Beneficiation: an analysis of South African Chrome Ore

A Research Report

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Masters of Business Administration Degree

by

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Plagiarism declaration

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2. I have used the APA referencing system for this research proposal.
3. This research proposal is my own work.
4. I have not allowed, and will not allow, anyone to copy my work with the intention of passing it off as his or her own work.
5. I acknowledge that copying someone else’s assignment or essay, or part of it, is wrong, and declare that this is my own work.
## Glossary of Acronym

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Expansion</th>
</tr>
</thead>
<tbody>
<tr>
<td>BRIC</td>
<td>Brazil, Russia, India, China</td>
</tr>
<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
</tr>
<tr>
<td>USA</td>
<td>United States of America</td>
</tr>
<tr>
<td>UCT</td>
<td>University of Cape Town</td>
</tr>
<tr>
<td>FeCr</td>
<td>Ferrochrome</td>
</tr>
<tr>
<td>Cr</td>
<td>Chrome</td>
</tr>
<tr>
<td>PMG</td>
<td>Platinum Group of Metals</td>
</tr>
<tr>
<td>EIA</td>
<td>Environmental Impact Assessment</td>
</tr>
<tr>
<td>CEO</td>
<td>Chief Executive Officer</td>
</tr>
<tr>
<td>DMR</td>
<td>Department of Mineral resources</td>
</tr>
<tr>
<td>SA</td>
<td>South Africa</td>
</tr>
</tbody>
</table>
1. **Introduction**

South Africa is the world’s largest producer of chrome ore. South Africa converts the chrome ore partly to ferrochrome. Ferrochrome is the intermediate product which is subsequently converted to Stainless Steel. Stainless Steel is the final product. South Africa sells both ferrochrome and chrome ore to stainless producing countries Stainless steel is the end product which is used in home appliances, white goods and metal goods, machinery & engineering, tabular product, transport. The special feature of stainless steel is its corrosion resistance property. The element chrome, the commercial source of which is chrome ore, gives this special feature to stainless steel.

There is a growing concern on the part of South African policy makers about the export of chrome ore in the non-beneficiated form. The export of ore is the easiest way to earn money, but not adding value in-house takes away its benefits like job creation, increased revenue earning of the economy in-terms of export of a value added product, growth of supporting businesses which grow along with the chrome business.

Currently most of South Africa’s chrome is exported as ore and is not beneficiated.

This research’s primary focus is to investigate why chrome ore is not being beneficiated in South Africa.
1.1. Research area and Problem

1.1.1. Research area and context:

Geology and types of the chrome ore deposit:

South African chrome ore is found in the Bushveld Igneous Complex (BIC) mainly in the form of LG6, MG-1 and MG-2. LG stands for lower group and MG stands for medium group. The LG6 and MG-1 and MG-2 are considered to be the primary Source of chrome ore and have been mined extensively. But, with increasing depth of the ore body the mining has become increasingly expensive.

UG2 is gradually becoming popular as the chrome ore, alternative to LG6, MG1 and MG2. The reason is its low cost. UG stands for upper group and the seam number is 2. UG2 is primarily mined for platinum group of metals (PMG) by the platinum producers and the chrome ore comes out as the by-product of the beneficiation process. UG2 was first mined in 1980, and since then an effort has been made by the South African ferrochrome producers to use of UG2 in the production of ferrochrome.

From the platinum miner’s point of view, although UG2 contains lesser quantities of base metal and of PGM grade than the Merensky Reef, but it is economical to extract PGM from UG2. The reason is Merensky Reef has long been mined for platinum and majority of the producers has gone into mining at higher depths which makes the mining expensive because of higher investments required in shaft system and refrigeration (L.A Cramer, 2004).

Country wise reserve and production of chrome ore:

Chrome ore, which is also called chromite, is the only commercial source of chromium. World reserves of chrome ore reserve and the quantities mined in 2008 are given in the table-
<table>
<thead>
<tr>
<th>Country</th>
<th>Chrome ore reserve in Mill t</th>
<th>In % of world’s total reserve</th>
<th>Rank</th>
<th>Chrome ore output in 2008, in Mill t</th>
<th>In % of world’s total output</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Africa</td>
<td>5500</td>
<td>72.4</td>
<td>1</td>
<td>8.4</td>
<td>39</td>
<td>1</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>930</td>
<td>12.2</td>
<td>2</td>
<td>0.9</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Kazakhstan</td>
<td>320</td>
<td>4.2</td>
<td>3</td>
<td>3.6</td>
<td>15</td>
<td>3</td>
</tr>
<tr>
<td>Finland</td>
<td>120</td>
<td>1.6</td>
<td>4</td>
<td>0.6</td>
<td>2.6</td>
<td>8</td>
</tr>
<tr>
<td>India</td>
<td>63</td>
<td>0.9</td>
<td>5</td>
<td>3.7</td>
<td>16.2</td>
<td>2</td>
</tr>
<tr>
<td>Turkey</td>
<td>20</td>
<td>0.3</td>
<td>6</td>
<td>0.9</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>Brazil</td>
<td>17</td>
<td>0.2</td>
<td>7</td>
<td>0.7</td>
<td>3.3</td>
<td>7</td>
</tr>
<tr>
<td>Others</td>
<td>626</td>
<td>8.2</td>
<td>8</td>
<td>2.2</td>
<td>14</td>
<td>4</td>
</tr>
</tbody>
</table>

Table-1 Global chrome ore reserve and production


From table-1, we can see that South Africa and Zimbabwe together have 84.6% of the world’s chrome ore reserves. Other countries with good quantities of reserve are Kazakhstan, Finland and India. In the year-2006, South Africa is the first, contributed 40% of world’s chrome ore, followed by India and Kazakhstan contributed 17.6% and 17.1% respectively.

Use of chrome ore:

As concluded from the figure-1, the main use of the chrome ore is in the metallurgical industry (almost 80%) and the rest comprises of its uses in the chemical, refractory and foundry industry; altogether it is only 20%.
If can also be seen that the metallurgical use of chrome ore has increased by almost 90% from 1996 to 2006.

In the metallurgical use of chrome ore, it is first converted to ferrochrome, which is the intermediate product, and then the Ferrochrome is used with other raw materials for stainless steel making.

*Figure-1 Use of chrome ore*

*Source: General Review Global Ferrochrome Industry, Heinz H Pariser, 2006*
The following flowchart briefly explains the use of chrome ore in the metallurgical industry:

![Flowchart of chrome value chain](image)

**Demand for chrome ore:**

The demand for chrome ore is mainly driven by the demand of stainless steel. From figure-3, we can see that the production of chrome ore is proportional to the production of stainless steel. The intermediate product of chrome, which is ferrochrome, also follows the same trend.
**Figure-3 Comparison of World Total Production of FeCr, Chrome Ore and Stainless Steel**

*Source: General Review Global Ferrochrome Industry, Heinz H. Pariser, 2006*

**Global chrome business (chrome ore supply-demand):**

Table-2 gives the:

1) Country wise chrome ore production as percentage of global chrome ore production
2) Export and import as a percentage of global chrome ore export and import respectively.
3) Ferrochrome production and stainless steel production as the percentages of global output
<table>
<thead>
<tr>
<th>chrome ore reserve</th>
<th>chrome ore production as a % of global production</th>
<th>ferrochrome production as a % of global production</th>
<th>chrome ore exporter as a % of global export</th>
<th>chrome ore importer as a % of global import</th>
<th>stainless steel production as a % of global production</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Africa (72%)</td>
<td>South Africa (40%)</td>
<td>South Africa (40%)</td>
<td>South Africa (30 %)</td>
<td>China (75%)</td>
<td>China (35%)</td>
</tr>
<tr>
<td>Zimbabwe (12%)</td>
<td>India (18%)</td>
<td>China (23%)</td>
<td>India (20.1%)</td>
<td>Russia (10%)</td>
<td>Total Europe (24%)</td>
</tr>
<tr>
<td>Kazakhstan (4%)</td>
<td>Kazakhstan (17%)</td>
<td>Kazakhstan (15%)</td>
<td>Kazakhstan (15%)</td>
<td>Other Europe (6%)</td>
<td>Japan (11%)</td>
</tr>
<tr>
<td>Finland (2%)</td>
<td>Turkey (4.5%)</td>
<td>India (11%)</td>
<td>Turkey (14%)</td>
<td>Sweden (3.5%)</td>
<td>India (7%)</td>
</tr>
<tr>
<td>India (1%)</td>
<td>Zimbabwe (4.3%)</td>
<td>Russia (3%)</td>
<td>Iran (3.8%)</td>
<td>USA (2.2%)</td>
<td>USA (7%)</td>
</tr>
<tr>
<td>Turkey (0.3%)</td>
<td>Brazil (3.2%)</td>
<td>Australia (3.4%)</td>
<td></td>
<td>Taiwan</td>
<td></td>
</tr>
<tr>
<td>Brazil (0.2%)</td>
<td></td>
<td></td>
<td>Pakistan (3.4%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table-2 Country wise chrome ore reserve, chrome ore production, ferrochrome production, chrome ore export, chrome ore import, stainless steel production


# Note-1: The percentage figures are the close approximations of the production, export, import figures of 2010.

Observations:

Supply side:

1) The major chrome ore producing countries are South Africa, India, Kazakhstan, Turkey, Zimbabwe, Brazil dominated by South Africa.

2) Out of those chrome ore producing countries, South Africa and Kazakhstan converts a part of the domestic chrome ore production to ferrochrome and sell the ferrochrome and the raw chrome ore to the stainless Steel and ferrochrome producing countries. South Africa and Kazakhstan do not produce stainless steel in substantial quantities.

3) India produces chrome ore and converts part of it into ferrochrome. Part of the ferrochrome produced by India is exported to the stainless steel producing countries and the rest is consumed domestically for the production of stainless steel. The chrome ore produced by India is partly consumed for domestic ferrochrome industry. The balance is exported to the ferrochrome and stainless steel producing countries.

4) Countries like Turkey, Australia, Iran and Pakistan produce chrome ore mainly for exporting it to the ferrochrome and stainless steel producing countries. They do not produce ferrochrome.

Demand side:

1) The demand for chrome ore is generated by the stainless steel producing countries like China, Total Europe, Japan, India, USA and Taiwan.

2) Except for India, all the countries mentioned above do not produce chrome ore, they import either chrome ore or ferrochrome or both in order to produce stainless steel.

So, the demand of chrome is driven by the following countries in descending order:

1) China, 2) European Union, 3) Japan, 4) USA, 5) India, 6) Korea.
Present and future demand of stainless steel:

1) From Figure 4 we can see that the major consumers of stainless steel are China/Hong Kong, (30%) European Union (25%), Japan (10%), India (8%), USA (7%), South Korea (4%), Taiwan (4%) Thailand (2%) in descending order. The percentage figures are the approximation from the graph. So these countries actually drive the demand of stainless steel thus the demand of ferrochrome.

2) In terms of rate of growth in stainless steel consumption, the countries are China (25%), India (13%), South Korea (9%), Thailand (8%), Japan (5%), Taiwan (3%), EU (3%), USA (-2%).

3) The main producers of stainless steel are China (35%), European Union (24%), Japan (11%), India (11%) etc (Antonie Dusart, 2011).

4) So, except USA, the major stainless steel producers are consumers as well. USA imports stainless steel from the producing nations.

5) Please note that the values are approximations from Figure 4.
The global trend of chrome ore export:

The figure-6 gives the chrome ore export figures of the major exporting countries as a percentage of total global export.

We can see that the major exporters of chrome ore are South Africa, Kazakhstan, India, Turkey, Iran and Pakistan. Although South Africa has reduced its chrome ore exports from 1996 to 2006 from 45% to 30% but still maintains the status of the biggest chrome exporter of the world. Turkey and Iran show a decreasing trend with regards to export of chrome ore. The countries which increased their chrome ore export are India, Kazakhstan, and Pakistan. Australia emerged as a new player.
The global trend of chrome ore import:

![Figure 6: Comparison of global chrome ore import 1996 vs. 2006](image)

*Source: General Review Global Ferrochrome Industry, Heinz H. Pariser, 2006*

China’s import has increased from merely 21% of global import in 1996 to 72.7% of the global import by 2006. The countries which show a major decline in the demand for chrome ore are other Europe, Japan, Sweden, USA and Italy. The only country that maintained a steady import of chrome ore is Russia.

In 2005, India was the number-1 exporter of chrome ore to China and South Africa was the 2nd largest by volume (Moisane, 2007). But, in 2006, South Africa became the number one exporter of chrome ore by volume.

The reason is that on 1st March’2007 Indian government imposed an export duty of USD 44/ton of chrome ore (friable and concentrate type of chrome ore) and also imposed a quota of 440,000 tons/year as the permissible limit for the export. This made a change in the global scenario and gradually South Africa became the largest exporter of chrome ore to China.
South Africa in the global chrome business:

The purpose of this section is to understand the year on year change in the chrome value chain of South Africa. From the figure-7, we can see that the chrome ore production increased from 4.7 mn tons in the year 1996 to 8.3 mn tons in the year 2006; the production of ferrochrome increased from 1.4 mn tons in the year 1996 to 2.9 mn tons in the year 2006; and the export of chrome ore has steadily increased from 1.4 mn tons in 2006 to 2 mn tons in year 2006.

![Figure-7 South Africa’s chrome ore production, chrome ore export, chrome ore export as a percentage of production, ferrochrome production](image)

*Source: General Review Global Ferrochrome Industry, Heinz H. Pariser, 2006*

According to Merafe’s statistics (Ryan, Miningmx, 2011), China imported 8.7million ton of chrome ore during 2010 of which 3.1million ton came from South Africa. In 2011, South Africa’s export of chrome ore to China has been stepped up accounting for 2 million ton of the 4.4million ton that China has imported year-to-date.
The players of South African chrome business:

The objective of this section is to know about the major players of the chrome business of South Africa. This sections talks about the production, and export dynamics of the chrome ore and ferrochrome of the major players of South African chrome business.

**SAMANCOR Chrome:** It started in 1975 as a merger of SA Manganese and AMCOR Ltd. Until 1st June’05, the majority share holders of this company were Billiton and Anglo American. In June 2005 the company was taken over by KERMAS group. Samancor’s chrome mines are located on the eastern - Eastern Chrome Mines (ECM) and western - Western Chrome Mines (WCM) limbs of the Bushveld Igneous Complex. In the year 2010, the typical production levels amount to some 3 Mt per annum of saleable chrome ores for both internal consumption (approximately 2.3million tonnes - Mt -per annum) and the export including domestic sales (approximately 0.7 million ton per annum) (SAMANCOR Cr).

**Xstrata Alloys:** It is the world’s largest producer of ferrochrome. They got major controlling stake in many mines in South Africa. Xstrata consumes its production of chrome ore for production of ferrochrome only. They also purchase and use chrome ore (the UG2 grade) produced by the leading Platinum producers. As of now, Xstrata’s production capacity is 1.76 million tonnes and in 2010 it produced 1.1165 million tonnes of Ferrochrome (Xstrata Alloys, 2011).

**The Other producers:** The other Ferrochrome producers are ASA metals, Hernic, Mogale and Asmang. They either owns captive mine or owns stake in the chrome mines. There is an increasing tendency among those ferroalloy producers to use UG2 and many of them locked in long term contract with major Platinum producers.

Apparently it looks like that the chrome business is separate from the platinum business, but there is a link between the two. The by-product of platinum mines, the UG2 can be used as chrome ore in ferroalloys production. So, this section will explore agreement
between the major platinum producers and major ferrochrome producers in terms of the use of UG2.

**Anglo Platinum:** The Company has not yet finally concluded the future allocation of UG2 tailings from their various operations. It is understood that Xstrata has the access to their tailings in the Rustenburg area. Information received that chrome from Anglo Platinum was sold to Japan, where the ore is directly used in melting ferritic stainless steel (RH Process) (Pariser, 2006, p. 18).

**Impala:** Partly committed to neighbouring Merafe who produces ferrochrome (Pariser, 2006, p. 18).

**Lonmin:** Partly committed to Xstrata (Pariser, 2006, p. 18)

**Aquarius:** Fully committed to Xstrata (Pariser, 2006, p. 18).

So, it is understood that the major ferrochrome producers of South Africa are aware of the business opportunity of using UG2 for ferrochrome production and getting locked into long term contract with the platinum producers.

### 1.1.2. Research Problem

The latest information available in 2010 shows that SA only beneficiated 60% of its chrome ore production. The research problem is to understand why the rest of the chrome ore is not being beneficiated.

### 1.1.3. Research Purpose

The purpose of this research is twofold. First is to investigate to investigate why South Africa is not beneficiating chrome. Second is to explore the potential of beneficiating the chrome ore that is currently exported.

This research will explore of the potential beneficiation of:

- Chrome ore to ferrochrome
- UG2 to ferrochrome
As mentioned above, UG2 is the by-product of platinum mines and far cheaper than prime chrome ore. If UG2 is used in higher proportions in ferrochrome production, then it will improve the competitiveness of South Africa with regards to production of ferrochrome.

The research followed deductive approach to vet the two alternatives. The pros and cons of beneficiation options are vetted to propose the optimal scenario. This research is explorative in nature because it was not known that which option will come out as the most beneficial for the South African economy. This research has come with recommendations to make South Africa more competitive in beneficiating Chrome ore.

1.1.4. Significance and Importance of Research

This research will give a direction to the debatable issues of export of non-beneficiated product. This research collected information both in quantitative and in qualitative terms to vet the different value addition options.

1.2. Research Question and Scope

Main question

The main question in this research is “Why is South Africa not converting all its chrome ore to ferrochrome?”

As mentioned above the research has done this by looking at the alternatives of converting chrome ore to ferrochrome or converting UG2 to ferrochrome.
**Scope of Research:**

First of all, the research has been done to understand why South Africa is not beneficiating all of its chrome ore production.

Then, the infrastructural needs of setting up a beneficiation facility has been examined and quantified.

Lastly, the pros and cons of the two alternatives of beneficiating chrome ore: converting chrome ore to ferrochrome and converting UG2 to ferrochrome are vetted with regards to the following:

1) Job creation in the country

2) Economic benefits of value addition like growth of supporting businesses that grows with the growth of beneficiation facility.

3) Increase in the revenue in-terms of export of a value added product.

4) Investment required for adding the beneficiation facility.

5) Comparison of the margins of export of ore with the export of beneficiated product.

6) Environmental impact of the beneficiation facility

1.3. Research Assumptions

**Assumptions, Impact of Assumptions and Mitigation Strategy**

Because of the unavailability of some of the relevant data, the research is based on a series of assumptions. The researcher has done scenario and sensitivity analysis to evaluate the variations in the assumption.

For example, the cost of ESKOM power is an important input to the cost of production of chrome ore, ferrochrome. The rise or fall in ESKOM power cost in the near future will increase or decrease the cost of production of the beneficiated product. It will affect the profit margins thus the benefits quantified by the financial model of this project. The company review reports of ESKOM gave some idea on the power tariff and its prediction for the next
few years. In this case, a scenario and sensitivity analysis is done to explain the variations in the assumption.

1.4. Research Ethics

This research is based on an analysis of the qualitative information and the quantitative data, available from various sources such as the report published in the website of ferroalloy producers, the annual report of various ferroalloys, stainless steel and electrical power producers. The available data collected from various sources is vetted by the interviews with executives of the concerned industries. Some of the data was not available, so sensitivity and scenario analysis is done to check the variations in the assumption. It is mentioned clearly in the research report.

As a part of the requirement for UCT submission of the Research proposal, Researcher has signed and handed in the ethical clearance form to the MBA administration department.
2. Literature Review

The literature review is subdivided into eight sections. The first section talks about different theories on trade and international competitiveness of countries. The second section briefly explains Michel Porter’s competitive theory of nations. The third section gives the global outlook on the demand of South Africa’s beneficiated product. The fourth and fifth sections describe the advantages and disadvantages of South Africa with regards to the theories mentioned in section one and in section two. The sixth section summarises the different studies done on the research question. The seventh section cites the views of the beneficiation industries of South Africa on the research question and the eighth section concludes the entire literature review.

2.1. Trade theories and international competitiveness of countries:

Adam Smith’s theory of absolute advantage, as cited in (Smit, 2010, p. 108), says that “a country can enhance its prosperity if it specializes in producing goods and services in which it has an absolute cost advantage over other countries and imports those goods and services in which it has an absolute cost disadvantage.”

On the contrary, the mercantilists of the 16th century, as cited in (Smit, 2010, p. 108), believed that “if countries wanted to become rich and powerful, they must export more and restrict imports to the minimum. Such a policy would result in an inflow of gold and silver that would make the country wealthy. They advocated strict government control and preached economic nationalism.

If the theory of absolute advantage is true then a country that can produce all the products and services with absolute advantage would not import because the country can produce more efficiently.

The Ricardo’s theory of comparative advantage, as mentioned in (Smit, 2010), says that a country must specialize in products that it can produce more efficiently than other countries. Ricardo’s theory of comparative advantage is based on the labour theory of value.

Salvator, as mentioned in (Smit, 2010), redefined the Recardian theory of competitive advantage in terms of opportunity cost. Salvator, as cited in (Smit, 2010, p. 19), said that “a
country will have a comparative advantage in the production of goods and services if such goods and services can be produced at lower opportunity cost than in other countries.”

A.J Smith (Smit, 2010) pointed out that the Richardian theory does not explain the direction of trade. Krugman (Krugman 1986) in an effort to explain the direction of trade cited the advantages resulted in large scale of production, cumulative experience and innovation. According to him, export of goods and services will flow from a country with the competitive advantage of cost along with the advantages such as economies of scale, cumulative experience and innovation.

Krugman (Krugman, 1988) explains that the location of production is determined by the underlying resource difference between countries.

2.2. Michel porter’s competitive theory of nations:

According to A.J Smith (Smit, 2010), Michel Porter’s competitive theory of nations helps to answer the question as to why some countries are more successful in particular industries than the others.

Porter, as mentioned in (Smit, 2010, pp. 115-119) identifies four classes of country attributes that add to the competitive advantage of the countries are-

1) Factors of conditions: Porter divided the factor conditions; those enhance the competitive advantage of a country, into basic factors and advanced factors. The basic factors are unskilled labour, raw materials, climatic conditions and water resources. These factors are inherited and require almost no new investment. The advanced factors are upgraded through innovation and reinvestment.

2) Demand conditions: According to Porter the size and sophistication of home demand forces the home country to innovate and upgrade its competitive position to meet the high standards.

3) Firm strategy, structure and rivalry: Porter identifies rivalry as the most critical driver of competitive advantage of a country’s firms. According to him the domestic rivalry encourages firms to be more competitive.

4) Related and support industry: According to Porter, as mentioned in (Smit, 2010), “it is the external economies of related and support clusters, such as network of specialized
input providers, institutions and the spill-over effects of local rivalry, that become the true source of competitive advantage.”

2.3. Global outlook on the demand of South Africa’s beneficiated products:

South Africa has been a resource economy in excess of a century. According to the report published by DTI (Department of Mineral Resources, 2011, p. iii), South Africa’s non-energy in-situ mineral wealth is estimated to at US$ 2.5 trillion, making the country the wealthiest mining jurisdiction.

Although, South Africa has steadily improved in terms of beneficiating raw ore since 1970, a considerable amount of its mineral resources are exported as raw ores or only partially processed (Department of Mineral Resources, 2011, p. iii).

According to International Monetary Fund (IMF) the GDP growth of developing countries is projected to exceed 6.5% in 2012 against a global forecast of 4% (Department of Mineral Resources, 2011, p. 2).

It is predicted that the next commodity boom will be underpinned by the insatiable appetite of steel from the developing countries and the increasing regional, country-wide present prospects for additional (and proximal) market access for South Africa’s beneficiated products (Department of Mineral Resources, 2011, p. 2).

2.4. Comparative advantage and competitive advantage of South Africa with regards to beneficiation/value addition in-house:

Paul Krugman, as mentioned in (Department of Mineral Resources, 2011, p. 4), supports the value addition of commodities from producer countries. He also proposes that comparative advantage can be readily translated into competitive advantage, if it is managed in a coordinated manner.

According to the report published by DMR (Department of Mineral Resources, 2011, pp. 4-5), South Africa’s strength of from the point of view of value addition has been categorized into the following:

1) Comparative advantage: It is the strength of South Africa’s historical mining industry which has got the potential to attract and develop technological excellence in mineral related industries to support side-stream and downstream value addition.
2) The competitive Advantage: South Africa continues to upgrade and create essential infrastructure, including an extensive transport network, information and communication and has a highly sophisticated finance and banking system.

2.5. The weaknesses of South Africa from the point of view of value addition in-house:

The department of mineral resources (Department of Mineral Resources, 2011, pp. 5-6) identified the following weaknesses:

1) Limited access to raw material for local beneficiation: The bulk of the current producers locked into long-term contracts with their international clients which makes the access of raw material for beneficiation limited.

2) Infrastructure: There is a shortage of critical infrastructure such as rail, water, ports and electricity. The shortage of electricity supply and its increasing prices are creating major hindrance to value addition activities as most of them require lots of power.

3) Research and Development: South Africa’s limited exposure to break-through research and development programs thwarts the prospects of innovation in creating new products for beneficiation.

4) Skill shortage: While the challenge for skills is not limited to South Africa, the skills-supply pipeline for scientists and engineers is a constraint.

5) Access to international markets: The current trade barriers (both tariff and non-tariff) in some prospective recipients of South Africa’s beneficiated products limit access to these markets.

2.6 Recent studies done on the research question:

In the report published by Department of Mineral Resources (DMR) on the impact of Chrome ore export on the local Ferrochrome industry (Department of Mineral and Energy, 2007), the impact of chrome ore export on the government earnings (revenue) and on the employment was quantified.

In the report published by Department of Mineral Resources (DMR) on the beneficiation strategy for the mineral industry of South Africa (Department of Mineral Resources, 2011) the opportunity loss in export revenues and the loss of employment creation have been recognised.
The section 26 of the Mineral and Petroleum Resources Development Act, as mentioned in (Department of Muneral Resources, 2011, p. 8), says that:

26. 1) The Minister may initiate or prescribe incentives to promote the beneficiation of minerals in the Republic.

26 2) If the Minister, acting on advise of the Board and after consultation with the Minister of Trade and Industry, finds that a particular mineral can be beneficiated economically in the Republic, the Minister promote such beneficiation subject to such terms and conditions as the Minister may determine.

According to the report published in “Who Owns Whom” on the “mining of chrome ore” (Klopper Hilary, 2011), an application to the department of mineral resources to impose duties on chrome ore exports has been made. The report also says that an independent study to investigate mechanisms to protect and support the competitiveness of existing beneficiation plants such as Ferrochrome smelter has been undertaken.

According to same report (Klopper Hilary, 2011), if South Africa bans export of chrome ore, then it will have to ensure enough power and more investment in the local beneficiation in the form of Ferrochrome manufacturing.

2.7. South African Industry’s view on the export of chrome ore:

Mr. David Kovarsky (SteelGURU, 2011), CEO of International Ferro Metals, said that “Chinese ferrochrome production has been growing in recent years. This year SA is expected to account for 39.9% of global ferrochrome production, from 43.2% in 2008, while China will make 26.7% compared to 20.2% in 2008”. He also says “an application to the department of mineral resources to impose duties on chrome ore exports is in the pipeline and will unfold in five or six months”, “If a company has excess chrome ore, it will sell it. Yes, by doing so we help our biggest competitor but it costs a lot of money to add new ferrochrome capacity.”

Mr. David Ellwood (SteelGURU, 2011), CEO of Metmar, says “the recent move by Zimbabwe to ban all exports of chrome ore is self defeating. Operating conditions are extremely difficult in Zimbabwe. Mining companies face shortage of external capital, electricity and engineering support services. Road and rail links are inadequate. In SA and
Zimbabwe, sales of raw chrome ore have been used to build enough capital to invest in ferrochrome smelters.”, “If SA bans the export of chrome ore; it has to provide an alternative, namely enough power for investment in local beneficiation.”

Therisa Resources, a chrome company that was founded by local entrepreneur Mr. Lucas Pouroulis, is rumoured to be planning to build a 600000 tonnes ferrochrome smelter in China, not in SA, because of the lower costs (SteelGURU, 2011).

Mr. Stuart Elliot (SteelGURU, 2011), CEO of Merafe Resources, said that “The industry is struggling.” He added that royalty taxes, rising electricity costs and a proposed carbon tax will make South Africa extremely expensive in the medium term and will damage the industry and lead to job losses.

According to a report published in Ore Alloy Development Corporation Limited (Ore alloy development corporation limited, 2010) the following points worth mentioning:

1) 42.9% of the total chrome ore imported by China came from South Africa. It is 11.5% more than that of last year.
2) China bought the 2.9-million tons from South Africa at a comparatively low average price of $215/t including cost, insurance and freight (CIF); compared with the $360/t CIF it paid for raw ore from India - 67% more. China also paid 35% more for the raw ore it bought from Turkey.

2.8. Conclusion

From the literature survey it is quite evident that there is a growing concern everywhere on the merits and demerits of doing value addition in-house.

From the literature survey it is also evident that the producers of intermediate product (Ferrochrome) appointed consultant to do an independent study and present it to the department of mineral resources with the expectation that there will be a ban on export of Chrome ore. But that result is not yet available.

The department of mineral resources conducted a study in 2007 which assess the impact of chrome ore export on the revenue generation of government and on the employment generation in the country.

The other researches done in this area are mostly qualitative in nature which identified pros and cons of in-house value addition but it does not summarizes all the value addition possibilities, then present it with numbers. The objective of this research is to vet all the
options of beneficiation in qualitative and quantitative terms and present a clear picture on the potential of value addition by South Africa with respect to chrome business.
3. Research Methodology

First of all, research is done to understand why is South Africa not beneficiating the chrome ore that is currently being exported? To understand it, research is done in the following areas:

1) The price behaviour of ferrochrome and chrome ore over the past several years. The factors affect the price of ferrochrome and chrome ore.
2) The elements of cost of production of Ferrochrome and Chrome ore.
3) The profitability of the options: export of ferrochrome vs export of ore in the un-beneficiated form.

Then, the opportunities and constraints of the beneficiation have been investigated with respect to the following:

**Opportunities:**

1) Revenue generation from the export of ferrochrome
2) Number of new jobs going to be created by the proposed ferrochrome production facility.

**Constraints:**

1) Loss of profit from the export of beneficiated product compared to the export of non-beneficiated product

The research is done in the following areas to estimate the infrastructural constraints to set up a ferrochrome production facility:

1) The capital expenditure required for setting up the facility.
2) The power requirement for running the facility.
3) ESKOM’s ability to supply power required for running the proposed Ferrochrome production facilities.
4) Skilled manpower required for running the beneficiation facility.
5) The facility of logistics (rail and road infrastructure required to support the beneficiation facility).
The research methodology proposed above is applicable to both the alternatives of beneficiation: chrome ore to ferrochrome, UG2 to ferrochrome.

Although, it was known that UG2 is getting the status of conventional chrome ore for the production of ferrochrome but before starting the research it was not known that the extent to which conventional chrome can be replaced by UG2. So, research is done in the following areas to investigate the ability of UG2 to replace conventional chrome ore:

1) The extent to which UG2 can be used for Ferrochrome production without negatively affecting the quality of Ferrochrome.
2) Any additional facility is to be installed to use UG2 in higher proportion in the ferrochrome production.
3) Cost analysis to identify the increase in profit margin by the use of UG2.

3.1 Assumptions underlying the research strategy, impact of assumptions and mitigation strategies:

The assumptions of the research, its impact and mitigation strategy is given below:

Assumption-1: For the purpose of this research the exchange rate is assumed to be Zar 8/USD.

Impact: Ferrochrome and chrome ore are export commodities. The prices of ferrochrome and chrome ore are decided in US dollar. So, weakening of rand makes ferrochrome and chrome ore export more profitable, and vice-versa.

Mitigation strategy: As exchange rate is quite unpredictable, so a sensitivity analysis is to see its impact on the profitability of ferrochrome and chrome ore.

Assumption-2: The interview with the leading technology and plant suppliers will give a correct indication of the capital cost of the ferrochrome and of the power plant.

Impact: The NPV model used to evaluate the cash flows depends on three things: the capital investment, the cash flows, the cash flows and its duration and the discount rate. If the figure of capital investment is not correct the NPV model gives a wrong indication to the investor with regards to the profitability of the investment decision.
Mitigation strategy: However, it can be safely be assumed that the capital cost figures received from the technology and plant suppliers will be within +/-20% accuracy. So, a sensitivity analysis is done by varying the capital costs within +/-20%, to check the impact of the variation of capital cost on the NPV.

Assumption-3: The interview with the technology/plant suppliers give a correct indication of the cost of production of ferrochrome, chrome ore etc.

Impact: Any mistake in determining the cost of production accurately changes the profit margins of exporting chrome ore and ferrochrome. If the ferrochrome producer has got captive mines then its decision of either chrome ore or ferrochrome will be driven by the amount of profit earned by the two options. Any mistake in determining the profit will take the research in a wrong direction. On top that, it will give a misleading figure of the revenue generation of the government in terms of collection of taxes on the profit earned by the export of chrome ore and ferrochrome.

Mitigation strategy: A sensitivity analysis is done to check the impact of the variation in the cost of production on the profit margins.

Assumption-4: The company review reports are used to get a fair idea on the employment generation of plants of similar nature and that can safely be used to estimate the employment generation of the plants for the purpose of this research.

Impact: The job creation is a positive outcome of doing value addition in-house. The accuracy in quantifying the new jobs created will accurately quantify one of the merits of doing value addition in-house.

Mitigation strategy: To make this estimation more accurate, an adjustment with regards to the difference in the size of the ferrochrome plant considered as the reference for estimating the new job creation and the size of the ferrochrome plant needed to beneficiate the entire quantity of chrome ore exported is done. The employment generation figures in-terms of ‘no of employees/ton’ of product are calculated for the other plants of similar nature, and then the average is taken. The average of this is to be multiplied by the designed capacity of the value addition facility (ferrochrome production) to be set up for the purpose of this research, to arrive at a better estimate of new job creation.
**Assumption-5** The interview with the technology experts will give a fair enough idea on the extent to which UG2 can be used for Ferrochrome production.

**Impact:** It is very important for evaluating the alternative of using conventional chrome ore for the production of ferrochrome. The UG2, being a by-product of Platinum Group of Mines, is cheaper than chrome ore. If UG2 can be used to a high proportion in the ferrochrome industry, then the profit margins can be increased by many folds. So, an estimation of the extent to which UG2 can be used in ferrochrome, is required to prepare a correct financial model showing the benefits of using UG2.

**Mitigation strategy:** There is a very little amount of research done in this area. On top of that the plants using UG2 is not ready to disclose information because it is a trade secret. The interview with the technology experts in this area is the only source used to get an idea about the extent up to which UG2 can be used in the value addition process. Considering the fact mentioned above, the researcher has done an option analysis showing the benefits of using UG2 at different extents.
3.2 Research Data to be collected, Data Collection Methods and Research Instruments

The following tables summarise the data to be collected, data collection methods and research instruments used to evaluate the two alternatives to produce ferrochrome:

Chrome ore to ferrochrome:

<table>
<thead>
<tr>
<th>Sl no.</th>
<th>Questions to be answered/data to be collected</th>
<th>Data collection methods/research instruments</th>
<th>Possible sources of error and its impact on the study</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Capital expenditure for setting up the ferrochrome facility of required capacity.</td>
<td>a) Interview with the leading ferrochrome furnace manufacturers of South Africa such as Pyromet, Metix etc to get an estimate of the capital requirement for setting up the beneficiation facility.</td>
<td>a) The capital expenditure estimated by this method will be a close approximation within +/- 20% accuracy. The exact cost can only be determined after detailed design and engineering, which are not possible considering the cost to be paid for it and the time required to complete the study.</td>
</tr>
<tr>
<td>2</td>
<td>Capital expenditure for</td>
<td>Similar approach is to be taken as proposed for point no-1.</td>
<td>Same as point no-1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
</tr>
</tbody>
</table>
| 3. | **Cost of production of ferrochrome** | a) Interview with leading technology/plant suppliers will give a fair enough idea on the cost of production.  
   b) The cost figure if available from the company annual review reports will be used to compare the data available from the interviews. . |
|   |   | Cost of production is a confidential data so it won’t be disclosed by any manufacturer but the cost estimated by the method proposed is the only way out. |
| 4. | **Cost of production of -chrome ore** | -Same as point no-3 |
|   |   | -Same as point no-3 |
| 6. | **The present power tariff and its prediction for the next few years.** | 1) Predictions with regards to the generation of power are given in ESKOM’s yearly/quarterly company review reports, which can be a useful source. |
|   |   | It is difficult to predict future, but there is no other approach to answer this question. |

**Table-3** Data collection methods, research instruments to be used to evaluate the option of beneficiation up to the stage of ferrochrome
In addition to the points mentioned in table no-1, the following are to be done for evaluating the alternative of using UG2 for ferrochrome production:

<table>
<thead>
<tr>
<th>SI no.</th>
<th>Questions to be answered/data to be collected</th>
<th>Steps to be taken/instruments to be used</th>
<th>Possible sources of error and its impact on the study</th>
</tr>
</thead>
</table>
| 1.     | The extent to which UG2 can be used for ferrochrome production and the details of the additional facilities required to enhance the use of UG2 in ferrochrome production. | 1) Interview with the leading ferrochrome furnace manufacturers: Pyromet and Metix. | 1) It is a new area of technology where much research is not done up-till now.  
2) The companies are not willing to reveal the technology secrets.  
3) However, it is for sure that UG2 is used in Ferrochrome production and assuming different rations of UG2 vs prime chrome ore that can be used to for ferrochrome production, an option analysis is done. |

*Table-4* Data collection methods, research instruments to be used to evaluate the alternative of using UG2 for ferrochrome production
3.3. Sampling

There is no sampling used in this research.

3.4. Research Criteria

Validity

The research instrument will be used in this research is the software package Microsoft-Excel. It is very popular instrument for doing the financial modelling, quantitative analysis. Microsoft excel is fitted with the statistical analysis tools such as regression, correlation etc which is going to be quite useful for this research. All together, Microsoft-Excel is a software trusted and utilised by the business economists, financial analysts and researchers.

Reliability

As mentioned earlier, Microsoft-Excel is widely used and trusted by millions of users. So, for the purpose of this research, Microsoft-Excel can safely be assumed reliable.

3.5. Data Analysis Methods

The excel spreadsheet model will be used in this research to summarise the pros and cons of beneficiation in quantitative terms. Where required, simulation and sensitivity analysis will be done to check the variations in the assumption
4. Research Analysis and discussion:

The research analysis starts with the primary objective of this research that is why South Africa not beneficiating chrome ore that is currently being exported. Then it goes to the analysis of the opportunities and constraints of beneficiation. To analyse the constraints it analyses the profitability constraints and infrastructural constrains. Then the research analyses the possible avenues to improve the profitability of ferrochrome business and compares, quantifies the impact of the improvements on the profitability.

4.1 Analysis on why South Africa is not beneficiating chrome ore that is being exported?

To understand why South Africa is not beneficiating chrome ore, it is very important to understand the competitiveness of South Africa in terms of beneficiating chrome ore up to ferrochrome. To understand the competitiveness of South Africa in beneficiating chrome ore the following sections analyse the elements of cost of production, the behaviour of the factor conditions of ferrochrome production over the past few years and the price fixing mechanisms of ferrochrome and chrome ore. The objective of this analysis is to understand the profitability of beneficiating chrome ore to ferrochrome then export it vs. exporting chrome ore in the un-beneficiated form. The objective of this section is also to understand the factors affecting the profitability of ferrochrome and chrome ore export.
A typical breakdown of the cost of production of Ferrochrome in International Ferro Metals, a Ferrochrome producer in South Africa, for the year 2010 is given below:

**Fig-8 Element wise break-up of the cost of production of ferrochrome in the year’11**

**Source: Annual report of International Ferro Metals**

Many firms perceive the cost of production is a confidential data, and the same could not be found from the annual report of other firms.

To vet the validity of the figures presented above, Mr. George Farmer, lead process engineer, Metix was interviewed and the data presented above were found to be correct (Farmer M. G., 2011). Although, the cost of production varies from company to company but the cost of production of IFM can be considered to be the industry average. But, it should be noted that depending on technology selection and depending on other factors, the cost of production varies from plant to plant.

The elements of cost of production of Ferrochrome are-

**Price of Chrome Ore:**

Most of the ferrochrome producers got their own captive mines so they get the chrome ore at cost of production. We have indicated above that the chrome ore is one of the major contributors to the cost of the production of Ferrochrome, contributes 30% of the cost of production of Ferrochrome. The typical cost of production of Chrome ore is Zar. 500/ton (Farmer J. , What is the cost of production of chrome ore, 2011)
Electricity price: It contributes 18% of the cost of production of ferrochrome. Electricity price was quite low in South Africa compared to other countries. In 2009, the power cost in South Africa was 3 USC/kwh compared to 8-9 USC/kwh in OECD countries but ESKOM has secured a rate hike of 24.8% in 2010, 25.8% in 2011 and 25.9% in 2012. So, the rising cost of electricity reduces the competitiveness of the Ferrochrome industry (Ideas 1st search, 2010, p. 14).

Cost of Coke:

It contributes the 28% of the cost of production of Ferrochrome. Ferrochrome production needs low ash, low phosphorus coking coal which makes sourcing of coking coal a concern. Normally this special grade coking coals sell at a premium price.

More over coking coal markets are not regulated and therefore over supply or shortages may break out anytime resulting in an enormous price fluctuation. In addition the prices of coking coal are majorly influenced by steel industry dynamics (Ideas 1st search, 2010, p. 18). Any increase in the cost of coke will reduce the competitiveness of ferrochrome industry to a great extent.
Discussion:

The prices of the elements of the cost of production are not in the control of the producers but the specific consumptions, such as quantity of reductant (coke, char etc) required to produce one ton of ferrochrome, can be reduced through use of advanced technology to minimize the cost of production. Ferrochrome production costs have risen rapidly, particularly since 2007 (at the rate of 11% per annum) due to escalating factor costs outside industry control (Mukherjee, Energy of furnace waste gas, 2010)

- The most significant is electricity prices that have more than doubled since 2007 (by 2011, electricity costs now represent ~18% of total production costs)
- Labour costs have increased by ~8-10% p.a. since 2007 in line with other overall metals and mining industry in South Africa significantly outpacing finished good price inflation
- Metallurgical coke import costs have increased at the rate of 8% per annum since 2007 (~15% p.a. from 2005-2010) due to impact of Chinese export tariffs in boosting global prices.

It is important to note that the rise in the costs of electricity is the most significant factor decreasing the competitiveness of South Africa in terms of beneficiating chrome ore to ferrochrome. Figure-10 represents the rising cost of production since 2008 uptill 2011.
4.1.1 Analysis of the price of ferrochrome:

We have indicated above that the chrome ore is one of the major contributors to the cost of the production of ferrochrome. From figure below, we can see that chrome ore price follows the same trend of ferrochrome price and ferrochrome price follows the same trend of Stainless Steel price. So, it is implied that the chrome ore and ferrochrome prices are determined by the stainless steel price, which is the end use.

Fig-10 The cost of production of ferrochrome from 2008(1) to 2011(4), Source- interview with Mr. S Mukherjee, Business Analyst, FAMD, Tata Steel
From the price trends of chrome and ferrochrome, we can conclude that the chrome ore and ferrochrome prices follow the same trend.

4.1.2 Analysis on the profitability of exporting ferrochrome vs exporting chrome ore:

The researcher is trying to investigate the potential of South Africa with regards to beneficiation up to the stage of making ferrochrome and approximately 2.5 tons of chrome ore is required to produce one ton of ferrochrome (Farmer J., 2011), so the profitability of exporting 2.5 tons of chrome ore is comparable to the profitability of exporting 1 ton of ferrochrome.

The following are the calculations of the profitability of export of ferrochrome and chrome ore for the year 2011. In the same way the profit figures of 2010, 2009 and 2008 are calculated.
Year- 2011

The following table calculates the profitability of selling chrome ore:

<table>
<thead>
<tr>
<th>Cost of production of Chrome ore</th>
<th>Quantity</th>
<th>Unit</th>
<th>Formula</th>
<th>Assumption</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chrome ore price</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Profit from selling 2.5 tons of chrome ore</td>
<td>414</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table-5: Profitability of selling chrome ore

The following table calculates the profitability of selling ferrochrome:

<table>
<thead>
<tr>
<th>Cost of production of ferrochrome</th>
<th>Quantity</th>
<th>Unit</th>
<th>Formula</th>
<th>Assumption</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferrochrome price</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Profit from selling ferrochrome</td>
<td>3.6</td>
<td>USC/lb of chrome unit</td>
<td>(93-89.4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Units of Chrome in lb (pound) contained in 1 ton of ferrochrome</td>
<td>1122</td>
<td>lb of chrome/ton of ferrochrome</td>
<td>(1000*51%*2.2)</td>
<td>1 ton=1000 kg, 1 kg=2.2 lb, units of chrome in ferrochrome=51%</td>
<td></td>
</tr>
<tr>
<td>Profit from selling ferrochrome</td>
<td>40</td>
<td>USD/ton of ferrochrome</td>
<td>(1122*3.6/100)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table-6: Profitability of selling ferrochrome

So, in the year 2011, the export of chrome ore was far more profitable than export of ferrochrome. So, the obvious question comes to the mind that why South Africa is not exporting the entire quantity of chrome ore produced without beneficiation. Instead, South
Africa is converting part of its production of ore into ferrochrome and part of the production of ore is being exported.

To know that, the profit calculations for export of 2.5 tons of chrome ore and export of 1 ton of ferrochrome from year 2008 to 2011 are summarised below:

<table>
<thead>
<tr>
<th>Year</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of production of ferrochrome in USC/lb</td>
<td>60</td>
<td>73</td>
<td>79.5</td>
<td>89.4</td>
<td>(Mukherjee S., 2011)</td>
</tr>
<tr>
<td>Price of ferrochrome (USD/lb)</td>
<td>183.75</td>
<td>86</td>
<td>126</td>
<td>93</td>
<td>(Mukherjee, Ferrochrome price in 2011, 2011)</td>
</tr>
<tr>
<td>Profit from export of 1 ton of ferrochrome in USD</td>
<td>1388</td>
<td>145</td>
<td>522</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Chrome ore price (USD/ton)</td>
<td>371</td>
<td>173.38</td>
<td>257</td>
<td>228</td>
<td>(Mukherjee, South African chrome ore price, 2011)</td>
</tr>
<tr>
<td>Cost of production of chrome ore (Zar/ton)</td>
<td>350</td>
<td>400</td>
<td>460</td>
<td>500</td>
<td>(Farmer G., 2011)</td>
</tr>
<tr>
<td>Profit from export of 2.5 tons of chrome ore in USD</td>
<td>818</td>
<td>308</td>
<td>499</td>
<td>414</td>
<td></td>
</tr>
</tbody>
</table>

From the table-7, we can see that the profitability of export of ferrochrome was USD 1388/ton compared to USD 818/2.5 tons of ore in the year 2008. But, if we look at the trend of profitability of ferrochrome up to 2011, we can see that it has come down significantly to USD 145/ton in the year 2009 and USD 40/ton in the year 2011. In those years selling chrome was more profitable, USD 308/2.5 ton and USD 414/2.5 ton respectively. So, in the recent years the export of chrome ore became more profitable. In the year 2010, the profitability was again in the favour of Ferrochrome.
Comparison of figure-12 and figure-13 show that in the year 2008 export of ferrochrome was more profitable, and in 2009 the export of chrome ore became more profitable. Simultaneously the export of chrome ore increased from 2008 to 2009 from 3.88 mn tons to 5.146 mn tons, and the export of ferrochrome has come down from 3.2 mn ton to 2.31 mn ton. In the year 2010 the export of ferrochrome became more profitable and the export of ferrochrome has gone up from 2.31mn ton in year 2009 to 3.5 mn ton in the year 2010, simultaneously the export of chrome ore has come down from 5.146 mn ton in year 2009 to 4.7 mn ton in year 2010. In the year 2011, the export of chrome ore became more profitable, as a result of that the export of chrome ore increased from 4.7 mn ton in the year 2010 to 5.48 mn ton in the year 2011. So, it can be concluded that the ratio of profitability of ferrochrome to chrome ore has affected the ratio of export of ferrochrome ore to chrome ore.

We can see that the chrome ore export has increased at a much higher rate from the year 2005 to 2011 compared to the rate of increase of ferrochrome production. One of the reasons is clear from the profitability analysis that the reduced profitability of ferrochrome export in the recent years and increased profitability of chrome ore export for the same period are responsible for increased export of chrome ore in the recent years.
According to Mr. Pat Davies (Davies, 2011) the cost of production of ferrochrome varies from production facility to production facility depending on factors such as technology selection. The cost analysis done in figure no-8, the cost of production of ferrochrome was taken as 89.4 USC/lb, which is the average of South Africa. Mr Davies says that there are many producers in South Africa who got higher cost of production higher than the average and when the price of ferrochrome is lower than the cost of production they are the first to close down the furnaces, and increase the export of chrome ore if it gives better margin.

For example, one of the major ferrochrome producers of South Africa, Xstrata-Merafe had a record profit in the year 2008 mainly because of higher prices of ferrochrome. From the figure-12, we can see that in year-2008, export of ferrochrome was much more profitable business than export of chrome ore, a profit of USD 1388/ ton of Ferrochrome vs USD 818/2.5 ton of chrome ore. But in the last quarter of 2008, X-strata cut production in response to the world economic slow-down; it suspended 11 furnaces. A further 11 furnaces were suspended in Jan’09, leaving three out of twenty furnaces operating (Merafe Resources, 2009). From figure-12, it is evident that in 2009 export of chrome ore become more profitable than the export of ferrochrome and from the fig-13, it is evident that in 2009 the chrome ore export increased significantly and the export of ferrochrome reduced compared to 2008.
From fig. 14, it is seen that the capacity utilisation of ferrochrome production facility varies proportionately with the market price of ferrochrome.

Another reason of increasing trend of chrome ore export is that the increasing cost pressure on the supply side of ferrochrome. The rising cost of electricity is eroding the profit margins of ferrochrome business. As discussed earlier, the Eskom power tariff has doubled from the year 2007 to 2010 and electricity contributes 18% of the cost of production of ferrochrome. But, the contribution of the cost of electricity to the cost of production of chrome ore was much lower compared to ferrochrome. So, the rising costs of electricity is not eroding the profitability of the chrome ore export to the extent it is eroding the profitability of ferrochrome export.

The question that can South Africa beneficiate chrome ore that is being exported in the recent years is discussed in detail in the later sections.

So, from producer’s point of view, at present market prices and costs of production, it is beneficial to increase the export of chrome ore at the expense of ferrochrome production. But,
it is important to understand the loss of opportunity of South Africa as a nation because of export of a non-beneficiated product.

According to minister of mineral resources Mr. Susan Shabangu (Howzit MSN news, 2011) South Africa is losing out by not beneficiating its vast mineral resources. She also said that this represents a national opportunity lost in export revenue and employment creation. The following section will analyse and quantify the opportunities and constraints of beneficiation over the export of the non-beneficiated product:

4.2 Analysis on the opportunities of beneficiation:

Before any further discussion on beneficiation continues, it is important to understand the loss of opportunity if the mined chrome ore is exported in the non-beneficiated form. In other words, the decision of setting up the beneficiation facility should be driven by its potential to create value. The purpose of this section is to analyse and quantify the opportunities of beneficiation. Beneficiation creates opportunities such as job creation, revenue generation, and growth of supporting businesses that grow with the beneficiation facility. The magnitude of the values created out of beneficiation depends to a great extent on the size of the beneficiation facility. In this section, first of all the size of the beneficiation facility is quantified. Then the values created by beneficiation are quantified where possible. If it is not quantified then the values created by beneficiation is explained qualitatively.

To compare the opportunities of production of ferrochrome over the export of non-beneficiated chrome ore, it is required to calculate the capacity of the ferrochrome production facility required to be set up to beneficiate the entire chrome ore exported by South Africa. South Africa exported 4.7 mn tonnes of chrome ore in 2010, and 5.146 mn tonnes in 2009 (Email. Comm, AVD Walt 2011). The average of the quantities exported in 2009 and 2010, was taken as the quantity to be beneficiated. The average of the chrome ore export figures of 2009 and 2010 was 4.92 mn tons. As discussed earlier 2.5 tons of chrome ore is required to produce 1 ton of ferrochrome. So, the beneficiation of 4.92 mn tons of chrome ore will yield 1.97 mn tons of ferrochrome. Henceforth, the comparison of export of the beneficiated product vs the export of non-beneficiated product will be a comparison of export of 1.97 mn tons of ferrochrome vs export of 4.92 mn tons of chrome ore. The following are the opportunities created from beneficiation:
4.2.1 Job creation:

This section quantifies job creation; one of the opportunities created by the beneficiation facility. To quantify the number of new jobs created, the reference data of other plants of similar nature is taken into consideration. The average of the employment generation figures other plants of similar nature are calculated in terms of number of jobs per 1000 ton of production. This figure is extrapolated to get the number of employment generation from the beneficiation facility required to be set up to beneficiate all the chrome ore currently being exported by South Africa.

Table-8 summarizes the employment generation (including permanent and contract employees) figures of different plants:

<table>
<thead>
<tr>
<th>Name of the plant</th>
<th>Capacity (in tons/anm)</th>
<th>No of employees including contractor employees</th>
<th>No of employees per 1000 tons of production</th>
<th>Data source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xstrata's Rustenburg plant</td>
<td>400,000</td>
<td>950</td>
<td>2.38</td>
<td>(xstrata alloys Rustenburg division)</td>
</tr>
<tr>
<td>Xstrata's Wonderkop plant</td>
<td>553,000</td>
<td>1200</td>
<td>2.17</td>
<td>(xstrata alloys Rustenburg division)</td>
</tr>
<tr>
<td>Xstrata Lion project</td>
<td>360,000</td>
<td>1000</td>
<td>2.78</td>
<td>(mining mx, 2011)</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td>2.44</td>
<td></td>
</tr>
</tbody>
</table>

Table -8: Employment generation figures of different plants in South Africa

The third column of table no-8, mentions the number of jobs created per 1000 tons of production for Xstrata’s Rustenburg plant, Wonderkop plant and Xstrata’s Lion project. The employment generation per 1000 ton of ferrochrome production for Rustenburg, Wonderkop and Lion project are 2.38, 2.17 & 2.78 respectively. The figures are close but not exactly the same. The reason is that the employment generation figures vary depending on the selection of technology and the level of automation.
For the ease of this research, the average is taken which comes to 2.44 no of employees/ 1000 tons of production. Then, this average figure is extrapolated to get the figure of employment generation for a ferrochrome production facility of 1.97 mn tons/annum.

The no of jobs created by a ferrochrome production facility of 1.97 mn tons/annum comes to 4800. It includes the permanent and contract employees.

This analysis shows that the opportunity created by the new beneficiation facility in terms of number of new jobs created is 4800.

4.2.2 Revenue generation:

Increased revenue generation is another opportunity created by the beneficiation facility. The revenue generation by the export of a value added product is always more that export of a non value added product. The purpose of this section is to quantify the additional revenue generation by the export of a value added product. The value added product is sold in the international market in US dollar, so another benefit of the export of a value added product is increased foreign exchange earnings.

In this section, the average quantity of chrome ore exported in the year 2009 and 2010 is taken as the quantity to be converted to ferrochrome. The difference in revenues generated from the export of ferrochrome and from the export of chrome is calculated.

Table-9 summarizes the steps taken, the assumptions of the calculations, the data sources to calculate revenue generation from the export of chrome ore, the non-beneficiated product:

<table>
<thead>
<tr>
<th>Qualtity</th>
<th>Unit</th>
<th>Assumption</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Chrome ore production of South Africa</strong></td>
<td>4.7</td>
<td>Mn ton/yr</td>
<td>average of 2008 &amp; 2009 (Email. Comm. AVD Walt 2011)</td>
</tr>
<tr>
<td><strong>The price of chrome ore</strong></td>
<td>228.0</td>
<td>USD/ton</td>
<td>(Mukherjee, South African chrome ore price, 2011)</td>
</tr>
<tr>
<td><strong>Revenue generation from export of chrome ore</strong></td>
<td>8572.8</td>
<td></td>
<td>Exchange rate- 8 Zar/USD</td>
</tr>
</tbody>
</table>

Table-9 Calculation of revenue generation from the export of chrome the un-beneficiated product
The revenue generation from export of 4.7 mn tons of chrome ore (the average export figures of 2009 & 2010) is 8573 mn zar/year. It is calculated by multiplying the figure 4.7 mn tons by the average chrome ore export price of 2010, which was USD 228/ton, and then by multiplying it by 8, which is the assumption of exchange rate.

The table-10, summarizes the steps taken to calculation of revenue generation from the export of 1.97 mn tons of ferrochrome, which would be the case if 4.7 mn tons of chrome ore is beneficiated instead of exporting in the non-beneficiated form.

<table>
<thead>
<tr>
<th></th>
<th>Quality</th>
<th>Unit</th>
<th>Assumption</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality of ferrochrome could</td>
<td>1.97</td>
<td>Mn ton/yr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>have been exported</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ferrochrome price</td>
<td>93.0</td>
<td>US C/Lb</td>
<td></td>
<td>(Mukherjee, Ferrochrome price in 2011, 2011)</td>
</tr>
<tr>
<td>Ferrochrome price</td>
<td>1043.5</td>
<td>USD/ton</td>
<td>Chrome units in ferrochrome is 51%</td>
<td></td>
</tr>
<tr>
<td>Ferrochrome price</td>
<td>8347.7</td>
<td>Zar/ton</td>
<td></td>
<td>Exchange rate-Zar8/USD</td>
</tr>
<tr>
<td>revenue generation from</td>
<td>16444.9</td>
<td>Z/mn</td>
<td></td>
<td></td>
</tr>
<tr>
<td>export of ferrochrome</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table-10 Revenue generation from the export of ferrochrome the beneficiated product

The average price of ferrochrome for the year 2011 was 93 USC/lb. The price of ferrochrome is quoted internationally in USC/lb. It means the price of ferrochrome is 93 US cents per pound of chrome unit. The average chromium content of ferrochrome is approximately 51% in South Africa (Malan, Average Chrome content of South African ferrochrome, 2011). The rest is iron, Silicon and other impurities. So, the chromium units available in 1 ton (1000kg) of ferrochrome is (1000 * 51%) = 510 kg. One kg is equivalent to 2.2 pound. So, 1 ton of ferrochrome contains (510 * 2.2) = 1122 pounds of chromium. Assuming the chromium content of the ferrochrome is 51%, the price of ferrochrome comes to (91 * 1122) = 1021 USD/ton. Assuming that the exchange rate is Zar 8/USD, the price of ferrochrome comes to (1021*8) = Zar 8168/ton. The total revenue generation from the export of 1.97 mn tons of ferrochrome comes to (8168* 1.97) = **16445 mn Zar.**
The extra revenue generation from the export of beneficiated product is \((16445-8573)= 7872\) mn rand per year. So, it is clearly seen that the value addition in-house will increase the revenue generation for the economy by a substantial amount. This will lead to additional foreign exchange earnings by 984 mn USD/year.

4.2.3 Growth of supporting businesses:

Value addition in-house will bring economic benefits like growth of supporting businesses that grows with the growth of ferrochrome production. The ferrochrome plants consume refractory, fabricated steel products etc. So, those businesses will grow with the beneficiation facility.

4.2.4 Discussion on the opportunities of beneficiation:

Export of ferrochrome increases revenue generation by 95% compared to the export of non-beneficiated product. The beneficiation increases revenue generation by 7872 mn rand/year. It increases forex earnings by 984 mn USD/year. Beneficiation also increases the job creation in the country by a substantially (4800 number of additional employment). So, the opportunities created by beneficiation can be summarised as the additional revenue and forex earnings, new job creation and growth of supporting businesses.

4.3 Analysis on the constraints of beneficiation:

In spite of huge opportunities associated with beneficiation, if the constraints are not overcome, the wish to set up the beneficiation facility will never come to reality. So, it is important to analyse the constraints of beneficiation.

This section analyses the constraints of beneficiation. This section is subdivided into two Sections:

4.3.1 Comparison of the profit abilities of export of ferrochrome with the export of chrome ore:

Analysis on the profit margins earned from the export of beneficiated product compared to the profit margins earned from the export of the non beneficiated product. The primary motif
behind any investment decision is driven by profit. So, the purpose of this section is to calculate the difference between the profit margins earned from the export of ferrochrome, the beneficiated product compared to the export of chrome ore, the non-beneficiated product. The objective of this section is to evaluate and compare the profitability of the export of beneficiated product compared to the export of non-beneficiated product at the current market prices and costs of production.

The government earns from the taxes on the profits earned from a business. It is the income of the government. This section evaluates then compares the earnings of the government in terms of collection of taxes on the export of ferrochrome vs the export of chrome ore.

Table-11 summarizes the profits earned from the export of ferrochrome at current prices:

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
<th>Unit</th>
<th>Assumption</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferrochrome produced from 4.7 mn tons of chrome ore</td>
<td>1.9</td>
<td>Mn ton/yr</td>
<td>2.5 tons of chrome ore is required to produce 1 ton of ferrochrome</td>
<td>(Mukherjee S., Ferrochrome price in 2011, 2011)</td>
</tr>
<tr>
<td>The price of ferrochrome</td>
<td>93.0</td>
<td>USC/lb</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost of production of Ferrochrome</td>
<td>89.4</td>
<td>US C/ton</td>
<td></td>
<td>(International Ferro Metals, 2011, p. 20)</td>
</tr>
<tr>
<td>Cost of production of Ferrochrome</td>
<td>1003.1</td>
<td>US C/ton</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Profit generation from export of ferrochrome</td>
<td>607.5</td>
<td>Mn Zar/year</td>
<td>Zar 8= 1 USD</td>
<td></td>
</tr>
</tbody>
</table>

Table-11 Profits earned from export of ferrochrome

Profit generation from the export of 1.97 mn tons/year of ferrochrome which can be produced if the 4.7 mn ton of Chrome ore is not exported= 607 mn rand/year.
Table-12 Summarizes the profit earned from export of chrome ore at current prices:

<table>
<thead>
<tr>
<th>Total Chrome ore exported from South Africa</th>
<th>Quantity</th>
<th>Unit</th>
<th>Assumption</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4.7</td>
<td>Mn ton/yr</td>
<td>average of 2009 &amp; 2010</td>
<td>(Mukherjee, South African chrome ore price, 2011)</td>
</tr>
<tr>
<td>The price of chrome ore</td>
<td>228.0</td>
<td>USD/ton</td>
<td></td>
<td>(Farmer G., 2011)</td>
</tr>
<tr>
<td>Cost of production of Chrome ore</td>
<td>500.0</td>
<td>Zar/ton</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost of production of Chrome ore</td>
<td>62.5</td>
<td>USD/ton</td>
<td>Zar8=1 USD</td>
<td></td>
</tr>
<tr>
<td>Profit generation from export of chrome ore</td>
<td>6222.8</td>
<td>Mn Zar/year</td>
<td>Zar 8=1 USD</td>
<td></td>
</tr>
</tbody>
</table>

Table-12 Profits earned from the export of chrome ore

Profit generation from the export of Chrome ore in the un-beneficiated form= \(6223 \text{ mn rand/year}\) (assumption exchange rate-8 rand/USD).

So, at current prices and current costs of production and market prices the loss of profit for the producer due to beneficiation will be \((6222.8-607)=5616 \text{ mn rand/year}\)

From the analysis, it is evident that at current market prices and costs of production the export of chrome ore is much more profitable than the export of ferrochrome. In this situation, it will be difficult to attract investors to set up the ferrochrome production facility because of the heavy profit margins lost from export of the beneficiated product.

The loss of earnings of the government because of reduced profit margins earned from export of ferrochrome is 1658 mn rand.

The steps taken to calculate this are as follows:

At present, from table-12, the profit from exporting 4.7 mn ton of ore= 6222.8 mn rand/year

At present, from table-11, the profit from exporting 1.97 mn ton of ferrochrome (which can be produced if the 4.7 mn tons of ore is converted to ferrochrome instead of exporting)= 607 mn rand/year

Reduction in tax revenue of the government if ore is beneficiated then exported instead of exported in the non-beneficiated form (assumption: tax rate-30%) \(= (6222.8-607)*30\%

\(= 1685 \text{ mn rand}\)
It shows a significant loss of earnings of the government from the export of the beneficiated product.

4.3.2 Analysis on the infrastructural needs of setting up the beneficiation (the ferrochrome production) facility:

The purpose of this section is to analyse the infrastructural needs of setting up the ferrochrome production facility. This section will also analyse the possibility of fulfilment of the infrastructural needs in the South African context. The analysis will reveal any constraint, if any, in terms of infrastructural needs. In this section, the infrastructural needs such as capital expenditure, requirement and availability of power, skilled labour, and logistics will be analysed and discussed.

4.3.2.1 Capital expenditure and power required for setting up the ferrochrome production facility:

This section calculates the capital expenditure required for setting up the beneficiation facility for different technology options. The capital expenditure required for setting up the beneficiation facility depends to a great extent on the selection of technology. The better is the technology the higher is the capital expenditure. The advantage of selecting better technology reduction in the operating costs. This section will give an idea of the capital expenditure for setting up the ferrochrome production facility because in any business model the capital expenditure is an important criterion to judge the investment decision. This section extrapolates the capital expenditure of setting up the a ferrochrome production facility of 1.97 mn tons per annum from the capital expenditure figures available for setting up a ferrochrome production facility of 0.35 mn tons per annum by using the following formula (no-1) (Farmer G., 2011):

\[
\text{Capital cost of setting up a } X \text{ TPA plant} = (\text{capital cost of setting up a } Y \text{ TPA plant}) \times \left(\frac{X}{Y}\right)^{0.75}
\]
The table no-13 summarizes the figures of capital expenditures and requirements of power for setting up a 350,000 TPA ferrochrome plant for different technology options:

<table>
<thead>
<tr>
<th>Option-1</th>
<th>Type of furnace</th>
<th>Sintering Pre-heating</th>
<th>CO-gas recovery and power generation</th>
<th>Cost of 0.35 TPA plant in mn Zar</th>
<th>Cost of 1.97 mn TPA plant in mn Zar</th>
<th>Sp. Power consumption (KWH/ton)</th>
<th>Power required for 2.1 mn TPA plant (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2100</td>
<td>7674</td>
<td>3200</td>
<td>947</td>
</tr>
<tr>
<td>Option-2</td>
<td>Closed AC furnace (2 * 33 MVA)</td>
<td>Yes</td>
<td>no</td>
<td>no</td>
<td>2210</td>
<td>8076</td>
<td>3000</td>
</tr>
<tr>
<td></td>
<td>Closed AC furnace (2 * 33 MVA)</td>
<td>Yes</td>
<td>yes</td>
<td>yes</td>
<td>2100</td>
<td>7674</td>
<td>2900</td>
</tr>
<tr>
<td>Option-3</td>
<td>Closed AC furnace (2 * 33 MVA)</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>1950</td>
<td>7126</td>
<td>3600</td>
</tr>
<tr>
<td>Option-4</td>
<td>Closed AC furnace (2 * 33 MVA)</td>
<td>Yes</td>
<td>no</td>
<td>no</td>
<td>1200</td>
<td>4385</td>
<td>3300</td>
</tr>
<tr>
<td>Option-5</td>
<td>Closed AC furnace (2 * 33 MVA) plant</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>1050</td>
<td>3837</td>
<td>3800</td>
</tr>
<tr>
<td>Option-6</td>
<td>Open AC furnace (2 * 33MVA)</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>1000</td>
<td>3654</td>
<td>4000</td>
</tr>
<tr>
<td>Option-7</td>
<td>Closed DC furnace (2 * 30 MW)</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>1600</td>
<td>5847</td>
<td>3600</td>
</tr>
<tr>
<td>Option-8</td>
<td>Closed DC furnace (2 * 30 MW)</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>1650</td>
<td>6030</td>
<td>3500</td>
</tr>
<tr>
<td>Option-9</td>
<td>Closed DC furnace (2 * 30 MW)</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>1550</td>
<td>5664</td>
<td>3300</td>
</tr>
<tr>
<td>Option-10</td>
<td>Closed DC furnace (2 * 30 MW)</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>1400</td>
<td>5116</td>
<td>4300</td>
</tr>
</tbody>
</table>

Table-13 Capital expenditure and power requirement of different technology options for ferrochrome production

In table no-13, the capital cost of setting up a 0.35 mn TPA plant with respect to different technology options have been received from METIX, one of the leading smelting furnace supplier of South Africa. The purpose of this research is to investigate the cost of setting up a 1.97 mn TPA plant. The cost of setting up a 1.97 mn TPA plant is calculated by extrapolating the cost of setting up a 0.35 TPA plant by using the formula no-1.

The cost of setting up a 1.97 mn TPA plant is given in the third column of table no-9. Depending on the technology selection the capital expenditure of setting up the plant will vary from 8076 mn rand to 3654 mn rand. The option of closed ferrochrome furnaces with sintering, preheating and CO-gas recovery and power generation plant is the costliest. The option of open ferrochrome furnace with no additional facility such as sintering, preheating, CO-gas recovery and power generation plant is the cheapest. In terms of production capacity there is no difference between the costliest and cheapest options but the different comes in
the operating costs. The specific power consumption, which contributes to the operating cost, for the costliest option is 3200 KWH. Tons of ferrochrome compared to 4000 KWH/ton of ferrochrome for the cheapest option.

4.3.2.2 Power requirement for running the ferrochrome facility:

The ferrochrome production facilities consume immense amount of power. So an important infrastructural need for running a ferrochrome production facility is the availability of electrical power. The objective of this section is to estimate the total power required for running the ferrochrome production facility. It will give an idea on the ability of ESKOM to supply the amount of power required for running the beneficiation facility.

The total power required for running the ferrochrome production facility can be calculated from the specific power requirement (the power required to produce 1 ton of ferrochrome) by using the following formula (no-2) (Farmer G., 2011):

\[
\frac{(\text{yearly production} \times \text{sp. power consumption})}{(\text{operating days in a year}) \times (\text{daily operating hours}) \times (\text{power factor}) \times (\text{load factor})}
\]

Assumptions:
- Operating days in a year = 350 (15 days is kept for shut downs)
- Daily operating hours = 22 Hrs
- Power factor = 94%
- Load factor = 98%

From table no-13, we can see that the total power required for setting up the beneficiation facility varies from 947 MW to 1300 MW depending on the selection of technology.

The following is an exercise to show the merits of using better technology achieved from the reduction in operating costs.

The most capital intensive technology is the closed AC furnace with sintering and preheating. It costs 8076 mn rand. The advantage of it is lowest specific power consumption of 3000 KWH/ton. The least capital intensive technology is open arc furnace with no preheating and
no sintering. It costs is 3654 mn rand with specific power consumption of 4000 kwh/ton. So, the difference between the capital expenditure of the most expensive technology and least expensive technology is 4422 mn rand but the savings in terms of electrical power is (4000-3000) = 1000 KWH/ton of ferrochrome. The power saving at current electricity prices (Zar cent 43/KWH), amounts to 430 rand/ton of ferrochrome, because of the use of the most expensive technology. It amounts to a saving of (430 * 1.97) = 847 mn rand/year. So, the pay-back period of extra investment for technology is (8076-3654)/847 = 5.22 years. This is not a very high pay-back period and motivated the investor in selecting better technology.

After knowing the higher amount of power required for running the ferrochrome production facility it now important to investigate the ability of South Africa to supply the power required to run the proposed facility. ESKOM is the only agency in South Africa that supplies the high amount of power required for running the ferrochrome production facility. This section investigates the current capacity of ESKOM to generate the power and its demand in South Africa to know if any surplus quantity is available to meet the requirement of the proposed ferrochrome production facilities.

In 2010 and 2011, the total generation of electricity including international purchases available for distribution were 248914 GWH and 242871 GWH respectively which were just equal to the demand (ESKOM Holdings Limited). So, there was no excess electricity available to meet the demand of the proposed ferrochrome plants.

According to Mr. Steve Phiri, CEO Merafe Resources (Ideas 1st search, 2010), no ferrochrome expansion is expected in South Africa over the next 3 years mainly due to power shortage.

ESKOM planned two power projects: one at Medupi of 4788 MW installed capacity, to be commissioned at 2012; the other one is at Kusile of 4800 MW capacity to be commissioned by 2014 (ESKOM). On top of that, the development bank of South Africa approved Rand 15 billion in November’10 that will support ESKOM’s capacity expansion programme. So, there is a chance that the power required for the proposed Ferrochrome facilities will be available in the near future, but definitely not in the next 2 years (Development bank of South Africa, 2010).
4.3.2.3 The availability of skilled man power to run the beneficiation facility:

The availability of skilled labour is another important infrastructural need for setting up the ferrochrome production facility. This section will investigate the availability of skilled labour in South Africa who can run the production facility.

Forty-one percent of South Africa's privately held businesses cite the availability of a skilled workforce as the biggest constraint to business growth, according to consultancy firm Grant Thornton's 2009 International Business Report (South Africa info, 2009).

So, skill shortage is a problem in South Africa.

4.3.2.4 The road and rail infrastructure:

The road and rail infrastructure is a critical factor for any business. The objective of this section is to analyse the ability of South Africa in providing the required logistics infrastructure for the proposed ferrochrome production facility.

As discussed previously, 2.5 tons of chrome ore is required to produce 1 ton of ferrochrome. So, if the quantity of chrome ore exported presently, is converted to ferrochrome then exported, there should not be any problem with regards to road, rail and port logistics because reduced volumes.

4.3.3 Discussion on the opportunities and constraints of setting up the beneficiation facility:

Investment in the range of billion rand is needed to set up the beneficiation facility. The availability of capital for setting up the ferrochrome production facility will quite naturally be driven by:

4.3.3.1 Profit earned from exporting the beneficiated product.

If the profit earned from the export of the beneficiated product is more than export of the un-beneficiated ore then naturally the motivation to set up the beneficiation facility will reduce. As we have seen in the earlier sections that the beneficiation facility to convert the current
The export of chrome ore will lead to a reduction in profit margins by 5616 mn rand. It is a significant amount of reduction in profit. Please note that this calculation is based on the current market prices and cost of production of ferrochrome and chrome ore. The market price of ferrochrome fluctuates a lot depending on the demand of stainless. So, in future the market prices can change and ferrochrome business may prove to be more profitable, as it happened in 2007, given in table-5.

4.3.3.2 The availability of critical infrastructure

Amongst the critical infrastructures needed for setting up the beneficiation facility is availability of power, which, as discussed above, will not be available in the next 2-3 years. The entrepreneurs can think of setting up a captive power station but the setting up a power plant requires a lot of infrastructure. The power plant projects need 2-3 years time to complete. So, the availability of power is out of question, at least in next 2-3 years and this is the reason no augmentation in the ferrochrome production facility is happening now a days.

ESKOM power is thermal power. Other non polluting methods of power generation such solar power, wind power can be thought of but the reliability of those sources of power is a question. Solar and thermal power was never tried in such a big scale.

From the analysis of infrastructural needs it is quite clear that the one of the critical infrastructure that is power is not going to be available in next 2-3 years, and it is not in control of the producers.

The other constraints of beneficiation are high capital investment required to set up the beneficiation facility especially when the current profit margins are not attractive.

As discussed earlier, the future of ferrochrome business is also uncertain considering the cost pressures in the supply side and the fluctuating nature of the price of ferrochrome.
4.4 Analysis on the avenues to make the beneficiation of chrome ore (up to the stage of ferrochrome) more profitable by reducing the cost of production:

The purpose of this section is to investigate the ways to reduce the cost of production of ferrochrome which can make the ferrochrome business more profitable and can motivate investors to invest in this business. The following section deals with the analysis of the different avenues to make the ferrochrome business more profitable by reducing the cost of production because the prices are not in the control of the producer. This section evaluates the following improvement initiatives which can be taken up to reduce the cost of production of ferrochrome:

- Use of UG2, which is the by-product of platinum mines and can be sources at much cheaper cost, in the production of ferrochrome.
- Setting up co-generation plant which can convert the energy available with the waste gas of the ferrochrome production facility into electrical energy. The reason is that this energy is much cheaper than Eskom power.

4.4.1 Use of UG2:

This section investigates the possibility of using UG2 and its impact on the cost of production of ferrochrome. As discussed earlier the cost of chrome ore contributes 30% of the total cost of production. Most of the ferrochrome producers got captive chrome ore mines. Other than manpower the main element of cost of production of chrome ore are diesel and electrical power. The diesel price is not in the control of the miners. The wages are bound to increase year on year depending on the inflation, so it is also not controllable.

It has been found that breakthrough improvement in terms of reduction of cost of production of ferrochrome can be achieved by the use of UG2 (Nurse, 2010). UG2 can be used as a source of chrome for ferrochrome production. UG2 is also a chrome containing material like conventional chrome ore (LG6, MG1, and MG2). The only difference between UG2 and conventional chrome ore is that the former is a by product of Platinum mines. With the increasing depth of platinum bearing material the cost effectiveness of platinum production is reducing (Sam, 2011). The platinum miners have been mining from the UG2 reef for quite some time. Along with the fresh production UG2, the huge UG2 dumps are
available near the platinum mines. The mined material from UG2 reef is send through the extraction process and after extracting the platinum group of metals, the discard is called UG2. Thus UG2 can be further beneficiated to separate traces of platinum group of metals from it. The product of the beneficiation process, other than the PGMs, can be used for ferrochrome production.

The use of UG2 needs an additional facility called sintering. The cost of a ferrochrome production facility with sintering is given in the table no-4. It also needs a beneficiation facility at the UG2 dump yard near the platinum mine. IFM started setting up a UG2 beneficiation facility in 2010 to produce a quantity of 15000 tons/month (30% of their total requirement of chrome ore to produce ferrochrome) at a cost of Zar. 150 mn (International Ferro Metals Limited, 2010)

The cost of production of UG2 will roughly be Zar. 90/ton (Meiring, 2011) compared to Zar. 500/ton for conventional ore (Farmer M. G., 2011). UG2 can be used to supplement 80% of total requirement of chrome ore for ferrochrome production (Nurse, 2010).

The following calculation summarizes the benefit of using UG2:

- Approximately 2.3 tons of chrome ore is required to produce 1 ton of ferrochrome
- If conventional ore is used then the cost of ore to produce 1 ton of ferrochrome = 2.3 * 500 = Zar. 1150
- If 80% UG2 and 20% conventional ore is used then the cost of ore to produce 1 ton of ferrochrome = 80% * 2.3 * 90 + 20% * 2.3 * 500 = Zar. 396
- The reduction in cost of ore required for ferrochrome production if UG2 is used compared to conventional ore = (Zar 1150 - Zar 396)/Zar 1150)% = 65.5%
- The cost of production of ferrochrome (International Ferro Metals, 2011) = US C 89.4/ton
- 30% of that cost is the cost of ore.
- Overall cost reduction could be achieved by the use of UG2 = 30% * 65.5% = 20%
- So, the use of UG2 can reduce the cost of production of ferrochrome by 20% which is equivalent to roughly 17.88 US C/ton.

So, a 20% reduction in cost of production which is equivalent to a reduction of US C 17.88/ton, can be achieved if UG2 is used in higher proportions for ferrochrome production.
4.4.2 Use of power from the co-generation plant:

The power required for the ferrochrome production facilities is supplied by ESKOM. The ESKOM power tariff is increasing year on year at a substantial rate. It is reducing the competency of all the beneficiation industries. The cost of power is 18% of the cost of production of Ferrochrome. The reduction in power consumption or the reduction in cost of power can bring down the cost of production. The purpose of this section is to evaluate the use of power generated by the co-generation plants to reduce the cost of production of ferrochrome.

The gas emitted by the ferrochrome production furnaces got roughly 3.14 KW/m3 of energy (Mukherjee, Energy of furnace waste gas, 2010). The waste gas from the furnaces can be used for generation of electricity if a co-generation power plant is set up. The electricity generated by co-generation plant is quite cheap compared to ESKOM power. In that way 10% of the power requirement for ferrochrome plants can be substituted by the power generated by the co-generation plant (Malan, 2010).

The cost of power generated by the cogeneration plant is Zar. Cent 2/KWH compared Zar C 43/kwh for ESKOM power (Malan, 2011).

The cost benefit of using the power generated from co-generation plant can be calculated as follows:

- As per the IFM’s annual report:
  The cost of production of ferrochrome= US C 89.4/ton
  18 % of the cost of production is the cost of power which is equivalent to 14.94 US C/ton.

- If co-generation plant is set up then 10% of the power consumption can be replaced with the power available from co-generation plant which costs Zar C 2/kwh compared Zar C 40/kwh.

- If co-generation plant is set up then the cost of electrical energy per ton of ferrochrome will be reduced by ((14.94 * 10% * (40-2)/40)= 1.42 US C/ton
  The cost of electrical energy per ton of ferrochrome can be reduced by 1.42 US C/ton
4.4.3 Impact of the cost benefits of the use of UG2 and co-generation power on the profitability of ferrochrome business:

The objective of this section is to evaluate the impact of the use of UG2 and co-generation power on the profitability of ferrochrome business and compare it with the profitability of ferrochrome business without the aforesaid improvement initiatives. It will help the research to evaluate if the improvement initiatives can make the ferrochrome business as profitable as the export of chrome ore.

Analysis of IFM’s process reveals that it has sintering and preheating technology, so out of the technology options mentioned in table no-8, it is the best in terms of operating costs. As per IFM’s annual report (International Ferro Metals, 2011), it has started setting up the co-generation plant and setting up a UG2 beneficiation facility that will supply 30% of its total chrome ore requirements. The following section discusses the impact of a co-generation facility and the impact of using UG2 to the extent of 80% of the ore feed:

At the present market prices:
- Cost of production of Ferrochrome (International Ferro Metals, 2011, p. 20)= US C 89.4/ton
- Reduction in cost of production of ferrochrome if UG2 is used to the extent of 80% of the chrome ore requirement for the production of ferrochrome= 17.88 US C/ton
- Reduction in cost if co-generation plant is set up to substitute 10% of the power consumption (supplied by ESKOM) by the power supplied by co-generation plant= 1.42 US C/ton
- The reduced cost of production of ferrochrome by the use of UG2 and co-gen power= US C 89.4 – US C17.88 – US C1.42= US C 70.1/ton

Running the model in table no-11, the profit generation from the export of 1.97 mn tons/year of ferrochrome which can be produced from 4.7 mn ton of Chrome ore which is currently being exported = 3864.3 mn rand/year (assumption-exchange rate = 8 rand/USD)

Figure-15 summarizes the following three scenarios at the current market prices and costs of production of ferrochrome and chrome ore:
Scenario-1
Export of chrome ore in the un-beneficiated form

Scenario-2
Export of the beneficiated product- ferrochrome

Scenario-3
Export of beneficiated product- ferrochrome (the benefits of reduction in the cost of production due to the use of UG2, to the extent of 80% of total ore requirement for ferrochrome production, and the use of power generated by the co-generation plant that uses the furnace waste gas to generate power, are taken into consideration)

Figure-15 Comparison of revenue vs profit margin of the 3 scenarios
4.4.4 Discussion:

From figure-15, we can see that implementation of improvement initiatives such as the use of UG2 and use of power supplied by Co-generation plant, can increase the profit margins of the option of beneficiation by 225% but still cannot make beneficiation as profitable as export of chrome at the current market prices of ferrochrome and chrome ore.

5. Research limitations:

In this research the calculations of profitability, revenue generation are done based on the current market prices and costs of production of ferrochrome and chrome ore, then conclusions are drawn. Depending on the future market price and future costs of production the scenario may change which may lead to change in some of the research conclusions. This was the main limitation of this research.

6. Conclusion:

The primary objective of the research is to investigate why South Africa is not beneficiating chrome ore that is currently being exported. It was found that the swing between the profit abilities of the export of chrome ore and of the export of ferrochrome drives the ratio of export of chrome ore to the export of ferrochrome. It was found that in the past e.g in the year 2008, the export of ferrochrome was more profitable compared to the export of chrome ore. As a result, the production then export of ferrochrome increased compared to export of chrome ore. In the recent years export of chrome ore become more profitable than the export of ferrochrome. As a result the chrome ore export increased over the export of ferrochrome. It was found that the prices of ferrochrome and chrome are not in the control of the producers. The ferrochrome industry is losing its competitiveness because of the cost increases in the supply side. It is mainly driven by the higher power tariffs proposed by ESKOM in the recent years.

The low market prices coupled with the higher production costs are eroding the profitability of the ferrochrome business in the recent years. It renders the export of chrome ore more profitable.
The secondary objectives of research were to analyse the opportunities and constraints of beneficiation. It is found that the beneficiation will increase the revenue generation 7281 mn rand/year and will increase the forex earnings by 910 mn USD/year. The beneficiation will also increase job creation in the economy by a number of 4800.

On the other hand, the reduced profit margin by 5620 mn rand/year is one of the major constraints of adding the new beneficiation facility. The reduced profit margins will not attract the investors to invest in setting up the new beneficiation facility. Because of reduced profit margins the earning of the government in terms of collection of taxes will also reduce significantly.

The other constrains of beneficiation are the high capital expenditure in the region of 4 to 8 billion rand required for setting up the beneficiation facility. The reducing profitability of the ferrochrome business and high capital expenditures required to set up the beneficiation facility will definitely not attract investor to set up beneficiation facility that can beneficiate the entire chrome ore that is currently being exported.

The research did analysis on the avenues to enhance the profitability of the ferrochrome business and found that the reduction in cost of production is the only way to enhance the profitability of the ferrochrome business. The research has also identified the following avenues that can reduce the cost of production of ferrochrome significantly.

1) Use of UG2, which is the by product of the platinum mines, at higher proportions for ferrochrome production. UG2 is the by product of the platinum mines and can be sourced and produced at much cheaper costs than the conventional chrome ore.

2) Use of the power generated by the co-generation plant which uses the waste gas generated by the ferrochrome production facilities for power generation. The power generated by co-generation plants is much cheaper that ESKOM power.

The research has found that by applying the two improvement initiatives, as mentioned above, the profitability of the new beneficiation facility can be increased from 607 mn rand/year to 3864 mn rand/year.

Even after the implementation of the improvement initiatives, the ferrochrome industry cannot be made as profitable as the export of chrome ore, at least at the current prices and costs of production.

The biggest constraint that will not allow any beneficiation facility from coming to South Africa is the constraint of power supply imposed by ESKOM. ESKOM is definitely not in a
position, at least for the next 2-3 years of supplying the quantity of power required to beneficiate the quantities of chrome ore currently being exported.

From the research it is understood that, currently the constraints are more than the opportunities, and beneficiation of chrome ore is impossible for the next 2-3 years. So, the based on the research findings the suggestion would be to try and improve the competitiveness of the ferrochrome industry by implementing the aforesaid improvement initiatives. One of the improvement initiatives is the use of UG2 which is nothing but an inferior quality of chrome ore available at reasonably cheap price. The producer with captive mines should try and use UG2 for ferrochrome production and export the prime grade ore at higher prices. The advantage is two folds. One is that the use of UG2 will enhance the profit margins of ferrochrome business, and the export of prime ore will also allow the producers to earn higher profits. Businesses grow with higher profits, and key word of the business is to maximise profits. It will also increase the income of the government in terms of collection of taxes. The higher profits earned can be invested in other businesses, which are more profitable than the ferrochrome business, to achieve the objective of the job creation and higher revenue/FOREX generation.

Nobody can predict the future. So, after 2-3 years, when the ESKOM power will be available, the decision of investment in ferrochrome business will be taken depending on the situation and profitability of the ferrochrome business.

7. Future research directions:

The end of use of chrome ore is ferrochrome and the end use of ferrochrome is stainless steel. In this research, the analysis is done with regards to the beneficiation potential of South Africa up to the stage of ferrochrome. The future research should be done to evaluate the potential of South Africa in beneficiation up to the stage of stainless steel. Making ferrochrome and stainless steel are only few alternatives of value addition. The other options of value addition should be evaluated and explored.

In this research only few of improvement initiatives, that can make ferrochrome business more profitable, have been explored. It is said that there is no end of improvement. So, the and effort should be consistently be given in the future researches to find out further avenues to make the ferrochrome industry more competitive.
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