ENERGY EFFICIENCY IN THE IRON AND STEEL INDUSTRY: CASES OF ZIMBABWE AND SOUTH AFRICA

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DECLARATION

I, Elizabeth Muguti declare that this dissertation is my own original work. It is being submitted in partial fulfilment of the requirements for the degree of Master of Science (Applied Science) at the University of Cape Town. It has not been submitted before for any degree or examination in any other university.

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Dated at ________________ this __________ day of ________________ 2004.

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I dedicate this dissertation to my niece Julie who mothered my beloved teenage son Daryl-Kudakwake in my absence, saw him through a critical time in his psychological development and was a calming force in my times of difficulty.

ABSTRACT

This study looks at possible improvements of energy efficiency in the iron and steel industry in Zimbabwe and the case of South Africa is studied also for comparison. Data required was obtained through field visits and international databases. The fieldwork findings, analysis and published literature contributed to the conclusions and recommendations.

There is a relationship between technology advancement, energy efficiency and energy intensity. The more modern technology a country's steel industry adopts the more energy efficient it becomes and so lowers its energy intensity. Countries such as South Korea, Japan and Germany have adopted modern technologies and they are among the most efficient steel producers and have the lowest energy intensities while India and China have low levels of modern technologies, low efficiencies and high intensities.

ZISCO, the iron and steel industry of Zimbabwe has a relatively high energy intensity (closer to China and India) compared to South Africa and other developing country producers. ZISCO has both new and old technology while industry in South Africa, which has retired most old technology and closed all its less efficient plants, is largely using new and even state of the art technology in some of its plants.

In Zimbabwe the national economic and industrial policies have had negative impacts on the growth and development of its iron and steel industry. ZISCO needs policies that support the adoption of energy efficient technology, create a level playing field for down stream steel industries since ZISCO has the potential to influence growth of this sector and the sector has prospects for significant foreign currency earnings.

The study recommends a restructuring of ZISCO to improve productivity, and energy efficiency through replacement of old technologies in the medium to long term and implementation of some identified less capital-intensive options that are typical in an integrated steel mill.

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LIST OF ACRONYMS AND ABBREVIATIONS

Btu	British Thermal Units
BIMCO	Buchwa Mining Company
IMR	Institute of Mining Research
GS	Geological Survey
Met. Lab	Metallurgical Laboratory
AASEC	An Average Specific Energy Consumption
AFREPREN	African Energy Policy Research Network
AIJ	Activities Implemented Jointly
ANRE	Agency for Natural Resources and Energy
BAT	Best Available Technology
BF	Blast furnace
BOF	Basic oxygen furnace
BPO	Best Practical Observed
C/O	Coke oven gas
DME	Department of Minerals and Energy
DRI	Direct Reduced Iron
EAF	Electric arc furnace
EDRC	Energy Development and Research Centre
EI	Energy intensity
EIA	Energy Information Administration
EOF	Energy Optimising Furnace
ERI	Energy Research Institute
ESAP	Economic Structural Adjustment Programs
EU	European Union
FDI	Foreign direct investment
GDP	Gross Domestic Product
GJ	Gigajoules
IASA	International Agency for Systems Analysis
IBRD	International Bank for Reconstruction and Development
IDC	Industrial Development Cooperation
IEA	International Energy Agency
IISI	International Iron and Steel Institute
IPCC	Intergovernmental Panel on Climate Change
ISCOR	South African Iron and Steel Company
ISP	Integrated steel plant
ISSB	Iron and Steel Statistics Bureau, UK
JI	Joint Implementation
kWh	kilo watt hour
LPG	Liquid Petroleum Gas
MECS	Manufacturing Energy Consumption Surveys
NAFTA	North American Free Trade Agreement
NICG	National Iranian Gas Company
OECD	Organisation for Economic Cooperation and Development
OHF	Open Hearth Furnace
OPEC	Organisation of Petroleum Exporting Countries
OTT	Office of Transport and Transformation
ppp	Purchasing price parity
SAB	South African Breweries
SADC	Southern African Development Community

SAISI	South African Iron and Steel Institute
SAPPI	South African Pulp and Paper Industry
SCC	Safety Critical Components
SCEE	Southern Centre for Energy and Environment
SEC	Specific energy consumption
SIEMP	SADC Industrial Energy Management Program
SIRDC	Scientific and Industrial Research and Development Centre
tcs	Tonnes of crude steel
TERI	Tata Energy Research Institute
TOE	Tonnes of oil equivalent
TWh	Tera watt hour
UN	United Nations
UNCTAD	United Nations
USGS	United States Government Statistics
WB	World Bank
WEC	World Energy Organisation
WEO	World Energy Outlook
WWF	World Wildlife Fund
ZIMASCO	Zimbabwe Mining and Smelting Company
ZISCO	Zimbabwe Iron and Steel Company
CSUN	California State University
RBZ	Reserve Bank of Zimbabwe

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND TO THE IRON AND STEEL INDUSTRY

The iron and steel industry is important for economic development because of demand of its products in infrastructural development and other areas. It is also important to both upstream and downstream industrial development. This industry makes significant contribution to the gross domestic product (GDP) of most countries. For example, in Canada it contributed 0.5% of GDP, valued at $10.69 billion and 2.6% of manufacturing GDP, 2.0% of manufacturing employment, equivalent to 33600 jobs (Statistics Canada, Industrial Monitor, 1995). In the United Kingdom, its direct contribution to manufacturing GDP was about 1%, accounting for about 60 000 jobs, which was about 0.6% of the workforce in 2000. Its contribution from exports and avoiding imports was estimated at 8.2 billion pounds (Business Strategies, 2001). The industry also makes significant contribution in developing countries. In South Africa, it contributes 3.5% of GDP and creates over 300 000 jobs while in Zimbabwe it employs 4700 people.

The iron and steel industry is also important for being inherently energy intensive. While industry in general accounts for over 50% of national commercial energy demand in most developed countries and less for developing countries, for most economies over 15% of this energy is consumed in the iron and steel industry (EIA, 2000). This industry is also characterised by high energy intensities. Intensity varies between 17-35GJ per tonne of product depending on the efficiency of production. Since it is highly dependent on fossil fuel in most countries, its activities account for a significant share of greenhouse gas (GHG) emissions in those countries.

Iron can be produced in two forms; either as liquid pig iron using the blast furnace technology or sponge iron using the direct reduced iron (DRI) furnace technology. Steel is typically produced from these two forms of iron. Primary steel is produced from pig iron in the open-hearth furnace (OHF), basic oxygen furnace (BOF) or energy-optimising furnace (EOF) in an integrated steel plant. Secondary steel is produced from sponge iron and scrap steel in an electric arc furnace (EAF), induction furnace (IF) or rotary hearth furnace (RHF). A new set of technologies, collectively termed smelt-reduction technology is used in very few countries but is still experimental. These technologies include the Corex, Hismelt and corex-midrex plants, which are the most advanced technologies in the industry, reducing both energy consumption and capital investment.

The industry has been undergoing changes both in its associated technologies and in its processes. Over the years, the industry has moved from less efficient technologies such as the OHF to more efficient ones such as the BOF. Steel making from scrap has also been on the increase thus reducing the energy requirements for Integrated Steel Plant (ISP) and consequently reducing the energy intensity. Conventional casting, which is highly energy intensive, has been rapidly replaced by continuous casting with further reductions in energy consumption and hence lowering of energy intensities. Observed trends show that countries that have adopted advanced and more efficient technologies have effectively lowered their energy intensities.

International benchmarks used for comparisons between developed and developing countries based on best practice show that energy intensities in developed countries are generally lower than those for developing countries.

1.2 PROBLEM DEFINITION

The iron and steel industry is crucial for economic development as it has major spin-offs to other industries. It supports the energy sector through its high demand for energy inputs, the mining sector through its demand for raw materials such as ore and limestone, and the manufacturing sector by supplying partially processed products as inputs. It also supports the construction industry and special sectors such as gas and chemical distribution. This position is also strengthened by its contribution to national export earnings. Over 70% of steel production in Zimbabwe is exported while in South Africa exports contribute a significant share of national GDP. Steel exports earn 16.9% of South Africa's foreign exchange earnings (ILO, 2000).

The iron and steel industry consumes a relatively large share of the total industrial energy demand. In South Africa, it consumes 22% of industrial energy, the highest industrial energy consumer (ERI, 2001), 11% of industrial consumption in Japan and 17.7% in Mexico (Ozawa et al, 1999). Most developing countries have huge energy import bills and high energy intensities. However savings are possible as indicated by studies done worldwide. In South Africa, potential savings in the industry have been estimated at 10-20% of total sub-sectoral consumption through implementation of energy efficiency improvement programs (DME, 2001). In the USA, studies showed that in 1999 the potential savings in the iron and steel industry could be as high as 18% (Sustainable Energy Coalition, 2000). In Mexico savings of 16.1% were achieved between 1990 and 1995 (Ozawa, 1999). These savings will reduce national energy bills. The contribution of energy to production cost ranges from 10-20 % in some EU countries to 30% in India (Europa 2001, United Kingdom Parliamentary Briefing, 1998 and Tata Steel 2000). Therefore, technology advancement that reduces energy consumption will impact positively on the profitability of the industry. Inversely, inefficient energy use will have negative impacts.

Although Zimbabwe is among the better-developed countries of sub-Saharan Africa, its technical capability particularly in the iron and steel sector can be improved and the country is highly dependent on technology imports. Technology use in the Zimbabwean iron and steel industry compared with that of South Africa clearly supports this argument. In order to reduce intensities and improve the capacity for economic development, Zimbabwe needs to improve its technical capability in the iron and steel industry. Useful lessons could be learnt from South Africa. A study of energy efficiency in the iron and steel industry of the two countries could offer information and insights on how Zimbabwe could improve its technical capacity. The iron and steel industry is a very competitive industry worldwide because of oversupply that is sometimes experienced due to overcapacity in the industry. Use of advanced technology and improving efficiency are options to improve survival in the highly competitive market. The iron and steel industry generally has higher energy intensities than most producers. A study of the linkages between technological advancement and energy efficiency will offer recommendations, which could further help Zimbabwe to achieve reduced intensities and consequently improved competitiveness.

Zimbabwe is a signatory to the United Nations Framework Convention on Climate Change (UNFCCC) and therefore has certain obligations to the convention, which include undertaking a sustainable development path in satisfying its economic development. Although this does not imply any obligations on Zimbabwe to reduce its emissions of GHG, but to assist the country to avoid GHG emissions.

1.3 COUNTRY BACKGROUND

Zimbabwe is located in Southern Africa with a population of just less than 12 million people on a total land area of 390 thousand square kilometres. The country's economy is mainly agro-based while mining and a well-established manufacturing sector make an important contribution to the economy. The mining sector mainly exports minerals and metals such as gold, iron and steel, chrome, copper, asbestos, nickel and platinum. The agricultural sector produces sugar, maize, cotton, tobacco, flowers, paprika and beef part of which are exported, with tobacco earning most of the country's foreign currency. Zimbabwe is highly dependent on imports of machinery and transport equipment, of which transport equipment is (27.7%), chemicals (16.7%) and liquid fuels (19.5%). It is a major exporter of tobacco, gold, asbestos, and other minerals (CSO, 2001).

Since the International Monetary Fund (IMF) and World Bank funded economic structural adjustment program (ESAP) in the country, both micro and macro economic conditions have deteriorated with annual inflation doubling between 1996 and 2000. The recent political problems resulting from the need to redress land distribution imbalances from the country's colonial past have worsened the economic conditions. Zimbabwe's Foreign Direct Investment (FDI) has been reduced by over 60% and inflation has risen to 115% (RBZ, 2002). The country's total value of external debt in 1998 was more than 4 billion US$, with total debt service requirements of just under 1 billion US$.

Currently investors require politically stable environments, good infrastructure, reasonable risk and some certainty about returns. They are also attracted by factors such as a broad technological base, skills availability, abundant labour supply and specialised financial institutions. Although some of these factors are abundantly available in Zimbabwe, the current macro and micro economic environment does not support foreign investments. Moreover, the current high debt burden affects the potential for investments particularly for the iron and steel industry, which is both capital and foreign currency intensive.

1.4 PURPOSE

This study investigates the potential to increase energy efficiency and lower energy intensities in the iron and steel industry through technological development. It also assesses the potential to increase energy efficiency and reduce energy intensities of the iron and steel industry of developing countries. The potential is demonstrated through case studies of South Africa and Zimbabwe, the major iron and steel producers in sub-Saharan Africa.

1.5 JUSTIFICATION

Industrialisation is a major contributor to economic development and is driven by energy. Energy resources are not infinite therefore if industrialisation is to be carried out sustainably, conservation of energy resources through more efficient use is necessary. Hence energy efficiency is very important as it contributes to both profit making and environmental protection. Industrialisation is often linked to technological development but it is important to understand the link between technological development and energy intensity in order to facilitate appropriate technology choice.

Therefore conservation efforts targeted at industry will result in significant energy savings. This has potential to lower national energy import bills, contribute positively to balance of payments and increase profitability.

Technological developments that have occurred in the iron and steel industry have resulted in reduced energy intensities and lower production costs, demonstrating that within the industry, energy intensity can be lowered and cost effectiveness improved through use of new technologies. A study of this nature can demonstrate that there are technological options for reducing energy intensity of production.

Furthermore, despite benefits of technological advancements such as high quality products, increased product and market diversity, the majority of developing countries still use old technology. Old technology limits their ability to access these benefits and restricts them to low value products with higher risks and small profit margins. A study like this one that illustrates the linkage between technological advancement and energy efficiency may promote change in perception by governments and industry towards technological investments.

Although energy efficiency improvement programs such as the Southern African Development Community Industrial Energy Efficiency Program (SIEMP), the Three E Earnings and the UNIDO/COMESA study that have carried out an assessment of energy efficiency in some South African and Zimbabwean industries, not many studies specifically targeted at the iron and steel industry seem to have been done. This study is particularly important because of the lessons that can be learnt from the technological advancement that South Africa has achieved while neighbouring Zimbabwe with considerable potential is still lagging behind.

It is against this background that this study was undertaken to investigate the impact of technology improvement on energy efficiency and reduction in energy intensity in the iron and steel industry and their potential to contribute to increased economic development in Zimbabwe.

1.6 OBJECTIVES OF THE STUDY

The objective of this study is to investigate the impact of technology improvements on energy efficiency, energy intensity and enhanced potential for improved product quality, product and market diversification and general growth and development of the iron and steel industry. The study has the following objectives.

- Illustrate the potential for energy savings in the iron and steel industry through review of the relevant literature
- Show trends in the iron and steel industry through a global overview of the industry
- Demonstrate linkages between technological advancement, energy efficiency, reduction in energy intensity and increased sustainability through an assessment of the industrial trends
- Provide suggestions for possible improvements in technology, energy efficiency, reduced intensities and enhanced production in the iron and steel industry of Zimbabwe

1.7 METHODOLOGY

The work had two major aspects. One involved plant visits and interviews with plant personnel and policy makers. The other was a desk study that surveyed literature on energy efficiency in industry in general and the iron and steel industry in particular to augment data that was obtained from plant visits. This data was analysed to establish the *energy intensity* of the various technologies and processes and to estimate the *energy efficiency levels* in the South African and Zimbabwean iron and steel industries, the calculated efficiencies were compared to those in other iron and steel producers worldwide.

The *relationship* between *technological advancement, energy efficiency* and *reduction in energy intensity* was determined through a comparison of technologies, related intensities and adoption levels in a given country.

Estimation of *potential savings* was achieved through a comparison of the energy intensities in iron and steel industry in South Africa and Zimbabwe to international benchmarks. The aim was to verify the impact of technological improvement on energy efficiency and energy intensity and establish whether technological advancement improves energy efficiency and reduces energy intensity. If technological advancement lowers energy intensity then the following outcomes should be observed.

- Advanced technologies should have lower energy intensity
- Countries with advanced technologies should have lower energy intensity
- Countries with high adoption levels of advanced technologies should have lower energy intensities and
- Energy intensities for countries with advanced technology should be closer to the international benchmarks.

The *policy implications* of these findings were also examined with a view to offer some recommendations to facilitate improved decision making regarding technology choice and improvement of energy efficiency in the Zimbabwean and South African iron and steel industry.

1.8 CHAPTER OUTLINE

Chapter one provides a brief background to the study and its justification, the purpose and objectives and scope of this study. It also introduces the methodology and provides a chapter outline.

Chapter two provides a global overview of the iron and steel industry including production and consumption of steel products.

Chapter three considers general energy efficiency studies done and those done in the iron and steel industry. It also looks at energy efficiency studies done in South Africa and Zimbabwe.

Chapter four gives a theoretical context for energy efficiency by discussing theoretical concepts for energy intensity and principles that are used for the calculation and assessment of energy efficiency and determination of energy intensity in the industrial sector and the iron and steel industry.

Chapter five describes both data collection and analysis methods and how relationships are identified between technological advancement, energy efficiency and reduction in energy intensity.

Chapter six contains the findings of this work and demonstrates the relationships between technology improvement, energy efficiency and reduced energy intensity. It also shows the potential for energy efficiency improvement for Zimbabwe and South Africa and how this compares to other steel producers.

Chapter seven identifies technologies that ZISCO could implement to improve energy efficiency. It deals with policy implications for technological change and the role of policies and strategies in advanced technology adoption for reduction of energy intensities. It discusses technology drivers and barriers to technology adoption and assesses policies and strategies that support or discourage technology adoption and their impacts on Zimbabwe, South Africa and other developing countries.

Chapter eight makes recommendations on suitable technologies and policies, which should be implemented to promote technology adoption and suggest some areas for further research.

CHAPTER 2

GLOBAL OVERVIEW OF THE IRON AND STEEL INDUSTRY

This chapter gives a global overview of the iron and steel industry and provides some indications of activities in the industry worldwide. The activities discussed include world consumption and production levels, technological developments and energy efficiency trends.

2.1 WORLD PRODUCTION AND CONSUMPTION LEVELS

2.1.1 Iron ore and iron

Of all the metallic elements, iron is the most useful, abundant and the cheapest. Iron ore provides the major raw material for the iron and steel industry and is almost exclusively used for iron making. Worldwide annual production of iron ore is estimated at 900 million metric tons, which is processed to about 560 million metric tons of pig iron and 40 million metric tons of direct reduced iron (DRI). There is about 200 million metric tons of scrap steel, and if taken into account, annual production for the year 2000 was about 800 million metric tons of iron (Mottie, 2000). Iron ore is either processed locally or exported. Table 2.1 below gives the iron ore reserve base, production and exports for the world's 10 major producers.

Table 2.1 Iron ore reserves, production and exports for ten major producers 2000 (in million metric tonnes)

Country	*Reserve Base*[1]			*Production*[2]			*Exports*[2]		
	Mt	*%*	*Rank*	*Mt*	*%*	*Rank*	*Mt*	*%*	*Rank*
Brazil	11 000	6.9	5	200	21.3	1	160	32.6	2
Australia	25 000	15.6	2	171	18.2	2	165	33.6	1
CIS	63 000	39.4	1	157	16.8	3	28	5.7	4
China	15 000	9.4	3	100	10.7	4	-	-	-
India	4 000	2.5	7	75	8.0	5	35	7.1	3
USA	14 000	8.8	4	63	6.7	6	6	1.2	9
Canada	2 500	1.6	8	36	3.8	7	27	5.5	5
South Africa[3]	1 500	0.9	9	34	3.6	8	21	4.3	6
Sweden	5 000	3.1	6	21	2.2	9	16	3.3	7
Venezuela	1 500	0.9	9	17	1.8	10	7	1.4	8
Other	17 500	10.9		63	6.7		26	5.3	
Total	160 000	100		937	100		491	100	

Source: [1] USGS, Mineral Commodity Summaries, January 2001(for reserve base)
[2] UNCTAD, Trust Fund on Iron Ore 2001 (in equivalent gross ore mass)
[3] Minerals Bureau (except for Reserve Base)

In Table 2.1, there is a discrepancy between the data given by the government for South Africa and that quoted in this table. The government gives 9300 Mt of mineable ore of 5900 Mt iron ore content and it is ranked sixth largest in the world. Thus South Africa is a major producer of iron ore.

2.1.2 Steel production

Apart from producers shown in Table 2.1 there are many more producers including the fast growing developing countries, however only a few nations account for the bulk of global production. In the year 2000, 96% of the 847 million tons of world crude steel was produced by only 36 countries with China producing 127.2 million tons (15%), while Japan and the USA produced 106.4 million tons and 101.5million tonnes amounting to 12.6% and 12% of the total respectively. Hence, these three countries account for almost 40% of world production, and over 70% came from only ten countries, while 87% from the top twenty steel producers (Steel Profiles., IISI 2000). However, this industry is still highly disintegrated considering that, only eight companies are responsible for world vehicle production.

Crude steel production has risen to over 800 million tons at a value of US$200 billion annually (Steel profiles, 2000., Phylipsen et al, 2002., IISI, 2000). The production levels of 10 major producers for year 2000 are given in Table 2.2 below.

Table 2.2 World crude steel production for ten major producers

Country	*Production*			
	Mass (Mt)	*2000/1999 Growth %*	*Share %*	*Rank*
China	127.2	2.6	15.0	1
Japan	106.4	13.0	12.6	2
USA	101.5	4.2	12.0	3
Russia	59.1	14.8	7.0	4
Germany	46.4	10.2	5.5	5
South Korea	43.1	5.1	5.1	6
Ukraine	31.4	14.3	3.7	7
Brazil	27.9	11.6	3.3	8
India	26.9	10.7	3.2	9
Italy	26.7	8.1	3.2	10
Others[a]	250.6	6.0	29.9	
World	847.2	7.5	100	

Source: International Iron and Steel Institute, 2001

[a]Among the others, South Africa contributed 8.4 million tons. It achieved a 6.3% growth and was ranked 21st in the world.

Table 2.2 shows that crude steel production grew by about 7.5% between 1999 and 2000. Comparison of the rankings in Table 2.1 and Table 2.2 shows that most of the highly efficient producers like Japan, South Korea, Germany and Italy do not have any or limited iron ore, and therefore depend on imports and the countries producing the ore have different ranking to those producing steel. The implication is that, they have concentrated on developing the manufacturing aspects rather than ore extracting using their technological competitive edge. This is further supported by case of South

Africa, which is among the top ten ore producers, but is out of the 20 major crude steel producers. Zimbabwe on the other hand is a minor producer in the world market.

Both South Africa and Zimbabwe are however important in the African region. They have the largest steel mills in sub-Saharan Africa and they are SADC's only integrated steel mill producers. Internationally, Zimbabwe is important as a producer of virgin steel, which has a niche market as most countries are increasing their scrap-based steel production, which may not meet certain quality standards that are possible with virgin steel. However, South Africa also enjoys the same advantage because of its two integrated steel mills that are even more technologically advanced than ZISCO in Zimbabwe.

2.1.3 Consumption of steel

Although there is an increase in both the world steel production and consumption, the consumption does not match production, implying over supply. This trend is not surprising because this sector is regarded as important and strategic nationally, and so attracts significant public funds and interests. Hence, in some cases, this results in over capacity as indicated in Table 2.3 below.

Table 2.3 World steel production capacity utilisation 1994 (million metric tonne and percentage)

Country/Region	*Effective capacity*	*Capacity utilisation*
OECD	503	77
FSU/CEE	218	51
ROW	279	82
China	92	99
Korea	35	96
South and Central America	47	76
World	1000	72

Source: IEA, 1996

Despite these problems, steel still remains the most important structural and engineering metal in the world though global consumption has declined. Table 2.4 shows that in general, consumption has either remained fairly constant or has been declining, except for countries like China, Russia, South Korea and India whose consumption has been steadily increasing. Internationally however, the industry is generally facing serious problems such as reduced market, loss of profits, plant closures and loss of jobs. A recent example is that of the British/Dutch, steel company Corus, which has been making huge losses in recent years and is threatened by reduced production and plant closure (BBC News.com.12/03/2003)

Table 2.4 **Apparent Steel Consumption 1995-2001 (million metric tonnes of finished product**

	1995	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*
China	87.4	97.3	103.5	113.9	130.8	141.2	169.9
Japan	80.0	80.6	82.1	70.3	68.9	76.1	73.2
USA	98.2	103.1	108.8	115.7	110.9	114.7	102.8
Russia	18.8	16.4	15.6	15.4	16.9	22.1	23.5
Germany	35.1	31.6	34.0	34.6	35.2	37.9	37.1
South Korea	35.5	37.6	38.1	24.7	33.8	38.5	38.2
Ukraine	5.9	5.4	4.1	3.0	2.4	2.1	2.7
Brazil	12.0	13.0	15.3	14.5	14.1	15.8	16.7
India	22.2	22.8	22.9	23.5	25.0	26.3	27.6
Italy	27.8	23.3	27.5	29.3	29.4	30.6	30.3
World	651.3	653.1	699.1	684.5	702.2	758.9	765.0

Source: IISI, 2002

Oversupply of steel in the world market has resulted in serious price falls, quotas, anti-dumping policies and over protection of the industry by respective governments. The world average consumption per capita also shows that consumption has generally declined over the years. The world average for 1973 was 177kg/capita while twenty years later in 1993; it had dropped to 133kg/capita (ERI, 1999). South Africa follows this trend with 223kg/capita and 120kg/capita for 1973 and 1993 respectively. This trend applies to developed countries more than developing countries because in some developing countries steel consumption is still rising.

As the demand for development is greater in developing countries, the production and consumption of energy intensive bulk materials such as steel and cement is growing in these countries. This trend will continue as these countries satisfy their socio-economic goals. For instance the average steel consumption per capita in developing countries was as low as one half to one twentieth of that of the OECD average (Price et al, 2000). This trend has been changing in recent years. Due to increased development efforts, use of energy intensive materials is increasing; hence consumption of energy intensive bulk materials is now on the increase in developing countries and is projected to grow. The implication is that demand for steel may grow and in view of the high-energy intensities, inherent in the production of these products, energy conservation efforts and more efficient use of these materials is necessary for sustainability.

Steel consumption at regional level as depicted in Table 2.5 shows that the highest consumption occurred in Asia, which is experiencing relatively high economic growth. The Middle East, Africa and Australia and New Zealand consumed the least while the EU, Europe and NAFTA consumed steadily at over 100 million metric tonnes annually.

Table 2.5 **Steel consumption by economic region (million metric tonnes of finished product)**

Region	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*
EU (15)	127.1	115.8	129.6	138.1	138.1	144.9	141.9
Europe	158.7	147.5	163.6	172.7	169.3	179.8	175.1
Former USSR	27.8	26.7	25.8	21.9	22.9	29.9	32.3
NAFTA	116.9	124.4	134.5	144.1	139.9	146.4	130.6
CSA	23.2	24.2	27.9	27.2	24.1	27.0	27.8
Africa	14.8	13.4	15.0	16.5	14.6	14.6	15.1
Middle East	13.1	13.5	15.2	14.5	14.5	16.4	15.5
Asia	290.3	296.9	310.6	281.1	310.3	338.4	362.7
Aus & NZL	6.5	6.5	6.5	6.6	6.6	6.4	5.9
World	651.3	653.1	699.1	684.5	702.2	758.9	765.0

Source: IISI, 2002

Steel intensity, which is defined as the tonnage of steel consumed per unit of GDP, has also been declining over the last two decades. The major reason for that is increased production and end-use efficiency that have both been supported by technological advancement in the sector.

It must be borne in mind that if the economic situation improves in other developing regions as in Asia, steel consumption will increase substantially.

2.2 RECENT TECHNOLOGICAL ADVANCEMENT

There are several reasons responsible for the general decline in steel consumption, including recent technological improvements in the industry. The advent of alternative materials to steel in manufacturing, triggered by the global push for efficient and environmentally friendly production systems and increasing saturation in some developed markets, has made diversification of raw materials popular, thus reducing the demand for steel. Also, the technology in the iron and steel industry has developed from simple inefficient open-hearth furnaces to sophisticated technologies such as COREX, MIDREX and HISmelt. Use of some of these new processes has resulted in reduced use of raw materials. Inefficient technologies such as batch casting are being phased out for more efficient ones such as continuous casting, which have significantly lower intensities and have greatly improved production efficiency. Blast furnaces have been improved from basic furnaces to very sophisticated and fully electronically monitored that has resulted in reduced energy consumption and increased productivity. In general, due to development of alternatives and technological advancement which, resulted in improved energy efficiency and de-materialisation, steel-making technology has advanced significantly allowing great strides in production efficiency throughout the industry from iron and steel production to related manufacturing industry.

For instance recent developments in the steel making process have had a significant impact on the form in which iron ore is processed. Over the last two decades the proportion of world steel output produced by EAFs has increased significantly. This is projected to grow in the foreseeable future as new technologies enable users of EAFs to search for new markets and make large savings on production costs (Roskill Consulting Group, 2000). Technological improvements have resulted in the production of specialty steels and this has significantly reduced steel content of manufactured products.

As an example, thin sheet steel technology has enabled the reduction of the mass of a 330ml steel beverage can to about a quarter of what it was 40 years ago (IISI, 2002). In general there has been increased efficiency in the use of steel, while on the other hand metals such as aluminium have provided good substitutes for steel. Developments in the motor vehicle industry also indicate this general trend for improved efficiency and use of alternatives. New steel-making technologies have allowed the development of advanced special steels that can offer a lot of advantages for the final manufacturer including strength, formability as well as a solution to sustainable development. An example is the creation of the Ultra Light Steel Auto body-Advanced Vehicle Concepts Program, which is aimed at offering steel solutions to meet the needs of society for a safe, affordable and environmentally responsible range of vehicles for the twenty first century (UNEPTIE, 2002).

In summary "*The steel industry has engineered a revolution in its performance over the last 20 years. There have been massive investments in new products, new plants and technology and in new methods of working. The result has been a dramatic improvement in the performance of steel products and a related reduction in energy use and consumption of raw materials in their manufacture (UNEPTIE, 2002)*".

CHAPTER 3

LITERATURE SURVEY

3.1 ENERGY AND DEVELOPMENT AND LINKS TO STEEL PRODUCTION

This chapter reviews literature on the importance of energy in economic development, and its linkages to steel production. The review also looks at energy efficiency studies in the industrial sector and those specific to the iron and steel industry. Energy is important for economic development and is the pivot of industrial development. Developing countries, particularly Africa, do not consume enough commercial energy to support adequate economic development. This is shown by the disparities in energy consumption patterns between the developed and the developing countries. About 1.2 billion people constituting 20% of world population, in the industrialised nations consume 60% of world energy supply, while 4.8 billion people, accounting for 80% of the world population, use only 40% of world energy (WEC, 1999). Developed countries consumption is high with an average of 5 toe/capita/year while the 2 billion poorest people of the world population, with an average annual (current ppp $) income of less than US$ 1000/annum consume only 0.2TOE /capita annually mainly in the form of biomass (WEC, 1999). Table 3.1 below gives the regional and per capita energy consumption patterns and this shows that Africa and India consume the least modern energy in the world resulting in low levels of industrial development in these regions.

Table 3.1 Primary energy consumption by region and per capita consumption in 1998

REGION	TPES (Mtoe)	Population (millions)	TPES/Capita (toe)
US/ Canada	2555	302	8.46
Japan/ Australia/ New Zealand	680	148	4.59
Western Europe	1660	385	4.31
CIS & CEE (includes Iran)	1250	410	3.05
Middle East	380	250	1.52
Latin America (includes Mexico)	685	505	1.36
China	1230	1260	0.98
Other Asia (includes Turkey)	890	910	0.98
Africa	480	760	0.63
India	590	980	0.60
WORLD	10 400	5910	1.76

Sources: BP/Amoco, 1999; and UNPF, 1999. with WEC adjustments.

This same trend is shown in electricity consumption, the driving power for industrialisation. Out of a total of 15000 TWh generated during the beginning of the 21st century, industrialised nations used; 10700TWh, while the developing countries used only 4300TWh, at a consumption level of 9000kWh/capita and 900kWh/capita respectively as shown on Table 3.2 (WEC, 1999).

Table 3.2 World electricity consumption Patterns

Market	Population	Consumption
Developed Market economies	800 million people	9000TWh
CIS-CEE	400 million people	1700TWh
China	1.3 billion people	1300TWh
Developing market economies	3.5 billion	3000TWh

Source: WEC, 1999

It shows that the more the commercial energy a nation consumes, the higher the economic development and industrialised they are. However, high energy consumption with higher energy intensity may have a negative impact on important factors such as competitiveness. Figure 3.1 below shows that economic development can be achieved with low energy intensity.

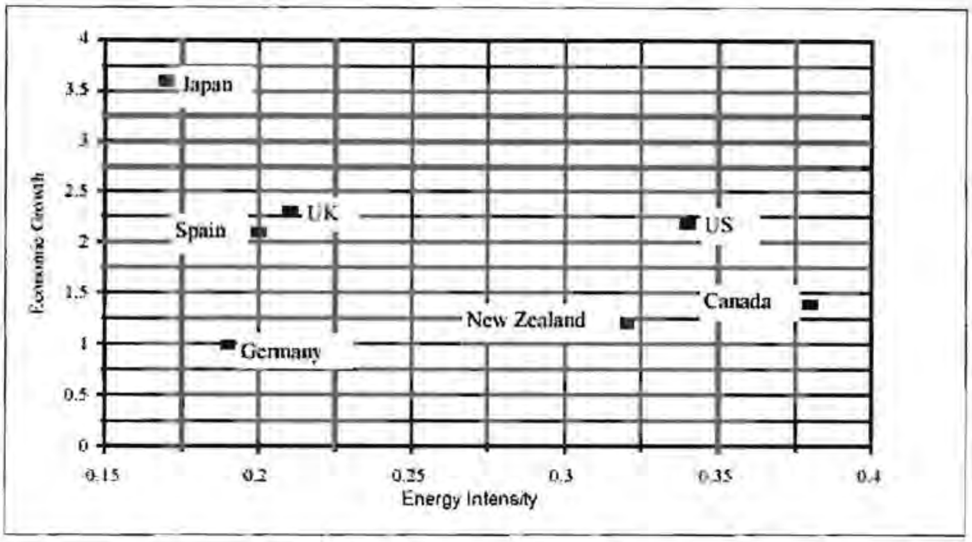

Figure 3.1 Comparison of energy intensity and economic growth

Source: WWF, UK. 1999

Japan, with an economy that was almost destroyed during World War II has now become an economic success with very low energy intensities. A comparison of Japan with other OECD countries provides a very good illustration of the benefits of energy efficiency.

3.1.1 Advent of energy efficiency

Previous development strategies, especially from North America are characterized by consumer wastefulness because of abundant space, energy and material resources. Historically, the developed countries easily accessed abundant resources such as labour and raw materials from their then colonies. As a result, high performing companies kept high levels of stock to meet changes in consumer demands. As long as capital and resources were cheap and storage space remained plentiful, this strategy was affordable and easily implementable. At that time the USA and Canada formed what (Schonberger 1982) calls "a throw away society". This trend grew until the raw material shortages of 1971 and the oil crisis of 1973. The oil crisis and the resultant multiple crude oil price increases (five fold increases) between 1970 and 1980 resulted in economic constraints the world over and producers of energy intensive products such as iron and steel, aluminium, copper and plastic industries were hit hardest. In addition shortages of petroleum products, scarcities of other raw materials hit almost all industries and resulted in major price rises.

In the meantime, Japan, which is very resource poor, had to work with resource constraints and so started implementing efficient production techniques long before the rest of the world.

When industry worldwide was subjected to high costs of raw materials, companies started to be resourceful consequently bringing in the concept of efficiency, and wastefulness ended. This is put well as *"Industry began to warm up to the concept of overhauling its materials management procedures, its plant and equipment, its product designs, its manufacturing control and its human resources management approaches, all of which affect the quantities of materials bought used stored and sold"* (Schonberger, 1982)

During the oil crisis, while most of the OECD as a whole was pressurizing OPEC for political and economic gains through quotas and price advantages, Japan was working hard at perfecting the total quality control management concept, improving the just-in-time production management tool and consequently increasing efficiencies. This greatly contributed to Japan's ability to achieve economic growth with low energy intensities. The outcome of this effort was that Japan gained major shares in world markets with excellent products such as automobiles and electronics. It should be noted that Japan achieved these gains not through dumping but by marketing high quality products and achieving very high rates of productivity. The strategy by Japan assisted them to cope better with the oil crisis through gains from their excellent energy and production efficiency. Thus energy efficiency became important to all countries from then.

In recent times, large organisations in the energy sector have also been showing signs of conversion to the ideas of increased conservation efforts, use of energy efficient technology and environmental protection. The following quote supports that. *"In an unlikely move, British Petroleum and Royal Dutch Shell, two of the largest oil companies, recently have begun to say it is time society started preparing for the decline of oil. In April, Shell became the first large oil company to announce support for the Kyoto greenhouse-gas reduction treaty, encouraging more efficient fossil-fuel use. The company's reasoning was that if increased petroleum efficiency is needed anyway, why not get climate protection as a bonus?" (OTT, 1998)*

3.1.2 The role of energy as a major industrial input

Since energy is the driving force behind industrialisation, the industrial sector consumes the bulk of energy worldwide with a total consumption of 32604 trillion Btu for 2001 (EIA 2003) (see figure 3.2 below). For most countries, industry accounts for more than 50% of national commercial energy. In China, it is as high as 60% in 2001 and 76% in 1997 (EIA, 2001), while in India it is 49% (TERI, 1999/2000). Even the more efficient economies like South Korea and Japan consume quite high percentages, 56% and 49% respectively (EIA, 2003, ANRE, 2000). Most of this energy is imported, implying expenditure of scarce foreign currency.

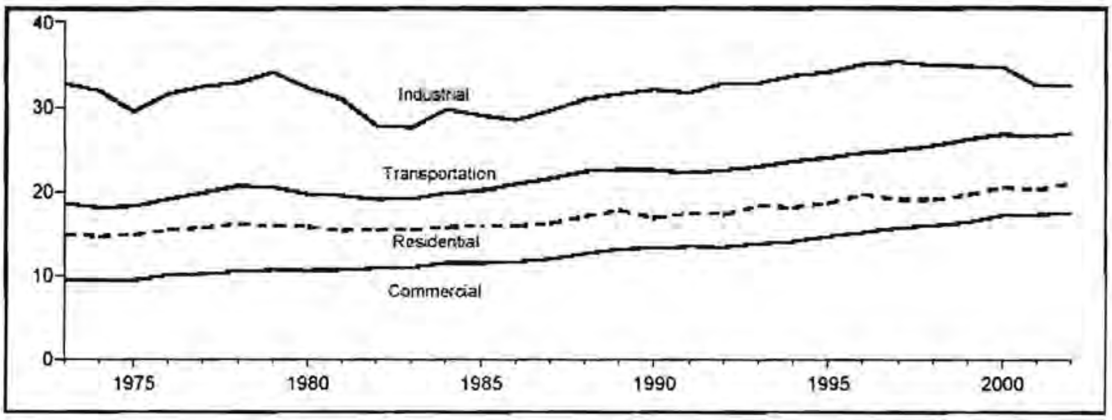

Figure 3.2 Total energy consumption by end-use sector, 1973-2002
Source: EIA, 2003

The world average is 40% of primary energy use (Price et al 2001). In South Africa, industry accounts for 54% of net national energy consumption, with mineral processing and mining using 50% of that energy and manufacturing using 20% (DME, 1998). In Zimbabwe industry contributes less than 30% of primary energy use. In the USA, industrial energy consumption accounts for 38% of national consumption and 10% of petroleum consumption (Sustainable Energy Coalition, 2000). These high levels of consumption are attributed to the highly energy intensive sub-sectors such as iron and steel making, cement production, pulp and paper and chemical production (Phylipsen et al, 1998).

3.2 TRENDS IN INDUSTRIAL ENERGY CONSUMPTION

Despite the high industrial energy consumption noted above the levels have been generally declining as demonstrated by Figure 3.3 and 3. 4. However, while the decline in consumption is apparent for Western Europe and North America, it has been rapidly growing for Asia. Since the first oil crisis, the Asian economies have been experiencing significant growth and their industrial energy consumption has grown significantly.

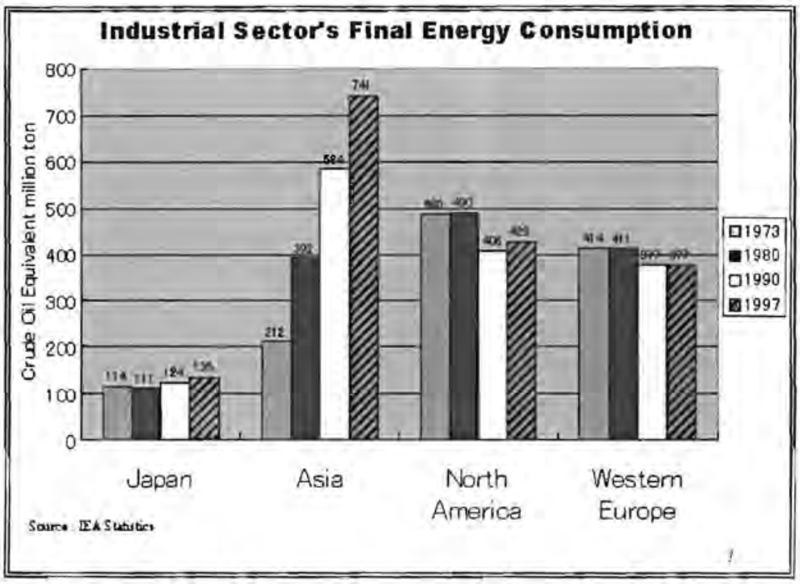

Figure 3.3 Final energy consumption in the industrial sector

Adapted from IEA, 2003

It is also worth noting that consumption per unit of GDP output (economic energy intensity) has been declining over the years particularly in the developed nations implying improved energy efficiency. Nonetheless energy intensities vary considerably among countries, and level of development. World trends indicate that as countries develop they tend to shift their energy intensive industries to the developing world in preference for service industries. Statistics by the World Bank on industrial sector's energy intensity indicate that some countries are more efficient than others. For instance, in 1997 the Japanese industry had the lowest intensity with 25 tons of crude oil equivalent per million US dollars. In contrast, the United States was at 46 tons, nearly twice that of Japan, while that of the United Kingdom was 34 tons, while the average among the OECD countries was 43 tons, and the world average was 67 tons (World Bank, 2003). The primary energy intensities (Figure 3.5) also shows this general trend.

Although energy intensities have been declining in most countries, particularly OECD countries, they have been growing for developing countries. Figure 3.3 above illustrates these trends. For instance, industrial energy intensity for 1990 – 1997 in Korea and Thailand increased by 28 tonnes and 25 tonnes of crude oil equivalent per million US dollars respectively (World Bank/IEA Statistics 1996-2003). Increases are also apparent in Asean, South Asia, Africa and the Middle East. This is a cause for concern particularly when the current world trends are to lower energy intensities in view of the climate change debate and greenhouse gas abatement. It is even more worrisome that except for a few oil producing developing countries, most of these producers are 100% dependent on oil imports (IEA Statistics 1996-2003). This has serious implications for foreign currency availability, balance of payments and development in general. High energy intensities for developing countries usually arise from the use of old, obsolete and inefficient technology and increased efforts at economic development, dominance of high energy intensive industry, low energy efficiency and under-priced energy.

Although it is rational for developing countries to consume more commercial energy to support increased economic development, it is possible for them to reach the same levels of development at lower energy intensities. Figure 3.1 (which in essence decouples energy consumption from increased development) clearly supports this argument. This is possible through technology leap frogging and increased use of energy efficiency measures. Thus massive efforts could be made to replace old/obsolete inefficient technology by state-of-the-art more efficient technology.

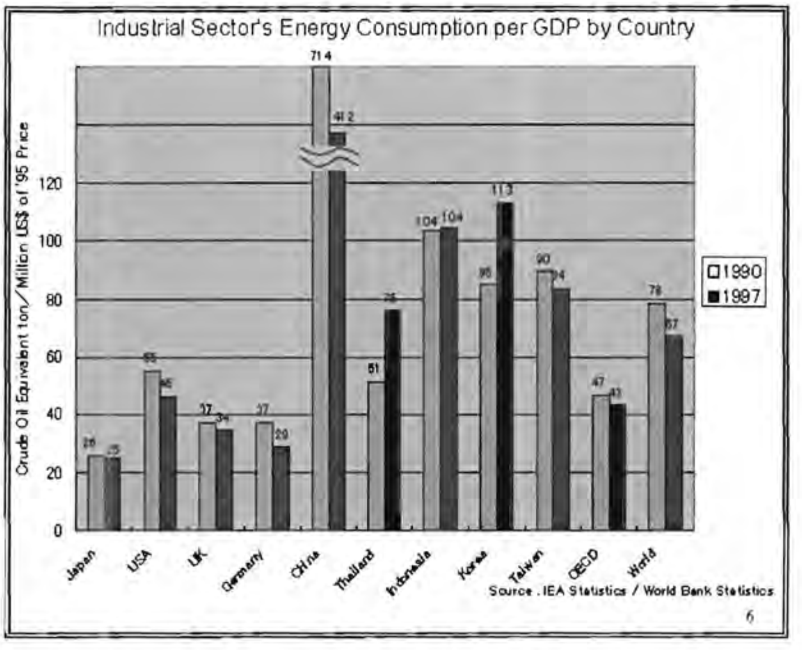

Figure 3.4: Industrial energy intensities by country

Adapted from World Bank, 2000.

The potential to lower intensities is confirmed by a number of regions that have intensities that are above world average and the existence of countries, which have very low intensities such as Japan, UK and Germany. This is apparent both from final energy consumption in Figure 3.4 and primary energy consumption as shown in Figure 3.5. Countries should therefore consider energy efficiency initiatives in view of this potential and the accruing benefits of saving energy and money, particularly for developing countries.

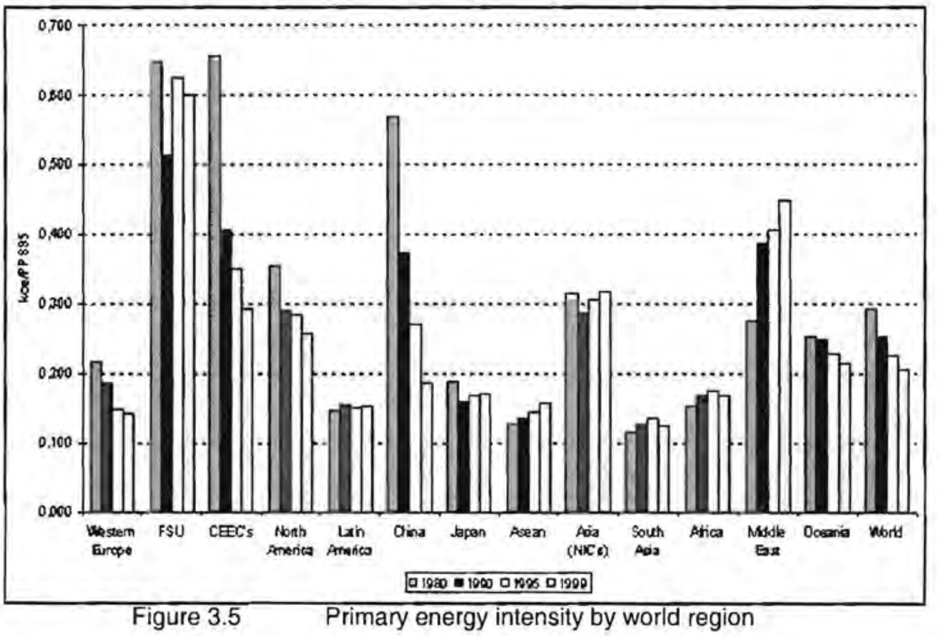

Figure 3.5 Primary energy intensity by world region

Adapted from WEC, 1997

3.3 POTENTIAL FOR INDUSTRIAL ENERGY REDUCTION

Over the years the manufacturing industry has been making efforts to reduce its energy intensity. Figures 3.3 to 3.5 show that there has been significant reduction in energy intensity for Japan, North America, China, Western Europe and Asia and CEEC. However, FSU, Latin America, South Asia and the Middle East have been experiencing increasing intensities. Figure 3.6 below shows that industrial energy intensity declined significantly in the US during 1973-85. This is attributed to increased capital outlays, fast industrial modernisation, and rapid expansion of highly technologically advanced industries that are less energy intensive and moving to more service industries. However it should be noted that they had a very high starting point.

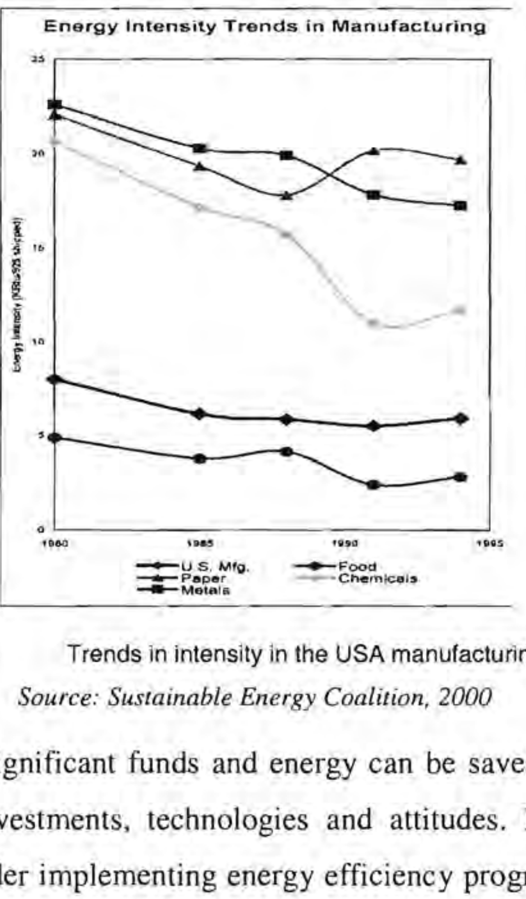

Figure 3.6 Trends in intensity in the USA manufacturing industry

Source: Sustainable Energy Coalition, 2000

It clearly shows that significant funds and energy can be saved through appropriate policies, strategies, investments, technologies and attitudes. In general, industries should seriously consider implementing energy efficiency programs as they consume the largest share of commercial energy in most countries and also because there is a very high potential for technological and process change, which enhances efficiency improvement. Energy efficiency programs should also be considered for their ability to contribute positively to environmental protection and materials conservation.

3.4 LINKAGES BETWEEN STEEL PRODUCTION AND ECONOMIC PROSPERITY

Steel industry development is positively correlated with economic development. Thus growing economies tend to have high steel production and consumption. For instance South Korea and Taiwan with an average GDP growth rate of 7.2% between 1990-1997 and 10.7% for 1999 consumed steel at 757kg/capita and 1109kg/capita respectively (UNEPTIE, 2003), clearly demonstrating the link between steel consumption and economic development. Steel use also increases when an economy grows. This is because when the economy is booming, government invests in infrastructure and constructs new factories, roads and residential areas. Tables 3.2, 3.3, and 3.4 show that the more developed a country is, the more steel it consumes while Figure 3.5 shows the gross national product (GNP) growth of the world. As further confirmation of this argument, Table 3.5 shows that steel consumption has been growing significantly in countries with growing economies.

Therefore steel consumption is high in industrialised countries and those developing countries whose economies are growing at higher rates. On the other hand, dips in steel production and use are usually experienced during economic recession. This was experienced in the Asian economy when steel consumption took a dip during the Asian crisis of 1997-1998. Dips were also experienced for the years of recession after the two world wars and the oil crisis, and increases were experienced during the prosperity years of 1950s and 1960s (Steel Profiles 2002).

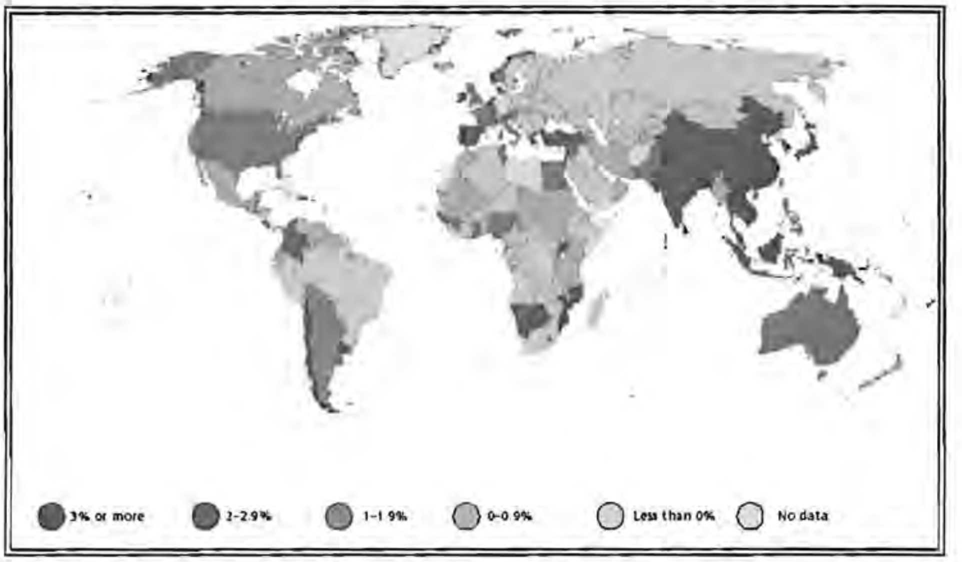

Figure 3.7 GNP per capita growth rates by region

Source: World Bank, 1995.

Steel consumption per capita, a measure of the social impact of steel on the world's social condition can also be used to judge the economic prosperity of a nation. It can be used as an estimate for economic development based on the view that the greater the steel consumption per capita in a given country, the higher the economic prosperity. Tables 3.3 and 3.4 also confirm this.

Table 3.3 Apparent consumption/capita for 1973 and 1993

Country	*Apparent Consumption/capita*	
	1973	1993
USA	737	400
Germany	621	401
Japan	822	646
China	35	110
India	13	22
S. Korea	84	606
Brazil	87	70
SA	223	120
World Ave,	177	133

Source:IEA, 1996

Table 3.4 Apparent consumption 1998/2002

Country	kg/capita
Industrialised countries	250-600
China	107
Brazil	99
South Africa	81
South Korea	757
Taiwan China	1109
UK[a]	253
Germany[a]	435
USA[a]	442
France[a]	296
World average	138.2

Source: UNEPTIE.ORG, 2002. [a]British Bureau of Statistics 1998

South Korea for instance, consumed steel at only 84kg/capita in 1973 and twenty years later the consumption had grown to over six times.

Table 3.5 Steel intensity rising rapidly in emerging economies

	Per capita steel consumption		*Average annual growth rate (%)*
	1992	*2001*	
EU 15	310	366	+1.8%
Poland	113	160	+4.2%
Former Soviet Union	284	109	-6.2%
USA	331	373	+1.3%
China	59	132	+12.4%
South Korea	499	809	+6.2%
Japan	635	575	-0.9%

Source: IISI, 2001

3.5 INDUSTRIAL ENERGY EFFICIENCY

Reduced use of steel and use of advanced technology also has implications for energy use. Energy efficiency is one of the major drivers to lower energy intensity, therefore in order to establish areas of focus, policies and strategies for improving energy efficiency in the iron and steel industry, an appreciation of the prevailing situation in both developing and developed countries is necessary. The discussion below will show the potential savings in industry, particularly in the iron and steel industry.

3.5.1 Energy efficiency studies in South Africa-The 3 E Strategy

The 3 E Strategy study was carried out to establish the potential for energy saving in South African companies. Four companies were involved, i.e. South African Breweries (SAB), South African Pulp and Paper Industries SAPPI Mandini, AngloGold Elandsrand Mine and Volkswagen South Africa. Energy audits established the current energy consumption, identified areas of potential savings and options and or measures, which could be used to achieve possible savings. The study was a joint effort between NOVEM as a representative of the European Union, the Energy Research Institute (ERI) of the University of Cape Town and Energy Consulting Services (ECS), a division of Technical Services International. These studies showed that there is potential for significant savings in the industry, evidence to prove that the industry has not attained optimum efficiency.

3.5.1.1 The SAB assessment

In the SAB assessment, the key areas investigated were electrical energy consumption, boilers and steam systems, compressed air use, refrigeration, air conditioning systems and energy management. A comprehensive electrical energy audit showed that the power factor correction in SAB could be improved, energy could be recovered from the boiler and steam system and that there was a need to use compressed air strategically. The audits also established that significant energy could be saved through refrigeration load scheduling, use of cooling towers and appropriate compressor sequencing and control. In order to conserve energy from air conditioning, use of centralised systems was recommended as opposed to the current system that uses smaller, inefficient systems. The study also established that in general, significant savings could be achieved through making conscious efforts to practice energy management, thus well planned and well timed production schedules could enhance energy management.

Options, identified for the improvement of energy efficiency were grouped as follows;

1. Improved house keeping
2. Low cost modification
3. Retrofit
4. Substantial change involving significant investment.

These are summarised in Table 3.6 below.

Table 3.6 SAB Energy efficiency improvement options

Option	Cost (R)	Return (R/Year)	Payback	Group
Improved power factor correction	60 000.00	120 000.00	Six months	3
Refrigeration load management	650 000.00	650 000.00	One year	1 & 4
Spent grain removal load management	Zero	6 000.00	immediate	1
Rigorous program for saving compressed air	75 000.00	150 000.00	Six months	1
Rigorous program for saving steam	100 000.00	200 000.00	Six months	1
Boiler automation	100 000.00	132 000.00	Nine months	3
Use of waste biogas	32 000.00	52 000.00	Nine months	2
Efficient light upgrades	165 000.00	165 000.00	One year	3

Source: Energy Research Institute, 2001

Implementation of these measures was estimated to cost R1.18 million, while the measures would result in an annual saving of R1.37 million. All measures have a very short pay back period. These investments represent an energy saving of 8% of total consumption. Adoption of these measures would result in a saving of 1600 tonnes of coal, making the plants environmentally friendly.

3.5.1.2 The Volkswagen assessment

The objective of this study was to identify energy and waste reduction opportunities in Volkswagen's manufacturing process and the related cost savings. In addition, the study assessed other related benefits, which included improved work place environment, improved safety, improved public image and potential for reduced negative environmental impacts. In order to be able to make the required recommendations, the team assessed all the energy forms used by the Volkswagen plant, as well as plant equipment with the highest energy consumption. The team also assessed opportunities for energy management.

The energy forms assessed included electricity, heavy fuel oil, LPG, and paraffin. The major energy consumers were air compressors, cooling towers, refrigeration, air driers, air conditioners, laser and resistance welding machines, spray painting and electro-coating machines. Opportunities for energy savings were identified for some of this equipment, while in energy management, the major issue was the need for continuous accountability for energy use and its cost. Thus increased departmental accountability was recommended as well as proper cost accounting. This enhanced accountability as departments and production centres paid for their actual consumption instead of averaging out bills between departments. The identified opportunities for saving energy were again classified in a similar manner as those for SAB and they are summarised in Table 3.7 below.

Table 3.7 Opportunities for saving energy in the Volkswagen plant

Opportunity	Cost (R)	Return (R/yr)	Payback	Group
1.Switch off compressors & main cooling towers during off production	zero	268 075	Zero	1
2.Turn off bay lights during non-production hours	included	446 190	Zero	1
3.Repair compressed air leaks & faulty blow-down valves to achieve a 10% leakage target	60 000	1 262 000	0.04	2
4.Avoid & discourage misuse of compressed air (blow-down valves & paint mix room)	30 000	263 189	0.11	1
5.Isolate areas of plant or individual machines that do not require compressed air when off production	40 000	219 869	0.20	2
6.Make use of heat pump heat recovery between ARP exhaust & supply air streams	2 750 000	3 187 385	0.90	3
7.Install direct acting electric heaters to air replacement plants serving colour line 1	4 000 000	4 355 536	0.90	4
8.Use waste heat to heat phosphate bath	300 000	190 000	1.60	2
9.Install suitable power factor correction equipment	1 007 500	516 690	2	3
10.Install high efficiency lighting	628 198	179 803	3.4	3
11.Extend existing thermic oil/HFO system to supply the ARPs (HFO instead of gas)	19 000 000	4 656 666	4.1	4

Source: ERI, 2001

All these measures with the exception of numbers 7 & 11 would require a total capital investment of R5 million, while the total energy savings are estimated at above R6.5 million. Except for numbers 8-11, all other measures have a payback period of less than one year. Implementation of these measures would result in a total energy saving of 16% of all energy costs. Most interesting however, is the fact that among the low cost opportunities, implementation of 1-5 will cost only R130 000 but will earn the company R2 million in just one month. Non implementation of such an opportunity shows lack of right information and appropriate education. The low cost opportunities also have a carbon dioxide reduction potential of 15 000 tonnes per year.

3.5.1.3 SAPPI Kraft and Anglogold Elandsrand Mine assessment

Similar studies were done for SAPPI Kraft and Anglogold, Elandsrand mine. The studies concluded that substantial savings could be achieved if options identified by the study were implemented. Below are the outcomes of the studies.

Table 3.8 Proposed options for energy saving at SAPPI Kraft

Option	Cost (R)	Return (R/Year)	Payback	Group
Improved power factor correction	270 000.00	540 000.00	Six months	3
Rigorous program for saving compressed air	53 000.00	106 000.00	Six months	1
Rigorous program for saving steam	2011 000.00	4020 000.00	Six months	1
Efficient light upgrades	888 000.00	888 000.00	One year	3

Source: Energy Research Institute, 2001

With a total investment cost of R3.33 million these options were going to achieve energy earnings of above R5.55 million, which represents a saving of more than 5% of the total energy consumption. These measures generally have a short pay back period of six months. The maintenance and low cost measures that were identified would cost a total of R2.06 million, achieving an annual energy saving of R4.13 million with an average pay back period of six months. Implementation of these measures would also achieve a yearly carbon dioxide reduction of 65 200 tonnes and a yearly sulphur dioxide reduction of 1185 tonnes. As in other case studies, improved energy management would be achieved by increased responsibility and accounting, proper cost allocation practices and rewarding initiatives and offering incentives to staff to encourage the effort to go that extra mile which is always desired in energy efficiency.

Table 3.9 Proposed option for saving energy at Anglogold Elandsrands mine

Option	Cost (R/yr)	Return (R/Year)	Payback	Group
Rigorous program for saving compressed air	192 000.00	384 000.00	Six months	1
Rigorous inter-stage cooling maintenance/retrofit for surface air compressors	500 000.00	1200 000.00	Five months	2/3
Rigorous after-stage cooling maintenance/retrofit for surface air compressors	500 000.00	See knock on effects	13months	2/3
Knock on effect on refrigeration from improving after-cooler performance		R308 000 (Value of additional heat input to mine		

Source: Energy Research Institute, 2001

Implementation of all measures required a total investment of R1.293 million and had a total energy earnings of R1.99 million annually and an average pay back period of eight months. Maintenance and low cost measures required less that half of their energy saving; a total investment of R692 000 and achieving an annual energy earning of R1 584 000 annually. These had a pay back period of about five months. These measures also resulted in huge environmental benefits. On a global, level they achieved a carbon dioxide reduction of 9 700 000 tonnes per annum while achieving a sulphur dioxide emission reduction of 70 000 tonnes per annum.

3.5.2 Energy efficiency studies in Zimbabwe

3.5.2.1 The SADC Industrial Energy Management Program (SIEMP)

In Zimbabwe, the SADC Industrial Energy Efficiency Improvement Program (SIEMP) carried energy efficiency assessment studies which have shown that savings of about 30% could be achieved through good housekeeping, another 20% through low cost investments while 10% savings could be achieved through capital investments, (SIEMP, 1993). This study was focused on the small to medium scale industry in the food beverages and textile industries. A significant outcome of this program is the improvements, which have been achieved at the National Breweries, whose energy intensity of production is now at the world average, while the average of the Zimbabwean economy is at four times the world average.

3.5.2.2 The ZISCO study

In 1991, Kaliyati carried out a study on the Zimbabwean iron and steel industry, with a completely different focus. The objective of the study was to answers 3 questions stated below and make policy recommendations on how ZISCO could play an important role in the industrialisation of the SADCC region.

- Why the Zimbabwean economy is so highly dependent on steel imports yet it has an iron and steel industry with such a large capacity? (Rated output 1 million tons per annum and maximum ever achieved 800 000tons).
- Why has the iron and steel industry been made an export enclave industry?
- Why progress in the development of the capital goods sector is at best limited and at worst non-existent, although there has been an iron and steel industry to back that up since 1948?

Some conclusions from this study were that Zimbabwe could play an important role in the industrialisation of SADC through the supply of various steel products from its large integrated mills. Although Angola, Mozambique, Tanzania and Zambia have steel processing facilities, these are dependent on scrap and only produce a very narrow range of products.

A capital goods market could be developed through the cooperation of SADCC member states. The lack of the capital goods market has hindered the development of the Zimbabwean iron and steel industry. This industry has been deliberately used as a foreign currency earner particularly for the regime before independence however; benefits from this were limited as these exports were made at low prices. This was a result of the fact that sales were being made to a market, which already had excess capacity but did not have basic raw materials. Zimbabwean products were thus bought as part of input materials. This study did not consider any energy efficiency issues at all.

In 2000 UNIDO/COMESA commissioned a study on energy conservation in ZISCO steel and Steel Makers Zimbabwe. The study established that savings of between 30-40% could be achieved through:

- Reduction of combustion heat losses and increasing heat recovery
- Integration of maintenance procedures related to energy efficiency into regular maintenance procedures
- Application of potential heat recovery systems from boilers and furnaces for preheating inputs such as water and air and use of exhaust gases
- Use of more efficient compact lamps instead of incandescent and fluorescent lamps for lighting in administrative offices and factory shades
- Power factor correction and use of automatic load control for electric motors

- The study also established that ZISCO could increase power generation for own use and export to the grid through high pressure Condensing Extraction Steam Turbines (CEST) technologies using BF and CO gas instead of the currently installed low pressure boilers. The first five measures had a payback period of less than one year while the last onehad a payback period of 2years and an energy saving of a factor of three.

3.5.2.3 The Department of Energy and SCEE studies

In 2000, the Southern Centre for Energy and Environment, in conjunction with the Department of Energy Zimbabwe, carried out a study to identify the barriers to energy efficiency in the Zimbabwean industry. They identified some major barriers discussed in Chapter 7. In 1996, the same team carried out a study on building partnerships for increasing capacity to achieve energy efficiency in industry.

A study carried out by the Southern Centre on developing methodologies for green house gas mitigation looked at possible technology improvements for ZISCO but not in much detail. Moreover nothing specific was recommended for the iron and steel industry except the possibility of looking into new more efficient technology (Southern Centre for Energy and Environment et al. 1992). It is thus apparent that although these studies looked at aspects of industrial energy use, they did not specifically address energy efficiency in the iron and steel industry.

3.6 ENERGY EFFICIENCY IN THE IRON AND STEEL INDUSTRY

Several studies have been carried out, which have shown that potential exists for energy savings in the iron and steel industry. Over the years, the iron and steel industries has undergone a lot of changes that were driven by social, political and technological environments. For instance, the demand for high quality steel in the 1950s and 1960s encouraged the industry to make large quantities of high quality steel. This led to the advent of highly capital intensive and rather inflexible large integrated mills (Chatterjee, 1995). Energy and production efficiency was not a major issue of concern for most countries that had over capacity. Table 2.3 has shown this trend in most of the major producers. However the energy crisis of the 1970s and 1980s demanded changes in the energy use patterns in order to survive in business. Moreover, the increase in competition due to reduced market as a result of the general decline in world steel consumption called for reduction in costs if companies were to stay competitive on the international market. Since energy costs are a major contribution to production costs in this industry, energy efficiency became an important and urgent issue. A number of studies have been carried out for both developing and developed countries, with a view to establish areas for potential energy efficiency and process improvement and related constraints. The brief discussions given below summarises the work that was done in this area.

Energy efficiency in the iron and steel industry can be improved through:

- *Increasing energy efficiency of steel production-: achievable through installation of more efficient equipment and implementing good house keeping measures*
- *Changing the manufacturing process-: installation of new technology/equipment*
- *Changing input raw materials, fuel and product mix and recovery and use of recovered fuels and changing working methods.*

3.6.1 An Asian study

The Asian Institute of Technology carried out a study for four Asian countries (China, India, Philippines and Sri Lanka), which showed that iron and steel industry was inefficient, responsible for significantly polluting the environment and that there were barriers to overcoming these problems which needed to be addressed (Mohanty, 1997). The activities carried out by this study are outlined below.

- Evaluation of the status of technologies in the selected energy intensive and environmentally polluting industries,
- Identification of potential areas for energy conservation and pollution abatement in these industries,
- Analysis of the technological development of energy intensive and polluting industries in relation with the national regulatory measures and
- Identification of major barriers to efficiency improvements and pollution abatement in the industrial sector.

The Study made the following conclusions;

- The Asian iron and steel industry had expanded plant capacities, built new factories thus consequently increasing production. However, there has been limited attention to efficient use of energy and control of environmental pollution.
- The major constraints to energy efficiency and environmental protection are: obsolete production technology, archaic industrial infrastructures, absence of appropriate management skills and an energy structure, which is dominated by coal.
- The iron and steel industry is the biggest culprit for both inefficient use of energy and pollution of the environment.

In view of their findings, they recommended that the industry should adopt an integrated planning approach for energy and environmental management to ensure that there is improved energy efficiency and that the industry is more sensitive to environmental protection.

3.6.2 A Mexican study

A study was carried out in Mexico, to assess the potential to improve energy efficiency in their iron and steel industry (Ozawa et al, 1999). The results showed that in 1995, the Mexican iron and steel industry consumed 17.7% of industrial energy demand. However although steel production increased by an annual growth of 4.7% between 1970 and 1995, the energy intensity in this industry declined considerably. The specific energy consumption of the Mexican iron and steel industry dropped from 28.4GJ/tonne to 23.8GJ/tonne of crude steel, a significant decrease of 16.1%. This reduction in intensity was attributed to the improvements in efficiency that the Mexican industry underwent. These improvements were due to two main factors, changes in technology and structure. In 1992, Mexico completely phased out the inefficient Open Hearth furnaces (Price et al 1999), while increasing the share of continuous casting which is a more efficient technology. The industry share of scrap input into steel making also increased (Ozawa et al, 1999).

3.6.3 Other studies

In 2002, a study aimed at comparing the energy efficiency in the USA and five major developing country steel producers was carried out (Phylipsen et al, 2002). The five developing countries analysed were Brazil, India, China, Mexico and South Korea. They looked at technological development, energy intensities, energy efficiency index and the levels of use of the various steel-making technologies in the countries studied. The study was related to the Climate Change debate by linking the countries' steel industry operations to the expected Clean Development Mechanism of the Kyoto Protocol through energy efficiency programs.

It was concluded that the general belief that energy efficiency of the iron and steel industry in developing countries is lower than that in developed countries is not necessarily correct. In fact, it was found that the industry in South Korea, a developing country, was more energy efficient than a similar industry in USA. The study also showed that over the years, Brazil, Mexico, India and China have adopted more energy efficient technologies in their iron and steel industries, which have improved their energy efficiency to levels that are comparable to those found in USA. Also, primary energy consumption per unit production in Brazil and Mexico was similar to that observed in USA, while that of China and India was found to be higher. It was also noted that Brazil and South Korea have had lower energy intensities than the USA for more than a decade, spanning from the early 1980s to about 1995. However except for South Korea, the rest of the countries were not operating at their most efficient levels. The study placed the rest of the countries energy consumption at over 25-70 % of the best plant. This implies that great potential exists to lower their energy consumption.

3.7 SUMMARY

It has been shown that iron and steel industry consumes the largest percentage of national energy demand. The iron and steel industry is important for economic development. The discussion has also shown that energy intensities are declining in developed countries while rising in developing countries, a cause for concern because most developing countries import a large share of their commercial energy. Although industry, particularly iron and steel industry, consumes a large share of energy, savings are possible with appropriate investments, policies, strategies and plans formulated and implemented as this would lead to the adoption of appropriate technologies.

This discussion has also shown that despite the importance of the iron and steel industry to national development and the possible energy savings through energy efficiency programs, not many studies have been done to establish the energy efficiency status of this industry and the potential to improve energy efficiency in South Africa and Zimbabwe. However the UNIDO/COMESA study established that savings of between 30-40% could be achieved in ZISCO. Furthermore, no study has been done to establish the technological development and energy intensities in both countries. Although industrial energy efficiency studies have been done in both South Africa and Zimbabwe, in South Africa none of these studies have addressed energy efficiency in the iron and steel industry. It is with this background in mind that this study wishes to address the issue of energy efficiency in the South African and Zimbabwean iron and steel industry with a focus on technological developments and their linkage to reduced energy intensity.

CHAPTER 4

THEORETICAL CONSIDERATIONS

4.1 RATIONALE FOR THEORETICAL CONSIDERATIONS

Certain theoretical concepts are useful for understanding energy efficiency and energy intensity. This chapter provides a theoretical background, aimed at enhancing that understanding. It gives a brief review of some of the theory, which forms the basis for the principles underlying energy intensities. Energy efficiency and energy intensity is estimated through the use of energy efficiency indicators. The concepts of energy efficiency indicators are briefly explained below. This includes how they are obtained, their usefulness and constraints associated with using them.

4.2 DEFINITION OF ENERGY EFFICIENCY

Energy efficiency is a measure of how effectively energy can be used or the usefulness of a unit of energy in producing a unit of a given product. An energy indicator can be obtained by dividing the energy consumption by the amount of units produced. Thus energy efficiency is a measure of the amount of activity or service that can be provided per unit of energy used. This value can be regarded as being entirely dependent on technical efficiency. It can also indicate how effectively a given piece of equipment performs its task. However, normally human behaviour also plays an important role in determining consumption patterns. For instance, a decision to take off a sweater or jacket in a hot room instead of switching on the air-conditioner makes a difference to the amount of energy consumed in the building, thus affecting energy efficiency.

Energy consumption in an economy is dependent on three important factors, which include;

- Level of overall production or activity,
- Output or activity per unit of energy consumed, and
- Composition or structure of the economy

Activity is defined in volume or weight. Thus firstly, activity levels are measured in tonnes, litres, or metres of the product produced. The second factor measures the efficiency of the economy (Phylipsen et al. 1998) and is normally referred to as the energy intensity of production. The energy intensity of production indicates how much energy is being used per unit of product (physical intensity) or per GDP produced (economic intensity). It also measures how much service or product a unit of energy provides. It therefore defines the efficiency or inefficiency of the economy, industry or plant. At times energy efficiency is used interchangeably with energy intensity and is defined by GJ/tonne at the plant or industrial level and GJ/$ at the industrial or economy level (Phylipsen et al.1998). Thus energy intensity is an indicator of the efficiency of a given economy.

Energy intensity is the most often used factor for assessing energy efficiency trends because it provides the most accurate measurement for energy efficiency. Another measure of energy efficiency can be obtained through rigorous measurements at a particular process or plant level (Farla et al. 1997; Phylipsen et al. 1997). However, this needs extensive and comprehensive data requirements, which are not always available and can make accurate work more cumbersome, time consuming and expensive.

Energy intensity is inversely related to efficiency. Implying that when a process, plant or economy requires less energy to produce a unit of output or service, it has a better energy efficiency than one, which requires more energy to produce a similar product or service. Therefore, in the absence of other factors affecting efficiency, it can be safely concluded that declining energy intensities in a given economy, plant or industry is an indication of increasing energy efficiency in that industry.

4.3 STRUCTURE AND EFFICIENCY OF AN ECONOMY

At the level of a national economy, the economic structure is determined by the mix of different activities. While at the industrial sector, the product and the process mix determine structure. At individual industry or plant level the input raw materials and product mix determine structure. Structure is an indication of how input raw materials and process types affect product quality, product mix and energy consumption. For instance poor quality iron ore and coal will increase the energy intensity of a steel mill and produce low quality pig iron. While the use of scrap in steel making and externally obtained clinker in cement making will lower the energy intensity of a steel mill or cement plant respectively (Phylipsen et al, 2002). These are both examples of structural effects of raw materials on energy consumption. However, in this case a positive result should not be regarded as an energy efficiency gain nor a negative impact an energy efficiency loss, but regarded as the impact of a change in structure.

Another important structural indicator is the use of imported and exported energy intensive intermediates such as coke for the iron and steel industry. This results in lowering the overall intensity of the plant as the coke making process has been skipped. However, it must be noted that feedstock and process type are not usually regarded as structural indicators, except in cases where they affect product mix or product quality. In view of the impacts of structural effects on process efficiency, energy efficiency analysis may require that the effects of energy efficiency be separated from structural effects. This can however be very complex and problematic particularly since data to support this kind of separation may not be readily available. Another important fact to consider in this kind of analysis is that energy efficiency indicators are always approximations of actual energy efficiency values (Phylipsen et al, 1998).

4.4 FACTORS AFFECTING ENERGY EFFICIENCY

Factors that affect energy efficiency vary from structural effects as already discussed above, to human behaviour and technological and process changes. Human attitude and behaviour can seriously affect and even erode a potential successful energy efficiency program, while the age, state and level of technological advancement will determine the potential for improving energy efficiency.

Human behaviour is very important in that in most cases where successful energy efficiency programs are implemented; change in attitude and perspective is required. If there is no change in attitude and perception on the part of management and engineers, energy efficiency improvement programs will not be realised. In addition, successful energy efficiency involves positive response of people involved. For instance, putting incentives that encourage managers and engineers to undertake extra effort and refrain from using bad habits is a prerequisite to successful energy efficiency programs. For example energy efficiency measures such as good house keeping require this kind of action with no real capital investment. Management also has an important part in choosing technology options and investments both of which ultimately affect energy efficiency improvements.

Technological change is crucial to improved energy efficiency. The type and age of technology used in an industry will to a very large extent determine the efficiency levels achieved within that industry and the right process changes would increase energy efficiency in a given industry.

4.5 TYPES OF INDICATORS

Available literature suggests that there are different measurements for energy efficiency, and in quantitative terms energy intensity indicators are used. Three such indicators can be identified in the literature namely, thermodynamic, physical and economic indicators (Patterson 1996).

4.5.1 Thermodynamic indicators

Thermodynamic indicators provide an objective measure for a given process in a particular environment, thus they define energy efficiency relative to the first or second law of thermodynamics. Hence, when efficiency is defined relative to the first law, it is based on the heat content of inputs and outputs of a given process or piece of equipment. Whereas if it is relative to the second law, it is based on the theoretical least amount of energy for a given task in relation to the heat content of inputs of the process or equipment.

4.5.2 Physical indicators

Physical indicators are ratios, which express energy consumption, or energy input in common units of measurement such as joules and outputs in common units of measurement such as tonnes or litres. Physical indicators offer an easy way to track energy efficiency as they provide a way to understand the relationship between a unit of goods produced and the amount of energy required to produce those goods. This is because many believe that changes in physical indicators offer a more dependable way for estimating changes in energy efficiency (Phylipsen et al. 1996, 1997; CIEEDAC 1996; Farla et al. 1997). The major draw back is that they require disaggregated data for their construction, which is not always easy to obtain. Moreover the diversity of industrial products and manufacturing processes make it difficult to develop a single aggregate measure of energy intensity using physical indicators. This is clear when industrial out put are given in tonnes, litres and metres which are not additive. Even in cases where products are measurable by the same unit, but produced through different processes, which have different intensities. In order to cope with this, sometimes, economic energy intensity indicators are used.

4.5.3 Economic energy intensity indicators

The estimated efficiency of an economy is expressed by using national economic indicators such as GDP or GNP. Energy intensity is calculated as the amount of energy required to produce a unit of GDP. Their advantage is that they resolve the problem of aggregation by using monetary values for all products. Economic indicators provide an important tool for policy makers. They provide a single number that portrays the energy consumption situation in an economy in a manner that physical indicators do not easily do. However, they have a disadvantage in that monetary proxies are used for non-monetary units. They also give a much weaker representation of the relationship between energy consumption and the value of output than does physical indicators. Moreover the accuracy with which they estimate changes in energy intensity will vary depending on the country and the data sets, more so in view of the differences in currencies and definition of monetary values (Worrell et al 1997). This is particularly so in view of the dearth in data for most developing countries. In fact economic energy indicators of this nature are generally regarded as good measures of economic efficiency much more than energy efficiency (Phylipsen et al. 1996).

4.6 CALCULATING ENERGY EFFICIENCY/INTENSITY

Since physical indicators have been identified as the best trackers/estimators for energy efficiency they will be used to calculate energy intensity in this research. Moreover they provide a simple and straightforward method of estimating energy efficiency and changes in energy efficiency trends.

The energy intensity of some good *(a)* can be defined as:

Equation 4.1: $$SEC_a = \frac{E_a}{P_a}$$

Where E is the specific amount of energy consumed by an activity or used to produce good (a) while P is the output produced by activity (a) or the amount of good (a) produced and SEC is the specific energy consumption value or the energy intensity indicator.

Therefore for a given sub-sector (*y)* for instance the iron and steel industry SEC is given by:

Equation 4.2: $$SEC_y = \frac{\sum_{a=1}^{n} E_a}{\sum_{x=1}^{n} P_a}$$

Where the numerator is the summation of the energy used to produce all goods in sub-sector (y) and the denominator is the summation of the quantity of goods produced by sub-sector (y). An important assumption made is that all goods are expressed in the same physical unit since their quantities are summed together in the denominator. Since this is not always the case and differences could also occur based on the type of output, to go around this problem (Worrell et al. 1996; Farla et al.1997) advocate the use of physical production index (PPI). This is basically a weighting, which enables the indicator to account for any changes in the composition of output from the sub-sector. Therefore for a given sub-sector, the PPI is defined as:

Equation 4.3: $$PPI = \sum_{a=1}^{n} (P_i)(w_i)$$

Where the output of each sub-sector y is weighted by some factor w. This factor reflects the total energy requirement for the production of all the goods in that sub-sector. According to Farla et al. 1997 the weighting factor must be chosen in such a way that it accurately portrays the amount of energy required to produce the sub-sector output. The weighting factors can be based on number of already defined standards in the sector. These include Best Practice Observed (BPO), Best Practical Means (BPM), Best Available Technologies (BAT) or An Average SEC (AASEC) (Phylipsen et al. 1997). These are representations of situations that are either possible or currently on the ground and operational. The meanings of these standards are given below

- BPO reflects what happens in a complete production plant that is fully operational and has attained the lowest SEC.

- BPM is derived from a potential lowest SEC production plant that can be attained with proven technology use and prudent investments
- BAT represents a lowest SEC production plant achievable with proven technologies
- AASEC is based on an average energy efficiency value that could be used as a benchmark for comparing countries and regions that have the same characteristics.

Although there are some problems related to the use of these weighting factors, they provide an easy way to compare and track energy efficiency changes. Weighting factors can be used to create reference SECs for a number of sectors and the sectoral indicator obtained through this method is given as Equation 4.4 below. Comparison of actual SEC to reference SEC gives an indication of how efficient a country or a sector is in comparison to other similar sectors.

$$\text{Equation 4.4:} \quad \text{Sectoral Indicator} = \frac{\sum E_a}{\sum E_{ref,a}}$$

Thus if the ratio of the specific energy consumption to that of the reference energy consumption is equal to one, it means the sector is using energy optimally, meaning it is as efficient as possible within the given operational parameters. If it is higher than one, then it is inefficient and less than one indicates that energy efficiency has improved. In theory this could be an indication of when a new benchmark is needed.

A sectoral indicator is an important tool for policymaking as it provides a single value for assessing levels of energy consumption in various sectors and sub-sectors. It allows the policy maker to identify, which sectors are efficient and which sectors are inefficient energy users. More importantly, it allows the policy maker to visualise the difference between actual energy use and a potential minimum energy use. Its simplicity and ease of application also renders it a lot more user friendly than other methods.

Since this study is only dealing with one plant and one product, steel, equations 4.1 and 4.2 have been applied for the required calculations. However the concept in equation 4.4 has been used to determine the relative efficiency of the South African and Zimbabwean steel industries in comparison to other producers. This concept has been applied based on already available values that have been calculated for best practice plants.

4.7 IMPORTANCE OF ENERGY INTENSITY INDICATORS

Energy intensity indicators are important in the economy as well as at the plant and the industrial level. They can be used to monitor progress in efficiency in cases where efficiency improvement policies and programs are implemented. Efficiency indicators provide a tool that allows a quantitative assessment of the factors, which contribute to changes in energy consumption. Thus it is important for understanding past and future consumption trends. More importantly these assessments enable the measurement of the performance of energy related policies and also provide a way to make projections on future trends for demand and supply. Furthermore, energy intensity provides necessary information to support energy efficiency and conservation programs (Farla et al. 1996). They can also be used to identify market trends and the potential and opportunities that are available for improvements. Energy intensity indicators are becoming more important not just as monitoring tools but they are also serving as the basis on which governments and organisations make energy efficiency policies, regulations and other interventions for better energy conservation.

In recent years, these indicators have made an important contribution to the climate change debate. They are now playing an important role in persuading governments to revisit their economic policies. Until after the second oil crisis in the early 80s', government policies in most countries were focused mainly on the impact of reduced energy consumption on economic growth. Thus energy policies for those countries who had policies because for most developing countries these were non existent (Karekezi & Davidson 1992) included some economic policies that focused only on increasing and expanding economic growth. More recently however, energy policies are being formulated such that they address both the economic growth aspects associated with improved energy management as well as the environmental benefits that accrue from increased energy efficiency (Golove and Schipper 1997; Bosseboeuf et al. 1997). For countries which use a lot of fossil fuel, energy intensity is closely related to carbon intensity and the higher the carbon intensity of a fuel the more polluting the economy is. Thus the more fossil fuels consumed in a given highly energy intensive country the higher the carbon emissions of that country (IPPC, 1995; Schipper et al. 1997).

Therefore trends in energy intensities can provide both national and international policy makers with appropriate information and a policy making tool that will enable them to formulate appropriate strategies and programs for green house gas mitigation. Furthermore energy intensity indicators can be used to identify the major industrial targets for these mitigation programs. They are also important for the formulation and targeting of industrial efficiency improvement programs.

4.8 UNCERTAINTIES OF ENERGY INTENSITY INDICATORS

Although energy indicators could be important as discussed above, there still remain a number of unresolved issues. These are enumerated below

- Disagreements and uncertainties surround development, interpretation and application of intensity indicators
- The best method of construction for both physical and economic energy indicators
- Trends illustrated by physical and economic indicators are sometimes very different and this raises interpretation issues.
- There are still a lot of uncertainties with regards to application of indicators.
- It is not yet clear whether intensity indicators are appropriate for all types of energy analysis.
- It cannot yet be said with certainty that they are applicable for policy making.
- It is also still not very clear which indicators are appropriate for which purposes.

These issues will limit the usefulness of energy intensity indicators particularly when they are used for cross-country comparisons.

In this work therefore estimation of efficiency in the iron and steel industry is based on the above theoretical framework. Energy intensity levels are estimated based on the equations given above and efficiency is estimated from comparisons among technologies and with other countries and plants.

CHAPTER 5

FIELDWORK AND RESULTS

This chapter describes the fieldwork carried out in South Africa and Zimbabwe. Data collected include energy use, composition of the iron and steel industry, technological status, production volumes and markets. However, because this data was not adequate, it was augmented by secondary sources. In certain instances, data had to be obtained from international organisations such as IISA.

5.1 FIELD WORK

For the field visits, the two plants visited were ZISCO in Zimbabwe and Vaal in South Africa. However, the visit to Vaal revealed that it is not an ISP.

5.1.1 Location of the industries

ZISCO is located in the small town of Kwekwe in the Midlands Province of Zimbabwe. The presence of the plant has led to significant increase in the population in the towns of both Kwekwe and Redcliff that are situated along the Great Dyke, an important mineral belt in Zimbabwe. In South Africa, the iron and steel plants are concentrated in the Gauteng area, with isolated ones in Kwazulu Natal and another in the Western Cape province. The location of the Zimbabwean and South African steel plants is shown in Appendix 1 and 2.

5.1.2 The Vaal Vereeniging visit

A one-day visit was made to ISCOR Vaal, and an interview was carried out with the Plant Maintenance Manager. The plant tour provided information on the production method, technology used, plant layout and set up as well as the production process. It was also a good way to see some of the actual products being made.

The interview provided data on production volumes, energy consumption and some policy, strategy and market issues. The discussion on policy issues was made possible because ISCOR is a private company and policies are largely made within the company unlike ZISCO, where policy making is by government. The data collected is indicated in section 5.3 below. Less time was spent at the Vaal plant for two main reasons. Vaal is completely computerised; therefore it was much easier to collect information. Moreover, Vaal is an EAF based plant so it is smaller than an integrated steel mill. Data from a South African ISP was important for a more complete analysis. However obtaining data from either New Castle or Vanderbijl Park was difficult. An estimate of the global energy intensity of South Africa was calculated from international data obtained from IISA.

5.1.3 The ZISCO visit

In Zimbabwe, a four-day visit was made to ZISCO. In the plant a tour was made and interviews were carried out with an Operations Manager, Power Station Manager, Director Finance Department, the Energy Centre Manager and Coke Ovens Manager. More time was needed in the ZISCO plant because as already mentioned an integrated steel plant is big, and one cannot see all the processes in one day. The ZISCO plant covers quite a significant area. For example, the Sinter plant is more than a kilometer from the main plant, while the coke ovens are about thirty minutes walk from the main administration block. The visit was however very useful as it indicated the operational levels of ZISCO and the reality of the problems that the company is facing.

Most of the plant was down either from lack of input or for maintenance. For sometime now ZISCO has been operating well below its capacity, thus quite a number of production centers were shut down. For the duration of this visit most of the equipment such as the BOF, the new sinter plant, the continuous caster, the cog mills, the bar rod mill, the LD converters and soaking pits were offline and it was not clear when they would be operational.

A serious constraint, which made it necessary to spend more time at ZISCO than at ISCOR, was that ZISCO data is not computerized, except for a part of the finance department and the production center. Thus a lot of time was spent looking at old files to retrieve some of the required information.

Another problem encountered with ZISCO data was that it was fairly raw. In some instances data such as monthly consumption had to be collated to get the required annual figures.

Integrated steel mills usually produce some of their electricity, however although the power plant was operating, it was not producing any electricity. Reasons given were that since the blast furnace was not operating at full capacity, the produced gas was insufficient for electricity generation. The type of data collected is indicated below.

A visit was also made to the Ministry of International Trade in Zimbabwe, which oversees ZISCO operations. This visit yielded information relating to policies that guide the operations of ZISCO. It also confirmed some of the information on the constraints and problems faced by ZISCO.

Since ZISCO is not computerised, several data sets were from various sources in the plant. For example, the Energy Centre had data on unit consumption but no cost related data. The Finance Department had most of the cost data, the only problem is that most of it was not computerised so had to be retrieved from files that were not always available. Although data was available from 1992 to 2001 and initially data for the years 1995-1999 had been used, after partial analysis some inconsistencies were revealed. Hence it was decided to use another set of data, whose 1995-1997 figures seemed consistent and complete except for the coal quantities and costs. Some of the files with coal cost and quantity data could not be accessed within the four days visit.

5.2 RESULTS OF THE FIELD VISITS

5.2.1 Identification of technologies and processes

In order to understand the relationship between iron and steel-making technology and energy efficiency, some appreciation of the types of technology used and the amount of energy they consume to produce iron and steel is needed. Therefore, the various technologies for iron and steel making are presented as well as an iron and steel production flow chart (Figure 5.1), which illustrates the technologies used in the iron and steel making process.

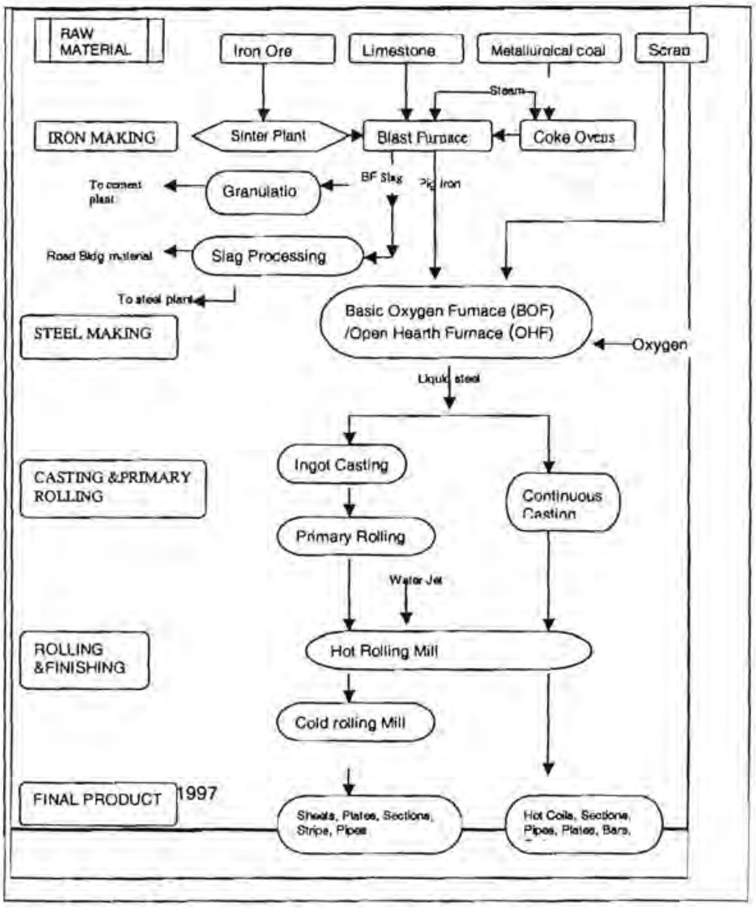

Figure 5.1 Process flow-chart of iron and steel making

Figure 5.1 above shows the technology and processes used at each stage of the iron and steel making. The technologies used in the ISP are almost standard. The major difference in efficiency arises from the age and type of technology and the size of the plant. In the ZISCO, plant the following technologies and processes were identified.

Table 5.1 Technology profile of ZISCO

Process	Product	Technology
Coal & Limestone fines coagulation	Sinter	Small old sinter plant, Massive new sinter plant
Coal gasification	Coke, coke oven gas, tar	Old coke ovens
Iron making	Liquid iron, BF gas, slag	4 Blast furnaces, 3 old ones all down, 1 new state of the art working one
Steel making	Liquid steel	BOFs, LD converters
Casting	Ingots, blooms & billets	Old conventional caster, one new 6 strand caster
Rolling mills	Bars, rods, blooms, billets sections	Old billet and bloom mill Old bar rod mill Old medium mill

Energy consumption and production data was collected for the whole plant and for most of these technologies and processes. The data collected is given in Tables 5.2-

5.5 below. All energy consumption data has been converted to gigajoules and data has been provided for 3 years.

5.2.2 Data collected

5.2.2.1 Energy consumption

ZISCO uses several types of energy in the production of iron and steel with coal contributing the largest amount in the form of coke, coke oven gas and blast furnace gas. ZISCO does not have the data to show the direct use of coal as a fuel, but have the data for coke, coke oven gas and blast furnace gas. Energy efficiency analysis has also been restricted to the actual operations of the plant. Data on energy was converted to gigajoules. Annual consumption was obtained for electricity, blast furnace gas, coal, coke, coke oven gas, and LPG. This is presented in Table 5.2 below.

Table 5.2 Energy consumption by technology/process and by fuel type

Energy Type (TJ)	*LPG*			*BF Gas*			*Coke Oven Gas*			*Electricity*			*Coke*		
Process/ technology	1995	1996	1997	1995	1996	1997	1995	1996	1997	1995	1996	1997	1995	1996	1997
Bar Rod Mill	1.67	1.14	1.34	18.58	26.54	183.81	150.90	179.62	139.86	353.48	46.20	40.02	150.89	179.62	139.86
Light Mill	0.42	0.33	0.35	7.41	8.84	6.80	59.09	60.67	536.63	9.55	7.50	9.53	59.09	60.67	536.63
Medium Mill	0.57	1.04	1.21	18.59	22.01	21.26	149.78	143.60	159.55	9.67	9.28	8.26	149.78	143.60	159.55
Heavy Mills	0.39	0.48	0.48	14.53	25.61	25.10	138.60	173.03	192.23	19.36	21.50	20.64	138.60	173.03	192.23
BF & BF ladles				440.59	442.65	406.04	50.90	59.27	72.87	33.88	30.93	27.66	4722.94	4734.09	
Steel Plant	4.78	2.90	2.80	4.78	2.90	28.00	211.27	210.83	206.62	57.77	57.77	58.30	211.27	210.83	206.62
Coke Ovens				708.47	607.02	916.66	348.36	352.92	289.87	33.33	31.05	31.75	348.36	352.92	289.87
Sinter Plant				6.93	5.32	14.93	51.82	35.97	104.19	24.83	16.59	0.41	51.82	359.68	104.19
Totals	7.83	5.90	6.17	1215.10	1138.00	1574.60	1160.72	1215.91	1218.84	223.74	220.80	196.56	1160.72	1215.91	121.89

Table 5.2 shows the amount of each type of energy used by the various processes/technologies. This data enables the calculation of the intensity resulting from use of each fuel by the various technologies/processes. It also gives an indication of the type of energy each process/technology uses.

Table 5.3 **Total annual energy consumption by type in (GJ)**

Year	BF Gas	C/O	LPG	Electricity	Coke
1995	1215096	1160721	7827.546	223735.5	4722942
1996	223735.5	1137988	5895.069	220794.3	4734088
1997	1574602	1218839	6167.271	196560.6	163381

The data in Table 5.3 shows the consumption pattern in the mill. For instance higher electricity consumption implies the combination of an ISP with an EAF operation, while high coke and coke oven gas consumption implies the operation of a typical ISP.

Table 5.4 **Total energy consumption by process/technology 1995-1997 in (GJ)**

	1995	1996	1997
Sinter Plant	58755	41283.9	119119.2
Coke Ovens	1056830	959942.4	1206521
Steel Plant	216044.9	213730.9	209419.6
BF# 3	3295892	3268789	2574456
Heavy Mills	172877.8	220614.7	238446.8
Medium Mill	178602.1	175923.9	190278.4
Light Mill	76479.47	77333.06	70344.59
Bar Rod Mill	206490.5	253502.4	365014.6
Total	5261973	5211120	4973600

Table 5.4 indicates the total energy consumption of each technology/process and along with data from Table 5.5 were used to calculate the energy intensity of each process/technology. The intensities of the various technologies are indicated in Chapter 6.

5.2.2.2 Production

Annual production values for each process/technology were also obtained and are given in Table 5.5 below.

Table 5.5 **ZISCO annual output by process/technology in (GJ)**

	1995	*1996*	*1997*
Bar Rod Mill (Steel)	66794	78398.2	61445.8
Light Mill (Steel)	17469.7	19900.7	17087.1
Medium Mill (Steel)	47714.4	45926.4	49832.3
Heavy Mills (Steel)	19794.6	32430.2	23795.5
BF & BF ladles (Iron)	207118	220317	216738
Steel Plant (Conventional Steel)	80218.5	110386.9	102163.6
Steel Plant (Conti-cast Steel)	148591.7	115432.4	116171.4
Coke Ovens (Coke)	293182	269641	317272
Sinter Plant (Sinter)	102994	90046	291591.9

From Table 5.5 it is apparent that the coke ovens produced the highest volume of product over the years, followed by the blast furnace, while the light mill produced the least volumes.

5.2.2.3 Production Costs

Annual production costs were also collected for the plant for stated years. These mainly included energy costs. Not much analysis could be done using the cost, as the information was incomplete. Moreover, international literature on cost is not easily accessible and comparisons could not be made.

The fieldwork yielded a lot of data on the operations of ZISCO and the guiding policies. However, the South African visit had limitations in that Vaal operates an EAF while for adequate comparisons an ISP would have been ideal. Reasonable analysis was done using this data and the outputs are discussed in Chapter 6.

CHAPTER 6

ANALYSIS AND DISCUSSION

This chapter describes the analysis of the findings of the fieldwork described in chapter 5. A comparison of the Zimbabwean and South African iron and steel industry is done by looking at the size, structure, ownership, technological status, production capacity and volumes, and energy use of the industry. The energy intensities of the Zimbabwean and South African iron and steel industry are compared to those of other steel producers by using international benchmarks of various technologies. Attempts will be made to establish relationships between technology advancement and reduced energy intensities as well as estimating the potential savings based on current intensities in the cases studied, international best practice and other producers.

6.1 FINDINGS FROM FIELDWORK

6.1.1 Size of industry and energy use

Zimbabwe and South Africa have the largest steel making facilities in Sub-Saharan Africa, but South Africa's is much larger. The industry in South Africa is more diversified and uses better technology than Zimbabwe. South Africa was rated 7th in the IISI steel producing countries in 2001 and 19th in 2002 ranking for highest net exporter of primary steel (IISI, 2002). Within Africa, South Africa accounted for 62% of total crude steel production in 2002. Out of the 11.5 million metric tonnes of steel produced in the Eastern and Southern African region, South Africa produced 9,0 million tons, 90% of total production (ISCOR, 2003).

6.1.2 Ownership

ZISCO in Zimbabwe is a public company because the government is by far the largest shareholder (see Table 6.1), as most African iron and steel industries, while the South African steel industry is privately owned, making it more commercial oriented. However, there could be some advantages in being government owned. For example, in Zimbabwe, prior to independence in 1980, this industry was used to support the war and also as a cushion for the country against sanctions. At that time, the country sacrificed economic development for state security and sold the steel produced at a price well below market prices, since the country was desperate for foreign currency (Kaliyati, 1991). Currently the company is being subsidised by government as it is making huge losses and struggling to survive. Privatisation has enhanced development of the South African iron and steel industry. A different institutional structure and policy direction could probably improve the situation in the Zimbabwean industry.

Table 6.1 ZISCO shareholding

Shareholder	*%*
Government	89
Louth Minerals, South Africa	3
Anglo American South Africa Ltd	2.79
Stewart and Lloyds Overseas	1.76
Lancashire Steel Pvt. Ltd	1.76
Tanganyika Investments	0.81
AmZim Limited	0.75
Zambia Copper Investments Ltd	0.13

Source: ZISCO reports 2000

As mentioned before, iron and steel industry is privately owned in South Africa, except for Saldhana and Columbus Steel in which government still has some interests. Privatising iron and steel industry in South Africa has exposed the industry to the international trends and forced them to develop various strategies for survival. Consequently, it would appear that this exposure has contributed to the advancement and prosperity of the industry. It has been able to make huge investments in the state-of-the-art technology for production and process control equipment thus improving energy efficiency. Independent policy direction without government influence has seen the closure of plants that were less efficient, and not viable.

6.1.3 The structure of the industry

The structure of the industry in the two countries is very different. Zimbabwe has one large integrated mill, the Zimbabwe Iron and Steel Company (ZISCO), a large-scale producer of hot rolled steel and semi finished steel products. The country also has few other smaller base metal processing-companies among which the most significant ones are the Zimbabwe Mining and Smelting Company (ZIMASCO) and Zimbabwe Alloys Limited. ZIMASCO is a producer of high carbon ferrochrome and is privately owned by local and international business partners. It was worth about US$200 million in 2000 (ZimBiz Magazine, 2000). ZIMASCO earns the country foreign currency as the plant was established to service export markets.

Zimbabwe Alloys Ltd is a subsidiary of Anglo-American and produces low carbon ferrochrome for the stainless steel industry. Zimbabwe Alloys Limited is upgrading its furnaces for the production of high carbon ferrochrome in order to be more competitive on the international market (ZimBiz, 2000). This was a result of the decline in world consumption of low carbon ferrochrome. This company is involved in chrome ore mining and processing. It uses the EAF for smelting, making it one of the major industrial energy user. The other significant companies are Buchwa Mine, which used to be the source of iron ore for ZISCO. However since the discovery of large amounts of ore at Ripple Creek, which is less than twenty kilometres from the ZISCO plant, Buchwa has become less important as a source of ore. Instead, BIMCO, which mines ore from Ripple Creek and also supplies ZISCO with limestone, has replaced Buchwa. Another industry is Lancashire steel, which produces downstream products such as coils. Zimbabwe's contribution to the international iron and steel industry is insignificant.

South Africa has one huge company, ISCOR, which accounts for 74% of national steel production with several small companies such as Highveld Steel, which contributes (14%), Scaw Metals (7%) and Davsteel (5%). ISCOR is composed of several companies, which include ISCOR Pretoria, Vanderbijl Park, New Castle, Vereeniging and Saldhana. New Castle produces long products, Vanderbijl Park flat products, Vereeniging produces speciality steel, while the Pretoria plant produces a mixture of products and Saldhana is an export oriented steel producer (Engineering News, 1997). Iron ore used in ISCOR is from Sisheni in the Gauteng province. South Africa does not have good quality metallurgical coal and imports some of the coke it uses. This led to the adoption of the Corex technology. South Africa has the largest Corex plant in the world and it is the only country, to successfully combine the Corex and Midrex technology into a continuous casting process (Engineering News, 1997). Another company is Columbus steel, which is South Africa's largest producer of stainless steel.

6.1.4 Markets

South Africa has a huge local market by virtue of the size of its economy. In 2002, South Africa produced about 8 million tonnes of steel and the local market consumed 4.640 million tonnes while 3.385 million tons were exported (SAISI, 2002). South Africa's market is big in comparison with Zimbabwe, and can still be expanded. This supports the strategic direction of the iron and steel industry of growing the local markets as well as the high profit international markets. Figure 6.1 below shows the industrial consumption shares by end user, and the linkage between steel consumption and economic growth. It is believed that the more vibrant the building and construction industry, the more robust the economy becomes. Moreover, growth in the building and construction industry can be used as an indication of growth in the economy.

Figure 6.1 Share of South African domestic market by end-user

Adapted from SAISA, 2003

The 3385 exported tons of steel are sold to quite a diversified market and Figure 6.2 below shows the share of each market.

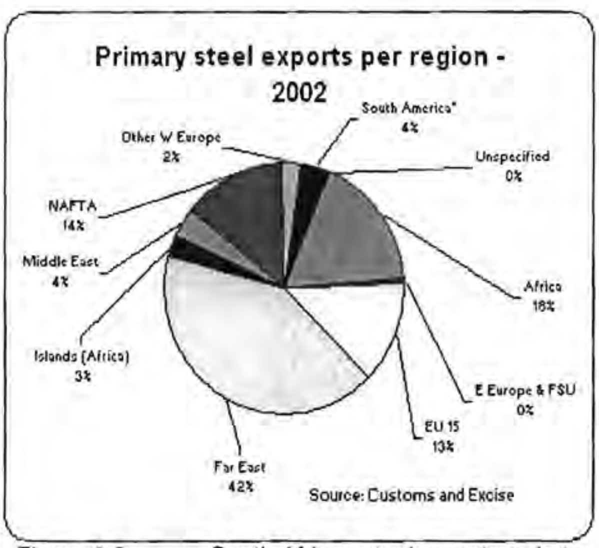

Figure 6.2 South African steel export markets

Source: Adapted from SAISI 2003

The Far East is South Africa's largest market accounting for 42% of South Africa's steel exports, followed by African countries that account for 18%, NAFTA 14% and the EU 13%. Steel is an expensive product to transport because of its low value to weight ratio, therefore it is always ideal to have markets closer to production.

However, for most developing countries, this is not possible because of small domestic and regional markets, which cannot absorb the bulk of their production. Therefore they are forced to supply to markets that are far away, which is not cost effective.

ZISCO has a relatively smaller local market. When the smaller blast furnace is working, 76% of its output is sold on the local market. The balance is sold on the international market, together with 70% of output from the larger blast furnace, which is mainly in the form of billets and blooms (ZISCO, 2000). However, ZISCO considers SADC and COMESA as part of its domestic market, which implies even smaller sales to the Zimbabwean market. As a strategy to effectively service their market, they use service centres in Harare, the capital, Kwekwe which is next to the plant and Bulawayo the second largest city. Regional centres are in South Africa and Zambia. ZISCO also sells crude steel to Botswana for further processing by Tswana Steel and also supplies markets out of Africa. Table 6.2 below indicates some of the regional and international markets of ZISCO.

Table 6.2 ZISCO markets for iron and steel

Region	*Direct*	*Indirect*	*Volume*	*Product*
Europe	Germany, UK	-	+/-15000 Mt /mth	Billets, Pig iron cast steel billets
SADC & Africa	SA & SADC	Egypt, Morocco, Nigeria	+/-15000Mt/ mth	Pig iron
Middle East	-	Saudi Arabia, Abu Dhabi, Dubai		Cast steel billets
Far East	-	China, Korea, Taiwan, Singapore, Malaysia, Phillipines		Cast steel billets

Source: Ministry of Trade and Commerce, 2000

The above table shows that ZISCO has a very limited range of products, and thus its markets are limited as well. An increased product range will give the industry more flexibility and increase its viability and competitiveness on the international market. Table 6.3 below shows the South African steel exports product range, which is considerably larger than ZISCO

Table 6.3 Sample of South African iron and steel industry exports

Intermediate products	Sections and Bars	Flat products
Ingots Billets Blooms Slabs Other Wire Rails	Wire rod Reinforcing bars Flat bars Other bars and rods Forged bars HR sections heavy/light Cold formed sections /bars	Plate in lengths>=5.75mm HR strip universal plate Cold rolled strip Electro galvanised strip HD galvanised strip Painted plastic coated strip Tin strip Other coated strip HR coil strip & plate coil Cold rolled sheet Electro galvanised sheet HD galvanised sheet Painted plastic coated sheet Tin sheet TFS Alu-zinc & other HD galvanised corrugated Plate in coil>=4.75mm

Source: SAISI, 2003

From the discussions in this section it is clear that South Africa has a much larger iron and steel industry than Zimbabwe, and has better and more advanced technology, which has been instrumental for product diversification and general development of the industry. Moreover, the fact that this industry is owned mainly by the private sector has contributed to its development and growth. In addition, the South African industry produces a larger range of products that enables the industry to service a variety of client requirements and niche markets. This strategy cushions the industry against intense international competition, which is inherent in the iron and steel industry. Zimbabwe, on the other hand, is not so advanced technologically and its product range is very limited, which restricts its expansion and growth potential. It can only service a limited market where it still competes with other companies. This discussion also supports the supposition that closure of old technology based plants and increased adoption of better technology must have reduced intensities in the industry in South Africa.

One of the comparative advantages of both Zimbabwe and South Africa is that they produces high quality virgin steel where other producers are moving into production of secondary steel through the use of scrap. However, Zimbabwe has not fully exploited this advantage.

It can be concluded that better and diversified technology enables product flexibility and diversification, which enhances the ability to service more clients and attract specialised markets. Zimbabwe currently cannot meet its demand, as their plant is producing at well below capacity. However, if full capacity is restored it will be helpful as there are interested potential customers. Therefore, serious consideration should be given to investments in new technology, which increase productivity, efficiency, effectiveness, flexibility, profitability and viability.

It can also be concluded that appropriate guiding policy determines the growth and extent of development, which occurs in a given industry. Privatisation with requisite government support has positively influenced growth and development in South Africa and elsewhere while public ownership has adversely affected growth and development in ZISCO.

6.1.5 Technological status

In general, ZISCO is operating a rather old technology. For instance, the light and medium mills use antiquated machinery and equipment that is over 60 years old. Out of its four blast furnaces, only two have been working in recent years. Currently, one is down and the other has been on line only for about 5 years. One of the blast furnaces is new with state-of-the-art loading, downloading and control technology. ZISCO also has an old batch caster and rolling mills, which are currently being refurbished. Iron and steel is produced through two main technologies. Thus all iron is produced through blast furnaces and all steel is produced through BOFs, unlike ISCOR that has several different processes for iron production and more than two processes for steel making. ZISCO has been making new investments to upgrade the plant in order to improve plant performance and output. For instance it has installed a new continuous six-strand caster, a 17 km iron ore conveyor belt from Ripple Creek, and a massive sinter plant. Parts of the ZISCO plant administration such as the finance section are also being computerised, while ISCOR in South Africa is fully computerized and has a website.

ISCOR has several plants ranging from integrated steel plants; electric arc furnace and these plants use several technologies and processes. It even has a plant that operates one of the world's best technology: COREX/MIDREX technology. Almost all the South African plants operate as specialist plants using either a special technology or producing for niche markets. Figure 6.3 below shows the share of each technology in iron production.

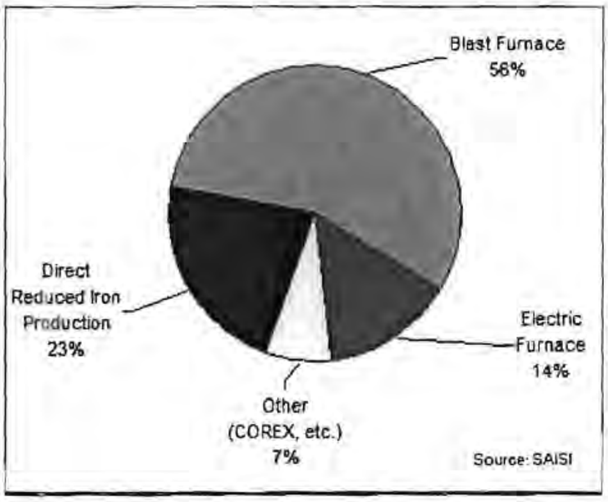

Figure 6.3 Share of each technology for iron making in South Africa

Source. Adapted from SAISI, 2003

The blast furnace plays a major role in the South African iron and steel industry, contributing 56% of iron production, while the new technology, COREX/MIDREX contribution is still quite small, only 7%. Two main processes are used for producing steel. The basic oxygen furnaces produce 55% of the steel while the Electric Arc furnaces and other technologies produce the balance of 45%. A brief description of the two ISP plants is given below.

New Castle Plant

This plant is located in Kwazulu Natal, and is one of the integrated steel mills, which runs one blast furnace and one induction furnace. New Castle is an ISO 9002 listed plant and produces rolled steel. The plant has high reliability and low cost production (ISCOR, 2003). This has been achieved through good maintenance programs, high quality standards and quality management systems, large investments into extensive plant refurbishment and the introduction of sophisticated information systems. This plant is also very environmentally friendly and has plans to invest in technology, which will totally eliminate the need for imported coke. Implementation of these plans will allow the plant to be in full compliance of ISO 14001 environmental standards.

The plant's strategic focus is to continuously expand its position in the domestic market and focusing on the high profit international niche markets. In addition, New Castle has also focused on the identification of global niche markets where it has a potential to reduce risk of exposure to unstable international markets through optimisation of volume and price. The plant produces a large profile of products ranging from low and medium-carbon commercial grades, low-carbon rimming steel substitutes, sulphur containing free-cutting steels, micro-alloyed steels, high-carbon wire-rod steels and low, medium and high-alloy steels, including tool and stainless steels.

ISCOR Vanderbijl Park Steel Works

This is an integrated steel plant and runs two blast furnaces, three electric arc furnaces and one basic oxygen furnace. It is located in the Gauteng area and is a qualified ISO 9002 operator. It is the largest supplier of flat sheet products in sub-Saharan Africa. It focuses mainly on the domestic market, providing 84% of South Africa's required flat steel products (ISCOR, 2003). Like the other plants, Vanderbijl Park wants to identify niche markets internationally while growing and maintaining its large share in the domestic markets.

To achieve growth in the local market, the plant has embarked on the development of additional value added products and developed a program that focuses on customer partnerships. Vanderbijl Park is a low cost producer and this has resulted in plant savings.

The plant uses a very efficient production and continuous casting process, liquid iron from the blast furnace goes through BOF and EAF where it is converted into liquid high purity steel, which is then continuously cast into slabs. The slabs are then hot rolled into either heavy plate in plate mills or coils in strip mills. The coils can either be sold as the final product or processed further into cold rolled and coated products.

6.1.6 Production capacity and volumes

ZISCO's two working blast furnaces have a rated capacity of over 1 million metric tonnes of liquid pig iron per annum. One has a capacity to produce 700 000 metric tones while the other has a capacity of 300 000 metric tonnes. ZISCO operations have been declining and deteriorating over the years. For instance, production levels have gone down as low as 26% of plant capacity utilisation (MIT, 2000). Effective capacity utilisation is one important way of improving efficiency and viability of a plant; hence the low capacity utilisation in ZISCO has resulted in accrued losses. Table 6.4 below shows the trend in production levels at ZISCO. It is also apparent from this table that in recent years ZISCO has been exporting more of its steel than selling it to the local market. In 2001 for instance, the plant exported 76.6% of all the steel produced. Most of the steel is sold in the form of blooms and billets, which have less value than further processed products. Increased exports of such low value products may be linked to the country's need for foreign exchange. In general, the product range is limited as shown in Table 6.5. The South African situation is very different. There is relatively high capacity utilisation, much higher production volumes and increased diversification. Table 6.6 shows the industry's capacity, while Table 6.7 shows the product range and Table 6.3 shows the diversity and sophistication of the country's exports. Table 6.3 also shows that the South African plants add a lot more value to their steel than ZISCO, consequently increasing the profitability and viability of the industry.

Table 6.4 ZISCO production and sales trends (tonnes of steel)

	1996/7	*1997/8*	*1999*	*2000*	*2001*
Liquid Steel	218 116	301 681	261 743	279 943	151 755
Local sales	169 287	209 170	160 823	78 990	63 074
Export sales	46 515	54 039	85 245	154 199	116 219
Total sales	215 802	263 209	246 209	233 189	179 293

Source: ZISCO Reports 2000

ZISCO produces a variety of products as indicated in Table 6.5 below.

Table 6.5 ZISCO product range

Heavy Mills	*Section Mill*	*Bar Rod Mill*	*Sundries*
Blooms	Angles	Rod in coil	Coke
Billets	Flats	Round bars	Coke nuts
	Channels	Square bars	Pig iron
	Window sections	Deformed bars	Slag
	Fencing standards	Square in coils	Benzole
	Plough beams	Angles	Coal tar
	Plough shares	Flats	
	Steel rails		

Source: ZISCO, 2000

The production capacity in the South African industry is huge, well over 5 times that of Zimbabwe. The finished steel capacity for the various plants is given in Table 6.6 below.

Table 6.6 Finished steel capacity for steel making facilities in South Africa

Facility	*Capacity (000 tons)*
ISCOR Pretoria	440
Highveld	950
Scaw Metals	550
Vanderbijl Park	260
Vereeniging	3788
New Castle	1440
Davsteel	475
Cisco	120
Saldhana	-

Source: Engineering News, 1997

South Africa produced a total of 9 million metric tonnes of crude steel in 2002. (IISI 2002). Some of the production and broad product range is given in Table 6.7.

Table 6.7 ISCOR product range

Plant	Products	000 Tonnes
Vanderbijl Park	Plates	184
	Slabs	375
	Hot rolled	1125
	Cold rolled	405
	Galvanized	498
	Tinplate	338
	Colour coated	77
Saldanha	Hot rolled coil	887
New Castle & Vereeining	Profiles	1495
	Seamless tubes	86
	Billets, ingots & forged	168

Source: SAISI, 2003

6.2 ENERGY USE PATTERNS

6.2.1 National energy intensity

Both countries have relatively high energy intensities. South Africa is one of the highest primary energy consumers in the world, with average energy intensity above the world's average. It is ranked as the world's 16th largest commercial primary energy consumer and only ten countries have higher energy intensities than South Africa (Government Year book, 2001). Its GDP is relatively high, 26th in the world but not well matched to its energy intensity. The energy sector is very crucial to the South African economy as it contributes 15% of GDP and employs over 250 000 people.

The structure of the South African economy has a major influence on energy intensity. The economy is dominated by large-scale, energy-intensive primary minerals beneficiation industries and mining industries which consumes 56% of national commercial energy (ERI, 2001). Its energy supply is heavily dependent on fossil fuels, 94% coal based electricity generation and a significant supply of liquid fuels from coal liquefaction. Although by developing country standards South Africa is regarded as technologically advanced, by international standards, it has generally not been using the latest energy-efficient technologies. This is largely a result of relatively low energy costs. Thus energy management in energy intensive sectors such as the iron and steel are important to South Africa in view of these characteristics and their implications on both national environment and global environmental debates. However South African energy intensities have been declining for the iron and steel industry since 1995 as shown below.

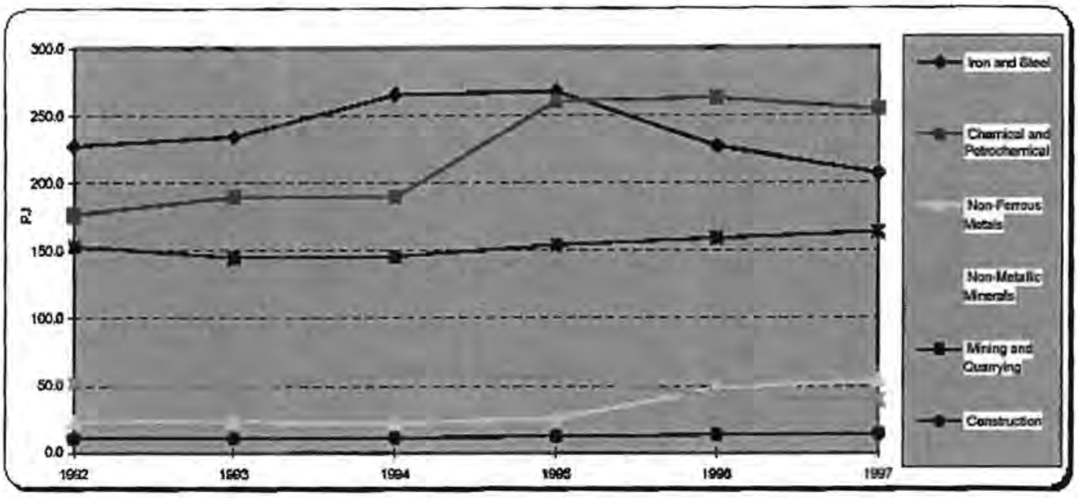

Figure 6.4 Trends in industry energy intensity in South Africa

Source: Trikam, 2003

Zimbabwe is also relatively highly dependent on thermal generation. Over 35% of the country's electricity comes from coal thermal plants. Its energy intensity is quite high; four times the world average, (Munjeri 2002). Figure 6.5 below shows the energy intensity of production for Zimbabwe. Except for the brewery whose energy intensity is at par with world standards the rest of the industry uses over twice the world average, (SCEE, 2001). The National Brewery is one of Zimbabwe's showcases for the SADC Industrial Energy Management Program. The low intensity has been due to the intensive efforts made by both the SIEMP and the National Breweries management, to reduce energy consumption and in general improve resource management in the company (SIEMP, 2003)

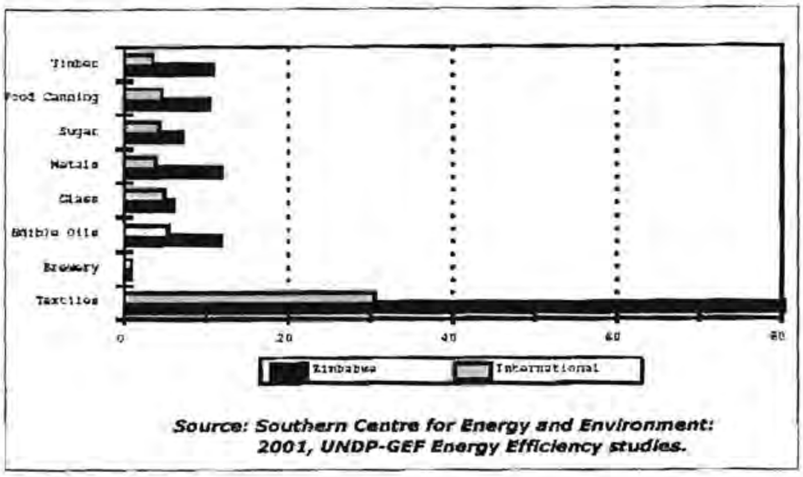

Figure 6.5 Zimbabwe energy intensity of production

Adapted from Munjeri 2002

6.2.2 Energy use patterns in the iron and steel industry

Both the Zimbabwean and the South African iron and steel industry display the typical characteristic consumption patterns of this industry with coal and coke supplying the largest amount of energy. The other types of energy consumed in the iron and steel industry are electricity, blast furnace gas, coke oven gas, basic oxygen furnace gas and LPG. A few countries use biomass, renewable energy, heavy fuel oil and tar.

It is important to note that coal and its derivatives play a very important role in iron and steel making. Hence lowering energy intensities implies reduced use of coal and consequently reduced green house gas emissions and pollution in general.

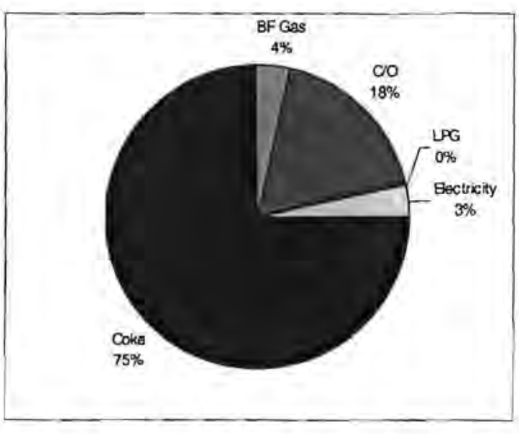

Figure 6.6 Energy consumption pattern in ZISCO

In 1996 coke contributed 75% of total energy used in the ZISCO steel mill, while, typically, electricity contributed only 3%, which is within the expected range of 2.5-

7% for an ISP. This could have been higher if energy consumption in the stainless steel industry had been taken into consideration.

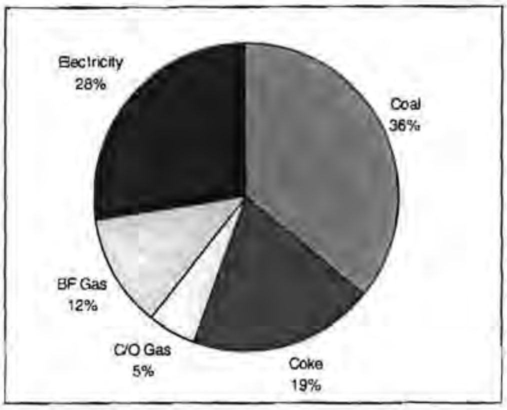

Figure 6.7 Energy consumption pattern in the South African iron and steel industry
Source: ERI 2000

South Africa has similar characteristics as other countries. However, a major difference in the South African industry is that electricity contributes a much higher percentage than in any of the countries with large production from ISPs. High electricity consumption is attributed to the fact that significant amounts of steel are produced through EAFs. Thus although coal and coke contribute the major share 55%, electricity contributes 28%. Similar consumption patterns are also displayed by the iron and steel industries of other countries such as Brazil, India and Poland (Bode et al, 2000).

These patterns confirm that the iron and steel industry is highly fossil fuel intensive and therefore its operations and development have serious implications for greenhouse gas emission and the climate change debate. More so reduction of energy intensities will lower these emissions. Energy use also varies with the process/technology depending on age, use and efficiency.

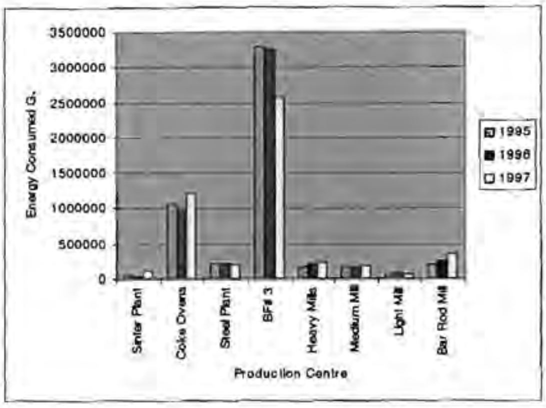

Figure 6.8 ZISCO Energy consumption by process/technology 1995-1997

Figure 6.8 shows that the blast furnace consumed most of the energy over the three years analysed. This is in line with global trends. The iron making process is the most energy intensive of all the processes in steel making. The BF has an average energy intensity ranging from 11-15GJ/tonne (Bode et al, 2000). The next highest consumer is the coke ovens. Both the coke ovens and the blast furnace are an important source and user of energy. The Bar Rod Mill seems to consume more energy than any of the other mills. The energy use pattern in 1997 is likely to be different from the current situation where most of the steel is being sold in the form of billets and blooms, therefore the heavy mills would show higher consumption than the other mills. The Sinter plant and the Light mill consumed the least of energy of all the processes. The implication of this is that more attention may need to be directed to the blast furnace and the coke ovens if efforts to reduce intensities are to be fruitful.

6.2.3 Energy intensities in Zimbabwe and South Africa

Energy efficiency is defined as unit output/unit energy, while energy intensity is defined as unit energy/unit output (Nyboer and Bailie, 1997). These two definitions can be used as indicators (see Chapter 4) and when they are based on physical units of output and there is a clear relationship between energy consumption and production units, changes in the indicator can provide useful information on changes in intensity.

6.2.3.1 Calculated intensities

Using the definitions and with equations 4.1 and 4.2 in Chapter Four, the estimated energy intensity for each process/technology is calculated and shown in Table 6.8. The energy intensity of the whole plant was also calculated using the same equations and shown in Table 6.9. Sectoral averages were calculated for the South African industry for about 10 years using data from IISA and the results are shown in Table

6.10. For Zimbabwe intensities are calculated in gigajoules/tonne of steel and in tonnes of oil equivalent/tonne of steel.

Table 6.8 **ZISCO energy intensity of production by technology/process 1995-1997 (GJ/tonne of product)**

	1995	1996	1997
Sinter Plant	0.57047	0.458476	0.408513
Coke Ovens	3.604691	3.560076	3.802798
Steel Plant	0.94421	0.946469	0.959167
BF# 3	15.91311	14.83675	11.87819
Heavy Mills	8.733585	6.802754	10.02067
Medium Mill	3.743149	3.830562	3.818376
Light Mill	4.377835	3.885947	4.116824
Bar Rod Mill	3.091452	3.233524	5.940433
Overall energy intensity	41.0	37.6	40.9

The blast furnace has the highest energy intensity followed by the heavy and the light mills. Surprisingly, although the coke ovens are a major energy consumer they seem to have a low intensity. However in order to know whether they are effective or not a comparison of their intensity either with coke ovens elsewhere or international benchmarks would be necessary. Such data were not available. Figure 6.9 below shows the above energy intensities graphically.

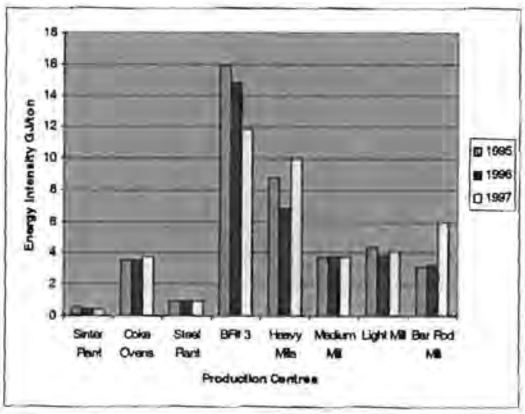

Figure 6.9 ZISCO energy intensity by process/technology

It is interesting to note that total energy consumption patterns for the centres does not follow the same trends as energy intensity implying that although some centres may be consuming a lot of energy, that energy is being used effectively. The impact of advanced technology on intensity is very apparent from Figure 6.9. The operation of the new blast furnace resulted in a significant reduction in intensity while the continued operation of the old heavy mills and the old bar rod mill resulted in a significant increase in intensity. It would have been interesting to see how this trend developed over a longer period but ZISCO is currently operating under difficult and abnormal conditions. This situation has been prevailing for about the last three years and analysis from recent year figures may not be very meaningful, since inefficiencies from factors such as low capacity utilisation and ad hoc planning may be inherent in the data.

Table 6.9 ZISCO energy intensity 1995-1997 GJ/tonne and TOE/tonne

	1995	*1996*	*1997*
Total energy used GJ	5261973	5211120	4973600
Energy intensity GJ/tsc	41.0	37.6	40.9
Total energy used TOE	125680	124466	118792
Energy intensity TOE/tcs	0.73	0.64	0.61

Table 6.10 Average energy intensity of the South African iron and steel industry

Years	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*
Tcs/TOE	1.24	1.46	1.99	1.59	1.54	1.6	1.89	1.35	1.38	1.47
TOE/tcs	0.81	0.68	0.50	0.63	0.65	0.63	0.53	0.74	0.72	0.68
GJ/tcs	33.76	28.68	21.04	26.33	27.19	26.17	22.15	31.01	30.34	28.48

Source: IISA, 2003

The main features of the Zimbabwean and South African iron and steel industry are summarised for comparison in Table 6.11 below.

Table 6.11 Comparison of the main features in the Zimbabwean and South African iron and steel industry

Feature		Zimbabwe	South Africa
Size		1 million MT/annum	3 million MT/annum
Ownership		About 90% Government	Private
Structure		1 major player ZISCO 3 smaller players; ZIMASCO, ZimAlloys, Lancashire Steel.	4 major players: Vanderbijl Park, New Castle, Vereeniging and Saldhana, other investments; Pretoria Plant, Suprachem, Collect a Can and Consolidated wire industries
Policy Making		Govt and ZISCO and Govt appointed Board	ISCOR Board and Company Management
Markets		Limited, see Table 4	Diversified see Figure 3
Technology	Iron making	4BFs, 1 working	3BFs, COREX/MIDREX, Induction furnace
	Steel Making	1BOF, 2EAF, 1conventional caster, 1six strand continuous caster	5BOF, 1Rotary Hearth Furnace, COREX/MIDREX continuous process, 3EAF & continuous casters, 1 induction furnace
	Process Control and Information Technology	Partially computerised, some areas still manually controlled, Quite behind in IT	Completely computerised with state of the art process control systems. Very up to date IT systems
	Mills	Hot & Cold rolling mills, antiquated, Bar rod mill-equipment over 60yrs old	Hot & Cold rolling mills, state-of-the-art thin gauge smooth surface rolling mills, Flat sheet rolling mills, coils and strip mills
Production, volumes capacity and products		Small capacity& limited volumes and diversity due to technological options, (see Table 2)	Relatively large, Very diversified products see Tables 3 and 5
Energy intensity		40GJ/tcs	27GJ/tcs

6.3 COMPARISON OF ENERGY INTENSITY AND ENERGY EFFICIENCY BETWEEN TECHNOLOGIES

Comparison of technologies and processes are made in order to study the relationship between technological advancement and intensity reduction. In the Zimbabwean case, this will be very limited due to the fact that Zimbabwe has limited technology and most of it is old. Unfortunately, data is not available for South Africa, which has more diversified technology and has also replaced a significant number of old technology plants. Hence, to get some indication of possible improvements, the comparisons are made of Zimbabwe and international literature.

6.3.1 Integrated Steel Plant and Electrical Arc Furnace

The ISP, which is the traditional way of making steel, has an average intensity of 40GJ/tcs, while that of an EAF, a more recent technology being adopted by many steel makers is only 7-12.5GJ/tcs. The type and age of the furnace used for steel making has a significant impact on the final intensity of the ISP. An ISP using the BOF, a new technology, has an intensity range of 19-40GJ/tcs, while that of one using an OHF which is an old technology which most producers are moving from, has an intensity range of 30-45GJ/tcs, (De Beer et al, 1999). ZISCO has no EAF; therefore no comparison can be made.

6.3.2 The Blast Furnace

Many improvements have been made to blast furnace iron making in recent years resulting in modern blast furnaces having better efficiency. The use of auxiliary equipment such as probes and sensors has enhanced automation, maximised yields and promoted cost reduction. In addition, this has enhanced process control equipment in the blast furnace resulting in optimal gas flows and burden distribution resulting in benefits such as increased productivity and reduced fuel consumption rates. It has been shown that productivity levels for sinter, pellet burdens and several injected fuels have improved greatly world wide due to improved designs of both medium 7.2 metre and large 14.8 metre blast furnaces (Ponghis, 1998., Hille, 1997., and Poveromo, 1999 cited in Stubbles 2000). These high productivity levels have resulted in other positive aspects such as optimised coke use, optimised coke burden distribution, which consequently increases ore reduction efficiency, high temperatures for the hot blast, oxygen enrichment and low quantities of slag. For Zimbabwe, this is clearly demonstrated by the changes seen in Figure 6.8. The old blast furnace has an energy intensity of 16GJ/tonne, while for the new blast furnace energy intensity was reduced to less than 12GJ/tonne.

6.3.3 Basic Oxygen Furnace and Open Hearth Furnace

The impact of technological advancement is also demonstrated by the difference in intensity between the BOF and the HOF. The BOF has a better efficiency than the OHF and is now used more predominantly for crude steel production worldwide (IISI, 1999). The energy intensity of the BOF is much lower than that of the OHF, 0.7GJ/ton of crude steel compared to 3.9GJ/ton of crude steel for OHF. Statistics show that OHFs were predominantly used in developing countries; long after the rest of the world had changed to BOFs (WEC, 1995). Examples of some countries, which were still using OHFs in 1995, are China, India and Eastern Europe. However the BOF technology is increasingly replacing the OHF technology in most parts of the world. The impact of the use of this old technology is reflected in the high energy intensities of these countries. Although ZISCO uses the BOF, its intensity is still very high. This can be attributed to the cumulative inefficiencies arising from the use of other less efficient processes and technologies in the plant coupled with other production inefficiencies. Moreover, ZISCO does not recover BOF gas and this could also contribute to the high intensity.

In addition to being less energy intensive, the BOF also offers increased productivity while its capital costs are lower (IISI, 1990). An added advantage is that the process does not require a net energy input. Instead it can be a net energy exporter since it produces BOF gas and steam. Its disadvantage is that it has a limited capacity for scrap steel. A typical BOF can take only 10-25% scrap steel (Price et al 1999) compared to an EAF, which can use 100% scrap.

6.3.4 Conventional casting and continuous casting

A classic example of how new technology result in lower intensity is demonstrated by the vast difference in intensity between continuous casting technology and batch or conventional casting technology as casting can either be a batch or a continuous process. The batch process (conventional casting) produces ingots, while the continuous process produces both intermediate and final products.

Continuous casting is a newer and a much more energy efficient technology than the batch process. For instance in the USA, on average continuous casting uses just under 10% of the energy that ingot casting uses. For every ton of steel produced ingot casting consumes 1.85GJ/ton while continuous casting only uses 0.15GJ/ton (Brown et al., 1985; Energetics, 1988; Worrell, 1994). Continuous casting is rapidly replacing ingot-casting worldwide and in 1998 only 17% of global steel was produced by ingot casting (IISI, 1999). It is therefore not surprising that the level of adoption of continuous casting in a given nation provides an indication of how energy efficient the nation's iron and steel industry is (Price et al, 1999). In Zimbabwe, continuous casting uses less than half the energy required for conventional casting. However, ZISCO's intensity remains high despite the presence of new technologies. One reason for this could be the continued use of both technologies in its operations.

Most steel producers are adopting more efficient technology. As a result, technologies such as conventional casting and OHFs are becoming extinct and the more efficient BOF and continuous casting is increasingly being adopted. Table 6.12 below shows the share of various technologies in some developing countries and the USA, while Table 6.13 shows levels of adoption and corresponding intensities.

Table 6.12 Percentage share of steel-making technology by country

	Brazil	*China*	*India*	*Mexico*	*S Korea*	*USA*
OHF	0	14	20	0	0	0
BOF	81	49	54	37	62	61
Continuous-casting	63	46	34	79	98	90
Conventional Casting	37	54	66	21	2	10

Source: Worrell et al. (1999) USA data 1994

Table 6.13 Percentage share of technology and energy intensity (GJ/tcs)

Country	*Share of BOF*	*Share of OHF*	*Share of EAF*	*Scrap input*	*SEC (GJ/tcs)*
Japan	69	0	31	33	21.3
France	66	0	34	33	24.1
Germany	78	2	20	29	20.2
USA	37	4	59	56	24.7
Brazil	26	0	74	23	33.9
Mexico (1990)	52	8	40	27	29.1
Mexico (1995)	37	0	63	31	24.6
Zimbabwe[a]	100	0	0	minimal	37.0
South Africa[b]	55	0	37	-	27

Adapted from Ozawa, 2000. [a]ZISCO data ;[b]IISA data

Countries that have adopted more advanced technology such BOF and continuous casting technology have lower energy intensity. South Korea for instance, which is among the lowest energy intensity producers, has an adoption rate for continuous casting of almost hundred percent, while Brazil which is among the more efficient developing country producers has an 81% adoption rate for BOF (Worrell et al 1999). In Table 6.13 Japan and Germany have the highest BOF adoption levels and the lowest intensities. Although Zimbabwe has 100% BOF use its plant has serious inefficiencies arising from other important factors such as age of the equipment and low capacity utilisation.

6.3.5 Electrical Arc Furnace gas based Direct Reduced Iron (DRI) and coal based DRI

While the EAF generally has a very low intensity, the type of raw material used as feedstock has a significant impact on the intensity. The intensity is dependent on the technology that was used to produce the feedstock raw material. The intensity range of 7-12.5GJ/tcs is obtained when the EAF is using mainly scrap steel. When DRI is used however, this situation changes drastically. When the EAF uses DRI produced using gas, which is a new process, the intensity shoots up to 22-30GJ/tcs while when coal based DRI; an older process, is used, the intensity shoots up even higher 30-40GJ/tcs (IISI, 1998; De Beer et al, 1999). ZISCO uses neither of these technologies.

6.3.6 Corex/Midrex and other technologies

This is one of the best technologies in the industry and by far the least energy intensive. While iron and steel making from ore to crude steel for all other technologies have average intensities above 20GJ/tcs, this technology has an average intensity of 19GJ/tcs. South Africa, who is a world leader in the Corex/Midrex technology, has significantly lowered intensities through use of this technology. Saldanha Steel Plant's energy intensity dropped from 30GJ/ton in the early nineties to 17.2GJ/ton through a shift from BF to Corex and Midrex technology by 2002 (ISCOR, SAISI).

The observed lower intensities of advanced technologies and the apparent relationship between adoption of advanced technology and lower intensities clearly demonstrates that technological advancement has a major role to play in improving energy efficiency and consequently lowers energy intensity. It can be concluded that the observed decline in energy intensities in the iron and steel industry has been largely a result of increased adoption of better technology as demonstrated by Table 6.12 and 6.13.

6.4 COMPARISON OF ENERGY EFFICIENCIES

In order to determine the energy efficiency levels in the iron and steel industry in Zimbabwe and South Africa, it is necessary to compare their intensities to other producers, particularly developing country producers. Table 6.14 shows these comparisons. Although the Zimbabwean and South African intensities fall within the observed international ranges, some of their values are on the higher end of the scale for the industry. This is particularly so when the level of intensities achieved in the more efficient countries like Japan, Germany and South Korea are considered. Zimbabwean values are almost double those of Korea and Japan. Although they are closer to those in China and India it must be noted that these are for 1995 and significant changes have occurred in these other countries since then. South Africa has achieved some reduction over the years as demonstrated in Table 6.10

Table 6.14 Some energy intensities in the iron and steel industry

Country	*Technology*	*E I (GJ/tcs)*	*E I (TOE/tcs)*
Zimbabwe[a]	ISP	40.9	0.72
	BF	15.9	
	BOF	0.94	
South Africa[b]	BF		
	DRI		
	Correx/Midrex	17.2	
	EAF	510kWh/tcs	
	Sector average	27.17	0.65
India[c]	DRI-EAF	Gas 25.3, Coal 35.6	
	EAF (DRI+ Scrap)	800kWh/tcs	
	EAF- (scrap)	18.8	
	ISP	36.4	
	Sector average	37.3	
Brazil[d]	" "	23	
Mexico[e]	" "	23.8	
China[f]	" "	40.7	
Poland[g]	Sector average	26	
USA[h]	" "	24.5	
South Korea[i]		20	

[a] and[b] were calculated
[c], [d] and [g] : Phylipsen, 2000; Worrell et al, 1997
[f]Phylipsen, 1999
[h]Price et al, 1999

Thus this table provides a good estimate of the level of efficiency in the South African and Zimbabwean iron and steel industry in comparison to other developing country producers.

6.5 COMPARISON WITH INTERNATIONAL BENCHMARKS- ESTIMATING POTENTIAL SAVINGS

In order to estimate the potential savings in a given country, a comparison of the current intensity with some established international benchmarks can be used. This comparison also indicates how far off countries are from these international standards. Benchmarks are based on definitions given in chapter three. Best practice values can be based on two important factors, independent international benchmarks or national circumstances based benchmarks. In the first example, they are based on international standards, which may include observations from best-operated plants, best available technology, and lowest achievable intensity. Best practice values of this nature are set strictly on the highest standards that have been achieved internationally. Some of these values are given in Table 6.15.

Table 6.15 Best actually observed SEC for different process in the iron and steel industry

Process	Best Actually Observed (GJ/tcs)	Energy Intensity ZISCO	EI South Africa	Potential Savings Zim	Potential Savings SA
ISP	22	40.9	27	18.9	5
BF	15.19	15.		0.19	

In the second example best practice values are set based on what is possible in a given country using best practice technology or best practice methods. Country based benchmarks are dependent on specific country parameters such as economic status, technological access and adoption capacity, funding, skills, product mix, policies and strategies. Thus a country is benchmarked based on what is feasible in that country. Table 6.16 shows the actual intensities in four developing countries and best practice intensities (country based benchmarks) and the technical potential for primary energy savings in those countries in 1995.

Table 6.16 Actual and Best Practice Intensities and Technical Potential for Primary Energy Savings

Country	*Actual Primary EI GJ/tcs*	*Best Practice EI (GJ/tcs)*	*Technical Potential Prim Energy Savings (GJ/tcs)*	*Potential Saving Zim*	*Potential Saving SA*
Brazil	23.1	18.6	4.5	22.3	8.59
China	40.7	20.2	20.5	20.7	6.99
India	37.7	20.5	16.8	20.4	6.69
Mexico	22.6	13.5	9.1	27.4	13.69

Source: Price et al 1999

The difference between the actual intensity in a given country and the international benchmark gives a rough indication of potential savings, while the difference between the actual intensity and the country based benchmark, gives a closer estimate to potential savings i.e. these values indicate what is possible within that country. Therefore Table 6.15 gives rough indications of potential savings for Zimbabwe and South Africa. Table 6.16 has country specific benchmarks, although the prevailing situations in these countries are not exactly the same as those in Zimbabwe and South Africa, estimates based on these values would give a better indication than one from international benchmarks since there may be similar conditions prevailing in developing countries.

Two main conclusions can be made from these comparisons. Firstly, it is apparent that countries, which have adopted advanced technology, have lower intensities and are much closer to the benchmarks. Furthermore, their potential savings are lower than those countries whose values are further off from benchmarks. The second conclusion is that Zimbabwe and South Africa have energy intensities that are above the benchmarks both international and country specific ones and they can achieve enormous savings by adopting more advanced technology and lowering their intensities.

For Zimbabwe, a comparison with international best practice shows that an estimated potential savings of 18.9GJ/tcs can be achieved, while based on the best practice for countries with similar intensities such as China and India a potential savings ranging from 20-27GJ/tcs could be possible in ZISCO. In the BF 0.19GJ/tcs could be saved while a saving of about 0.13GJ/tcs could be possible in the BOF.

In South Africa although intensities are generally lower than the Zimbabwean industry significant potential for savings still exists. South Africa has either closed old mills or refurbished them and new state-of-the-art technology has been installed. Therefore, relatively lower savings can be achieved. Comparison with other developing countries shows that these savings range from a high of about 13GJ/tcs, if compared to the more efficient developing countries, to a low of about 6GJ/tcs, if compared to the less efficient ones. Savings could also be achieved in EAFs. For instance the EAF at Vaal records an actual intensity of 510kWh/tcs while internationally, figures of 350kWh/tcs have been achieved.

This chapter has shown that changing from old technology to more advanced ones results in lower energy intensity. A look at the levels of intensity between old and new technology, and comparisons of levels of technology and energy intensity among countries demonstrates this in the iron and steel industry.

It is also clear that Zimbabwe and South Africa have high intensities, hence lower efficiencies than other developing countries implying prospects for improving energy efficiencies and a great potential for reducing energy intensities. The observation that ZISCO is using old technology in some of its operations makes adoption of new technology even more attractive. However, the types of technologies, which it should adopt, can only be confirmed by a financial analysis. The next chapter will give some indication of the technologies that are available and what polices are needed to support adoption.

CHAPTER 7

POLICY IMPLICATIONS OF ADOPTING ADVANCED TECHNOLOGY

This chapter identifies the technology drivers such as policies, strategies and measures that will promote the adoption of energy efficient technologies in the iron and steel industry. These drivers are discussed as they relate mainly both to Zimbabwe and South Africa.

7.1 TECHNOLOGY IMPROVEMENTS FOR ZISCO

Although technology plays an important part in the high energy intensity of ZISCO, it appears that a large share of these inefficiencies come from other factors that include production planning, management, shortage of working capital and raw materials and capacity under-utilisation. Based on Figure 6.9, the areas of focus for technology improvement in ZISCO are the heavy mills, the bar rod mill and the coke ovens because of the related high consumption levels and high intensities. New coke ovens would improve efficiency, while state of the art rolling mills would improve both efficiency, product quality and product diversification. However, these mills are currently being refurbished, extending their lifetime while they are still highly energy inefficient. Replacement may therefore be a medium to long-term recommendation. Table 8. 2 shows some of the technology improvements that can be done in the short term. ZISCO will also need to update its information technology (IT) system both for data collection and plant operations. This is imperative in view of the current global trends and the impact of IT of performance.

7.2 TYPES OF TECHNOLOGY DRIVERS

Technology adoption is a function of a number of factors, which include broad aspects such as general economic policies, industrial development policies and strategies, institutional framework and financial mechanisms. These can either be barriers or promoters of energy efficiency technologies depending on how they are formulated, structured and applied. The Department of Energy, Zimbabwe and Southern Centre for Energy and Development, 2000; Karekezi and Ranja, 1997 & Bennett, 2001 identified some of the more important drivers as:

- Institutional structure

- Industrial planning policies
- Government controls on raw material and product access, distribution and pricing
- Energy pricing and tariffs
- Finance
- Skilled manpower
- Baseline information and
- Uncertainty regarding the future

7.3 IMPACT OF BARRIERS AND INCENTIVES ON ENERGY EFFICIENCY

7.3.1 Institutional structure

Institutional structure refers to the establishment of institutions and interactions between them. These may include confederation of industries, associations for specific industries, energy efficiency supporting industries such as energy services companies (ESCOs), and financial institutions, which are established to support energy efficiency. It also includes the energy sector institutions, which either oversee or make policies that impact on energy efficiency and research institutions that carry out supportive research and development. Poor institutional structure is a significant barrier to energy efficiency and technology adoption.

Although Zimbabwe has organisations such as the Confederation of Zimbabwean Industries and Chamber of Mines, their influence on ZISCO is limited because ZISCO is mainly government-owned. Organisations such as the Scientific and Industrial Research and Development Centre (SIRDC) do not work directly with ZISCO, though recently they undertook research initiatives in recycling ZISCO slag. Other institutions such as Institute of Mining Research, Goelogical Survey and Metallurgical Laboratory do not offer much support to ZISCO. Thus very little backup research and development is available to ZISCO.

Although in the early 1990s government implemented structural adjustment programs which included corporatisation and privatisation of government parastatals, ZISCO was considered a strategic asset by government and was not affected. The existing structure is not well suited for effective technology adoption.

ZISCO being a public enterprise may suffer from social overheads, controlled prices and distribution and political interference, which, hinders productivity. Either privatising, corporatising, or using contract management can improve the situation, though additional measures will be needed to achieve efficient production. Strengthening the institutional framework can also be useful; as results elsewhere have shown that institutional strengthening has generally yielded technology upgrades and industrial modernisation and so improved energy efficiency.

In South Africa the situation is quite different. Except for Columbus steel and Saldhana, where government still has some share holding through the IDC, the industry is privately owned. In addition there is extensive infrastructure to support the iron and steel industry. This includes organisations such as South African Iron and Steel Institute, South African Stainless Steel Development Association, South African Institute of Mining and Metallurgy and Minerals and Technology Council. These institutions have played an important role in promoting development of the industry and adoption of better technology through research and development.

7.3.2 Inadequate industrial planning policies

In general, policies can affect the direction, speed and level of economic development. Good, clear and supportive policies will promote development while weak, fuzzy and non-supportive policies will hinder development and adoption of technology. Ownership policies have had different impacts on the iron and steel industries in South Africa and Zimbabwe. Privatisation in South Africa seems to have enhanced growth while public ownership in Zimbabwe has seriously affected the viability of the industry. However, privatisation per se does not necessarily yield benefits, as a conducive environment for privatisation must be created for positive results. The apparent progress made by iron and steel industries in India and China has been attributed to privatisation (Wu, 2000) (see section 7.5). Privatisation has enabled the South African industry to adopt better technology because it exposed the industry to both local and international competition, which forced the industry to change and stay competitive. Being competitive internationally has also forced the industry to keep to global trends as well as adopt good survival strategies. Zimbabwe may need to restructure ZISCO to give it the opportunity to change.

7.3.3 Government controls – Raw material, product distribution and pricing

Depending on the type of government controls and their application, they can adversely affect effective operations and profitability of the industry, particularly those that pertain to access, pricing and distribution of raw materials such as iron ore, scrap steel and coal. However, other aspects such as level of duties, taxes and allowable import volumes for scrap steel and product pricing can have the same effect. Pricing and distribution of raw materials such as coal in Zimbabwe is essentially a government mandate.

Government can also interfere with the downstream activities and create unfair distribution of steel mill products by having biases towards government subsidiaries, which may be at the expense of others. However, government's control can promote effective employment creation, especially if the downstream industry has foreign owned firms that may have very little national interests. Government should consider putting in place a regulatory framework, which ensures equitable distribution of ZISCO products. This could be achieved through deregulation of the sector. Zimbabwe needs policies that enable ZISCO to work closely with downstream industries that are supporting local innovation and employment creation.

7.3.4 Energy pricing

Low energy pricing can affect industrial energy efficiency because the industries then view energy as a minor input to their total cost, relative to raw materials and labour, and concentrate on other areas for cost reductions. However in general, energy accounts for about 10-30% of production costs, and can be a significant share of the cost for serious attention from industrialists. Therefore in order for tariffs to support energy efficiency they need to be reflective of production costs.

In Zimbabwe, tariffs have often not reflected the true cost of production. Tariff increases have to be approved by the Minister of Energy and have been affected by political and non-economic decisions. Furthermore large industries such as ZISCO have negotiated tariffs, which may not be truly reflective of production costs. This has resulted in artificially low energy costs that have discouraged energy efficiency improvement. Zimbabwe needs to revisit energy pricing policies so that they are reflective of production costs.

7.3.5 Finance

Usually, there are three generic energy efficiency improvement areas as demonstrated in Table 7.1 below:

Table 7.1 Generic energy efficiency options

No cost options	Improved house keeping Switch off when not needed Go to lowest electricity tariffs Manage maximum demand Manage consumption through increased accountability
Low cost options	Insulation Repair leaks for compressed air & steam Other modest investments
High cost options	Capital expenditure to replace equipment, installation of state of the art equipment and machinery

The first and second options are usually possible within company budgets. However implementation of the third option usually requires financial support. Most developing countries do not have dedicated financial institutions to support energy efficiency. Most of the institutions that normally invest in energy projects are generally unwilling to fund unfamiliar areas such as energy efficiency. There are no financial institutions and mechanisms to support energy efficiency improvement in both South Africa and Zimbabwe. The establishment of supporting institutions such as Energy Services Companies (ESCOs) and energy efficiency improvement funds would assist the adoption of energy improvement technologies. Supporting mechanisms such as taxes and customs duties relief for energy efficiency related equipment might also encourage acquisition of energy efficient technology. However, it should be noted that technology upgrades could result in displacements and retrenchments. It is therefore important to approach this issue with caution particularly for ZISCO and ISCOR that employ a significant share of the workforce.

Investment in energy efficiency equipment for ZISCO presents huge challenges particularly when capital is needed for survival. The current economic situation only worsened the problem and has adversely affected operations at the plant. Another problem is being a government-owned organisation, foreign currency earnings are not necessarily used back in the industry.

Policy support in the form of special funding mechanisms and a change in foreign currency control policies may ease this problem. Joint ventures with external partners may lead to providing the required technology and may be one way of approaching this constraint. Recently, initiatives like the CDM in the Kyoto protocol may be a source for future potential funding.

In South Africa on the other hand, the industry has been able to create surplus both in local and foreign sales. It has also been able to plough back these profits into the industry and enhance development and expansion of the industry, enabling investments in advanced technology, which in turn has fueled developments and transformation of the industry. Although losses are sometimes incurred, the industry is robust enough to recover from the losses (ISCOR 2003). For instance the strategy to install the corex midrex technology at Saldanha resulted in huge losses being made for about two years. However, the technology later made them a world leader and a producer of very specialized steel giving them a competitive edge in the industry. ZISCO needs innovative financing mechanisms to support both development and energy efficiency improvement.

7.3.6 Lack of skilled manpower

Human resources deficiency needs attention for most developing countries. Skills for energy efficiency promotion and management are even less available as this is a relatively new area for most developing countries. Targeted training such as the SIEMP may enhance these skills. The skills base for energy efficiency in both South Africa and Zimbabwe is not very high for reasons already indicated. However, South Africa has an advantage in that its skills base for the iron and steel industry is much higher than Zimbabwe by virtue of its size, technology, process and product diversity. In ZISCO skill diversity is required much more than specialization. The technology currently in use requires personnel who have worked with these technologies for a longtime and they are labour intensive. The situation before independence favoured this as black cheap labour was abundant, this has however resulted in a technology lag that will be difficult to cure. Diversity is required in skills to computerize the plant for instance instead of manual data collection.

7.3.7 Baseline information

Information plays a major role in adoption of advanced technology in industry. Moreover, it is known from the theory of change that the majority of individuals are resistant to change, because of the transformations, instability, power imbalances and the distabilising effect it inherently has. This resistance is also linked to the fact that if outsiders identify opportunities it may imply incompetence on the part of management. However it has been shown that adequate and proper information on achievable savings in a given industry and the accompanying investments and overall benefits can change this mindset. Therefore ZISCO needs energy efficiency programs that are supported by accurate and solid information and education.

7.3.8 Uncertainty about the future

Naturally investments are accompanied by risks and benefits and a careful assessment of these factors is necessary before any commitment. At times it is necessary for returns to be as close to the investment as possible thus short payback periods are always very persuasive. Investors are sometimes reluctant to commit resources to long-term projects, understandably so given the financial instability both internationally and within regions. This may reduce the opportunities for energy efficiency investment. In order to improve the investment potential in ZISCO good macro, and micro economic policies, adequate institutional structures, good governance and information would be needed to attract investors.

7.4 IMPACTS OF POLICIES IN THE IRON AND STEEL INDUSTRY IN OTHER DEVELOPING COUNTRIES: CHINA AND INDIA

In China, the industrial growth has been due mainly to the country's industrial policy. For decades, the Chinese industrial policy has been supporting development of heavy industry. Changes in institutional setup have also influenced growth and development. These included reforms that encouraged change of ownership, reduction of government role as a controller of operations to a policy maker and regulator (Zhang and Zhang 1998). Although private ownership was encouraged from the 1970s, until the 1990s China's iron and steel industry was largely owned by the state (Wu, 2000). However, due to the reforms, private ownership is now playing a significant role, (Zhang, 1998). Other policy changes in China included market oriented production and consequently reduction in mandatory purchase by the state. At the same time the pricing structure has been reviewed to reflect prevailing market conditions. These changes have since 1997 enabled 33 companies to be listed either on the domestic or international stock market. Although its steel industry has not attracted large investments, these changes have opened up the industry for competition, technology improvement, increased viability and in general improvements in energy efficiency as well as reduction in pollution.

In India, the industrial policy also affected the iron and steel industry, which until the early 1990s had a very highly controlled iron and steel industry. Government had direct strict control over distribution of available steel and indirect control through pricing and import levies (Mongia and Sathaye 1998). However, after 1992 policy initiatives enabled the decontrolling of the industry and instigate mechanisms, which enabled access of iron and steel materials at uniform prices in the country. This consequently enhanced equitable countrywide industrial development. These policies also ensured that the priority sector demands where met and supported the operation of mini-mills through the following:

- Duty free importation of sponge iron and scrap
- Encouraging diversification into all grades of carbon and alloy steels
- Installation of captive rolling mills
- Establishment of facilities for investment in continuous casting machines and heat treatment furnaces

Another policy measure referred to as broad banding encouraged production diversity depending on aspects such as market demand and raw material availability. Broad banding set a maximum production capacity and allowed manufacturers to produce an optimum product range as long as the total volume was within the licensed capacity. These policy changes positively impacted the productivity and development of the industry and significantly improved capacity utilisation and energy efficiency.

Table 7.2 and 7.3 summarise policies and their impacts in the iron and steel industry in Zimbabwe and South Africa.

Table 7.2 Technology drivers and their impacts on the South African iron and steel industry

Drivers South Africa	Existence	Technology adopted	Impacts of drivers
Institutional structure	++	3BFs, COREX/MIDREX, 2 Induction furnace 5BOF, 1Rotary Hearth Furnace, COREX/MIDREX continuous process, 3EAF & continuous casters, Completely computerised with state of the art process control systems. Very up to date IT systems Hot & Cold rolling mills, State-of-the-art thin gauge smooth surface rolling mills, Flat sheet rolling mills, coils and strip mills	Absence of ESCOs but other supporting institutions influenced development
Adequate industrial planning policies e.g. privatisation	+++		Promoted development, closure of non-efficient and non viable operations: results-improved energy efficiency & low intensities
Raw material and product access, distribution and pricing	-		Market forces determine prices, effective distribution infrastructure, working with clients to better meet needs
Low energy prices and tariffs	++		Promoted industrial development but until recently worked against energy efficiency
Supporting financial instruments	-		No supporting financial instruments industry ploughed back profits for more development & technology investment
Availability of Foreign currency	+++		Industry creating own from sales while economy has attracted significant FDI facilitating investment in new technology
Skilled manpower	++		Available for the iron and steel industry limited for energy efficiency improvement
Adequate baseline information	+		Energy efficiency audits and studies done, none specific to iron and steel industry, need for information on energy efficiency benefits to educate managers in this sector
Uncertainty regarding the future	--		Industry has a very clear focus and has strategies for the future, which enables long term investment into technology and industrial development
Markets	+++		Product and markets diversification. encouraging specialised technology

Table 7.3 Technology drivers and their impacts on technology adoption in the Zimbabwean iron and steel industry

Drivers Zimbabwe	Existence	Technology	Impacts
Institutional structure	+	4BFs, 1 working 1BOF, 2EAF, 1conventional caster, 1six strand continuous caster. System Partially computerised, some areas still manually controlled, Quite behind in IT Hot & Cold rolling mills, antiquated, Bar rod mill-equipment over 60yrs old	No ESCOs and limited support and influence from other organisations, some consultancy services available
Adequate industrial planning policies e.g. privatisation	--		Government control has limited growth and adoption of new technology, continued use of old technology
Raw material and product access, distribution and pricing	-		Some government control, stifled competition, distribution infrastructure has constraints and bottlenecks
Low energy prices and tariffs	++		Promoted industrial development but until recently worked against energy efficiency
Supporting financial instruments	-		No supporting financial instruments, huge losses, no capital base to promote efficient technology and industrial development
Availability of Foreign currency	--		Critical shortages economy not attracting any FDI to facilitate investment in new technology
Skilled manpower	++		Inadequate for iron and steel industry, limited specialists for energy efficiency improvement
Adequate baseline information	+		Energy efficiency audits and studies done, none specific to iron and steel industry, need for information on energy efficiency benefits to educate managers in this sector
Uncertainty regarding the future	+		government wants to improve productivity, current economic crisis creates uncertainties discouraging sectoral long term investment
Markets	+		Limited markets and technology to meet demands of diversified markets

Key to symbols

+++ *High presence and positive contribution*
++ *Medium presence and positive contribution*
+ *Low presence and positive contribution*
-- *High presence and negative contribution*
- *Low presence and negative contribution*

The above discussion shows that policies play an important role in technology adoption.

7.5 OTHER ISSUES IN IRON AND STEEL PRODUCTION

Energy intensity in manufacturing is a function not only of technology, production, processes, policies and strategies; it is also a function of other factors such as

- Production techniques such as total productive maintenance/manufacturing (TPM)
- Waste minimisation
- Quality control
- Labour productivity
- Cultural values and
- Human resource issues such as change management, leadership, motivation, self-management and teamwork.

The impacts of production techniques are clearly demonstrated by Japanese manufacturing processes. Japanese pioneered techniques such as TPM and Just-In-Time (JIT) production. JIT brought about concepts such as lean production, waste reduction, work reorganisation and quality circles, while TPM is based on the experience that equipment and process problems are the major cause of many unplanned events that result in crisis management (Nakajima, 1994). Although technology is important for improved efficiency, productivity and world-class performance, it should be supported by appropriate maintenance and improving the total integrity of the organisation through involvement of both management and those on the shop floor. The goal of TPM is to hold emergencies and unscheduled maintenance to a minimum. TPM requires complete commitment from top management, employee empowerment to initiate corrective action, change in employee mind set towards job responsibilities and a long-term outlook. However implementing this may require going through a learning curve that is represented below. This learning curve is also important to capacity utilisation.

Equation 7.1 The learning curve: $2v = 2/3C$

Where v is the volume of production and C is the unit cost of production

Thus the more effectively capacity is utilised the lower the production costs. Doubling production volume results in two thirds of the unit cost. Conversely capacity underutilisation results in high production costs and losses. Capacity underutilisation in ZISCO arises from inadequate supplies of raw materials, power cuts, transport bottlenecks and in some instances labour disputes and industrial action.

7.5.1 Application of the lean production concept to ZISCO

JIT and TPM both lead to lean production that exposes unused resources through visual management, so that potential wastage can be easily seen. Sources of wastage are surplus inventory, labour, bad management, energy costs, recyclable materials, and excessive meetings. Thus lean production, which aims at reducing most of these, is applicable to ZISCO since some of these weaknesses were observed during the visit.

The Japanese system controls waste directly through removal of idle inventories that waste limited space and indirectly through the reduction of energy use for material conversion and refining. Thus indirectly waste is eliminated through the reduction of defective parts, sub-assemblies and final lower quality products that are a waste of material and energy. Some aspects of JIT such as quality control could be implemented at ZISCO, however others such as removal of stockpiles and work in progress may present big challenges because ZISCO is dependent on other players for inputs who would have to change their production processes and ZISCO has no control over them. JIT requires that quality be controlled as part of the moving production process instead of as an independent process carried out on batches of finished products. It also ensures that the work force works as a team and motivates them to produce high quality with minimal supervision. Retraining and good control equipment, work reorganisation, changes in production procedures and work methods would achieve this. Due to the current bottlenecks in ZISCO this may initially present a huge challenge.

7.5.2 Labour productivity

Labour productivity is an important concept in production as it measures how effectively labour is being utilised. It can also be used as a measure of efficiency in manufacturing. Nevertheless, there are other factors, which contribute to higher production costs. Labour productivity has improved considerably in the steel industry for some developed countries. In the USA, for example the man-hours required to produce a ton of steel has been reduced by about 60% over the last 15 years. Productivity has risen from a 100 tonnes of steel per man-hour to over 150 tonnes of steel per man-hour. Some EU countries show similar trends as demonstrated in Figure 7.1. Productivity per employee has almost trebled since 1979. In Figure7.2 the individual plants show similar trends but also show much higher productivity levels. Posco of South Korea, Nippon Steel and Kawasaki of Japan show some of the highest productivity levels. The productivity per employee ranges from about 500-1000 tonnes for the least productive plant BHP in Australia and the most productive plant Posco in South Korea. Based on the high efficiencies in South Korea and Japan, it can be concluded that energy efficiency is closely linked to increased productivity.

Compared with the cases of Zimbabwe and South Africa which are both below 100 tonnes per employee (MIT, 2000), there is potential for productivity improvement in the Zimbabwean and South African iron and steel industry. Productivity gets even worse when considered as per employee contribution to revenue. For instance in 1998 the sales per employee were USD 7 125 for ZISCO, 46 161 for ISCOR and 201 282 for Thyssen Krupp of Germany. Although labour productivity is very low for both Zimbabwe and South Africa the revenue for South Africa are higher due to product diversity and specialisation. Therefore labour productivity can still be increased in ZISCO through energy efficiency and removal of identified bottlenecks

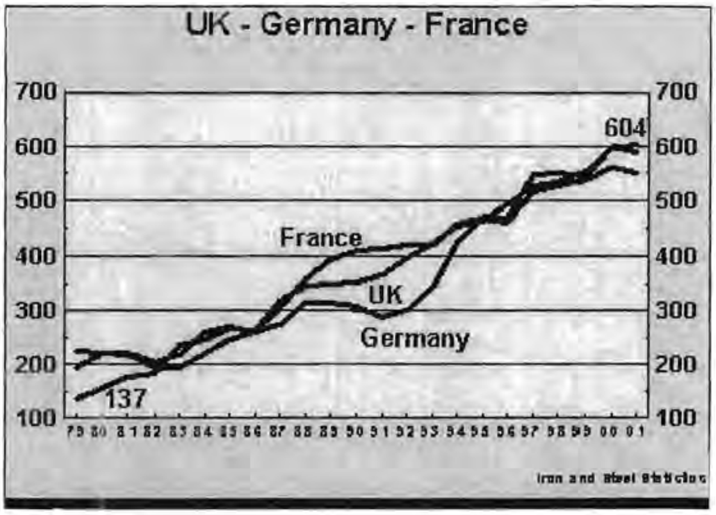

Figure 7.1 Productivity in the iron and steel industry of some EU countries

Source: ISSB, 2001

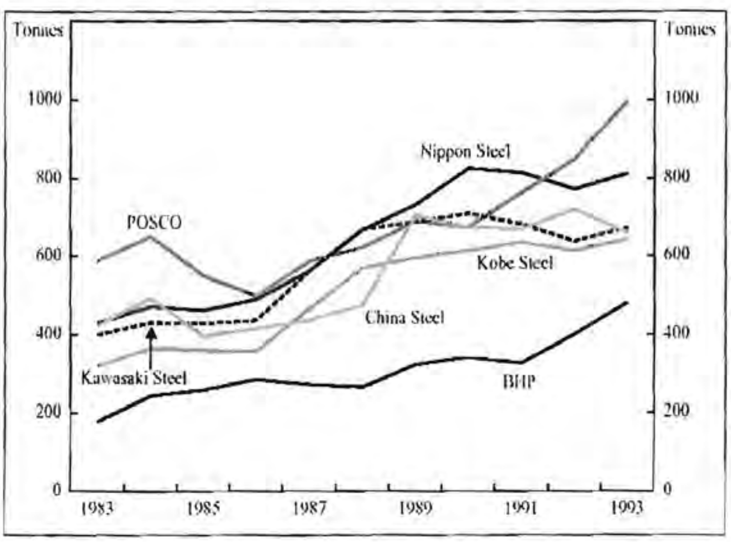

Figure 7.2 Productivity in iron and steel industries for some plants.
Source: Adapted from (Demura: 1995)

7.5.3 Impact of culture on production

Organisational culture is defined as the shared meanings, patterns of beliefs, symbols, rituals, myths, code of ethics and moral values, perceptions and ideologies that evolve over time and are a function of social bonding. Culture emerges in an organisation as a group of individuals tackle problems and deal with life experiences in an organisation (Ott, 1989, Krefting and Frost 1985, Schein 1999 cited in Naidoo, 2000). Adaptation to organisational culture is a function of educational level, ethical and moral values, skills level and ethnic background. The impact of culture on productivity is demonstrated by Japan's production system. The Japanese have an efficiency and quality culture and this is apparent in their industry and their products. For ZISCO and most developing countries to become more efficient industrial producers, they need a culture change that involves the following;

- Definition of major strategies
- Skills change
- Work systems change
- Policies and strategies change
- Process change

Some of these areas that define a culture change are also infused in the technology drivers, therefore technology advancement and culture change are complimentary and ZISCO would need to consider these issues. A change in organisational culture can improve efficiency and productivity.

This chapter shows that technology drivers play an important role in technology adoption and consequently in productivity improvement. It also shows that management and maintenance issues are important to increased efficiency in manufacturing.

CHAPTER 8

RECOMMENDATIONS AND CONCLUSION

8.1 POLICIES AND TECHNOLOGY CHOICE

Technology choice in the iron and steel industry greatly depends on the industrial policies. Policies that will adequately address concerns for the iron and steel industry must consider the issues listed in Table 8.1.

Table 8.1 Issues important for iron and steel industry policymaking

Issue	Reasons	Implications
Market analysis of national situation	Avoids making policy in a vacuum	Identification of strengths and weaknesses of current policy, current and potential policy focus areas, current production areas, potential areas for development, optimum resource use
Scope of operation – export	Production focus and technology choice, skills base	Specialized technology, skills, products, product & market diversification service external market, but imports of basic outputs
Scope of operation – local	Production focus and technology choice, skills base	Standard but up to date technology, upstream and downstream industrial development, self sufficiency in basic products, specialized small scale producers, employment creation, new policies
Capacities	Demand requirements, adequate support infrastructure for raw material and other inputs	Investment capability and resources to run plant, return on investment, avoid capacity under-utilisation
Existing policy framework	Create level playing field for all, create mechanisms for successful new policy implementation	Adequacy, shortfalls, can these be addressed, current beneficiaries, potential beneficiaries

The planning matrix above may be useful for policy makers in both government and ZISCO as a guide to have a comprehensive coverage of important issues, assist in achieving optimal use of resources and identify important areas for attention. It ensures that technology choice will be linked to the targeted markets, capacities matched to demand, identify existence of adequate supporting infrastructure, and create a balance between the macro-economic environment in which the plant operates, its viability and sustainability.

Based on the above analysis, there are two major policy directions regarding iron and steel industry development i.e. production can be for local use or for exports. The policy choice is dependent on a number of factors in a given country, which may include the industrial structure, technological levels, economic growth and stability, marketing and industrial development policies, strategies and goals.

8.1.1 Local industrial development focused policies

If the focus is on local industrial development, the main objective of the iron and steel industry is to boost the development of both down stream and up stream industries. This requires the creation of an environment, which encourages the emergency of and promotes the existence of down stream industries to satisfy local demand. In the case of Zimbabwe although the primary plants such as ZISCO offer products such as blooms and billets to the export market, their major share of production should be targeted at local industries. Thus the focus should be inputs into the construction industry, agricultural sector and specialized manufacturing sector as these sectors add value to the primary products, and so Zimbabwe can exploit such a policy.

Small smelting, engineering companies and foundries have emerged that were servicing the local market as well as venturing into specialized export production. For instance, Connolly's, an engineering company in the country has the potential to produce axle wagons for railway goods transportation, fixed industrial cranes and specialised bearings. This is a potentially lucrative business even for the SADC region and internationally. While others like Trinity Engineering had started production and export of large trailers, some small companies had emerged that were undertaking production of very basic yet much needed agricultural implements such as plough shares and other accessories and marketing them to the remote areas where large companies are normally unwilling to operate. However factors such as shortages, distribution policies of ZISCO outputs and lack of support for these emergent business people have seriously hindered these operations. ZISCO is now mainly producing for the export market yet the plant may really not be geared for that.

Therefore, setting up effective policy that target local development in Zimbabwe, requires ZISCO to improve its production levels, operating framework and implementation mechanisms to ensure equitable distribution of outputs to the various demand sub-sectors. Deliberate support by government should be given to small companies in recognition of the crucial role these small-scale enterprises can play in economic development and job creation, the desire of Zimbabwe. Thus ZISCO plant can create export value through policies that improve synergies between the plant and down stream industries. Foreign currency generated from the downstream industries could be used to buy specialized products, which the industry is unable to produce. However there may be limitations in technological advancement in the industry and may also affect product and market diversification, factors that are important for the iron and steel industry in the long term.

8.1.2 External market focused policies

These policies lead to the establishment of plants that are mainly export-oriented. These plants are designed mainly to earn foreign currency through exports and specialized products although they may also have some production for local consumption. They may also be set up to service specialized markets such as gas petro-chemical and modern manufacturing industry. These plants therefore require state-of-the-art specialized technology to service their targeted markets. Specialised skills are also required to run these plants. The South African plants are good examples of this.

8.2 POLICY CHOICE AND BENEFITS

Local market promotion policies are best for countries, which are undergoing significant infrustructural development and have a large local demand, China is a case in point. In China, the steel industry has been used to support its own growth because of the market size, growth of other industries such as the motor vehicle industry and domestic appliances industry. The iron and steel industry is also projected to have a huge impact on the growth of the power sector (Wu 2000; Zhang and Zhang 1998). This policy will be effective if profits accrued are put back into the development of the industry, since foreign currency earned could be used for other government-defined priorities.

This policy makes economic sense for ZISCO and most developing countries, provided the market size is greatly enlarged. Furthermore it supports local industrial development, which in the long term creates export earnings, employment and contributes to economic development and sustainability, Japanese steel industry after the Second World War is an example (Crocker, 1988. Tsutsumi, 1998).

ZISCO has a great potential to influence expansion and growth of foundries and engineering companies in the country and SADC, and this will have huge prospects of generating foreign currency.

This is even more important bearing in mind some of the policies of the country's ESAP that promoted development of export-processing zones. The main aim was to encourage small and medium entrepreneurs to break into the export market by providing them with training opportunities in management, quality production, and marketing strategies, among others, and by establishing links with big companies. Companies were also encouraged to attain ISO 9002 and ISO 14001 status. Inward looking and inefficient import substitution, policies which prevailed in the period prior to and soon after independence were discouraged through exposure to international competition, education through international trade fairs, and modernization of production equipment (Government of Zimbabwe, 1996). However, for this to occur, policies that create a level playing field for all parties and address current shortages are needed.

ESAP policies also advocated for corporatisation and privatization, and this gives an opportunity to revisit the ownership policy of ZISCO. Restructuring ZISCO may improve production efficiency without even technology change. This move has been done for former government entities such as the Dairy Marketing Board, the Cotton Marketing Board and ZESA that have long since achieved impressive turn around results and are now profitable (Mlambo, 1997). More so privatization of this sector has worked for South Africa, China and India

It is also important to note that structural changes and reforms bring about changes in the other areas such as organizational development and management issues that were discussed in chapter seven. Corporatisation and privatization bring about exposure to competition, organizational changes relating to, production and work methods, ethics and technology. Therefore as a major strategy to improve efficiency in the iron and steel industry, Zimbabwe may seriously consider the restructuring of ZISCO.

An area of major concern is capital support for energy efficiency programs. Currently ZISCO is not in a position to invest in new technology yet at the moment Zimbabwe has no specific financial mechanisms to support energy efficiency improvement. The government could use incentives such as reduced taxes and duties for energy efficiency equipment and formulate strategies to support this move. ZISCO could also link up with international companies and investors who could be willing to invest in production improvement. However before any international investors may consider investing in ZISCO there is need to develop a homegrown plan on possible improvements in the plant operations. Although local investments may be available, since most of the required technology is available external, foreign exchange will still be needed and so limits the use of local investments.

ZISCO presently has achieved some reductions in energy use through recovery of process gases such as coke oven gas and blast furnace gas, which provide an important source of energy. A constraint in this area is that for plants that were not initially designed to recover the gases, the additional cost to achieve this is relatively high and may not be justified for ISPs such as ZISCO that have other investment priorities. Steel plant improvements can be achieved in the various production centres through different options and measures. Table 8.2 below gives some process and centre specific measures, which can be undertaken in order to improve energy efficiency.

Table 8. 2 Energy efficiency improvement measures for ISP steel making

Production centre	Energy improvement category	Measure/Option
Sinter Plant	Improved input material	Control particle size[z], distribution and raw materials quality[z]
	Efficient energy use	Increased bed depth, ignition furnace combustion control and double layer charging
	Energy loss reduction	Prevention of air leakage from wind box
	Waste energy recovery and recycling	Preheat ignition furnace combustion air with Sinter cooler waste heat
	Power saving	Fit main exhaust gas fan with high efficiency impeller and rotating speed control
Coke ovens	Improved material treatment	Charge preheated, dried and/ briquetted coal
	Efficient energy use	Improved operational control-coking time, combustion chamber temperature, automised combustion control, operating schedule control, programmed heating, use of thinner walls
	Energy loss reduction	Automatic ignition of C/O gas flare[z]
	Waste energy recovery and recycling	C/O gas and ammonia sensible heat recovery,
Blast furnace	Improved input material	Charge improved quality sinter[z], reducing slug volume Improved charge distribution, optimise blast temperature and humidity, automised control systems[z]
	Efficient energy use	BF gas flare automatic ignition, BF gas recovery[z], cold blast main tuyeres insulation
	Prevention of energy losses	Charge warm sinter and coke[z]
	Reduce process time Waste energy recovery and recycling	Recover: top gas, BF gas and slag sensible heat, hot stove exhaust gas sensible heat, install evaporative cooling for stoves, BF gas in (CEST) technologies to increase power generation for own use & export to grid
BOF steel making	Improved material input	Improved quality of hot metal
	Efficient energy utilisation	Optimised blowing, ladle preheating[z], programmed control, combined blowing
	Reduction energy loss	Preheat ladle[z], automised BOF gas flare ignition, install lid on transfer ladle
	Reduce process time	Higher temperature hot metal into BOF, shorten ladle cycle time
	Waste energy recovery and recycling	Recover BOF gas, BOF slag and continuous casting sensible heat,
Casting	Efficient energy use	Use continuous casting[z], phase out batch casting
Rolling	Efficient energy use	Replace old technology with new advanced technology
Overall	Improve processes	Computer controls

The visit to ZISCO showed that most of the recommendations listed in Table 8.2 have not been implemented by ZISCO; only those marked with (z) have been implemented in the plant. Lowering its current high energy intensity will need the implementation of these measures. However, the choice of measures to be implemented in the short term and in the long term will depend on the local circumstances. Nevertheless it is apparent from the options that most do not need high capital investments, except those like changing rolling technology and replacing coke ovens.

As a general observation Zimbabwe needs more government- induced policies to stimulate rapid technological development and acquisition. To be effective such policies must be comprehensive and address all functional sectors of society. Also, incentives for technological development have often been implicit and offered through investment incentives for industry. Unfortunately energy improvement technology has not received the necessary attention. For instance in the national environmental assessment policy there is no consideration for the need to assess technologies, yet studies have shown that countries which develop a strong internal capacity to search for and evaluate technologies are usually able to acquire them on satisfactory terms. Therefore skills at national and specific industry level are required for technology assessment and development.

8.4 CONCLUSION

The iron and steel industry is important for economic development, but unfortunately it is very energy intensive. Therefore interventions targeted at improving efficiency have positive impacts on energy intensity and for economic development.

Zimbabwe's iron and steel industry has relatively high energy intensities, improved energy and production efficiency will lower its energy intensity. Zimbabwe is completely dependent on imports for all its petroleum needs, imports close to 45% of electricity and currently has a very huge debt burden. Energy savings in the iron and steel industry will reduce the energy import bill.

Zimbabwe has the potential to reduce the prevailing high intensities in the iron and steel industry because it is currently using mostly old technology. Comparison of energy intensities and types of technology used strongly supports this argument. Due to the fact that ZISCO products have currently a very high demand in the local market and ZISCO can be instrumental in growing local industry, it is therefore recommended that the company in the medium to long term should focus on production for the local market, although for the time being it is being used as an export oriented producer. ZISCO needs to improve productivity and presently this does not require state of the art technology. Retiring old technology and acquiring new technology may result in technology leap-frogging. This would increase the efficiency levels and lower energy intensities. As already indicated reforms in ZISCO could bring positive changes in the organization with regards to both efficiency and productivity.

8.5 AREAS FOR FURTHER RESEARCH

The analysis carried out in this work show that further work is needed. The areas include:

- Estimate and quantify the potential energy savings and benefits from the iron and steel industry
- Estimate and quantify the investments required for such savings and benefits to be achieved
- Estimate the magnitude of economic and non-economic disincentives to conservation
- Investigate current incentives for energy efficiency improvement and general industrial development and create a model to help analyse the effects of various incentive programs
- Investigate economic and non-economic disincentives to energy efficiency in various developing countries to identify implementation problems, and
- Investigate the linkages between inefficient energy use and inefficiency in the overall economy

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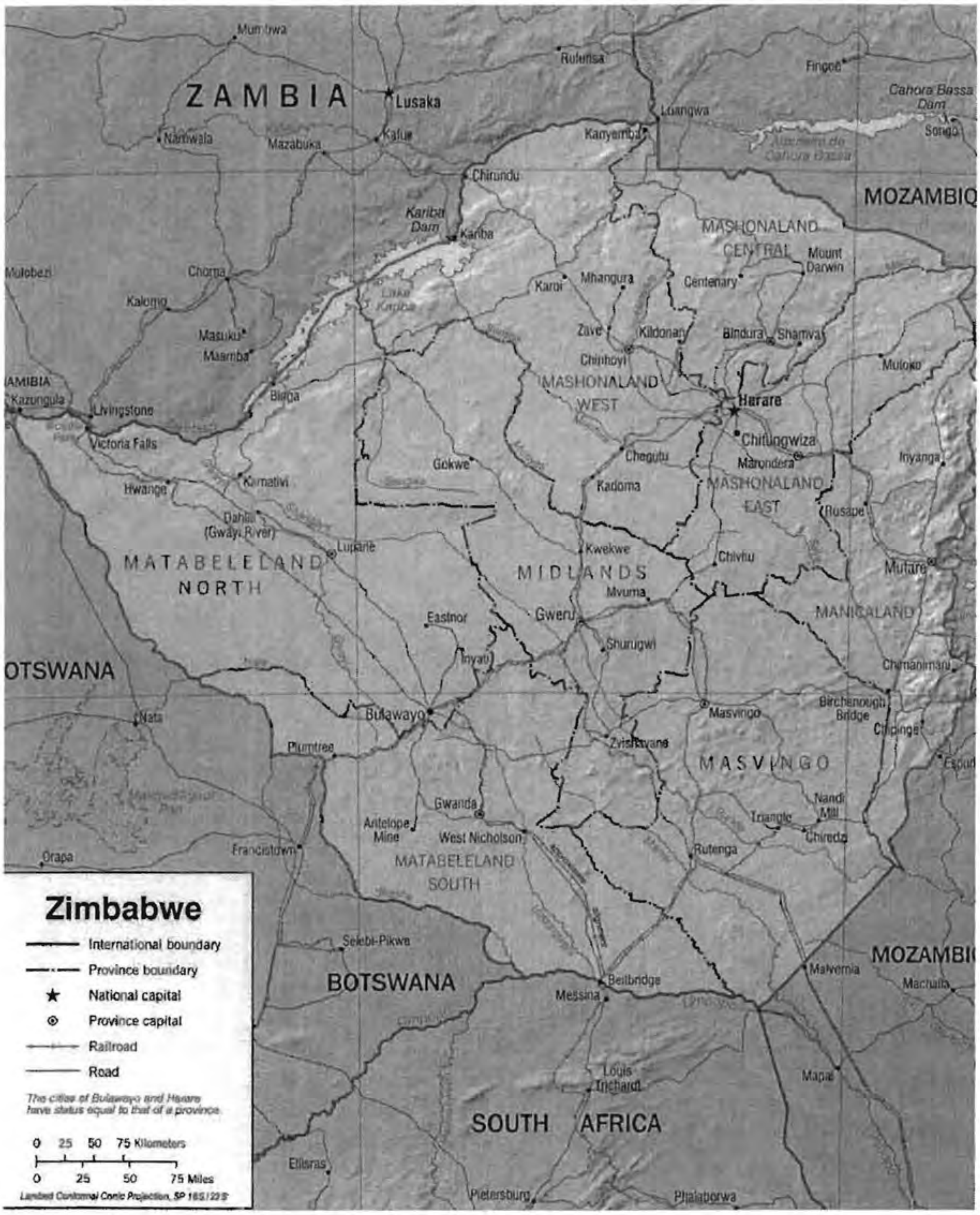
APPENDICES

APPENDIX 1 MAP OF ZIMBABWE: ZISCO IS LOCATED IN KWEKWE



APPENDIX 2: LOCATION OF THE SOUTH AFRICAN STEEL PLANTS