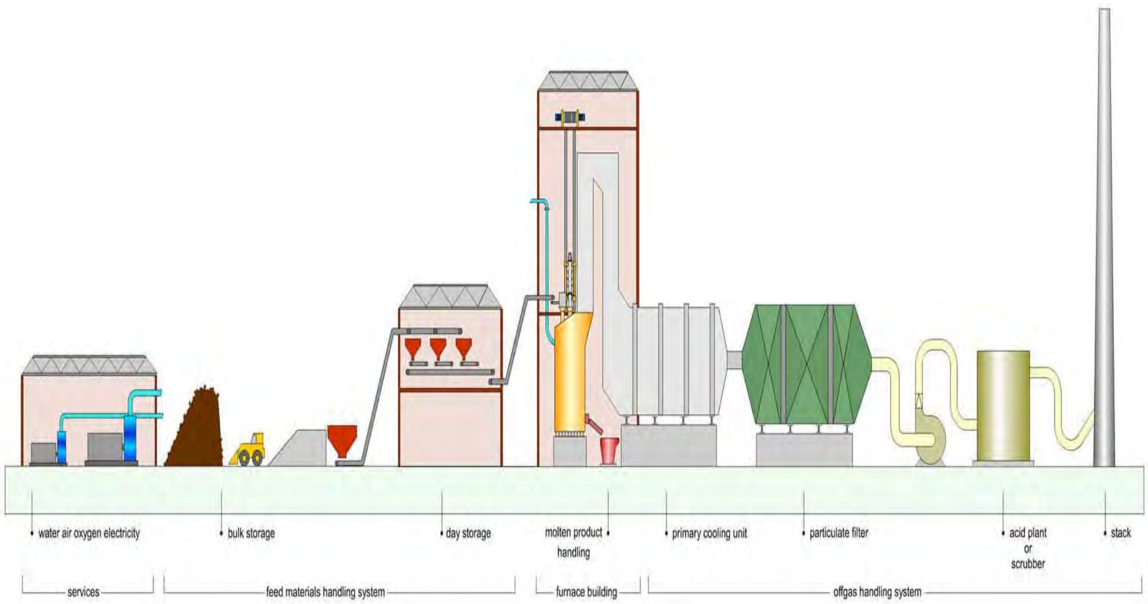
The plant features 'state of the art ; copper cooling with graphite lining > 2000 kW/m^2. A liquid layer of iron ore is frozen on the surface and provides the protection for the inner lining.

Experiments to date have been reasonably successful but a commercial unit is some 7-10 years away. Given this timeline, the HIsarna process is therefore not considered to be a candidate for this project.

TATA STEEL

TATA

5.1.12 Ausmelt



Ausmelt is smelting reduction production using a cold oxygen-enriched air and between 400-900kg/t of coal to produce hot metal and, as such, is not particularly energy efficient, It can be fed with ore or DRI and was established initially to process Cu. Pb. Ti and Zn

The process is simple – taking place in un-pressurised vessels- but is essentially small scale and is unlikely to be scaled beyond 250,000t/y and is rejected for this reason and because it is not yet commercially available.

5.2 OPTIONS FOR STEELMAKING

Two steelmaking options have been considered. These are:

- Electric Arc Steelmaking (EAF)
- Basic Oxygen Steelmaking (BOS/BOF)

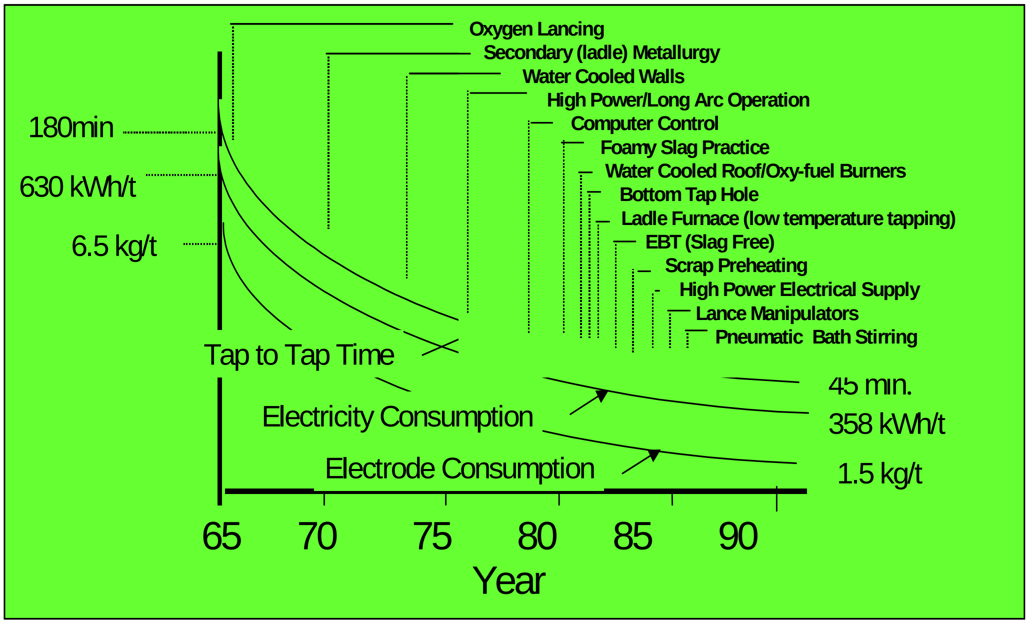
5.2.1 Electric Arc Furnace

The EAF is a proven technology with the first commercial furnace being commissioned in the late 19^{th} century and now they account for approximately 30% of global crude steel production (circa 410 Mt in 2010).

TATA STEEL

TATA

EAF efficiency has improved significantly over the past 40 years through a series of different innovations:



Modern EAF's have performance data as follows:

Item	Unit	Performance
Tap to Tap Time	mins.	45
Annual Production	ktonnes	1,500
Scrap Weight	tonnes	338 (largest)
Electrical Power Consumption*	KWh/t	358
Electrode Consumption*	Kg/t	1.2

*based on 100% scrap charge.

The main advantages of the EAF process route when compared to the more traditional BF / BOS route are as follows:

- Flexibility – can turn on & off by simply operating circuit breaker
- Environmentally Friendly
    - 100% recycled material (scrap)
    - Lower carbon footprint than BF/BOS (if scrap is used)
- Lower capital investment

The main disadvantages of the EAF process are:

PROJECT IRON BOOMERANG
east west line parks pty ltd

- Low productivity (when compared to Basic Oxygen Steelmaking)
- Typical EAF units produce circa 1.5 MTPA with very few references above 2MTPA
- Higher residual content not suitable for many flat product applications (based on 100% scrap input)
- High electricity costs compared to BF/BOS route
- Requires a large stable electricity supply infrastructure
- Requirement for a good source of scrap supply

If the EAF route was to be considered for PIB, the likely scenario would be a mix of DRI and Scrap charge.

5.2.2 Basic Oxygen Steelmaking (BOS)

The BOS is the most proven steelmaking technology available with the first Bessemer Convertor being commissioned in the mid 19th century and the basic oxygen convertor being developed in Linz, Austria, by the mid 20th century. The BOS now accounts for approximately 70% of global crude steel production (circa 990 Mt in 2010).

Modern BOS vessels equipped with sub-lances, off-gas analysers, sophisticated process control models and slag splashing are achieving productivity levels in excess of 470 t/h.

The main advantages of the BOS process route when compared to the EAF are:

- High productivity
- No external fuel source
- Suitable for the rapid production of a wide range of steel grades

Whilst the typical scrap to hot metal ratio operated within Europe is typically between 15 – 20%, numerous converters around the world are operated at far lower scrap levels, including Tata Steel operations at Jamshedpur. Tata Steel operates at an average scrap consumption of 7%, however, it has experience of operating BOF converters with no scrap addition at all. It uses iron ore as the coolant in such cases.

Company	Country	% Hot Metal	% Scrap
Tata Steel, Jamshedpur	India	93	7
Anshan Iron & Steel	China	92	8
JFE, Mirushima	Japan	95	5
Kobe Steel	Japan	93	7
Nisshin Steel	Japan	96	4

Hence with the use of works arising scrap, which is assumed to be approximately 3%, and the purchase of a minimal amount of merchant scrap (assumed to be nominally 3%) a proven process route can be adopted to produce quality liquid steel and a competitive conversion cost.

6. MATERIAL FLOW / LOGISTICS WITHIN THE STEEL COMPLEX

Based on 22MTPA finished slab output from each steel complex, the following sections give an indication of the main raw material requirements and material flows for the complex. The figures have been derived from a combination of Industry norms and TSC's extensive experience in steel plant layout and operation.

6.1 RAW MATERIAL HANDLING

In global terms the raw materials facility will need to handle the following quantities derived from process modelling work:

Coking Coal	Te/yr	11,306,253
Coal Injection Coal	Te/Yr	3,266,801
Total Coal	Te/Yr	14,573,054
Lump Ore	Te/Yr	5,417,383
Fines	Te/Yr	27,028,388
Total Ore	Te/yr	32,445,770
Limestone	Te/yr	8,309,372
Dolomite	Te/yr	2,475,788
Total Te Conveyed	Te/Yr	57,803,984

In addition to the above significant quantities of other materials will be required, in the main alloy additions to arrive at finished slab chemistry. These could include:

- Olivine
- Quartzite
- Fluorospar
- Aluminium
- Ferrosilicon
- Ferromanganese
- Ferrochrome
- Ferronickel
- Ferromolybdenum
- Ferrovanadium
- Ferrotitanium

6.1.1 Incoming rail materials

From the previous work undertaken by EWLP, each EWL train will consist of 300 wagons pulled by 4 loco units. The payload of each train is as follows:

	Iron Ore	Coal
Payload/Wagon(te)	109	65
Payload/Train(te)	32,700	19,500

Based on 340 days per year operation an average of 2.92 trains of iron Ore and 2.2 trains of Coal will be required at each steel complex per day.

However on the basis of the 2 steel complexes, one at each end of the E-W line, the net traffic each way ideally should be equal to capitalise on transporting loaded trains in both directions as such will be equal at an average of 2.92 trains per day each way for both Iron Ore and Coal.

This will require each train to be unloaded in approximately 8.2 hrs.

These discharge rates are equivalent to 4000 TPH for Ore and 1800 TPH for Coal.

In terms of wagon discharge there are 2 methods that can be used.

Gondola/Tippler Haulage systems

The Gondola/Tippler system has box carriages (Gondolas) linked with rotary connecting couplings. When the wagon rake arrives laden at the discharge point it is positioned by a hydraulic system and the carriage(s) are clamped and rotated about the rotating coupling, emptying the contents of the Gondola(s) into a discharge hopper from where it can be transported to the stocking areas by a conveyor system.

Emptying of the wagon should pose no problems or issues with material “hanging up” in the wagon

The Gondolas themselves are relatively simple, strong and light boxes with any complexity being in the rotating couplings. Benchmark Gondola systems have carriages of approximately 19t tare weight able to carry 130t across four axles based on the normal 32Te axle load.

Hopper/Bottom unloading system

The carriages of the bottom unloading systems each have pneumatically operated doors on the bottom of each carriage. This involves having additional equipment on each carriage that accounts for between 3 & 4 tonnes of extra tare weight above that of the Gondola system. The hopper itself has to be shaped to allow the material to flow to the exit doors. These are usually angled on both sides and ends. The doors themselves have to be within the axle base thus likely increasing the length of the wagon for a given storage capacity.

Discussion of the merits/issues of each system

Bottom unloading systems are prone to problems in cold climates; however this should not effect operation in tropical Australia, however issues could occur due to increased moisture, largely offset by use of wagon covers (see below)

Bottom unloading systems are generally designed to ensure the product unloads using “mass flow” rather than “funnel flow”. This can be an issue dependant on space limitations and the wagon design.

With bottom unloading, the material, if it is cohesive enough, can form bridges or arches that hold the overburden material in place reducing flow or even preventing unloading. This effect does not happen with Tippler systems.

The bottom unloading design allows the option to cover the wagons. This is a positive aspect for PIB in that over the 3000KM journey, this would:

- Reduce moisture to the product
- Allow for a reduction of drag from the carriage
- Reduce possible material loss due to windage

With the tippler wagon, covered wagons would be very difficult to accommodate requiring additional facilities and manual intervention.

The capital cost of the bottom unloading wagons will be greater than that of the Tippler type. TSC experience suggests circa $k10 per wagon difference based on Indian manufacture. This would need to be offset against the increased Capital cost of the tippler rotating station which would likely be some $5m more than a bottom unloading system (based on Indian prices) and the savings in fuel and windage loss with a more aerodynamic covered wagon.

The EWLP preferred unloading option is to use bottom unloading wagons into a discharge hopper and then feed from the hopper by conveyor to the stocking grounds.

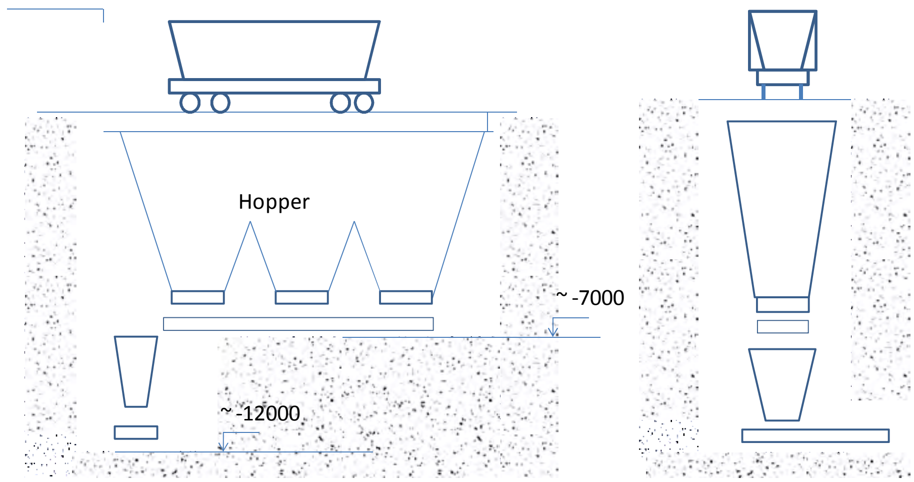
At this stage the design of the wagons is not finalised, however calculations indicate that assuming a wagon bottom opening of 6 doors each 0.7m x 1m in size, unloading times to the hopper once the door is open will be approximately 10 seconds for coal and 5 seconds for ore.

These values are well in excess of the requirements for unloading. In order to provide some comfort in terms of excess capacity, discharge conveyors with throughput rates sufficient to discharge a train in circa 5 hrs, equating to some 6500 TPH for Ore and 3900 TPH for Coal, are suggested.

Based on a wagon length of approximately 20m, the speed of the train during discharge and the time to discharge a train can be estimated.

Material	Wagon Load Te	Discharge Rate TPH	Train Speed kM/hr
Iron Ore	109	6500	1.2
Coal	65	3900	1.2

In terms of the basic arrangement of the discharge equipment, the sketch below, indicates a view of typical requirements



Two (2) wagon unloading stations each for Coal and Ore are proposed.

6.1.2 Raw Material Storage Capacity

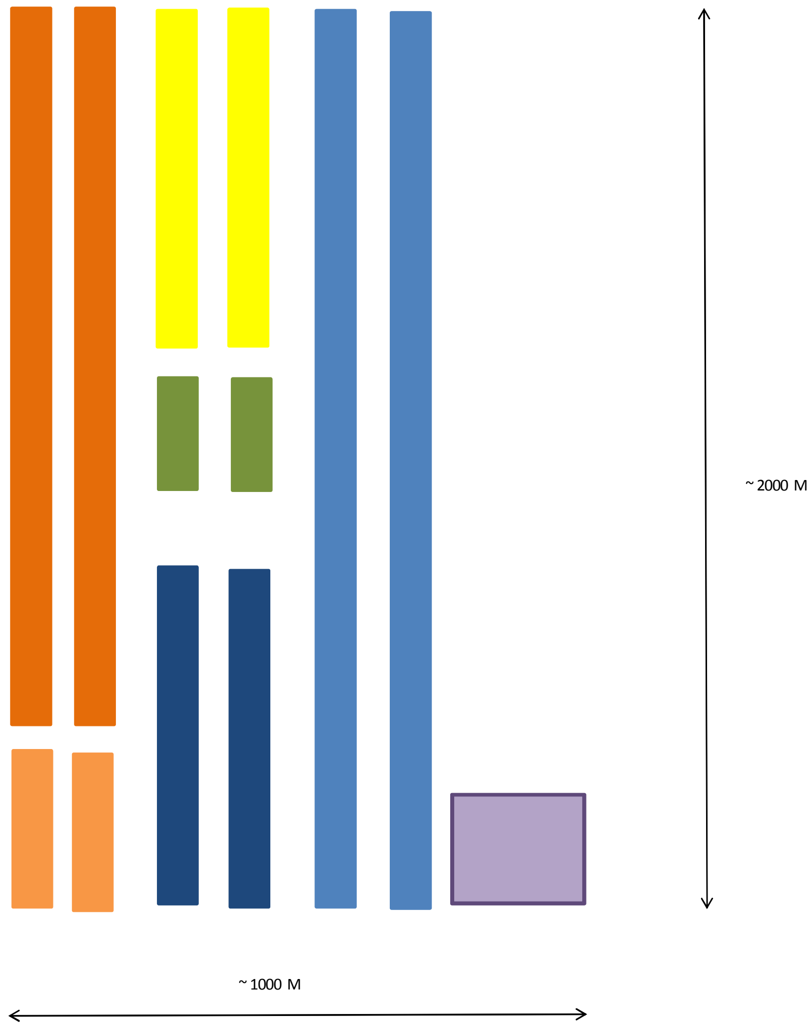
Although all major raw materials will be imported direct by rail on a regular basis, to take into account possible delays due to adverse weather in this tropical region It has been assumed that space will be required for 6 weeks production.
The table below gives indicative quantities of the material stocks required.

Material	MTe for 6 wks
Coking Coal	1.3
PCI Coal	0.4
Lump Ore	0.6
Fines	3.1
Limestone	1.0
Dolomite	0.3
Misc Fluxes	0.3

A typical layout of the raw materials stocks for this arrangement is shown below

TATA STEEL

TATA



In terms of ground area, this would amount to some 200 Hectares.

It is proposed that operations of the Coal and Ore stocks would be on the basis of one stockpile being built whilst one is being emptied. As such charge and discharge conveyors and stacker/reclaimers should be sufficient to process coal and ore to match the arrival rates from the wagon unloading stations.

- 6500TPH Ore handling capacity
- 3900TPH Coal handling

The following are proposed:

- 2 off 4000TPH stacker reclaimers for coking coal
- 1 off 1500TPH stacker reclaimers for PCI coal
- 1 off 2000TPH stacker reclaimers for lump ore
- 2 off 6500TPH stacker reclaimers for Fines
- 1 off 1500TPH stacker reclaimers for Limestone/Dolomite

PROJECT IRON BOOMERANG
east west line parks pty ltd

TATA STEEL

TATA

6.2 SINTER PLANT OPERATIONAL PARAMETERS

Process Modelling indicates the following typical approximate inputs into the sinter making process in terms of annual tonnes:

Material	Annual Tonnes
Iron ore	27,000,000
Coke	1,320,000
Limestone	3,233,000
Dolomite	2,350,000
Burnt Lime	440,000
Quartzite	352,000
Olivine	588,000

In addition to the above, miscellaneous recycled products from other processes such as:

- Blast furnace dust
- Continuous casting machine scale
- BOS slag and sludge

The output from the sinter making process will be approximately 29.4 million tonnes of sinter per annum.

For the purposes of the proposed Steel Complex, 4 Sinter Plants (in total) would be required to produce the necessary plant outputs, with each plant having to produce approximately 7.5 million tonnes of sinter per annum.

There are currently 9 Sinter plants in the world with quoted outputs greater than 7 million tonnes per annum, these are summarised below:

Country	Company	Works	Manufacturer	Yr Built or Uprated	Strand Area m^2	Strand w x L	Nom Capacity MTpa
Japan	NSC	Oita	Hitachi-Zosen / Lurgi	1976	600	5 x 120	8.2
Japan	JFE	Fukuyama	Hitachi-Zosen / Lurgi	1973 / 2003	605	5 x 121	8.0
France	Arcelor Mittal	Dunkerque	Lurgi	1971 / 1992	525	5 x 105	7.5
South Korea	Posco	Gwangyang	VAI	2011	600	5 x 120	7.5
Russia	NMLK	Lipetzk	Uralmash	1964	3 x 312		7.3
Russia	NLMK	Lipetzk	Uralmash	1972 / 2011	3 x 312		7.3
Kazakhstan	Arcelor Mittal	Temirtau	Uralmash	1975 / 1990	3 x 312		7.2
Japan	NSC	Kimitsu	Hitachi Zosen	1971	550	5.5 x 100	7.2
South Korea	Posco	Gwangyang	VAI	1992 / 2009	497	4.5 x 110.5	7.1

PROJECT IRON BOOMERANG east west line parks pty ltd

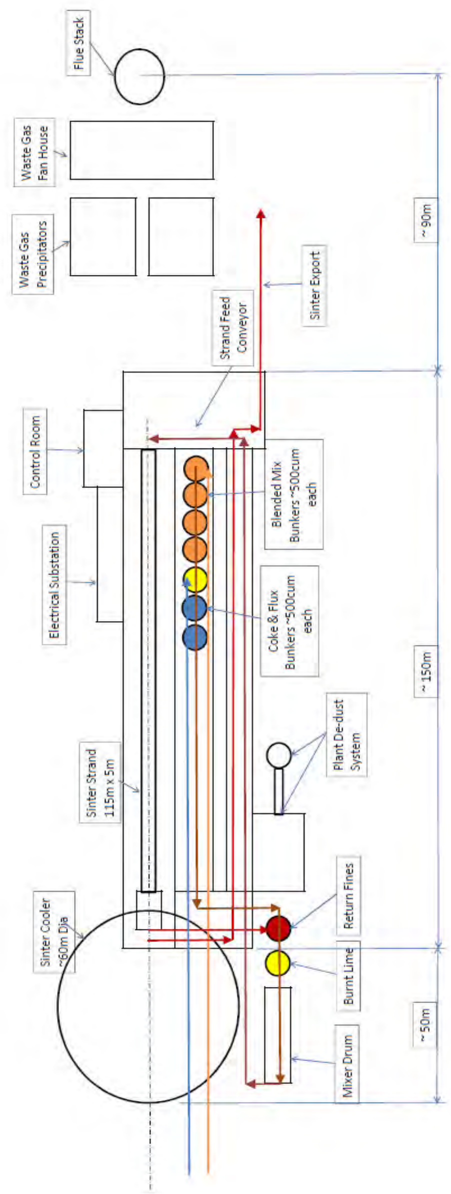
It can be seen from the above table that the bulk of the large single strand machines have all been manufactured to a Lurgi design.

A typical sinter plant output is 38 tonnes of sinter per day per m^2 of strand area, for the purposes of this study a Plant with a strand area of $575m^2$ based on a strand width of 5m and length of 115m is proposed.

An indicative plant layout of a single sinter plant is shown on the sketch below:

TATA STEEL

TATA



Additional space would be required for sinter feed blending yards; these will need to be capable of handling circa 7000 TPH of material on a continual basis.

Based on typical Barrel Reclaimer capacities of up to 4000 TPH, TSC would suggest 2 off Barrel Reclaimers recovering from 2 stockpiles at any one time with 2 stockpiles being built, i.e. 2 stacker units each feeding 2 stockpiles, capacity circa 4000 TPH each.

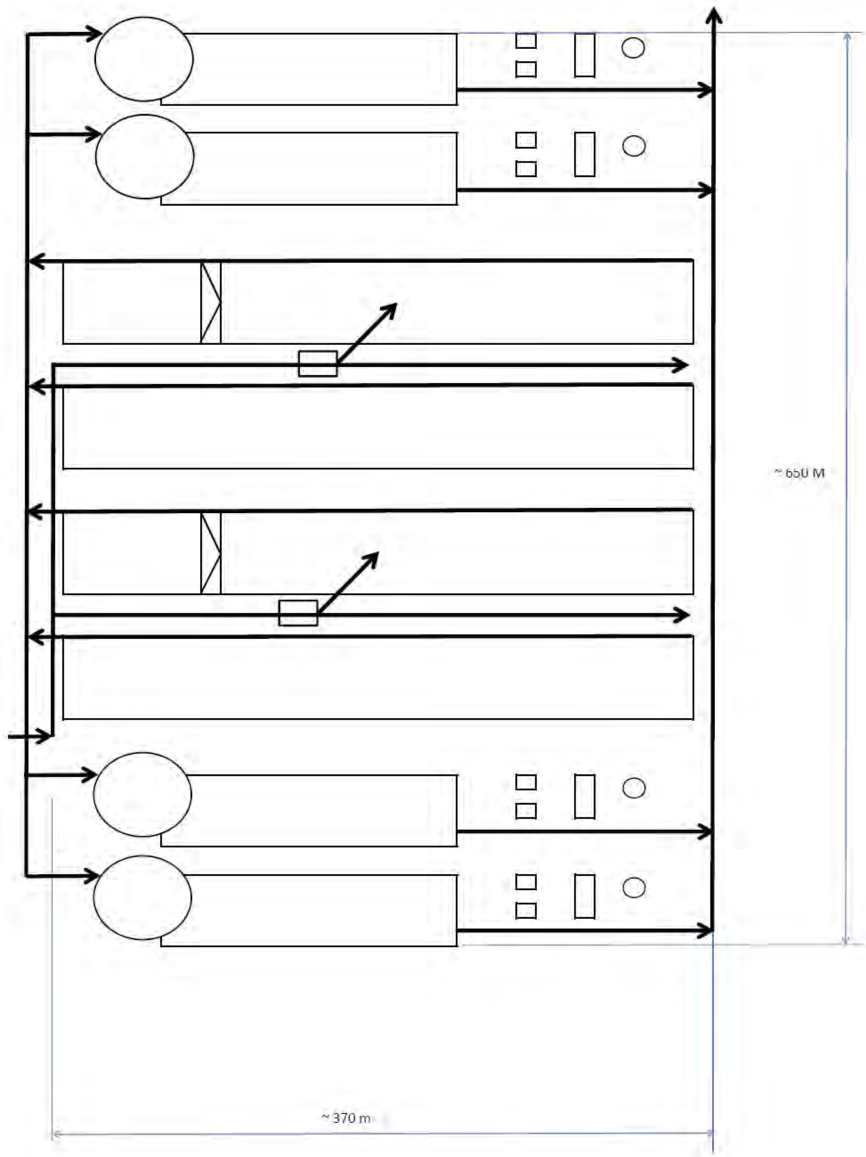
To achieve sufficient blending circa 500 passes on each bed will be required by the stacker, Stack dimensions will be 60m wide by 15m high (Cross Sectional Area circa 450m^2) Each stack will be approximately 350m long giving a capacity of 1 week bedding and 1 week

PROJECT IRON BOOMERANG east west line parks pty ltd

TATA STEEL TATA

reclaiming capacity.

The Schematic layout of the sinter complex is shown below:



To account for potential disruptions to the process flow, some sinter buffer storage should be considered to allow sinter to be stockpiled if downstream processing units are not operational. With the proposed 5 blast furnace operation it is unlikely that all furnaces would be shutdown at any one time, so an emergency stockpile of only 1 to 2 days production ~ 120kTe is suggested.

The above solution is seen as an "Optimised" design in terms of equipment and space to achieve the required steel complex output. This solution however is very much dependant on the Steel Producers working together to receive a common sinter blend.

If individual blast furnace blends are required, the sinter plant layout becomes more complex. With this scenario, it is proposed that each sinter plant feeds an individual blast furnace. In this case each plant would need to produce approximately 5.9 MTe of sinter per year, which could be supplied by a hearth area of 460m^2, which could be achieved by a reduced hearth length of approximately 92m.

The sinter blending yards would be more complex, requiring 2 beds per sinter plant (one being built / one being reclaimed at any one time). Each bed would be approximately 280m long and be serviced by a shared boom stacker of circa 2500TPH capacity and a barrel reclaimer of 2500TPH capacity across the 2 beds.

6.3 COKE OVEN OPERATIONAL PARAMETERS

Process Modelling indicates that to produce the necessary amount of coke feed to the blast furnaces and sinter plants (circa 8.7 MTPA) a total of around 11.3MT of coal will be required.

For the purposes of the proposed Steel Complex, in total 3 coke oven plants of two batteries each with a common By-Products plant are proposed. To produce the necessary plant outputs, each plant will need to produce approximately 2.9 million tonnes of coke per annum.

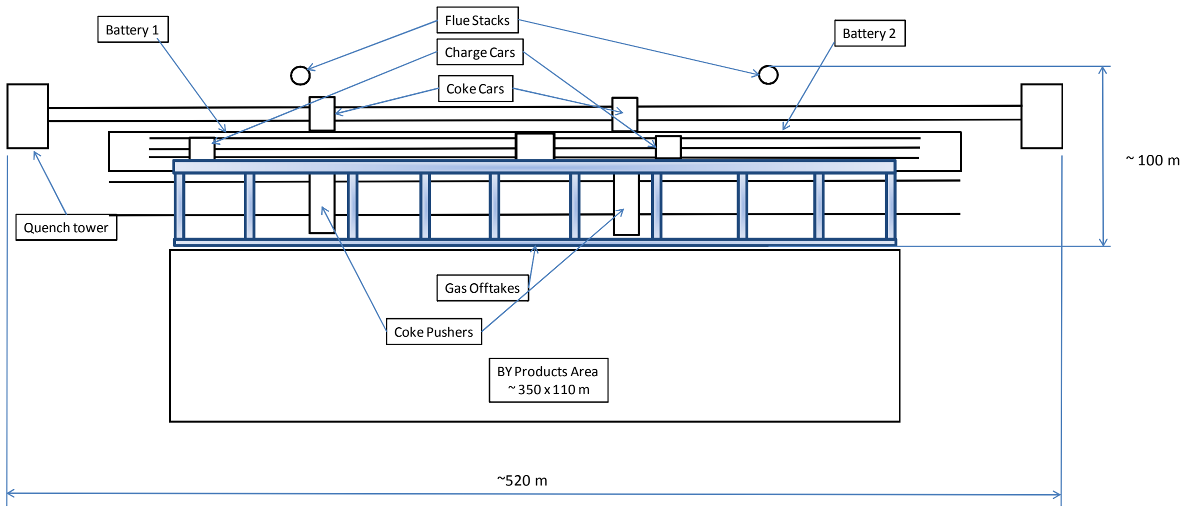
There are currently 6 coke plants in the world with quoted outputs greater than 2 million tonnes per annum from 2 batteries, these are summarised below:

Country	Company	Works	Manuf.	Year	No. Ovens	H (m)	L (m)	W (m)	Charge Vol (m^3)	Cool - ing	Nom Cap KTPA
Germany	TKS	Duisberg	Uhde	2003	140	8.3	20.8	.59	93	Wet	2640
Japan	JFE	Keihin	Still	1976	198	7.55	17	.45	38	Dry	2480
China	Maanshan	Maanshan	Uhde	2006	140	7.63	18	.59	76	Wet	2300
China	Wuhan	Hubei	Uhde	2008	140	7.63	18	.59	76	Dry	2200
China	Shagang	Zhang Jiagang	Chinese	2009	220	6	-	.45	-	Dry	2200
China	Shadong	Jining City	Uhde	2006	120	7.63	18	.61	76	Dry	2000

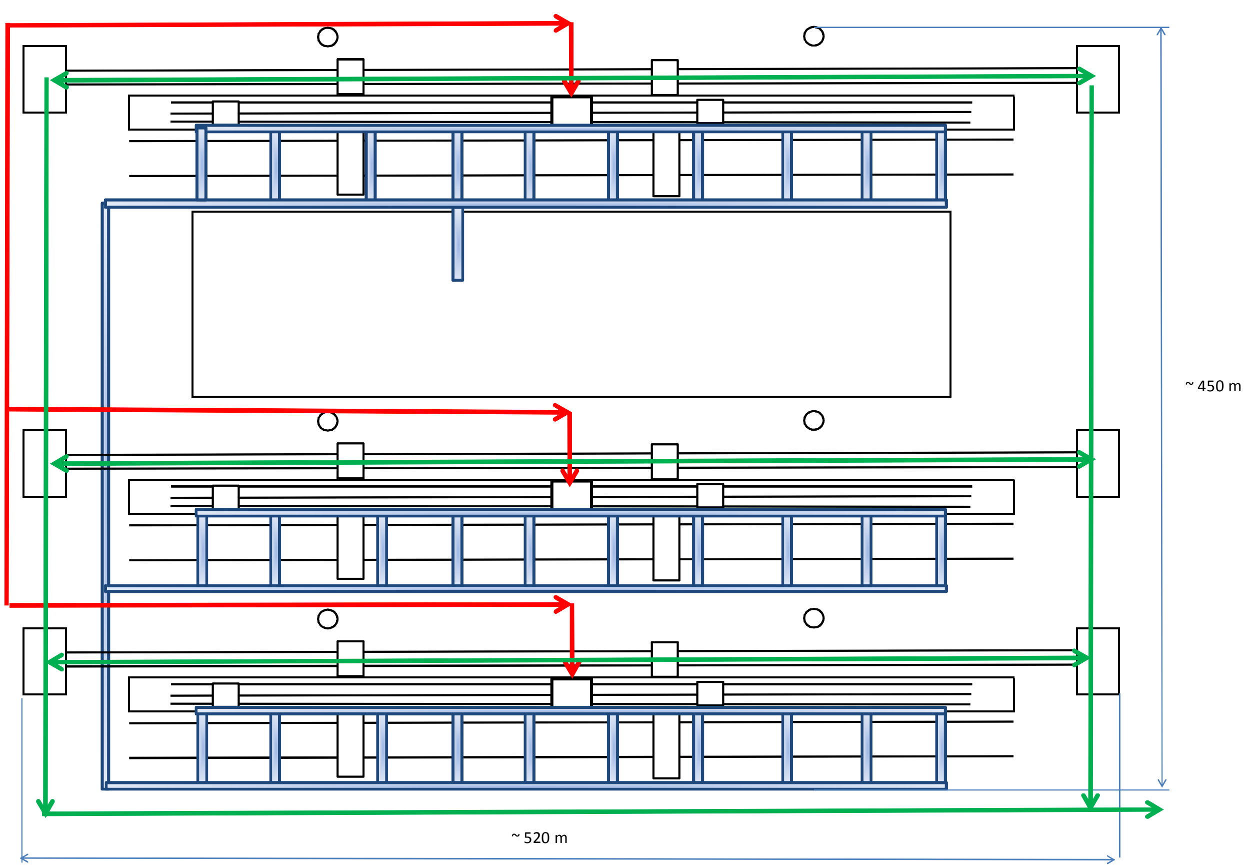
It can be seen from the above table that the bulk of the large twin battery coke plants have all been manufactured to an Uhde design. The trend in all these units has been to go for a large oven of around 80m^3 coal charge volume or more.

For PIB, a unit based around similar lines to the Duisberg-Schwelgern design is recommended. To give the required output of 2.9MTPA additional 10-15 ovens would be required, taking the total to say 154 made up of 2 batteries of 77 ovens each.

The single ovens layout is shown below:



The basic schematic of the 3 oven units making up the full coke plant is shown below with the proposed material flows:



To account for potential disruptions to the process flow, some coke buffer storage should be considered to allow sinter to be stockpiled if downstream processing units are not operational, with the proposed 5 blast furnace operation it is unlikely that all furnaces would be shutdown at any one time, so an emergency stockpile of 1 to 2 days production ~ 30kTe is suggested.

6.4 LIME PLANT OPERATIONAL PARAMETERS

Process Modelling indicates that to produce the necessary amount of burnt lime to feed the sinter plants and steel plants, a facility producing approximately 8000 tonnes per day will be required.

One of the world leaders in Lime producing equipment is Maerz who manufacture a wide variety of kilns of up to 800 tonnes per day.

For the purposes of the proposed Steel Complex, a total of 10 of the largest Maerz type lime kilns is proposed

6.5 AIR SEPARATION PLANT OPERATIONAL PARAMETERS

Process modelling indicates the following requirements for Oxygen, Argon and Nitrogen.

Oxygen
Blast Furnace blast enrichment - 57.6 NM^3/ THM = 1.26×10^9 NM^3 / annum
Hot Metal treatment – 15 NM^3/ THM = 3.21×10^8 NM^3 / annum
BOF Steelmaking - 58 NM^3/ TLS = 1.26×10^9 NM^3 / annum
Continuous Casting - 4 NM^3/ Tonne cast slab = 9.0×10^7 NM^3 / annum
Slab Processing - 16.8 NM^3/ Tonne finished slab = 3.69×10^8 NM^3 / annum

Total Oxygen requirement is therefore 3.3×10^9 NM^3 / annum which is equivalent to 12928 tonnes per day based on a 365 day per year operation.

Argon
BOF Steelmaking - 0.8 NM^3/ TLS = 2.8×10^7 NM^3 / annum
Continuous Casting - 1 NM^3/ TLS = 2.3×10^7 NM^3 / annum

Total Argon requirement is therefore 5.1×10^7 NM^3 / annum which is equivalent to 247 tonnes per day based on a 365 day per year operation.

Nitrogen
Coke Dry Quench - 50 NM^3/ Tonne of Coke = 4.3×10^8 NM^3 / annum
Blast Furnace - 43 NM^3/ THM = 9.4×10^8 NM^3 / annum
Hot Metal treatment – 30 NM^3/ THM = 6.4×10^8 NM^3 / annum
BOF Steelmaking - 15 NM^3/ TLS = 3.45×10^8 NM^3 / annum
Continuous Casting - 0.16 NM^3/ Tonne cast slab = 3.6×10^6 NM^3 / annum

Total Nitrogen requirement is therefore 2.37×10^9 NM^3 / annum which is equivalent to 8120 tonnes per day based on a 365 day per year operation.

Based on the above requirements, the total quantity of air requiring separation is based on the Oxygen requirements and will be equivalent to 55840 TPD of Air, which will provide a surplus of 468 tonnes of Argon per day and 34100 tonnes of Nitrogen.

TATA STEEL

TATA

6.6 BLAST FURNACE OPERATIONAL PARAMETERS

As described in section 4 of this report, Iron production has been based around 5 large blast furnace units, each producing circa 4.4 million tonnes of hot metal per annum.

The table below indicates all current and known planned blast furnaces with annual outputs greater than 4 MTPA, a total of 24 Units.

PROJECT IRON BOOMERANG
east west line parks pty ltd

TATA STEEL

TATA

COUNTRY	COMPANY	LOCATION/WORKS	MANUF.	YEAR OF START UP / Reline	INNER VOLUME	HEARTH DIAMETER	INJECTION	TOP DESIGN	TRT	TRT RATED POWER	DAILY HOT METAL PROD'N	NOM CAP'y
					M^3	M				MW	T/DAY	KT/YEAR
SOUTH KOREA	POSCO	POHANG	IHI, Nippon Steel JP	1981 / 2010	5600	15,6	PULV. COAL, ARMCO	BELL-LESS-TOP®, P.WURTH	YES	28,6	14600	5310
CHINA	JIANGSU SHAGANG GROUP	ZHANGJIAGANG II, JIANGSU	MCC, CN	2009	5800	15,7	PULV. COAL	BELL-LESS-TOP®, P.WURTH	YES		14000	5000
SOUTH KOREA	POSCO	GWANGYANG	DAVY-MCKEE, UK: Korea Heavy Ind.	1992 / 2009	5500	15,6	PULV. COAL, ARMCO	BELL-LESS-TOP®, P.WURTH	YES	14,3	14000	5000
JAPAN	NIPPON STEEL CORP	OITA, KYUSHU	NIPPON STEEL, JP	1972 / 2009	5775	15,6	PULV. COAL	DOUBLE BELL NSC	YES	24,96	13500	4800
JAPAN	NIPPON STEEL CORP	OITA, KYUSHU	NIPPON STEEL, JP	1976 / 2004	5775	15,6	PULV. COAL	DOUBLE BELL NSC	YES	27,9	13500	4800
CHINA	BAOSTEEL ZHANJIANG I&S	ZHANJIANG CITY, GUANGDONG		2014	5700	15,6	PULV. COAL	BELL-LESS	YES		13000	4600
CHINA	BAOSTEEL ZHANJIANG I&S	ZHANJIANG CITY, GUANGDONG		2014	5700	15,6	PULV. COAL	BELL-LESS	YES		13000	4600
JAPAN	NIPPON STEEL CORP	KIMITSU, CHIBA	NIPPON STEEL, JP	1975	5555	15,5	PULV. COAL	BELL-LESS-TOP®, P.WURTH	YES		12770	4530
CHINA	SHOUGANG JINGTANG UNITED I&S	CAOFEIDIAN ISLAND, HEBEI	CHINA-MANUFACTURER	2009	5500	15,5	PULV. COAL	BELL-LESS	YES			4490
CHINA	SHOUGANG JINGTANG UNITED I&S	CAOFEIDIAN ISLAND, HEBEI	CHINA-MANUFACTURER	2010	5500	15,5	PULV. COAL	BELL-LESS	YES			4490
GERMANY	THYSSENKRUPP STEEL EUROPE AG	DUISBURG-SCHWELGERN	MAN GHH, DE: Ansaldo, IT	1993	5513	14,9	PULV. COAL, KÜTTNER	BELL-LESS-TOP®, P.WURTH	YES	18	12000	4300
JAPAN	NIPPON STEEL CORP	NAGOYA, AICHI	NIPPON STEEL, JP	1979 / 2007	5443	15,2	PULV. COAL	BELL-LESS-TOP®, P.WURTH	YES		12000	4250
CHINA	WUHAN I&S CO	FANGCHENGGANG, GUANGXI		2014	5200	14,8	PULV. COAL	BELL-LESS	YES			4200

PROJECT IRON BOOMERANG east west line parks pty ltd

TATA STEEL

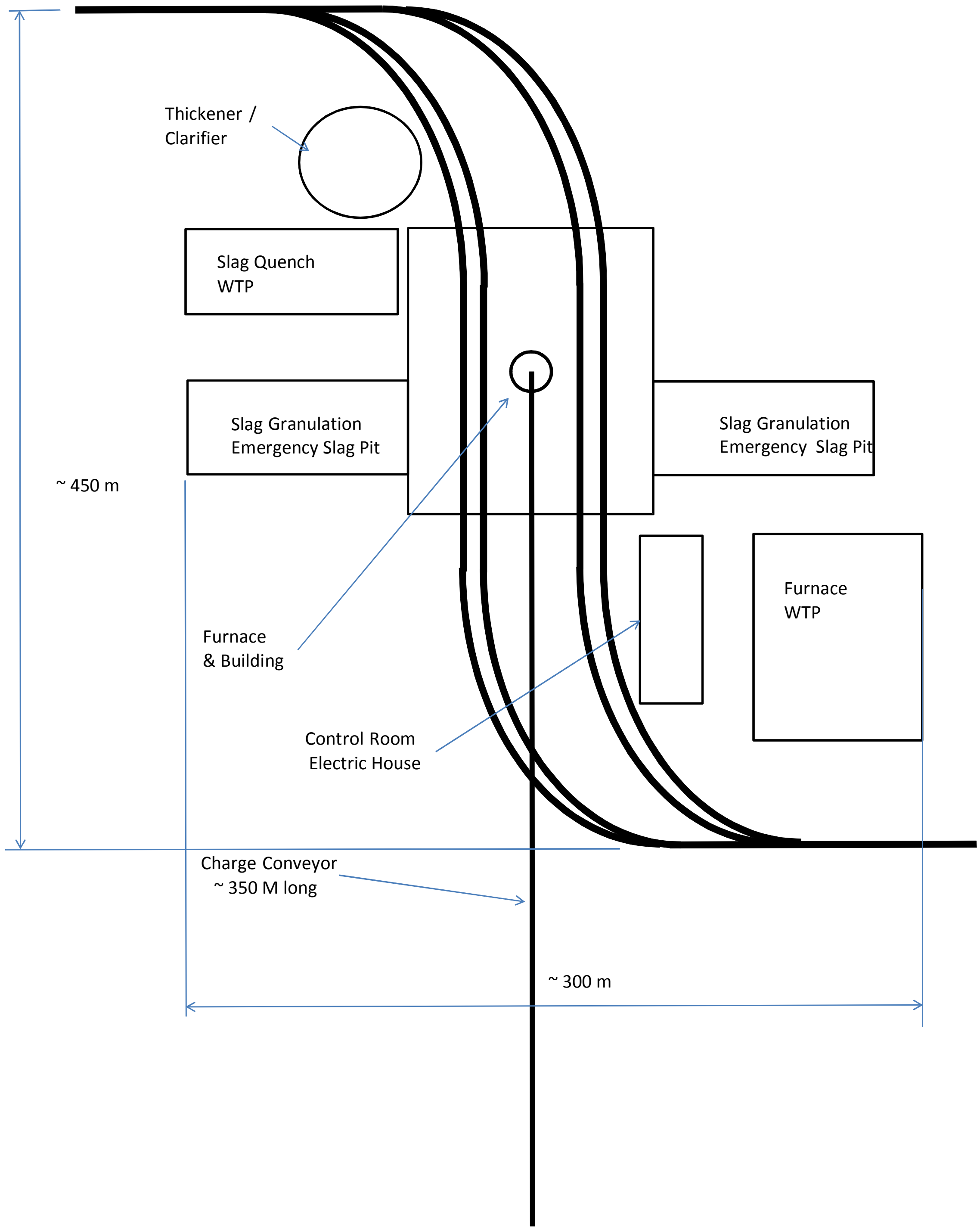
TATA

CHINA	WUHAN I&S CO	FANGCHENGGANG, GUANGXI		2014	5200	14,8	PULV. COAL	BELL-LESS	YES			4200
JAPAN	JFE STEEL	WEST WORKS (FUKUYAMA)	NKK, JP	1973 / 2005	5500	15,6	PULV. COAL	BELL-LESS-TOP®, P.WURTH	YES	23	11800	4180
CHINA	BAOSHAN I&S CO LTD	BAOSHAN, SHANGHAI	CISDI, CN: Paul Wurth, Lu.	2005	4747	14,5	PULV. COAL	BELL-LESS-TOP®, P.WURTH	YES		11700	4100
JAPAN	JFE STEEL	EAST WORKS (CHIBA)	KAWASAKI H. IND., JP	1977 / 1998	5153	15	PULV. COAL, KAWASAKI-SUMITOMO	BELL-LESS-TOP®, P.WURTH	YES	24	11500	4070
JAPAN	JFE STEEL	EAST WORKS (KEIHIN)	NKK, JP	1979 / 2004	5000	14,8	PULV. COAL	BELL-LESS-TOP®, P.WURTH	YES		11500	4050
JAPAN	SUMITOMO METAL IND.	KASHIMA	IHI, JP	2004	5370	15	PULV. COAL	BELL-LESS-TOP®, P.WURTH	YES	19	11000	4000
JAPAN	SUMITOMO METAL IND.	KASHIMA		1976 / 2007	5370	15	PULV. COAL	BELL-LESS-TOP®, P.WURTH	YES	19	11000	4000
SOUTH KOREA	HYUNDAI STEEL	DANGJIN B	PAUL WURTH, LU	2010	5250	14,8	PULV. COAL, P.WURTH	BELL-LESS-TOP®, P.WURTH	YES		11650	4000
SOUTH KOREA	HYUNDAI STEEL	DANGJIN B	PAUL WURTH, LU	2010	5250	14,8	PULV. COAL, P.WURTH	BELL-LESS-TOP®, P.WURTH	YES		11650	4000
SOUTH KOREA	HYUNDAI STEEL	DANGJIN B	PAUL WURTH, LU	2013	5250	14,8	PULV. COAL, P.WURTH	BELL-LESS-TOP®, P.WURTH	YES		11650	4000
CHINA	BAOSHAN I&S CO LTD	BAOSHAN, SHANGHAI	NIPPON STEEL, JP	1985 / 2008	4966	14,6	PULV. COAL	BELL-LESS-TOP®, P.WURTH	YES		11500	4000

PROJECT IRON BOOMERANG
east west line parks pty ltd

TATA STEEL TATA

A typical indicative single blast furnace layout of this size is shown on the sketch below:



The above sketch shows the approximate ground area covered by the main Blast Furnace components, together with the rail tracks feeding the torpedoes under the tap-hole runners. The proposed 5 furnaces can be stacked on approximately 350m centres to provide the full output of 22 MTPA.

PROJECT IRON BOOMERANG
east west line parks pty ltd

Each Blast furnace will consist of 4 tap-holes; typical production philosophy will be by utilising the "Continuous Tapping" method to try to achieve a consistent liquid level in the hearth. This is explained schematically below with the shaded areas representing the tapping time per tap-hole.

Taphole 1												
Taphole 2												
Taphole 3												
Taphole 4												
Time Hrs	2	4	6	8	10	12	14	16	18	20	22	24

Based on this philosophy approximately 1188 tonnes of hot metal and 326 tonnes of slag will be cast for each tap-hole sequence.

6.7 HOT METAL TRANSFER TO THE STEEL PLANT

From the analysis above, based on 1188 tonnes of hot metal being cast per tap-hole sequence, it has been assumed that the iron will be tapped into 4 torpedo ladles each of a nominal 300 tonne iron capacity. The torpedo ladles will be arranged in 2 groups of 2 being fed by a "rocking spout" arrangement. Based on typical information for these units, the tare weight of each torpedo ladle will be the order of 280 tonnes split across 16 axles giving an axle weight of just over 36 tonnes.

Minimum rail radius of a unit of this size is 75m and all up weight based on 2 torpedoes per train will be approximately 1150 tonnes.

Modelling work indicates that a typical cycle time for a train of 2 torpedoes, tapping at the Blast furnace, transfer to the Steel plant, Hot metal treatment at the steel plant to reduce Sulphur, Silicon and Phosphorus, pour into transfer ladles and return to the blast furnace will take from between 175 and 190 minutes per group. This gives a processing capability of each group of around 4400 tonnes per day. To meet the requirement for PIB of 22MTPA finished steel, 2.6 trains from each furnace will be required giving 14 in total (56 torpedoes) not including spares or allowance for torpedoes being wrecked and relined. It is assumed that this would constitute circa 15% of the fleet giving a requirement of say 64 torpedo ladles.

6.8 STEEL PLANT OPERATIONAL PARAMETERS

Steel plant liquid steel production requirements will be approximately 23MTPA. It has been assumed that this requirement will be met by 3 BOF shops each with 3 BOF vessels, each shop producing just over 7.5MTPA of liquid steel.

There are a total of 12 BOF shops based on this configuration with the capability of producing more than 7MTPA, the table below give details:

Country	Company	Plant	Manufacturer	Date Built / Enhanced	Tap Weight Te	Nominal Output MTPA
Russia	Magnitogorsk	Magnitogorsk	USSR	1990 / 2012	370	10.5
China	Shougang	Caofeidian Island	SVAI	2009	300	9.7
Russia	Severstal	Cherepovets	USSR	1980 / 1999	350	9.5
Japan	NSC	Oita		1972 / 1976	397	9.4
Korea	Posco	Pohang		1978 / 1981	300	9.1
Russia	Novolipetsk	Lipetzk	USSR / SVAI	1974 / 2011	330	9
Korea	Hyundai	Dangjin B	JP Plantech	2010	300	8.4
Brazil	AM Tubarao	Vitoria	Italipianti	1985 / 1991	300	7.6
China	Baoshan	Shanghai	NSC	1985 / 1991	300	7.5
China	Wuhan	Wuhan	MDH / VAI	1996 / 2005	300	7.3
Netherlands	Tata Steel	Ijmuiden	MDH	1968 / 1976	330	7.2
Korea	Posco	Gwangyang	VAI / Hyundai	1987	265	7.1

A nominal steel tap weight of 275 tonnes has been assumed, which is a typical value for a 3 vessel basic oxygen furnace (BOF) shop. The BOF cycle time will be typically 40 minutes made up as follows:

Activity	Time (mins)
Waiting for scrap charge	1
Charge Scrap	3
Charge Hot Metal	3
Oxygen Blow	16
Reblow 10% of time	1.6
Sample	5
Tap Steel	6
Slag Splash	4
Slag tapping	3
Total Tap/Tap	42.6

Allowing for a vessel life of 6000 heats with 15 days to reline a vessel and with 4% for refractory maintenance, 5% engineering downtime and 5 days annual shutdown, this facility should be capable of up to 8.0 MTPA per BOF shop.

Material flows within the steel plant are very complex and dependant on the final product mix that is agreed for the finished slab, this is to take into account the requirements for

- Secondary steel making such as ladle furnace and vacuum degassing.
- Slab thickness, width and length range.
- Slab cooling requirements such as percentage air cooled and quantity that requires slow cooling for product quality purposes.
- Slab surface dressing and rectification requirements to suit the demanded quality requirements
- Slab further cutting to length and slitting requirements to suit the customer requirements

All these factors have a significant impact on the time taken to process product through the plant. Many of the activities are sequential in nature and dependant on the customer requirements and throughput will have a significant effect on CAPEX both in terms of the technological equipment and the handling equipment such as cranage, transfer cars etc.

As such based on 3 vessel operation some 94 taps per day will be required from each shop. This is at the top end of the production capability for BOF.

Steel will be cast into steel ladles and transferred through the steel plant by a combination of steel transfer car and ladle overhead crane. With a tap weight of 275 Te, the ladle handling facilities will have to be capable of handling an all up ladle weight of some 400 – 420 tonnes.

Ladle furnaces will be required to allow for:

- Additional desulphurisation to suit final steel chemistry requirements
- Adjustment to the steel chemistry by ladle alloy additions
- Steel reheating to cater for extended refining times
- Final adjustment of steel temperature prior to delivery to the caster
- Typical cycle times in the ladle furnace – dependant on chemistry and temperature is 45 – 60 minutes per ladle.

Vacuum Degassing will be required on some grades to:

- Carry out further desulphurisation,
- Hydrogen and nitrogen gas removal.
- Final analysis trim, calcium treatment, flotation rinse (micro stir).
- Temperature checks are then made prior to despatching the ladle to the CCM.
- Typical cycle times in Vacuum degassing – dependant on chemistry and temperature is 30 – 50 minutes per ladle.

At the Continuous casting machine, the teeming ladle is placed by an overhead crane onto a ladle turret, which rotates the ladle into the casting position. The ladle slide gate is then opened and liquid steel flows into a tundish, which serves as an intermediate container / distributor between the ladle and the mould.

The CCM moulds are mounted on oscillating frames and the mould copper plates are cooled by closed primary cooling water system. Due to the cooling in the mould a solidified strand shell is formed and is subsequently supported by the mould foot rollers and segmented support on broad face. Air-mist sprays cool the hot strand as it is slowly withdrawn through the roller segments. At the end of the roller segments pinch roll straightening units are arranged to straighten and withdraw the hot strand. Soft reduction is applied in the straightener withdrawal unit to minimise centreline segregation to ensure slab internal quality. These units serve also for inserting and withdrawal of the dummy bar chain.

A chain type dummy bar is used to seal the mould at the start of casting and to withdraw the hot strand to the withdrawal / straightening units. After separation of the dummy bar from the hot strand the dummy bar is parked in a storage position to stand-by for the next start to cast.

The hot strand is cut into slabs of the desired length by in-line oxy-gas torches, which clamp onto the moving strand. The slabs are transported on run-out roller tables to de-burring and identification stations, and weighing units and then to the final stop. From here the slabs are transported to stacks for air-cooling or to slow cooling pens (for API / NACE grades) using an overhead crane equipped with a tong arrangement.

In terms of subsequent slab handling within the steel plant, the following indicative processes would be required dependant on the slab quality.

API / NACE Grades

- Slow cool for hydrogen removal, dependant on quality and thickness (5 days)
- Sulphur print and / or hot etch
- Potential sub-dividing (aim for >300 ^{o}C)
- Visual inspection + hand de-seaming as required (> 60 ^{o}C)
- Potential 4-face scarfing (aim for 60 ^{o}C – 150 ^{o}C)
- Re-identify individual slabs
- Weigh + dimension check
- Despatch

Merchant Slab Grades

- Stack to cooling area in close proximity to CCM run-out table
- Can be loaded out for despatch after approximately 48 hours, may need longer for material greater than 300mm thick to allow for hydrogen diffusion and product cooling
- Sulphur print as required (1 sample per ladle minimum)
- Subdividing as required
- Visual inspection + hand de-seam as required
- Weight + dimensional checks as required (rely on on-line weighing as an option)
- Despatch

In practice the above regimes will have a direct effect on space requirements to allow products to air cool and slow cool.

Cooling of API / NACE Grades

These materials will need to be cooled in slow cooling pens, a typical pen plan view dimensions will be circa 12m x 12m. Each pen would be able to hold approximately 44 slabs based on average slab size. For the average slab size, production will be some 2060 slabs per day. Slow cooling of slabs will take approximately 5 days, which means that there will need to be sufficient slow cooling capacity to store some 10300 slabs. This is equivalent to 234 cooling pens. If the slab export bays are arranged such that 3 pits can be located along the width of the bay (Bay width circa 40M to allow for this plus hook approach and rail tracks), the cooling bay total length will need to be some 1100m long allowing circa 2m between each row of pens.

Allowance for Scarfing facilities etc would increase this length by approximately 600m assuming a scarfing facility in each of the 3 steel plants. If we assume this storage area is provided by 2 bays, each bay will need to be approximately 460m long to accommodate the above storage plus allowance for crane hospital bays, clear areas for slab discharge tables and inter bay transfer equipment. This would equate to some 36000m^2 of storage area per steel plant.

Cooling of Merchant Slab Grades

These materials can be air cooled and can be despatched after about 2 days cooling, assuming these slabs are stacked up to 11 slabs high, a stack would take up approximately 38m^2. A storage capacity of some 4200 slabs would be required (circa 2 days production). As before assuming 3 stacks stored across the bay, the bay length would need to be approximately 500m in length. Scarfing would unlikely be required and only a small area for inspection (allow say 50m for each plant) this gives a length of approximately 400m per steel plant, 1 bay only required(16000m^2 per steel plant).

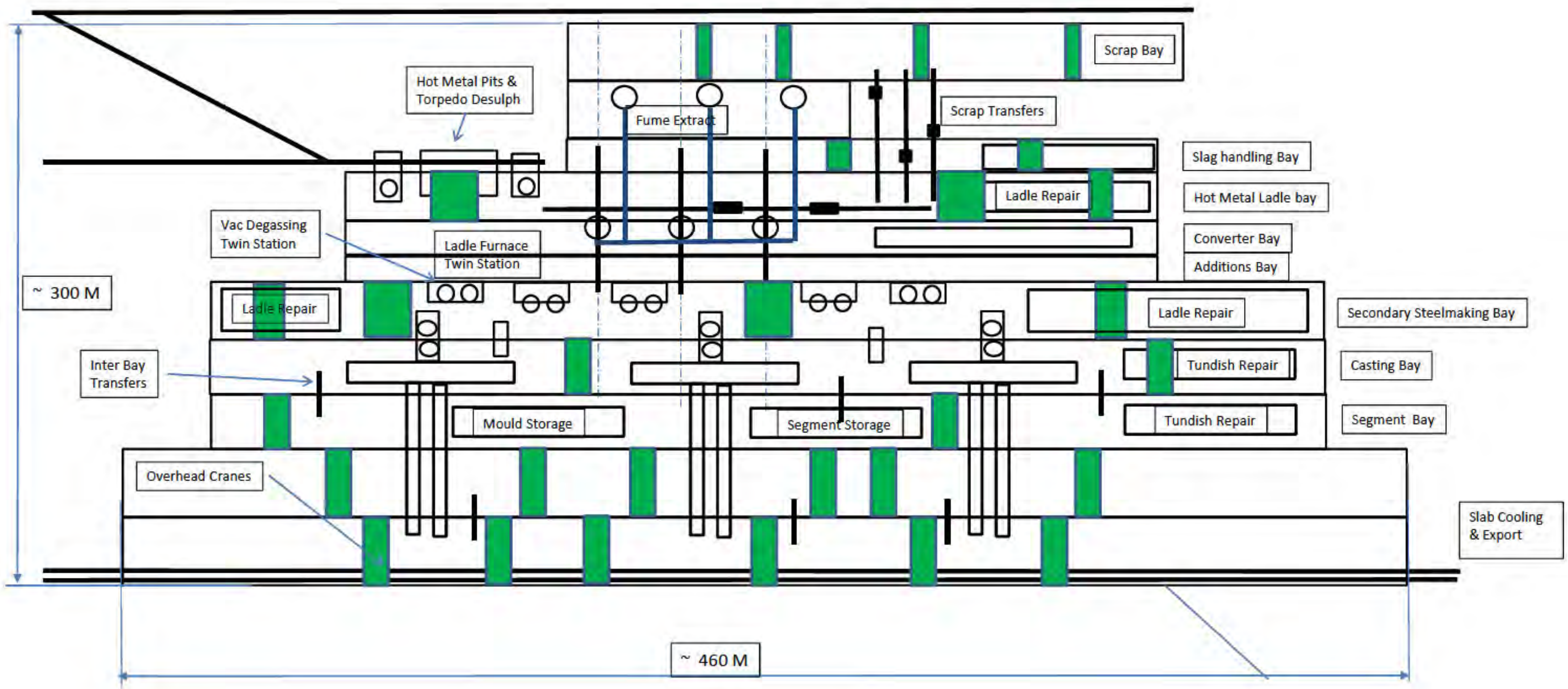
This then gives the 2 extremes in terms of the product mix.

An indicative view of the steel plant layout is shown below for the high proportion of NACE/API Option.
For the merchant slab option one of the export bays would not be required together with the slab handling cranes in that bay and the number of Ladle furnace stations and Vacuum degassing stations could be reviewed. Merchant grades can often be cast faster than the more difficult grades so there is also a possible potential to reduce the number of slab casters from 9 to 8.

TSC conservatively estimates a difference of approximately $M60-70 per steel plant or some $M380-410 per steel complex if the cost saving of a slab caster is also taken into account.

TATA STEEL

TATA



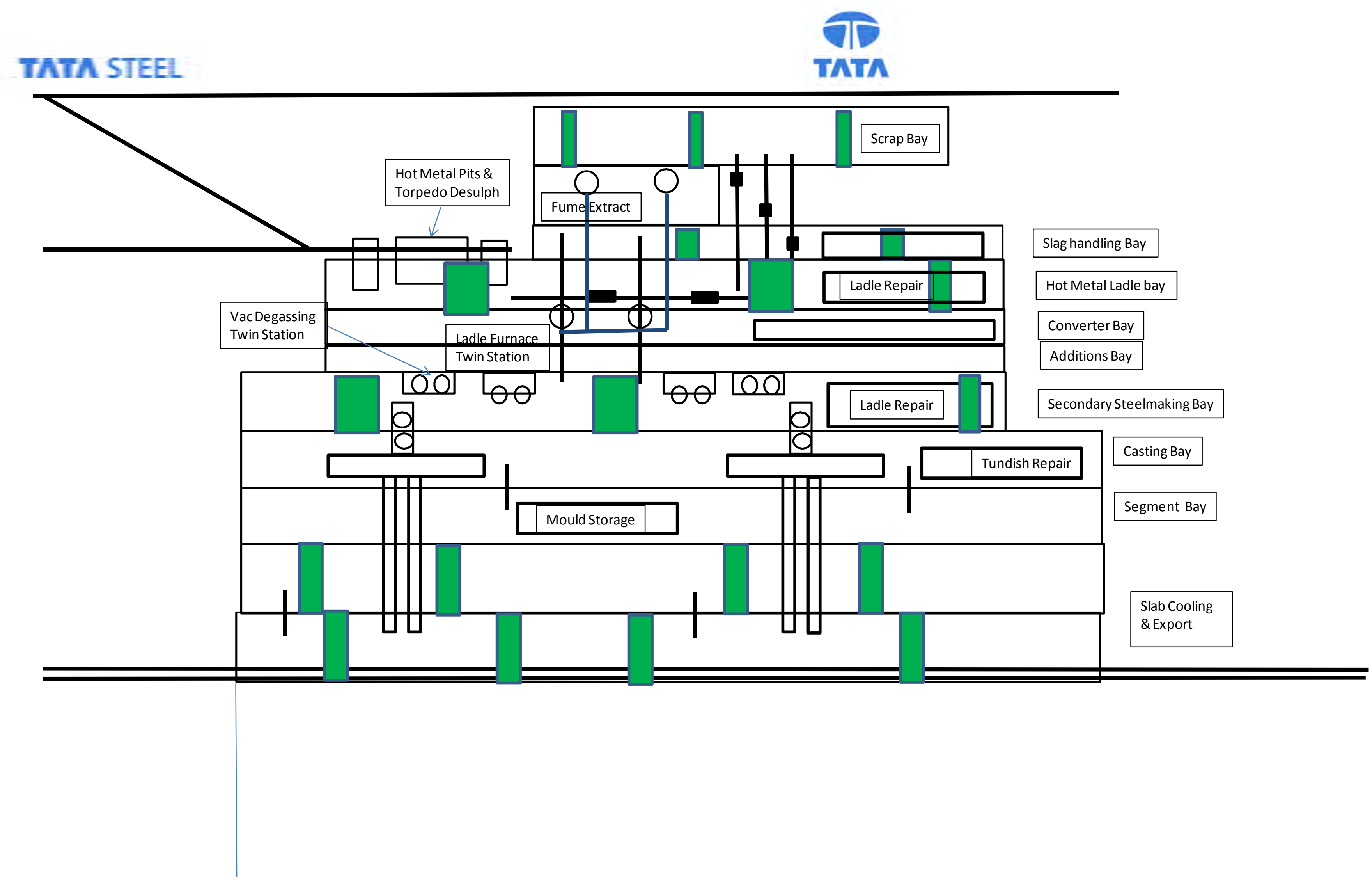
PROJECT IRON BOOMERANG east west line parks pty ltd

In the above case it has been assumed that there would be significant co-operation between the Steel Producers to allow an efficient steel plant design to be completed. As with the case of the Sinter plant, it may be that the Steel Producers would want to keep their options open, particularly with regard to sensitive steel chemistries and process confidentiality. As such up to 5 steel plants may be required each producing nominally 4.4MTPA.

To suit this possible scenario, the layout has been revisited.

BOS capacity could be achieved by 2 vessels per steel shop and output of slabs by 2 twin strand slab casters. 2 Process routes through the plant are envisaged from BOS vessel, through secondary steel making through to the casters and despatch. The cooling/despatch bay length could be reduced for each steel plant.

Based on these assumptions the indicative layout is shown below.



PROJECT IRON BOOMERANG
east west line parks pty ltd

TATA STEEL TATA

6.9 SLAB EXPORT TO THE PORT

In terms of slab export requirements, for initial calculations the following in terms of slab output has been assumed.

- Maximum slab weight 75 tonnes
- Slab width range 1500 – 2400 mm
- Slab thicknesses
  - o 250 mm thick 30% of the mix
  - o 300 mm thick 35% of the mix
  - o 350 mm thick 35% of the mix
- Slab length 4.5 m to 10.5 m giving an average of 7.5 m
- Average slab weight is 33.3 tonnes
- Estimated number of slabs to be shipped is 660,000 slabs per annum

EWLP are proposing a novel "roll-on roll-off" ship design to allow wagons to be transported onto the ship and offloaded using overhead cranes built into the ship's structure.

The length of wagon rake within the ship will be limited to approximately 150m and will be pulled onto the ship by a purpose designed haulage mechanism. As such the rake from the steel plant will need decoupling from the shunting engine prior to loading on the ship.

To minimise wagon cycle time, it is assumed that the rake of wagons to the port will be about 300m to allow the rake to be split into 2 and hauled onto the ship. On this basis the export bay in each of the steel plants will be capable of holding 2 rakes of wagons to be loaded at any one time.

In terms of loading operations at the steel plant, this will be undertaken by Overhead crane using tong lifters, crane safe working load on the tongs will be nominally 75T. TSC have assumed2 cranes loading a rake of 22 wagons (car length will be ~ 13.5m so 22 cars ~300m), each lift will take approximately 3.4 minutes, based on a lift /lower speed of 8m/min, long travel speed of 80m/min and a lift height of circa 6m with an average travel distance of ~60m. The cycle time per slab will be circa 1.7 minutes.

In terms of transport of the rake to the port, if we assume 13KM distance to the port with the train averaging 32km/hr and the facilities are sufficient to empty slabs at the rate of 1.6 per minute we can arrive at the following requirements/capabilities.

Axle Load Te	Max Car Wt Te	Tare Wt Est T	Cargo Wt	No. Slabs /rake of 11	Te/ Train	Train Cycle (round trip) Mins	Te Per Day/ Train	Te Per year per train Million Te	Trains required	Trains/ Day
30	120	22	98	44	1,467	219	9,658	3.53	7	41.1
35	140	25	115	66	2,201	278	11,389	4.16	6	27.4
40	160	28	132	66	2,201	278	11,389	4.16	6	27.4
42	168	28.5	139.5	88	2,935	338	12,509	4.56	5	20.5

The above shows the sensitivity on Axle load based on the average slab size.

The Train Corridor will need to include 2 tracks - 1 to and 1 return from the port, based on the 42 Te axle loads a train will need to be dealt with every 70 minutes.

7. HIGH LEVEL ENERGY BALANCE

7.1 ELECTRICAL ENERGY

In terms of electrical energy the following table outlines the estimated usage by process group

Process Area	Estimated Usage MWH/Annum
Raw Material handling	179,192
Coke Plant	369,627
Sinter Plant	852,509
Lime Plant	86,287
Blast Furnace	2,173,511
Hot Metal Treatment	65,336
Oxygen Plant	1,652,176
Steel Plant	1,630,888
Continuous Casting	435,487
Slab Processing	39,600
Miscellaneous Buildings, Workshops, etc	48,400
Total Usage	7,533,013

Within the process, there will be secondary generation of electricity on both the Blast Furnaces and the Coke Plants by the use of Blast Furnace top pressure recovery turbines (TRT) and Coke Dry Quenching (CDQ).

The Blast Furnace TRT systems will recover approximately 672,961 MWH per annum and the CDQ system assuming all surplus steam is converted to power at 40% efficiency, approximately 1,449,520 MWH

The Net requirement of Electrical Power is therefore 5,410,532 MWH per annum which is equivalent to annualised loading of 617.6 MW.

7.2 COKE OVEN GAS

In terms of Coke Oven Gas (COG) produced during the coke making process, various other processing units will have some requirement for this gas; the table below outlines the distribution:

Process Area	Estimated Production / Usage GJ/Annum
Coke plant COG Production	65,576,267
Coke Plant Underfiring	30,526,883
Sinter Plant	2,792,701
Lime Plant	10,623,596
Blast Furnace	8,275,896
Steel Plant	4,823,754
Continuous Casting	1,782,564
Total Usage	58,825,394

Nett Surplus	6,750,873

7.3 BLAST FURNACE GAS

In terms of Blast Furnace Gas (BFG) the only process user is the Blast furnace stoves together with COG for stoves heating.

Process Area	Estimated Production / Usage GJ/Annum
BF plant BFG Production	111,286,179
BF Stoves Heating	33,103,585
Nett Surplus	78,182,594

7.4 BOS GAS

In terms of Basic Oxygen Steelmaking (BOSG), all this is available for use; the production in terms of gas calorific value is 16,777,475 GJ/Annum.

7.5 TOTAL ENERGY BALANCE

From the above we can produce a total energy balance for the process, this is summarised in the table below and equated into GJ per tonne of slab produced:

Process Area	Electrical GJ/Tonne Slab	COG Used GJ/Tonne Slab	BFG Used GJ/Tonne Slab	Coal Energy GJ/Tonne Slab	Coke Energy GJ/Tonne Slab	Gases Made GJ/Tonne Slab	Coke By Products GJ/Tonne Slab	Electricity Generated GJ/Tonne Slab	Nett Energy GJ/Tonne Slab
Raw Material handling	-0.029	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.029
Coke Plant	-0.060	-1.388	0.000	-15.932	11.781	2.981	0.777	0.237	-1.604
Sinter Plant	-0.140	-0.127	0.000	0.000	-1.792	0.000	0.000	0.000	-2.058
Lime Plant	-0.014	-0.483	0.000	0.000	0.000	0.000	0.000	0.000	-0.497
Blast Furnace	-0.356	-0.376	-1.505	-4.603	-9.989	5.058	0.000	0.110	-11.66
Hot Metal Treatment	-0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.011
Oxygen Plant	-0.270	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.270
Steel Plant	-0.267	-0.219	0.000	0.000	0.000	0.763	0.000	0.000	0.276
Continuous Casting	-0.071	-0.081	0.000	0.000	0.000	0.000	0.000	0.000	-0.152
Slab Processing	-0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.006

Miscellaneous Buildings, Workshops, etc	-0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.008
Total Usage	-1.233	-2.674	-1.505	-20.535	0.000	8.802	0.777	0.347	-16.02

The above figure of just over 16GJ/tonne of slab produced should be compared in context with estimated average world figures for steel production of about 24GJ/tonne of liquid steel in 1990 (De Beer, Worrell & Blok 1998).

Since that date there have been steady increases in efficiency. Worldsteel estimates an improvement of a further 17% reduction in energy use since 1990 which would give an average value to slab production of around 20GJ/Te of slab.

7.5 POTENTIAL SURPLUS GAS USAGE

From the above table a total of some 101,710,942 GJ of fuel is available surplus to the steelmaking requirements.

In a conventional integrated steel works, a large proportion of this (approximately 66%) would have been used to heat slabs in reheating furnaces for subsequent rolling into finished products. This is a particular advantage of an integrated plant over a slab plant as the heating efficiency is typically 60-70% coupled with the potential to have slabs hot charged into the reheat furnaces for greater efficiency.

The PIB project however does not have the downstream mills local to the plant so benefits from hot charging and use of gases for efficient heating will not be available as such an alternative use for the excess gas is required.

7.5.1 Generate Electricity

One option would be to use all the surplus gas to generate electricity in a purpose built Power station. If we assume a typical thermal efficiency of 40% for the station some 1290 MW would be generated giving a surplus to export to the grid of some 670MW.

7.5.2 Supply to a Blast Furnace Slag Cement Plant

A further option would be to feed Gas and Electricity to a BF slag cement plant located adjacent to the Steel Complex. In the developed PIB case some 6MTPA of blast furnace slag is produced which is a sufficient quantity to make approximately 10MTPA of cement (typical quantities of the finished cement are 60% BF slag, 5% gypsum, 35% clinker), quoted energy requirements for this process are of the order of 85kWH/Tonne electricity and 1.45GJ/Tonne of fuel. (Source - World Best Practice Energy Intensity Values for Selected Industrial Sectors, by Berkeley National Laboratory, Feb 2008)

On this basis capacity of some 100 MW would be required together with 14,500,000 GJ of fuel per annum.

In terms of efficiency, the electricity would be generated at 40%, the fuel would provide heating at some 65-70% efficiency.

With this option approximately 87,211,000 GJ would still be left to generate electricity in a plant of some 1100 MW leaving some 380 MW surplus power after feeding the steel plant and the Cement plant.

7.5.3 Install additional Cokemaking Capacity

A further option could be to install an additional 2 batteries of coke ovens to produce additional Coke for sale which would have the added benefit of producing more surplus coke oven gas and steam for electrical generation.

It is estimated that if the additional; batteries were identical to those already proposed in this report the benefits would be as follows:

- Additional coke sales of circa 2.9 million tonnes per year.
- Production of 11,683,130GJ of surplus coke oven gas, which could be converted to 1,298,125MWH of electricity.
- Generation of 483,173MWH of electricity through coke dry quench.
- Offset of 123,209MWH additional electricity required to run the additional coke batteries.
- Offset of circa 11,300MWH for the additional raw material handling
- Offset in terms of increased nitrogen consumption, circa 1.45 x $10^8 m^3$.
- Offset in terms of Water consumption, circa 2.6 million m^3 of industrial water and approximately $660,000 m^3$ of potable water.
- Offset in terms of additional manpower to operate the ovens.
- Net electricity benefit would be 1,646,789MWH, which is equivalent to 188MW on a 365 day basis.

7.5.4 Other Potential Energy Saving Areas

Other areas that should be considered for a steel complex on this scale is as follows:

- High efficiency electric motors – this technology is commercially available, the motors tend to be more expensive than conventional motors in terms of initial capital spend but do offer a payback in terms of energy savings.
- Use of variable frequency inverter drives – this technology is commercially available and offers significant energy savings over other motor control methods particularly on fans and pumps. A further benefit is much reduced shock loading of drive trains.
- Extensive Automation to balance demand through the process, this also minimises manpower requirements.
- Coke Oven Gas Heat Recovery – A number of companies are looking to implement technology to recover heat from the very large quantities of energy present within the hot coke oven gas produced in the ovens. The waste heat is removed using heat exchangers to generate steam which can be used for subsequent electrical generation.
- Blast Furnace Slag heat recovery – Again this is an area under development by a number of companies to use the high heat capacity of the blast furnace slag produced from the blast furnace to raise steam and then generate electricity.
- BOS Gas steam generation – This system is commercially available and similar to the above processes produces steam and then generates electricity from the hot gas offtake in the basic oxygen steelmaking process.
- Continuous casting slab heat recovery – This is a further area where vast amounts of heat generated by the production process currently go to waste.

8. WATER USAGE

Estimated water usage (both Industrial and potable qualities for the various processing units and based on typical consumption figures) is summarised below.

	Industrial M^3/Annum	Potable M^3/Annum
Raw material handling	132,949	809,256
Coke Plant	7,914,377	1,978,594
Sinter Plant	2,792,701	264,572
Lime Plant		
Blast Furnace	10,889,337	544,467
HM Treatment	5,444,669	
Oxygen Plant	41,805,986	
Steel Plant	5,283,159	5,283,159
Misc	2,200,000	1,100,000
Total	76,463,178	9,980,048
M^3/Tonne Slab	3.48	0.45
Exclude O2 Prod	1.58	0.45

At this stage it has not been possible to validate water consumptions for the oxygen plant or the lime plant. Net water consumption per tonne of slab is estimated at $2M^3$ excluding these 2 items.

Based on the above estimates, it is estimated that in order to provide **2 days** water supply on site, a raw water reservoir of some $480{,}000m^3$ capacity will be required, this would be provided by a reservoir constructed nominally from ground level by embankments and would be 310m x 310m x 5m deep.

TATA STEEL

TATA

9. STEEL COMPLEX WORKFORCE LABOUR REQUIREMENTS

An assessment of the workforce labour requirements to operate and maintain the plant has been undertaken.

The final numbers of personnel required is very much dependant on a number of factors that will need to be discussed and agreed between the various Steel Producers within the PIB project and will include:

- Level of co-operation between the relevant Steel Producers covering:
    - Ability to centralise operational work crews across the various departments such as Sinter, Coke, Iron, Steel and slab production
    - Ability to centralise day and shift maintenance crews across the various departments such as Sinter, Coke, Iron, Steel and slab production
- How will central functions be handled such as:
    - Central Engineering Workshops
    - Site contracts
    - Purchasing
    - Stores
    - Slag & Waste handling
    - Design and Project Engineering
    - Power and Energy
    - Order Entry and Capacity planning and Scheduling
    - Transport and Shipping
    - Finance
    - Human Resources
- Some of the options already described in this report will have a direct bearing on the workforce requirements such as:
    - Sinter plant configuration – will the project be based on 4 large units to give the necessary output or 5 smaller units each one feeding a single blast furnace?
    - Steel Plant configuration – will the project be based on 3 large 3 vessel shops or 5 smaller 2 vessel shops?
- Actual workforce requirements will also depend on a number of external factors such as:
    - Local, and Government legislation;
    - Existing or "new" Company culture;
    - Local "Culture";
    - Existing labour agreements;
    - Cost of labour.
- The numbers quoted below for Operational and Craft grades is based on a modern, automated plant and would include "fully integrated" duties carried out by "teams". This would reduce the overall manning and includes such things as:
    - Flexibility between jobs;
    - Basic engineering skills for production operators;
    - Low level engineering maintenance duties carried out by operatives;
    - Inspections.

In terms of Current operating units, the table below shows typical workforce requirements directly involved in slab production and productivity figures in terms of hrs worked per tonne of slab for a range of facilities. The information was supplied by CRU and is from 2006.

Plant	Country	Slabs Mte pa	Work Force	Hrs /Year/ person	Hrs/Te Slab
Anshan	China	13	4000	2023	0.62
Baoshan	China	10.28	7330	2023	1.44
Wuhan	China	9.4	7330	2023	1.58
Oita	Japan	8.5	1421	1768	0.30
Kwangyang	Korea	13.33	3282	2006	0.49
Pohang	Korea	9	2772	2006	0.62
Taranto	Italy	9	3311	1669	0.61
Burns Harbor	USA	4.31	1700	1890	0.75
Port Talbot	UK	4.64	1388	1733	0.52
Teesside	UK	3.2	1250	1733	0.68
Port Kembla	Australia	5.1	1984	1860	0.72

To give an indication of the extremes of workforce requirements, the manpower requirements based on a single 4.4MTPA slab plant have been estimated. The plant is modern with high levels of automation and flexible working practices are in place between crews. The workforce summary is tabulated below and amounts to just under 1700 staff.

TATA STEEL

TATA

	Director	Works M'ger	Dep't M'ger	Profess Technical	First line superv./clerical	Oper / Craft	Trainee	Subgroup Total
Slab production Unit	1	2						3
Safety, Health & Environm			1					1
SHE Health & Safety				4				4
SHE Environment				6				6
Technical & Continuous Impr				4				4
Sub Total SHE	0	0	1	14	0	0	0	15
Ironmaking		1						1
BF (Dept.)			1	13	1	66		81
Coke Ovens (Dept.)			1	12		124		137
Raw materials (Dept.)			1	8	3	60		72
Sinter				6	2	22		30
Subtotal Manufacture	0	1	3	39	6	272	0	321
Ironmaking Engineering								0
Maintenance Engineering (Dept.		1		4	13	35		53
Eng Coke (Dept.)			1	6	10	25		42
Eng Raw materials(Dept.)			1	9	7	18		35
Eng Sinter				4	7	16		27
Eng BF (Dept.)			1	9	8	20		38
Subtotal Engineering	0	1	3	32	45	114	0	195
Technical			1	6		10		17
Total Ironmaking	0	2	7	77	51	396	0	533
Quarry & Lime production (Dept.)			1	5	7	19		32
Steelmaking		1						1
Steelmaking Manufacturing				6				6
S/Manf BOS (Dept.)			1	11	2	218		232
S/Manf Concast (Dept.)			1	18	2	244		265
Subtotal Manufacture	0	1	2	35	4	462	0	504
Steelmaking Engineering		1						1
Maintenance Engineering (Dept.						28		28
S/Eng BOS (Dept.)			1	8	4	15		28
S/Eng Concast (Dept.)			1	7	5	17		30
Subtotal Engineering	0	1	2	15	9	60	0	87
Technical (Dept.)			1	12		15		28
Subtotal Steelmaking	0	2	5	62	13	537	0	619
Central Engineering		1						1
Shops & Services (Dept.)			1	35	12	200		248
Legislation (Dept.)				4				4
Site Contracts, Systems, purchasing, stores			1	12	30	25		68
Design / Project Eng			1	10	5			16
Central Engineering Total	0	1	3	61	47	225	0	337
Power, Energy & Services			1	20	9	55		85
Ord.Ent Capacity Plnng & Sch			1	8				9
Transport & Shipping			1	10	15			26
Finance (Dept.)		1	3	10	4			18
Human Resources (Dept.)		1	2	2	3		6	14
Overall totals	1	9	25	269	149	1232	6	1691

On a like for like basis compared with the productivity of the other steel plants listed, 1152 people would be directly involved in the production of slab which would give a typical hour/Te production

PROJECT IRON BOOMERANG
east west line parks pty ltd

of 0.48 based on Australian working hours per annum of 1860 which would be near the top of the productivity league.

With limited sharing across the steel complex, based on the production requirements for a 4.4MTPA unit, the potential manpower requirements for PIB could be as high as 8500 staff.

With optimum sharing across the complex including a rationalisation of the sinter and steel production coupled with centralised shared services, the following requirement for a 22MTPA plant has been estimated.

TATA STEEL

TATA

	Director	Works M'ger	Dep't M'ger	Profess Technical	First line superv./clerical	Oper / Craft	Graduates	Subgroup Total
Slab production Unit	1	2						3
Safety, Health & Environm			1					1
SHE Health & Safety				10				10
SHE Environment				15				15
Technical & Continuous Impr				10				10
Sub Total SHE	0	0	1	35	0	0	0	36
Ironmaking		1						1
BF (Dept.)			5	52	4	264		325
Coke Ovens (Dept.)			3	29		298		330
Raw materials & Sinter (Dept.)			4	26	10	192		232
Subtotal Manufacture	0	1	12	107	14	754	0	888
Ironmaking Engineering								0
Maintenance Engineering (Dept.		1		10	33	88		132
I/Eng Coke (Dept.)			1	15	24	60		100
I/Eng Raw materials & Sinter(Dept.)			1	29	23	58		111
I/Eng BF (Dept.)			1	36	32	80		149
Subtotal Engineering	0	1	3	90	112	286	0	492
Technical			3	15		25		43
Total Ironmaking	0	2	18	212	126	1065	0	1423
Quarry & Lime production (Dept.)			5	20	28	76		129
Steelmaking		1						1
Steelmaking Manufacturing				15				15
S/Manf BOS (Dept.)			3	27	5	524		559
S/Manf Concast (Dept.)			3	44	5	586		638
Subtotal Manufacture	0	1	6	86	10	1110	0	1213
Steelmaking Engineering		1						1
Maintenance Engineering (Dept.						68		68
S/Eng BOS (Dept.)			1	20	10	36		67
S/Eng Concast (Dept.)			1	17	12	41		71
Subtotal Engineering	0	1	2	37	22	145	0	207
Technical (Dept.)			3	29		36		68
Subtotal Steelmaking	0	2	11	152	32	1291	0	1488
Central Engineering		1						1
Shops & Services (Dept.)			1	88	30	500		619
Legislation (Dept.)				10				10
Site Contracts, Systems, purchasing, stores			1	30	75	63		169
Design / Project Eng			1	25	13			39
Central Engineering Total	0	1	3	153	118	563	0	838
Power, Energy & Services			1	20	9	55		85
Ord.Ent Capacity Plnng & S			3	20				23
Transport & Shipping			1	25	38			64
Finance (Dept.)		1	8	25	4			38
Human Resources (Dept.)		1	5	5	8		15	34
Overall totals	1	9	56	667	363	3050	15	4161

From the table above it can be seen that potential efficiencies of over 50% in terms of manning

PROJECT IRON BOOMERANG
east west line parks pty ltd

numbers can be achieved with maximum sharing and cooperation. The number of employees involved in actual production would be 2911 people giving a productivity value of 0.25 hours per tonne of slab which, in TSC opinion, would be best in world.

Actual manpower productivity is not the only measure when estimating the labour cost element of the slab cost, the other being the actual labour rate. Labour rates have been investigated in some detail during this study using information from the US Bureau of Labour Statistics, the National statistics offices of Korea and China, steel company published accounts. On this basis the following annual labour costs have been assumed.

Country	Annual Labour Cost US$	Relative labour Cost
China	6,890	1
Korea	37,000	5.37
Australia	97,000	14.1

From the above it can be seen that even with the much improved productivity of the developed case, labour costs per tonne of slab are likely to be significantly higher in Australia than in the base case.

At this stage TSC gives some element of caution in that it has been difficult to establish exact “like for like” comparisons for particularly the Chinese labour rate ensuring the cost includes all the employment cost elements. This is an area for further investigation.

10. OUTLINE DESCRIPTION OF COST MODEL

The cost model developed by Tata Steel Consulting is shown schematically in the figure below illustrating the evaluation methodology for the direct cost of the slab production.

The model is robust, dynamic and flexible that suits the evaluation of the cost of producing steel from a steel complex that would require considerations for multi-processes interacting with each other, using several raw materials (externally and locally sourced), and producing several by-products, intermediate products and main products.

This cost model can be developed to include for the cost of the direct CO_2 emissions from the various processes within the defined boundary limit of the steel complex.

The key features of the model are as follows:

The main product only considered in the current version of the cost model used by this study is steel merchant slab. However, it should be noted that cost model could be modified to provide multi products options. If multi-products are evaluated, then it would be essential that some constraint (i.e. limitation to define the level of degree of freedom) should be established to determine the break even cost of these multi-products.

For this study – the basic assumptions for the current cost model are:

1. Intermediate Products of a plant or process within the boundary limit would become a

"Local" raw material to other plants/processes. These are expressed as specific cost per tonne of intermediate product. The users of the intermediate product/s are sold by using the direct cost of its producer(s) – this represents the "internal price".

2. All the by-products produced by any plants / processes are sold at a fixed price set in the assumptions and revenues are internally credited to the producer(s).
3. This model is based on a cascading cost model for each plants /major processes leading to the direct cost of producing the steel slab.
4. The break even cost of producing the slab was determined from the cash flow analysis over the economic life of the plant considering the capital cost and indirect cost of the whole steel complex defined by the boundary limit., and the direct cost specifically to the Continuous Casting (plant that produce the Slab) only.
5. The direct costs of each plants / processes are evaluated based on the consumption of the externally sourced or "imported" raw materials, "local" raw materials, fuel and energy (imported, local or both), consumables, direct labour cost, maintenance, and other OPEX and work's expenses specific to the plant.
6. By-products that go out of the boundary limit are sold at a fixed price over the economic life of the plant. The revenue of this by-product is then credited to the plants / processes that produced it.
7. The users of "by-product" energy in the form of off-gases or steam that are produced from certain plant(s) or process(es) are also sold at a fixed price over the economic life; and credit was also given to the producer(s) of the by-product energy.

TATA STEEL TATA

11. CAPEX ASSUMPTIONS

The basis of estimating the total investment cost for each of the cases considered takes into account the following:

- Total installed cost for plant and equipment
- Site Development and Construction
- Recurring Capital Expenditure

11.1 PLANT AND EQUIPMENT – MAJOR PROCESSES

The capital cost of the major plant and equipment considered for each case have been estimated and subdivided according to the following main production units:

- Coke Production
- Sinter Production
- Blast Furnace
- Steelmaking
- Continuous Casting

The total installed cost for each plant or process accounts for (but is not limited to):

- Direct material – including plant, equipment and bulk materials
- Plant Construction
  - Installation cost includes the mechanical erection, piping installation, etc...;
  - Instrumentation, process control automation and electrical installation;
  - Civil works, and where necessary other site preparation.
- EPC Services – including contractor's home office and construction supervision.
- Other Costs - including temporary buildings, training and plant start up (excl. First fill).

The equipment cost was estimated from TSC's database of Capital costs, adjusted to 2011 prices. All capital cost estimates should be within ±25% accuracy.

For some of the main production items, the database contains costs for equipment installed in both Western economies and China. As part of this evaluation, TSC has attempted to estimate the relative installed capital cost of equipment for a number of scenarios covering:

- Korea for the base case (Western Supply)
- China – sensitivity on the base case (Chinese Supply)
- Australia – all other cases (Western supply)
- Australia – sensitivity on Western design and key component supply, Chinese manufacture for balance, local supply for construction and materials.

As a further data check, TSC has access to a detailed cost breakdown for an Integrated Iron works facility in SE Asia from both a Western plus local standpoint and Chinese plus local standpoint.

In order to estimate relative costs of labour and construction services across international boundaries, TSC has developed a number of Indices to cover relative productivity for the various countries and the relative purchasing power parity (PPP) indices.

TATA STEEL

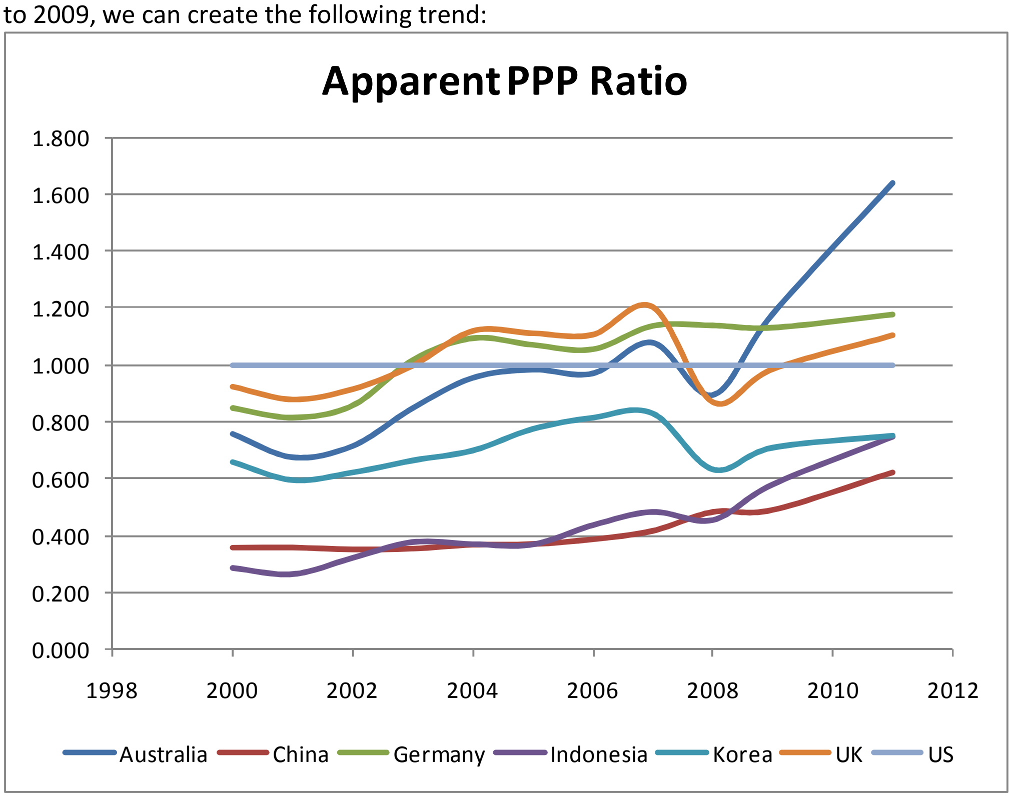
TATA

Taking Figures for 2011 and equating to US$ at prevailing 2011 exchange rates the following table Indicates the process adopted using a range of sources including the USA Bureau of Labour Statistics, the National Bureau of Statistics of China and The National Statistical Office of Korea.

Item / Country	Australia	China	Germany	Indonesia	Korea	UK	USA
GDP/Capita (US$)@ PPP	40100	8400	37900	4700	31700	35900	48100
Employment Cost (Manuf)	85000	5800	73400	2700	37000	59800	68000
Productivity Ratio Cost/Prod	2.1	0.69	1.94	0.57	1.17	1.66	1.41
Productivity relative to Indonesia*	3.68	1.21	3.4	1	2.05	2.91	2.47
PPP Ratio**	1.6	0.62	1.18	0.75	0.75	1.1	1

*Interpretation of Productivity relative to Indonesia means that to carry out an amount of work that costs $1 in Indonesia will cost $3.68 for the same amount of work in Australia.
**Interpretation of the PPP Ratio relative to the US means that a schedule of goods costing $1 in the US will cost the equivalent of US$1.6 in Australia.

If we incorporate this data with Published data collated by "Penn World tables" for the period 2000 to 2009, we can create the following trend:



What the above graph shows is the relative cost in US dollars in a particular country for $1 worth of goods in the US. The graph shows a rapid rise for Australia since 2008 which coincides with the significant strengthening of the AUD$ against the US$. A similar effect is shown for China over the

PROJECT IRON BOOMERANG
east west line parks pty ltd

same period.

As a further indicative comparator, to estimate the relative cost of manufacture of Steel plant components, TSC has used information in terms of material and labour cost splits for manufacturing facilities in the UK producing steel plant equipment in terms of machining, fabrication, assembly and electrical fit out, the comparison using the relative productivity and PPP ratios compared to the UK are as follows.

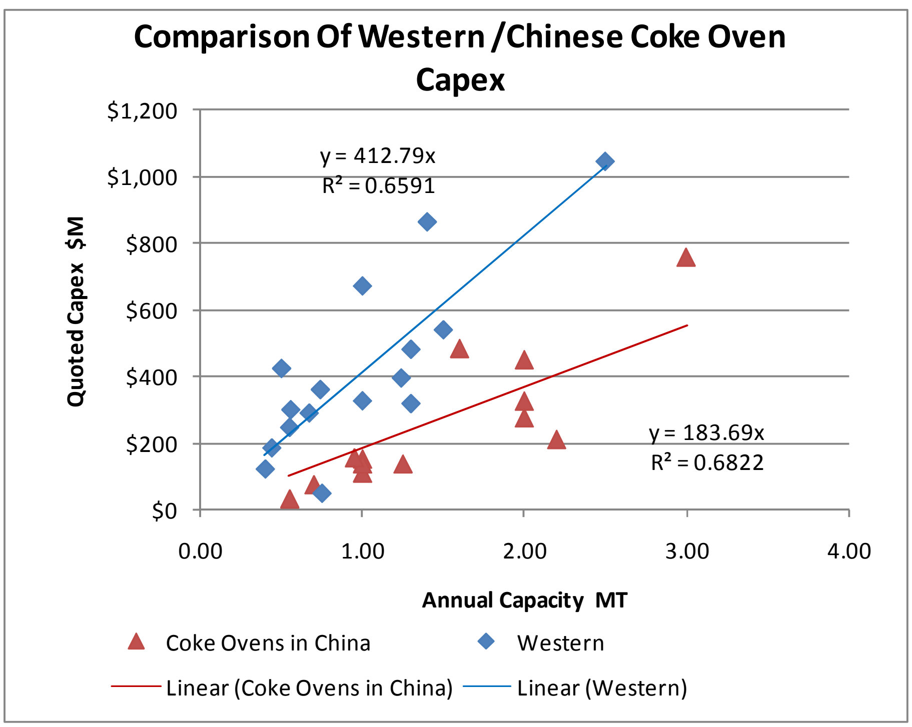
Item / Country	Australia	China	Germany	Indonesia	Korea	UK	USA
Labour Cost %	63.2	20.8	58.4	17.2	35.2	50	42.4
Material Cost %	75.8	27.4	54	34.0	34.2	50	45.5
Total compared to UK	1.39	0.482	1.12	0.51	0.694	1.0	0.88

Discussion on each of the main Production areas is considered below.

11.1.1 Coke Production

In arriving at Capital costs for coke production, a total of 31 installations that have been constructed or planned from 2003 onwards have been considered. Of these 13 had been constructed in China to Chinese design and some 16 had been “Western” supply.

From the published data, converted to US$ at the time of the announcement and escalated by the US CEPCI index to 2011 prices and the Chinese supply equated to 2011 exchange rates, the following comparison can be made in terms of Western/Chinese costs.



The above Graphs show strong correlation in terms of CAPEX by annual capacity for both the Western and Chinese costs. The data covers Investment announcements from 2003 up to 2009 for Chinese supply and 2010 for Western.

It can be seen from the above that the costs of the Chinese Ovens are significantly less than those in the Western economy.

Since around 2007, legislation has changed in China in that new plants need to be installed with modern processes to reduce the environmental impact of the process, such as Dust emissions and heat recovery. There has also been an upward trend in the ovens size to achieve a better coke product. These changes happened in the Western economies circa 5-10 years earlier.

A further development that has been introduced in the last few years to Coke oven units built in China is Coke Dry Quenching technology. This facility to extract heat and therefore power from the hot coke has been used extensively in Coke oven plants in Japan and Korea for about 15 years, with the bulk of the plants in the “Western” price trend including for this.

Most of the “Chinese” trend plants do not have the CDQ technology, the cost of this facility is typically $30M for a 500KTPA coke plant rising to some $M50 for a 1700KTPA plant.

A further development in terms of Chinese supply has been the strengthening of the Chinese Yuan against the US dollar coupled with large increases (circa 10% PA) in employment costs over the past few years

On the basis of the above the trend for the Chinese supply is likely to be underestimated in terms of the most modern equipment. It is recommended that an addition of 20% be made to the Chinese costs from the trend to account for the introduction of new environmental technology from 2007 onwards plus a factor dependant on the coke plant size to include for CDQ. In terms of Inflation cost, an additional 8% is recommended to account for the increased labour cost (a total labour element of approximately 36-38% for a coke oven facility in China is estimated).

To estimate the effects of using the most modern Western technology and Chinese manufacture, there are a number of references where major European Coke oven plant builders have carried out this approach, typically charging approximately $M150 for the basic engineering, procurement of critical parts, supervision of erection and commissioning and leaving detailed engineering, manufacture and construction to local supply. (Hyundai’s Dangjin development and Posco’s Kwangyang ovens are examples of these).

To estimate the CAPEX requirements for the various PIB cases, a combination of Western and Chinese trends has been used and cognizance taken of the likely split in local and imported elements for the work.

A typical breakdown of local to imported elements for a European Coke oven manufacturer supplying into South East Asia is:

Eng, PM, Sup of Construction & Commissioning	Imported Elements	Delivery	Local Supply
7.3%	59.1%	1.9%	31.7%

The local supply element is split into 80% materials and 20% labour element.

Case Considered	Steel Output	Coke Required	Estimated CAPEX			
			Western Design, Korea Local supply, Installation Korea	Western Design, Australia local supply, Installation Australia	Western Design, Chinese Manufacture, Local Supply & installation Australia	Chinese Design Manufacture and Install China
	MT	MT	US$M	US$M	US$M	US$M
Base Case/Case 1	4.5	1.8	750	825*	725**	450
Case 2***	9.0	3.6	1390	1525	1340	835
Case3****	22.0	8.7	3235	3550	3005	1920

* increased CAPEX for Australia to allow for increased local labour costs compared to Korea .
** assumed that circa $150M worth of engineering and equipment would be supplied from Europe, the balance of the imported items could be made in China with the assumption that Chinese manufacturing costs are 48% of Western for the balance.
***For Case 2, assumed that savings in detail design and procurement will mean that subsequent units will be reduced by the design cost plus an element of the engineering supervision and commissioning plus an element for procurement savings of the original unit cost. On balance 15% on subsequent units has been assumed.
****For Case 3, assumed 3 off units of 2.9MTPA with the second and third sharing the same design as the first, same by-products plant and savings in procurement.

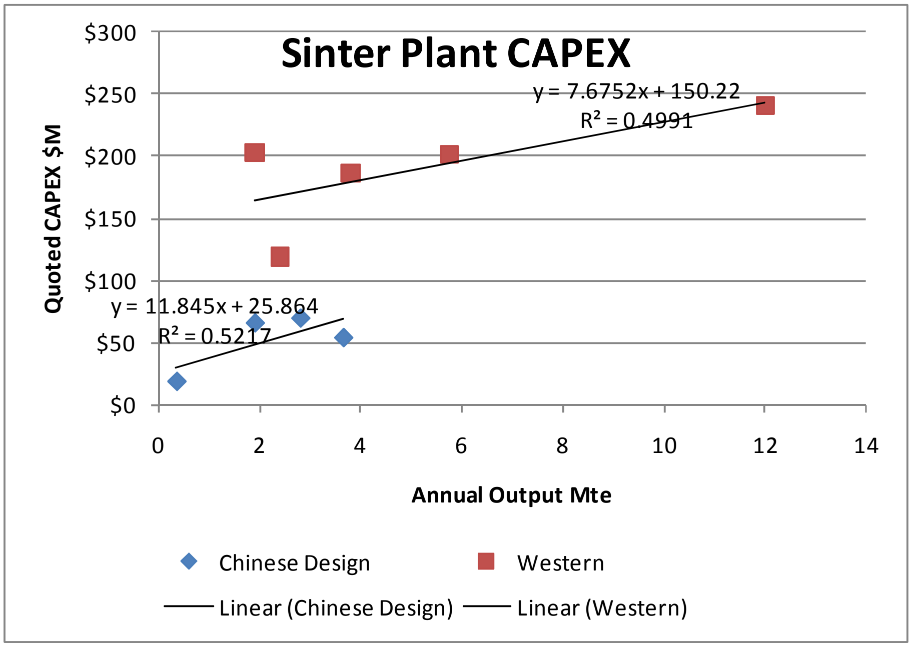
11.1.2 Sinter Production

In terms of Sinter plant CAPEX, there is not as much reference information as that for Coke Ovens. However a total of 9 Installations are considered, 5 to Western Design covering years 2007 to 2010and 4 to Chinese design covering years 2008 to 2010. In all Cases of the western design, the units were to be installed in the BRIC economies and are based on the Western Supplier carrying out Basic Engineering and detailed for critical items, procurement of critical items and supervision of erection and commissioning. The remaining activities would be carried out locally. Typical Costs for the western element are the order of $M50.

The trend of CAPEX against Capacity is shown below:

TATA STEEL

TATA



The above Graphs show strong correlation in terms of CAPEX by annual capacity for both the Western and Chinese costs.

It can be seen from the above that the costs of the Chinese Sinter Plants are significantly less than those in the Western economy; however there are no references for Chinese supply greater than 4MTPA output. For PIB in all cases considered, the sinter plant output will need to be at least 6.2MTPA up to 7.5MTPA in the developed case.

The above costs covers only up to early 2010, as such to take into account Chinese wage rises since then. It is suggested that a further 5% be added to account for increases on the manpower element of the cost (estimated at 35-38% of the total).

In a similar vein to the development of the coke ovens costs described above, the Chinese government has been applying changes to legislation in terms of the environmental performance of Sinter plants to bring those more in line with modern Western design. As such to account for this and the lack of references above 4MTPA, it is recommended that an addition 25% be made to account for this.

In terms of Price Breakdown, the following representative split for Western supply to an installation in SE Asia has been assumed. (values as % of total CAPEX).

Eng, PM, Sup of Construction & Commissioning	Imported Elements	Delivery	Local Supply
13.5%	62.8%	1.5%	22.2%

PROJECT IRON BOOMERANG
east west line parks pty ltd

TATA STEEL TATA

In terms of the local element of work, it has been established that 80% covered the supply of materials and equipment and 20% covered labour.

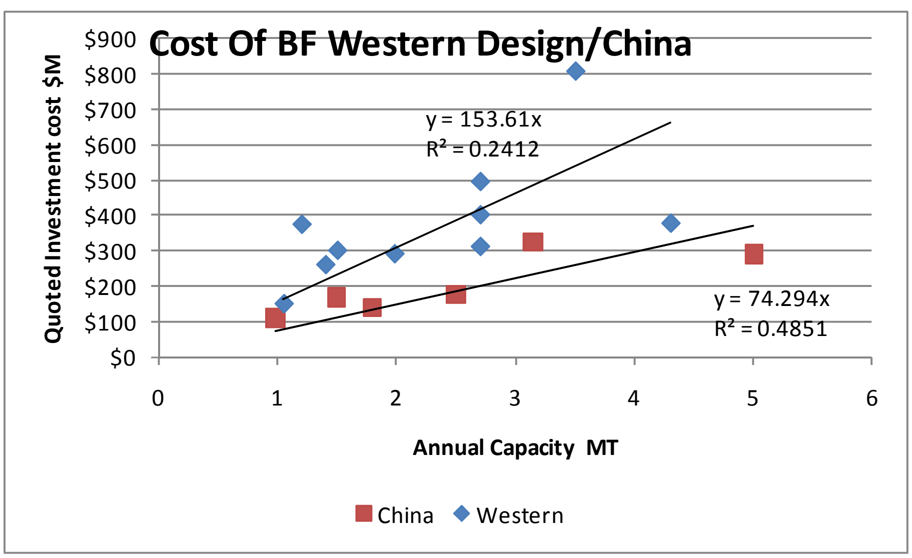
Using similar assumptions as that for the Coke Ovens above:

Case Considered	Steel Output	Sinter Required	Estimated CAPEX			
			Western Design, Korea Local supply, Installation Korea	Western Design, Australia local supply, Installation Australia	Western Design, Chinese Manufacture, Local Supply & installation Australia	Chinese Design Manufacture and Install China
	MT	MT	US$M	US$M	US$M	US$M
Base Case/Case 1	4.5	6.2	200	215	195	130
Case 2	9.0	12.4	365	390	360	245
Case3	22.0	30.5	730	785	710	550

For multiple units, because the design and engineering cost is a larger proportion than with Coke ovens, a 17.5% saving on subsequent units to the same design for Western design and 12% saving for Chinese design has been assumed (Proportion of Engineering Costs are different).

11.1.3 Blast Furnace

In terms of Blast Furnace (BF) plant CAPEX, some 16 references have been analysed, with the majority being to Western design but for projects executed in BRIC countries from 2006 to 2010. To estimate the requirements for this the same general philosophy to the Sinter Plants and Coke Ovens has been adopted.



PROJECT IRON BOOMERANG east west line parks pty ltd

As with the Coke ovens and Sinter plant units, there has been an increased emphasis on improvements to the environmental performance of Blast Furnaces in China, particularly with the addition of furnace top recovery turbines and fume emission control. TSC has some concerns as to whether the cost quoted for the 5MTPA plant in the trend above includes all the costs associated with the blast furnace CAPEX as it is significantly lower than the other Chinese plants in the trend. As such it is recommended that an allowance of 20% be included to account for these items.

The above costs cover only up to early 2010, as such to take into account Chinese wage rises since then, it is suggested that a further 5% be added to account for increases on the manpower element of the cost (estimated at 35-38% of the total)

In terms of Price Breakdown, the following representative split for the Western supply to an installation in SE Asia has been assumed. (values as % of total CAPEX)

Eng, PM, Sup of Construction & Commissioning	Imported Elements	Delivery	Local Supply
8%	56.7%	2%	33.3%

In terms of the local element of work, TSC it has been established that 80% covered the supply of was for materials and equipment and 20% covered for labour.

For the technological equipment supplied from the western sources, it has been assumed that, including the engineering element, this would amount to nominally $M150. Saving on multiple units would be 15% on subsequent units.

Case Considered	Steel Output	Hot Metal Required	Estimated CAPEX			
			Western Design, Korea Local supply, Installation Korea	Western Design, Australia local supply, Installation Australia	Western Design, Chinese Manufacture, Local Supply & installation Australia	Chinese Design Manufacture and Install China
	MT	MT	US$M	US$M	US$M	US$M
Base Case/Case 1	4.5	4.4	675	775	700	410
Case 2	9.0	8.8	1250	1435	1295	760
Case3	22.0	22.0	2970	3410	3080	1805

11.1.4 Steelmaking

In terms of Basic Oxygen Steelmaking equipment, there are relatively few references and those that exist are based on the cost of the convertor units and associated fume extraction equipment not the total cost of the steel plant.

However there exists plentiful reference cost information for the associated handling equipment that would be required including:

- Ladle repair and handling facilities
- Steel ladles
- Preheating stations
- Ladle furnaces
- Vacuum degassing units
- Overhead cranes
- Ladle transfer cars
- Buildings etc.

From this information it has been possible to estimate the cost of the steel plants required, these are presented below. The building requirements for continuous casting are presented separately, although in reality they would be within the same building structure. It has been assumed that subsequent units would save 17.5% due to economies of scale design commonality etc.

Case Considered	Steel Output	Estimated CAPEX			
		Western Design, Korea Local supply, Installation Korea	Western Design, Australia local supply, Installation Australia	Western Design, Chinese Manufacture, Local Supply & installation Australia	Chinese Design Manufacture and Install China
	MT	US$M	US$M	US$M	US$M
Base Case/Case 1	4.5	407	447	414	334
Case 2	9.0	743	816	756	610
Case3	22.0	1748	1920	1780	1435

11.1.5 Continuous Casting

References for large slab caster units are more common. A typical cost based on western supply only is ~$M150 for the casting machine capable of producing circa 2.5MTPA of slab. In terms of the requirement for PIB, the following has been estimated on the assumption that the casters are identical with savings in design, procurement; economies of scale subsequent units would save 12.5%.

Case Considered	Steel Output	Estimated CAPEX			
		Western Design, Korea Local supply, Installation	Western Design, Australia local supply, Installation	Western Design, Chinese Manufacture, Local Supply & installation	Chinese Design Manufacture and Install China

		Korea	Australia	Australia	
	MT	US$M	US$M	US$M	US$M
Base Case/Case 1	4.5	415	425	372	241
Case 2	9.0	778	797	698	452
Case3	22.0	1867	1913	1674	1085

11.1.6 Alternative Steel plant Design

The analysis in the two previous sections on Steelmaking and Continuous casting has assumed that subsequent capacity would be achieved by adding units of 4.4 MTPA in terms of the Steelmaking facilities and additional continuous slab casting machines.

From TSC experience it would be possible for the requirements of Case2, for example, to be met by a single BOS shop of 3 vessels coupled with 3 large slab casters (this would need greater study once the product mix has been established further). If this was the case substantial savings for the Case 2 steel plant could be made.

11.2 SUMMARY OF OVERALL CAPEX COST FOR EACH CASE

11.2.1 Base case 4.4MTPA plant location at Port in Korea

The summary of CAPEX for this case is tabulated below:

	PROJECT COSTS - CAPEX		
		$ x 1000	
	FIXED ASSETS		
1	Land	0	
2	Building, construction & civil	397,883	10.2%
3	Plant & Machinery	2,894,723	74.1%
4	Water/Utilities Distribution	40,000	1.0%
5	HV Distribution	150,000	3.8%
5	Auxiliary Equipment	306,405	7.8%
7	Contingencies	0	0%
8	Project Engineering	115,000	2.9%
	TOTAL FIXED ASSETS	**3,904,011**	100.0%

11.2.2 Base case 4.4MTPA plant Sensitivity China

The summary of CAPEX for this case is tabulated below:

	PROJECT COSTS - CAPEX		
		$ x 1000	
	FIXED ASSETS		

1	Land	0	
2	Building, construction & civil	306,493	11.2%
3	Plant & Machinery	1,971,485	72.2%
4	Water/Utilities Distribution	34,000	1.2%
5	HV Distribution	112,500	4.1%
5	Auxiliary Equipment	227,778	8.3%
7	Contingencies	0	0%
8	Project Engineering	80,000	3.0%
	TOTAL FIXED ASSETS	**2,732,255**	100.0%

11.2.3 Case 1 – 4.4MTPA plant QLD Australia

The summary of CAPEX for this case is tabulated below:

	PROJECT COSTS - CAPEX		
		$ x 1000	
	FIXED ASSETS		
1	Land	0	
2	Building, construction & civil	405,053	9.5%
3	Plant & Machinery	3,201,023	75.3%
4	Water/Utilities Distribution	40,000	0.9%
5	HV Distribution	150,000	3.5%
5	Auxiliary Equipment	328,548	6.1%
7	Contingencies	0	0%
8	Project Engineering	128,000	3.0%
	TOTAL FIXED ASSETS	**4,252,624**	100.0%

11.2.4 Case 1A – 4.4MTPA plant QLD Australia – Chinese Manufacture

The summary of CAPEX for this case is tabulated below:

	PROJECT COSTS - CAPEX		
		$ x 1000	
	FIXED ASSETS		
1	Land	0	
2	Building, construction & civil	405,053	10.4%
3	Plant & Machinery	2,869,503	73.7%
4	Water/Utilities Distribution	40,000	1.0%
5	HV Distribution	150,000	3.9%
5	Auxiliary Equipment	308,657	7.9%
7	Contingencies	0	0%
8	Project Engineering	118,000	3.0%
	TOTAL FIXED ASSETS	**3,891,213**	100.0%

11.2.5 Case 2– 8.8MTPA plant QLD Australia

The summary of CAPEX for this case is tabulated below:

	PROJECT COSTS - CAPEX		
		$ x 1000	
	FIXED ASSETS		
1	Land	0	
2	Building, construction & civil	660,852	8.7%
3	Plant & Machinery	5,937,130	78%
4	Water/Utilities Distribution	62,000	0.8%
5	HV Distribution	240,000	3.2%
5	Auxiliary Equipment	525,515	6.9%
7	Contingencies	0	0%
8	Project Engineering	190,000	2.5%
	TOTAL FIXED ASSETS	7,615,497	100.0%

11.2.6 Case 2A– 8.8MTPA plant QLD Australia – Chinese Manufacture

The summary of CAPEX for this case is tabulated below:

	PROJECT COSTS - CAPEX		
		$ x 1000	
	FIXED ASSETS		
1	Land	0	
2	Building, construction & civil	660,852	9.5%
3	Plant & Machinery	5,303,746	76.5%
4	Water/Utilities Distribution	62,000	0.9%
5	HV Distribution	240,000	3.5%
5	Auxiliary Equipment	493,846	7.1%
7	Contingencies	0	0%
8	Project Engineering	170,000	2.5%
	TOTAL FIXED ASSETS	6,930,444	100.0%

11.2.7 Case 3– 22MTPA plant QLD Australia

The summary of CAPEX for this case is tabulated below:

	PROJECT COSTS - CAPEX		
		$ x 1000	
	FIXED ASSETS		
1	Land	0	
2	Building, construction & civil	1,670,186	9.6%
3	Plant & Machinery	13,673,555	78.6%
4	Water/Utilities Distribution	150,000	0.9%
5	HV Distribution	525,000	3.0%

5	Auxiliary Equipment	1,034,504	5.9%
7	Contingencies	0	0%
8	Project Engineering	350,000	2.0%
	TOTAL FIXED ASSETS	**17,403,245**	100.0%

11.2.8 Case 3A– 22MTPA plant QLD Australia – Chinese Manufacture

The summary of CAPEX for this case is tabulated below:

	PROJECT COSTS - CAPEX		
		$ x 1000	
	FIXED ASSETS		
1	Land	0	
2	Building, construction & civil	1,670,186	10.6%
3	Plant & Machinery	12,101,144	76.9%
4	Water/Utilities Distribution	150,000	1.0%
5	HV Distribution	525,000	3.3%
5	Auxiliary Equipment	971,607	6.2%
7	Contingencies	0	0%
8	Project Engineering	320,000	2.0%
	TOTAL FIXED ASSETS	**15,737,938**	100.0%

TATA STEEL

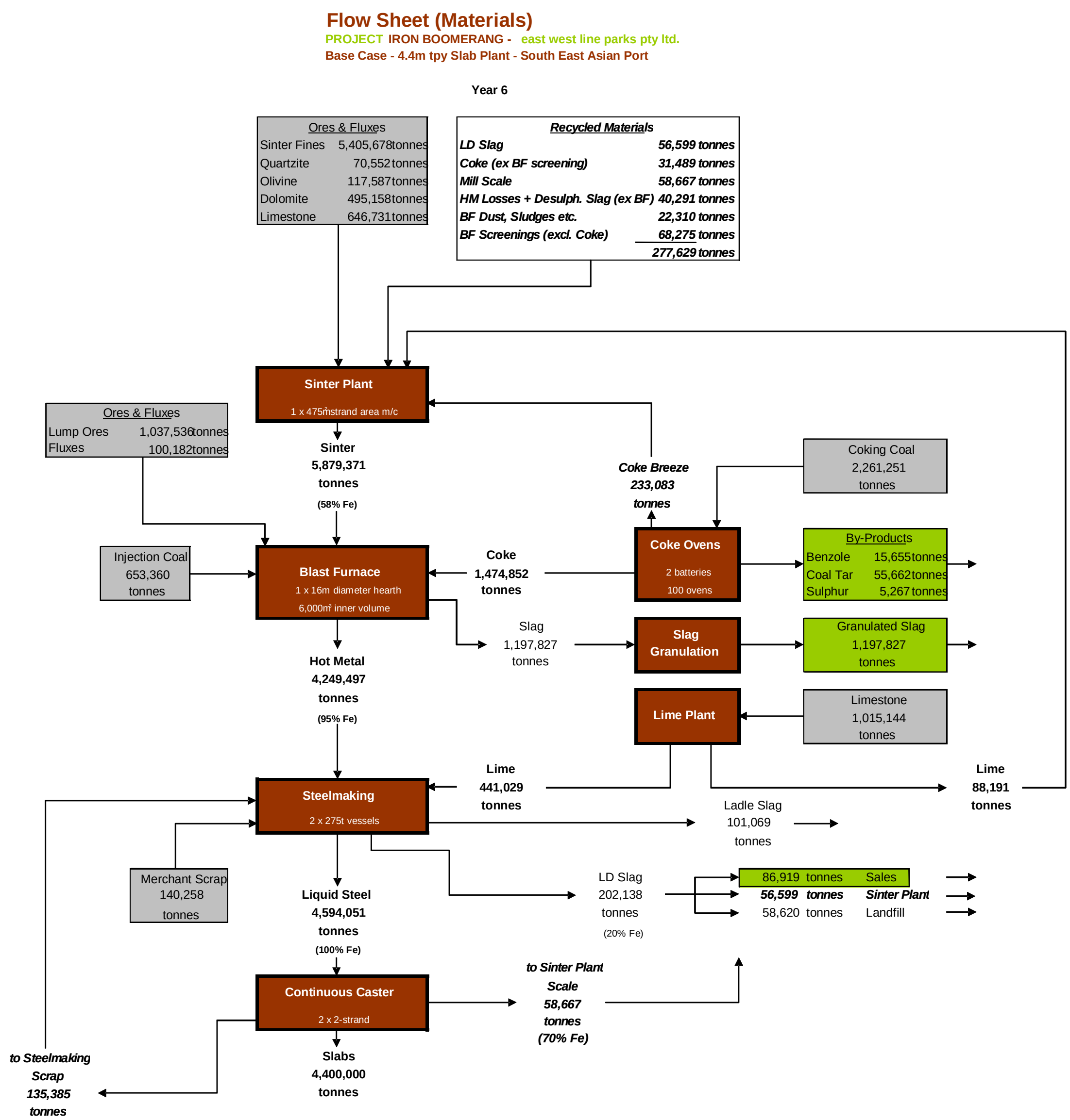
TATA

12. SUMMARY OF FINANCIAL EVALUATION

12.1 BASE CASE - 4.4 MTPA PLANT PORT LOCATION-KOREA.

This base case reference plant has been analysed using the TSC developed cost model.

The material Flow Sheet for this case is shown below:

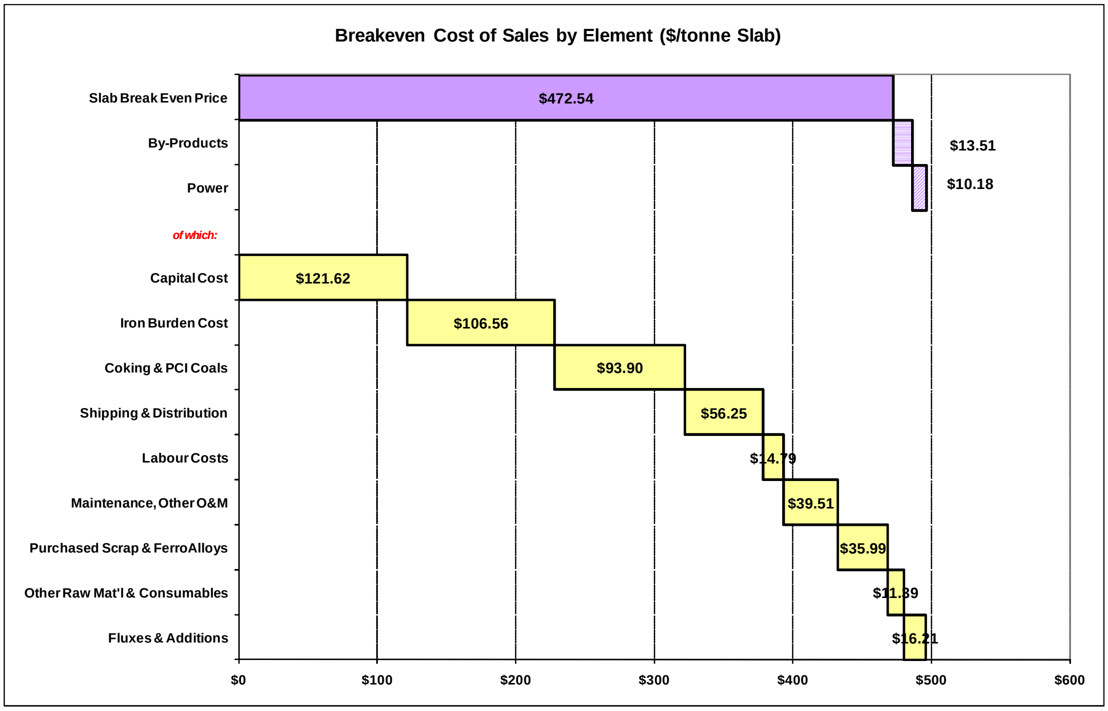


The breakdown of slab cost is shown on the graphic below and indicates a breakeven slab cost of $472.54/Tonne for slab FOB at a Korean port.

PROJECT IRON BOOMERANG east west line parks pty ltd

TATA STEEL TATA

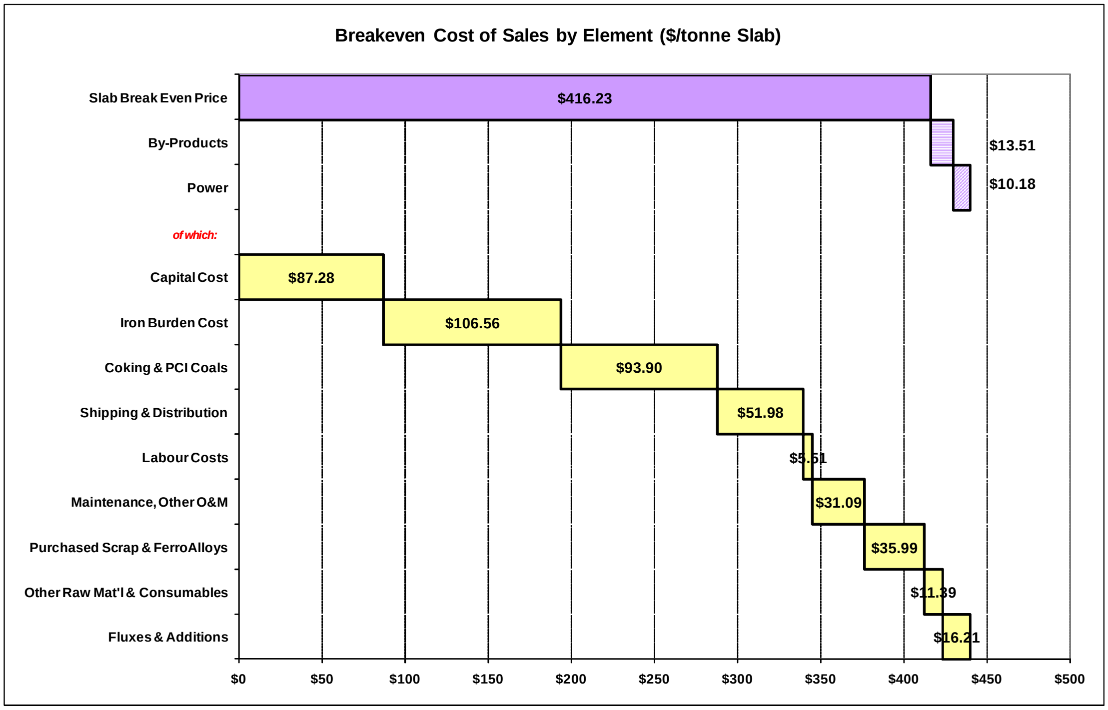
It can be seen from the graphic that raw materials, shipping and distribution account for over 64% of the total operating cost with the balance being labour and maintenance.



12.2 BASE CASE –SENSITIVITY - 4.4 MTPA PLANT - CHINA

As sensitivity, the expected cost of slab assuming a Chinese location using equipment to Chinese design and manufacture has been assessed. The results are shown below and show that for the Chinese plant, the expected breakeven cost of slab is $416.23 /tonne FOB to South China port, which is some $56.31 per tonne less than the Korean base case.

PROJECT IRON BOOMERANG east west line parks pty ltd



The main differences over the base case are:

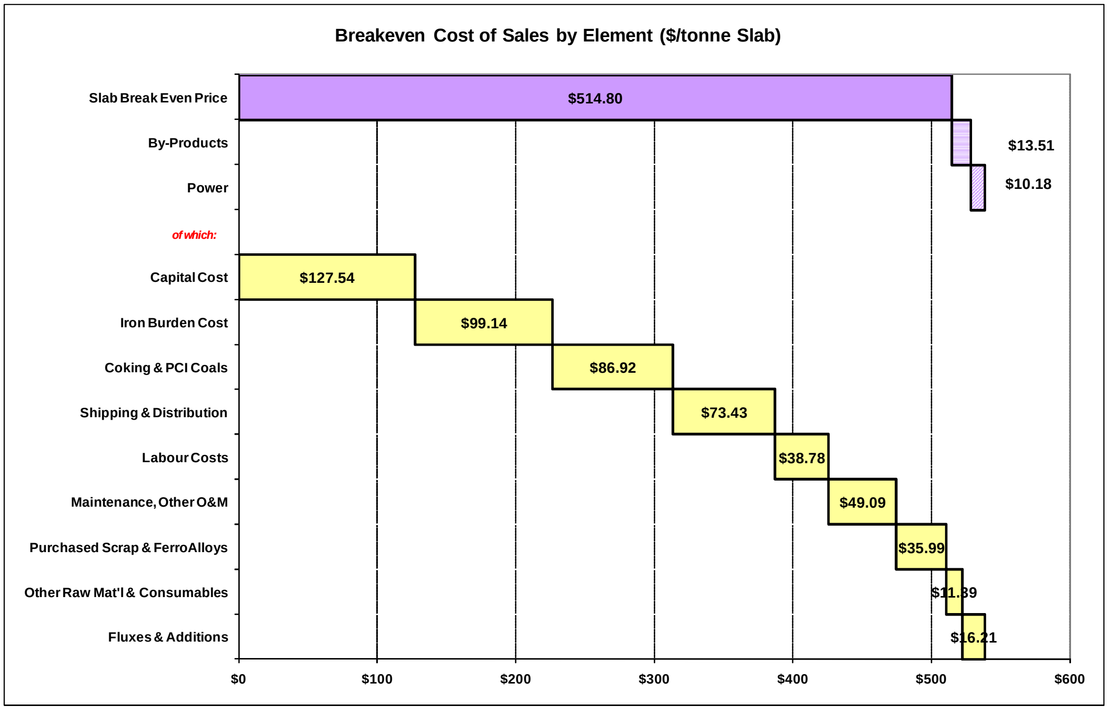
- Capital Cost - $34.34 / Te less
- Shipping and Distribution - $4.27 / Te less
- Labour Costs - $9.28 / Te less
- Maintenance, Other O&M - $8.42/Te less

At this stage TSC would voice some caution in the figures above from the following viewpoint:

- Obtaining valid capital cost of equipment on an equivalent scale and to an equivalent specification in terms of the latest environmental legislation etc. This has been discussed in section 11 of this report.
- Labour costs in China have been very difficult to obtain and compare on a like for like basis with other economies. This element impacts both on the cost of capital, labour and maintenance in the above analysis.

12.3 CASE 1 - 4.4 MTPA PLANT -ABBOT POINT, QLD, AUS

For this case the results are shown below:



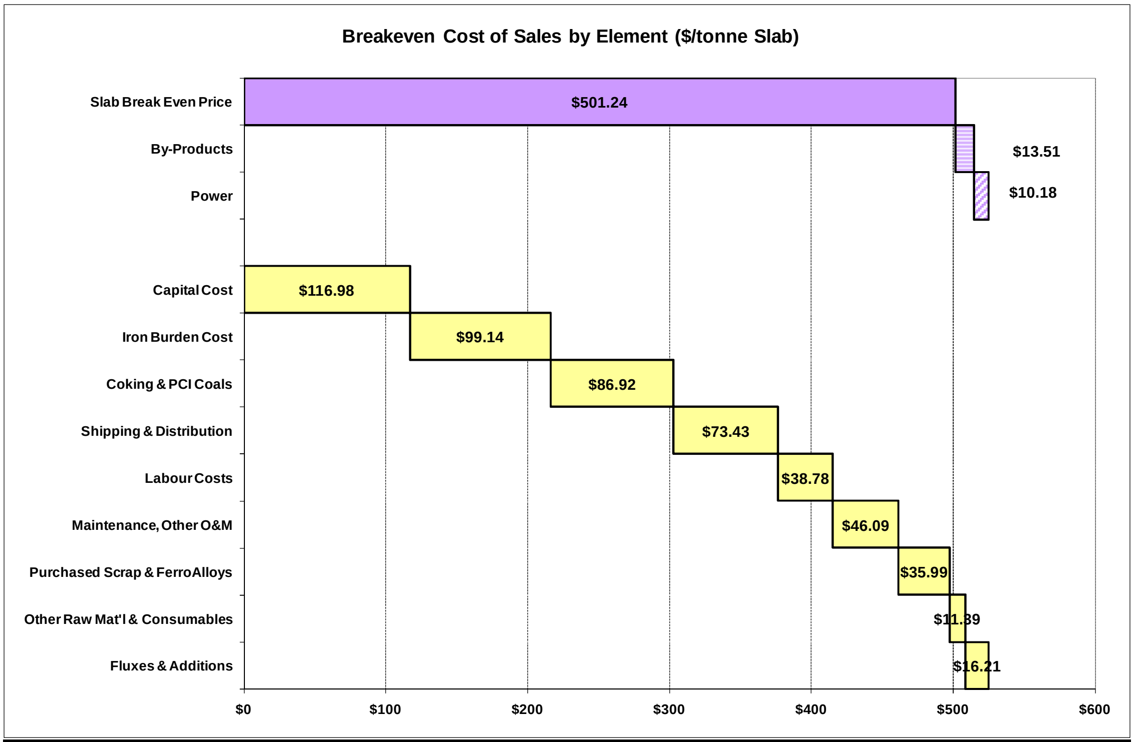
This case was based on Western Supply of equipment with local cost of Installation, civil and buildings. In terms of the transport costs within Australia, the rates provided by EWLP in their 2008 report have been utilised and include an allowance for inflation since then to arrive at 2012 figures. The shipping costs of delivered slab to Korean Port have been estimated based on latest shipping cost information. The Breakeven slab price is some $42.26 /tonne more than the base case.

The increase is due to:

- Higher capital costs
- Higher labour costs
- Increase maintenance costs (labour and materials driven)
- Increased Shipping cost to get slab to a Korean port.

12.4 CASE 1A - 4.4 MTPA PLANT -ABBOT POINT- CHINESE MANUFACTURE

For this case the results are shown below:

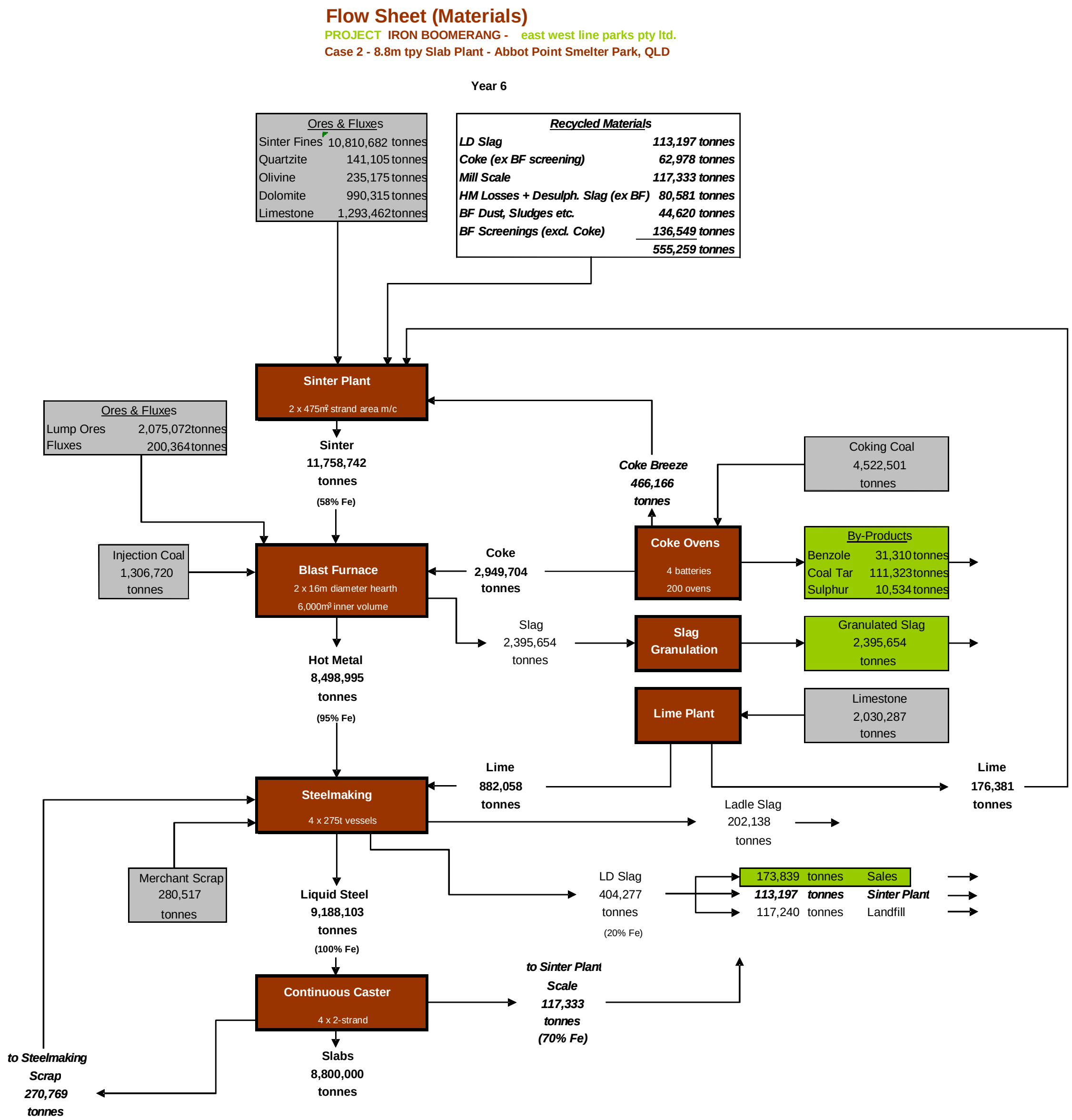


This case shows a breakeven slab cost of $501.24 /tonne which is significantly less than the previous case by some $13.56 /tonne less due to the reduced Capital cost.

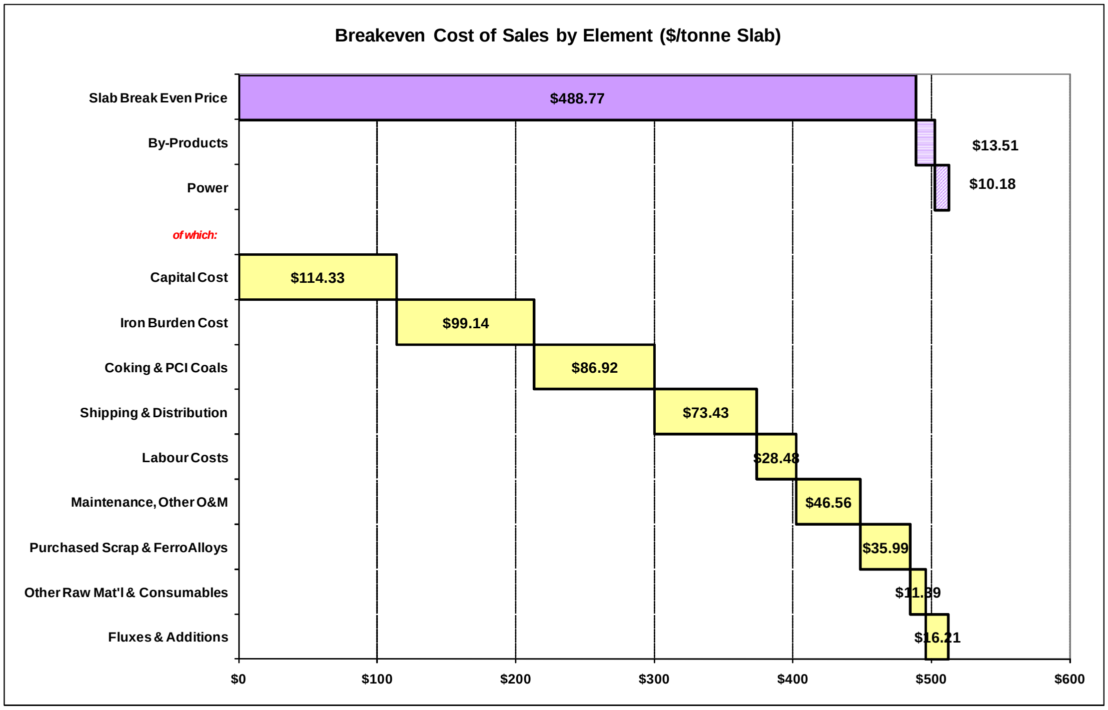
The result however is still significantly higher than the Korean base case by some $28.70/tonne.

12.5 CASE 2 - 8.8 MTPA PLANT - ABBOT POINT, QLD, AUS

The material flowsheet for this case is shown below.



For this case which is based on supply of "western" equipment the results are shown below:

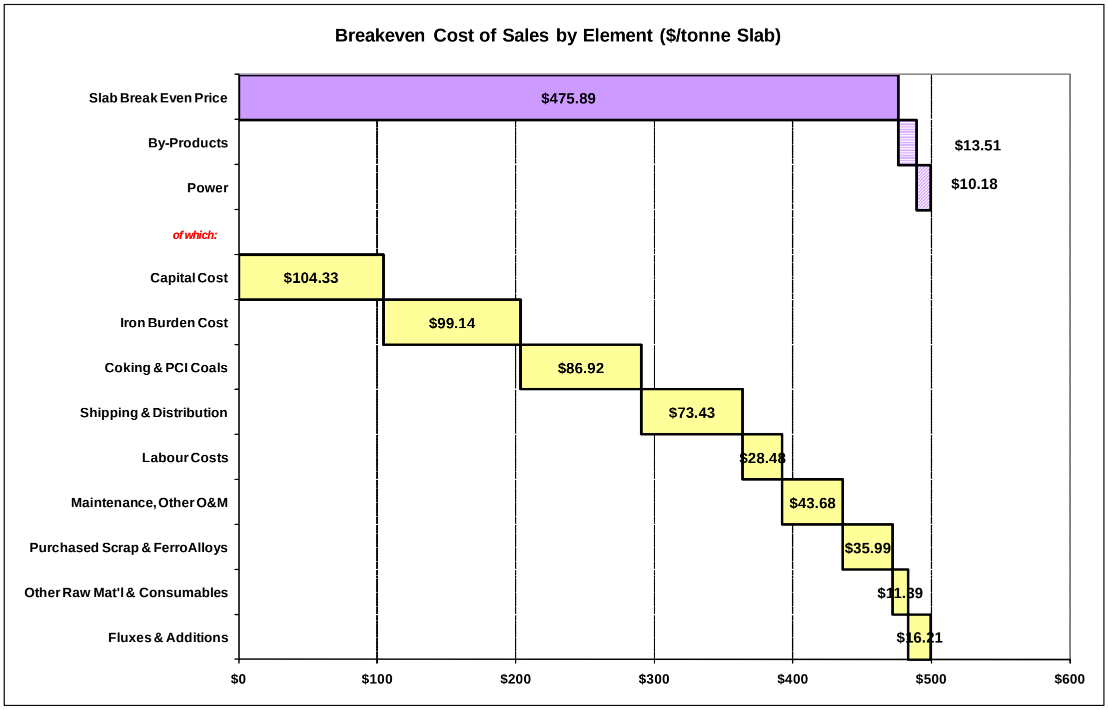


This case shows the effect of scale on the breakeven slab cost reducing the cost by some $26.03/tonne over the equivalent 4.4MTPA plant. The result however is still some $16.23/tonne more than the base case.

12.6 CASE 2A - 8.8 MTPA PLANT - ABBOT POINT – CHINESE MANUFACTURE

The slab cost breakdown for this case is shown below.

TATA STEEL TATA



This case shows the added effect of cheaper Chinese manufacture together with scale on the breakeven slab cost. The cost of $475.89/tonne is only $3.35/tonne more than the Korean base case.

12.7 CASE 3 - 22 MTPA PLANT - ABBOT POINT, QLD, AUS

For this case, the material flowsheet is shown below.

PROJECT IRON BOOMERANG east west line parks pty ltd

TATA STEEL

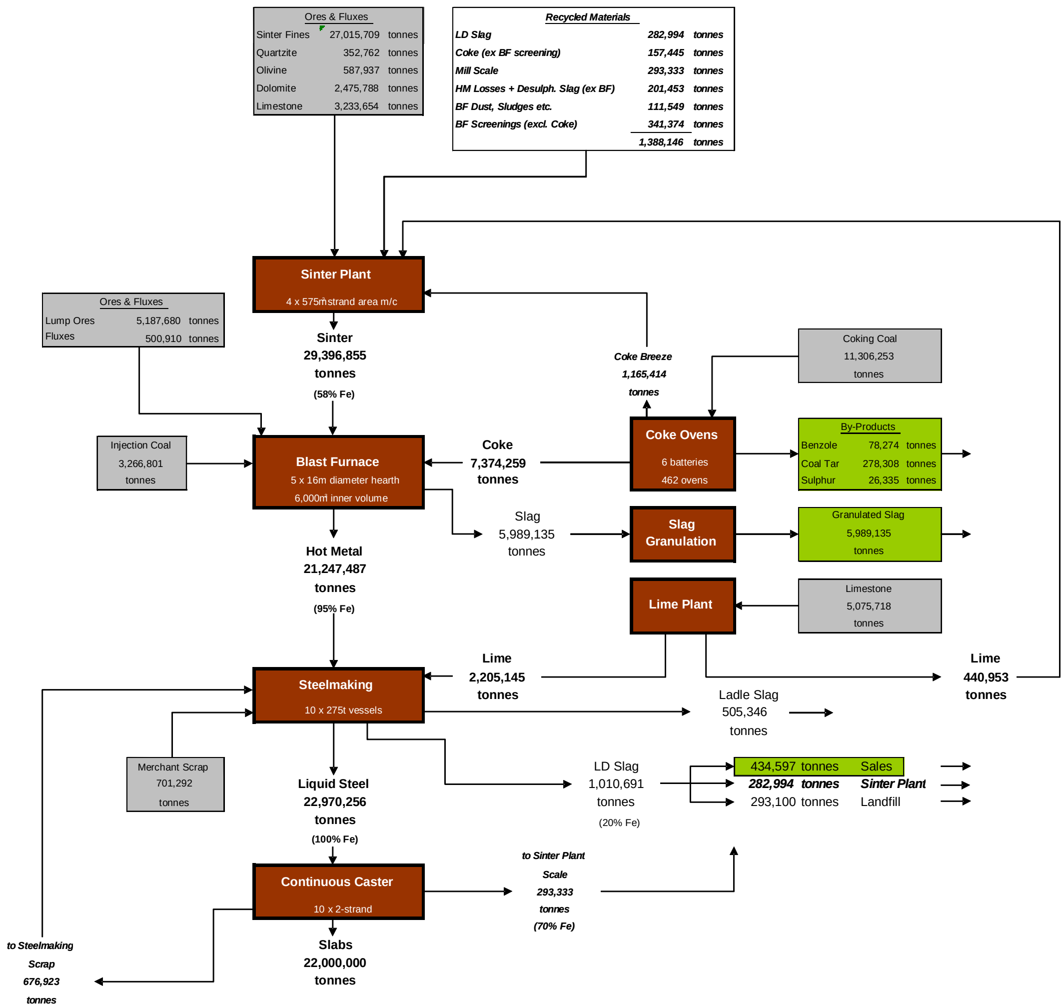
TATA

Flow Sheet (Materials)

PROJECT IRON BOOMERANG - east west line parks pty ltd.

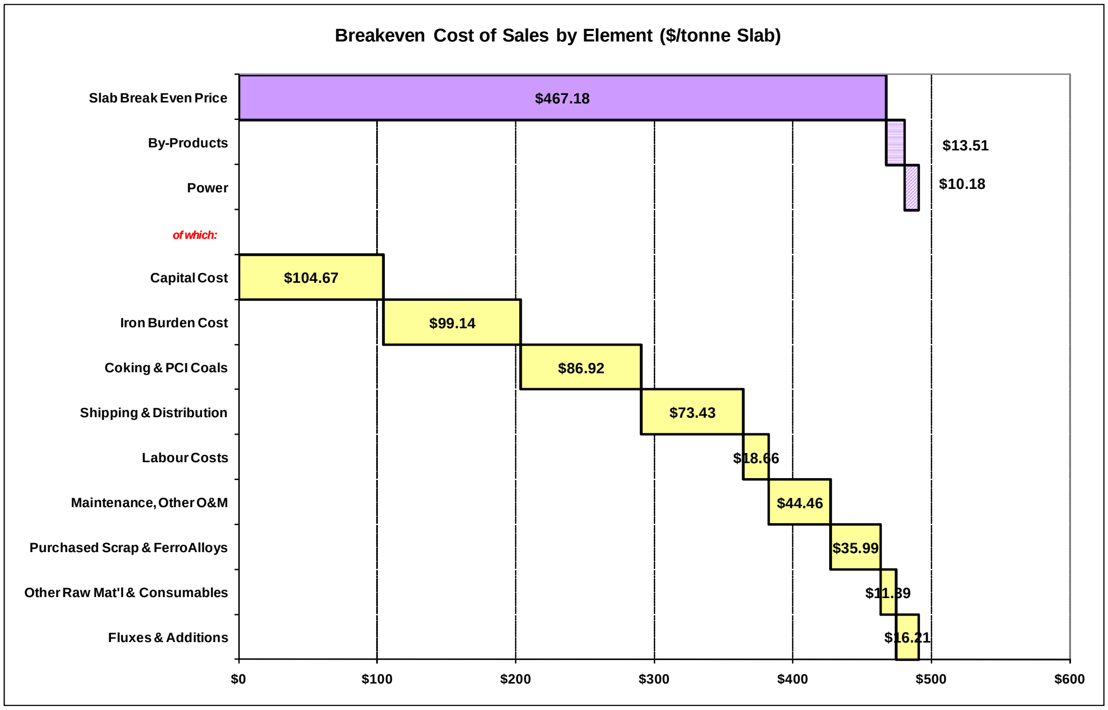
Case 3 - 22m tpy Slab Plant - Abbot Point Smelter Park, QLD

Year 6



The slab breakdown cost for this the developed case with western supply is shown below.

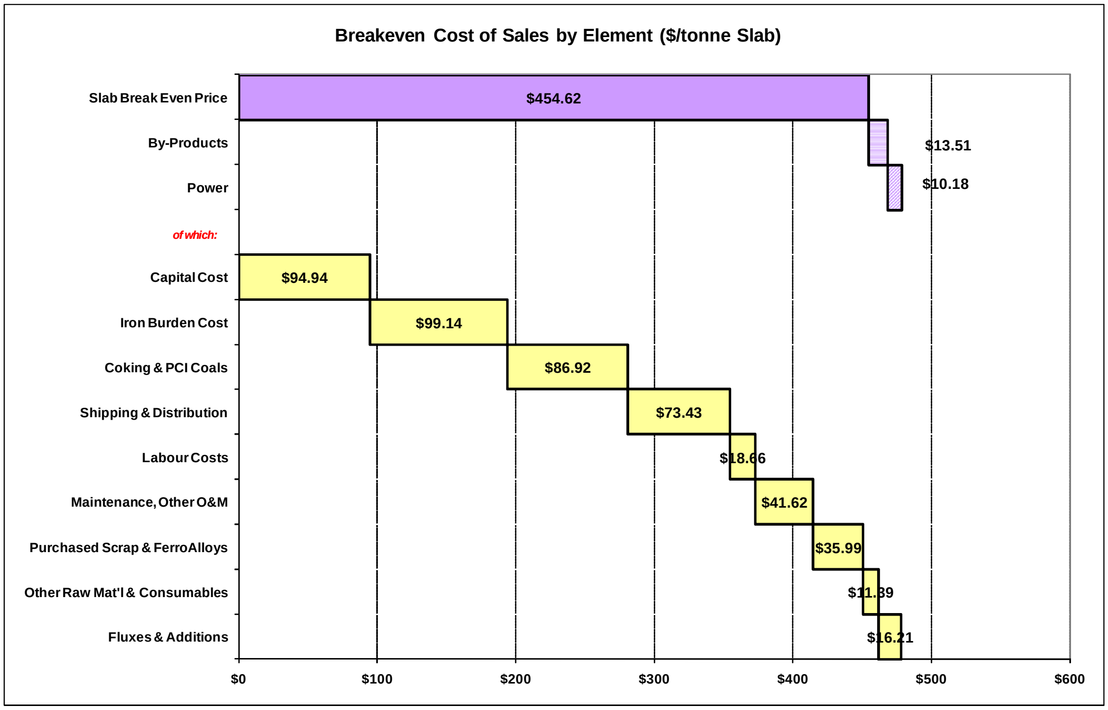
PROJECT IRON BOOMERANG
east west line parks pty ltd



The breakeven cost of this case of $467.28 is $5.26/tonne cheaper than the Korean base case.

12.8 CASE 3A - 22 MTPA PLANT - ABBOT POINT – CHINESE MANUFACTURE

The breakeven cost for this case is shown below.



This case shows that the addition of scale and Chinese manufacture, the breakeven slab cost can be reduced to some $454.62/tonne which is some $17.92/tonne less than the Korean base case.

13. CONCLUSIONS

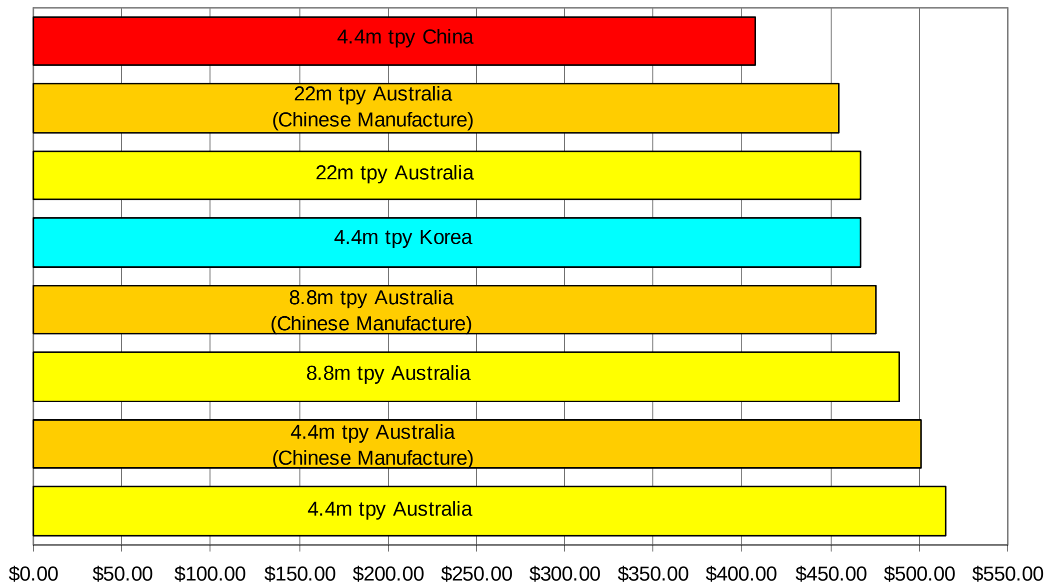
This report has reviewed a number of pre-feasibility options for the development of primary slab production in Australia and compared the production cost against a base case of a new 4.4MTPA slab making facility located in Korea.

The main findings of the report are as follows:

- Based on the developed case in Australia (22MTPA plant in QLD.) the estimated cost per tonne is some $17.92/tonne of slab cheaper in terms of delivered slab FOB Korea compared with a 4.4MTPA slab plant located in Korea.
- The scale of the fully developed case provides the opportunity for the export of substantial quantities of surplus energy to the surrounding economy. There are various options (considered in section 7 of this report) to utilise the estimated 4.6GJ/tonne surplus of energy in the form of blast furnace, coke oven and BOS gas.
- Energy consumption of the facility is estimated to be approximately 16GJ/tonne of slab, which is the order of 15-20% better than typical world practice.
- A further benefit of the scale of the developed case is that it should allow PIB to approach "world's best" productivity benchmarks for slab production, TSC estimates a productivity figure of 0.25 manhours/tonne of slab produced will be achieved compared to a typical world figure of around 0.5 manhours/tonne.
- There will be substantial savings of green house gas (GHG) emissions mainly due to the supply chain consolidation by only shipping finished slab outside Australia, rather than shipping iron making raw materials (coal and iron ore) as is currently the case. In volume terms this represents a saving of over 50% in the quantities of materials shipped.
- Due to the reduced energy consumption of the developed facility there will be significant savings in GHG emissions during the iron and steelmaking process compared to world steel average. As yet this has not been evaluated.
- On the basis that the proposed Steel Producers will co-operate in terms of process routes, significant savings can be made by standardising on the design of the main iron and steel making processing units, this will generate savings in the following areas:
    - Design costs for repeat designs
    - Economies of scale in ordering & scheduling multiple units through procurement and subsequent erection
    - Savings in spares holding due to the commonality of design
    - Savings in project management and execution
    - Manufacture of equipment in low cost markets such as China
    - Savings associated with the above equate to an estimated US$B3.8 for the developed case as opposed to having 5 stand alone facilities in Korea.
- In evaluating the relative cost of shipping ore and coal from Australia to Korea as opposed to moving the ore and coal within Australia and subsequently shipping the slab to Korea, the original savings identified by EWLP in 2007/8 have been eroded due to the collapse of the bulk freight price. This is demonstrated in the shipping and distribution element of the base case being $56.25/tonne of slab verses the developed case being $73.43/tonne of slab.
- Whilst there are substantial savings in productivity levels for the developed scheme compared to the base case and world benchmark levels, due to the relative high level of employment costs in Australia, these benefits are eroded. This shown in the labour cost, $14.79/tonne of slab compared to $18.66/tonne of slab for the developed case. The labour

cost differential also impacts on the capital and maintenance costs of the equipment.

The financial summary of the various options considered in this report is presented in the chart below in terms of breakeven slab cost.



The detailed make up of slab cost is shown in the table below:

	Slab Breakeven Price	By-Products	Power		Capital Cost	Iron Brden Cost	Coking & PCI Coals	Shipping & Distribution	Labour	Maintenance, Other O & M	Purchased Scrap & Ferroalloys	Other Raw Materials & Consumables	Fluxes & Additions
4.4m tpy China	$416.23	$13.51	$10.18		$87.28	$106.56	$93.90	$51.98	$5.51	$31.09	$35.99	$11.39	$16.21
22m tpy Australia (Chinese Manufacture)	$454.62	$13.51	$10.18		$94.94	$99.14	$86.92	$73.43	$18.66	$41.62	$35.99	$11.39	$16.21
22m tpy Australia	$467.18	$13.51	$10.18		$104.67	$99.14	$86.92	$73.43	$18.66	$44.46	$35.99	$11.39	$16.21
4.4m tpy Korea	$472.54	$13.51	$10.18		$121.62	$106.56	$93.90	$56.25	$14.79	$39.51	$35.99	$11.39	$16.21
8.8m tpy Australia (Chinese Manufacture)	$475.89	$13.51	$10.18		$104.33	$99.14	$86.92	$73.43	$28.48	$43.68	$35.99	$11.39	$16.21
8.8m tpy Australia	$488.77	$13.51	$10.18		$114.33	$99.14	$86.92	$73.43	$28.48	$46.56	$35.99	$11.39	$16.21
4.4m tpy Australia (Chinese Manufacture)	$501.24	$13.51	$10.18		$116.98	$99.14	$86.92	$73.43	$38.78	$46.09	$35.99	$11.39	$16.21
4.4m tpy Australia	$514.80	$13.51	$10.18		$127.54	$99.14	$86.92	$73.43	$38.78	$49.09	$35.99	$11.39	$16.21

14. RECOMMENDATIONS FOR FURTHER WORK

In developing and evaluating this project the following further study work is recommended.

- Explore means to increase the OPEX differential between the PIB case and the base case. This might include raw material costs, labour costs, detailed exploration with suppliers of savings in capital costs as scale increases, cost of rail transportation(for example use of additional freight other than ore and coal on the E-W rail line),etc
- Gain a more detailed appreciation of the iron ore and coal chemistries available to this project and evaluate their impact on the blend and production cost of slab, particularly with regard to the magnetite ores that may be available from mines along the proposed E-W rail line.
- Gain a greater understanding of the proposed Steel Producers product mix to further develop the steel complex operational configuration with particular regard to the steel plant layout and logistics.
- This developed facility will “extend the envelope” in terms of the scale of the main processing units. There are currently very few equipment manufacturers with references producing plants of this size it would therefore be prudent to develop high level facility specifications and approach the technological equipment designers and manufacturers to gain latest budget information on operating and capital cost of equipment taking into account economies of scale, Chinese manufacture etc. Once this is established review the impact on the cost estimates produced to date.
- Investigate further the logistical flow of material from the steel complex to the port and subsequent loading onto the proposed “roll-on-roll-off” facility and the impact on slab cost.
- Look at further shipping options in terms of long term Charter or buying the necessary cargo vessels. In particular reviewing further the effects of the roll-on roll off slab vessel on shipping costs
- Investigate further the effect of green house gas emissions, not just from a transport viewpoint but to include the potential emission savings from the developed facility due to the much improved energy efficiency of this project compared to world steel average.
- Start to develop equivalent proposals for the Newman steel complex in WA, taking into account the particular differences in logistics with regard to slab transfer to the port.