REPORT NO. GEN 169

FINAL REPORT

DEVELOPMENT OF A DRAFT MANUFACTURING AND MINING ENERGY EFFECTIVENESS STRATEGY FOR SOUTH AFRICA

PART 2: THE POTENTIAL BENEFITS OF IMPROVED ENERGY EFFECTIVENESS IN MANUFACTURING AND MINING IN SOUTH AFRICA

M G DE VILLIERS

R K DUTKIEWICZ

Energy Research Institute
University of Cape Town
P.O. Box 33
Plumstead 7800
South Africa

June 1994

Department of Mineral and energy Affairs
Private Bag X59
PRETORIA
0001

Departement van Mineraal- en Energiesake
Privaatsak X59
PRETORIA
0001

Tel : (012) 322-8561
Fax : (012) 322-3416

PREPARED FOR THE CHIEF DIRECTORATE ENERGY BY:

Mr M G de Villiers
ERI
University of Cape Town
P O Box 33
7800 PLUMSTEAD

Prof R K Dutkiewicz
ERI
University of Cape Town
P O Box 33
7800 PLUMSTEAD

Title: Development of a draft manufacturing and mining energy effectiveness strategy for SA
Part 2: The potential benefits of improved energy effectiveness in manufacturing and mining in SA

Duration of Project: 1992/11 - 1994/01
Energy Division: Energy Efficiency
Project Ref No: ED9210

CERTIFIED AN OFFICIAL FINAL REPORT: Gaston **DATE:** 94/06/03.

This report was prepared as a result of work sponsored by the Chief Directorate: Energy. The report has been submitted to, reviewed and accepted by the Chief Directorate: Energy. However, the view or opinions of the authors expressed herein do not necessarily confirm or reflect those of the Chief Directorate: Energy. Material in this report may be quoted provided the necessary acknowledgement is made.

Copies of this publication may be obtained from the Department of Mineral and Energy Affairs.

Eksemplare van hierdie publikasie kan van die Departement van Mineraal- en Energiesake aangekoop word.

ABSTRACT

South African industry is more energy intensive than most developed countries. This is partly due to the energy-intensive structure of industry in South Africa and greater specific energy consumption for most products. This has been attributed to (1) the relative costs of labour, energy, and capital which in South Africa favour labour and energy, (2) external factors such as the quality of raw materials, and (3) the level of energy effectiveness which depends largely on awareness and knowledge. All these factors must be considered when estimating the potential for improved energy effectiveness.

Two energy consumption scenarios were developed - a business-as-usual scenario and an energy-effective scenario. Under the business-as-usual scenario energy use between 1990 and 2015 will decrease at an average rate of 0,94-1,38%/annum compared to energy use if efficiencies were frozen. However under the energy-effective scenario energy use between 1995 and 2015 can be further reduced by 0,62-0,8%/annum. These rates of reduction are consistent with the findings of studies conducted for other countries.

Annual energy costs could be reduced by about 9-12% in 2005 and 14-16% in 2015 through improved energy effectiveness. It is estimated that the average pay-back period is 1,5 years, and thus the total investment required by industry is roughly 1,5 times the annual saving in energy cost. These savings can only be realized through increased awareness, knowledge, training, incentives, and research support.

EXECUTIVE SUMMARY

The main objective of this report is to provide policy makers with an estimate of the benefits of improved industrial energy effectiveness in South Africa. This is accomplished by comparing energy use up to the year 2015 under two scenarios:

(1) A 'business-as-usual' scenario with no extra energy effectiveness initiatives.
(2) An 'energy effective' scenario where authorities embark on an energy effectiveness programme from 1995 similar to those of other countries who have successfully promoted energy effectiveness.

A comparison of energy intensities with other developed countries shows that South Africa's industrial energy intensity would be 26% less if it's industrial structure is adjusted to that of a typical developed country.

Specific energy consumption, independent of industrial structure, for paper, bricks, cement, and steel are generally greater in South Africa than in developed countries, but generally at the lower end of the range for developing countries. Reasons for specific energy consumption being higher in South Africa than developed countries are:

(1) The relative costs of energy, labour, and capital favour greater use of energy and labour, and less capital expenditure, than in most developed countries.
(2) A number of external factors, beyond the control of industry, favour increased specific energy consumption in South Africa. Examples are quality of raw materials, quality and mix of products, fuels mix, cost of energy-effective equipment, age of plants, utilisation of production capacity, and size of production units.
(3) The likelihood that energy is not used effectively in South Africa: For instance energy losses are sometimes higher than necessary, waste energy is not always recovered when cost-effective, maintenance and operating procedures are often inadequate, there is insufficient accountability for energy use, and insufficient attention is given to energy in the design stage.

The two energy consumption scenarios were developed for both a low and high growth in the economy. A frozen efficiency scenario was also developed for energy use in order to compare energy efficiency improvement rates with other studies. Under the business as usual scenario energy use between 1990 and 2015 will decrease at an average rate of 0,94-1,38%/annum over the frozen efficiency

scenario. However under the energy effective scenario energy use between 1995 and 2015 can be further reduced by 0,62-0,8%/annum. These rates of reduction are consistent with the findings of studies conducted for other countries.

The following summarises the energy cost scenarios (Rmillion, 1993 prices):

	2005		2015	
	LOW	HIGH	LOW	HIGH
Business-as-usual	12 998	15 445	13 676	20 752
Energy effective	11 846	13 651	11 830	17 479
Potential saving	1 152	1 794	1 847	3 273

Annual energy costs could be reduced by about 9-12% in 2005 and 14-16% in 2015 through improved energy effectiveness. It is estimated that the average pay-back period is 1,5 years, and thus the total investment required by industry is roughly 1,5 times the annual saving in energy cost. The alternative to improved energy effectiveness will be investment in new capacity.

This potential could be realised through government providing a seed from which greater industrial energy effectiveness can grow. It is recommended that broad categories of government assistance should include a general awareness campaign, subsidised energy audits, demonstration schemes, training, cogeneration incentives, and joint R&D projects.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

The purpose of this report is to assess the potential benefits of improved energy effectiveness in manufacturing and mining in South Africa. Energy effectiveness is usually quantified by calculating energy intensity or specific energy consumption which both indicate energy consumption per unit of output. In order to understand these terms and a number of others unambiguously it is necessary that they be defined.

1.1 DEFINITIONS

Energy effectiveness is the use of energy in such a way so as to provide maximum benefit to society as a whole: economically, socially, environmentally, and politically. Improved energy effectiveness is usually accomplished through fuel switching, reduction of energy consumption, and energy demand reduction.

Primary energy refers to the energy content of primary sources, mainly fuels as mined. Primary energy should include the energy loss in the production of fuels and electricity, as well as transmission losses. Primary energy is thus useful when considering resources.

Net energy refers to the energy content of fuels and electricity supplied. For electricity the net energy equivalent is 3,6 MJ/KWh. Net energy is useful when assessing end-use of energy.

Physical output is the actual mass, volume, or number of end-products. A problem with using physical output is that in many industries the output is not homogeneous or well defined, such as the food industry. In order to use meaningful physical outputs it is necessary that industries be disaggregated to a point where physical outputs are well defined. This means that for some industries the use of physical outputs is impractical as the degree of disaggregation required is too extensive.

Economic output is usually expressed as value added which is defined as the economic value added to raw materials in production. Value added is equal to the difference between total value of sales and cost of materials.

Energy intensity is defined as the ratio of primary or net energy consumption to economic output. Energy intensity is useful when comparing the various subgroups of industry for one country, and for inter-country comparisons. A problem of using energy intensity for inter-country comparisons is the conversion of national currencies to a common base. The use of market exchange rates, derived from the internationally traded component of national output, is not always well adapted for the conversion of the much larger non-trade component. An alternative has been the use of estimated exchange rates reflecting purchasing power parities.

It is possible for a country to have a higher industrial energy intensity simply because of the predominance of inherently energy-intensive activities. In order to exclude structural effects from energy intensities, it is necessary to disaggregate industry to a point where physical output is well defined.

Specific energy consumption (SEC) is defined as the ratio of net energy consumption to physical output. SEC is usually used for inter-country and time-series comparisons of energy effectiveness for specific products. SEC is often based on a well-defined intermediate product (such as pulp) rather than a more varied final product (such as paper). SEC is affected by age of equipment, type of processes, economies of scale, energy prices, and energy management practices. These factors may be manifestations of more fundamental features such as energy resources, stage of development, skills, and economic policies.

1.2 OBJECTIVES

The objective of this report is to provide policy-makers with an estimate of the benefits of improved industrial energy effectiveness in South Africa. This is accomplished by comparing energy use up to the year 2015 under two scenarios:

(1) A 'business-as-usual' scenario with no extra energy effectiveness initiatives.
(2) An 'energy effective' scenario where authorities embark on an energy effectiveness programme from 1995 similar to those of other countries who have successfully promoted energy effectiveness.

Two important results of energy effectiveness are quantified: energy reduction and electricity demand reduction which are converted to economic benefit to industry. These economic benefits will filter through to the entire population through reduced consumer costs, greater international competitiveness, decreased investment in the energy sector, and increased employment. Other impacts of energy effectiveness which are more difficult to quantify are reduced environmental impact of energy use and conservation of energy resources.

Once the economic benefits to industry are quantified, manpower and costs associated with promoting energy effectiveness can then be seen in better perspective. In addition, this report highlights those industries and common energy end-uses where the potential is greatest, indicating where emphasis on promoting energy efficiency should be focused.

1.3 SCOPE OF THIS STUDY

This study covers energy effectiveness in mining and manufacturing, and excludes:

Electricity, gas, and steam production
Construction
Petroleum refining from oil and coal

Mining and manufacturing will be collectively referred to as industry. Industrial groups have been classified according to the Standard Industrial Classification (SIC) system.

2. METHODOLOGY

2.1 INTRODUCTION

Net potential for improved energy effectiveness in the future will depend on:

(1) Market penetration rate of **existing potential**.
(2) Aging and obsolescence of existing equipment giving rise to **replacement potential**.
(3) Growth of industry and the resulting design options giving rise to **new capacity potential**.

Energy prices will have an effect on both potential and realised energy effectiveness opportunities. It is assumed that energy prices will not change significantly in real terms, although it is possible that energy prices will increase in the long term due to the internalization of environmental costs. The energy price effect is not quantified since the data available are not comprehensive enough to examine the effect of price.

In order to construct the two energy scenarios and calculate the potential economic benefits, the following information is necessary:

(1) An industrial production scenario until 2015.
(2) Growth of new industrial capacity until 2015.
(3) Energy effectiveness potential including existing potential, replacement potential, and new capacity potential.
(4) Market penetration curves.
(5) Energy prices to convert energy effectiveness improvement to economic savings.

2.2 INDUSTRIAL PRODUCTION SCENARIO

In order to calculate the potential for improved energy effectiveness, a scenario for growth in industrial production is necessary. Changes in industrial production in each industrial group were estimated from correlations with an appropriate statistic such as GDP, population, or GDP/capita. In some industrial sectors estimates of production growth were obtained from other studies which based their estimates on plans for increased capacity, and supply and demand projections.

2.3 GROWTH OF NEW INDUSTRIAL CAPACITY

Growth of new industrial capacity depends on current excess capacity, future capacity closure, and required future production. Current excess capacity is estimated from the analysis of each industrial group. A capacity closure rate is estimated, based on observed rates in the past.

2.4 ENERGY EFFECTIVENESS POTENTIAL

Energy effectiveness is usually accomplished through:

(1) Fuel switching
(2) Energy reduction
(3) Demand reduction

2.4.1 Fuel switching

Fuel switching potential is usually confined to specific applications with varied benefits and is therefore difficult to assess. The potential for fuel switching is therefore not quantified, although it is possible that a large potential for fuel switching does exist. With the possibility of the introduction of natural gas to the South African market, it is expected that a potential will arise for switching from other fuels to gas. It is also likely that there will be continued switching from fuels to electricity until the electricity market is saturated.

2.4.2 Energy reduction

The importance of choosing appropriate estimates of energy reduction potential is illustrated by the results of a study in the USA[1]. The reduction in electricity use was calculated between 1987 and 2000 for different assumptions. The results are shown in Table 2.1.

Table 2.1 Potential reduction in electricity use in the USA between 1987 and 2000 (mean values)

Scenario	% Reduction in electricity use
Frozen efficiency	0
Business-as-usual	11,5
Economic potential	19
Technical potential	34

The 7,5% difference between the economic potential and business-as-usual potential is the maximum electricity reduction possible through enhanced energy effectiveness. Taking into account market penetration rates, realistic potential will be even less. In the context of this study quoting potential relative to frozen efficiencies, as opposed to business-as-usual, would be grossly incorrect. Using technical potential instead of economic potential would be violating the definition of energy effectiveness.

There are a number of methods by which the potential for energy reduction can be assessed. One is to compare energy intensities and SEC's in South Africa with those in developed countries and, taking the specific situation in South Africa into account, infer the potential for energy reduction. A second approach is to analyse energy use in industry in South Africa and identify areas where less energy could be used. Such an analysis could be done by examining each industrial group or by examining common industrial end-uses such as boilers, furnaces, electric motors, etc.

Very little research has been directed to the potential for energy reduction in the various industrial groups of South Africa. In some studies possible measures are identified but not quantified. Some studies have looked at only a subdivision of an industrial group, too small to be representative of the industrial group to which it belongs. Other studies consider technical potential but not economic potential. Because of numerous gaps in information, a combination of all the above approaches is used to estimate existing, replacement, and new capacity potential.

2.4.3 Demand reduction

Demand reduction potential is applicable only to gas and electricity, but electricity use far outweighs gas use and thus only electricity is considered. Demand reduction can arise from an improved load factor and from energy reduction. Energy reduction has already been covered. Potential load factor improvement is calculated from an estimation of existing potential and new capacity potential.

2.5 MARKET PENETRATION

Based on historical data, market penetration of energy effective opportunities usually follows an S-shaped curve. In the early period after a new process or product is released adoption is slow because of high perceived risk and lack of information by consumers. The rate of adoption then increases as perceived risk decreases and consumer awareness increases, and uncertainty about price and quality decrease. Finally the rate of adoption slows as the product saturates the market. Energy effectiveness programmes can both accelerate market penetration and increase long-run market share.

Market penetration models are usually based on modified Mansfield models. The Mansfield/Blackman Market Penetration Model was used in this study. Two market penetration scenarios are used, one for the business-as-usual scenario and one for the energy effective scenario. The following assumptions are made:

- Energy prices will remain unchanged in real terms.
- No financial incentives will be provided which would alter the economic feasibility of some possibilities.
- A government campaign does not change the size of the potential market.
- No major technological breakthroughs.

2.6 CONVERTING ENERGY REDUCTION TO ECONOMIC SAVING

All economic savings are calculated in 1993 Rands. Cost-effective energy effectiveness measures will generally have payback periods of under two years. By estimating an average pay-back period, the investment required for these annual energy cost savings is crudely estimated.

2.7 SUMMARY OF THE METHODOLOGY

Potential industrial energy effectiveness improvement is estimated by:

(1) Estimating production and new capacity requirements by each industrial group until 2015.

(2) Estimating the energy reduction potential for each industrial group including existing, replacement, and new capacity potential.

(3) Estimating the total electricity demand reduction potential due to load factor reduction and energy reduction.

(4) Calculating total industrial electricity demand and energy use until 2015 for two scenarios: a 'business-as-usual' scenario and an 'energy-effective' scenario.

(5) Converting potential demand reduction and potential energy reduction to economic savings to industry.

3. THE PRESENT STATE OF INDUSTRIAL ENERGY EFFECTIVENESS IN SOUTH AFRICA

3.1 INDUSTRIAL ENERGY USAGE IN SOUTH AFRICA

3.1.1 Energy consumption and energy intensity

Sectorial energy data were obtained from Cooper[(4)] who has initiated an energy database for South Africa. Data collection has not yet been refined to a point of adequate accuracy, although response to questionnaires has steadily improved. In some cases energy resources used for non-energy purposes have been included in the data. Nevertheless the database is the most comprehensive available, although the accuracy of the data should not be taken for granted.

The latest value added statistics for industry, from the Central Statistical Services[(5)], are for 1988, but only more recent energy data for 1990 and 1991 is available. In order to calculate energy intensities it was necessary to update the value added statistics to 1991. This was achieved by calculating the ratio of value added to sales for 1988 and then multiplying the ratio with 1991 sales[(6)].

Table 3.1 shows net energy consumption, value added, and energy intensities for industry in 1991 disaggregated to the three-digit SIC level. Five of the thirty-three industrial groups (gold mining, food, paper and paper products, other non-metallic minerals, and basic metals) consume 71% of total industrial net energy use. The five most energy-intensive industries are ferrous metals, other non-metallic minerals (dominated by cement and bricks), paper and paper products, pottery, and non-ferrous metals. The energy intensity of mining is less than the manufacturing average.

Table 3.1 Net energy consumption, value added, and energy intensity for major industrial groups in South Africa in 1991

SIC	MAJOR GROUPS	NET ENERGY CONSUMPTION (PJ)	VALUE ADDED (Rmillion)	ENERGY INTENSITY (MJ/Rand)
210	Coal	11.1	4797	2.3
230	Metal ore	29.4	2910	10.1
240	Gold and uranium	87.2	13138	6.6
270	Diamond	3.7	1390	2.7
280	Other	5.3	4770	1.1
	Total mining	136.7	27005	5.1
311	Food	90.0	8697	10.4
313	Beverages	11.0	2685	4.1
314	Tobacco	0.9	401	2.2
321	Textiles	17.5	2617	6.7
322	Clothing	1.6	2099	0.8
323	Leather	1.3	277	4.8
324	Footwear	0.4	759	0.6
331	Wood except furniture	8.0	1404	5.7
332	Wood furniture	1.1	1015	1.0
341	Paper and paper products	66.4	3319	20.0
342	Printing	2.9	2863	1.0
351	Industrial chemicals	54.9	3211	17.1
352	Other chemicals	12.8	1982	6.5
355	Rubber	5.8	991	5.8
356	Plastics	3.6	1860	1.9
361	Pottery	2.3	111	21.1
362	Glass	8.1	781	10.4
369	Other non-metal minerals	82.9	2170	38.2
371	Ferrous basic metals	288.1	4413	65.3
372	Non-ferrous basic metals	25.4	1407	18.0
381	Fabricated metal	14.0	4888	2.9
382	Machinery	5.8	3407	1.7
383	Electrical machinery	5.1	3175	1.6
384	Motor vehicles	6.5	3699	1.8
385	Transport equipment	1.1	1082	1.0
386	Professional & scientific	0.4	360	1.2
390	Other manufacturing	7.3	583	12.5
	Total manufacturing	725.3	60254	12.0
	Total industry	862.0	87259	9.9

3.1.2 Energy costs

Industrial energy costs, also expressed as a percent of value added, are shown in Table 3.2. Included is electricity as a percent of total energy consumption, since electricity is the most expensive energy carrier. A survey of European industrial managers indicated that industries with energy costs less than ten percent of manufacturing costs were likely to pay significantly less attention to energy efficiency[25].

Table 3.2 Industrial energy costs for South Africa in 1991

SIC	MAJOR GROUPS	ENERGY COST (Rmillion)	ELEC. USE (%)	ENERGY COST\ VALUE ADDED (%)
210	Coal	217	77	4.5
230	Metal ore	516	71	17.7
240	Gold and uranium	1678	94	12.8
270	Diamond	81	95	5.8
280	Other	119	100	2.5
	Total mining	2611	88	9.7
311	Food	823	20	9.5
313	Beverages	126	25	4.7
314	Tobacco	19	52	4.8
321	Textiles	291	39	11.1
322	Clothing	53	81	2.5
323	Leather	15	24	5.3
324	Footwear	17	95	2.2
331	Wood except furniture	112	32	8.0
332	Wood furniture	39	94	3.9
341	Paper and paper products	433	21	13.0
342	Printing	59	89	2.1
351	Industrial chemicals	476	31	14.8
352	Other chemicals	246	83	12.4
355	Rubber	97	38	9.8
356	Plastics	115	73	6.2
361	Pottery	56	38	50.7
362	Glass	176	39	22.5
369	Other non-metal minerals	629	12	29.0
371	Ferrous basic metals	1900	21	43.1
372	Non-ferrous basic metals	380	58	27.0
381	Fabricated metal	382	47	7.8
382	Machinery	202	82	5.9
383	Electrical machinery	167	75	5.3
384	Motor vehicles	192	67	5.2
385	Transport equipment	36	76	3.3
386	Professional & scientific	14	86	4.0
390	Other manufacturing	89	8	15.3
	Total manufacturing	7144	26	11.9
	Total industry	9755	34	11.2

3.2 INTER-COUNTRY COMPARISON OF ENERGY INTENSITY

A number of problems arise when trying to perform inter-country comparisons of energy intensity based on value added, and these are:

- Converting national currencies to a common base.
- The classification of industrial activity. Although most countries adhere to the SIC classification, there are some activities, such as the manufacture of ferroalloys, that are not well defined in terms of the SIC system.
- The inclusion of fuels used as feedstocks.
- The inclusion of non-purchased energy.
- Variations of the product mix within each industrial group.

One study[9] examining manufacturing energy intensities attempted to overcome some of these problems by using purchasing power parities to convert national currencies to US$, collecting energy data from the energy statistics authority in each country and, where possible, adapting energy statistics to conform to a common classification. In order to exclude structural effects, a manufacturing energy intensity was calculated for each country using the average manufacturing structure of the eight countries analysed. The same methodology was applied to South Africa and Table 3.3 shows the result.

1988 energy intensities were used in the study, but since no accurate 1988 energy information is available for South Africa, 1991 energy intensities were used. The relevant purchasing power parity rate for South Africa is uncertain and hence the exchange rate was used. One article[10] gives the relevant purchasing power parity rate for South Africa to be 71% of the exchange rate, but it is based on a number of assumptions and generalisations. In that case energy intensities would be 71% of those shown in Table 3.3. Mining is not included in the above analysis, but mining has a lower energy intensity than manufacturing, and is more prevalent in South Africa. The inclusion of mining in the above analysis would reduce South Africa's energy intensity, and reduce the difference between actual energy intensity and structure-adjusted energy intensity for South Africa.

Table 3.3 Inter-country comparison of manufacturing energy intensities (MJ/1980 US$)

	FRG	DENMRK	FRANCE	JAPAN	NORWAY	SWEDEN	UK	USA	SA
Paper and pulp	30	29	30	43	100	153	18	82	65
Chemicals	25	15	26	17	43	24	20	39	41
Stone, clay, and glass	42	64	31	34	44	49	25	49	98
Iron and steel	90	53	102	80	216	81	119	111	212
Nonferrous metals	32	23	23	15	146	83	34	62	59
Other	4	12	5	5	12	10	9	6	14
Total manufacturing	12	16	13	13	41	27	14	17	39
Structure adjusted	12	16	13	11	29	21	15	18	29
Percent change	-2	6	-0	-11	-30	-23	5	6	-26

Inter-country differences in energy intensities for each industrial sector indicate that influences, in addition to energy effectiveness, are present. This may be partly due to purchasing power parities being inaccurate or inadequate. In order to exclude the problem of converting currencies to a common base it is necessary to analyse specific energy consumption. The above analysis is thus insufficient in drawing any conclusions on the level of energy effectiveness. All that can be concluded is that if the structure of industry in South Africa was adjusted to that of a typical developed country then South Africa's industrial energy intensity would decrease by about 26%.

3.3 INTER-COUNTRY COMPARISON OF SPECIFIC ENERGY CONSUMPTION

3.3.1 Sectorial analysis

Six industrial groups were chosen for detailed analysis, some general statistics of which are presented in Table 3.4. Details of each industrial group appear in the appendices. The six industries analysed consumed about 62% of total industrial energy consumption in 1991, and accounted for 27% of total value added for industry. The industries were selected on the basis of the following criteria:

- Energy intensive.
- Large user of energy.
- Homogeneous and well defined output.
- Sufficient local and international information.

Table 3.4 General statistics of the industrial groups chosen for detailed analysis

Industry	SIC	1991 Energy consumption (PJ)	1991 Value added (R million)	Energy intensity (MJ/Rand)	Energy cost/ value added[a]
Gold mining	24	87	13138	6,6	13
Pulp and paper	341	66	3319	20,0	13
Structural clay	3691	35	699	50,1	24
Cement	3692	34	528	64,4	25
Ferrous metals	371	288	4413	65,2	43
Non-ferrous metals	372	26	1407	18,0	27
Total		536	23504	22,8	20,1
Industry total		862	87259	9,9	11,2

a Energy costs were assumed to be 0,21 c/MJ for coal, 0,98 c/MJ for liquid fuels, 2,16 c/MJ for electricity sold by ESKOM to manufacturers, and 3,9 c/MJ for electricity sold by municipalities to manufacturers. Gold electricity costs were obtained from the Chamber of Mines.

3.3.2 Comparison with other countries

Table 3.5 compares the specific energy consumption (SEC) of a number of products. It is evident that South Africa has consistently higher SEC's than developed countries, and falls on the lower end of SEC's of developing countries.

Table 3.5 Comparison of average national SEC of South Africa with other countries in GJ/ton (the range indicates uncertainty or the range reported by different sources)

	Paper	Bricks	Cement	Steel
South Africa	31-37	4,0-4,5	4,6	29,0
USA	28-35		4,1	21,4
UK	26	2,9		19,8
Sweden	22			19,7
Japan			3,0-4,0	17,6
Brazil	20		4,2	20,6
Hungary			4,2	25,6
Taiwan			3,7	23,2
Canada		3,5		23,7
Western Europe	22-29	2,6-3,8	3,6-3,8	16-21
Developing countries	23-54	4,0-5,0	4,0-6,0	24-39

These statistics are more fully detailed and discussed in the appendix section, but it is evident that numerous discrepancies exist in the reporting of some of these statistics. Reasons for these discrepancies are:

- Interpretation of energy consumption and whether in-house energy production and use of waste materials for energy should be included.
- Use of physical output may be different. For instance, the SEC of cement may be based on production of clinker or production of cement.
- Import or export of intermediate products which will affect SEC. For instance, Sweden is a major exporter of pulp, and if SEC was based on paper production, then the energy use for export pulp will be included.

Only when these factors are clearly defined can one begin to compare SEC. The reasons for differences in SEC can then be attributed to:

(1) The relative costs of energy, labour, and capital.

(2) External factors which are beyond the control of industrialists.

(3) The level of energy effectiveness

When estimating the potential for improved energy effectiveness the above factors were taken into account as far as possible.

3.4 FACTORS AFFECTING SPECIFIC ENERGY CONSUMPTION

3.4.1 The relative cost of energy

Important considerations in deciding upon an appropriate industrial process are the relative costs of energy, labour, and capital, each of which is interchangeable. Energy effectiveness includes choosing the optimum mix of these costs, and for the industrialist this means choosing the most cost-effective mix. In order to partly explain inter-country differences in specific energy consumption it is necessary to compare the relative costs of energy, labour, and capital.

Table 3.6 shows industrial energy prices for various countries converted to US$ using the exchange rate[11].

Table 3.6 Industrial energy prices of various countries in 1990 based on exchange rates (1990 US$/Toe)

	COAL	H.F.O.	GAS	ELEC
Australia	52	138	137	532
Canada	87	114	93	416
France	135	134	172	655
Hungary	144	136	239	699
Japan	119	196	458	1462
SA	33	199	297	390
Taiwan	142	170	348	940
UK	126	137	176	791
USA	59	114	124	552

On the basis of the exchange rate coal and electricity in South Africa, which constitute over 90% of industrial energy consumption, are considerably cheaper than in developed countries. The cost of labour in South Africa is generally accepted to be cheaper than in developed countries (based on the exchange rate). A large portion of capital equipment that can be used in industry in South Africa must be imported in which case import duties are charged. Capital in South Africa is thus more expensive in South Africa than the developed countries from where it is imported. In addition investors in South Africa require a higher return on investment because of high inflation. The optimum mix of energy, labour, and capital in South Africa will therefore favour greater use of energy and labour, and less capital expenditure, than in developed countries.

Table 3.7 shows that energy cost as a percent of value added for industry in South Africa is higher than for developed countries despite the low cost of energy in South Africa. Apart from the reasons given for higher SEC's in South Africa, this is also due to the energy-intensive structure of South African industry.

Table 3.7 Energy costs as a percent of value added in 1990[11,12,35]

Country	Industrial energy cost/ Industrial GDP (%)
USA	5,1
UK	5,1
France	5,2
Canada	5,4
Australia	6,5
Taiwan	7,3
China	8,5
Japan	8,6
South Africa[a]	11,6
Hungary	16,8

[a] For 1991

3.4.2 External factors

Quality of raw materials:
Energy use in mining depends largely on the grade of ore mined and the depth of the ore. In many industries, such as clay and cement industries, raw material characteristics can vary from region to region, and hence energy requirements for processing can vary too.

Quality and mix of products:
No industry produces exactly the same quality or mix of product. For instance, the paper industry produces a mix of tissue, newsprint, writing paper, cardboard, etc., each of which has a different energy requirement. In addition, some countries export pulp while others import their pulp, and different countries may produce a different quality of product, depending on demand.

Climate:
South Africa has higher ambient temperatures than most developed countries. Heating requirements will thus be lower, and cooling requirements higher, but because heating is the larger effect, South Africa's climate favours reduced energy requirements. In the USA it is estimated that 1,6%[13] to 2%[14] of industrial energy use was for space heating. Comparison of residential space heating indicates that the USA has a slightly lower space heating intensity than most European countries. In many cases space heating energy in industry is provided by low-grade process heat that cannot be utilised in South Africa. Also South Africa will have higher air conditioning energy requirements. It is thus likely that space conditioning is not a significant factor in the comparison of industrial energy intensities, especially for the energy intensive industries.

Fuel mix:
Fuel mix is largely dependent on the availability of indigenous fuel resources, relative costs, government policy, and the industrial structure. The conversion efficiency of coal to heat is less than for that oil or natural gas. For example, typical theoretical efficiencies of coal boilers are about 5% less than for oil or natural gas boilers. Electricity is a higher form of energy than fuels since losses are usually less, but electricity is more expensive. Table 3.8 shows the industrial fuel mix of various countries[12].

Table 3.8 Industrial fuel mix of various countries (%)

	COAL	OIL	GAS	ELEC	OTHER	TOTAL
Australia	31	14	30	25	0	100
Brazil	26	30	7	37	0	100
Canada	20	15	34	29	1	100
China	73	10	2	11	4	100
France	26	19	27	28	0	100
Hungary	15	15	43	20	7	100
Japan	35	28	4	33	0	100
SA	49	9	2	39	1	100
Taiwan	39	36	2	23	0	100
UK	23	18	35	24	0	100
USA	24	22	37	18	0	100

Electricity use is highest in South Africa and this partly explains the high relative energy costs. If one excludes gold mining then the electricity share falls from 39% to 29% which is normal for a developed country. South Africa has the second highest coal share after China, and if one excludes gold mining the coal share in industry is even larger. The effect of a higher coal share at the expense of oil and gas is that the conversion of fuels to heat will be unavoidably slightly less efficient.

Recycling:

The following are ranges of possible reduction in SEC by substituting raw materials with secondary materials(15).

Paper	23-74%
Glass	4-32%
Aluminium	90-97%
Steel	47-74%

Table 3.9 shows recycling in South Africa. Since South Africa is generally an exporter of basic materials, a lower proportion of scrap is available.

Table 3.9 Recycling in South Africa compared to typical developed countries

Material	% of Production	% of Consumption	Typical developed country
Paper	27	31	30-60
Aluminium	22	36	40-85
Steel	26	48	40-60
Glass	14	14	20-60

Cost of energy-efficient equipment:
In South Africa most energy-efficient equipment must be imported because the demand for such equipment is not great enough to warrant local production. Imported equipment will be more expensive for South African industry because of the unfavourable exchange rate and import duties.

Age of plants:
Industrial processes have become more energy efficient with time, and thus newer industrial production capacity is likely to be more energy effective than older plants. The age of plants is determined by the stage of development and the growth of the country.

Utilization of production capacity:
Plants are designed to run at full capacity, and as one decreases production so energy efficiency will fall. When demand is low, running at less than full capacity is sometimes unavoidable.

Size of production units:
Generally larger production units are more energy effective than smaller units. The size of production units is limited by demand.

3.4.3 Level of energy effectiveness

Energy effectiveness was examined in a previous report of this project. Energy effective practices result in:

- adequate maintenance and operating procedures
- optimum selection of fuels
- reduced energy losses and recovery of waste energy where feasible
- accountability for energy use
- appropriate consideration of energy costs in the choice of process technologies
- prompt equipment replacement once it is economically feasible
- energy awareness amongst employees
- regular plant energy audits

4. THE POTENTIAL FOR IMPROVED ENERGY EFFECTIVENESS IN SOUTH AFRICA

4.1 PRODUCTION SCENARIOS

Scenarios of average GDP growth rates were obtained for the period up to 2000, but not beyond. The average GDP growth rate between 1985 and 1990 was 1,3%/annum, but between 1990 and 1992 it was -1,2%/annum. The Normative Economic Model[17] asserts that a 3,6%/annum growth rate in GDP between 1992 and 2000 is possible only if a number of economic policy changes are introduced. The secondary sector, dominated by manufacturing, is pivotal to this growth and a growth rate of 4,5%/annum in this sector is then necessary. The growth rate in the primary sector, mainly mining, is expected to be 2,5%/annum under this scenario. The Bureau for Economic Research expects an average GDP growth rate of 2,1%/annum up to 2000, considering the current infrastructure and assuming no major economic policy changes[18]. The Institute for Futures Research assumed low and high GDP growth rates of 2%/annum and 5%/annum respectively between 1991 and 2000[30].

Considering the above, the low growth scenario GDP growth rate is expected to increase linearly from -1% for 1990/1991 to 3% for 1999/2000. The high scenario GDP growth rate is expected to increase linearly from -1% for 1990/1991 to 7% for 1999/2000. For the period 1992 to 2000 the low scenario gives an average GDP growth of 1,5%/annum and the high scenario 4,4%/annum. For the period 2000 to 2015 GDP growth is assumed to remain unchanged at 3%/annum and 7%/annum for the low and high scenarios respectively.

Appendix I has graphs indicating the correlation between GDP, population, or GDP/capita and production in those industrial groups whose production scenarios are based on these parameters. Population growth is expected to be 2,35 %/annum between 1990 and 2000, and 2,1 %/annum between 2000 and 2015[30]. Production scenarios for metal manufacturing were obtained from Granville et al.[23], and coal production from Cooper and Kotze[34]. Maintaining energy intensities at 1990 levels until 2015, structural change will increase energy intensity by 16% for the low scenario and by 7% for the high scenario. The increase is due to the growth of more energy-intensive activities. However, in the high growth scenario there will also be increased growth in the tertiary industrial sector, with low energy intensity activities, thus reducing the effect of the growth of energy-intensive activities.

In calculating the required new capacity, a 1,5%/annum closure rate of current capacity is assumed. Appendix J shows production up to 2015 relative to 1990, and the percent of production that will require new capacity.

4.2 ESTIMATING ENERGY EFFECTIVENESS POTENTIAL

As outlined in Chapter 2, two results of energy effectiveness are quantified in this study: energy reduction and electricity demand reduction.

4.2.1 Energy reduction

In order to cover the full scope of energy reduction potential, its effect on energy use in the future is divided into three portions:

(1) **Existing potential** represents those energy-effective opportunities which can be undertaken immediately. However, due to a number of barriers such as lack of awareness, knowledge and financing, these opportunities require time to penetrate the market or will never be realised. Under the energy-effective scenario the market penetration rate of existing potential will be greater.

(2) **Future replacement potential** represents potential arising from ageing and obsolescence of equipment. Future replacement potential may not be realised if equipment is not replaced when it is economically feasible to do so, or the equipment is not replaced with the most energy-effective equipment. Equipment replacement will generally result in lower specific energy consumption (SEC). The effect of future replacement potential is estimated by the resulting rate of decrease in SEC. This rate of decrease in SEC will be greater under the energy-effective scenario.

(3) **New capacity potential** represents potential arising from the design of new energy-effective plants. Generally, a new plant will have a lower SEC than an existing plant, and a plant designed with suitable attention to energy effectiveness will have an even lower SEC. The effect of new capacity potential on energy consumption is estimated by estimating the SEC of new plants for each of the two scenarios.

Existing potential:

A summary of the analysis of common industrial end-uses (details in Appendix H) is given in Table 4.1. Industry could reduce energy consumption by 9-17% through cost-effectively through improved energy effectiveness, excluding specific process opportunities.

Table 4.1 Potential energy reductions for common industrial energy end-uses

Measure	Reduction (PJ)
Electricity	
Motors	20,1-40,2
Mechanical equipment	10,1-13,5
Furnaces	3,8-7,6
Electrolysis	1,6-2,4
Lighting	3,5-6,2
Fuels	
Furnaces	10,4-20,7
Boilers	10,4-20,7
Steam systems	10,4-20,7
Other	6,0-18,1
Total	76,3-150,1

Existing potential for each industrial group is estimated from the analysis of industrial groups (Appendices A to G), with the above analysis being used as a check on the total. Those groups which were not examined are assumed to a have an existing potential of 15%. Energy use in 1990 and the estimates of existing potential are shown in Table 4.2. Total existing industrial potential is 14% of energy use, which is slightly conservative in comparison to the above 9-17% which excludes specific process opportunities.

Table 4.2 Energy use in 1990 and estimates of existing potential

Industry	Energy use in 1990 (PJ)	Existing potential (%)
Steel	194,0	10
Gold	89,0	10
Food	85,4	20
Ferroalloys	76,9	10
Paper	66,0	15
Textiles	51,2	25
Bricks	43,0	25
Cement	34,0	15
Other metals	20,8	10
Titania	13,2	10
Aluminium	12,5	10
Stainless steel	0,6	10
Other	170,7	15
Total	857,3	14,2

Figures 4.1 and 4.2 show market penetration rates of existing potential used in this study. Appendix K explains the derivation of these curves. It was assumed that under the high growth scenario market penetration rates would be greater than for the low growth scenario.

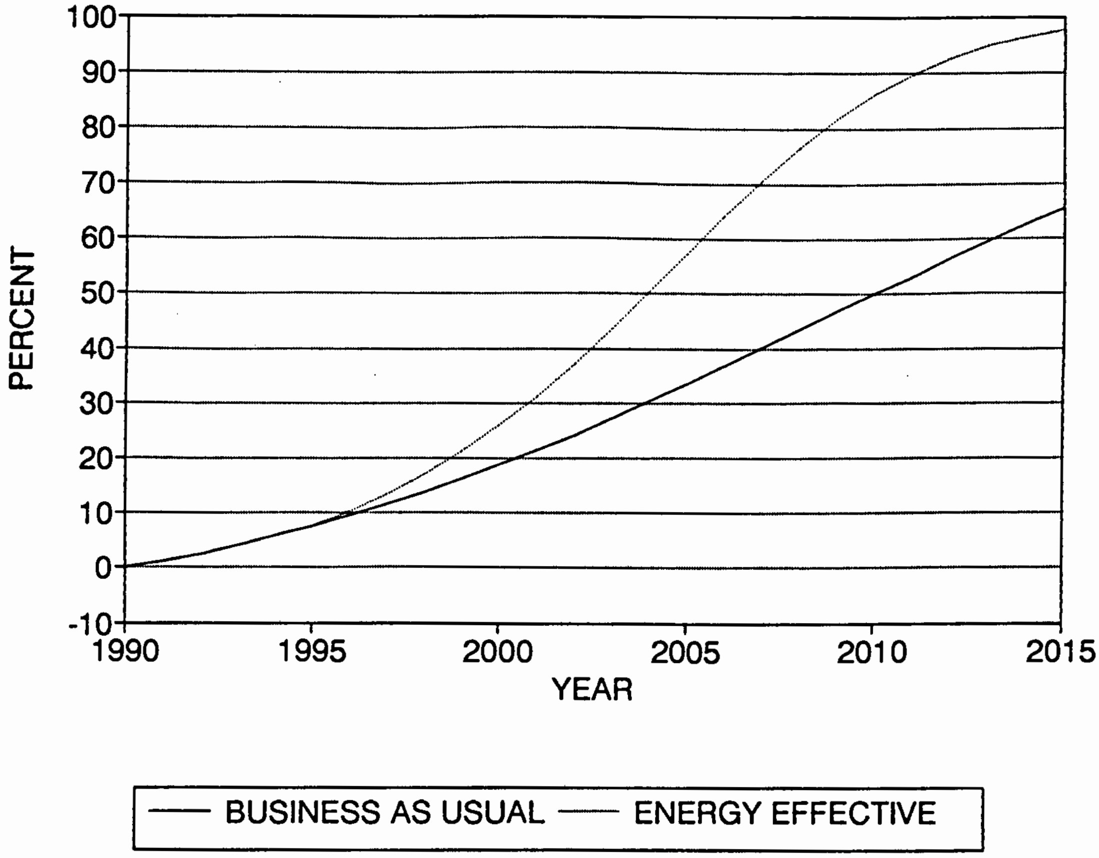


Figure 4.1 **Market penetration rates for the low growth scenario**

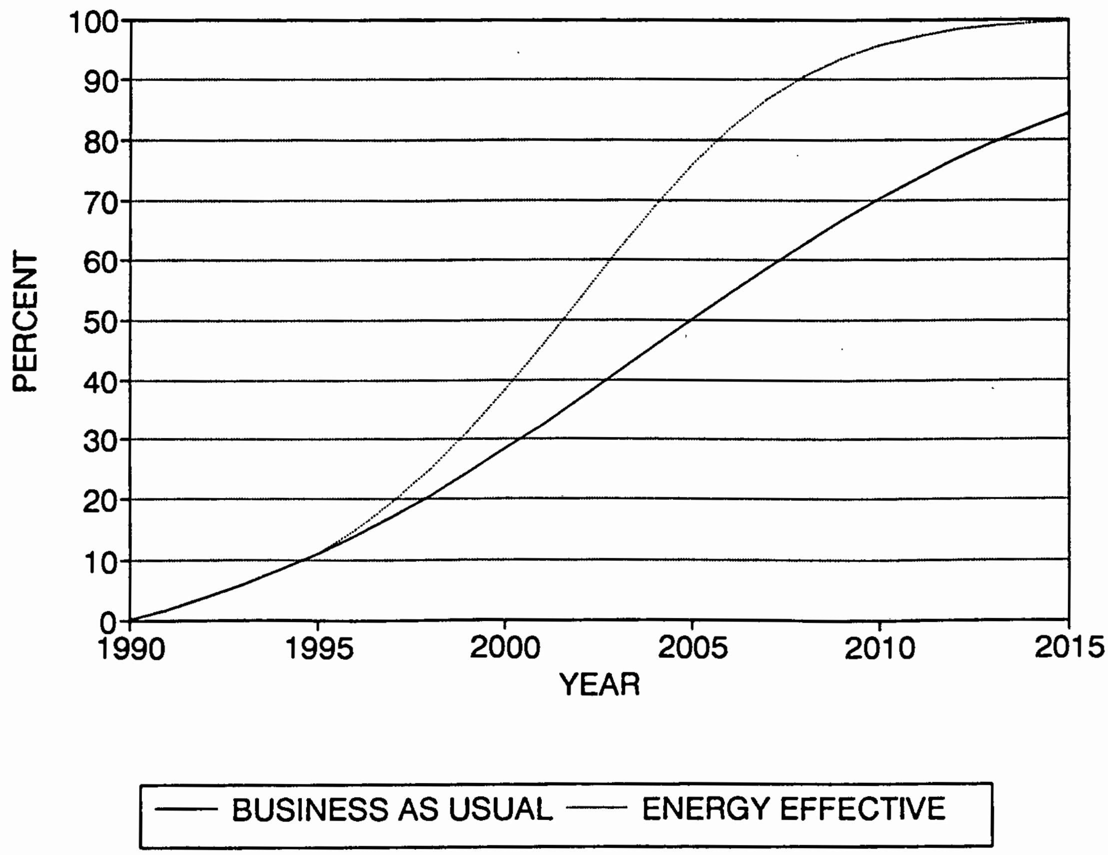


Figure 4.2 **Market penetration rates for the high growth scenario**

Future replacement potential:
Future replacement potential is difficult to estimate from past trends because of the effects of structural change and energy price fluctuations. In general, studies of expected future energy consumption in developed countries have estimated energy efficiency improvements of 0,5-1,5%/annum. Most of the backlog of existing potential has already been realised in developed countries following increased awareness and government programmes in the seventies and eighties. Much of the potential identified for the future is therefore due to equipment replacement and the development of new technology. Generally, efficiency improvement rates under energy-effective scenarios are assumed to be about one and a half times greater than business as usual rates. Table 4.3 shows future replacement potential values used in the two scenarios.

Table 4.3 Energy efficiency improvement rates due to replacement (%/annum)

	Low Scenario	High Scenario
Business as usual	0,3	0,5
Energy effective	0,45	0,75

New capacity potential:
The SEC of new capacity, under the business-as-usual scenario, is estimated from current SEC of recently commissioned plants in South Africa, or from estimates of SEC for a new plant in South Africa. It is expected that under the energy-effective scenario the SEC of plants will lie somewhere between business-as-usual SEC and SEC of new plants in developed countries. For the energy-effective scenario it is assumed that SEC of new plants in South Africa will be halfway between business-as-usual SEC in South Africa and best practice in other countries. Those industries which were not examined in this study are assumed to have a new capacity SEC of 85% of that of the existing average SEC of the industry under the business-as-usual scenario, and 75% of the industry average under the energy-effective scenario. Table 4.4 shows SEC values used in this study.

Table 4.4 SEC of new capacity (for the ratios current average SEC is the denominator)

Group	Current average SEC (GJ/ton)	Business-as-usual ratio	Overseas best practice (GJ/ton)	Energy-effective ratio
Gold ore[a]	0,76	0,95	-	0,85
Paper	32	0,84	19	0,72
Bricks	4,4	0,79	1,7	0,59
Cement	4,6	0,87	3,2	0,78
Steel	29	0,83	17	0,71
Stainless Steel[a]	6,0	2,00	-	1,80
Ferroalloys[a]	42,5	1,00	-	0,90
Aluminium	67	0,91	54	0,86
Other	-	0,85	-	0,75

[a] A 10% decrease in SEC is assumed for new energy-effective plants.

The SEC of new plants will decrease with time due to improved technology. This rate of decrease is difficult to separate from influences such as changes in products, increased recycling, and greater economies of scale. Nevertheless the average rate of decrease of SEC for some industries has been estimated from a variety of sources and the ranges are shown in Table 4.5. In recent years the rate has become flatter, although existing efficiencies indicate that there is still room for considerable decrease in SEC.

Table 4.5 Average rate of SEC decrease due to technology improvements, in the last few decades, and existing efficiencies[3,19,20,21,22,23,33]

Material	SEC Decrease (%/annum)	Current SEC/ Theoretical SEC (%)
Steel	1,2-1,8	25
Aluminium	0,4-0,8	15
Cement	1,2-2,1	55

It is assumed that technology improvement will decrease the SEC of new plants by 0,5%/annum.

4.2.2 Demand reduction

Electricity demand reduction is divided between energy reduction and load factor improvement.

Energy reduction:
It is assumed that the electricity proportion of energy consumption of each industrial group will remain constant at 1990 proportions. The average annual demand is then calculated for each industrial group. The average monthly maximum demand, on which demand charge is based, is calculated from estimated load factors and power factors.

Load factor:
Load factor improvement is derived from market penetration of existing potential and new capacity potential. Existing potential is based on the study by Gervais[24]; in which a potential of 1202 MW for mining and manufacturing was identified. No information on potential load factor improvement of new plants was found. It was thus conservatively estimated that in the energy-effective scenario load factor could be potentially increased by 5% for a new plant.

4.3 ENERGY PRICES

Average prices in 1993 were used to cost energy and electricity demand reductions. Energy prices used are shown in Table 4.6.

Table 4.6 Energy prices used in the study

Electricity demand charge	R29,50/kVA
Electricity unit charge	
ESKOM-supplied (Tariff E)	1,49 c/MJ
Municipal-supplied	1,97 c/MJ
Coal	0,25 c/MJ
Heavy fuel oil	1,22 c/MJ
Gas	2,82 c/MJ

4.4 SCENARIOS OF ENERGY USAGE

Figures 4.3 and 4.4 show the energy use scenarios for low and high growth rates respectively. Included is hypothetical energy use if efficiencies were frozen at 1990 levels. Under the business-as-usual scenario, energy use between 1990 and 2015 will decrease at an average rate of 0,94-1,38%/annum over the frozen efficiency scenario. However under the energy-effective scenario energy use between 1995 and 2015 can be further reduced by 0,62-0,8%/annum. If this were realised electricity demand could be reduced by 17-18% by 2015. This would defer R7,3-11,7 billion investment in new electricity capacity by 2015 (assuming R3000/kVA). More detailed results are presented in Appendix L.

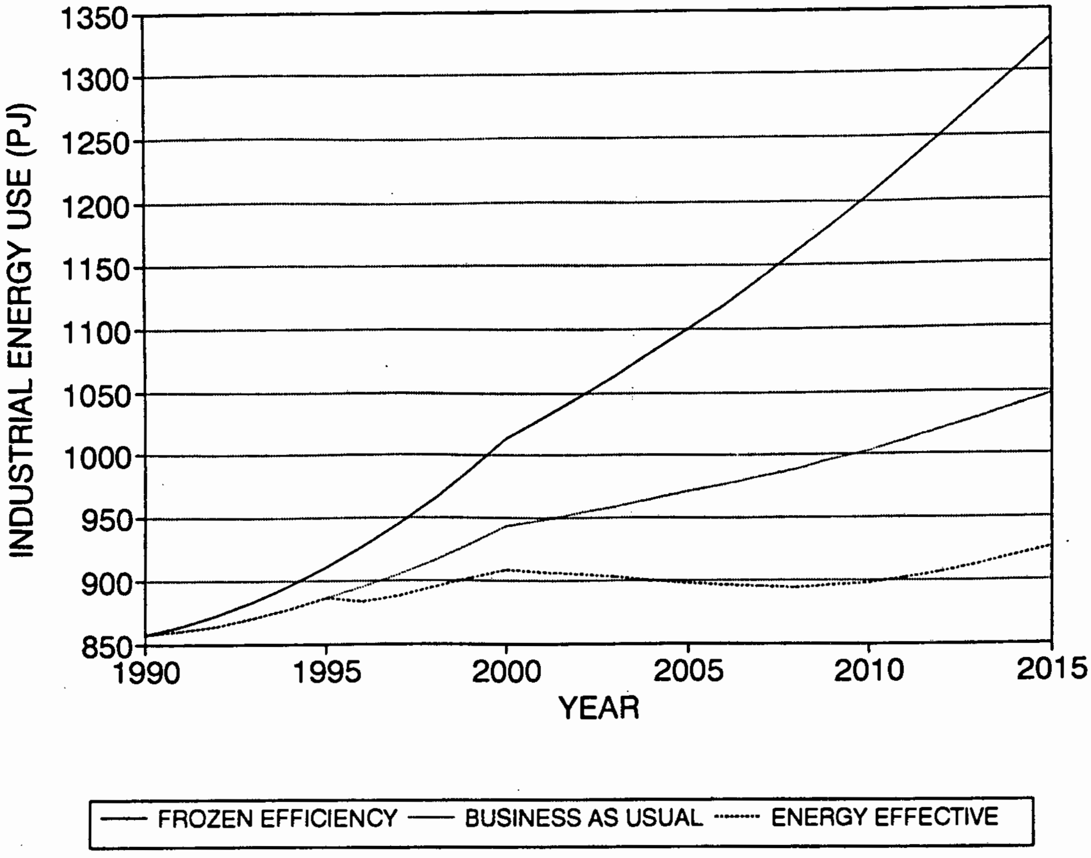


Figure 4.3 **Industrial net energy consumption scenarios for low growth**

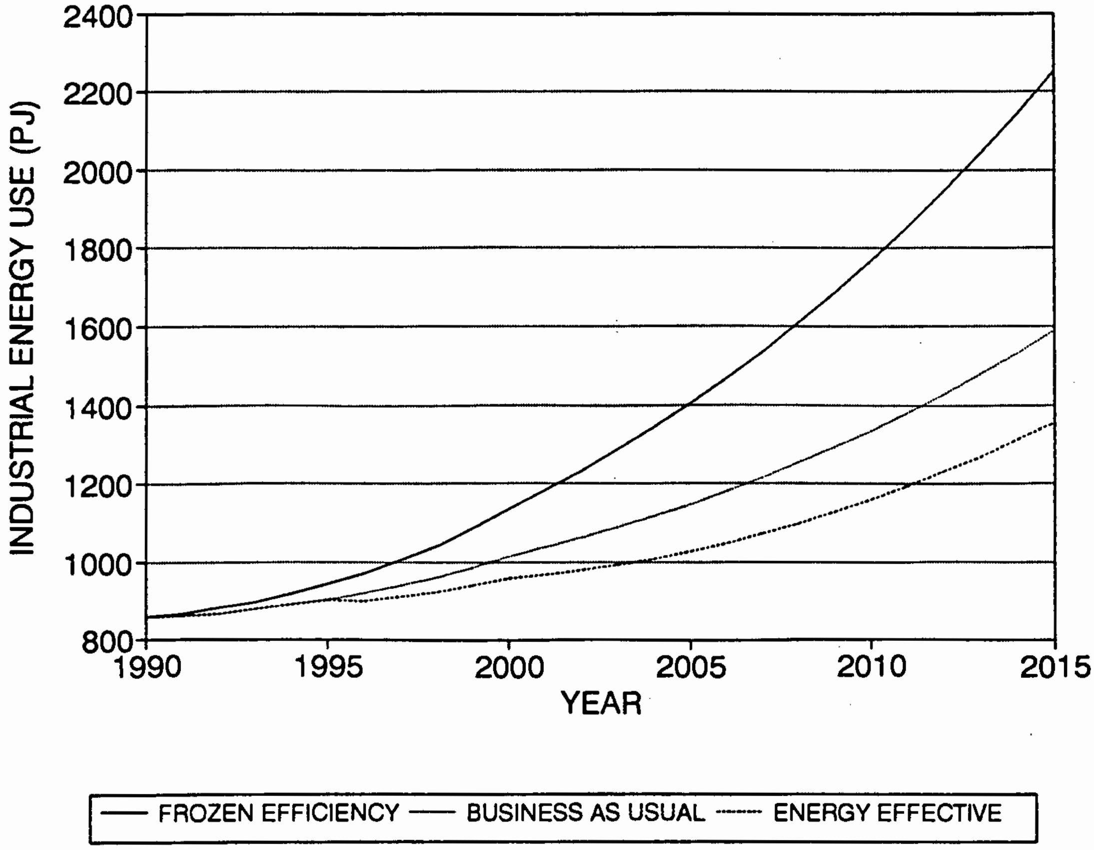


Figure 4.4 **Industrial net energy consumption scenarios for high growth**

The estimated cost of energy to industry in 2005 and 2015 is shown in Table 4.7. Annual energy costs could be reduced by about 9-12% in 2005 and 14-16% in 2015 through improved energy effectiveness. It is estimated that the average pay-back period is 1,5 years, consistent with other studies(25). The total investment required by industry is thus roughly 1,5 times the annual saving in energy cost.

Table 4.7 Annual cost of energy to industry in 2005 and 2015 (Rmillion, 1993 prices)

	2005		2015	
	Low	High	Low	High
Business as usual	12 998	15 445	13 676	20 752
Energy effective	11 846	13 651	11 830	17 479
Potential saving	1 152	1 794	1 847	3 273

The effect of increasing energy prices will be to increase the potential for improved energy effectiveness and also increase the rate of adoption of energy effectiveness opportunities. Insufficient data is available to quantify either effect, and thus the effect of energy prices on the potential benefits of improved energy effectiveness is unknown.

4.5 COMPARISON WITH OTHER COUNTRIES

4.5.1 Past trends

The rate of energy efficiency improvement is difficult to assess from the past since this potential has been significantly affected by fluctuating energy prices and structural shifts. In the seventies and eighties the average rate of improvement in energy efficiency was 2,2%/annum in European countries(26), 3,3%/annum in Japan, and 2,0% in the USA(32). Generally, about half to two-thirds of this improvement has been attributed to improvements in efficiency and the rest due to structural change. These rates have fallen off substantially in the past few years.

One study analysed time series data of the seventies for a number of regions by regression analysis and separated industrial energy intensity between structural effects and efficiency effects[27]. In Table 4.8 these effects are compared to those projected for South Africa between 1990 and 2015.

Table 4.8 Average annual percentage reduction rates of industrial energy intensity in the seventies

Region	Energy Intensity	Structural Changes	Energy Efficiency
North America	2,9	0,5	2,4
West Europe	2,7	0,5	2,2
East Europe	2,6	0,6	2,0
Japan	2,6	0,7	1,9
Other developed	2,1	0,2	1,9
Latin America	1,7	0,5	1,2
Sub-Saharan Africa	-0,1	-2,0	1,9
West Asia, N Africa	1,0	-1,3	2,3
Indian sub-continent	2,5	0,4	2,1
S-E Asia	3,9	1,7	2,2
South Africa			
Business as usual	0,3-1,1	-(0,6-0,3)	0,9-1,4
Energy effective	0,8-1,7	-(0,6-0,3)	1,4-2,0

The study also calculated annual efficiency improvement rates for a number of industries in the seventies, which are compared to those estimated for South Africa between 1990 and 2015 (Table 4.9).

Table 4.9 Annual efficiency improvement rates (%/annum)

Country	Basic metals	Building materials	Chemicals	Pulp and paper
FRG	1,3	1,8	3,8	0,9
Austria	0,7	1,9	0,2	
Japan	0,9	1,0	3,6	2,5
Hungary	1,1	3,9	-0,2	
UK	2,6	3,0		3,8
France	0,9	1,3	0,8	1,3
USA	1,8	2,6	3,3	3,0
Italy	1,5	2,7	6,8	4,1
South Africa				
Business as usual	0,8-1,2	1,1-1,6	1,0-1,5	1,1-1,5
Energy effective	1,2-1,8	1,7-2,4	1,5-2,2	1,7-2,3

4.5.2 Future scenarios

Table 4.10 shows estimates, derived from previous studies, of potential energy reductions resulting from the implementation of cost-effective opportunities. Potential percent reduction has been converted to potential annual percent reduction since the studies were conducted over different time periods. No such scenario was calculated for South Africa since this study included market penetration in the scenarios.

Table 4.10 Estimates of potential reduction in industrial energy use in various countries, using frozen efficiency as a basis

Country	Base Year	Target Year	Economic Potential (%)	Economic Potential (%/annum)
USA[28]	1988	2000	24-40	2,4-4,2
USA[31]	1984	2000	35-40	2,7-3,1
USA[14]	1990	2010	29	1,7
USA[22]	1985	2000	35	2,8
UK[2]	1980	2000	29	1,7
Sweden[25]	1983	1990	20-50	3,1-9,4
Canada[25]	1986	2000	15	1,2
Netherlands[25]	1985	2000	21	1,6
Europe[25]	1986	2000	25	2,0
West Europe[19]	1985	2000	30	2,3

Table 4.11 shows estimates of likely reductions in industrial energy use compared to industrial energy use with frozen energy efficiencies. In this case market penetration is considered. These estimates are analogous to the business-as-usual scenario of this study which is included in the comparison.

Table 4.11 **Estimates of likely reduction in industrial energy use in various countries, using frozen efficiency as a basis**

Country	Base Year	Target Year	Likely Reduction (%)	(%/annum)
USA[20]	1988	2010	20	1,0
USA[14]	1990	2010	17	0,9
USA[22]	1985	2000	19	1,4
UK[2]	1980	2000	21-25	1,2-1,4
Switzerland[19]	1985	2005	15	0,8
South Africa				
Low scenario	1990	2015	21	0,94
High scenario	1990	2015	29	1,38

Included in economic potential and likely reductions in energy use are opportunities that will be realised through non-energy decisions, such as closure of old plants and commissioning of new plants. Of more interest in this study is the effect of an increased energy effectiveness drive on energy use. Table 4.12 indicates such potential.

Table 4.12 Estimates of potential reduction in industrial energy use using business-as-usual as a reference

Country	Base Year	Target Year	Energy-effective potential (%)	(%/annum)
USA[28]	1988	2000	8	0,7
USA[20]	1988	2010	11	0,5
Canada[25]	1986	2000	9	0,7
Norway[29]	1984	2010	12	0,5
Europe[25]	1986	2000	10	0,8
Switzerland[14]	1985	2005	18	1,0
South Africa				
Low scenario	1995	2015	12	0,62
High scenario	1995	2015	15	0,8

A detailed bottom-up study of the USA was recently completed[15] and estimated energy efficiency improvements are shown in Table 4.13. The reference case reflects current policies and trends and is synonymous with the South Africa business-as-usual scenario, the results of which are indicated in brackets. The market case reflects energy usage if the cost of energy services were minimized. The South African energy-effective scenario is somewhere between the reference and market cases and is indicated in brackets next to the market case. The environmental case is the market case with the environmental impacts of energy usage assigned monetary values.

Table 4.13 Annual rates of energy intensity reduction in the USA between 1990 and 2010

Sector	Reference Case	Market Case	Environmental Case
Chemicals	1,8 (1,0-1,5)	2,4 (1,5-2,2)	2,9
Primary metals	1,0 (0,8-1,2)	2,1 (1,2-1,8)	3,1
Paper and pulp	1,2 (1,1-1,5)	1,7 (1,7-2,3)	2,0
Non-metallic minerals	1,3 (1,1-1,6)	2,2 (1,5-2,2)	3,3
Food	0,8 (1,1-1,4)	1,9 (1,7-2,0)	4,3
Machinery	0,9 (0,8-1,4)	1,6 (1,2-1,9)	2,7
Mining	0,2 (0,8-1,3)	1,4 (1,3-1,9)	1,8

Table 4.14 shows the results of a series of detailed reports on manufacturing energy usage in the UK[3], with the corresponding South African business-as-usual results.

Table 4.14 Average projected annual rates of SEC reduction in the UK between 1980 and 2000 (%/annum)

Sector	Annual projected rate of SEC decrease UK	South Africa
Iron and steel	1,3	1,0-1,4
Aluminium	2,9[a]	1,0-1,3
Cement	2,0	0,9-1,4
Bricks	2,7[b]	1,3-1,8
Chemical	1,6	1,0-1,5
Paper	1,4	1,1-1,5
Food	0,9	1,1-1,4
Engineering	0,8	0,8-1,4
Textiles	1,0	1,1-1,6

a Much of this is due to a projected increase in the proportion of secondary to primary aluminium. The rate of SEC decrease would be 0,8%/annum if this effect is excluded.

b About half of this potential is due to increased carbonaceous additions to the bricks, which is not included in SEC.

It can be concluded that the findings of this study are consistent with studies in other countries. It does however appear that there is generally more variation in energy efficiency improvement rates between individual industrial sectors in other studies than in this study. This can be attributed the lack of information available for this study and the greater number of generalisations that had to be made.

5. CONCLUSIONS

South African industry is more energy intensive than most developed countries. The energy-intensive structure of industry in South Africa alone results in approximately a 26% increase in industrial energy intensity compared to a typical developed country. Nevertheless specific energy consumption for specific products is still higher in South Africa compared to developed countries. This has been attributed to (1) the relative costs of labour, energy, and capital which in South Africa favour labour and energy, (2) external factors such as the quality of raw materials, and (3) the level of energy effectiveness which depends largely on awareness and knowledge. All these factors must be considered when estimating the potential for improved energy effectiveness.

It is estimated that total industrial energy use can be reduced by 0,62-0,8%/annum through enhanced energy effectiveness. This will require an energy effectiveness campaign similar to those of developed countries. Potential savings to industry due to reduced energy costs could then be R1,1-1,8 billion by 2005 and R1,8-3,3 billion by 2015. The findings of this study are consistent with past trends and projections in other countries.

A sectorial approach was necessary in order to calculate the potential for improved energy effectiveness. Tables 5.1 and 5.2 show potential energy reduction, demand reduction, and the energy cost savings that could be achieved in 2005 and 2015 through improved energy effectiveness. The order of importance of sectors is different for low growth and high growth. Growth of the food sector is assumed to be independent of GDP growth, depending only on population growth, and thus its potential is far more prevalent for low growth. It should be cautioned that not too much detailed information should be read from Tables 5.1 and 5.2 since sectorial results are based on a number of assumptions.

Table 5.1 **Potential reduction in energy consumption, electricity demand, and energy cost in 2005 and 2015 through improved energy effectiveness - low economic growth**

SIC	SECTOR	2005 ENERGY (PJ)	2005 DEMAND (MVA)	2005 COST (Rmillion)	2015 ENERGY (PJ)	2015 DEMAND (MVA)	2015 COST (Rmillion)
21	Coal mining	0.9	43	28	1.4	68	44
23	Metal-ore mining	1.6	71	45	2.5	108	69
24	Gold mining	2.9	210	116	2.6	160	94
27	Diamond mining	0.2	11	6	0.3	15	9
28	Other mining	0.4	22	14	0.8	40	25
31	Food	9.1	155	135	14.1	245	211
32	Textiles	3.6	83	62	5.3	114	88
33	Wood	0.8	27	20	1.4	50	35
34	Paper	6.4	97	80	11.5	176	145
35	Chemicals	4.5	121	91	8.3	220	167
36	Non-metallic min.						
	Bricks	4.2	20	28	9.8	40	63
	Cement	2.4	16	17	4.9	30	34
	Other	2.4	11	24	4.2	20	42
37	Basic metals						
	iron & steel	16.0	128	121	25.1	198	189
	stainless steel	1.6	48	33	4.0	142	89
	ferroalloys	6.7	181	117	12.0	323	210
	Al, primary	1.9	96	60	2.6	156	91
	Al, secondary	0.1	3	3	0.2	6	5
	titania slag	2.6	77	51	3.8	126	80
	other metals	1.9	47	32	3.2	80	54
38	Equipment	2.1	82	59	3.3	113	88
39	Other	0.4	10	7	0.6	18	13
	Total	72.7	1559	1152	121.8	2445	1847

Table 5.2 **Potential reduction in energy consumption, electricity demand, and energy cost in 2005 and 2015 through improved energy effectiveness - high economic growth**

SIC	SECTOR	2005 ENERGY (PJ)	2005 DEMAND (MVA)	2005 COST (Rmillion)	2015 ENERGY (PJ)	2015 DEMAND (MVA)	2015 COST (Rmillion)
21	Coal mining	1.9	83	57	3.7	157	108
23	Metal-ore mining	2.3	94	63	4.4	169	115
24	Gold mining	3.8	235	138	2.7	127	83
27	Diamond mining	0.4	19	12	0.7	36	23
28	Other mining	0.9	39	26	2.0	88	59
31	Food	10.4	166	150	13.6	208	193
32	Textiles	6.9	142	112	11.6	239	189
33	Wood	1.5	48	36	3.5	108	83
34	Paper	12.7	171	152	29.2	391	348
35	Chemicals	9.0	212	172	20.9	483	396
36	Non-metallic min.						
	Bricks	10.2	40	65	25.1	93	159
	Cement	5.1	29	35	12.4	66	84
	Other	4.6	19	45	10.0	42	98
37	Basic metals						
	iron & steel	24.1	172	176	48.6	325	346
	stainless steel	1.7	50	35	4.4	136	91
	ferroalloys	10.3	245	169	16.0	357	254
	Al, primary	4.0	186	121	7.9	376	241
	Al, secondary	0.3	6	6	0.6	15	14
	titania slag	2.8	82	56	4.1	116	80
	other metals	2.2	51	36	3.4	72	53
38	Equipment	4.6	148	118	9.1	273	226
39	Other	0.7	17	13	1.6	38	30
	Total	120.6	2255	1794	235.3	3913	3273

The following conclusions are derived from the sectorial analyses detailed in the appendices.

Gold mining: The level of energy awareness and energy management is advanced compared to the rest of industry. The energy effectiveness of gold mining depends mostly on R&D into new technologies, which appears to be effectively controlled by the mining houses. There is also scope for improved load management, and research assistance in this regard could be provided.

Pulp and paper: Energy awareness appears to be intermediate. A key concern of this industry is pollution, and energy effectiveness could be promoted through addressing pollution. There is potential for additional cogeneration although cogeneration is claimed by the industry to be uneconomic at present. A cogeneration feasibility study could be supported to ensure that adequate cost accounting is used, and the appropriateness of additional cogeneration incentives could be evaluated.

Bricks: Energy awareness appears to be low. The industry is fragmented, although it produces a relatively uniform product and is therefore suited to a sectorial energy audit. Areas of specific interest include addition of carbonaceous material to unfired bricks, production of hollow bricks, use of waste heat, and kiln control.

Cement: Energy awareness appears to be reasonable. Important areas of assistance could be production of blends of Portland cement and kiln control.

Iron and steel: Energy management appears to be of a high standard, although SEC is considerably higher than for most developed countries. No adequate explanation for the higher SEC was found, and this could be an area of investigation, perhaps part of a sectorial energy audit. Energy effectiveness will depend to a large extent on local R&D since South Africa has unique local conditions. Assistance could be provided in the form of joint R&D ventures. Cogeneration is claimed by the industry to be uneconomic at present, although it is common in other countries.

Ferroalloys: South Africa is a major world producer of ferroalloys and the industry is expected to grow substantially. Energy effectiveness will depend on technological innovation, and assistance could be provided by means of joint R&D ventures.

Food: Little is known of this industry, although energy awareness appears to be low since energy is only a small proportion of production costs. The industry would therefore derive benefit from a general awareness campaign and plant audits. Sectorial audits of sub-sectors of the food industry may also be of benefit.

Chemicals: Little is known of this industry which is diverse in nature. The application of pinch technology to this industry has produced significant energy savings in other countries, and its use should be encouraged locally. General awareness and plant audits are expected to be of benefit to the industry.

6. RECOMMENDATIONS

Through the sectorial analyses a number of important areas requiring further attention have become apparent. These include:

(1) Increasing awareness of the potential benefits of improved energy effectiveness.
(2) Providing training necessary for more effective management and use of energy.
(3) Increasing knowledge through energy audits and demonstration.
(4) Increasing awareness and providing incentives for cogeneration.
(5) Support for joint research and development projects.

The following common industrial energy end-uses have been identified as possible areas of assistance:

(1) The potential benefits from the more effective use of electric motors are undisputed and a number options have been proposed to achieve this. A plan of action should now be developed.
(2) Air compressor systems are a source of substantial wasted energy. A method of communicating the benefits to industries should be developed.
(3) Investigate the extent and effect of the over-design of motors and mechanical equipment and develop a strategy to reduce this problem.
(4) Boilers are a relatively standard item of equipment yet a large potential for improvement appears to exist. The potential for improving boiler efficiencies should be investigated and a plan of action developed.

7. REFERENCES

(1) GELLINGS C W, FARUQUI A and SHAFFER S S (1993). Savings from efficient electricity use: a US case study. OPEC Review, vol xvii, Summer No.2.

(2) ALLIANCE TO SAVE ENERGY (1983). Utility Promotion of Investment in Energy Efficiency: Engineering, Legal and Economic Analyses. United States of America, August.

(3) ENERGY TECHNOLOGY SUPPORT UNIT (1984). Energy use and energy efficiency in UK manufacturing industry up to the year 2000: Volume 1. Executive summary and main report. Her Majesty's Stationery Office, London, October.

(4) COOPER C J (1993). National commercial energy consumption summary 1991. Produced for the Energy Branch of the Department of Mineral and Energy Affairs, Pretoria, March.

(5) CENTRAL STATISTICAL SERVICES (1988). Census of manufacturing: News release.

(6) CENTRAL STATISTICAL SERVICES (1992). South African Statistics.

(7) CENTRAL STATISTICAL SERVICES (1985). Census of manufacturing.

(8) OWEN-THOMAS D (1993). Chamber of Mines Statistical Services. Personal communication, 24 August.

(9) HOWARTH R B and SCHIPPER L (1991). Manufacturing energy use in eight OECD countries: Trends through 1988. Prepared for the US Department of Energy by Lawrence Berkeley Laboratory, University of California, September.

(10) SUMMERS R and HESTON A (1984). Improved international comparisons of real product and its composition: 1950-1980, University of Pennsylvania.

(11) INTERNATIONAL ENERGY AGENCY (1992). Energy prices and taxes: Fourth quarter 1992. OECD Publishers, Paris.

(12) INTERNATIONAL ENERGY AGENCY (1992). Energy balances of OECD countries 1989-1990. OECD Publishers, Paris.

(13) AYRES R U (1990). Energy conservation in the industrial sector. Proceeding of the conference on Energy and the Environment in the 21st century, Massachusetts Institute of Technology, Cambridge, Massachussets, March 26-28.

(14) GIOVANNINI B and PAIN D (1990). Scientific and technical arguments for the optimal use of energy. Centre Universitaire d'Etude des Problemes de l'Energie, Universit de Geneve, April.

(15) POLLOCK C. Mining urban wastes: The potential for recycling. Worldwatch Paper No. 76.

(16) ALLIANCE TO SAVE ENERGY (1992). American Council for an Energy-Efficient Economy, Natural Resources Defense Council, and the Union of Concerned Scientists. America's Energy Choices. Published by the Union of Concerned Scientists. Cambridge, MA.

(17) CENTRAL ECONOMIC ADVISORY SERVICE (1993). The restructuring of the South African economy: A normative model approach. Compiled by the Central Economic Advisory Service for the Minister of Finance, March.

(18) DE JAGER N (1993). Personal Communication. Bureau for Economic Research, University of Stellenbosch, Sepember.

(19) ALBINSSON H (1986). Energy consumption in industrial processes. Report presented to the 13th Congress of the World Energy Conference, Cannes.

(20) CARLSMITH R S, CHANDLER W U, MCMAHON J E and SANTINI D J (1990). Energy efficiency: How far can we go. Oak Ridge National Laboratory, prepared for the U.S. Department of Energy, January.

(21) GOLDEMBERG J, JOHANSSON T B, REDDY A K N and WILLIAMS R H (1987). Energy for a sustainable world. World Resources Institute, Washington.

(22) SCHIPPER L, HOWARTH R B and GELLER H S (1990). United States Energy usage for 1973-1987: The impacts of improved efficiency, Annual Review of Energy, 15.

(23) GRANVILLE A, STANKO J S and FREEMAN M J (1992). Review and analysis of energy use in the metal industries. Prepared for the Energy Branch of the Department of Mineral and Energy Affairs, Report No. ED9101, August.

(24) GERVAIS J S (1985). The potential for electric load and electricity conservation in South Africa. Prepared for the National Program for Energy Research, Pretoria, June.

(25) INTERNATIONAL ENERGY AGENCY (1987). Energy conservation in IEA countries. OECD Publications, Paris.

(26) COMMISSION OF THE EUROPEAN COMMUNITIES (1987). Towards a continuing policy for energy efficiency in the European Communities. Communication from the Commission, COM(87), Brussels, 13 May.

(27) UNIDO (1985). Analysis of the energy sector in relation to industrialization scenarios for the year 2000. Prepared for the United Nations Industrial Development Organisation, 10 January.

(28) GELLER H S (1989). National energy efficiency platform: Description and potential impacts. American Council for Energy-Efficient Economy, Washington, DC, August.

(29) NORWAY MINISTRY OF PETROLEUM AND ENERGY (1984). Action plan for energy conservation. Report No.37 to the Storting, November.

(30) SPIES P H. Business Futures 1992 (1992). Institute for Futures Research, University of Stellenbosch, Stellenbosch.

(31) SANT R W. Creating abundance: America's least cost energy strategy (1984). McGraw-Hill, pp.90-92.

(32) DOBLIN C P (1988). Declining energy intensity in the US manufacturing sector. The Energy Journal, 9(2), p109.

(33) WILLIAMS R H, LARSON E D, and ROSS M H (1987). Materials, affluence, and industrial energy use. Annual Review of Energy, 12, pp.99-144.

(34) COOPER C J and KOTZE D J (1989). Energy projections for South Africa. Institute for Energy Studies, RAU.

(35) INTERNATIONAL ENERGY AGENCY (1992). Energy balances of non-OECD countries 1989-1990. OECD Publishers, Paris.

APPENDIX A

GOLD MINING (SIC 24)

PROCESS DESCRIPTION

Gold mining includes mining, hoisting and crushing the ore, environmental control, and gold extraction. Ore is removed from the rock face by drilling holes in the rock face and then blasting. The ore is then transported to a mineshaft and mechanically hoisted to the surface. After undergoing a number of milling stages gold is extracted from the crushed ore by chemical processes. The used ore is then pumped back into the mines as a slurry referred to as backfill.

The underground mining environment is hot and humid. Two systems, the air system and the water system, are employed to improve the underground environment. Fans are used to circulate air via ventilation shafts. Chilled water is produced in large refrigeration plants and fed down into the mines where it is circulated and then pumped to the surface again. The power required to pump the water to the surface is partially offset by recovering energy from the chilled water flowing down the mine shafts. Large Pelton turbines are employed for this purpose.

THE INDUSTRY IN SOUTH AFRICA

Gold mining is dominated by six mining houses, with the Chamber of Mines being a co-ordinating body which makes available to its members advisory and service functions. Many joint venture projects are undertaken between the mining houses, research organisations and universities.

ENERGY CONSUMPTION

Electricity is the major energy source for gold mines, and the electricity cost is typically 10-15% of working costs[2,3]. Table A.1 shows that electricity's share of total energy use in gold mining has increased since 1980. In 1970 electricity accounted for 68% of total energy use, and in 1950 it accounted for only 19%. Since 1980 electricity costs have accounted for over 95% of energy costs. Energy costs, expressed as a percent of value added, have steadily increased since 1980. This can be accounted for by increasing SEC for gold production and a decreasing gold price. If value added is multiplied by a gold price factor (gold price/1985 gold price), then energy cost does not vary as much. SEC, based on ore treated, has not changed much since 1974. This can be attributed to increased efficiency but with increased mining depths. The different trends of SEC based on gold produced and SEC based on ore treated is due to declining ore grades. Trends in SEC and ore grade are shown in Figure A.1.

Table A.1 Energy and electricity consumption in gold mining[7]

Year	Total energy use (PJ)	Share of elec. (%)	Elec. cost as a % of value added	Total energy cost as a % of value added[a]	
				Actual	Price adjusted
1980	82,2	81	2,9	3,0	3,7
1981	85,2	82	4,4	4,6	4,4
1982	85,0	85	5,7	5,9	5,2
1983	85,3	87	6,1	6,3	5,4
1984	88,6	87	6,3	6,5	5,6
1985	88,8	90	5,7	5,9	5,9
1986	91,0	90	6,6	6,8	7,0
1987	92,3	91	8,0	8,2	8,1
1988	94,7	93	8,8	9,0	8,6
1989	91,9	95	9,2	9,4	7,9
1990	89,0	97	11,7	12,0	8,6
1991	87,2	94	11,1	11,4	7,2

[a] Assuming liquid fuels consumption to be 2% of total consumption, and coal to make up the remainder of total energy consumption.

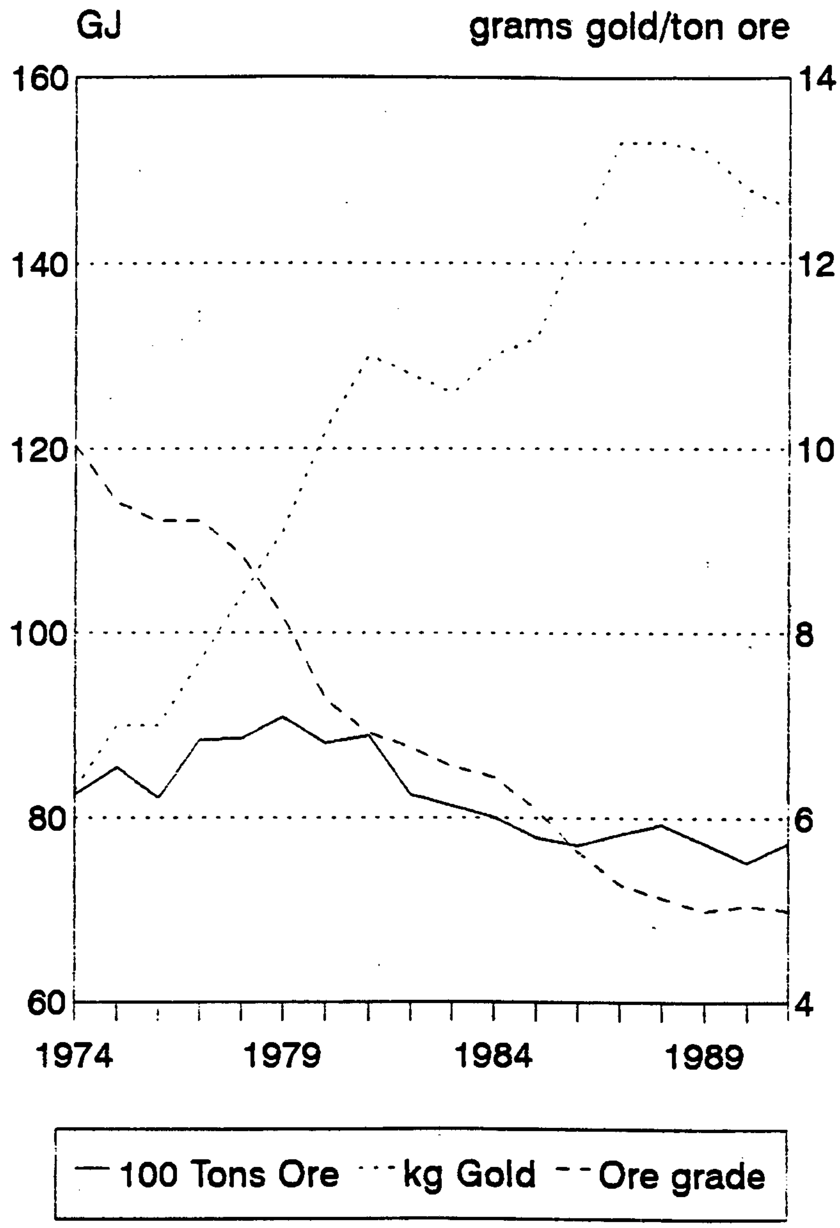


Figure A.1 **SEC in gold mining**

It is seldom meaningful to compare energy intensities of mines because they are affected by layout, depth, methods, and processes. A breakdown of electricity usage of a typical gold/uranium mine is indicated in Table A.2. Figure A.2 shows a stacked load profile for a typical week of one gold mine[11]. The diversity of the electricity loads in gold mining creates a wide range of opportunities for integrated mine electricity planning.

Table A.2 Breakdown of electricity usage of a typical gold/uranium mine[1]

Electricity use	% of total consumption
Pumping	19
Refrigeration	5
Compressed air	23
Fans, ventilators	11
Milling	11
Gold treatment	4
Uranium plant	7
Winding, driving mech. equipment	10
Hostel	2
Lighting, workshops	4
Other	4
Total	100

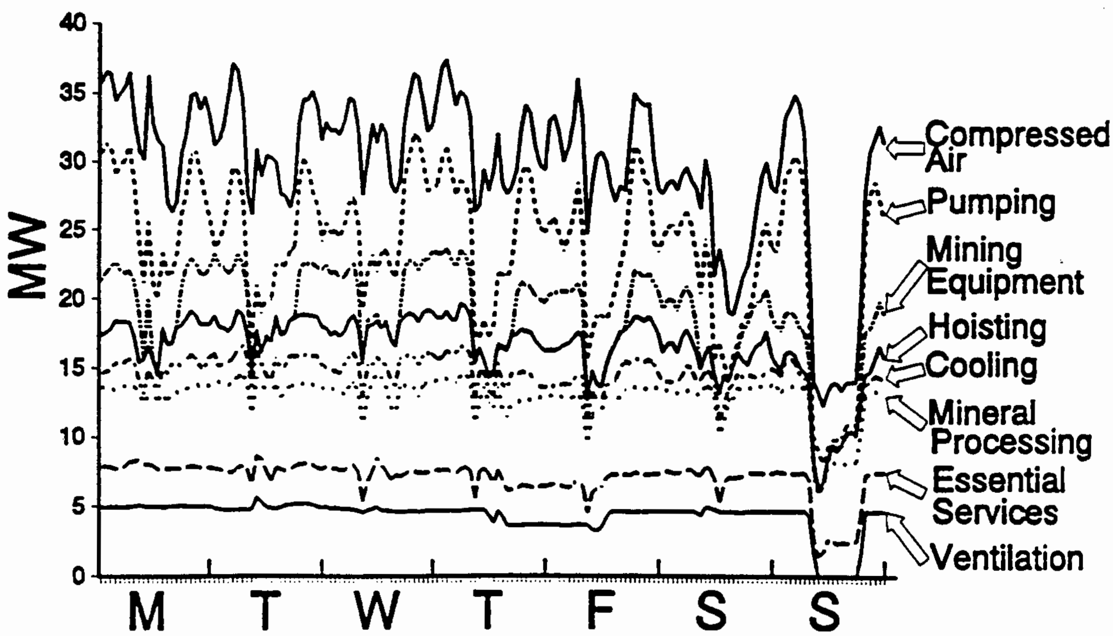


Figure A.2 **Stacked electricity profile for a typical week**

The following are areas where there are still possibilities for improved electricity effectiveness.

Load factor improvement: Mines generally operate with an electricity load factor of 0,75-0,9 and thus load scheduling to improve the load factor is an area that has still not been exhausted. There is scope for filling in of the valleys in early morning periods and on weekends, but this will depend on the tariff scheme. Possibilities include compressed air storage, thermal energy storage, and shifting of milling operations. Pumping and air compression are two important areas with potential for additional load factor improvement. It has been calculated that 600 to 800 MW could be moved off the evening peak if all deep-level mines move pumping to off-peak periods, and 300 to 500 MW could be moved off the morning peak if all mines found it feasible to store air underground.(11)

Recently a detailed study was completed for Vaal Reefs Mine on load scheduling. In order to obtain co-operation from all areas of the mine, an internal energy costing system is planned(3).

Mine cooling: As mines become deeper so cooling costs become proportionately higher with the increased virgin rock temperature. Mines are cooled by pumping chilled water underground, using Pelton turbines to recover most of the gravitational energy of the water, before being pumped to the surface again. However these systems operate with only a 55-65% efficiency. The use of ice slurry, or displacement systems for mine cooling has been researched recently in South Africa. More efficient mine design, the application of backfill, and airway insulation are all methods by which heat loads can be further reduced in the future. As an example it was shown, by comparison of two shafts at Vaal Reefs, that heat flow can be reduced by 36% by improved design of a mine. Effective backfill can reduce total heat load by 15%(4).

Pumping: At a Vaal Reef mine with a pump efficiency of 76% and a turbine efficiency of 86% the turbine/pump efficiency is 65%, meaning that 35% of the water put down the mine must be pumped to the surface by electric motor-driven pumps. Through improved efficiencies and alternative cooling mediums such as slurry ice, there is substantial potential for reduced pumping energy requirements. A hydro-transformer system in Germany has an efficiency of 96%(5).

Rock drilling: Presently all rock drills are pneumatic, using 12-20 kWh/hole. Hydraulic rock drills are now being investigated which require only 1,5 kWh/hole(6).

Waste heat recovery: A vast amount of low-grade waste heat is generated on mines by refrigeration plants and through the main fans. It is possible that through technological advances and increased power costs this waste heat will be utilised in the future.

In the medium term there may be a move towards more shallow mines with lower grade ores. The effect on SEC is not known at present.

Energy norms: Energy norms for a few mines have been developed through electrical audits. These norms can be used to identify inefficient activities on other mines, and could be invaluable in design and planning[10].

ENERGY MANAGEMENT

Gold mines have all implemented some form of energy management programme, with the most common elements being load shedding, off-peak pumping of water and power factor correction. Sophisticated computerized maximum demand control systems have been installed on large mines. One mine reduced compressed air consumption by 20% in one year by conducting an intensive energy awareness campaign[10].

FUTURE ENERGY CONSUMPTION

Granville et al. have estimated future gold production based on treated ore. From 116 million treated tons of ore in 1990, they predict this to fall to 110 million tons in 2000, and 50 million tons in 2015. During this period average ore quality will decline further and mines will deepen. It is expected that in the near future many marginal mines may face closure unless the gold price increases sharply. These mines will be the more energy-intensive mines and thus the rate of closure of these mines will influence future energy consumption. Gold mining energy intensities based on treated ore appear to have decreased slightly over the past twenty years. It is assumed that the same trend will continue in the future, despite the deepening of mines, due to the closure of marginal mines and improved technology.

CONCLUSIONS

With increasing costs of labour and services, and lower profit margins, energy effectiveness has become an area of increasing importance on mines and will probably become even more important in the future. Technological improvement will continue to improve SEC, but the deepening of mines will work against this effect. Continued research and development on new technologies is essential since South Africa is a world leader in deep level gold mining, and the environment is continuously changing as mines deepen. With an evolving electricity use pattern ongoing load management is essential.

REFERENCES

(1) OLIVIER L R (1988). An overview of the energy-efficient use of electric motors in the RSA. Prepared for the National Energy Council, Pretoria, Project No. ETC 29, November.

(2) MCKECHNIE R M K (1992). The possibilities of energy conservation on mines. Enerconomy 92' Seminar, Pretoria, 8/9 June.

(3) HAUPTFLEISCH L (1991). Electrical energy management. The Certified Engineer, 64(1), March/April, pp. 24,26,28,31.

(4) STROH R M (1986). Energy conservation possibilities on gold mines. Proceedings of the first Group Engineering Symposium "Engineering on the Mines in the 90's", Randburg.

(5) BUTLER G I (1986). Energy recovery by Pelton wheel turbines and hydro-transformers. Proceedings of the first Group Engineering Symposium "Engineering on the Mines in the 90's", Randburg.

(6) WILLIAMS A T (1987). Energy conservation policy in RSA. Workshop on Energy Use and Efficiency, Pretoria, 23 March.

(7) OWEN-THOMAS D (1993). Chamber of Mines Statistical Services. Personal communication, 24 August.

(8) LANE I E AND DELPORT G J (1992). New approaches to end-use management in deep level mining. IEA New Electricity 21 Conference, Tokyo, May.

(9) DELPORT G J AND LANE I E (1993). Load audits and simulations to develop DSM options in the mining sector. Paper presented at the DSM Participants Seminar, Department of Mineral and Energy Affairs, April.

(10) Tissink L (1992). Energy conservation at Vaal Reefs. SAIEE Management and Auditing of Electrical Energy Symposium, March.

(11) LANE I E (1993). Demand-side management - Database and knowledge tools. Report No. ED 8910, prepared for the Department of Mineral and Energy Affairs, July.

APPENDIX B

PULP AND PAPER (SIC 341)

PROCESS DESCRIPTION

The primary raw material used in paper manufacture is cellulose fibre, mainly derived from wood, although other sources have been used as well such as bagasse. The wood is debarked and then mechanically chipped, after which it is ready for pulping.

In pulping the chips are broken down to their constituents which are mainly lignin and cellulose fibre. Pulping is carried out chemically or mechanically.

Chemical pulping: The most common chemical process is the Kraft process, which removes the lignin through cooking with chemicals in a digester. The spent cooking liquor (black liquor) is concentrated in evaporators to 55-65% solids. The concentrated black liquor, containing the lignin and other unwanted constituents of the wood, is burned for energy. Molten inorganic salts remaining after the burning of the black liquor are chemically treated to enable the reuse of chemicals in the digester. Kraft paper is used for printing and writing papers, and paper board.

Mechanical pulping: These processes have a much higher yield than the chemical process because mechanical pulp contains all the wood constituents. The pulp is of low grade and used for newsprint and tissue paper. Mechanical pulping is less capital intensive, but more energy intensive than chemical pulping.

It is sometimes necessary to then bleach the pulp, which is achieved with oxygen or chlorine processes.

The pulp suspensions of around 5% solids are dried and pressed to produce paper. The degree of pressing and drying determines the properties of the paper produced. Additive materials may be added to reduce the porosity and absorptivity, reduce the transparency, and improve the surface of the paper for printing. Dyestuffs for colouring may also be added.

Waste paper may also be used as a raw material, but it must first be cleaned. De-inking may also be necessary for higher quality products. In industrialised countries up to 50% of paper is recycled.

Some mills produce only pulp and others only paper or board. The more integrated the mill the better the waste products and waste heat can be utilised.

THE INDUSTRY IN SOUTH AFRICA

The pulp and paper industry comprises four main groups of companies and one small independent company. Installed capacity of these companies in 1989 is shown in Table B.1[5].

Table B.1 Structure of the pulp and paper industry in South Africa

Company	Number of mills	Paper production capacity (tons/annum)
SAPPI	6	950 000
Mondi Paper	7	950 000
Nampak Paper	3	110 000
Carlton Paper Corporation	2	60 000
Vanessa	1	6 000
Total	20	2 076 000

In addition, the SAPPI Saiccor plant produces about 450 000 tons/annum dissolving pulp, all of which is exported for the manufacture of rayon. Some regular pulp is also exported. Paper and board production in 1990 was about 1,81 million tons, and South Africa was a net exporter of 263 000 tons. By 1992 South Africa recycled about 600 000 tons of paper and board per year, which was about 31% of overall consumption. Nevertheless, paper waste must still be imported. This is partly due to South Africa being a net exporter of paper products which will not be returned to the waste stream[6].

ENERGY CONSUMPTION

Because the pulp and paper industry requires so much steam and electricity and a large amount of cheap fuel, it is ideally suited to cogeneration. Up to half the energy requirements of this industry can be supplied by burning waste products of the process. The South Africa pulp and paper industry uses about 590 MW, of which it self-generates 255 MW[4]. Little scope for further self-generation of electricity is seen at present because of unfavourable economics, although technically it is possible for the industry to generate much more of its power requirements.

SEC can be based on total or purchased energy. Total energy is often difficult to determine since in-house energy inputs are not always accurately recorded. SEC can be based on output of pulp, paper, or air-dried output including pulp and paper. SEC is affected by the mix and grade of products, as shown in Table B.2. Some countries import pulp (such as Italy), thus reducing energy consumption per ton of paper produced, or export pulp (such as Sweden). Recycling is more of a material issue than an energy issue in Kraft paper-making since although less energy is required, no cheap fuel is provided to self-generate energy. In the case of mechanical pulping, about 12 MJ/ton paper of purchased energy will be saved.

Table B.2 SEC for different paper grades in the USA and Scandinavia in 1980 (MJ/ton)[3]

Paper Grade	USA	Scandinavia
Bleached softwood pulp	24	20
Groundwood	6	5
Newsprint	9	8
Magazine paper	17	14
Linerboard	15	10
Fluting	15	10
Paperboard	16	12

Table B.3 shows SEC for various countries. Wide discrepancies are evident due to the wide range of methods of reporting specific energy statistics.

Table B.3 SEC for paper-making in various countries

Country	Year	Specific Energy Consumption (GJ/ton)
Brazil[3]	1982	13,9 (purchased)
Brazil[10]	1988	19,5
Sweden[3]	1982	21,4
Sweden[3]	1982	8,8 (purchased)
Sweden[8]	1984	22,2
Japan[3]	1982	19,3 (purchased)
UK[11]	1988	25,8
USA[3]	1982	31,1
USA[1]	1985	28,1
USA[2]	1988	35
USA[2]	1988	18 (purchased)

Figure B.1 shows SEC for paper-making in South Africa between 1975 and 1984[12]. SEC appears to have remained relatively constant over that period, but it is acknowledged that too many factors were at play to be sure of this trend. In developing countries energy consumption in paper-making was decreasing by over 1% per year during this period.

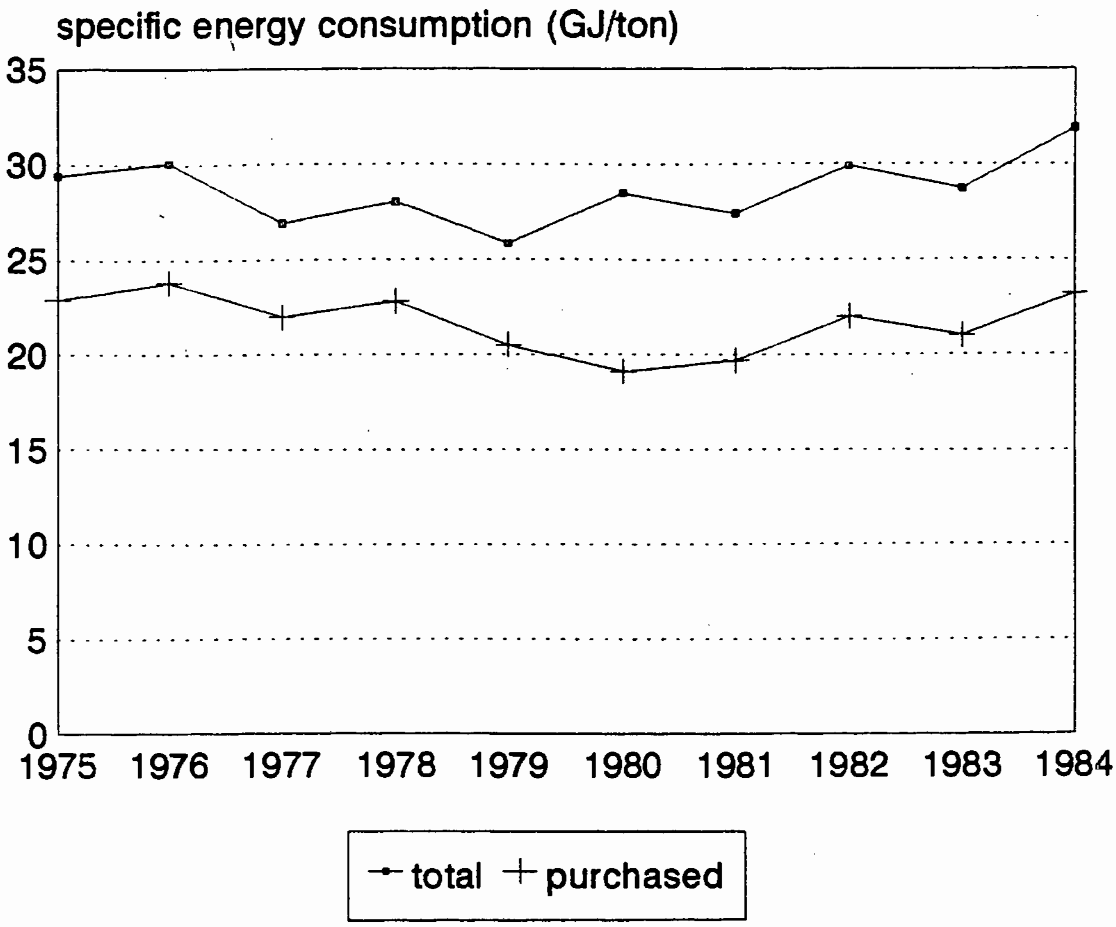


Figure B.1 **SEC for paper-making in South Africa**

According to Figure B.1 SEC in South Africa in the eighties was about 30 GJ/ton or 23 GJ purchased energy/ton[12]. Table B.4 shows SEC in 1991 calculated by a number of methods.

Table B.4 **SEC for paper-making in South Africa in 1991**

Method	GJ/ton
Total energy use/Total paper produced	36,9
Total energy produced (excl. Saiccor)/ Total paper produced	32,8
Total energy use (excl. that in export pulp)/ Total paper produced[a]	30,6

a Assuming 16 GJ/ton pulp, and 460 000 tons dissolving pulp and 250 000 tons regular pulp exported in 1991.

Total energy use may well be incorrect because it is unlikely that in-house energy use is adequately recorded. Nevertheless it would appear from the statistics and the opinions of some[12,7] that SEC in South Africa is probably higher than in most developed countries. Age of plants and technology used are similar to other countries and thus cannot account for higher specific energy use. Possible reasons for the higher SEC in South Africa are:

- Energy is cheap.
- The mills are small compared to major paper producing countries.
- Many mills are not integrated. For example, Usutu has an abundance of steam with no use for the steam.

ENERGY MANAGEMENT

According to a survey conducted in 1984[12] the pulp and paper industry has a high level of energy awareness, and energy effectiveness is of a high priority. It nevertheless concludes that energy monitoring is not always sufficient, and there still appears to be potential for improved energy efficiency. According to the SAPPI energy engineer[7], the staff on some mills are not concerned with energy effectiveness, only pollution, suggesting a strategy for selling energy effectiveness to these mills.

FUTURE ENERGY CONSUMPTION

Although many possibilities to reduce energy consumption exist, they are not cost effective with the low cost of energy in South Africa. It is believed that most energy-efficient improvements will come from the upgrading of machinery, mostly motivated by increased productivity with the same steam rates[7]. It is also believed that old fashioned boilers will be replaced by cogeneration of electric power, and concern for the environment will result in a range of improvements being made[9]. The application of pinch technology to paper mills has seen steam savings of over 20% in both new designs and retrofits in other countries, and may be a possible route to take in South Africa.

Extrapolation of SEC for the US paper industry indicates that by 2010 a 20% reduction will result, i.e. 1% reduction per year. However technology exists to reduce SEC by 2010 by 50%. Economics will determine the real magnitude of this reduction[2]. Energy intensities have decreased even faster in other developed countries. Not enough accurate information is available in South Africa to determine past trends in paper-making. It is nevertheless expected that energy consumption per ton of pulp will decrease in the future, but not at as high a rate as was experienced in developing counties in the past twenty years.

CONCLUSIONS

Energy effectiveness in the pulp and paper industry cannot be assessed by comparing SEC since it is affected by so many factors. The industry in South Africa appears to be particularly influenced by the low cost of energy which has excluded many marginal possibilities for energy effectiveness that have been adopted in other countries. Energy efficiency improvements in the near future are most likely to come from modifications of existing processes and equipment. Energy awareness promotion, financial incentives, and energy audits would assist in improving energy effectiveness. Pollution abatement could be used as motivation for energy effectiveness.

REFERENCES

(1) LEVINE M D, GADGIL A, MEYERS S, SATHAYE J, STAFURIK J, AND WILBANKS T (1991). Energy Efficiency, Developing Nations, and Eastern Europe. A report to the US Working Group on Global Energy Efficiency, June.

(2) HERZOG H J AND TESTER J W (1990). Energy management and conservation in the pulp and paper industry. Proceedings of the conference on Energy and the Environment in the 21st Century, MIT, Cambridge, Massachusetts, 26-28 March.

(3) EWING A.J (1985). Energy efficiency in the pulp and paper industry with emphasis on developing countries. World Bank Technical Paper No. 34, USA, February.

(4) ANDERSON R B (1993). A survey of cogeneration and independent power production worldwide and the potential for its application in South Africa. Prepared for the Energy Branch of the Department of Mineral and Energy Affairs, Pretoria, April.

(5) ASSOCIATION OF PULP, PAPER, AND BOARD MANUFACTURERS IN SOUTH AFRICA (1989). A survey of the pulp, paper, and board industry in South Africa, November.

(6) ENGINEERING WEEK. 6-13 August 1993.

(7) PALSGRAAF A (1993). Steam and Power Engineer, SAPPI. Personal communication, September.

(8) SWEDISH NATIONAL BOARD (1984).

(9) VIOK A G J (1990). Requirements of industrial consumers with special reference to the pulp and paper industry. 1990 Coal Outlook Conference, Mintek, Johannesburg, 28 March.

(10) GELLER H S AND ZYLBERSZTAJN D (1991). Energy-intensity trends in Brazil. Annual Review of Energy and the Environment, 16, pp. 179-203.

(11) ENERGY TECHNOLOGY SUPPORT UNIT (1989). Energy efficiency demonstration scheme: June 1988 review of ETSU portfolio. Department of Energy, UK, April.

(12) HUGGET A C (1986). Energy utilisation in selected industrial sectors in South Africa. Thesis for the Energy Research Institute, University of Cape Town, April.

APPENDIX C

STRUCTURAL CLAY PRODUCTS (SIC 3691)

PROCESS DESCRIPTION

Structural clay products include clay bricks, tiles, earthenware pipes, and refractories.

Stages in the manufacture of clay products are:
- Winning of the clay
- Clay preparation
- Shaping
- Drying
- Firing

Clay works are usually sited as close as possible to the clay source. The clay is quarried by opencast methods using multi-bucket excavators, scrapers, bulldozers, and mechanical shovels, and sometimes blasting is necessary.

The clay is then crushed and ground, and then screened and blended to obtain uniform composition. It is then mixed with water, and sometimes other ingredients such as carbonaceous material, and transported for shaping.

Clay products are usually shaped by:

Full plastic moulding: Involves the extrusion of soft clay into a composite mould for a number of bricks.

Extrusion: Clay is forced through a die and the clay column is cut into suitable lengths by wire cutters. Products may be re-pressed to provide a better surface finish. Tiles are often then pressed into their final shape after extrusion.

Dry press process: Clay with a low moisture content is compressed into the required shape. The drying stage can then be omitted.

In drying the moisture content is reduced to 0,5-6% prior to entering the kiln. Drying is necessary to remove water that would interfere in the firing process. Drying methods are:

Open air drying: Goods are stacked in the sun and allowed to dry naturally.
Hot floor drying: Goods are stacked on a floor which is heated below.
Tunnel dryers: Goods are moved continuously through a tunnel which is heated by kiln exhaust gases or by direct firing of a heat exchanger.
Chamber dryers: Goods are stacked in chambers which are heated by exhaust gases from the kiln. The gases are circulated from chamber to chamber so that the wet goods do not encounter the hottest gases which would cause cracking. Once the goods are dry the chamber is allowed to cool before unloading.

Firing usually proceeds in stages. Water is evaporated up to 150°C. Between 150°C and 900°C chemical water is removed and the clay undergoes a number of chemical transformations. Between 900°C and 1200°C the clay attains its strength through vitrification. The following kilns are commonly used:

Intermittent kilns: These are used only for the production of small quantities of products. The heat given off during cooling cannot be recycled. Intermittent kilns used are the clamp kilns, scove kilns, scotch kilns, and downdraught kilns.

Semi-continuous kilns: This consists of a number of intermittent kilns built together and interconnected. They are operated cyclically so that the exhaust gases from one kiln can be used to preheat bricks to another kiln.

Continuous kilns: Either the zone of maximum temperature moves advances around the kiln, or the goods are moved through a tunnel with the desired temperature profile. Moving fire kilns are generally modifications of the Hoffman kiln and include longitudinal or barrel arch kilns, and traverse or chamber kilns.

THE INDUSTRY IN SOUTH AFRICA

The brick industry is dominated by Corobrick which is responsible for about 40% of brick manufacture in South Africa, although its share has been declining due to the recent mothballing of plants. Technologies used in South Africa range from technologies developed over a hundred years ago to modern computerized technology. The breakdown of the different technologies is not known, although it appears that clamp kilns predominate in South Africa[11].

In 1985 energy costs were 21% of value added for the brick industry. Until 1991 the Clay-brick Association, representing 70-85% of the total South Africa market, collected general statistics. In 1991 larger association members utilised 61% of their production capacity[6]. Recent estimates of brick production vary substantially, ranging from 2,5 to 4,0 billion bricks per annum[6,7,8,9].

ENERGY CONSUMPTION

Assuming 3,5 billion bricks were produced in 1991, and 4,1 MJ/kg, and 3,0 kg/brick, energy use in the clay-brick industry was about 43 PJ. It is estimated that about 85% of the energy used in the structural clay industry is used in brickmaking, and therefore total energy use in the structural clay industry was about 51 PJ. If one assumes that the proportion of total SIC 369 energy used by the structural clay industry was unchanged since 1985, then 35 PJ was used in 1991. This discrepancy indicates the lack of adequate statistics on production and energy use in the structural clay industry in South Africa.

The amount of energy consumed in the manufacture of clay products depends on the raw materials used, the method of manufacture, the type of kiln used, the firing temperature, firing times, and the type and quality of product produced. Some raw materials contain carbon, such as carbonaceous shales, which reduces the energy input requirement. Sometimes coal ash or fly ash is mixed into the bricks before firing. The carbon content of goods to be fired should be considered when comparing energy usage.

About 95% of the total energy used is used in drying and firing. Table C.1 shows SEC for different kiln types for Corobrick.

Table C.1 Range of SEC by kiln type including brick drying for Corobrick in 1984[2]

Kiln type	Range (GJ/ton)	Average (GJ/ton)
Traverse arch	1,5-4,0	2,9
Hoffman	1,3-3,7	2,0
Tunnel	2,1-5,7	3,5
Clamp	2,0-5,8	3,7
Downdraught	6,1-11,3	8,5

If one were to include all kilns in South Africa, then the variation would be even greater. The wide range of specific energy requirements suggests that there is substantial scope for improvement in the operation of many kilns in South Africa. Table C.2 is a typical breakdown of the destiny of input energy to a kiln.

Table C.2 Destiny of input energy to a kiln[10]

Wall losses	25%
Waste gas loss	30%
Losses by cooling air	30%
Goods leaving the kiln	10%
Vitrification	5%

More modern kilns are better designed to reduce these losses, and retrofit measures on existing kilns can also reduce these losses. Some of the methods employed to reduce losses are:

- Heated cooling air can be used in driers or as preheated air for combustion.
- Kiln exhaust gases can be recirculated, but heat exchangers are usually required because of the presence of sulphur and other compounds.

- Heat losses from goods leaving the kiln can be reduced by more efficient cooling. Heat losses can be reduced from kiln cars by using modern lightweight refractory blocks, and by rapid off-loading and re-loading.
- Heat losses through the walls of kilns can be reduced by better insulation. Ceramic fibre is a relatively new form of efficient insulation.
- Improved operation and control.
- Good housekeeping such sealing of leaks and ensuring that dryer doors are in good repair.
- The use of oxygen in kilns can increase kiln capacity, and reduce exhaust gases.
- Quicker drying rates would reduce losses substantially, but many brickmakers believe that this would damage bricks. Recently considerably faster drying rates were demonstrated successfully in South Africa(3).

Most bricks produced in South Africa are solid, whereas in many countries it is common practice to use hollow bricks. Already in 1981 only 20% of bricks produced in Europe were solid. Perforations in the brick increase the surface area to volume ratio of the brick, enabling quicker heat penetration. It has been calculated that hollow bricks can use up to 40% less energy per square metre than solid bricks(3). Recently it has been demonstrated that hollow bricks can be fired in clamp kilns which account for a considerable portion of production capacity in South Africa(3).

SEC is significantly affected by the nature of the raw materials. The carbon content of raw materials affects both firing time and fuel consumption. Only clay deposits in the Witbank and Natal regions contain carbonaceous material. Other materials added are ash, anthracite, duff, and filter cake. Other options are sawdust, paper and pulp waste, and sewerage. Although these additions have an energy content, in most cases they are discard material and are thus a more effective use of resources. Other advantages are reduced density resulting in a greater quantity of bricks from a fixed quantity of clay, more uniform firing is achieved resulting in less scrap, and full firing within the brick is achieved more rapidly resulting in reducing SEC. Scope still exists in South Africa for clay additions, but the following limitations exist:

- Excessive carbonaceous additions will cause burning.
- The sulphur content in the exhaust gases increases.
- The appearance of bricks can alter.

If less water is used in the making process, less energy would be required in drying. The optimum water content must minimize drying costs and power costs for extrusion. New stiff extrusion processes are reducing the optimum water content. In some areas the raw clay already has a water content above that desired.

Climatic conditions in South Africa favour open-air drying all year around, with the exception of the coastal areas where seasonal brickmaking is sometimes practised[11]. This means that less energy but more labour should be required for drying than most other developed countries. With extra handling requirements, product waste levels for open-air drying can be significant and are typically 12-20% for clamp kilns. Many brick manufacturers in South Africa reuse this waste.

The size of kiln also affects SEC, with kilns producing less than 30 000 tons/year having significantly higher energy intensities[5].

In most European countries the average SEC for brick production was 2,5 MJ/kg in 1986 and the newest plants were using 1,5-2,0 MJ/kg[4]. Table C.3 gives SEC's for a number of countries in 1981. Generally SEC will have improved since 1981.

Table C.3 SEC in brickmaking in 1981 for various countries[5]

Country	Specific Energy Consumption (MJ/kg)
Denmark	2,6
Netherlands	3,2
France	2,6
Italy	3,8
Germany	2,8
UK[a]	2,9

a Excluding fletton bricks which are derived from a unique type of clay.

Currently, average SEC for Corobrick is 4,14 GJ/ton including carbonaceous material[1]. It would thus appear that the clay-brick industry in South Africa has a higher SEC than most other developed countries, which is not surprising considering the low cost of energy.

ENERGY MANAGEMENT

One study conducted in 1984[11] concluded that the level of energy effectiveness on the limited number of plants analysed was low. Barriers to improved energy effectiveness are unawareness of energy saving opportunities due to lack of monitoring, lack of available capital, and resistance to change.

FUTURE ENERGY CONSUMPTION

It would appear that there is substantial potential to reduce SEC through:
- Increased production of hollow bricks.
- Improved operation of kilns.
- Improved process integration reducing energy losses.

Also, the addition of waste carbonaceous materials to the bricks before firing, without a decrease in the quality of the final product, would result in the more effective use of resources. Optimisation of water content and extrusion process can also reduce energy costs and may reduce SEC. Average SEC in South Africa is approximately 40% higher than developed countries. Considering the excess production capacity at present, the commissioning of new plants will be slow. Nevertheless the potential for cost-effective retrofit measures is undoubtedly large and it is estimated that SEC could be reduced cost-effectively by at least 25%.

CONCLUSIONS

Little information is available on the structural clay industry in South Africa. It would appear that SEC in South Africa is considerably more than in other countries. Energy awareness appears to be low and considerable potential exists to improve energy effectiveness. The brick industry would derive substantial benefit from government information programmes including general awareness, demonstration, and audits.

REFERENCES

(1) RUTHERFORD E C (1993). Executive Chairman, Corobrick. Personal communication, August.

(2) CAREY D (1984). Quantitative measurement of energy consumption in the brick industry. 16th Annual Symposium of the South African Ceramic Society, Pretoria.

(3) DE LA HUNT H W G (1993). Personal communication.

(4) INTERNATIONAL ENERGY AGENCY (1987). Energy conservation in IEA countries. OECD Publications, Paris.

(5) COMMISSION OF THE EUROPEAN COMMUNITIES (1985). Energy audit No. 5: Clay-brick industry in the European Economic Community. Luxembourg.

(6) VAN RHYN P (1993). Van Rhyn Brickworks. Personal Communication, September.

(7) PRETORIOUS P (1993). Sterkfontein Bricks. Personal Communication, September.

(8) VAN GRAAN B (1993). Personal Communication, September.

(9) WILKINSON (1993). Chairman of the Clay-brick Association. Personal communication, September.

(10) HEIMSOTH D A (1984). Energy saving in ceramic firing. 16th Annual Symposium of the South African Ceramic Society, Pretoria.

(11) HUIRAS A H (1988). Clamp kiln firing of bricks in South Africa. Ziegelindustrie International, 12, pp. 676-681.

(12) HUGGET A C (1986). Energy utilisation in selected industrial sectors in South Africa. Thesis for the Energy Research Institute, University of Cape Town, April.

APPENDIX D

CEMENT (SIC 3692)

PROCESS DESCRIPTION

Cement is produced by taking limestone (95%) and shale (5%), grinding them into a fine homogeneous powder, called raw meal, to ensure that they have a reasonable reaction rate. The raw meal is then fed to the kilns either as a wet slurry or a dry powder, depending on the grinding process. The raw meal is burnt in a kiln, which is almost always a rotary kiln, at a maximum temperature of about 1500^{o}C to produce cement clinker. The clinker is cooled and then ground with about 5% gypsum to give Portland Cement powder.

A major trend in the cement process has been the de-commissioning of the wet process, and the introduction of the more energy-efficient dry process. Drying of the material in the raw feed mills and cement mills, and reheating of the raw meal using exhaust gases of the kiln is common practice. Cooling takes place in rotary, planetary, or grate coolers.

THE INDUSTRY IN SOUTH AFRICA

Cement is produced by three companies in South Africa: Anglo Alpha Cement, Pretoria Portland Cement, and Blue Circle Cement. Natal Portland Cement is a joint venture between these three groups. The South African Cement Producers' Association collects production and energy statistics annually for all cement producers. In 1992 7 028 million tons of cement were produced, 5,4% less than 1991 (7 426 million tons)(1). Energy accounts for about 50% of cement production costs and thus there is strong incentive for energy effectiveness(2).

About 59% of available production capacity was used in 1992. About 8% of cement-producing capacity is the wet process, but it is not known if this capacity is being utilised. About 48% of cement production capacity is over 20 years old, but most of the old capacity is not being utilised. If cement production should increase sharply in the near future, then it may occur that energy intensities will increase due to the utilization of older less efficient plants.

ENERGY CONSUMPTION

Wet grinding, which produces a slurry with 25-40% water, used to be standard practice. However the large amount of heat required in the kilns to evaporate the water was a major disadvantage. But with the advent of dry milling, which produces raw meal with a water content of only about 1%, the required energy consumption in the kilns could be reduced substantially. Nevertheless about 80% of total energy consumption is used by the kiln.

The exhaust gases of the kilns account for about 34% of the energy consumption. This heat is usually utilised by the drying and preheating of the raw meal. The raw meal is often preheated in a series of about four suspension preheaters. Another method of preheating the raw meal is by addition of 10-15% water to produce nodules which can be preheated on a travelling grate. However there is then generally insufficient heat to dry the raw meal in the mills, thus necessitating another heat source. This process is referred to as the semi-dry or Lepol process. Table D.1 shows ideal heat requirements for each of the above-mentioned processes. Electricity is excluded, and a small amount of diesel or fuel oil for starting up the kiln is also used. The theoretical minimum is 1,86 MJ/ton of clinker.

Table D.1 Idealized heat balance data for four types of kilns[(2)]

	4-stage suspension preheater	Long dry	Semi-dry (Lepol)	Wet
Theoretical heat of clinker formation	1760	1760	1760	1760
Drying the kiln feed	25	25	510	2370
Exhaust gas losses	710	1490	315	755
Radiation & convection losses	435	625	455	540
Cooling & exhaust gas losses	300	345	305	100
Other losses	115	195	70	85
Total	3345	4440	3415	5610

Lately decarbonisation of the limestone prior to the kiln (precalcining) using kiln exhaust gases has been introduced. This measure initially had more of an effect on capital cost than energy use. However new precalcining technology can reduce energy requirements considerably.

An average cement plant uses about 110 kWh of electricity for every ton of clinker produced. About a third is used in raw milling, another third in cement milling, and the final third is consumed by the rest of the factory. The trend towards the dry process has resulted in an increase in electricity consumption, mainly due to the extra requirements in raw milling. Wet milling is 30-40% more efficient then dry milling, and consequently some attention has been focused on improving the efficiency of dry milling.

In other countries some cement producers generate their own electricity using exhaust gases. It is probable that this will not occur in South Africa unless the price of electricity increases in real terms.

In many countries secondary materials such as blast furnace slags and fly ash are added to the cement. In the US these secondary materials are added to the concrete rather than the cement, mainly due to marketing problems. However the more energy-effective route is the addition of these materials to the cement. There is also the possibility that certain naturally occurring minerals can be treated to produce a hydraulic cement that may need far less energy than Portland cement.

The average SEC in most European countries was 3,6-3,8 MJ/kg in 1987 and the newest plants were using 3,3 MJ/kg[(3)]. Figure D.1 shows SEC in the South Africa cement industry between 1970 and 1992.

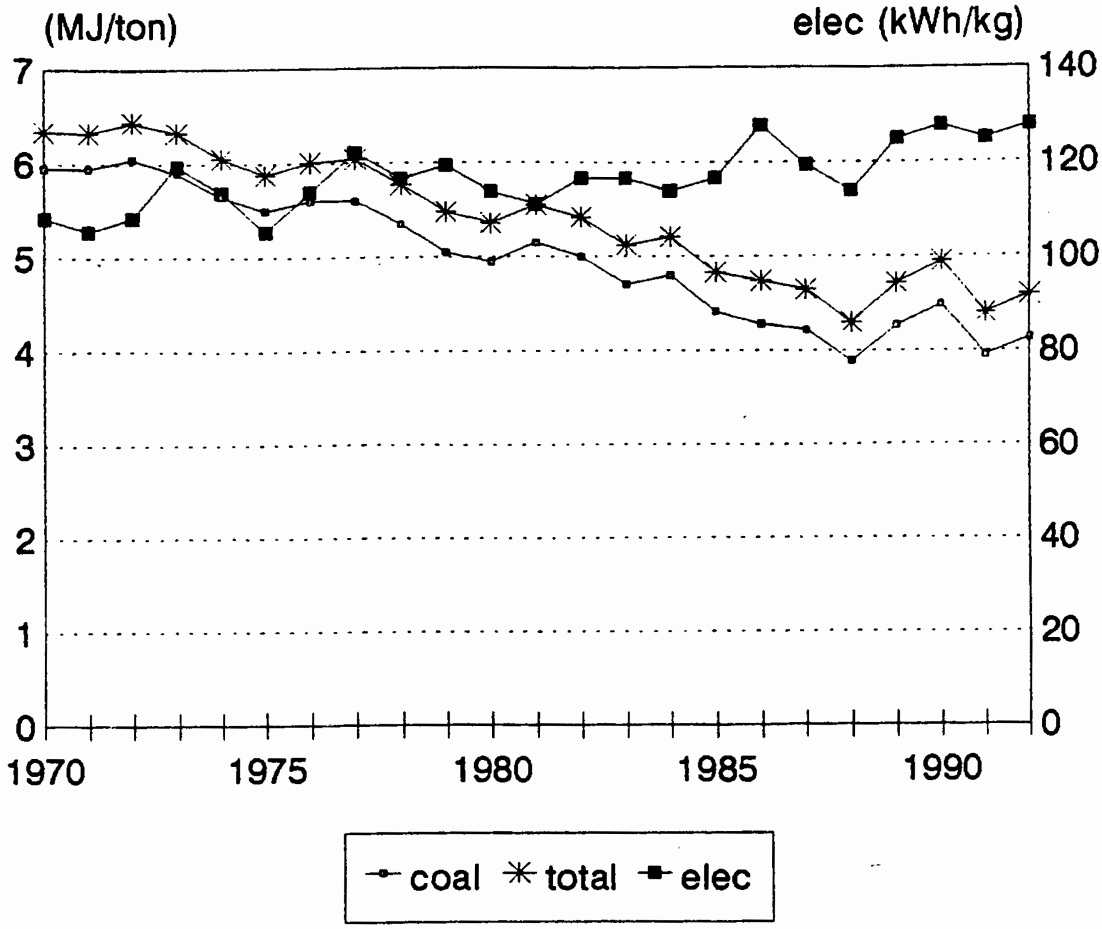


Figure D.1 SEC in cement manufacture in South Africa between 1970 and 1992[2,5]

The decline in SEC in the cement industry in South Africa is mostly accounted for by the increasing proportion of dry process kilns used. SEC in South Africa is about 30% higher than developing countries.

The incentive to reduce energy consumption has been increasing because energy costs have been increasing relative to other costs. Between 1976 and 1984 energy costs rose from 32 to 44% of production costs[5].

The average capacity of a US kiln is 336 000 tons per year, and the Japanese kiln is 714 000 tons per year. Much of the improvement in SEC in the Japanese kiln was due to falling cement demand and the corresponding concentration of production at more efficient plants. Many kilns today produce one million or more tons annually and these kilns and new plants are the efficient operations[4]. In 1984 in South Africa there were 28 kilns in production and total production for that year was 8 188 tons, giving an average kiln capacity of 292 000 tons/year. Figure D.2 shows how SEC increases with the age of a kiln.

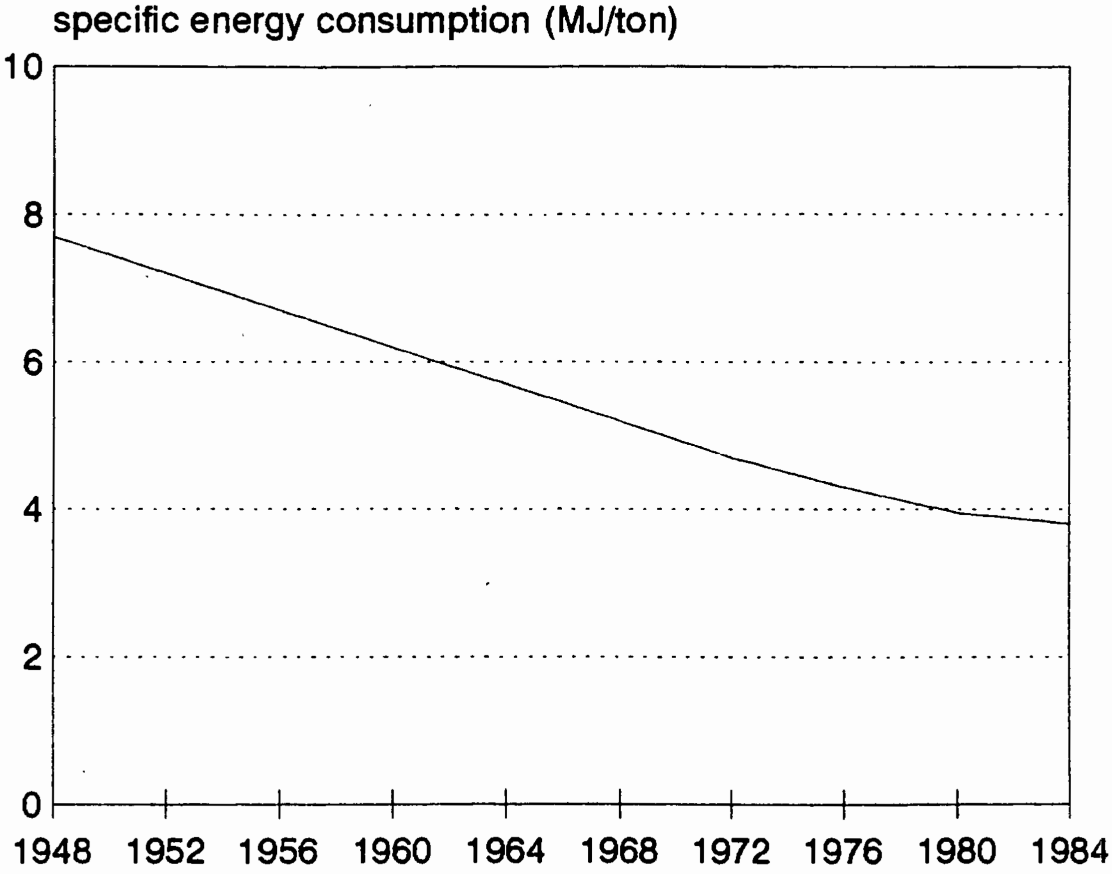


Figure D.2 Average SEC for kilns depending on year of commissioning[5]

ENERGY MANAGEMENT

In 1984 a survey was carried out to ascertain the level of energy management in the cement industry. The survey accounted for 70% of cement manufacture in 1984. Findings were[5]:

- At least one person was allocated to energy monitoring and optimization, but this was not his sole responsibility.
- All plants held discussions regarding energy management with employees.
- Less than half the plants conducted energy awareness drives.
- Most plants have made efforts to reduce their electricity costs, but there was still room for improvement.

FUTURE ENERGY CONSUMPTION

Developments in the future which are likely to further reduce SEC are:
- Larger precalciner kilns.
- More efficient raw milling and cement milling technologies.
- More efficient kiln design.
- Better insulation of existing kilns.
- Alteration of the Portland cement composition. Blended cements with similar properties to Portland cement can result in up to 75% energy savings.
- The introduction of computerized energy management systems.

It unlikely that new cement plants will be commissioned in the near future, and major plant renovations are unlikely. When demand for cement increases, SEC will initially be adversely affected by the use of older existing production capacity. It has been estimated that SEC will reduce to about 3,8 GJ/ton by 2000[2], which is a 16% decline from the early nineties.

CONCLUSIONS

SEC in the cement industry is largely a function of type of process used, and age of plant. Energy management appears to be practised at a reasonable level in South Africa. SEC could be reduced with improved kiln operation and increased production of blends of Portland cement. These are important areas of research.

REFERENCES

(1) SOUTH AFRICAN CEMENT PRODUCERS' ASSOCIATION (1992). Annual Review.

(2) BETTERTON E A (1984). Energy trends in the cement industry. 16th Annual Symposium of the South African Ceramic Society, Pretoria.

(3) TRESOUTHICK S W AND MISHULOVICH A (1990). Energy and environmental considerations for the cement industry. Proceedings of the conference on Energy and the Environment in the 21st Century, MIT, Cambridge, Massachusetts, 26-28 March.

(4) SUGIHARA N (1988). The Japanese cement industry and its restructuring plan. World Cement, March, pp. 108-110.

(5) HUGGET A C (1986). Energy utilisation in selected industrial sectors in South Africa. Thesis for the Energy Research Institute, University of Cape Town, April.

APPENDIX E

FERROUS METALS (SIC 371)

1. IRON AND STEEL

PROCESS DESCRIPTION

In the steel-making process iron ore is reduced to iron. This has been traditionally achieved in blast furnaces using coke and limestone. The coke provides heat and a porous support for the ore, and reduces the iron oxide to iron, producing an off-gas. This gas is used for energy purposes in other parts of the plant. The iron is removed from the blast furnace as a liquid 'hot metal' or is cast as 'pig-iron'. Recently direct reduction has been used instead of the blast furnace, and this process does not require coke.

Primary steel is then produced by removing impurities from the metallic iron. This is achieved using either the open hearth furnace, the basic oxygen furnace, or the electric arc furnace. The open hearth furnace has a high energy consumption and is being phased out. The basic oxygen furnace (BOF) is currently most commonly used, but the electric arc furnace (EAF) has greater control and flexibility and is becoming increasingly used. In 1988 in South Africa 67% of liquid steel was produced in BOF's and the remainder in EAF's. The steel is then either cast into ingots which are reheated and rolled, or continuously cast into slabs or blooms.

In developing countries steel is consumed in significant quantities in the form of large bars, beams, rods structural sections, mostly used for construction. Developing countries also export raw steel which does not undergo further refinement. There will thus be a difference in the output mix from country to country, making comparison difficult. Consequently the International Iron and Steel Institute (IISI) has laid out a specific procedure for calculating SEC, and has laid down a set of reference standards of what can be achieved with current best technology. They have laid down a basis for adjustments to conditions differing from those in the reference plant.

THE INDUSTRY IN SOUTH AFRICA

In 1990 South Africa produced 8,6 Mt of crude steel. The largest producer is ISCOR which produces about 65% of total production.

ENERGY CONSUMPTION

Energy consumption in producing crude steel is as follows[1]:

Iron making	58%
Rolling, etc.	15%
Steel-making	11%
Services	12%
Losses	4%

Iron-making is carried out using:

(1) Blast furnaces.

(2) The Corex process which does not require coking coal.

(3) Direct reduction which normally takes place in rotary kilns.

(4) As a co-product of vanadium (Highveld Steel and Vanadium) or titanium slag (Richards Bay Iron and Titanium).

The SEC of each of the above iron-making routes in 1988 are estimated to be[1]:

Richards Bay Iron and Titanium	74,2
Highveld Steel and Vanadium	43,8
Blast furnace	19,8
Direct reduction	19,6
Corex	19,6
South Africa total	26,1
Major countries	14,5

Specific net energy consumption in 1988 for the liquid steel production in South Africa was 29 GJ/ton (excluding Richards Bay Iron and Titanium). The split between various fuels is[1]:

Coking coal	52%
Non-coking coal	23%
Electricity	24%
Other	1%

Table E.1 shows SEC for crude steel production in various countries. Between 1970 and 1985 the average rate of increase of energy efficiency in steel production globally was 1-2%/annum[5].

Table E.1 SEC for crude steel production in 1988[1]

Country	Year	GJ/ton
Australia	1986	22,9
Brazil	1988	20,8
Canada	1988	23,7
Japan	1988	17,6
South Africa	1988	29,0
Taiwan	1986	23,2
UK	1988	19,8
USA	1988	21,4

In the rolling and finishing of steel South African industry used 4,3 GJ/ton compared the average from the ISII list of 4,0 GJ/ton, despite of the fact that South Africa is a high exporter of semi-finished products.

It was estimated in 1984 that about 20% of the total heat input to the industry is lost as waste heat. The destination of waste heat is approximately as follows[4]:

Sinter cooling air (250-400°C)	6%
Sensible heat of coke (1000°C)	9%
CO gas (600-800°C)	6%
Blast furnace gas (100°C)	5%
BOF gas (1650°C)	10%
Cooling water (30-60°C)	13%
Sensible heat of slag (1550-1600°C)	8%
Exhaust gases (300-700°C)	32%
Other	9%

Sinter cooling air can be used for generating hot water or steam. In some countries heat recovery from the coke by dry cooling is practised but is usually only feasible if enforced by environmental legislation. Heat recovery from the coke oven CO gas is problematic because of its tar content. The blast furnace and BOF gas could be used for cogeneration using turbines. Heat recovery from the slag is not economically feasible. The energy of some of the exhaust gases could be recovered, but some of the gases are corrosive. The cooling water temperature is too low for heat recovery. It is thus evident that some of this waste heat can be recovered in the future, but currently recovery of most of the waste heat is not economically viable.

Factors affecting energy consumption in South Africa are[2,6]:

Proportion of scrap used: In 1988 the proportion of scrap in steel-making materials was 26% compared to 50% for the USA. Steel production from scrap requires less than half the energy consumption than does steel production from direct reduced iron. Since South Africa is a net exporter of steel the proportion of scrap available is less than for non-exporters.

Iron ore quality: South Africa has a high alkali content and a low proportion of Sinter.

Coking coal quality: South Africa's coking coal has a high ash content, low coke strength, high volatiles content. The Corex process has avoided coke usage, greatly reducing energy costs by as much as one-third compared to the conventional blast furnace route. It may however result in a higher specific energy usage, although overall the process is more effective.

Pre-refining of iron ore: In South Africa blast furnaces are run on 100% lump ore, while other countries also make use of pre-refined iron ore pellets. South Africa does not have the facilities to produce iron-ore pellets, and importing these facilities is claimed by ISCOR to be prohibitively expensive.

Production of co-products: Vanadium and titanium are produced as co-products of iron, and consequently the processes used have been adapted to their specific requirements.

Price of electricity: The energy of the off gas from the furnaces is usually all recovered by waste heat recovery and electricity generation. However in South

Africa some of this gas is wasted, the reason being that under current electricity prices it is not economically viable to generate electricity[2].

ENERGY MANAGEMENT

Energy management at ISCOR is carried out by its corporate centres, each of which is responsible for its own energy management. The managing director appoints a Corporate Energy Board, which appoints a Corporate Energy Advisory Council representing each works centre, mining operations, and headquarters. Each centre manager appoints a Centre Management Committee. The above bodies act under the guidance of the Corporate Energy Policy. Recently energy management was removed as a function of headquarters, and the Corporate Board and Advisory Council were dissolved.

Energy management in the iron and steel industry in South Africa is of a high standard because:

- The industry is dominated by a few large companies who have the economy of scale and resources to carry out effective energy management.
- Energy is a major production cost.
- Much attention has been focussed on energy use in the iron and steel industry internationally and information on new technologies and performance standards are readily available.

FUTURE ENERGY REQUIREMENTS

Table D.2 shows estimated steel production in South Africa[1].

Table D.2 Forecast of liquid steel production in South Africa in 2000 and 2015 (Mt/annum)

Process	1990	2000 low	2015 high	2015
Blast furnace	4,5	4,5	4,5	6
Corex	0,4	1	1	5
Corex-Midrex	0	0	1	7,5
DRI + EAF	1,5	2	2	3
Scrap + EAF	1	1,5	1,5	3
Highveld	1,2	1,5	1,5	2
Plasma	0	0,5	1,5	3
Total	8,6	11	13	29,5

Table D.3 shows SEC used by Granville et al.[1] in their calculation of future energy demand by the iron and steel industry. In 1991 gas and liquid fuel usage was about 3% of coal and electricity usage in the ferrous metals industry. Consequently an additional 3% energy is added to coal and electricity to obtain overall energy requirements.

Table D.3 SEC requirements for steel production (GJ/ton)

Process	Coal	Electricity	Total
Blast furnace	21,6	2,2	24,5
Corex	21,6	2,5	24,8
Corex-Midrex	18,9	2,2	21,7
DRI+EAF	21,6	2,2	24,5
Scrap+EAF	0	2,2	2,3
Highveld	27	5,4	33,4
Plasma	13,5	9,4	23,6

Contrary to the assumption of Granville et al.[1], it is expected that within each technology there will be an improvement in SEC due to:

- Replacement of old equipment and plants with more efficient technology.
- The introduction of new and appropriate local technology such as the Corex process.
- The introduction of new technology resulting from international research, largely motivated by the desire to reduce CO_2 emissions.
- Increased usage of scrap iron.

In addition, greater incentives for cogeneration will also reduce SEC.

CONCLUSIONS

It is evident that energy management in the iron and steel industry in South Africa has been of a high standard even though commitment to energy effectiveness has fallen with the removal of the ISCOR Corporate Energy Board. Providing of incentives for cogeneration could be beneficial to the effective use of energy in the industry. Improved energy effectiveness will depend to a large extent on the success of local research and development since South Africa has unique local conditions. It would be of benefit to try and quantify the reasons for steel SEC in South Africa being so much higher than that in developed countries. However, such research should be conducted by an impartial organisation outside the steel industry.

2. STAINLESS STEEL

In 1990 South Africa produced 100 kt of stainless steel using 0,6 PJ. Stainless steel is produced by melting iron (usually scrap steel) and alloying elements (nickel, ferrochrome, etc.) in submerged arc furnaces. Approximately 3,6 GJ of electricity and 2,5 GJ of coal are required per ton of stainless steel. It is anticipated that major technological changes in stainless steel making will be introduced in the next twenty-five years. The Columbus project will quadruple South Africa's installed capacity. Production of stainless steel is estimated to grow at 24,2%/annum between 1990 and 2000, and 8,8%/annum between 2000 and 2015. SEC is expected to remain unchanged until 2000, but at a later date there will not be sufficient scrap iron, and some stainless steel will have to be produced from raw molten metal which will increase the overall SEC to about 15,1 GJ/ton by 2015[1].

3. FERROALLOYS

PROCESS DESCRIPTION

The most important ferroalloys produced are those of chromium, manganese, and silicon. Other materials are also used together with iron and steel (such as calcium carbide), but this is not their main use and thus they are not included under ferroalloys. Ferroalloys are generally produced in electric smelting furnaces using a carbon-based reductant.

THE INDUSTRY IN SOUTH AFRICA

South Africa is responsible for 12% of the world production of ferroalloys. In 1990 South Africa produced 1 022 kt of ferrochrome, 672 kt ferromanganese, and 114 kt ferrosilicon. Production of ferroalloys by the largest producers is shown in Table D.3.

Table D.3 Percentage production of main ferroalloys by producers in 1990[3]

Company	Chrome	Manganese	Silicon
Samancor	40	58	60
Middelburg Steel	23	-	-
Consol. Metal Ind.	20	-	-
Chromecorp	11	-	-
Ferroalloys	6	17	-
Transalloys	-	25	-
Rand Carbide	-	-	40

A 20% electricity rebate was instituted by the Department of Trade and Industry in 1973 for a number of companies which were mainly ferroalloy producers. The rebates were progressively raised to 45% in 1982, and then reduced again to 30%. This scheme terminated at the end of 1992.

ENERGY CONSUMPTION

Table D.4 lists the average energy intensities for the production of ferroalloys in 1990, and Table D.5 gives energy consumption. A small amount of liquid fuel is used, but comprises only about 2% of energy use, which is included in the total SEC.

Table D.4 SEC for the production of ferroalloys in South Africa in 1990[3]

Alloy	Electricity (GJ/ton)	Coal (GJ/ton)	Total (GJ/ton)
Chromium	14,4	25,6	40,8
Manganese	13,0	17,7	31,2
Silicon	37,8	29,1	68,2

There are a number of process options for the reduction of ores. For instance, options for ferrochrome include type of furnace, size of the feed, degree of pre-reduction, type of reductant, degree of exit gas cleaning, and use of off-gases. In some countries off-gases are used for cogeneration, but this is claimed to be uneconomical in South Africa.

Table D.5 Energy consumption by ferroalloys in South Africa in 1990

Alloy	Electricity (PJ)	Coal (PJ)	Total (PJ)
Chromium	16,9	27,5	46,8
Manganese	9,7	10,8	21,4
Silicon	4,8	3,5	8,6
Total	31,4	41,8	76,8

ENERGY MANAGEMENT

No information on energy management in the ferroalloy industry could be found.

FUTURE ENERGY REQUIREMENTS

Future ferrochrome production depends on world demand for stainless steel and South Africa's share of the ferrochrome market. The future of ferromanganese depends on the growth in world steel production, while ferrosilicon depends more on the growth of the local steel market. Overall ferroalloy production in South Africa is expected to grow at 3,1-4,8%/annum between 1990 and 2000.

It is expected that plants in the future will use less electricity and more coal in South Africa. The overall effect will be a slight increase in overall SEC for new plants, although energy costs may be decreased.

CONCLUSIONS

Small to moderate improvements are expected in the energy effectiveness of the processes, but the major effect on energy will be the rate of introduction of new technologies. The industry in South Africa has shown some innovation in modifying the process to suit local conditions. Assistance that may be of benefit to the ferroalloy industry includes joint R&D projects to investigate and develop processes for South Africa that will minimize production costs and improve electricity load management.

REFERENCES

(1) GRANVILLE A, STANKO J S, AND FREEMAN M J (1992). Review and analysis of energy use in the metal industries. Prepared for the Energy Branch of the Department of Mineral and Energy Affairs, Report No. ED9101, August.

(2) HOLMES A T AND MOSTERT E S (1992). Corporate energy management at ISCOR. Enerconomy 92 Seminar, Pretoria, 8/9 June.

(3) GRANVILLE A AND FREEAMAN M J (1991). Review and analysis of energy use in the metal industries. Part 1: Ferroalloys. Prepared for the National Energy Council, Pretoria, July.

(4) KAISER G AND JOHANNSEN A (1987). Potential of heat recovery in South Africa. Council for Scientific and Industrial Research, Research Report No. 649, Pretoria, June.

(5) UNIDO (1985). Analysis of the energy sector in relation to industrialization scenarios for the year 2000. Prepared for the United Nations Industrial Development Organisation, 10 January.

(6) HOLMES A T (1993). Manager of Commercial Activities, ISCOR, Personnal communication, 22 June.

APPENDIX F

NON-FERROUS METALS

Energy consumption of non-ferrous metals in 1990 (excluding mining and liquid fuels) is shown in Table F.1.

Table F.1 Energy consumption of non-ferrous metals in South Africa in 1990[(1)]

Metal	Prodn. (kt)	Elec. (PJ)	Coal (PJ)	Total (PJ)
Aluminium, primary	170	10,1	1,1	11,4a
Aluminium, secondary	130	0,5		1,1[a]
Titania slag	640	7,3	5,9	13,2
Zinc	92	1,6		1,6
PGM	0,139	1,4		1,4
Nickel	36	0,4	1,1	1,5
Copper, secondary	60	0,4	0,2	0,5
Other	2,0	0	0,1	0,1
Total		20,6	8,3	30,8

a Includes liquid or gaseous fuels.

ALUMINIUM

PROCESS DESCRIPTION

Primary aluminium production consists of extracting alumina from the bauxite ore and reduction of the alumina to the metal.

Reduction of the alumina to aluminium is carried out exclusively by the Hall-Heroult process which has dominated primary aluminium production for more than a century. The process involves electrolysing alumina dissolved in molten cryolite at about 960°C in a smelting pot. The modern smelting pot is lined with refractory insulation, and the pots are placed next to each other to form a long pot line. Current enters the pots through pre-baked anodes, and the aluminium is deposited molten onto a carbon cathode which also serves as the melt container. Molten aluminium, which is 99,6 to 99,9% pure, is removed from the cells and cast into ingots or together with alloying materials cast into products.

Scrap aluminium is used to produce secondary aluminium, using as little as 5% of the energy required for primary aluminium production. In 1987 secondary aluminium accounted for about 25% of aluminium consumption.

Since all smelters use the same technology, the difference in SEC between countries is not great, with only the plant's age making any real difference. Aluminium smelters worldwide often pay a different electricity tariff to other electricity users, and thus their international competitiveness depends greatly on the price of electricity. Lower electricity tariffs for smelters is justified to a degree in that they use large constant loads, and aluminium acts as stored energy. It is often the case that electricity utilities and smelters become partners.

THE INDUSTRY IN SOUTH AFRICA

Alusaf is the sole producer of primary aluminium in South Africa, producing 169,2 kt of primary aluminium in 1991. About 40 kt of secondary aluminium was produced in 1991. 130 kt of aluminium were consumed locally. However, a decision was made in 1992 to go ahead with the construction of a new plant with a capacity of 466 kt/a. Full production should be reached in 1996. The new smelter will require 800 MW of electricity, which is hoped may come from the Cahora Bassa Scheme[2].

South Africa's primary aluminium is produced entirely from imported alumina. Research into the production of primary aluminium from local sources indicates that for the near future at least production would be uneconomic. However there is a possibility that alumina could be produced from phlogoplite at Phalaborwa together with other co-products.

Since all subsidies and tariffs fell away Alusaf has paid the normal ESKOM electricity tariff. However ESKOM and Alusaf have entered into a 25-year power supply contract whereby the electricity tariff will be directly linked to the London Metal Exchange price for aluminium. The electricity cost per ton of aluminium produced will be equivalent to 16,3% of the price of aluminium. The deal should reduce electricity costs for Alusaf.

ENERGY CONSUMPTION

Electricity accounts for 90% of the energy used in smelting, with the world average specific electricity consumption being 16,7 kWh/kg in 1985. The latest smelters use 14,5 kWh/kg, with the cell alone consuming 13,5 kWh/kg. These figures include rectifier losses and auxiliaries(1).

Non-electrical energy for smelters is mostly used in the baking of anodes and the cast-house furnaces. In South Africa producer gas from coal supplies most of this energy.

Specific net energy consumption in South Africa for a ton of primary aluminium in 1990 was(1):

Electricity	59,4 GJ/ton (16,5 MWh/ton)
Liquid fuels	1,1 GJ/ton
Coal	6,4 GJ/ton
Total	66.9 GJ/ton

Table F.2 compares specific electricity consumption for South Africa to those in other countries.

Table F.2 **Comparison of specific electricity consumption for aluminium production[3]**

Country	kWh/ton
Italy	13,3
Netherlands	13,3
France	13,5
Brazil	14,0
West Germany	14,5
Japan	14,9
USA	15,4
Australia	16,1
South Africa	16,5
Canada	20,0

South Africa's specific electricity consumption is similar to the world average. The production of secondary aluminium has a specific electricity consumption of about 4,0 GJ/ton (1,1 MWh/ton) and a specific liquid fuel consumption of 4,9 GJ/ton. The aluminium can is one of the only packaging materials that can be 100% recycled. Europe recycles 40%, the USA 55%, Canada 65%, and Sweden 85%.

ENERGY MANAGEMENT

No information on the aluminium industry could be found.

FUTURE ENERGY REQUIREMENTS

After 1995 Alusaf will have an installed capacity of 680 kt/a. A high forecast of primary aluminium production in 2000 is thus 680 kt/a, with the low forecast being 466 kt/a. The high forecast for 2015 is 1500 kt/a and the low forecast 600 kt/a[1].

It is unlikely that an alternative aluminium process will be commercially available before 2010. The theoretical minimum SEC for a cell is 6,3 kWh/kg, which is about half of the best technology, and thus there appears to be potential to improve the electrical efficiency of the cells. It is estimated that top-of-the-range cells will not break 11,5 kWh/kg before 2000[1].

The present smelter, upgraded, is expected to use 15,8 MWh/ton and the new smelters 15 MWh/ton, giving an average of 15,3 MWh/ton for 2000. By 2015 it is expected that specific electricity requirements will be between 13,0 and 14,0 MWh/ton. Specific coal and liquid fuels requirements are not expected to change significantly, and secondary aluminium production is also assumed to remain unchanged[1].

CONCLUSIONS

Aluminium production is set to soar in South Africa. Although aluminium production does not use a large proportion of total energy in the basic metals industry, it does represent a large proportion of energy costs. Since South Africa will be using the latest technology, there does not appear to be much potential for improved energy effectiveness. Increased recycling of aluminium may be an area of possible improvement.

REFERENCES

(1) GRANVILLE A, STANKO J S, AND FREEMAN M J (1992). Review and analysis of energy use in the metal industries. Prepared for the Energy Branch of the Department of Mineral and Energy Affairs, Report No. ED9101, August.

(2) ENGINEERING WEEK, 19/3/93.

(3) ALUMINIUM ASSOCIATION (1984). Aluminium Statistical Review for 1983. Washington, D.C.

APPENDIX G

OTHER INDUSTRIAL GROUPS

Other groups in industry not included in the above analysis are not normally targeted for improved energy effectiveness because their energy intensities are lower. Many of these groups will not place as much emphasis on effective energy management, and thus it would be expected that their potential to improve energy effectiveness is greater. These industries will be a prime target for information dissemination. The results of some studies of these industries are summarised below.

FOOD, BEVERAGES, AND TOBACCO

This sector is highly diverse in products and patterns of energy use. Energy costs in this sector are generally less than 10% of production costs, and therefore energy management receives little attention. However this sector consumed 90 PJ of energy in 1991, 10% of that for industry. The UK energy efficiency demonstration scheme identified typical savings of 20-40%, with 5-10% through better housekeeping, 10-20% through conventional technology improvements, and 5-10% through innovation(6). Some innovations which may improve SEC are(6):

(1) Mechanical vapour recompression techniques may be used as a preconcentration technology.
(2) New techniques of blanching, sterilization, and pasteurization have occurred recently.
(3) Thermo-compression techniques.
(4) It is likely that there will be a move from batch to continuous processing resulting in increased control and the maximization of heat recovery.

In South Africa a number of quick energy audits are being conducted in the food sector. Initial results indicate that energy savings of 8-32% can be saved through low-cost energy-effective improvements(4). It was noted that the potential was higher in the less energy-intensive industries. Cost-effective potential will be higher if higher investment schemes were included.

TEXTILES, CLOTHING, AND LEATHER

Only one study on the textile industry was found, and the report was completed in 1980. This study[1] estimated possible savings which are summarised below.

Conservation measure	Possible energy savings
Improved boiler operation	5-10%
Improved steam distribution	3- 8%
Improved steam utilization	3- 5%
Improved electricity use	10-15%
Reduced dyeing energy requirements	10-35%
Reduced drying energy requirements	10-40%

These savings are not additive but indicate the large potential that existed for energy conservation at the time. If it is assumed that the SEC of the textile industry has not improved significantly since 1980, then much of this potential will still exist.

CHEMICALS

There is a limited growth potential locally, but exports could be a new growth area. South Africa first needs to upgrade its plants, which were designed for the local market, to increase the international competitiveness of its products[2]. SEC could potentially be reduced significantly through the development of improved catalysts. By applying the principles of pinch technology, energy savings of 20-70% have been identified in other countries. Pinch technology was applied to an oil refinery in South Africa and a cost-effective energy reduction of 10% was identified, with a further 11% possible through improvements in steam generation[3]. One chemical company achieved an energy saving of 10% in one year through the implementation of low-cost energy effectiveness measures[5].

REFERENCES

(1) RYAN T B (1980). Energy conservation in the textile industry. Thesis submitted for the degree of Master in Industrial Administration, University of Cape Town, April.

(2) ENGINEERING WEEK, 15/2/93.

(3) FRASER D M (1992). Energy conservation and integration in a chemical plant. Prepared for the Energy Branch of the Department of Mineral and Energy Affairs, April.

(4) DIONISIO R AND TULLY N (1993). Energy auditing experience in the food industry. Paper present at 'Enerconomy 93', Pretoria, 13 October.

(5) WALLIS L G (1993). Energy conservation at a chemical company. Paper presented at 'Enerconomy 93', Pretoria, 13 October.

(6) ENERGY TECHNOLOGY SUPPORT UNIT (1984). Energy use and energy efficiency in UK manufacturing industry up to the year 2000: Volume I, II, and III. Her Majesty's Stationery Office, London, October.

APPENDIX H

ENERGY ANALYSIS BY COMMON INDUSTRIAL ACTIVITIES

1. ENERGY BASE

Table H.1 shows estimated energy consumption for mining and manufacturing for 1990. Most of the data was obtained from the Cooper database[7], but some adjustments were made to the data.

Table H.1 Energy use in mining and manufacturing in 1990 (PJ)

Sector	Elec.	Coal[a]	Liquid Fuels	Gas[b]	Biomass	Total
Mining	122	9	9	1		141
Manufacturing	200	432	44	26	14	716
Total	322	441	53	27	14	857

a Includes coke, blast furnace gas, and coke oven gas.
b Includes coal gas, producer gas, and refinery gas.

From an average stacked winter weekday electricity load profile in 1989, it would appear that industry contributes about 62% towards the daily peak. This amounts to a 13 555 MW peak for 1990.

Tables H.2 and H.3 show energy consumption by energy use for mining and manufacturing, and electricity and fuel respectively[7].

Table H.2 Final use of energy in mining and manufacturing (%)

Use	Mining	Manufacturing	Total
Thermal	16,6	59,2	52,5
Mechanical	73,4	15,9	25,0
Chemical	1,0	15,3	13,0
Light	2,7	1,9	2,0
Transport	4,9	1,5	2,0
Other	1,5	6,3	5,5
Total	100	100	100

Table H.3 Final use of electricity and fuel in industry (%)

Use	Electricity	Fuel	Total
Thermal	23,8	68,9	52,5
Mechanical	62,4	3,7	25,0
Chemical	7,2	16,3	13,0
Light	5,5	0,0	2,0
Transport	0,9	2,6	2,0
Other	0,2	8,5	5,5
Total	100	96,9	100

2. ELECTRICITY

DEMAND REDUCTION

Only one comprehensive study has been conducted on potential demand reduction[4]. The study was performed in 1985 and since then some of this potential will have been realised, but additional potential will also have arisen. It is assumed that the estimated potential then is similar to the current potential. Conclusions of the study were:

(1) ESKOM's peak load could be reduced by 486 MW (3-4%) if the following used sophisticated load control systems:
   - manufacturing using manual load control systems (40 MW),
   - manufacturing having no load control systems (360 MW), and
   - mines with inadequate load control (86 MW)

(2) ESKOM's peak load could be reduced by about 716 MW (500 MW in manufacturing and 216 MW in mining) through load shifting.

(3) The potential for improved power factor correction in manufacturing is small as most manufacturing have already made use it. However, since mines do not pay for their peak demand on an MVA basis, but on a MW basis, there is little incentive to improve their power factor above the mandatory 0,85. The average power factor of the mines was about 0,913, indicating scope for improvement, but only if mines were to be charged on an MW basis.

CONSERVATION

For electricity, mechanical energy use refers to electric motors. Most electricity used for thermal purposes is used in furnaces, and most electricity used for chemical purposes is used for electrolysis.

Motors: Motors are the largest user of electricity in industry in most countries, with most of the motors powering pumps, fans, compressors, and machine tools. One international review of the effective use of motors indicates a 5 to 50% estimate range for the potential reduction in electricity use, although typically potential savings are 20-30%. It has been estimated for the USA that 16-40% of industrial electric motor energy can be saved by measures shown in Table H.4[2].

Table H.4 Potential electric motor energy reduction in the USA

	Savings (TWh/yr)
Induction motors	
Replacement with high efficiency motors	59
Elimination of past rewind damage	15
Correction of previous oversizing	8
Electrical Tune-ups	14-72
Controls	75-298
DC and synchronous motors	
All measures	3
Drivetrain, lubrication, and maintenance	
Measures on all motors	34-98
Indirect savings	
Reduced distribution loss	24-55
Reduced HVAC effect	13-24
Total savings	**245-632**

It is estimated for the United Kingdom that efficiency measures, with payback periods of two years or less, could reduce motor electricity consumption by 10%(13). A study of Brazil(12) estimates that about 6% of electricity used by electric motors could be saved through equipment replacement, and installation of motor-speed controls could reduce electricity consumption by 9%. This is an overall reduction of 15% excluding smaller opportunities.

An overview of the energy-efficient use of electric motors in South Africa has been dealt with in detail in a study in 1988(5). Only salient details of the study will be outlined. It was estimated that electric motors account for 59% of electricity consumed in South Africa. Electricity used for electric motors in industry is summarised in Table H.5.

Table H.5 Electric motor energy use in industry

	Electricity use by electric motors (GWh)	% of total electricity use
Industry		
Metal related	8 800	30
Chemical related	8 800	74
Non-metallic minerals	1 700	90
Paper and pulp	2 100	90
Other	5 500	90
Total/average	26 900	52
Mining		
Gold and platinum mining	20 700	79
Coal mining	1 700	83
Copper mining	1 300	95
Other	260	85
Total/average	23 960	80
Total/average	50 860	62

Table H.6 shows the importance of efficiency relative to other selection criteria.

Table H.6 Importance of selection criteria for electric motors in industry

Selection criteria	Importance (%)
Reliability	87
Speed/voltage/current	85
Load	84
Environmental fit	82
After-sales service	82
Availability	82
Price	81
Interchangeability	75
Life time costs	75
Efficiency	60

Efficiency is of low priority in South Africa, and thus it is likely that the potential is at least equal to developed countries. Based on international experience, a 10-20% reduction in energy use appears to be a reasonable estimate for the potential. Prevention of oversizing, cited as being the most frequently applied energy efficiency technique in industry(5), is included in the estimate.

Mechanical equipment:
Motors operate on mechanical equipment such as pumps, air compressors, and fans, which can also be improved to reduce energy requirements. The whole system, of which motors and mechanical equipment form part, can also be improved so that energy requirements are reduced. Electric motors can also be broken down according to application, as shown in Table H.7.

Table H.7 Breakdown of electric motor usage according to application (GWh)

Application	Manufacturing	Mining	Total
Pumping	3 230	6 000	9 230
Refrigeration	1 070	1 500	2 570
Air compressors	11 840	5 700	17 540
Air conditioning	540	50	590
Fans	2 150	3 300	5 450
Driving mech. equip.	7 000	510	13 150
Other	1 070	900	1 970
Total	26 900	23 960	50 860

Pumping: Typically, the work done on the fluid accounts for about 40% of the energy input, the rest being losses in the motor, pump, valves, and piping(9). It is estimated(4) that improvements in pumping can reduce energy usage by 5%.

Air compression: Air leaks can contribute significantly to wasted energy. It has been conservatively estimated(4) that improvements in mechanical equipment and usage of compressed air can result in a 5-10% reduction in energy usage over a period of five years.

Fans and ventilation: It was estimated(4) that excluding motor efficiency, equipment improvements for fans and ventilation could decrease electricity consumption by 5% in industry over five years.

It is assumed for all other mechanical equipment that 5% of electric motor energy usage could potentially be conserved.

Electric furnaces:

It has been estimated that electric furnace electricity can be reduced by 10% through improved energy effectiveness in Brazil(12). Technologies to improve the efficiency of electric furnaces include preheating the scrap using waste gases, the use of oxygen lancing to assist melting, the use of improved electrodes, computerized control, and ultra-high power furnaces[1]. In 1985[4] it was suggested that potential savings in electric furnaces should be investigated, and it was assumed that a 5% improvement in consumption could be obtained through R&D on higher efficiency and/or better use patterns. No further research on electric furnaces has been conducted in South Africa. It is assumed that potential reduction in energy use is 5-10%.

Electrolysis:
Electrolysis is used mostly in the production of aluminium and industrial chemicals. No information could be found on the potential for improved electricity effectiveness in electrolysis, but the processes used are sophisticated, and it is expected that energy effectiveness improvement will depend on replacement of existing technologies with improved technologies. It has been estimated that 7-10% of electrolytic energy use could be saved in Brazil[12], and the same assumption is made for South Africa.

Lighting:
It has been estimated that cost-effective potential energy savings in lighting energy for the USA industry is 36%, and lighting energy comprises 10% of USA industrial electricity usage[1]. Measures include substitution of lighting systems with more efficient systems, and improved lighting design and controls. In Brazil the potential is estimated at 50%[12]. It is estimated that lighting electricity in South Africa could be reduced by 20-35% through economically feasible measures.

3. FUELS

Most coal, coal gas, and liquid fuels are used for heating either directly in furnaces or indirectly through steam in boilers, although the split is unknown. Fuels used for mechanical purposes will first be combusted in boilers to produce steam. Some coal is also used in coke ovens to produce coke and coke oven gas (included under chemical energy in Tables 6.2 and 6.3), and some liquid fuels are used for transport.

FUEL SWITCHING

Assessment of fuel switching possibilities should consider cost, reliability, fuel security, etc. Fuel switching may not reduce energy usage although reducing energy costs. It is necessary that a study be conducted into the relative efficiencies of different types of boilers and furnaces. The study should be holistic and consider other factors such as cost, reliability, energy, emissions, etc. No attempt is made in this study to quantify the potential benefits of fuel switching.

FUEL CONSERVATION

Furnaces:

It is now often possible to save energy in furnaces using retrofit measures with payback periods of under three years. Such measures include improved control, insulation, efficient burners, modified geometry, e.g. baffles, waste heat recovery, and improved loading factors. It is possible to operate boilers at 80% efficiency, but inevitably average efficiencies are lower since furnace loading conditions are often non-optimal because of delays and part-loading. Little is known about furnace efficiencies in South Africa and thus it is difficult to assess the potential for improved energy efficiency. It is estimated that on average fuel requirements for industrial furnaces in South Africa can be reduced cost-effectively by 5-10%. It is assumed that half the heating fuel is used in furnaces and the other half in boilers.

Boilers:

Boiler efficiencies can be improved through better control, flue gas heat recovery, and blowdown control and/or heat recovery. As with furnaces, maximum boiler efficiencies cannot always be attained due to part-loading of boilers. Little is known about boiler efficiencies in South Africa, but it has been estimated that boiler efficiency in South Africa can generally be improved by 3% by reducing excess air levels closer to the design point. Including other efficiency measures, it is estimated that on average fuel requirements for industrial boilers in South Africa can be reduced cost-effectively by 5-10%.

Steam systems:

Steam produced in boilers can be utilised more efficiently through repairing of steam leaks, maintenance of steam traps, insulation of piping and equipment, use of steam accumulators, condensate recovery, flash steam recovery, and better load management. It is estimated that on average fuel requirements for industrial boilers in South Africa can be reduced by a further 5-10% through economically feasible measures to reduce steam requirements. This excludes process changes which could also reduce steam requirements.

Other:

It is assumed that all other uses of fuel have a conservation potential of 5-15%.

SUMMARY

Table H.8 Potential energy reductions for common industrial energy end-uses

Measure	Reduction (PJ)
Electricity	
Motors	20,1-40,2
Mechanical equipment	10,1-13,5
Furnaces	3,8-7,6
Electrolysis	1,6-2,4
Lighting	3,5-6,2
Fuels	
Furnaces	10,4-20,7
Boilers	10,4-20,7
Steam systems	10,4-20,7
Other	6,0-18,1
Total	76,3-150,1

Table H.9 Potential electricity demand load reductions

Measure	Saving (MW)
Load control	486
Load shifting	716
Power factor correction	-
Electricity reduction	
motors	637-1275
mechanical equipment	320-428
furnaces	120-141
electrolysis	51-76
lighting	111-197
Total	2441-3319

REFERENCES

(1) LEVINE M D, GELLER H, KOOMEY J, NADEL S, AND PRICE L (1992). Electricity End-use Efficiency: Experience with Technologies, Markets, and Policies throughout the world. American Council for Energy-Efficient Economy, Washington, DC, March.

(2) NADEL S, SHEPARD M, GREENBERG S, KATZ G, AND DE ALMEIDA A.T (1991). Energy Efficient Motor Systems: A Handbook on Technology, Program, and Policy Opportunities. American Council for Energy-Efficient Economy, Washington DC.

(3) ALLIANCE TO SAVE ENERGY (1983). Utility Promotion of Investment in Energy Efficiency: Engineering, Legal and Economic Analyses. United States, August.

(4) GERVAIS J S (1985). The potential for electric load and electricity conservation in South Africa. Prepared for the National Program for Energy Research, Pretoria, June.

(5) OLIVIER L R (1988). An overview of the energy-efficient use of electric motors in the RSA. Prepared for the National Energy Council, Pretoria, Project No. ETC 29, November.

(6) ENERGY TECHNOLOGY SUPPORT UNIT (1984). Energy use and energy efficiency in UK manufacturing industry up to the year 2000: Volume 1. Executive summary and main report. Her Majesty's Stationery Office, London, October.

(7) COOPER C J (1993). National commercial energy consumption summary 1991. Produced for the Energy Branch of the Department of Mineral and Energy Affairs, Pretoria, March.

(8) NAUDE D (1993). John Thompson Africa (Pty) Ltd, personal Commumication, September.

(9) GIOVANNINI B AND PAIN D (1990). Scientific and technical arguments foe the optimal use of energy. Centre Universitaire d'Etude des Problemes de l'Energie, Universit de Geneve, April.

(10) ALLIANCE TO SAVE ENERGY, AMERICAN COUNCIL FOR AN ENERGY-EFFICIENT ECONOMY, NATURAL RESOURCES DEFENSE COUNCIL, AND THE UNION OF CONCERNED SCIENTISTS (1992). America's Energy Choices, published by the Union of Concerned Scientists, Cambridge, MA.

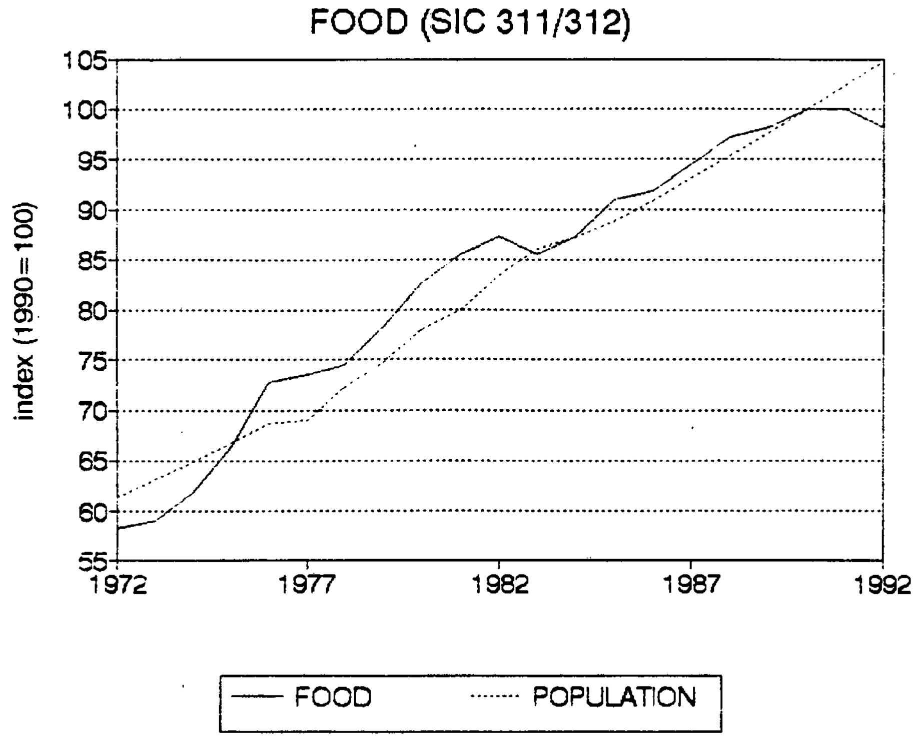
(11) LANE I E, HOOGENBOEZEM J J, AND DELPORT G J (1991). The present and future national electricity demand. Prepared for ESKOM by the Electricity Management Information and Load Analysis Centre, Potchefstroom University, Pretoria, May.

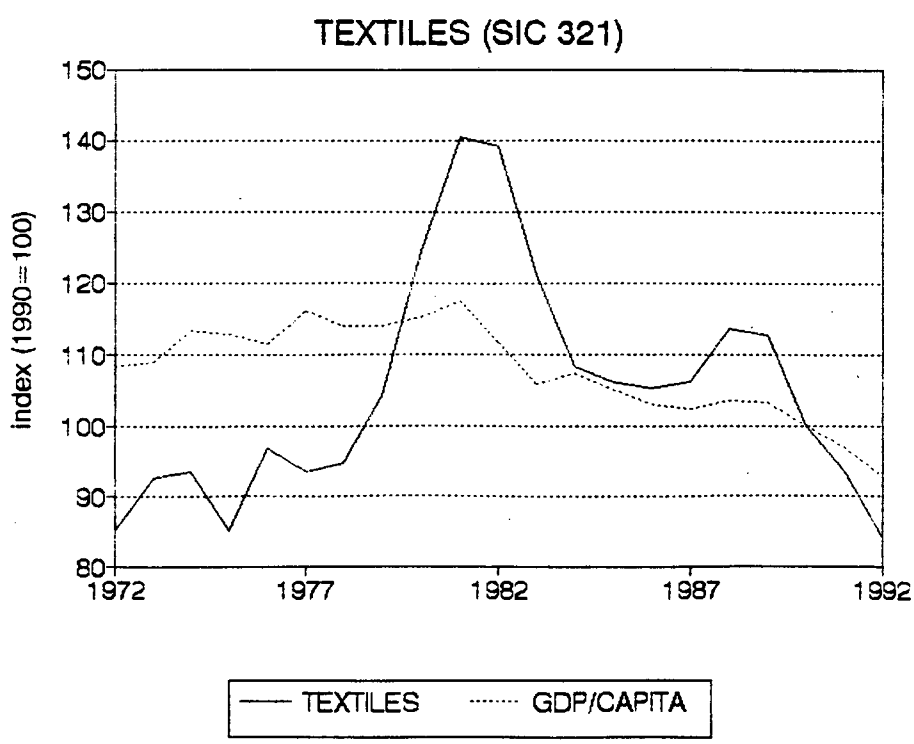
(12) GELLER H S (1990). Efficient electricity use: A development strategy for Brazil. American Council for an Energy-Efficient Economy, Washington, DC.

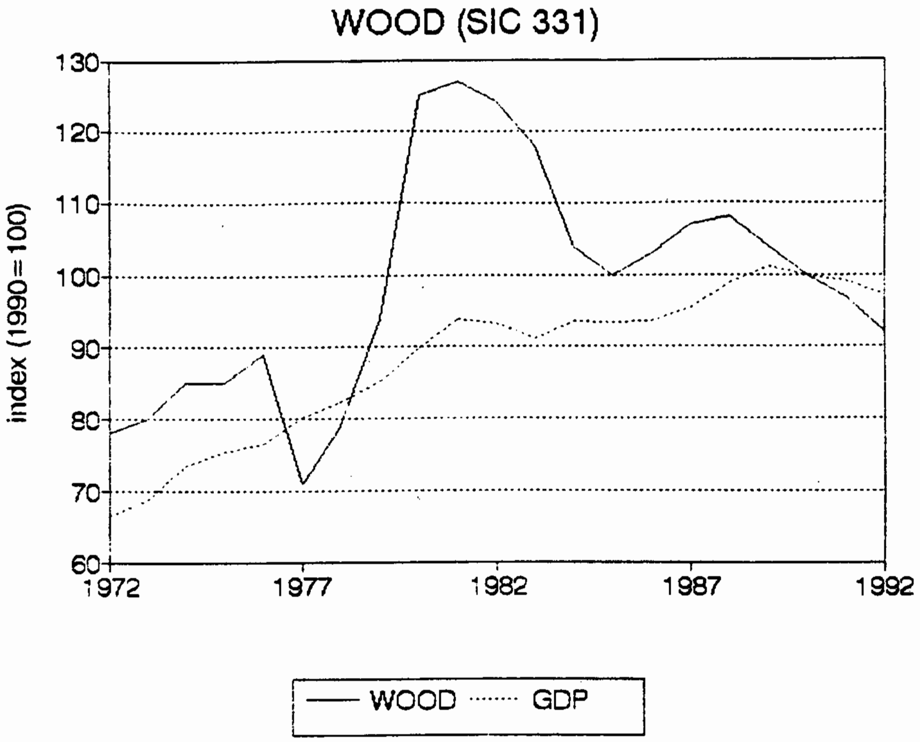
(13) MCNAUGHT C (1993). Running Smoothly: making motors more efficient. IEE Review, 39(2), March.

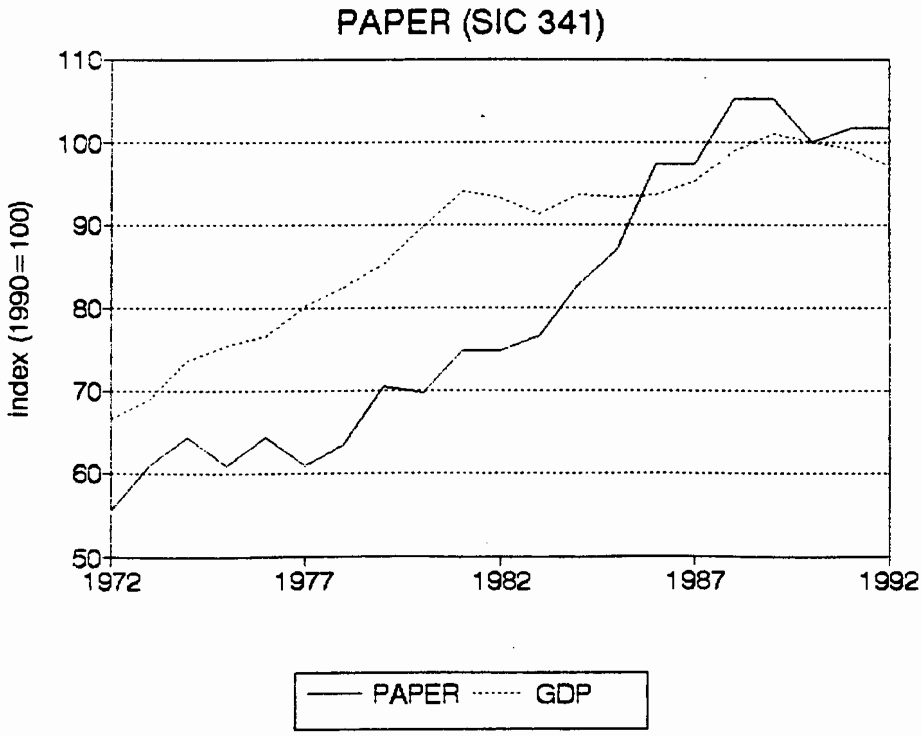
APPENDIX I

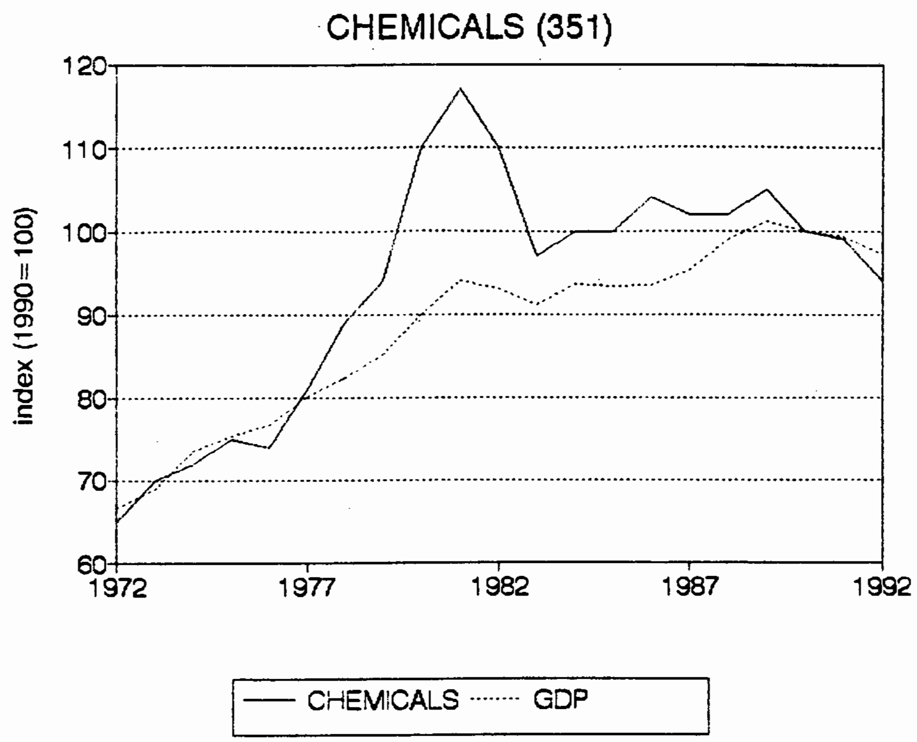
PRODUCTION CORRELATIONS

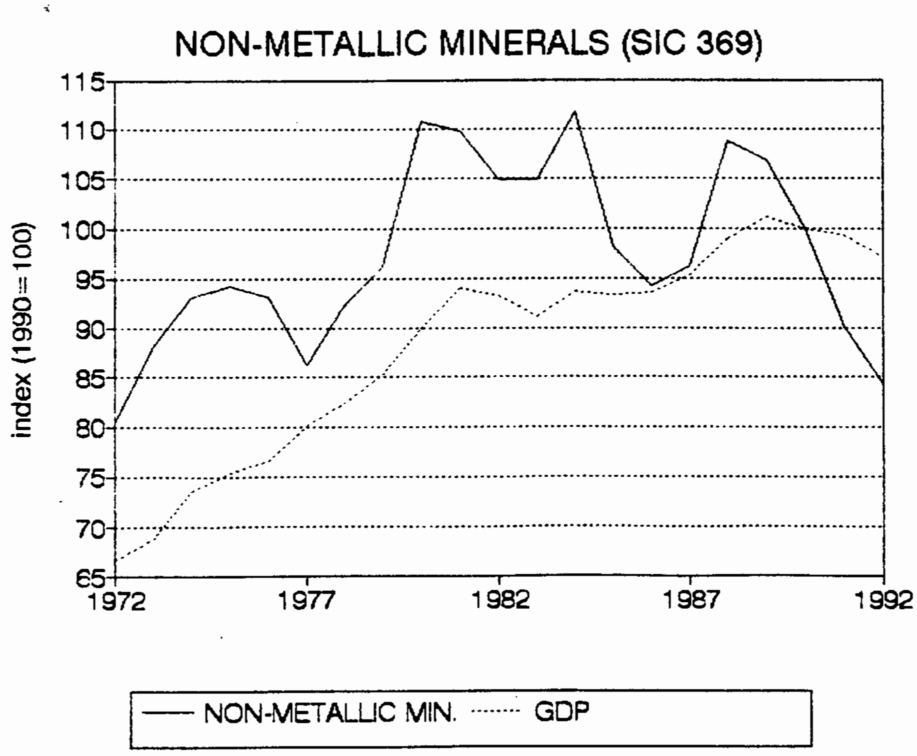


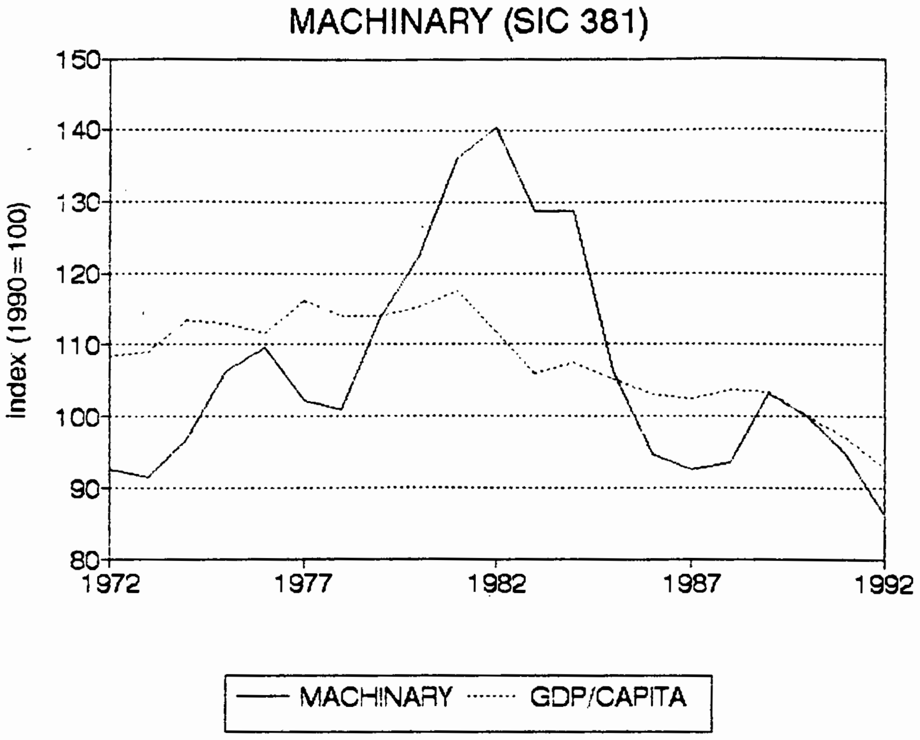



WOOD (SIC 331)
index (1990=100)
130
120
110
100
90
80
70
60
1972
1977
1982
1987
1992
WOOD
GDP


PAPER (SIC 341)
index (1990=100)
110
100
90
80
70
60
50
1972
1977
1982
1987
1992
PAPER
GDP


CHEMICALS (351)
120
110
100
90
80
70
60
index (1990=100)
1972
1977
1982
1987
1992
CHEMICALS
GDP


NON-METALLIC MINERALS (SIC 369)
115
110
105
100
95
90
85
80
75
70
65
index (1990=100)
1972
1977
1982
1987
1992
NON-METALLIC MIN.
GDP


MACHINARY (SIC 381)
Index (1990=100)
150
140
130
120
110
100
90
80
1972
1977
1982
1987
1992
MACHINARY
GDP/CAPITA

APPENDIX J

PRODUCTION AND NEW CAPACITY

Table J1. Production relative to 1990 - low growth

SIC	SECTOR	1995	2000	2005	2010	2015
21	Coal mining	1.11	1.24	1.35	1.47	1.60
23	Metal-ore mining	1.09	1.20	1.28	1.37	1.47
24	Gold mining	0.98	0.96	0.76	0.61	0.48
27	Diamond mining	0.90	0.89	0.93	0.97	1.02
28	Other mining	1.01	1.13	1.31	1.51	1.75
31	Food	1.12	1.26	1.40	1.55	1.72
32	Textiles	0.90	0.89	0.93	0.97	1.02
33	Wood	1.01	1.13	1.31	1.51	1.75
34	Paper	1.01	1.13	1.31	1.51	1.75
35	Chemicals	1.01	1.13	1.31	1.51	1.75
36	Non-metallic min.					
	Bricks	1.01	1.13	1.31	1.51	1.75
	Cement	1.01	1.13	1.31	1.51	1.75
	Other	1.01	1.13	1.31	1.51	1.75
37	Basic metals					
	iron & steel	1.09	1.20	1.28	1.37	1.47
	stainless steel	2.96	8.73	13.32	20.30	30.95
	ferroalloys	1.16	1.36	1.53	1.72	1.94
	Al. primary	1.65	2.74	2.98	3.24	3.53
	Al. secondary	1.16	1.34	1.55	1.79	2.06
	titania slag	1.48	2.18	2.45	2.76	3.11
	other metals	1.15	1.32	1.47	1.64	1.83
38	Equipment	0.90	0.89	0.93	0.97	1.02
39	Other	1.01	1.13	1.31	1.51	1.75

Table J.2 Production relative to 1990 - high growth

SIC	SECTOR	1995	2000	2005	2010	2015
21	Coal mining	1.30	1.69	2.19	2.84	3.67
23	Metal-ore mining	1.09	1.20	1.50	1.89	2.38
24	Gold mining	0.98	0.96	0.76	0.61	0.48
27	Diamond mining	0.95	1.11	1.41	1.79	2.27
28	Other mining	1.07	1.39	1.95	2.74	3.84
31	Food	1.12	1.26	1.40	1.55	1.72
32	Textiles	0.95	1.11	1.41	1.79	2.27
33	Wood	1.07	1.39	1.95	2.74	3.84
34	Paper	1.07	1.39	1.95	2.74	3.84
35	Chemicals	1.07	1.39	1.95	2.74	3.84
36	Non-metallic min.					
	Bricks	1.07	1.39	1.95	2.74	3.84
	Cement	1.07	1.39	1.95	2.74	3.84
	Other	1.07	1.39	1.95	2.74	3.84
37	Basic metals					
	iron & steel	1.09	1.20	1.50	1.89	2.38
	stainless steel	2.96	8.73	13.32	20.30	30.95
	ferroalloys	1.26	1.60	1.80	2.03	2.28
	Al. primary	2.00	4.01	5.22	6.79	8.93
	Al. secondary	1.39	1.93	2.72	3.83	5.40
	titania slag	1.48	2.18	2.45	2.76	3.11
	other metals	1.15	1.32	1.47	1.64	1.83
38	Equipment	0.95	1.11	1.41	1.79	2.27
39	Other	1.07	1.39	1.95	2.74	3.84

Table J.3 Percentage new capacity after 1990 - low scenario

SIC	SECTOR	1995	2000	2005	2010	2015
21	Coal mining	0.00	0.14	0.26	0.37	0.46
23	Metal-ore mining	0.00	0.10	0.22	0.33	0.42
24	Gold mining	0.00	0.00	0.00	0.00	0.00
27	Diamond mining	0.00	0.00	0.00	0.05	0.16
28	Other mining	0.00	0.05	0.24	0.39	0.51
31	Food	0.00	0.17	0.31	0.42	0.51
32	Textiles	0.00	0.00	0.02	0.13	0.23
33	Wood	0.00	0.10	0.28	0.43	0.54
34	Paper	0.00	0.13	0.31	0.44	0.56
35	Chemicals	0.00	0.02	0.22	0.37	0.50
36	Non-metallic min.					
	Bricks	0.00	0.00	0.00	0.20	0.36
	Cement	0.00	0.00	0.00	0.17	0.34
	Other	0.00	0.05	0.24	0.39	0.51
37	Basic metals					
	iron & steel	0.01	0.16	0.28	0.37	0.46
	stainless steel	0.67	0.90	0.94	0.96	0.98
	ferroalloys	0.00	0.09	0.25	0.39	0.49
	Al, primary	0.40	0.66	0.71	0.75	0.79
	Al, secondary	0.14	0.31	0.45	0.56	0.64
	titania slag	0.21	0.51	0.59	0.67	0.72
	other metals	0.00	0.18	0.32	0.44	0.53
38	Equipment	0.00	0.00	0.00	0.00	0.10
39	Other	0.00	0.10	0.28	0.43	0.54

Table J.4 Percentage new capacity after 1990 - high scenario

SIC	SECTOR	1995	2000	2005	2010	2015
21	Coal mining	0.11	0.36	0.55	0.67	0.77
23	Metal-ore mining	0.00	0.10	0.34	0.51	0.64
24	Gold mining	0.00	0.00	0.00	0.00	0.00
27	Diamond mining	0.00	0.03	0.29	0.48	0.62
28	Other mining	0.00	0.23	0.49	0.66	0.78
31	Food	0.00	0.17	0.31	0.42	0.51
32	Textiles	0.00	0.11	0.35	0.52	0.65
33	Wood	0.00	0.27	0.52	0.68	0.79
34	Paper	0.02	0.30	0.54	0.69	0.80
35	Chemicals	0.00	0.21	0.48	0.65	0.77
36	Non-metallic min.					
	Bricks	0.00	0.00	0.33	0.56	0.71
	Cement	0.00	0.00	0.31	0.54	0.70
	Other	0.00	0.23	0.49	0.66	0.78
37	Basic metals					
	iron & steel	0.01	0.16	0.38	0.55	0.67
	stainless steel	0.67	0.90	0.94	0.96	0.98
	ferroalloys	0.00	0.23	0.37	0.48	0.57
	Al, primary	0.50	0.77	0.84	0.88	0.92
	Al, secondary	0.28	0.52	0.68	0.79	0.86
	titania slag	0.21	0.51	0.59	0.67	0.72
	other metals	0.00	0.18	0.32	0.44	0.53
38	Equipment	0.00	0.00	0.24	0.45	0.60
39	Other	0.00	0.27	0.52	0.68	0.79

APPENDIX K

MARKET PENETRATION

Modified Mansfield models have been used in a number of studies[1,2,3]. The Mansfield/Blackman model is shown below.

$$\ln [M/(L-M)] = -\ln [L/N - 1] + Q^*(t - t_o)$$

where
M = market share at time t
L = upper market share limit
N = initial market share (year t_o)
Q = constant representing rate of penetration
t = time in years

Q is a function of the payback period and the size of an investment. Blackman derived the following relationship for Q:

$$Q = Z + 0{,}53^*P - 0{,}027^*S$$

where
Z = an constant representing an industry's propensity to innovate
P = required payback/actual payback
S = original cost of investment x 100/average firm asset value.

Investment cost is generally far outweighed by payback time. For the purposes of this study it is assumed that there is an initial 5% market penetration of any energy effective option. Q can be calculated from if the time required for a 50% penetration is known. In the UK it has been found imperically that the time required for 50% penetration was 18 years for a typical innovation, 6 years for a highly profitable innovation, and 30 years for a marginal innovation[2]. In a study of efficient electric motors, it was assumed that it would take between 10 and 15 years for a 50% market penetration, depending on motor size[4].

In this study it is assumed that under the business-as-usual scenario 50% penetration will take 20 years for low growth and 15 years for high growth. Under the energy-effective scenario, beginning in 1995, Q is assumed to increase at 3%/annum.

REFERENCES

(1) NADEL S (1990). Lessons learned: A review of utility experience with conservation and load management programs for commercial and industrial customers. American Council for an Energy-Efficient Economy, April.

(2) ENERGY TECHNOLOGY SUPPORT UNIT (1984). Energy use and energy efficiency in UK manufacturing industry up to the year 2000: Vols I, II, and III. Her Majesty's Stationery Office, London, October.

(3) NORLAND D L. Assessing demand-side management options for utility strategic resource planning: A microcomputer application.

(4) TEOTIA A P S, KLEIN Y L, AND WYANT F R.(1982). Estimating market penetration of new energy products: A case example of new energy-efficient electric motors. Energy and Environmental Systems Division, Argonne National Laboratory, Argonne, Illinois.

SIC	SECTOR	CAPACITY UTILISED (%)	CLOSUR RATE (%/annum	ENERGY (PJ) 1990	EXISTING POTENTIAL (%)	NEW CAPACITY SE (dimensionless) BAU	EE	TECHNOLOG IMPROVEME (%/annum)	ELEC USE 1990 (%)	COAL US 1990 (%)	LIQ USE 1990 (%)	GAS USE 1990 (%)	ELEC COS 1993 (c/MJ)	LOAD FACTOR
21	Coal mining	80	1.5	9.8	15	0.85	0.75	0.5	81	0	19	0	1.49	0.8
23	Metal-ore mining	80	1.5	19.2	15	0.85	0.75	0.5	73	16	11	0	1.49	0.8
24	Gold mining	60	1.5	89	10	0.95	0.85	0	95	4	1	0	1.49	0.8
27	Diamond mining	80	1.5	3.3	15	0.85	0.75	0.5	95	0	5	0	1.49	0.8
28	Other mining	80	1.5	5	15	0.85	0.75	0.5	85	5	10	0	1.49	0.8
31	Food	82	1.5	85.4	20	0.85	0.75	0.5	26	61	11	2	1.97	0.7
32	Textiles	87	1.5	51.2	25	0.85	0.75	0.5	35	62	3	0	1.97	0.7
33	Wood	85	1.5	8.7	15	0.85	0.75	0.5	52	41	4	3	1.97	0.7
34	Paper	88	1.5	66	15	0.84	0.72	0.5	23	74	2	1	1.97	0.7
35	Chemicals	78	1.5	53	15	0.85	0.75	0.5	44	43	6	7	1.49	0.8
36	Non-metallic min.													
	Bricks	61	1.5	43	25	0.79	0.59	0.5	8	87	3	2	1.97	0.8
	Cement	59	1.5	34	15	0.87	0.78	0.5	10	88	1	1	1.97	0.8
	Other	80	1.5	25	20	0.85	0.75	0.5	8	73	7	12	1.97	0.8
37	Basic metals													
	iron & steel	86	1.5	194	10	0.83	0.71	0.5	13	85	1	1	1.49	0.8
	stainless steel	95	1.5	0.6	10	2	1.8	0.5	57	42	1	0	1.49	0.8
	ferroalloys	70	1.5	76.9	10	1	0.91	0.5	41	57	2	0	1.49	0.8
	Al. primary	93	1.5	11.4	10	0.91	0.86	0.5	89	9	2	0	1.49	0.9
	Al, secondary	93	1.5	1.1	10	0.85	0.75	0.5	44	0	56	0	1.49	0.8
	titania slag	80	1.5	13.2	10	0.85	0.75	0.5	54	45	1	0	1.49	0.8
	other metals	80	1.5	20.8	10	0.85	0.75	0.5	40	57	2	1	1.49	0.8
38	Equipment	75	1.5	42.7	15	0.85	0.75	0.5	57	31	9	3	1.97	0.8
39	Other	85	1.5	4	15	0.85	0.75	0.5	40	50	10	0	1.97	0.7

Table L.1 Various input parameters

Table L.2 Energy consumption for frozen efficiencies - low growth (PJ)

SIC	SECTOR	1990	1995	2000	2005	2010	2015
21	Coal mining	9.8	10.9	12.2	13.3	14.4	15.7
23	Metal-ore mining	19.2	21.0	22.9	24.6	26.4	28.3
24	Gold mining	89.0	87.2	85.5	67.9	54.0	42.9
27	Diamond mining	3.3	3.0	2.9	3.1	3.2	3.4
28	Other mining	5.0	5.0	5.6	6.5	7.6	8.8
31	Food	85.4	95.9	107.7	119.5	132.6	147.1
32	Textiles	51.2	45.9	45.6	47.7	49.8	52.1
33	Wood	8.7	8.8	9.8	11.4	13.2	15.3
34	Paper	66.0	66.7	74.3	86.1	99.9	115.8
35	Chemicals	53.0	53.5	59.7	69.2	80.2	93.0
36	Non-metallic min.						
	Bricks	43.0	43.4	48.4	56.1	65.1	75.4
	Cement	34.0	34.3	38.3	44.4	51.4	59.6
	Other	25.0	25.2	28.1	32.6	37.8	43.9
37	Basic metals						
	iron & steel	194.0	212.1	231.9	248.6	266.5	285.7
	stainless steel	0.6	1.8	5.2	8.0	12.2	18.6
	ferroalloys	76.9	89.6	104.4	117.5	132.3	148.9
	Al, primary	11.4	18.9	31.2	34.0	37.0	40.2
	Al, secondary	1.1	1.3	1.5	1.7	2.0	2.3
	titania slag	13.2	19.5	28.8	32.4	36.5	41.1
	other metals	20.8	23.9	27.4	30.6	34.1	38.0
38	Equipment	42.7	38.3	38.0	39.8	41.6	43.5
39	Other	4.0	4.0	4.5	5.2	6.1	7.0
	Total	857.3	910.3	1014.0	1100.1	1203.6	1326.3

Table L.3 Energy consumption for frozen efficiencies - high growth (PJ)

SIC	SECTOR	1990	1995	2000	2005	2010	2015
21	Coal mining	9.8	12.7	16.6	21.5	27.8	36.0
23	Metal-ore mining	19.2	21.0	22.9	28.9	36.3	45.7
24	Gold mining	89.0	87.2	85.5	67.9	54.0	42.9
27	Diamond mining	3.3	3.1	3.7	4.6	5.9	7.5
28	Other mining	5.0	5.4	7.0	9.8	13.7	19.2
31	Food	85.4	95.9	107.7	119.5	132.6	147.1
32	Textiles	51.2	48.8	56.7	72.0	91.5	116.2
33	Wood	8.7	9.3	12.1	17.0	23.9	33.5
34	Paper	66.0	70.7	92.0	129.0	180.9	253.8
35	Chemicals	53.0	56.8	73.9	103.6	145.3	203.8
36	Non-metallic min.						
	Bricks	43.0	46.1	59.9	84.0	117.9	165.3
	Cement	34.0	36.4	47.4	66.5	93.2	130.7
	Other	25.0	26.8	34.8	48.9	68.5	96.1
37	Basic metals						
	iron & steel	194.0	212.1	231.9	291.8	367.1	461.8
	stainless steel	0.6	1.8	5.2	8.0	12.2	18.6
	ferroalloys	76.9	97.2	122.9	138.4	155.8	175.4
	Al, primary	11.4	22.8	45.7	59.5	77.4	100.6
	Al, secondary	1.1	1.5	2.1	3.0	4.2	5.9
	titania slag	13.2	19.5	28.8	32.4	36.5	41.1
	other metals	20.8	23.9	27.4	30.6	34.1	38.0
38	Equipment	42.7	40.7	47.3	60.1	76.3	96.9
39	Other	4.0	4.3	5.6	7.8	11.0	15.4
	Total	857.3	944.1	1137.1	1404.6	1765.9	2251.5

Table L.4 Energy consumption for Business as usual - low growth (PJ)

SIC	SECTOR	1990	1995	2000	2005	2010	2015
21	Coal mining	9.8	10.6	11.2	11.5	11.8	12.1
23	Metal-ore mining	19.2	20.4	21.3	21.5	21.7	22.0
24	Gold mining	89.0	85.3	81.4	62.8	48.3	37.2
27	Diamond mining	3.3	2.9	2.8	2.8	2.8	2.7
28	Other mining	5.0	4.9	5.3	5.7	6.2	6.7
31	Food	85.4	93.1	97.9	101.6	105.5	110.2
32	Textiles	51.2	44.4	42.2	41.7	40.4	39.5
33	Wood	8.7	8.6	9.1	9.8	10.6	11.6
34	Paper	66.0	64.9	68.4	73.9	80.1	87.2
35	Chemicals	53.0	52.1	56.1	60.5	65.5	71.2
36	Non-metallic min.						
	Bricks	43.0	42.0	44.8	49.2	51.7	55.0
	Cement	34.0	33.4	36.1	40.3	43.7	47.4
	Other	25.0	24.5	26.1	28.0	30.2	32.9
37	Basic metals						
	iron & steel	194.0	206.8	213.7	216.7	219.7	223.0
	stainless steel	0.6	2.9	9.2	13.7	20.4	30.1
	ferroalloys	76.9	87.6	99.1	107.4	116.2	125.5
	Al, primary	11.4	17.7	27.4	28.6	29.7	31.0
	Al, secondary	1.1	1.2	1.3	1.4	1.6	1.7
	titania slag	13.2	18.4	24.9	26.6	28.5	30.5
	other metals	20.8	23.3	25.3	26.6	28.0	29.5
38	Equipment	42.7	37.3	35.8	36.1	36.2	35.7
39	Other	4.0	3.9	4.2	4.5	4.9	5.3
	Total	857.3	886.2	943.5	970.9	1003.4	1048.1

Table L.5 Energy consumption for Business as usual - high growth (PJ)

SIC	SECTOR	1990	1995	2000	2005	2010	2015
21	Coal mining	9.8	12.0	14.2	16.9	20.4	24.7
23	Metal-ore mining	19.2	20.1	20.6	23.5	27.3	32.0
24	Gold mining	89.0	84.1	79.0	59.8	45.4	34.6
27	Diamond mining	3.3	3.0	3.3	3.8	4.4	5.3
28	Other mining	5.0	5.1	6.1	7.8	10.1	13.2
31	Food	85.4	91.5	94.3	96.0	98.6	102.5
32	Textiles	51.2	46.3	49.4	56.4	65.8	78.3
33	Wood	8.7	8.9	10.6	13.5	17.4	22.9
34	Paper	66.0	67.7	79.6	101.3	131.1	171.9
35	Chemicals	53.0	54.5	65.1	82.6	106.8	139.9
36	Non-metallic min.						
	Bricks	43.0	43.7	52.9	64.5	81.4	105.6
	Cement	34.0	34.9	43.1	54.8	70.5	92.2
	Other	25.0	25.6	30.2	38.3	49.6	65.1
37	Basic metals						
	iron & steel	194.0	204.1	207.7	238.4	276.3	323.4
	stainless steel	0.6	2.8	9.0	13.3	19.6	28.6
	ferroalloys	76.9	93.8	113.0	120.9	129.3	138.7
	Al, primary	11.4	20.9	38.7	47.5	58.5	72.1
	Al, secondary	1.1	1.4	1.8	2.3	3.1	4.0
	titania slag	13.2	18.1	24.3	25.7	27.1	28.8
	other metals	20.8	23.0	24.5	25.5	26.5	27.7
38	Equipment	42.7	39.0	43.1	49.7	57.8	68.4
39	Other	4.0	4.1	4.9	6.2	8.0	10.5
	Total	857.3	904.8	1015.5	1148.6	1334.9	1590.5

Table L.6 Energy consumption - energy effective - low growth (PJ)

SIC	SECTOR	1990	1995	2000	2005	2010	2015
21	Coal mining	9.8	10.6	10.8	10.6	10.5	10.7
23	Metal-ore mining	19.2	20.4	20.5	19.9	19.5	19.5
24	Gold mining	89.0	85.3	79.6	59.8	45.1	34.6
27	Diamond mining	3.3	2.9	2.7	2.6	2.5	2.5
28	Other mining	5.0	4.9	5.1	5.3	5.5	5.9
31	Food	85.4	93.1	93.5	92.4	92.7	96.1
32	Textiles	51.2	44.4	40.7	38.0	35.1	34.2
33	Wood	8.7	8.6	8.8	9.0	9.5	10.2
34	Paper	66.0	64.9	65.7	67.5	70.6	75.7
35	Chemicals	53.0	52.1	54.5	56.0	58.5	62.9
36	Non-metallic min.						
	Bricks	43.0	42.0	43.3	44.9	43.7	45.2
	Cement	34.0	33.4	35.2	37.9	39.6	42.5
	Other	25.0	24.5	25.2	25.6	26.6	28.7
37	Basic metals						
	iron & steel	194.0	206.8	205.1	200.7	197.8	198.0
	stainless steel	0.6	2.9	8.2	12.1	17.8	26.1
	ferroalloys	76.9	87.6	96.1	100.8	106.2	113.5
	Al, primary	11.4	17.7	26.0	26.6	27.4	28.3
	Al, secondary	1.1	1.2	1.3	1.3	1.4	1.5
	titania slag	13.2	18.4	23.1	24.1	25.2	26.7
	other metals	20.8	23.3	24.3	24.7	25.3	26.3
38	Equipment	42.7	37.3	34.9	34.0	33.1	32.4
39	Other	4.0	3.9	4.0	4.2	4.4	4.7
	Total	857.3	886.2	908.6	898.2	897.9	926.3

Table L.7 Energy consumption - energy effective - high growth (PJ)

SIC	SECTOR	1990	1995	2000	2005	2010	2015
21	Coal mining	9.8	12.0	13.2	15.0	17.6	21.0
23	Metal-ore mining	19.2	20.1	19.6	21.2	23.9	27.6
24	Gold mining	89.0	84.1	76.3	56.1	42.0	32.0
27	Diamond mining	3.3	3.0	3.2	3.4	3.9	4.5
28	Other mining	5.0	5.1	5.8	6.9	8.7	11.2
31	Food	85.4	91.5	88.7	85.6	86.0	88.9
32	Textiles	51.2	46.3	46.5	49.5	56.5	66.7
33	Wood	8.7	8.9	9.9	12.0	15.1	19.4
34	Paper	66.0	67.7	73.8	88.6	111.2	142.7
35	Chemicals	53.0	54.5	61.3	73.6	92.5	119.0
36	Non-metallic min.						
	Bricks	43.0	43.7	50.3	54.3	64.3	80.5
	Cement	34.0	34.9	41.4	49.6	62.1	79.8
	Other	25.0	25.6	28.3	33.8	42.6	55.2
37	Basic metals						
	iron & steel	194.0	204.1	196.7	214.3	240.4	274.7
	stainless steel	0.6	2.8	7.9	11.6	16.8	24.2
	ferroalloys	76.9	93.8	107.1	110.6	116.0	122.7
	Al, primary	11.4	20.9	36.1	43.5	52.8	64.2
	Al, secondary	1.1	1.4	1.6	2.1	2.6	3.4
	titania slag	13.2	18.1	22.3	22.8	23.6	24.7
	other metals	20.8	23.0	23.3	23.2	23.6	24.4
38	Equipment	42.7	39.0	41.3	45.0	51.0	59.2
39	Other	4.0	4.1	4.5	5.5	6.9	8.9
	Total	857.3	904.8	959.1	1028.0	1160.0	1355.2

Table L.8 Maximum electricity demand - low growth (MVA)

SIC	SECTOR	2005 SCEN1	2005 SCEN2	2005 SCEN3	2015 SCEN1	2015 SCEN2	2015 SCEN3
21	Coal mining	448	361	317	530	380	313
23	Metal-ore mining	749	608	536	861	623	515
24	Gold mining	2692	2308	2098	1699	1370	1211
27	Diamond mining	122	103	92	133	101	86
28	Other mining	231	187	165	311	221	181
31	Food	1482	1169	1014	1824	1272	1027
32	Textiles	795	645	562	870	613	499
33	Wood	282	226	198	378	268	218
34	Paper	945	752	655	1270	890	714
35	Chemicals	1270	1031	910	1707	1217	997
36	Non-metallic min.						
	Bricks	187	152	133	252	171	131
	Cement	185	156	140	249	184	154
	Other	109	87	76	146	102	82
37	Basic metals						
	iron & steel	1348	1091	963	1549	1126	928
	stainless steel	190	303	255	442	665	523
	ferroalloys	2010	1706	1525	2548	1998	1675
	Al, primary	1121	875	778	1327	951	795
	Al, secondary	31	25	22	42	29	24
	titania slag	730	557	480	925	639	513
	other metals	510	411	364	634	458	378
38	Equipment	945	797	714	1034	791	678
39	Other	100	80	70	134	95	77
	Total	16483	13628	12069	18865	14165	11719

Table L.9 Maximum electricity demand - high growth (MVA)

SIC	SECTOR	2005 SCEN1	2005 SCEN2	2005 SCEN3	2015 SCEN1	2015 SCEN2	2015 SCEN3
21	Coal mining	726	531	449	1216	785	629
23	Metal-ore mining	879	665	571	1392	917	749
24	Gold mining	2692	2201	1966	1699	1290	1163
27	Diamond mining	184	140	121	297	196	160
28	Other mining	347	256	217	682	440	351
31	Food	1482	1104	939	1824	1194	986
32	Textiles	1202	874	732	1939	1228	989
33	Wood	422	310	262	829	534	426
34	Paper	1415	1031	860	2783	1772	1382
35	Chemicals	1902	1407	1195	3741	2414	1931
36	Non-metallic min.						
	Bricks	281	200	160	552	331	238
	Cement	277	212	183	545	362	296
	Other	163	119	100	321	204	163
37	Basic metals						
	iron & steel	1582	1200	1028	2505	1649	1324
	stainless steel	190	294	244	442	639	503
	ferroalloys	2367	1919	1674	3001	2231	1874
	Al. primary	1963	1456	1270	3321	2238	1861
	Al. secondary	55	40	33	109	70	55
	titania slag	730	536	455	925	610	494
	other metals	510	394	343	634	435	363
38	Equipment	1428	1096	948	2304	1528	1256
39	Other	149	110	93	293	189	151
	Total	20945	16095	13841	31355	21258	17345

SCEN1 - Frozen efficiency **SCEN2 - Business as usual**

SCEN3 - Energy effective

Table L.10 Energy costs - low growth (R Million)

		2005			2015		
SIC	SECTOR	SCEN2	SCEN3	SAVING	SCEN2	SCEN3	SAVING
21	Coal mining	293	265	28	309	265	44
23	Metal-ore mining	487	442	45	499	430	69
24	Gold mining	1720	1604	116	1020	926	94
27	Diamond mining	78	71	6	76	67	9
28	Other mining	146	132	14	172	147	25
31	Food	1309	1174	135	1422	1211	211
32	Textiles	603	541	62	572	485	88
33	Wood	206	186	20	244	209	35
34	Paper	796	716	80	941	796	145
35	Chemicals	1015	924	91	1196	1029	167
36	Non-metallic min.	0	0	0			
	Bricks	301	273	28	337	274	63
	Cement	252	234	17	296	262	34
	Other	265	241	24	310	268	42
37	Basic metals	0	0	0			
	iron & steel	1418	1297	121	1460	1271	189
	stainless steel	242	209	33	530	440	89
	ferroalloys	1458	1341	117	1705	1495	210
	Al. primary	702	642	60	763	671	91
	Al, secondary	28	25	3	33	29	5
	titania slag	448	397	51	514	433	80
	other metals	361	329	32	402	347	54
38	Equipment	793	734	59	786	699	88
39	Other	76	69	7	90	77	13
	Total	12998	11846	1152	13676	11830	1847

Table L.11 Energy costs - high growth (R Million)

		2005			2015		
SIC	SECTOR	SCEN2	SCEN3	SAVING	SCEN2	SCEN3	SAVING
21	Coal mining	432	375	57	634	525	108
23	Metal-ore mining	534	471	63	730	615	115
24	Gold mining	1640	1503	138	955	872	83
27	Diamond mining	106	94	12	147	124	23
28	Other mining	200	174	26	341	282	59
31	Food	1237	1087	150	1326	1133	193
32	Textiles	817	705	112	1139	950	189
33	Wood	283	246	36	483	400	83
34	Paper	1091	940	152	1860	1512	348
35	Chemicals	1386	1214	172	2358	1962	396
36	Non-metallic min.						
	Bricks	395	329	65	648	489	159
	Cement	342	307	35	578	494	84
	Other	361	317	45	615	518	98
37	Basic metals						
	iron & steel	1560	1384	176	2123	1777	346
	stainless steel	235	200	35	506	415	91
	ferroalloys	1640	1471	169	1893	1639	254
	Al, primary	1169	1048	121	1784	1543	241
	Al. secondary	45	39	6	79	65	14
	titania slag	432	376	56	488	408	80
	other metals	346	310	36	379	326	53
38	Equipment	1091	973	118	1509	1283	226
39	Other	104	91	13	177	147	30
	Total	15445	13651	1794	20752	17479	3273

REPORT NO. GEN 169

THE POTENTIAL BENEFITS OF IMPROVED ENERGY EFFECTIVENESS IN MANUFACTURING AND MINING IN SOUTH AFRICA (PART 2 OF 3)

FINAL REPORT

M G DE VILLIERS
R K DUTKIEWICZ

JUNE 1994