ANALYSIS OF END USE ELECTROTECHNOLOGY IN MINING AND MINERALS PROCESSING AS A DETERMINANT FOR ELECTRICITY GROWTH WITH SPECIAL REFERENCE TO THE RSA

Marie Talitha Davison

A project report submitted to the Faculty of Engineering,
University of the Witwatersrand, Johannesburg,
in partial fulfilment of the requirements for
the degree of Master of Science in Engineering.

George, 1996

DECLARATION

I declare that this project report is my own unaided work.

It is being submitted in partial fulfilment of the requirements for the degree of Master of Science in Engineering at the University of the Witwatersrand, Johannesburg.

It has not been submitted before for any degree or examination in any other University.

M J Dawson

Fifteenth day of August 1996

ABSTRACT

The history of electricity growth in South Africa has been one of rapid growth. This reached as high as 13% in one year with the increase in electrification of mining and industry from the 1960's to 1980's. In addition the development of new mines and new minerals beneficiation plants, especially metals beneficiation, accelerated electricity growth due to the electricity intensive end use technologies implemented that were specific to those industries.

The increasing electrification of metal production and metals processing industry in the RSA has shown a parallel with that of the USA in the 1980's, despite their relatively low price for natural gas, which also has an overall thermal efficiency advantage.

In the specific period from 1989 through to 1992, the impact of reduced growth in gold mining electricity consumption and physical shutting down of major metals production plant due to low world commodity prices had a profound effect on the growth rate of electrical energy demand in the Republic of South Africa. The change in the customer mix of electrical energy consumed (GWh) in the RSA and distributed to the neighbouring states, and also on the power (MW) demand profile of the integrated ESKOM power system has revealed the significance of the underlying technologies and processes in use by key industrial and mining electricity customers in this country. As new markets and technologies have become available subsequent to the 1994 political changes in the Republic of South Africa, the renewal of major production plant in the sectors of interest in this report and introduction of state-of-the-art process equipment has accelerated.

The importance of understanding both the nature of specific end-use electrotechnology and the way in which it is used, that increases energy consumption volumes and power demand levels or alternatively decreases these levels and re-shapes the demand profile, has been reviewed in this report.

The report has focussed on the major industry sectors of the South African economy, namely mining, metals and non - metallic minerals. In the mining sector, the emphasis has been placed on gold, coal and platinum. The metallic minerals sector covers mainly the ferrous metals and aluminium. The non - metallic minerals processing sector includes glass, cement, ceramics.

Within these sectors, this report highlights the key processes involved, the major equipment used within these processes, the electricity intensity of production and the electrical load profile of demand characteristic of the sector or sub-sector. Future electrotechnology potential for change in each of the sectors have been considered, along with possible implications for change in electricity demand characteristics.

Current end-use electrotechnologies have been assessed from the perspective of the main application benefit such as heating or motion, as well as newer or emergent technologies which may compete with those in current use. Such competition is typically due to greater efficiency, product quality, or enhanced environmental impact performance.

Internationally, there has been a progressive development by electricity utilities to take into consideration both "supply side" options i.e. power generation, transmission and distribution, as well as "demand side" options i.e. customer power usage, in an approach usually referred to as Integrated Resource Planning (IRP).

The use of IRP has been strongly influenced by the insights gained into the role that the end-use electrotechnology choice of the customer plays and also by the impact of research and development innovations of process equipment developers. The underlying influences of environmental sustainability, energy costs, and global product competition have, in turn, directed the nature of investment and incentives for research, development and implementation choices.

This report highlights key findings in the areas of industrial end-use equipment changes, implications for Government policy in energy efficiency and industrial competitiveness, research imperatives, and considerations for engineering curricula in higher education.

Recommendations are made for decision makers in industry, government, educational institutions and research organisations for strategic shifts of benefit to a growing economy which is increasingly thrust into competitive world markets, and which is deemed the leader in the renaissance of Africa as a continent of relevance.

ACKNOWLEDGEMENTS

My sincere appreciation is extended to the executive management of ESKOM for encouragement to undertake this project and permission to use selected material available to ESKOM, my many former ESKOM colleagues and members of staff for their support and assistance.

My thanks go to special people in industry for their willingness to locate and provide information. I prefer not to name individuals, as there is always the risk and attendant embarrassment of accidental omissions.

A special record of my gratitude must go to my husband, Eric Davison for his remarkable forebearance, and personal support of my studies, and this project report in particular. His unique sense of humour, positive attitude and continued encouragement, made it possible for me to complete this project.

My supervisor, Professor J P Reynders, has been both supportive and challenging in his supervision of this project. My thanks and appreciation go to him for his insight, guidance and patience.

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EXECUTIVE SUMMARY - KEY FINDINGS AND RECOMMENDATIONS

Introduction

The electricity usage of key minerals and processes in selected industry sectors are reviewed in Sections 2, 5, 6 and 7. Sections 2, 3, 4, 8 and 10 focus on the electricity demand or load profile and energy consumption across the spectrum of these sectors and their associated electrotechnologies. Section 9 covers a brief history of electricity pricing in South Africa. Tables 8.1, 8.2, and 8.3 show estimated electricity use in selected mining and minerals sectors.

Table 8.1 is repeated below for ease of reference. (Cooper (1991))

Table 8.1 Electricity End- Use in the Selected Sectors of Mining and Minerals (GWh) for 1990.

SECTORS	HEAT	MECHAN -ICAL	CHEM -ICAL	LIGHT -ING	TRANS -PORT	NON ENERGY	TOTAL
Coal Mining	120	2 042	0	63	1	0	2 226
Metal ore Mining	676	3 756	282	231	0	342	5 287
Gold Mining	3 297	19 923	0	667	149	0	24 036
Diamond Mining	46	831	0	40	0	0	917
Other Mining	139	1 183	0	70	0	0	1 392
Mining TOTAL	4 278	27 735	282	1 071	150	342	33 858
%	12,6	81,9	0,8	3,2	0,4	1,0	100,0
Ferrous basic Metals	10 081	3 251	1 827	365	0	15	15 539
Non-ferrous basic Metals	539	865	2 373	223	0	1	4 001
Metals TOTAL	10 620	4 116	4 200	588	0	16	19 540
%	54,4	21,1	21,5	3,0	0	0,1	100,0
Pottery	135	110	0	12	0	57	314
Glass	268	149	0	46	0	0	463
Other non-metallic minerals	239	2 703	1	97	1	1	3 042
Non-metallic TOTAL	642	2 962	1	155	1	58	3 819
%	16,8	77,6	-	4,1	-	1,5	100,0
Sectors TOTAL	15 541	34 813	4 483	1 814	151	416	57 217
%	27,2	60,8	7,8	3,2	0,3	0,7	100,0

A comparison of the key sector totals for 1990, 1991 and 1993 from Tables 8.1, 8.2 and 8.3 is shown in Table 8.4.

Table 8.4 Comparison of Electricity End-Use 1990, 1991, 1993

SECTOR	HEAT	MECHAN -ICAL	CHEM -ICAL	LIGHT -ING	TRANS -PORT	NON ENERGY	TOTAL
Mining TOTAL	4 278	27 735	282	1 071	150	342	33 858
1990 %	12,6	81,9	0,8	3,2	0,4	1,0	100,0
Mining TOTAL	3 591	27 036	361	1 010	824	560	33 381
1991 %	10.8	81.0	1.1	3.0	2.5	1.7	100.0
Mining TOTAL	3 024	26 860	74	1 334	1 471	-	32 764
1993 %	9.2	82.0	0.2	4.1	4.5	-	100.0
METALS							
Metals TOTAL	10 620	4 116	4 200	588	0	16	19 540
1990 %	54,4	21,1	21,5	3,0	0	0,1	100,0
Metals TOTAL	10 610	6 460	2 722	863	-	13	20 668
1991 %	51.3	31.3	13.2	4.2	-	-	100.0
Metals TOTAL	13 926	4 488	1 489	686	3	10	20 602
1993 %	67.6	21.8	7.2	3.3	-	-	100.0
NON-METALLIC							
Non-metallic TOTAL	642	2 962	1	155	1	58	3 819
1990 %	16,[illegible]	77,6	-	4,1	-	1,5	100,0
Non-metallic 1991 TOTAL	797	2 849	1	272	-	68	3 986
%	20.0	71.5	-	6.8	-	1.7	100.0
Non-metallic TOTAL	761	2 787	43	257	1	7	3 855
1993 %	19.7	72.3	1.1	6.7	-	-	100.0
SECTORS TOTAL							
Sectors TOTAL	15 541	34 813	4 483	1 814	151	416	57 217
1990 %	27,2	60,8	7,8	3,2	0,3	0,7	100,0
Sectors TOTAL	14 998	36 344	3 084	2 144	824	641	58 035
1991 %	25.8	62.6	5.3	3.7	1.4	1.1	100.0
Sectors TOTAL	17 711	34 135	1 606	2 277	1 475	18	57 221
1993 %	31.0	60.0	2.5	4.0	2.6	-	100.0

Summary of Sectors and Electrotechnologies

The period covered in the data collection project (Cooper, 1995) was one of stagnant fixed investment in a stagnant economy. The variations shown are primarily those of capacity utilisation rather than substantial shifts in technologies.

From Tables 8.1 and 8.4, it can be seen that for the sectors covered in this report, the electricity required for mechanical end-use ranged from 60.0 to 62.6%. It is as high as 82% for the mining sector. Energy conversion into mechanical energy through electric motors, across the majority of end-use sectors leads to predominant use of electricity nationally, namely 47% to 48.6% in 1993 (Table 8.3). This represents a substantial end-use electrotechnology in South Africa. In a study undertaken for Chile by Alvarado, S. and Maldonado, P.(1995), they report drive power for mechanical energy of 88 to 92% in copper and iron mining respectively in 1993.

From the study by EPRI (1985a), the rapid penetration of electronic a.c. adjustable speed drive technology nearly tripled over the period from 4% to 11% of total electricity used in motor drives. The benefits of improved controllability and energy efficiency improvements were believed to be the driving forces for the rapid rate of growth. The saving in electricity through efficiency quoted by EPRI were large, namely 5TWh in 1980 and 15TWh in 1985. *This implied an efficiency improvement of 1% and 2.9% in those years respectively through the use of electronic a.c. adjustable speed drive control.*

South African applications technology and competence in the field of motors and drives has been recognised world wide. The intense importance of very large motor drives for application in mining for ventilation, for materials hoisting and milling has had major influence in South African development of skills in this field.

With reasonable expectation of economic growth and exploitation of mineral resources and further beneficiation of those minerals in South Africa, it appears reasonable to expect that the share of electricity consumed by motors will be maintained. The type of efficiency and productivity improvements experienced in the USA through electronic drive control can be expected to be implemented in South Africa over time.

The intensive use of electricity in electric motors in the sectors of interest and the efficiency improvements claimed for the USA suggest that energy savings in the RSA could be substantial. At the derived EPRI estimate of 2.9% this would represent a total saving of 1010 GWh.

The initiation of a single lift shaft for operation in 1996 at the new South Deep mine, with a depth of 2750m, which is 250m deeper than the world record (Creamer, M. (1995) reinforces this dependence on motor technology. The supply to this new shaft complex is 160MVA (Ruffini, A. (1995).

The information on electricity for heat energy purposes in South Africa shown in Table 8.1 is unfortunately not divided into the different types of heating processes. Nevertheless it does show that 27% (1990) to 31% (1993) of the electricity used in the sectors of interest is for heat energy, which is the second largest end-use application. The data does however highlight the substantial use of electricity for heating in gold mining, metal ore mining, ferrous basic metals and glass processing. This identifies areas for energy efficiency targeting and investment in more energy efficient plant.

Use of electric arc furnaces in South Africa was well established with the advent of the ferro-metals industry which has been a major user of the technology. Aided by extensive research by Mintech, South African producers have become the worlds lowest cost producers and largest exporters especially of ferro-chrome.

Comparing the South African data on electricity for heating with the USA data (EPRI, 1985), admittedly for periods differing by 5 years, the RSA total figure of 27% is very high relative to the 8% in the USA, confirming the large impact of primary metals and mining industry on total RSA electricity consumption. Additional investment in the RSA in primary metals beneficiation which has been mooted, could lead to a substantial increase in the use of electricity for thermal processes. In the iron and steel industry the phasing out of Basic Oxygen Furnaces in favour of electric arc furnaces could see a major shift in electricity use, subject to the management of the dust production which has environmental impact problems. For 1991, the USA used 37% of electricity for thermal processes in the primary metals industries for Blast Furnaces and Steel Mills (DOE/EIA, 1994). This demonstrates that the technology growth expectations in the EPRI study of 1988 were achieved.

The same 1988 EPRI study concluded that plasma arc systems would be in use by the year 2000 for steelmaking cupola retrofits, for electric arc furnace dust processing, for ferro alloy production and for direct ore reduction. The review by Garz,1992 confirmed this trend. South Africa has been a world leader in plasma arc systems. This could still represent competitive advantage for this country.

Conversion to electrotechnologies for metal melting was driven more by the technology developments and their associated benefits, than the relative cost of electrical energy (EPRI,1986).

Metal melting applications of induction furnaces include the refining and holding of metals in the casting industry, and in melting and superheating steel for subsequent processing in e.g. Basic oxygen furnaces. With the use of higher frequencies for induction furnaces which has been made possible by power electronics developments, and the ability to achieve better products and performance, the extended use of induction furnaces for the metals industry in South Africa appears likely. Product quality improvement for export products can be expected to stimulate increased use of this technology, while adding to the challenges of supply system designers to deal with the effects of the high speed switching electronic systems.

The importance of metal melting technology application in South Africa is confirmed in Tables 8.1, 8.2 and 8.3. The predominant application in the non-ferrous metals industry is for aluminium.

A total of 7.8% of electricity in the sectors of interest is used for chemical energy. In the USA in 1985, 40% of electricity consumption for electrolytic processes was concentrated in the metals production industries, as the technology had wide application in many other sectors such as waste stream treatment in the chemical, paper and pulp and textile industries.

In the study by EPRI (1988) it was estimated that there was an installed capacity of 500 to 1000MW of RF heating and drying equipment in the USA in 1980 and the rate of growth was 2% per annum. Electromagnetic radiation in the radio frequency range, typically 13.56 MHz to 27.12 MHz, has been used to heat dielectric materials. These systems have not been used intensively in the mining, metals and minerals sectors, but have been primarily used in plastics, wood, paper, textiles and the food preparation industries. They have progressively found use in drying of thin cross section ceramics, and small dimension post insulators prior to firing in kilns.

RF heating installations are relatively expensive and as a heating source electricity is also relatively expensive compared with fossil fuels both in South Africa and the USA. Hence its use is usually dependent on specific product and process requirements which cannot be provided readily by the alternative heating processes. Much experience has been gained over the time since RF heating was introduced in 1941 (EPRI, 1987c). Assuming the example of the USA and the proliferation of installations, believed to have been between 50 000 and 100 000 with an average size of 10kW (EPRI, 1987c), there appears to be potential for increased use of RF in a variety of applications in industry in South Africa.

The estimated installed capacity of all industrial microwave equipment in the USA was 24MW in 1980, and this was expected to double by 2000 (EPRI, 1988). Since the efficiency of conversion of electrical energy to energy in the workpiece is some 50%, the energy cost of operation is relatively high, and the application has to justify the combined high cost of capital and running costs. Candidate materials that justify special treatment are those which have thick cross sections that are prone to overheating the surface in order to heat the internal parts, heat sensitive material, and expensive material (EPRI, 1984a). Combinations of hot air and microwave drying have been tested and found cost-effective for bulk drying of selected polymers. Destruction of organic waste has been demonstrated with the assistance of microwave plasmas at Rockwell, in the USA ([illegible], 1984a).

As South Africa moves progressively down the path of more beneficiation of metals and minerals towards more manufacturing, the under-represented electrotechnologies for materials processing will become more important and influence the relatively low existing electricity demands of manufacturing.

Impact of Electrotechnology Development in Mining and Minerals Sectors

A substantial shift in end-use electrotechnologies in the various sectors which could impact the electricity load profile, and the nature of supply needed by the specific type of load, can significantly impact not only the planning, design and cost of electricity supply systems, but also the nature of services and quality of supply needed by customers. The industrial development policy and also the science and technology research and development policy of the country will have a direct influence on these issues. In turn the education and training needed by members of the engineering team, particularly the electrical engineers, in order to meet these needs will be influenced.

At the level of application of electricity in industrial processes, the implications are that education and training in the electrical engineering disciplines will require special attention. For such a transition into new or under-represented technologies to be sustainable and successful, bridges between engineering disciplines will need to be strengthened.

The underlying driving forces that lead to changes in end use technologies and processes are closely tied to increasing pressure for sustainable environmental practises, and global competition based on quality products and keenly structured prices.

A change in the electricity intensity of major industry has the potential to change the gross primary energy needs of the country in a positive sense, if new electrotechnology is more efficient than the older technology that was in use. This has constructive implications for the environment both from the point of view of pollution and extended life of non-renewable energy forms.

The sectors described already operate at relatively high electrical load factors. The electrotechnologies which have been successful within these sectors and those which could have further impact, mostly represent demand of a high load factor type. This is typical of continuous thermal processing. Such an increase in base load demand would be significant for the electricity supply industry. An improvement of the daily, weekly, and annual load factor is intrinsically advantageous from the point of view of the supply system as both generation and distribution utilisation improvement can lead to savings over the longer term and lower price increases to customers. The historical power plant mix for the RSA as provided by ESKOM has favoured base load generation.

There is at this stage a demonstrated decline in the South African system load factor as an increasing number of residential customers with very low load factors are connected on to the system. As is discussed in the report, there has been a newly emerging evening winter peak that has shown progressive increase in size. This effect is expected to continue as the national imperative for electrification of homes, schools and primary health clinics is accelerated to meet the historical backlog.

The load profile needs to be managed at various levels in the supply chain and in the customer environment to ensure that electricity service and prices are maintained or improved. Characteristics of sector process loads and flexibility of operation of technologies can be harnessed to aid in the overall management of the supply-demand balance.

There is however a substantial risk in the growth of capacity of an even-larger-than-present customer base that has a process load which is dependent on world commodity markets, combined with a weak domestic demand. The cyclic fluctuation of that load as productive capacity becomes idle as it follows the international price cycles, can impose severe limits on the ingenuity of planners of electrical capacity as well as of developers of customer interventions in the electricity supply industry. The effects on related industries that suffer a ripple effect of the commodity cycle through the national economy are also severe, as is also seen in historical electricity consumption figures.

An advantage of a substantial thermally based customer pool is that it offers the potential to structure interruptible supply agreements in an innovative way to suit the thermal characteristics of the process plant. With appropriate price incentives for the customer on the basis of either instantaneous or pre-arranged load reductions this approach has been used successfully in for example the USA and France. It has recently been estimated that interruptible loads on the current South African system could be as high as 3 000MW. (Etzinger, 1995)

The emphasis in the curricula of electrical engineering departments at universities and technikons has for many years been on the generation, transmission and distribution of electricity and the use of electricity in electrical motors. Until recently this has been appropriate and has adequately covered the needs of industry as users of electricity and also the electricity supply industry in dealing with the challenges of supply performance.

With the stronger emergence of substantial electrotechnologies associated with thermal processes, dependent on a deep appreciation of materials science and thermodynamics, a new dimension has been added which has not been part of traditional curricula of electrical engineers. In addition the complexity of designing integrated supply - demand systems with considerable uncertainties has also progressively changed the nature and complexity of power system planning.

Operational control of power systems with the increased flexibility and economic trade-offs of power plant versus customer load modification has become more complex. Where customer load modification options include customer - owned generation, the greater penetration of distributed embedded generation in a power system which has traditionally been able to be treated as a virtually single source of supply viz the Eastern Transvaal Highveld, will impose more system interconnection design and dispatching complexities than before.

Most of the technologies described are dependent on sophisticated electronic control systems. Large loads are electronically switched. These often require special treatment for maintaining quality of supply.

From an educational perspective the electronics designers require a substantial insight into the impact of their designs on power systems. The electrical engineers need an understanding of the impact of the electronic control systems on power systems and the means to introduce appropriate interventions to retain quality of supply within reasonable bounds. Measurement of these phenomena has a vital role to play in successfully intervening and managing these interactive systems.

The topic of environmental management and the related issues is very large, and cannot be dealt with in depth in a report of this nature. However, the linkage of energy and electricity utilisation up the chain of delivery processes through to production has been recognised as an important means of reshaping primary energy use and its conversion to electricity.

Non-renewable primary energy carriers used for electricity generation such as coal and nuclear fuel, have been specifically targeted for reduced utilisation world wide. This has also been occurring to some extent in South Africa.

Where greater end use efficiencies can be achieved through more effective and efficient electrotechnologies, the beneficial impact all along the supply/conversion chain has been recognised. This has been a major driving force within the USA regulatory development which imposed demand side management (DSM) programmes on electricity suppliers over a period of some 23 years since the 1973 oil price and availability shocks. The increase in environmental benefits has however been at the cost of increased investment in energy efficient customer equipment and some increase in per unit electricity costs. The latter have been partially offset by reduced volumes of consumption. The increased effectiveness in customer production quality and overall performance has been assumed to make up the difference in input costs. Customer cross subsidies have become an issue in the USA between the DSM programme participants and non-participants, especially those which have little flexibility to improve processes (Sioshansi, 1995), however this type of regulatory DSM appears to be on the wane (Sioshansi, 1996).

The development of initiatives and regulations in the RSA for demand side management to delay investment in new power plant through load shaping and energy efficiency measures has been a topic of debate for some time. Various policy research and demonstration initiatives were launched by the National Energy Council from its inception in 1987, and since it was restructured as part of the Department of Mineral and Energy Affairs. ESKOM has committed to using a process of Integrated Electricity Planning (IEP) to optimise the mix of supply and demand side options in the RSA (ESKOM, 1994). In July 1996, ESKOM announced key proposals of its Fifth IEP in a press release.

From 1995 a National Electricity Regulator has been established for South Africa. This body has the right to issue licenses for generation and distribution of electricity and for regulating pricing systems and quality of customer services.

Scope exists for a further development of the electricity supply industry in a way that could change the pricing structure through allowing innovative independent power producers to compete with a tax paying electricity supply industry. (Creamer T, 1995) This could stimulate change in the nature of costing and pricing of electricity to the advantage of the economy. The National Energy Policy White Paper is expected to address this issue later in 1996.

The availability of natural gas imported into the South African energy economy could well be the pre-cursor to such developments. If prices of delivered gas can be made attractive and competitive with existing local primary fuel and conversion system costs, then new participants in the electricity supply industry as well as competitive end use technologies will change the energy profile of the country.

It is too early in the development of the gas industry to attempt to prejudge the potential outcome. However since natural gas is a clean fuel to burn, it could well compete with electricity for direct heating purposes. As a consequence it may find its place as a premium heating fuel and gas technologies would then compete for the base load, bulk, thermal applications with the various electrotechnologies which have been discussed in this report. The metals melting industries could be the most influenced by such developments. Load shape benefits from thermal electrotechnologies would be lost to the gas processes, with consequent deterioration in electricity load factors.

Conclusions and Summary of Recommendations

From the review of electricity growth and end-use electro-technologies in the key economic and electricity intensive sectors in the RSA in this report, conclusions reached have been described in Section 11. Recommendations arising from these conclusions are covered in Section 12. These recommendations are summarised below for convenience.

Recommendation 1

Promotion of energy efficient end-use electrotechnology by means of an investment incentive formula for new plant investment in the RSA.

Recommendation 2

Extensive collection and publication of appropriately aggregated, formatted electricity demand data for practitioners in a user-friendly format. Establishment of non-partisan organisation/s to facilitate such collection and dissemination for the benefit of enhanced research, development and implementation of end-use electrotechnologies.

Recommendation 3

Criteria for licensing of new distribution and generation participants should include energy efficiency commitments

Recommendation 4

Policy decisions for the electricity industry structure need to be made in the very near term. Allowing competition through independent power producers, facilitated by an open access transmission system.

Establishing the reasonable level of dependency on imported primary energy and electrical energy.

This may be a means of taking a quantum step in line with the developed economies and current developments in Africa, as an encouragement to new industrial and power sector investment.

Recommendation 5

Excellence in research and development for the minerals sector and potential electrotechnologies should be stimulated by creative incentives for "partnering" within South Africa, Southern Africa and with global centres of excellence.

University electrical, mechanical, and materials engineering faculties should be funded to encourage and enable them to undertake research projects of a multi-disciplinary nature.

Recommendation 6

Specific research should be conducted to establish the realistic and viable basis for energy decision making in the RSA by clarifying the debate between the opposing views of "low cost energy (electricity) is needed for economic health" versus "high energy (electricity) costs are needed to ensure good energy efficient decisions for environmental health and hence sustainable economic health".

Recommendation 7

Attention should be given to the development of electricity utilisation and end-use electrotechnology courses as an option for undergraduate, postgraduate and continuing engineering education, at universities and technikons. These would require multi-disciplinary skills currently found in the separate departments of mechanical, electrical, and metallurgical engineering to be harnessed into new programmes.

The establishment of one or more "centres of excellence" with a particular industry focus might well be a useful model. (This approach has been used successfully in the USA, facilitated by EPRI and its members.)

Recommendation 8

The measurement of plant load performance, management of volumes of data, interpretation and modelling of process and application options within a production system is complex and needs at least statistical, computer programming, electrical engineering, production management and product specific skills. Development of courses to educate practitioners in this area of engineering endeavour, which is new to South African industry and consulting, also requires putting together disciplines in a novel fashion.

Recommendation 9

Engineering institutes such as the South African Institute of Electrical Engineers (SAIEE), South African Institute of Mechanical Engineers (SAIME), South African Institute of Energy (SAIE), South African Institute of Mining and Metallurgy (SAIMM) should play their part in stimulating debate and extending knowledge in this area of end-use electrotechnology in the mining and minerals sectors.

Concluding comment

The recommendations made represent some key areas of decision making and opportunity revealed by the review conducted for this report. The scope of the topic covered in the report has greater impact than the end-use electrotechnologies themselves, because of the context and interconnectedness of electricity supplier and the end-user.

The impact of the electricity supply - demand chain on the national economy and its associated energy economy, is significant as a result of the energy intensity, the capital investment and labour intensity involved.

Disclaimer
The views expressed in this report are entirely my own, and do not reflect the views of my former employers, ESKOM, or the South African Institute of Electrical Engineers (SAIEE) with which I have been closely associated as a Council Member for several years.

Prepared by : Marie Talitha Davison

Date : August 1996

1 INTRODUCTION

The response to growth in forecast electricity consumption in terms of energy (as expressed in Watthours) and peak demand (expressed in Watts) has both internationally and locally been traditionally approached from the "supply side" i.e. the response has been to build power generation plant best suited economically to the duration of the loads expected on the power system. The same philosophy has normally been applied to transmission and distribution capacity as well.

The approach to estimated future demand for electricity has also primarily been based on modelling of energy need, with derived power demand levels using load factor trend calculations.

More recently, there has been a set of imperatives that have substantially changed the thinking of electricity utility decision makers - namely that opportunities exist to change not only the peak load, but also the shape of the load in a way that can be mutually beneficial to the consumer and the electricity utility.

The concept referred to here has commonly been termed "Demand Side Management", and has been applied in the USA for some thirteen years, and has also found favour in some utilities in Europe in recent years.

The combined effort of supply side planning and demand side planning is normally referred to as Integrated Resource Planning, since the resources of the electricity supplier and the customer are taken into account.

Some imperatives that have induced this shift in approach by privately owned electricity companies and public utilities have been :

* Oil price shocks of the 1970's which drove up the cost of oil fired generation, and the creation of international efforts to conserve energy which relied on oil. The aftermath of these induced shortages and high prices for oil was a widely held belief that the lifespan of these resources was so limited that massive efforts should be made to reduce the rate of growth of energy demand in general.

* Regulatory rulings established in the USA that compelled utilities to apply and publicly debate the use of Demand Side Management options when seeking Rate Price adjustments (i.e. Tariff changes and price increases).

* Environmental concerns about global levels of the consequences of primary energy consumption, and also localised effects of energy consumption, in particular concern about global warming "greenhouse" gases like CO_2 directly attributed to burning of fossil fuels.

* Limited site approval for new power plant especially nuclear plant, and servitude approval for new transmission systems.

* Cost of new power generation plant exceeding the estimated cost of incentives to customers and investments for reducing load. Some USA regulators have allowed the utility to receive a return on investment on the expenditure incurred in reducing or re-shaping the customer's load, in the same way that they would allow a return on capital invested in productive plant.

* Development of new technologies for processing of materials, manufacturing of products, and for conditioning the working/living environment which have impacted load shapes and load levels of the utilities. These technologies have also increased customer product quality and profitability, or enhanced consumer quality of life and cost of energy.

In the RSA there is a steady emergence of some of these same imperatives, albeit for slightly different reasons than the experience in the USA :-

* Increased access to electricity for households which have low load factors, in particular for small, new consumers, is steadily transforming the high national load factors historically characteristic of the RSA power system, due to the typically time concentrated nature of domestic loads. This is exacerbated in the RSA by the poor quality insulation levels in low income and informal housing generally.

* Portions of the transmission system are nearing the levels of loading which require upgrading if traditional decision criteria were to be used like the conventional "grow and build" decision logic.

* The cost of service to provide generation, transmission, distribution, reticulation is being better analysed than before, due largely to the critical assessment of the costs of the massive electrification projects being undertaken in the RSA - this has exposed the importance of a more holistic framework of decision making for capital investments.

* As the country emerges from a long period of isolation, access to "new" technologies is available. Local distributors and promoters are progressively being established. Although there is not yet a strong resurgence nor a recent track record developed to build confidence in innovative electrotechnologies, the drive to regain a competitive role in world trade is emerging.

* Open competition in the domestic market with high quality/low priced goods imported from all over the world is a reality for local producers. This compels industrialists to seek cost reductions for inputs, productivity improvements in processes, and quality enhancements for products and services provided into the domestic and export markets. Innovative electrical processes often provide desirable solutions.

* State influenced and ESKOM voluntary commitment to the capping of electricity price increases below the inflation rate in order to assist SA exporters who use energy intensive processes. This has helped retain an element of competitiveness for exporters despite input cost pressures.

* Income constraints induced by such price increase limits have had a profound influence on the decision making processes of ESKOM as a major participant in the Electricity Supply Industry from the classical approach of building new generating and transmission plant which characterised the history of the industry.

* Surplus electricity generating capacity of ESKOM creates a beneficial "window of opportunity" to build load at reasonable prices of electricity for an extended period in the low growth SA economy. This low growth has existed for the past ten years and recent scenario analyses suggest that the time frame for restoring the economy to sustainable growth which is also reflected in electricity growth, may be of the same order of time.

* The appointment of a National Electricity Regulator (NER) for the RSA, although strongly focussed on the domestic pricing and domestic electrification issues in the country, will in all likelihood also seek to promote a more cost effective electricity industry as a contributor to the economic restructuring of the RSA. The NER is likely to adopt a methodology like IRP which has had some success in the USA. IRP is also being treated as a solution to the environmental concerns of European countries such as Denmark, Ireland, Netherlands, France, and Germany.

* Environmental sensitivity is beginning to have an effect on the RSA energy industry, and industry in general. Servitudes in some areas are becoming congested with increased urbanisation of an informal type.

The changing pressures in the RSA energy economy in which primary energy supply constraints are not the focal issue, drives the need to understand the role that end-use of energy plays.

In the context of this report, the end-use of electricity and the associated technology, is taken as the particular area of interest. This is stimulated both by the high penetration of electricity into the South African secondary energy market, which at 26% compares favourably with the UK which has some 18% penetration, and also the existence of electricity intensive industries in this country. Research results (Surtees and Bluff, 1992) indicate that a trend break is occurring in the RSA electricity market demand behaviour.

Both the technology used in the key economic sectors which use electricity, and changes in the capacity of those sectors, influenced the growth of electricity demand. It is important to understand both in terms of the level of electrical energy demanded and shape as expressed by load factor, load duration curve or average daily/weekly/ load profiles.

SCOPE OF REPORT

This research report covers the assessment of the key economic sectors of mining and minerals processing and their end use electrotechnologies. These are considered to have had a major effect on setting the level and shaping electricity base demand in this country.

Some views and recommendations on the potential for future change in electricity demand that could be primarily technology driven are presented. The implications of these changes for SA industry, technology, research, education and the ESI are discussed.

The key findings which are covered in the report relate to implications for changing industrial plant capacity and electricity supply and demand responses, government policy on energy efficiency and the environment, investment in research, and innovation in engineering curricula in institutions of higher education. Conclusions and recommendations are presented in response to the assessment of the research project results.

2 ELECTRICITY CONSUMING SECTORS IN THE RSA

The relevance for selecting a study of the mining and minerals processing sectors can be established by an appreciation of the electricity consumed in these sectors in relation to consumption in all the sectors of the South African electricity market.

Table 2.1 is extracted from a unique energy data base developed by Cooper (1992) of the Institute of Energy Studies (IES), Rand Afrikaans University. This was for a project sponsored by the Department of Mineral and Energy Affairs (Energy Branch), ESKOM and SASOL. The electricity data available for 1990 has been used, by special arrangement with Mr C.J Cooper, as the report contained also liquid fuel data and was hence classified as Secret under the legislation existing at the time.

The data structure in Cooper's work is unique for South Africa. The South African energy data base project was planned for the periods 1989 to 1993 (Cooper, 1995). Review of the shifts in energy applied to end use over an extended period may enable analysts to derive important insights into the development of the country's energy economy, and potential changes in the future. Comparison of electricity use in sectors in the RSA with other countries may assist in encouraging more efficient industry processes through benchmarking and establishing models of "best practise".

It is appreciated that significant changes have occurred in legislation around energy information that now allows access and publication of such information, however still excluding liquid fuels.

By inspection of the sectors of Table 2.1, it is clear that the mining and minerals sectors together represent substantial sectors for electricity consumption. Table 2.2 shows that the mining and minerals sectors represent 40% of electricity energy consumption.

Table 3.1 in Section 3 indicates that these sectors contribute approximately one third of the system peak measured in Megawatts in summer and winter. Hence, logically, the focus of this project is on these sectors which are also representative of traditionally high load factor, or base loads, for the electricity supply system.

A summary of the key data for the selected sectors for 1991 and 1993 is provided in Tables 8.2 and 8.3 respectively, derived from results in the reports by Cooper in 1993 and 1995 respectively.

Table 2.1 Electricity Consuming Sectors in the RSA (1990)

(Sheet 1 of 2)

SECTORS		HEAT	MECHAN -ICAL	CHEMI -ICAL	LIGHT -ING	TRANS -PORT	NON ENERGY	TOTAL
Domestic	GWh	17 277	1 028	0	2 262	0	0	20 567
	%	84	5	-	11	-	-	100
Agriculture	GWh	2 450	1 429	0	204	0	0	4 083
	%	60	35	-	5	-	-	100
Coal Mining	GWh	120	2 042	0	63	1	0	2 226
	%	5	92	-	3	-	-	100
Metal Ore	GWh	676	3 756	282	231	0	342	5 287
Mining	%	13	71	5	4	-	7	100
Gold Mining	GWh	3 297	19 923	0	667	149	0	24 036
	%	14	82	-	3	1	-	100
Diamond	GWh	46	831	0	40	0	0	917
Mining	%	5	91	-	4	-	-	100
Other	GWh	139	1 183	0	70	0	0	1 392
Mining	%	10	85	-	5	-	-	100
Food	GWh	828	4 070	49	435	0	15	5 397
	%	15	75	1	8	-	-	100
Beverages	GWh	14	596	0	62	0	5	677
	%	2	88	-	9	-	1	100
Tobacco	GWh	6	106	1	20	0	0	133
	%	4	79	-	15	-	-	100
Textiles	GWh	492	1 869	26	241	1	49	2 677
	%	18	70	1	9	-	2	100
Clothing	GWh	137	294	0	76	0	0	507
	%	27	58	-	15	-	-	100
Leather	GWh	39	48	0	10	0	0	97
	%	40	49	-	11	-	-	100
Footwear	GWh	50	177	0	47	0	3	277
	%	18	64	-	17	-	1	100
Wood except	GWh	90	761	1	55	0	0	907
furniture	%	10	84	-	6	-	-	100
Paper (inc	GWh	647	1 505	330	207	0	1	2 690
products)	%	24	56	12	8	-	-	100
Printing	GWh	35	491	11	47	0	0	584
	%	6	84	2	8	-	-	100
Industrial	GWh	1 526	4 415	823	214	0	650	7 628
Chemicals	%	20	58	11	3	-	9	100
Other	GWh	180	906	26	153	0	12	1 277
Chemicals	%	14	71	2	12	-	1	100
Refineries	GWh	885	5 551	0	133	0	0	6 569
	%	14	84	-	2	-	-	100

Table 2.1 Electricity Consuming Sectors in the RSA (1990)

(Sheet 2 of 2)

SECTORS		HEAT	MECHAN-ICAL	CHEM-ICAL	LIGHT-ING	TRANS-PORT	NON-ENERGY	TOTAL
Oil & Coal	GWh	172	35	0	13	0	0	220
products	%	78	16	-	2	-	-	100
Rubber	GWh	35	504	0	60	0	0	599
	%	6	84	-	10	-	-	100
Plastics	GWh	396	494	0	78	0	0	968
nec	%	41	51	-	8	-	-	100
Pottery	GWh	135	110	0	12	0	57	314
	%	43	35	-	4	-	18	100
Glass	GWh	268	149	0	46	0	0	463
	%	58	32	-	10	-	-	100
Other non-	GWh	239	2 703	1	97	1	1	3 042
met minerals	%	8	89	-	3	-	-	100
Ferrous	GWh	10 081	3 251	1 827	365	0	15	15 539
basic metals	%	65	21	12	2	-	-	100
Non-ferrous	GWh	539	865	2 373	223	0	1	4 001
basic metals	%	13	22	59	5	-	-	100
Fabricated	GWh	906	860	479	98	0	8	2 351
metal	%	39	37	20	4	-	-	100
Machinery	GWh	462	951	14	93	0	14	1 534
	%	30	62	1	6	-	1	100
Electrical	GWh	050	585	65	141	0	0	1 296
machinery	%	39	45	5	11	-	-	100
Motor	GWh	333	770	22	222	0	15	1 362
vehicles	%	24	57	2	16	-	1	100
Transport	GWh	175	121	6	16	0	0	318
equipment	%	5	38	2	5	-	-	100
Professional	GWh	30	44	0	8	0	0	82
& scientific	%	37	53	-	10	-	-	100
Other manu-	GWh	12	199	0	24	0	0	235
facturing	%	5	85	-	10	-	-	100
Electricity,	GWh	55	442	0	55	0	0	552
gas & steam	%	10	80	-	10	-	-	100
Commercial	GWh	10 467	3 221	0	2 415	0	0	16 103
	%	65	20	-	15	-	-	
Transport	GWh	0	0	0	0	3 958	0	3 958
	%	-	-	-	-	100	-	100
TOTAL	GWh	53 762	66 563	6 334	9 259	4 110	1 188	141 216
	%	38	47	4	7	3	1	100

Table 2.2 Mining and Minerals Electricity Consumption (1990)

		GWh	%
Mining :	Gold	24 036	17.0
	Coal	2 226	1.5
	Metal ores	5 287	3.7
	Other	2 309	1.6
Metals-ferrous :	Basic	15 539	11.0
	Non-ferrous	4 001	2.8
Non-metallic minerals :	Glass	463	0.3
	Pottery	314	0.2
	Other	3 042	2.1
Mining and Minerals	TOTAL	57 217	40.0
All Sectors	TOTAL	141 216	100.0

The data set of Table 2.2 does not dis-aggregate the Non-metallic minerals sector in any great detail other than pottery, glass and other (Cooper, 1992). For a further breakdown, Table 2.3 was constructed from a study of this sector (Sater, 1992).

The disaggregation of data in Table 2.3 when compared with the RAU data base for the sector demonstrates the problems inherent in the sets of energy data available in South Africa. Electricity data is a problem in all the sectors supplied by municipalities as the customers are not classified and hence readily accessible information is not available (Cooper, 1993).

However the data set of Table 2.3 does not include e.g. Brick making, nor uranium oxide manufacture. The latter could largely account for the discrepancy. Confidentiality surrounding the manufacture of uranium oxide has set certain bounds on access and publication of such data.

Table 2.3 Estimated Electricity Consumption and Composition of Non-metallic Minerals Sector

	TJ	GWh
Pottery, china & earthenware :		
Ceramic tiles	215	59
Sanitaryware	112	31
Industrial ceramic products	150	42
Ornamental pottery	18	5
China & tableware	200	56
Other - unspecified	47	13
SUBTOTAL	742	206
Glass & glass products :		
General - non-flat	1 821	506
General - flat	379	105
Other	90	24
SUBTOTAL	2 290	636
Cement	3 349	930
Lime	623	173
Gypsum	155	43
Plaster and Grouts	395	110
Concrete & other products :		
Construction materials	38	10
Stone & slate products	2	1
Minerals processors :		
Vermiculite	4	1
Milling	71	20
Other - unspecified	455	126
GRAND TOTAL - NON-METALLIC MINERALS	8 124	2 257

From the ESKOM Statistical Yearbook for 1990, Granville and Stanko (1990), and the Mintek studies for the Department of Mineral and Energy Affairs by Granville, Stanko and Freeman (1991) and also Granville, Stanko and Freeman (1993), it is possible to construct a breakdown for 1990 of the ferrous metals sector as in Table 2.4, and the non-ferrous metals sector as in Table 2.5.

Table 2.4 Ferrous Metals Electricity Consumption (1990)

	GWh	
Iron and steel	8 100	*1
Ferro-chrome	3 900	
Ferro-manganese	1 800	*1
Ferro-silicon	1 000	*1
Ferro subtotal	6 700	*1
Stainless steel	100	
TOTAL	14 900	*2

Note *1 : The Mintek reports for the DMEA/NEC give Iron and primary carbon as 8 600GWh, Ferro - manganese and manganese metal combined as 2 400 GWh, and Ferro-silicon and silicon metal combined as 1 300GWh, with a total of 17 100GWh vs the 14 900GWh shown above. This inclusion of a component of "non-ferrous" materials causes the discrepancy with the figures above.

*2 : Discrepancy of 639GWh relative to Table 2.1, because only major participants in the industry are covered in the study references. Smaller plants in municipalities are excluded.

Table 2.5 Selected Non-Ferrous Metals Electricity Consumption (1990)

	GWh	
Aluminium	3 000	
Copper	1 440	*
Subtotal	4 440	£

Note * : Includes mining component; hence discrepancy of 440 GWh relative to Table 2.2

£ : Gold is not included here as gold processing is included in the mining statistics

3 DISAGGREGATED ELECTRICITY DEMAND PROFILE

The percentage contributions of the key measurable sectors to the load profile for 1990 (Bluff, 1992) is as in Table 3.1.

Table 3.1 Percentage Contribution of Various Sectors to Electricity Demand Profile

	1990(%)					1992(%)
	Morning peak		Average weekday	Evening peak		
SECTOR	Winter	Summer	Consumptn.	Winter	Summer	Winter
Gold mines	15.2	16.0	17.6	15.5	16.6	13,7
Other mines	6.1	6.3	6.9	6.3	6.8	5,4
Base industries	10.5	11.1	12.8	11.1	11.5	10,4
Other industries	10.3	10.9	12.3	11.0	11.7	10,4
Munics. & other	52.0	50.0	44.2	49.1	45.8	52,0
Dev. communities	3.3	3.1	2.9	4.4	4.7	5,7
Traction	2.5	2.6	2.9	2.6	2.9	2,3
% Total	99.9	100.0	99.6	100.0	100.0	99.9
TOTAL ACTUAL	21 TW	18.9TW	139 GWh	21 TW	18.3TW	22,4TW

The emergence of the evening peak in 1992 (Surtees and Bluff, 1992) confirmed the trend progressively emerging in the early part of the decade.

The growing influence of the household loads of developing communities, both directly supplied by ESKOM and also by other electricity distributors, shows strongly in the contribution to the peak in Table 3.1 and in Figure 3.1.

The emergence of a new national evening peak is in line internationally in countries with more normally developed energy economies, which have a substantial domestic sector served by electricity (Lane, 1991). This development at the same time as a downturn in demand from traditional base load industries was a new experience for SA (Surtees and Bluff, 1992), as shown in Figure 3.2.

The annual integrated system load factor is calculated as electrical energy sent out divided by the maximum electricity that could have been sent out if the annual peak demand had been sustained for all the hours of the year, and is in fact a utilisation ratio for available capacity on the power system, namely:-

Load factor = electricity sent out (in GWh) / system peak (in GW) x 8760hours.

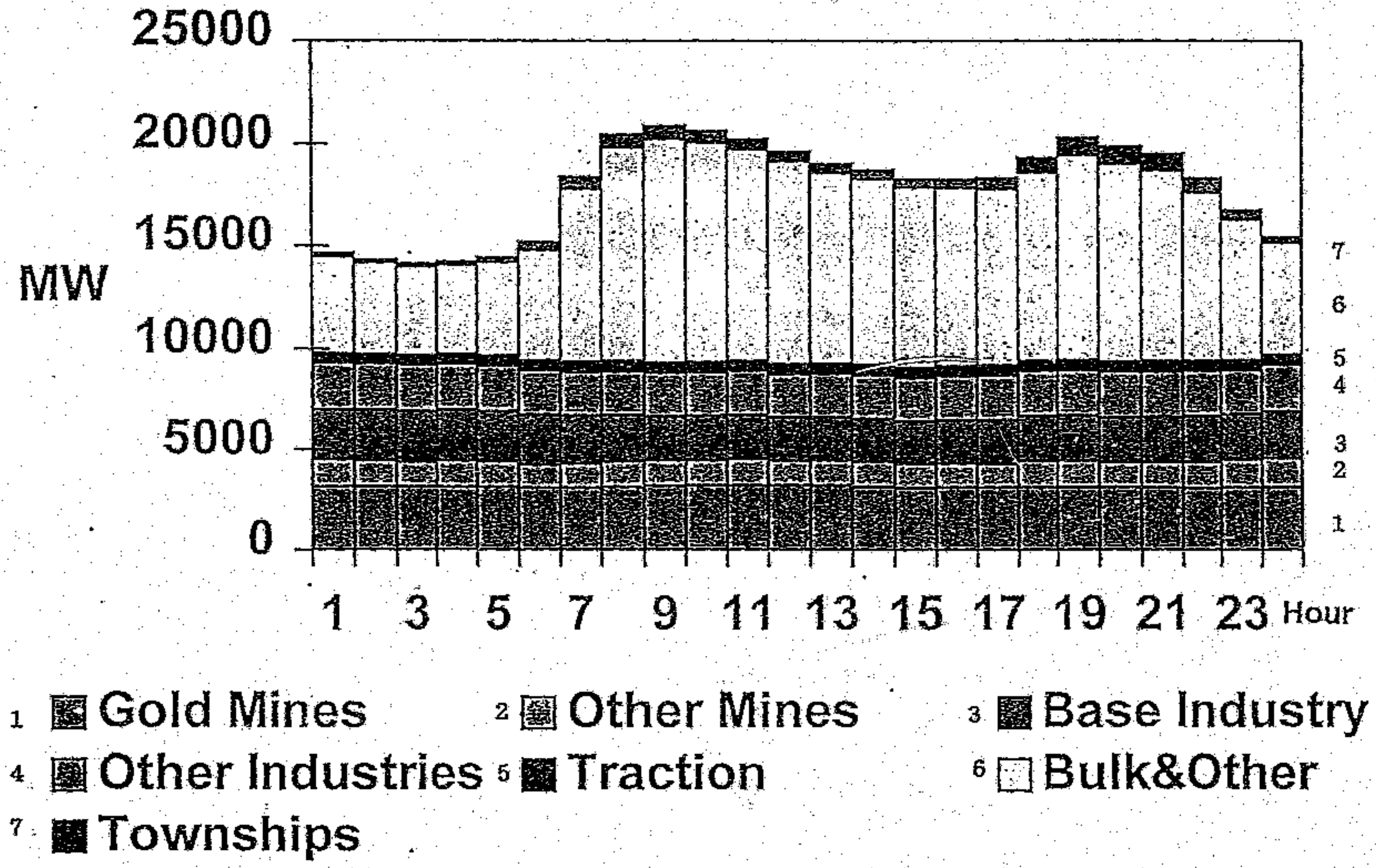
From examination of the data in Table 3.1, the contributions of gold mining (15,2%), other mining (6,1%) and base industries (10.5%), which are the sectors of interest in this project report, comprise an estimated 31.8% of the annual winter peak load. Graphic display of the disaggregated annual load profile is included as Figure 3.1, showing the relevance of these sectors for an average winter weekday.

The variations in load patterns of the individual sectors cannot be observed in this figure.Individual sector load profiles are included with sector reviews in Sections 5, 6 and 7 which focus in on the impact of the processes and the influence of end use electro - technologies which impact on load levels and load patterns.

Figure 3.2 (a) shows the increasing trend in electricity demand from municipalities and the decreasing share demanded by mines and industry. Figure 3.2 (b) shows the trend in Load Factor for the ESKOM national electricity load on the integrated system from 1950 to 1990. The trend break in load factor since 1980 is noticeable from the curve fitting, which shows a progressive turning point from the early 1980's (Surtees and Bluff, 1992). Suppression of the zero axis enables the variations around the historical average load factor of 76 to 77% to be more readily plotted and visible.

The load factor deterioration is expected to increase with increasing electrification of some 1.75 million households by 2000, despite measures taken by ESKOM and municipalities to introduce load shaping and load shifting incentives (ESKOM Press Release, 16 July, 1996).

An objective of this report is to review the load profiles of the selected sectors relevant to the main end-use electrotechnology predominant in that sector and to consider the effect of sector changes and new technologies.



(NOTE : Average Winter Weekday 1990)

Figure 3.1 Disaggregated Annual Electricity Load Profile - 1990

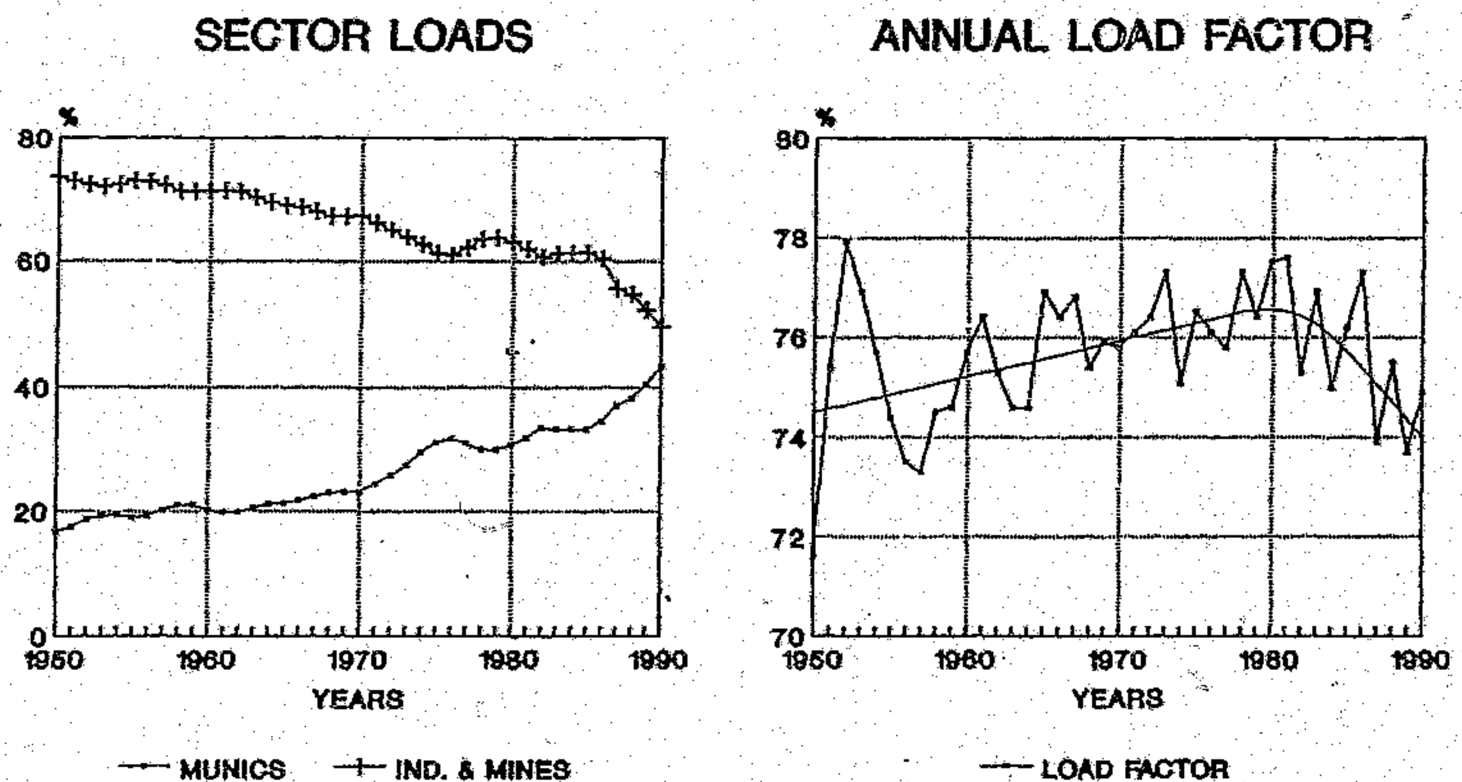


Figure 3.2 Trend in Load Factor for the ESKOM National Load

4 KEY END USE SECTORS FOR PRESENTLY APPLIED DOMINANT ELECTROTECHNOLOGIES IN SOUTH AFRICA

The table constructed in this section as Table 4.1, is intended to highlight the relationships of sector, common end-use energy process or requirement and the associated current dominant electrotechnology in use. Where *real names* are used, these are recognised patented processes. The table is not meant to be an exhaustive set of processes and technologies.

The sectors used are those covered in the report. The listed electrotechnologies are those in typical use at present.

The topic covered in Section 10 deals with the shift of existing technologies being introduced into applications in new sectors, and also new technologies being introduced into the sectors.

Many of the spaces in the table marked "Not applicable" represent opportunities for innovation either for energy efficiency, product quality improvement or perhaps even process innovation. The latter is beyond the scope of this report.

Table 4.1 Summary of Sectors and Dominant Electrotechnology in Use in the Republi· of South Africa
(Sheet 1 of 4)

SECTOR	DOMINANT ELECTROTECHNOLOGY							
	Motors	Power Electron-ics	Electric Arc Furnace	Induction Smelter/ Heater	Cooling	Electro-Chemical	Infrared (IR) Heating	RF/ microwave
Gold	Hoists Pumps Fans Mills Comprs	* * * * *	Gold reduction plant	Gold reduction plant	*Ice *Ammonia *Plate-exchange *Shell & tube	Carbon in Pulp Leaching	Not applic-able	Not applic-able
Coal	Hoists Cutters Fans Conveyrs Pumps	* * * * *	Not applic-able	Not applic-able	Various- but not as hot as gold	Not applic-able	Not applic-able	Not applic-able
Platinum	As for gold	*	Concentr-ate smelt to matte	Process of matte	As for Gold	Mintek high temp process	Not applic-able	Not applic-able
Other	Hoists Fans Conveyrs Mills Crushers Pumps	* * * * * *	Not applic-able	Not applic-able	Not applic-able	Copper refining	Not applic-able	Not applic-able

Table 4.1 Summary of Sectors and Dominant Electrotechnology in use in the Republic of South Africa
(page 1 of 4)

Table 4.1 Summary of Sectors and Dominant Electrotechnology in Use in the Republic of South Africa
(Sheet 2 of 4)

SECTOR	DOMINANT ELECTROTECHNOLOGY							
	Motors	Power Electronics	Electric Furnace	Induction Smelter/ Heater	Cooling	Electro-Chemical	Infrared (IR) Heating	RF/ microwave
FERROUS METALS :								
Iron & steel	Crushers Conveyrs Fans Mills Rollers	* * * * *	Electric Arc Scrap & melting of Direct Reduced Iron(DRI)	Ladle refining	Not applicable	Not applicable	Not applicable	Not applicable
Ferro-chrome/ manganese Ferro - silicon	As for Iron & steel	*	Submerged arc furnace Plasma arc	Holding tunnels	Not applicable	Plasma arc	Not applicable	Not applicable

Table 4.1 Summary of Sectors and Dominant Electrotechnology in use in the Republic of South Africa
(page 2 of 4)

Table 4.1 Summary of Sectors and Dominant Electrotechnology in Use in the Republic of South Africa
(Sheet 3 of 4)

SECTOR	DOMINANT ELECTROTECHNOLOGY							
	Motors	Power Elect-ronic	Electric Furnace	Induction Smelter/ Heater	Cooling	Electro Chemical	Infrared (IR) Heating	RF/ microwave
NON-FERROUS METALS :								
Aluminium	Rollers Extruders	*	Submerged arc for re-duction	Fine scrap smelting	Not applic-able	Hall-Heroult process (elect. arc)	Not applic-able	Not applic-able
Copper	Trolley assisted vehicles Crushers Conveyrs Milling	* * * *	Not applic-able	Recycled material smalting	Not applic-able	Electro-lytic refining of anodes	Not applic-able	Not applic-able
Titanium	Fans Mixing Milling	* * *	Electric Arc Furnace-melt slag from rutile	Holding vessels	Not applic-able	Not applic-able	Not applic-able	Not applic-able

Table 4.1 Summary of Sectors and Dominant Electrotechnology in use in the Republic of South Africa
(page 3 of 4)

Table 4.1 Summary of Sectors and Dominant Electrotechnology in Use in the Republic of South Africa
(Sheet 4 of 4)

SECTOR	DOMINANT ELECTROTECHNOLOGY							
	Motors	Power Elect-ronic	Electric Arc Furnace	Induction Smelter/ Heater	Cooling	Electro Chemical	Infrared (IR) Heating	RF/ microwave
NON-METALLIC MINERALS :								
Pottery etc	Mixing Conveyers	*	Not applic.	Not applic.	Not applic.	Not applic.	Top-hat kilns	Not applic.
Glass etc	Mixing & prepar-ation of raw material	*	Electrode boosting or all - elect melting Condition-ing	Not appl-icable	Not applic-able	Not applic-able	Annealing Decorating	Not applic-able
Other ceramics	Crushing Grinding Blending Fans Rotary kiln drives	*	Calcining kilns	Not applic-able	Not applic-able	Not applic-able	Some Curing	Some Curing

Table 4.1 Summary of Sectors and Dominant Electrotechnology in use in the Republic of South Africa
(page 4 of 4)

5 MINING SECTOR

5.1 GOLD MINING

5.1.1 General

The South African gold mining industry is a mature one, already over 100 years old. There are more than 40 substantial gold mines and several small mines.

Reference to Figure 5.1 which shows gold mining electricity consumption levels in GWh, identifies a turning point in the growth of electrical energy which occurred in 1988/89.

With rising operating costs and low world gold prices, declining ore grades and minable ore bodies, a number of mines and shafts have closed. The quantity of gold mined decreased from a high of 1 000 tons in 1970 to 599 tons in 1991 (Minerals Bureau). Many mines are marginal in terms of profitability. They remain operational, attempting to reduce costs and in the hopes of improved Rand gold prices. Although there is an estimated 40 thousand tons of gold left to mine, most of it is very deep underground, which is difficult and expensive to mine.

5.1.2 Percentage Distribution of Electricity used in Gold Mines

Table 5.1 shows the estimated distribution of electricity used in gold mining as quoted by Granville (1992,b) from various mining sources. Actual consumption listed is from ESKOM Statistical Yearbook time series for gold mining.

Table 5.1 Estimated Percentage Distribution of Electricity used in Gold Mines.

	1974	1990
Compressed Air	22	18
Cooling	22	27
Hoisting	12	14
Reduction	16	12
Pumping	17	17
Other	11	12
TOTAL %	100	100
Actual TWh	13	24

This table shows the use of electricity mainly in motor-based end-use, demonstrating the high 82% allocation of electricity to mechanical application given in Table 2.2.

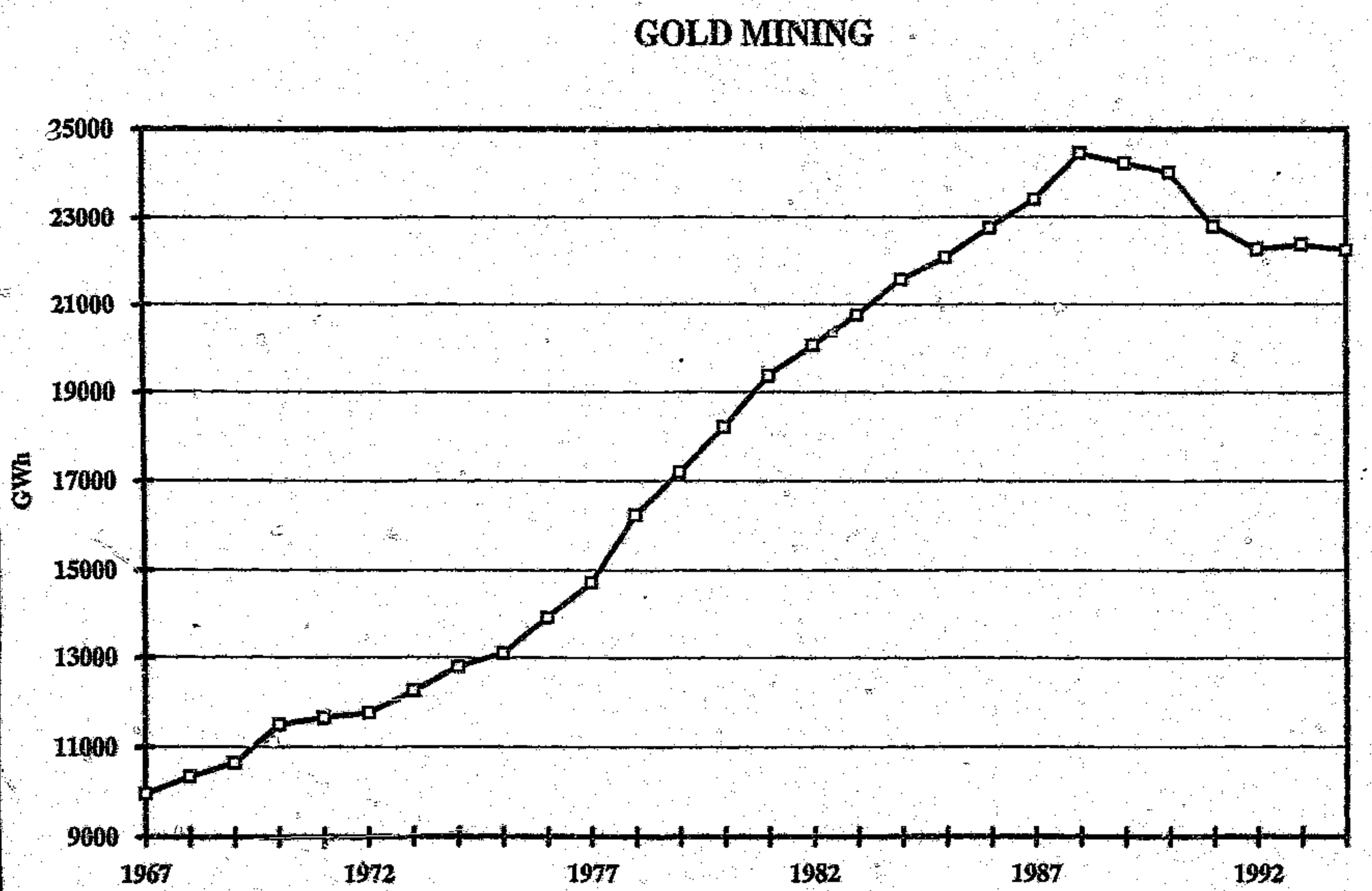


Figure 5.1 Electricity Consumption for Gold Mining
(Source - ESKOM)

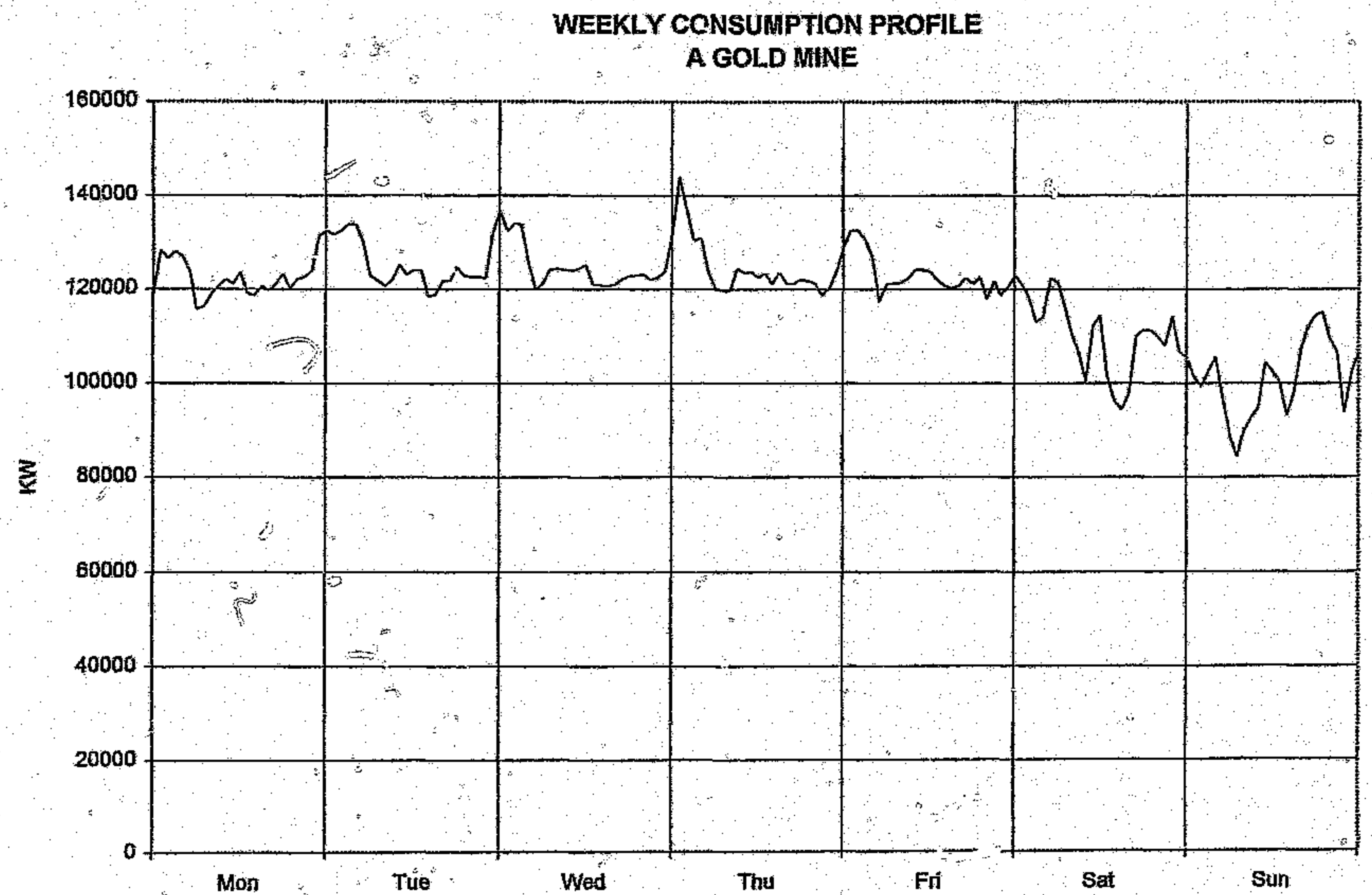


Figure 5.2 Average Demand of a Gold Mine (MW)
(Source - ESKOM)

5.1.3 Gold Mining Contribution to ESKOM System Peak

Gold mining a consistent base load on the national electricity supply system. Figure 3.1 demonstrates this for the disaggregated loads on the power system. This sector represented 15,2% of the contribution to the ESKOM system winter peak in 1990, declining to 13,7% in 1992. In the context of this report, the gold mining sector is more than half of the estimated 31,8% contribution to the 1990 system peak by the mining, metals and minerals sectors covered in this report (See Section 3, Table 3.1).

There is also some seasonality in this sector. For example the winter evening peak in 1990 of 3300MW was 300MW higher than the summer peak in the same year (Bluff, 1992).

The contribution of gold mining to the ESKOM system peak is depicted in Table 5.2, which is extracted from Table 3.1.

Table 5.2 Gold Mining Contribution to ESKOM System Peak

	MORNING PEAK (9h00)		EVENING PEAK (19h00)		
	1990				1992
	Winter	Summer	Winter	Summer	Winter
% of Total	15.2	16.0	15.4	16.6	13,7
ESKOM Load in GW	3.2	3.0	3.3	3.0	3,0

5.1.4 Load Profile of a typical Gold Mine

The graphical representation, Figure 5.2, of the average demand (MW) of a large gold mine, is indicative of the high daily load factor typical of these mines. It demonstrates the current effect of only working a statutory six day week underground. In this example the reduced load on the weekend is not as pronounced because of gold refinery operation.

Agreement of Government and Trade Unions to allow a seven day working may have an important effect. For those mines which are deemed marginal i.e. their gold grades are low and working costs are high, hence at low gold prices their profitability is low or even negative, their life may be extended. Improved utilisation of installed underground plant is expected to reduce average working costs per ton mined. The overall decline in electricity consumption of the sector, which is visible in Figure 5.1 may be slowed.

For the sector in general, the load profiles which currently show a substantial weekend decline in load, would be expected to show an increase to mid-week levels. This would contribute to better use of installed base load power generating plant on the ESKOM system.

The current range of load factor in gold mining is 78% to 88%, with an average of 84% (Granville, 1990).

By far the dominant electrical end-use equipment on a gold mine is the electric motor. This is the workhorse for winding, pumping air and water, driving the crushing and milling plant, compressed air supply and the refrigeration plant (Cooper, 1991; 1995).

From Table 2.1 the predominance of the use of 82% of electricity for mechanical, mostly motive power, relative to other energy uses confirms this.

The 14% of electricity used for thermal purposes is for cooling of deep underground workings and, at some mines, the use of arc furnaces for gold smelting. Where smelters are located at some mines, the electricity consumed is included in the overall thermal consumption figures.

5.1.5 Gold Mining Processes in the RSA

The following brief description of gold mining processes is intended to cover the key technologies used and the role played by the electro-technologies. Current mining processes as developed in the 100 years of gold mining have determined the major technologies in use today.

Deep underground mining operations have vertical shafts sunk into them and some mines have sub-vertical shafts to reach into deeper reefs. Horizontal workings extend from these shafts. At the working and development faces, holes are drilled into the rock, charges of dynamite are placed and wired up.

While the mine is empty of workers, the blasting is done, and the fumes are cleared through the ventilation system over a period of several hours. The rock is checked for stability and the next working shift is initiated to load and clear the broken rock.

Hand-getting is still extensively used in the older mines, rock is loaded into trolleys, transported to the shaft and hoisted to surface in a skip. Only one blast is allowed per day, so effectively only half of a twenty-four hour day is used for mining. Because of low grades, as low as 4 grams/ton, superfluous rock is hoisted to surface for milling. In some more modern mines, the use of underground load haul dumper trucks has improved the rate of operation. But introduction of these vehicles depends on reefs that are wide enough to accommodate their roadways.

Extensive use is made of compressed air for underground equipment, like drilling and rock cutting.

The average mine depth in 1962 was 1 300 metres, and the virgin rock temperature (VRT) was 33° Celsius. By 1990 workings were down to 3 600 metres with a VRT of 60° Celsius. To achieve safe productive human effort, underground temperatures of less than 28° Celsius wet bulb are required.

To achieve these reduced temperatures approximately 8.8 tons of air per ton of rock broken is circulated.

The power rating of the fans alone was 550 MW in 1980, and with refrigeration plant and pumping of the water included, was estimated at 1040 MW. Progressive increases have occurred as mines have been deepened to ensure acceptable working conditions.

Refrigeration plant producing ice underground have been introduced. Freegold North installed a three chamber heat exchanger. However, mostly conventional shell and tube exchangers are still in use. Replacement of CFC in terms of the RSA's commitment to the Montreal Protocol is ongoing.
For the new South Deep shaft, due for commissioning in 1996, the electricity supply capacity is 160MVA for the single wind 2 750m deep shaft and the split ammonia cooling plant (Ruffini, 1995; Creamer,1995).

Extensive de-watering of mines is a major user of large motors for pumping. East Driefontein needs to pump 150 Megalitres daily through a height of 1000 metres. A 25 MW pumping station was designed for the purpose. Another configuration of mine requires 75 Megalitres removed daily through a head of 2000 metres. With several marginal mines closing, special arrangements are made among mining houses to retain pumping loads.

Progressively as shafts have been sunk deeper so the winder motors have increased in size to deal with single depth shafts of a planned new maximum of 2 750 metres. Winder motors have evolved with the use of sophisticated electronic control for speed, safety and efficiency benefits. Thyristor drives have unfortunately introduced low power factor on start-up, and harmonics as problems on the supply side of the electricity system.

Material on surface is transported from the winder headgear by conveyor to be sorted, crushed, milled and the gold recovered, usually in a leaching process.

In some mines, sorting is done by radiometric means, but many mines feed run-of-mine ore into grinding mills, and no sorting and crushing is done.

Comminution, reducing the size of the particles to be processed, includes crushing and subsequent milling or grinding. In principle methods have changed little since the original patents were registered e.g. for the jaw crusher by Blake in 1858 in the US, and the gyrating crusher by Gates in 1883 in the US. The cone crusher of the 1920s is a modification of the gyrating crusher design. The ball mill was invented by Bruckner in 1876 and variants of the design are still in use.

Extraction using Carbon in Pulp (CIP) recovery has reduced electricity requirements in this stage of the process by an estimated 20%, when compared with leaching, solid/liquid separation, clarification and precipitation. (Granville, 1992b)

Electricity generating sets for use as emergency standby are a legal requirement for all mines. Diesel and gas turbine generator sets are typically used. The estimated capacity of diesel units was 120 MW and of gas turbines was 115 MW in 1989 for the mining industry, in which gold mining predominates.

A unique battery energy storage system useful also as a peak lopping unit was installed at Vaal Reefs. The capacity of this unit was 4 MW, and proved useful during its short life before being damaged by fire. (Reynders, Landy and Raynham,1989)

Average electricity consumption per ton milled is a useful indicator of the electricity intensity of this sector. It ranged from 233 kWh/ton for underground operations (allowing for hoisting) to 18 kWh/ton for surface operations. Mixed sources of ore (underground and surface) lead to an industry average of 132 kWh/ton milled for the last quarter of 1991. (Reference ESKOM data base of gold mining energy sales).

5.1.6 Future Electrotechnology Development

No substantial changes are foreseen through the introduction of new electrotechnologies. Changes in mining methods in order to introduce cost savings and improve productivity are more likely to have an impact (Granville, 1992b). Underground water use for driving hydraulic plant has already displaced some current electricity using devices. Underground crushing and milling can reduce hoist loads and hence change the hoist drive requirements.

Introduction of rock cutting equipment and continuous miners (i.e. eliminating blasting) will substantially reduce ventilation fan capacity and designs, and introduce new loads for conveyors and continuous mining plant. Backfilling of stopes after mining in order to support the roof, and also to reduce heat evolution from deep rock has already been implemented in several mines. This has the twin effects of reducing loads to be hoisted, and also the volume of cooling air.

The use of electronic control systems for electrical load management to reduce peak loading and high charges for peak demand has increased as mining managements have struggled to keep costs down in the face of low gold prices over the past years.

5.2 COAL MINING

5.2.1 General

South African coal mining is well developed and the national reserves are estimated at 53 Billion tons. Mining levels are currently of the order of 150 Million tons annually, having peaked in 1988 at 224 Million tons. Export levels have been in excess of some 80 Million tons. The world coal trade is highly competitive and SA prices determine the size of achievable exports.

Sanctions in the 1980's limited access to markets which have been re-opened since the political changes in the country subsequent to 1990. Approximately half the domestic coal sales are used in electricity generation. The balance is used in oil-from-coal production, industrial heating and household use.

5.2.2 Basic Processes

There are both underground and open cast mines in operation. The dominant electrotechnology in underground mining is the motor hoisting and motor driven conveyor systems. A few mines have had the correct coal seam geology to support longwall continuous mining processes. These also have predominantly motor drives as the major electricity consuming equipment.

The open cast mining process is dependent on dragline operation viz. enormous tracked mobile excavators which drag a bucket across the exposed, released coal bed. The motors driving these units are the dominant electricity consumers.

In both cases of mining systems, power electronics to control the motors and electric control systems to manage the overall process are vital to the success of the mining operation.

Washing of mined material to enhance coal quality is also a motor driven process.

The estimated proportions of coal extracted by the different processes is shown in Table 5.3, derived from Granville and Stanko (1992).

A movement away from open cast mining is expected to occur into the future, as the number of reserves accessible by this method is limited.

Table 5.3 Coal Extraction Percentage for the RSA for different mining methods

	1988
Underground share	62%
by Board & Pillar	46%
by Longwall	8%
by Pillar Recovery	8%
Open Cast share	38%
Total	100

5.2.3 Specific Electricity Consumption

Within the coal mining industry, the electricity intensity of the processes has been estimated (Granville and Stanko,1992) as shown in Table 5.4.

Table 5.4 Specific Electricity Consumption for Coal Mining

TOTAL ESTIMATED	12,8 kWh/TON of COAL SOLD
Washing Plant	1,4 kWh/run of mine ton for jig type washing 8,0 kWh/run of mine ton for complex washing 3,4 kWh/run of mine ton estimated average
Mining, Heating conveying	9,4 kWh/run of mine ton estimated average

5.2.4 Electricity Demand by Coal Mining

Figure 5.3 shows the growth of total electrical energy consumption in GWh for coal mining over the period 1980 to 1994. Demand profiles for typical underground coal mines are illustrated in Figures 5.4 (a) and (b). Figure 5.4(c) is an example of an extensively automated mine with an inclined shaft.

Electrical Energy

Growth in electricity consumption for coal mining shown in Figure 5.3 was slow but positive during the period 1985 to 1993. This was in line with relatively little export growth, low industrial growth and very low power generation growth.

Electrical Maximum Demand

Figures 5.4 a) and b) of the demand profile for underground coal mining reveal a substantial peak to trough ratio of as much as 50% in a day. The peak achieved on a Saturday can be of a shorter duration than the weekday, but of the same order of magnitude.

Mechanisation achieved in coal mines in South Africa is already extensive. The level of automation for improved mine productivity and safety has been stimulated by electronic control systems.

The performance of the mine shown in Figure 5.4 c) suggests a different operating process to those illustrated in Figures 5.4 a) and b). Despite the installed automation which may optimise coal extraction, the benefits of load management of the electricity demand does not appear to have been achieved.

For all the examples shown, opportunity appears to exist to modify the load profile to achieve a better load factor and overall beneficially improve the integrated system load factor.

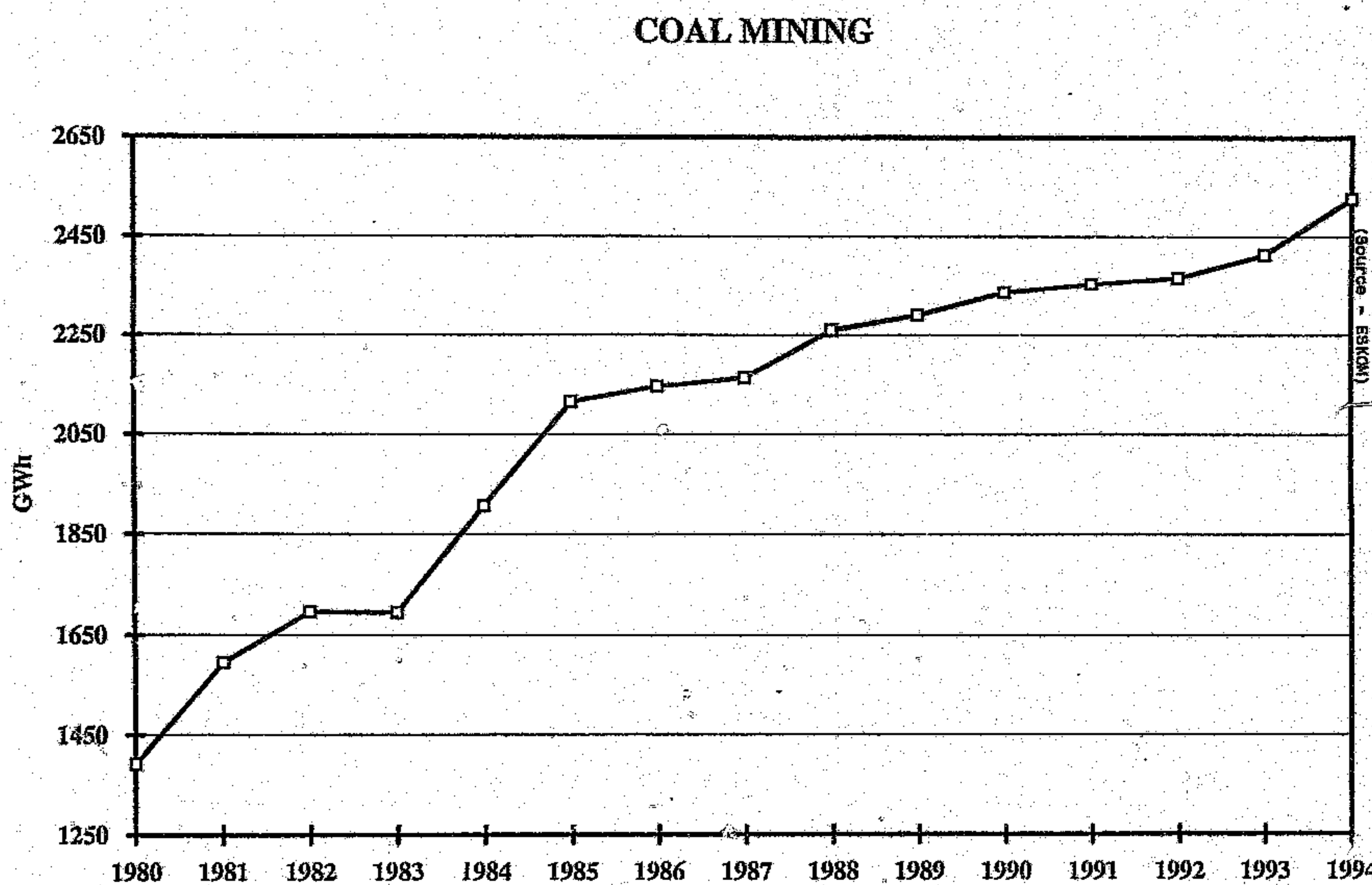


Figure 5.3 Electricity Consumption for Coal Mining
(Source - ESKOM)

Figure 5.4 a) Demand Profile for Typical Underground Coal Mine (Mine X) (Source - ESKOM)

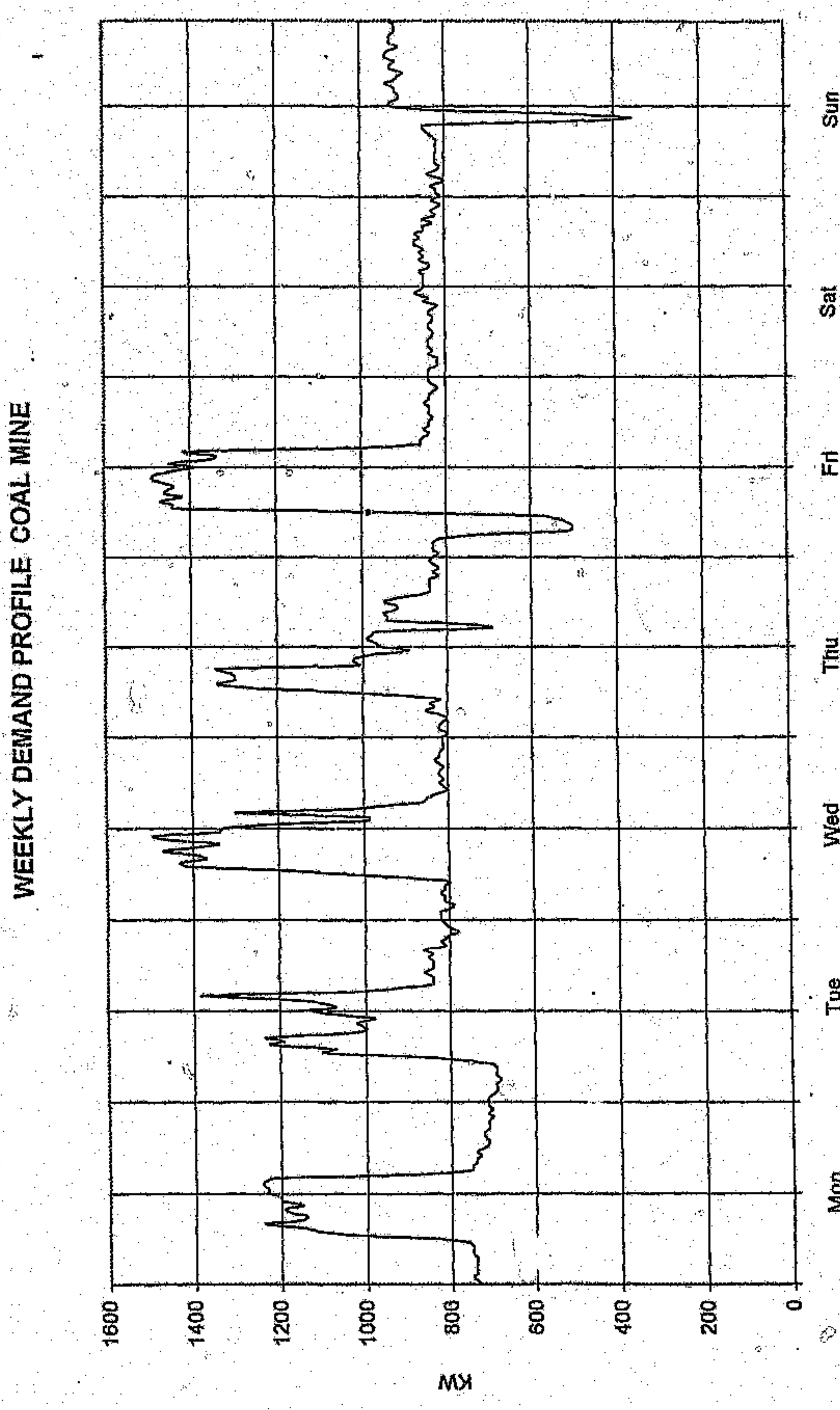


Figure 5.4 b) Demand Profile for Typical Underground Coal Mine (Mine Y). (Source - ESKOM)

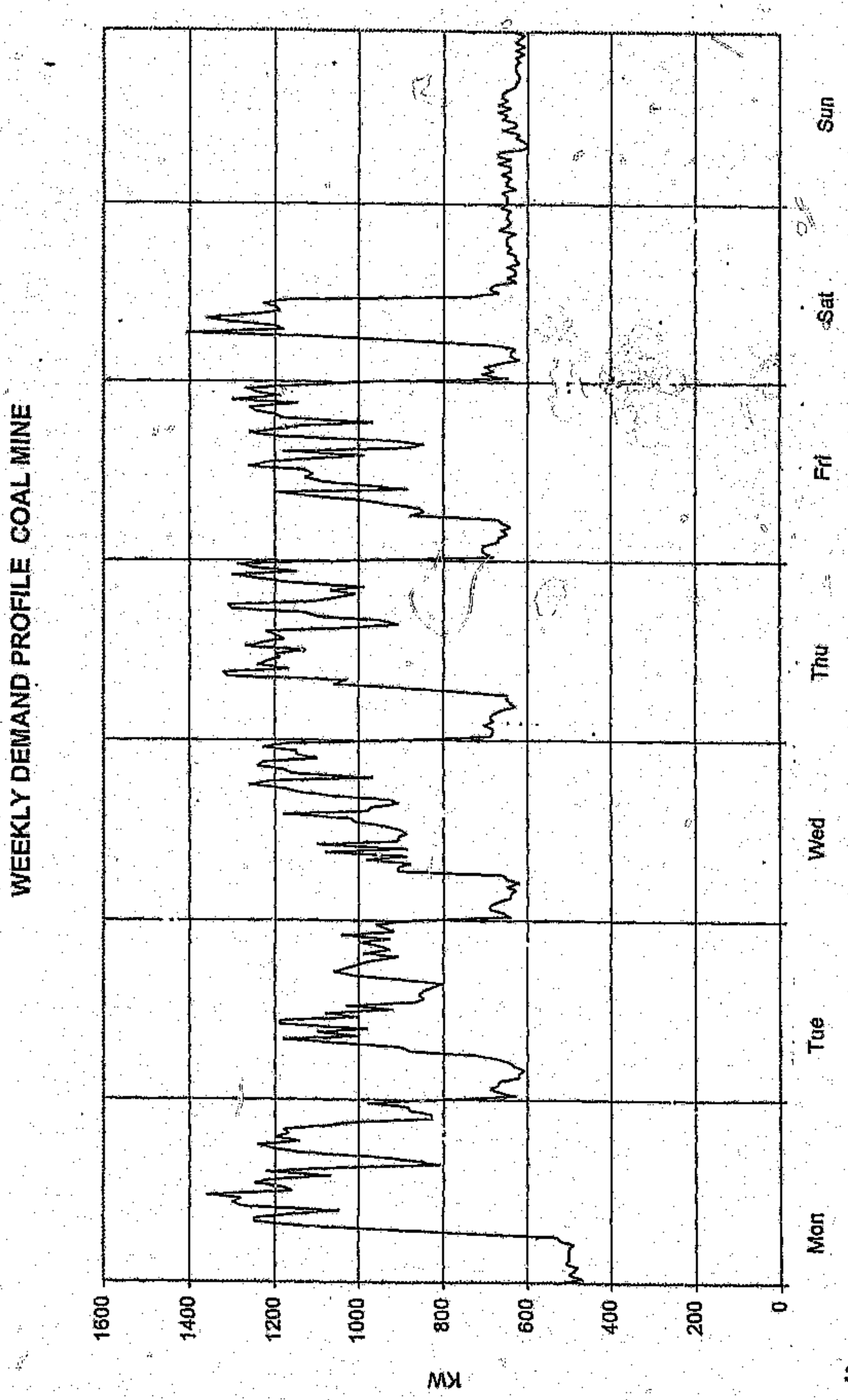
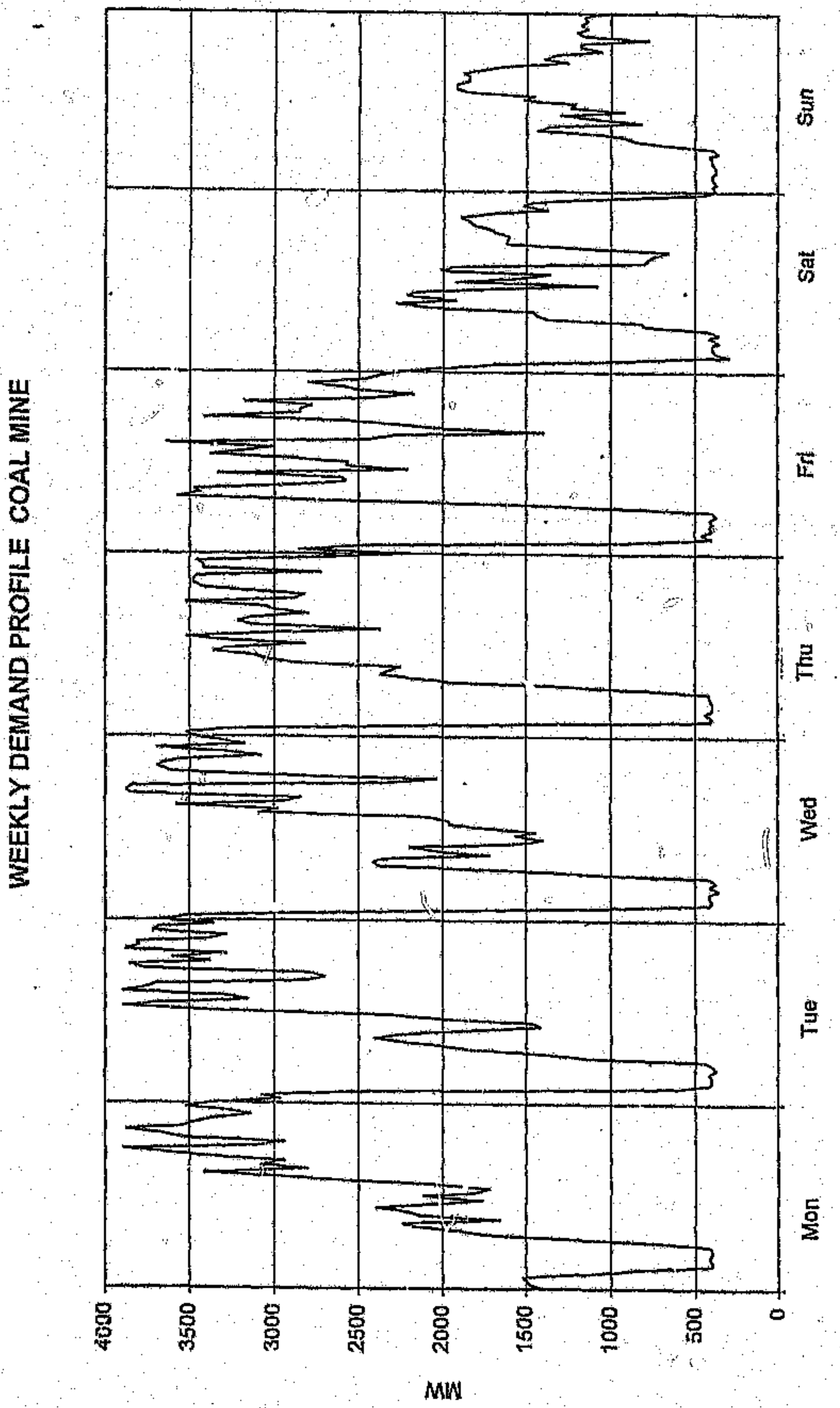


Figure 5.4 c) Demand Profile for Typical Underground Coal Mine (Mine Z) (Source - ESKOM)



5.2.5 Potential Future Technology

Increased mechanisation and washing of coal products offer some opportunities for future improvement. However these are all motor-based technologies. The electronic control systems do represent potential for efficiency improvement, but also for supply system interference from control circuitry. New alternative electrotechnologies of large impact do not yet appear likely.

Management of environmentally sensitive waste from coal preparation processes, both very low grade coals which are discarded in substantial quantities, and also waste water from coal washing represent opportunities for future application of new technology.

The use of discard coal in fluidised bed reactors for steam raising has been mooted by the Department of Mineral and Energy Affairs, but is not an end-use electotechnology, hence it is beyond the scope of this report. Membrane technology for separation of hazardous wastes and recovery of valuable materials from waste water has also gained attention. The effect on electricity load growth or shape at this stage is not expected to be significant.

The development of coal-bed methane extraction in deposits may have a substantial impact, as the extraction process requires pumping, and the pressure of the gas is low hence compression is needed for transmission in pipelines. The United States Department of Energy has committed to development support as a result of the USA/RSA Energy Summit of 23 August 1995 held in South Africa (Presentation by Hazel O'Leary, Secretary for Energy, USA).

5.3 PLATINUM MINING

5.3.1 General

South Africa is well endowed with platinum group minerals (PGM), with estimated production of 127 tons from 24 Million tons of ore in 1989. This is estimated at more than 60% of the world's platinum production and nearly 50% of PGM production. The minerals of platinum, palladium and rhodium are included in the PGM's extracted in SA. (Granville and Stanko, 1992).

Mining for PGM's has grown into a substantial industry in relatively recent years, with international market increases in PGM prices. The latter has been stimulated by demand from users of platinum and rhodium in catalytic converters for motor vehicles, and for platinum-based catalysts in cracking of heavy crude oils. Demand from Eastern countries for platinum jewellery and coins has been a strong driver for PGM mining and production increases.

5.3.2 Basic Process

PGM is mined at depths less than for gold, but in conditions similar to gold mines. After mining the ore is milled. Concentration is by flotation. The concentrated product is dried and pelletised, then smelted to a matte in electric furnaces.

The matte contains PGM and base metal by-products. Sulphur and iron are removed in a converter, and from the resulting converter matte, base metals are pressure leached.

The PGMs and gold as a by-product are separated and refined.

5.3.3 Specific Electricity Consumption

The development of the platinum mining industry has represented an important new growth of mining and electricity demand in the past decade. Tables 5 5 and 5.6 show the specific electricity intensity for the mining of this metal from two different types of deposit, namely the Merensky and the UG2 reefs.

Table 5.5 Trend in specific electricity consumption for PGM's

	kWh/oz PGM	change kWh/oz
Specific consumption 1977 to 1983	1 250	
After development of new mines by 1989	1 664	+ 414
Projected future steady state level	1 460	- 204

Table 5.6 Merensky vs UG2 Ore - specific electricity consumption

	kWh/ton of ore
Smelting for Merensky ore	29
Smelting for UG2 ore	14
Milling	18
Flotation	10
Total for Merensky	57
Total for UG2	42

Typically for grade of 3,24 grams/ton, the average electricity consumption is 152 kWh/ton. Hence 38% of electricity is used in platinum production and the balance is in the mining process.

A "step function " increase from 1983 to 1989 in specific electricity consumed per ounce of platinum produced (Granville and Stanko, 1992) is shown in Table 5.6. This could be attributed to the gradual replacement of blast furnaces by electrical furnaces.

The refining step is estimated to require 2,7GWh/ton of product refined (Granville, Stanko and Freeman, 1993).

5.3.4 Electricity Demand Characteristics

Electrical Energy

Figure 5.5 depicts GWh consumption in the platinum industry over the period 1980 to 1994. The continuous high level of growth in this precious metal since 1984 is reflected in the electricity consumed by existing and new mines, stimulated by increased use of electrical arc furnaces in the production of matte.

Electricity Maximum Demand

Figure 5.6 and 5.7 depict typical platinum mine weekly demand profiles. However, 5.6 is a mine with a refinery. The process of mining for platinum is very similar to that of gold mining and hence the demand curves might be assumed to be comparable. The profile of Figure 5.7 resembles a gold mining profile, as it does not have on-site refining.

However, the platinum mine depicted in Figure 5.6 shows a daily load that is relatively "spiky", and the pattern over the week is at a consistent demand level. The extensive use of electric arc furnaces for production of matte adds to the level of the load for the site throughout the week. For example, in the case of Northam Platinum Mine, this comprises a 15MW furnace with 6 electrodes capable of smelting 15 tons an hour of flotation concentrate into a matte (Engineering News Mining Vol 13 no7 26 February 1993 p27)

In addition most of the platinum mines have their own base metals refineries.

The reduced depth of mining does however mean that the need for refrigeration is reduced, and mostly ventilation is required to maintain working conditions at acceptable levels.

5.3.5 Future Electrotechnology Potential

Plasma smelting has been researched, but not yet implemented for platinum production in South Africa. However with the experience already gained and the expertise available in the country this may well be applied in this country.

As the depth of mining increases, this will influence the introduction of refrigeration and automated underground systems, similar to gold mining processes.

Some pre-drying of platinum matte concentrates have been introduced in order to increase efficiency of the smelting process, but further improvements in efficiency would be beneficial.

At this stage only the new platinum mine at Northam has a temperature profile that needs refrigeration facilities to deal with a temperature of 55ºC at the working face at 2000m below surface. Mining in the Platreef may have totally different capacities and performance characteristics to the conventional underground mines as the reef inclines at 50 to 55º and a part may be accessible to open cast mining (Granville and Stanko, 1990).

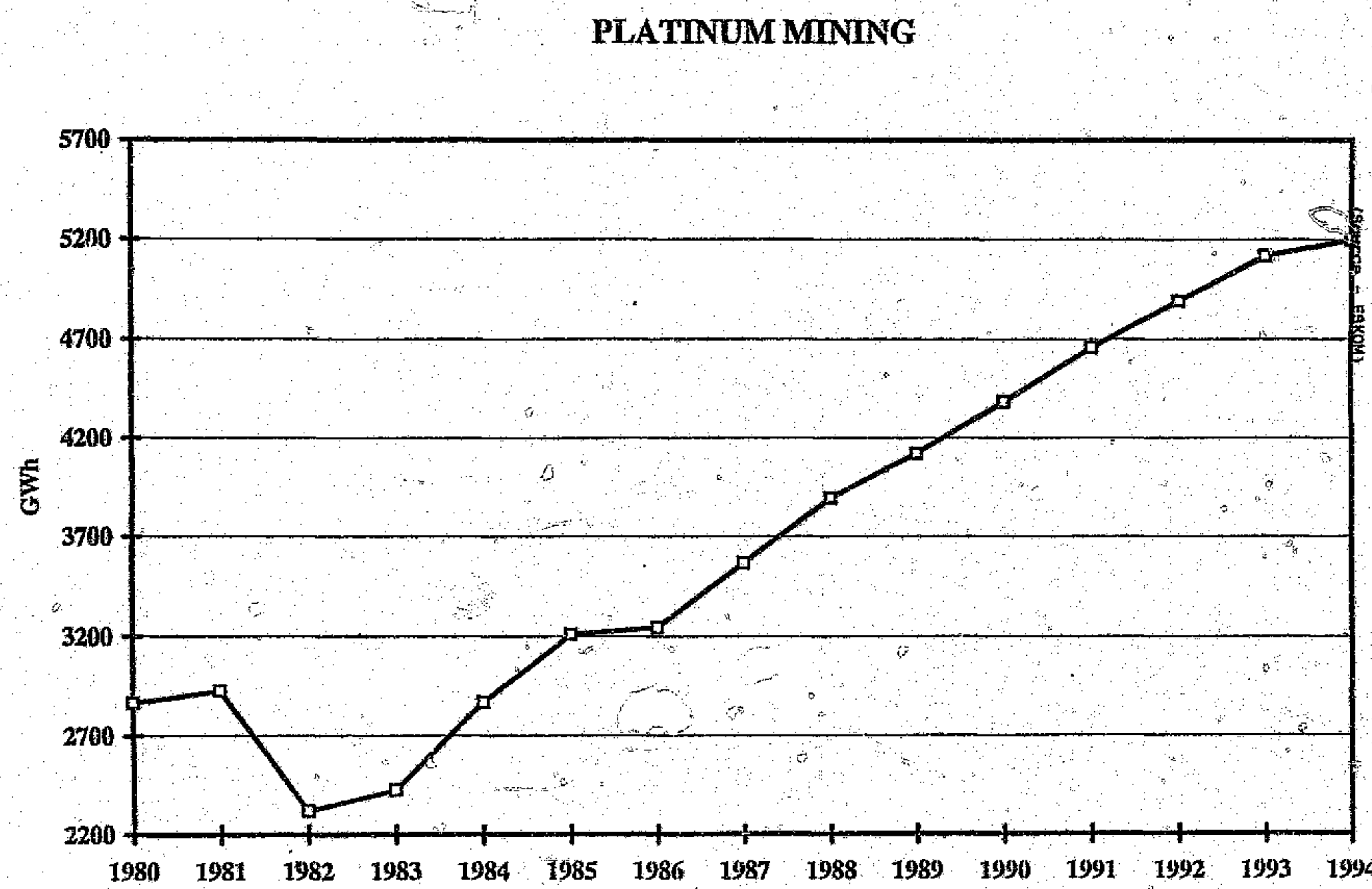
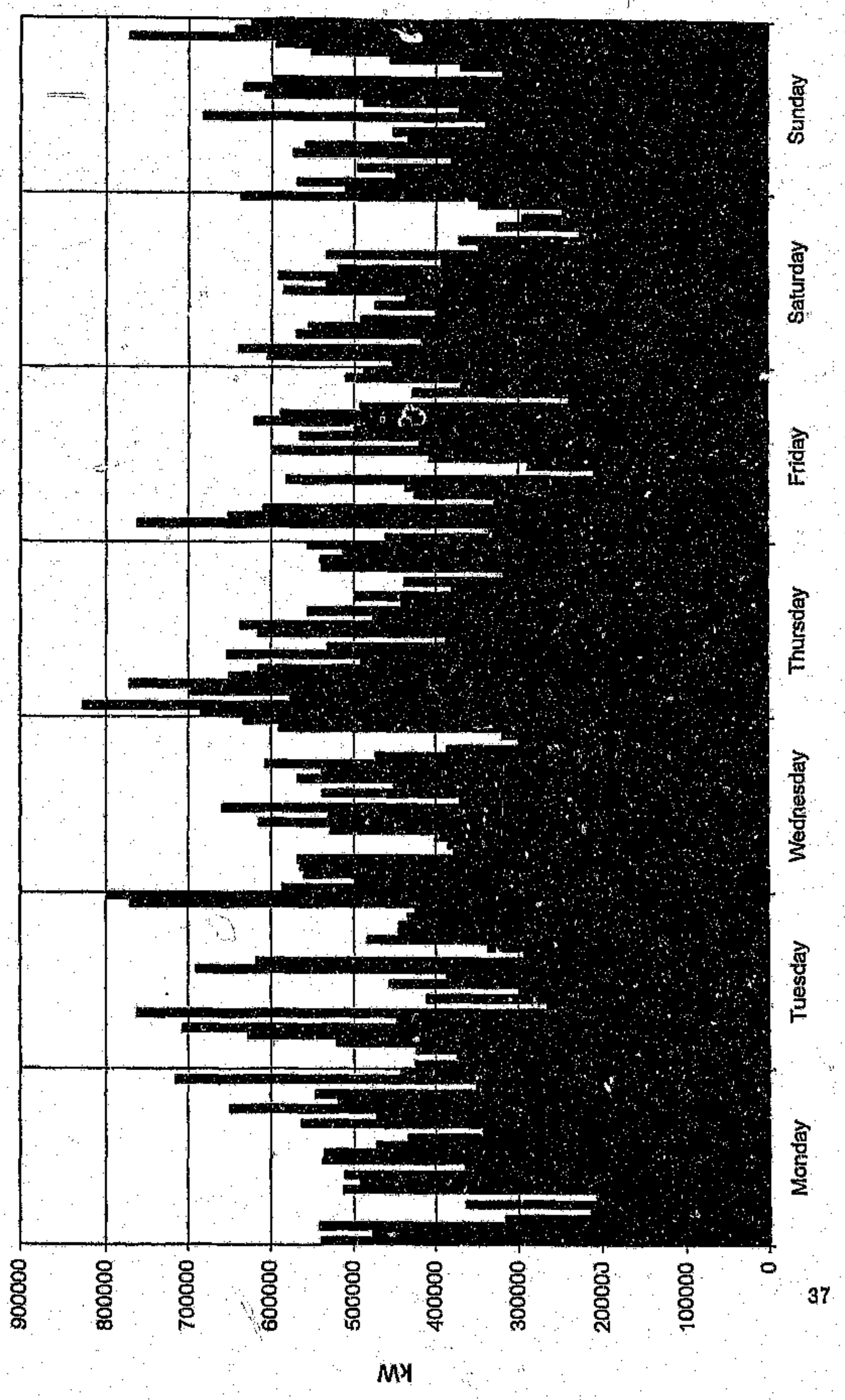


Figure 5.5 Electricity Consumption for Platinum
(Source - ESKOM)

Figure 5.6 Platinum Mine with Refinery Weekly Demand Profile
(Source – ESKOM)



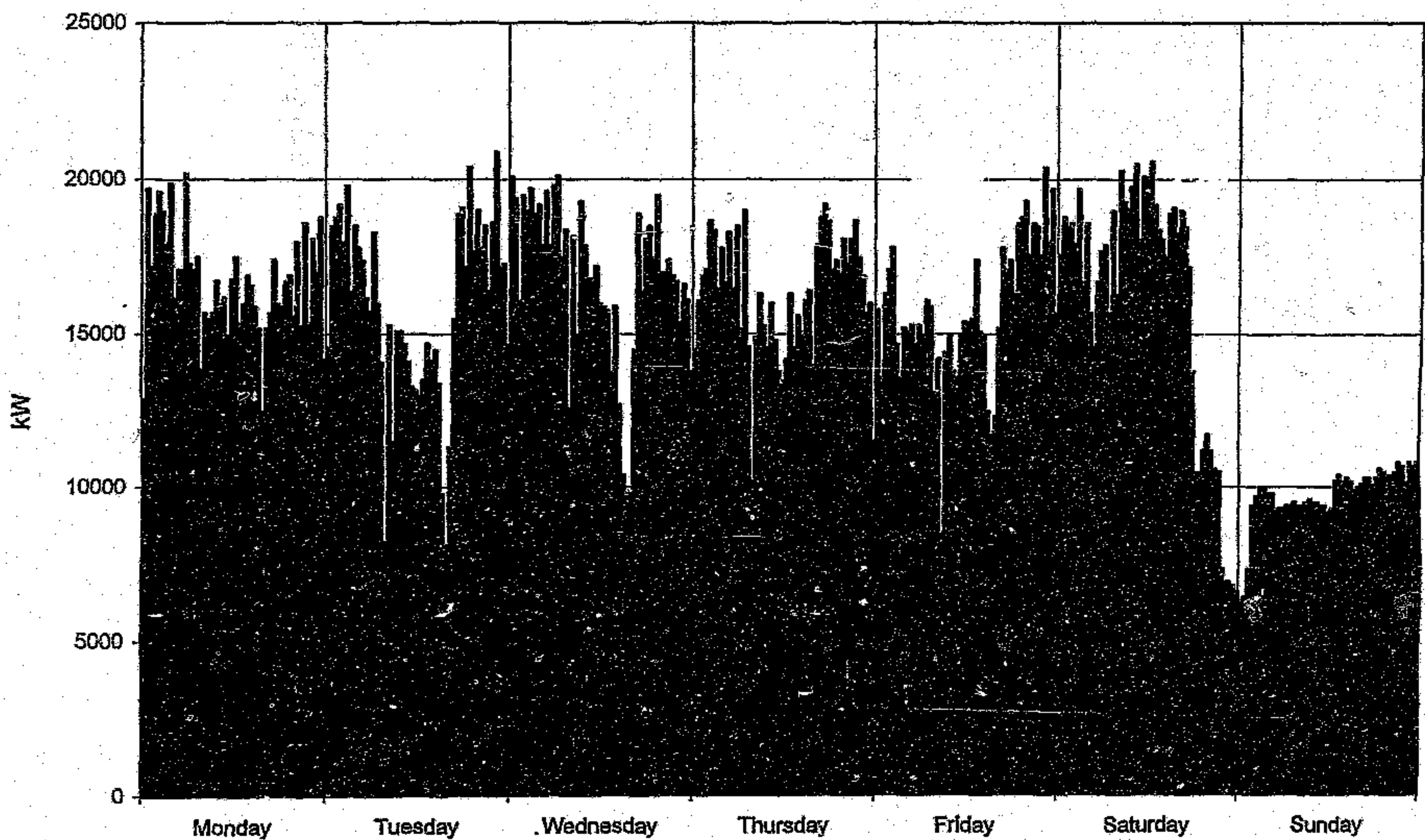


Figure 5.7 Platinum Mine Weekly Demand Profile
(Source - ESKOM)

5.4 OTHER MINING

5.4.1 Copper Mining

Basic Processes in Copper Mining

Open cast and underground mining methods have been used. In 1996 Palaborwa Mining Company (PMC) announced a project to sink a shaft to access copper deposits at its large open pit mine in the Northern Province. This will extend the life of the mine.

Conventional processes in underground mining are used, hence motors predominate. This is confirmed from Table 2.1, namely 85% of electricity used for mechanical processes in "Other Mining".

Open pit mines as in the case of PMC have in-pit crushers and trolley assist transport out of the mine, where 77 kWh/km is used to replace approximately 19,2 l/km of diesel fuel for the vehicles. Computerised truck dispatching optimises transport.

Autogenous milling as well as ball milling are used. The former uses more electricity and computerised control avoids over-grinding.

Processes in Extracting Copper

Froth flotation is used to produce a concentrate from the milled ore. The concentrate is smelted to matte in coal fired reverberatory furnaces, the furnace matte is blown to blister copper in converters. The resulting metal is cast into anodes. Electrolytic refining is used to purify the anodes.

Production of sulphur as a by-product of the process requires specific handling of the flue gases, acid production or neutralising of dilute acid.

Downstream treatment of copper to form rod, slabs or billets include electrical induction furnaces and gas furnaces. Rolling and extrusion is done by electrically driven mills and presses.

Tables 5.7 and 5.8 indicate the intensity of and process distribution of electricity consumption per ton of processed material (Granville, Stanko, Freeman, 1993).

Table 5.7 Specific Electricity Consumption in Copper Mining(1990)

Extraction Process stage	MWh/ton
Milling Flotation Smelting Refining	1.2 2.4 0.5 0.3
Average for extraction process	3.6
Total primary copper industry	6,7 MWh/ton

Table 5.8 Percentage useage of Electricity in Various Copper Mining processes

USEAGE of ELECTRICITY	%
Mining	45
Milling	15
Flotation	30
Smelting	6
Refining	4
Total	100

Electricity Demand Characteristics

Figure 5.8 shows the GWh history over the past 10 years with an estimated 1 225 GWh in 1990. The peak consumption was in 1987 and this sector has shown a progressive decline as economically minable reserves have dwindled.

The performance of the copper mining industry has been dominated by poor commodity prices for a prolonged period, rather than by major technological influences.

For a representative copper mine with extraction plant on site, the daily load factor is 81% and the weekly load factor is 73%.

Future Electrotechnology Potential

Electric arc furnaces for heating to replace coal fired furnaces would seem to be the major area of application. Induction heating in place of gas heating has some potential for development. Additional conveyor and transport systems using electricity has limited scope (Granville and Stanko, 1992).

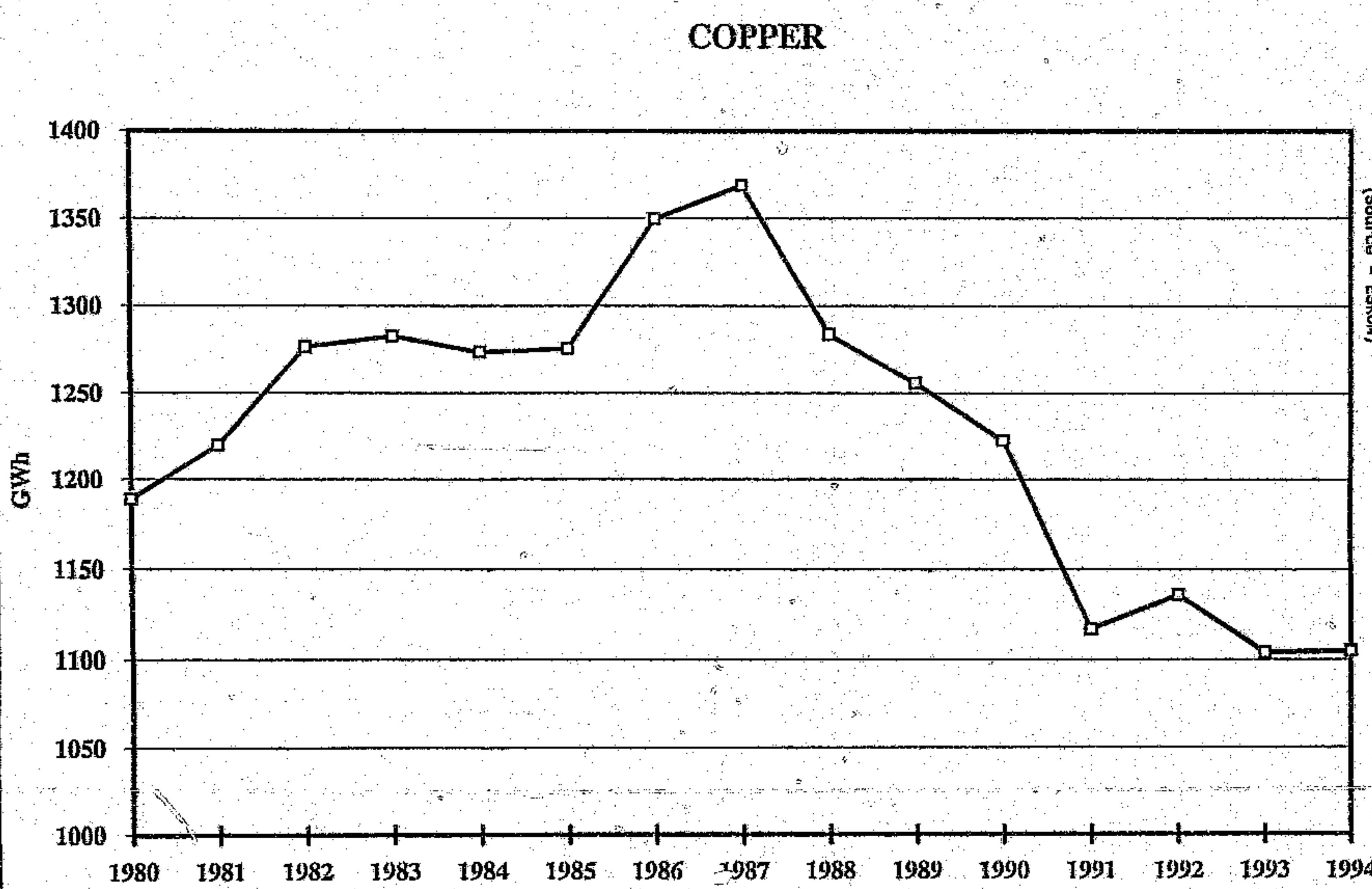


Figure 5.8Electricity Consumption for Copper
(Source - ESKOM)

5.4.2 Diamond Mining

Diamonds are mined from kimberlite (pipes), alluvial deposits and marine deposits. Material handling using motor drives of various types on land represents a major useage of electricity. Enhanced computer control is introduced to streamline processes. Identification of gemstones using UV and scintillation methods is a low electricity consuming process, but important in the industry.

In 1990, this sector represented 957GWh. Unfortunately it appears to be in a decline as RSA sources reduce, and world market prices decline. Massive stockpiling has occurred, and progressive weakening of the controls which have traditionally managed the level of trade in gem quality diamonds, have driven the decline to a large extent. It is expected that changes in the level of electricity demand will be driven by world diamond demand, not by electrotechnology developments. It is unlikely that productivity improvements in technology will change the position of *onshore* SA diamond mining capacity.

5.4.3 Other Surface Mining

Categories included under Other Surface Mining

Mining of iron ore, chrome, asbestos, manganese, fluorspar, phosphate, lead, antimony, beach sands, and tin are all surface mining operations. Together they represented 1 552GWh in 1990. These consumption contributions are shown in Table 5.9.

Table 5.9 Summary of Other Surface Mining Electricity Consumption including minerals extraction (1990)

	TOTAL MINERAL GWh	MILLION Tons	SPECIFIC Consumption kWh/ton
Iron ore	318	38.0	8.4
Phosphates	285	*	*
Chrome	198	4.3	46.0
Lead	150	0.16	937.5
Fluospar	130	0.27	481.5
Manganese	170	3.8	44.7
Antimony	80	*	*
Beach Sands	55	17.0	3.2
Tin	40	0.2	200.0
TOTAL	1 552		

* Quantities of production classified by Minerals Bureau

Sources : Granville, Stanko and Freeman, 1993; Granville and Stanko, 1992; Minerals Bureau

Electrotechnologies in Other Surface Mining Applications

The methodologies have all been motor intensive for application in drag line operation, conveyor systems, and also processing such as crushing and milling where appropriate.

Further scope for electrification is expected in transport applications such as increased replacement of trucks by conveyors, and optimisation of plant by use of more centralised computer control and remote operations.

Environmental considerations for restoration of mined areas may add to the mechanical process loads e.g. conveyors to return landfill material to excavated areas. (Granville and Stanko,1992)

6 METALLIC MINERALS PROCESSING SECTOR

6.1 BASIC IRON AND STEEL PROCESSING

6.1.1 General

South Africa's steel is approximately one percent of the world steel production. A relatively small component is exported as raw steel and pig iron billets. A substantial proportion of the world's iron and special alloys such as manganese, chrome and silicon exist in South Africa.

Approximately two-thirds of the 9,6 million tons of steel production in South Africa in 1989, and 8.7 million tons in 1990, was by the basic oxygen furnace (BOF) route and one third by the submerged electric arc furnace (EAF) route (Granville, Stanko and Freeman, 1993). Internationally 770 million tons were produced in 1990, of which the USA produced 88.7 million tons. In 1989, this had been 785 million tons. Of this production 51% was produced by the BOF route, 35 % by the EAF route and 14% by the somewhat outmoded open hearth route (Granville and Stanko, 1992). In the USA in 1987, 36 of the 77 million tons of steel produced used the EAF process (EPRI, 1987a). In 1970, the proportion of shipments from mini-mills was only 3%, and this increased to 21% in 1985 (Barnett, 1989).

Progressively the trend has been toward the EAF route, especially in the USA with the development of "mini mills". The latter are particularly relevant because they can use recycled scrap providing some one third of annual raw steel supply. Their growth was largely stimulated by the surplus of scrap to be recycled that could not be handled by the BOFs which had been installed at integrated mills to replace inefficient open hearth furnaces. The term "mini-mill" is based on the limited range of products produced, not production capacity. (EPRI, 1984b, 1987a)

This shift toward more EAF-based production has manifested in South Africa already. Proposed new plant in the RSA is based on EAF technology, which follows the projections by EPRI for growth in use of EAFs to 50% of USA steelmaking, and similar trends worldwide (EPRI,1984b). The range of forecasts for world steel demand by 2015 ranged from a high of 1 739 million tons to a low of 698 million tons with a mid-range projection of 1 200 million tons (Granville, Stanko and Freeman, 1993).

Implications for electricity demand in South Africa could be affected significantly were a transition to occur from non-electrical to electric arc furnace production in the next decade of the development of the country's industrial base. Additional capacity to meet international demand growth would compound such demand for electricity.

6.1.2 Basic Processes in Iron and Steel Making

Iron oxide ore (of haematite or magnetite form) is smelted in a blast furnace with limestone and a reductant at temperatures over 1000° Celsius. Traditionally coke has been used as the reductant in blast furnaces. Newer processes such as the Iskor Corex, based on the Kohle-Reduction process, use raw coal. Molten pig iron is produced in this stage. (Granville and Stanko, 1992; Granville, Stanko and Freeman, 1993)

The separation of impurities including excess carbon from the reaction product viz pig iron, requires higher temperatures, about 1400° Celsius. Steel is produced from the molten pig iron and excess carbon is removed by oxygen either in a basic oxygen furnace or an electric arc furnace. Other impurities are removed by metallurgical processes. Ferro-manganese, ferro-chrome and ferro-silicon can be added to impart enhanced properties to the steel to produce alloy steels. (EPRI, 1987a)

A progressively growing part of the industry in South Africa is the direct reduced iron (DRI) method which is used in place of the blast furnace stage. The metal in the ore is reduced at temperatures below the melting point of the metal, i.e. it does not produce a molten product. Subsequent smelting is required by BOF or EAF, for example. The DRI stage is not a predominantly electrical process other than material handling, e.g. large motor drives for rotating kilns.

The DRI process using gas as a reductant is called Midrex and internationally the DRI (with coal) process is named SL/RN. The input material requirement is for an iron content of about 65%, implying either a good run of mine ore or beneficiated ore, e.g. in pellet form. DRI then produces typically a 92% metallised product. There is potential for Midrex, with the development of a natural gas industry in the country, or using synthetically produced methane-rich gas from e.g. SASOL.

Additional DRI capacity of 160 000 tons per year, was announced by Scaw Metals (Engineering News, 17 March 1995, p3). This would add to their existing two DRI kilns, each of which have 80 000 tons per year sponge iron capability to feed the electric arc furnace stage. The decision was motivated by the shortage of scrap ferrous metal in South Africa.

The Electric Arc Furnace design concept is well established. These EAFs are treated as two vintages in the study report by EPRI (1984b) namely pre-1945 and post 1945. The early designs were suited to production of carbon and alloy steel, and the later version could produce carbon, alloy and stainless steel.

Specific electricity consumption in the USA quoted for the pre-1945 EAF is typically 525 kWh/ton for carbon steel production and 740 kWh/ton for alloy and stainless steel. Post 1945, the design of EAFs are some 10% more efficient in specific electricity requirements. A further 15% electricity reduction has been achieved by use of a hood to capture off-gases and pre-heat scrap charge for carbon steel production. (EPRI,1984b)

Although there were a number of very large EAFs of over 300 ton capacity per tapping cycle in the USA in the mid-1980's, the majority of the units were less than 50 tons with transformer ratings of 30MVA and less.(EPRI, 1987a)

Because the overall energy required per ton of steel produced by the EAF route is half of that required with the blast furnace-basic oxygen furnace route (BF-BOF), projections made in the EPRI report (EPRI, 1984b) were for an increase in EAF share of steel making to grow from 34% to 50% of USA steelmaking.

6.1.3 Specific Electricity Consumption

In order to appreciate the electricity intensity of the steelmaking process in the RSA, Table 6.1 was assembled from information contained in the report by Granville, Stanko and Freeman, 1993.

The electricity intensity per ton for EAF is comparable in the South African processes with the figures quoted in the EPRI report on steelmaking (EPRI, 1984b:pp 3-21), viz average normal carbon of 600kWh per ton, best normal carbon 475 kWh/ton, and average hooded carbon 430kWh/ton of steel production, and 520kWh/ton referred to in the communication by Granville and Stanko (1992).

Table 6.1 Specific Electricity Consumption for Steelmaking in RSA (1989)

MTONS	PROCESS / ROUTE	SPECIFIC CONSUMPTION MWh/TON		
		Production	Rolling Mills	TOTAL
6,1	Blast furnace	0,3	0,4	0,75
	(Corex plant) - direct - oxygen	0,075 0,3		0,775
2,2	(Midrex Plant) - DRI - smelting	0,7 0,56		1,56
	EAF using scrap	0,52		0,92
1,1	In conjunction with Vanadium (i.e. Highveld)	1,5		1,5

6.1.4 Electricity Demand Characteristics for Iron and Steel

Electrical energy

Figure 6.1 shows the growth in GWh for this sector from 1980. No substantial capacity was added in the 1980s, and the consumption pattern reflects the economic demand for products in the domestic and export markets. The typical cyclic nature of commodity demand shows with low points in electricity consumption in 1983 and 1992.

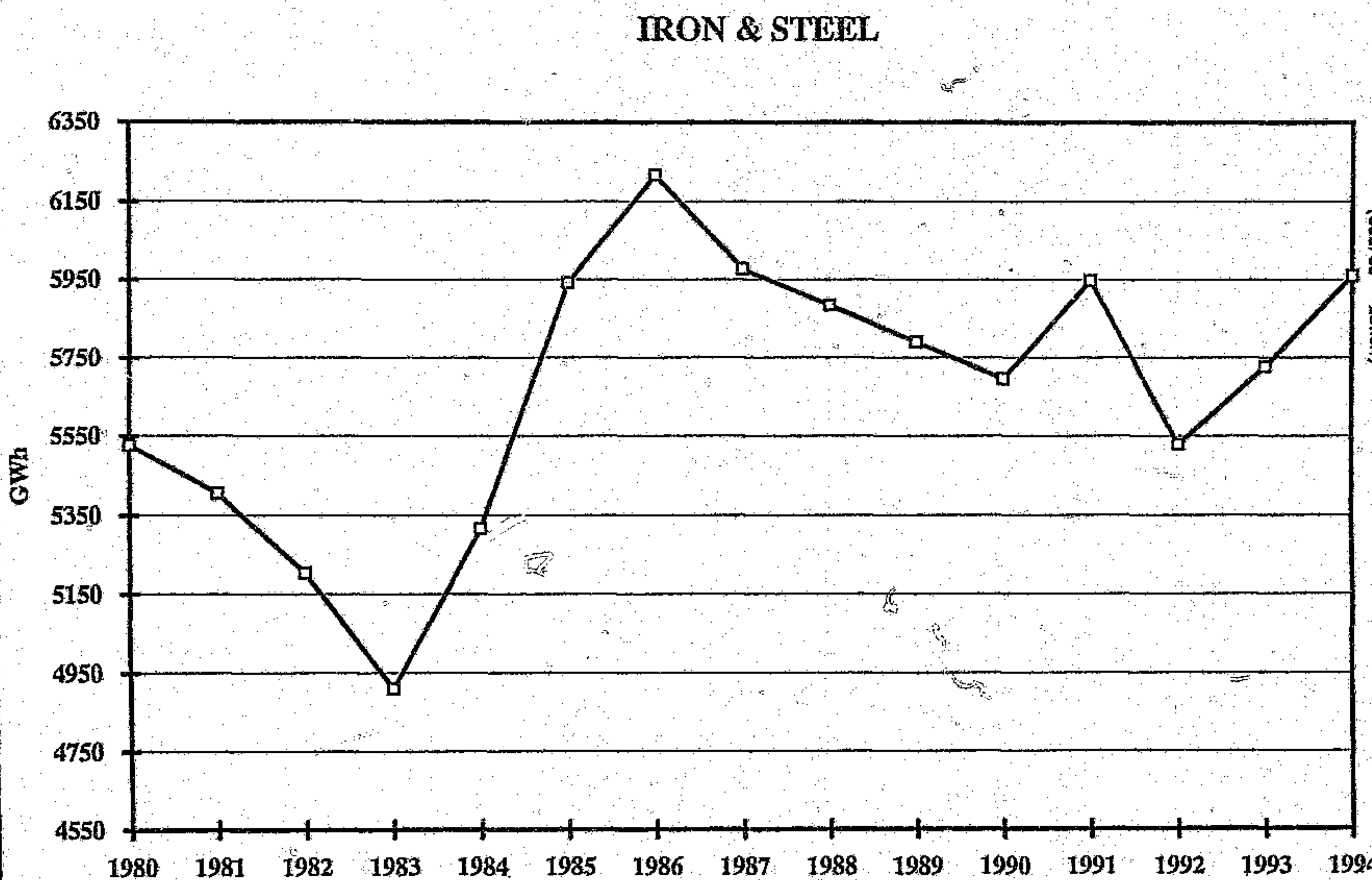


Figure 6.1 Electricity Consumption for Iron and Steel
(Source - ESKOM)

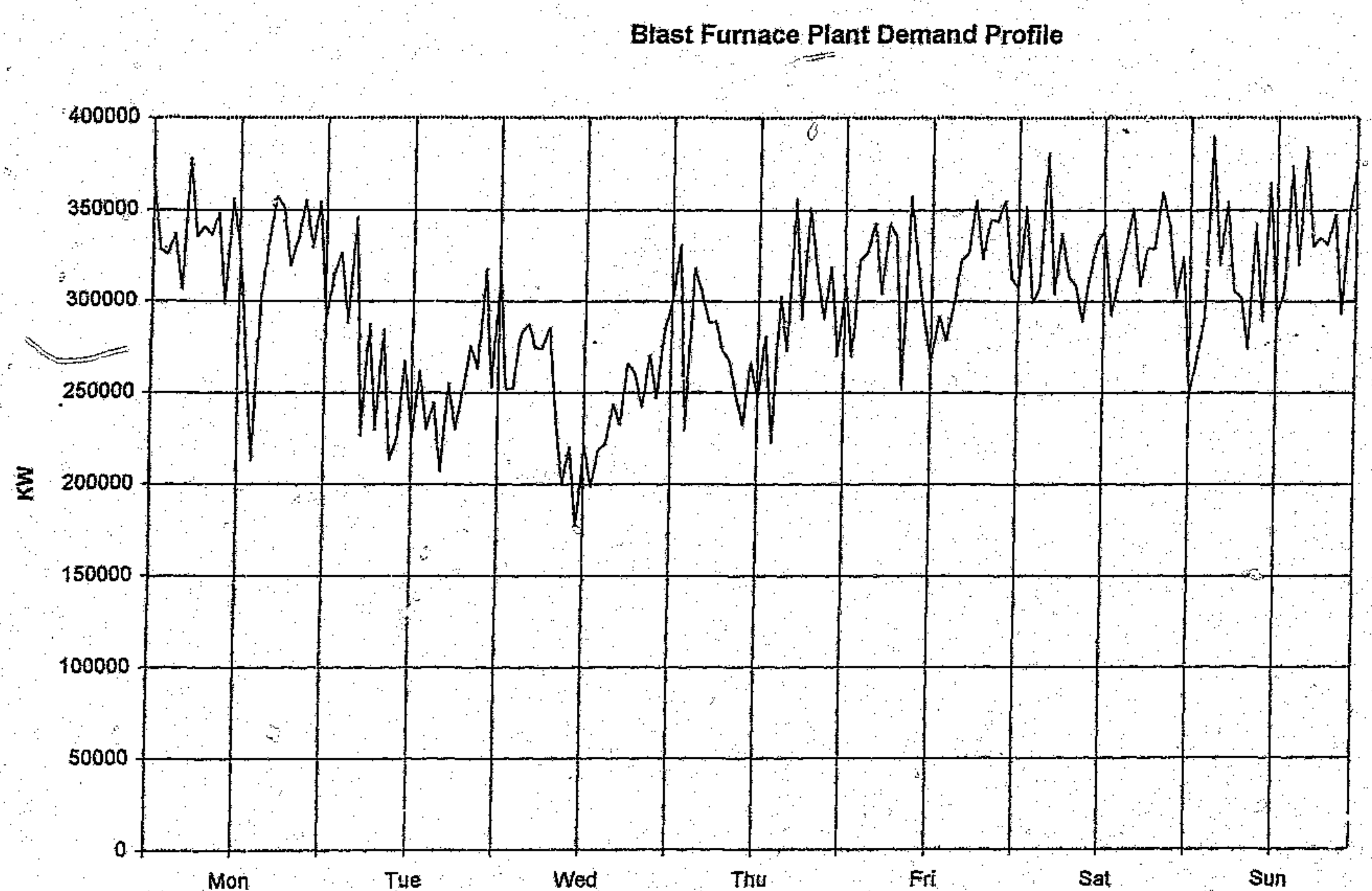


Figure 6.2 Blast Furnace Plant Demand Profile
(Source - ESKOM)

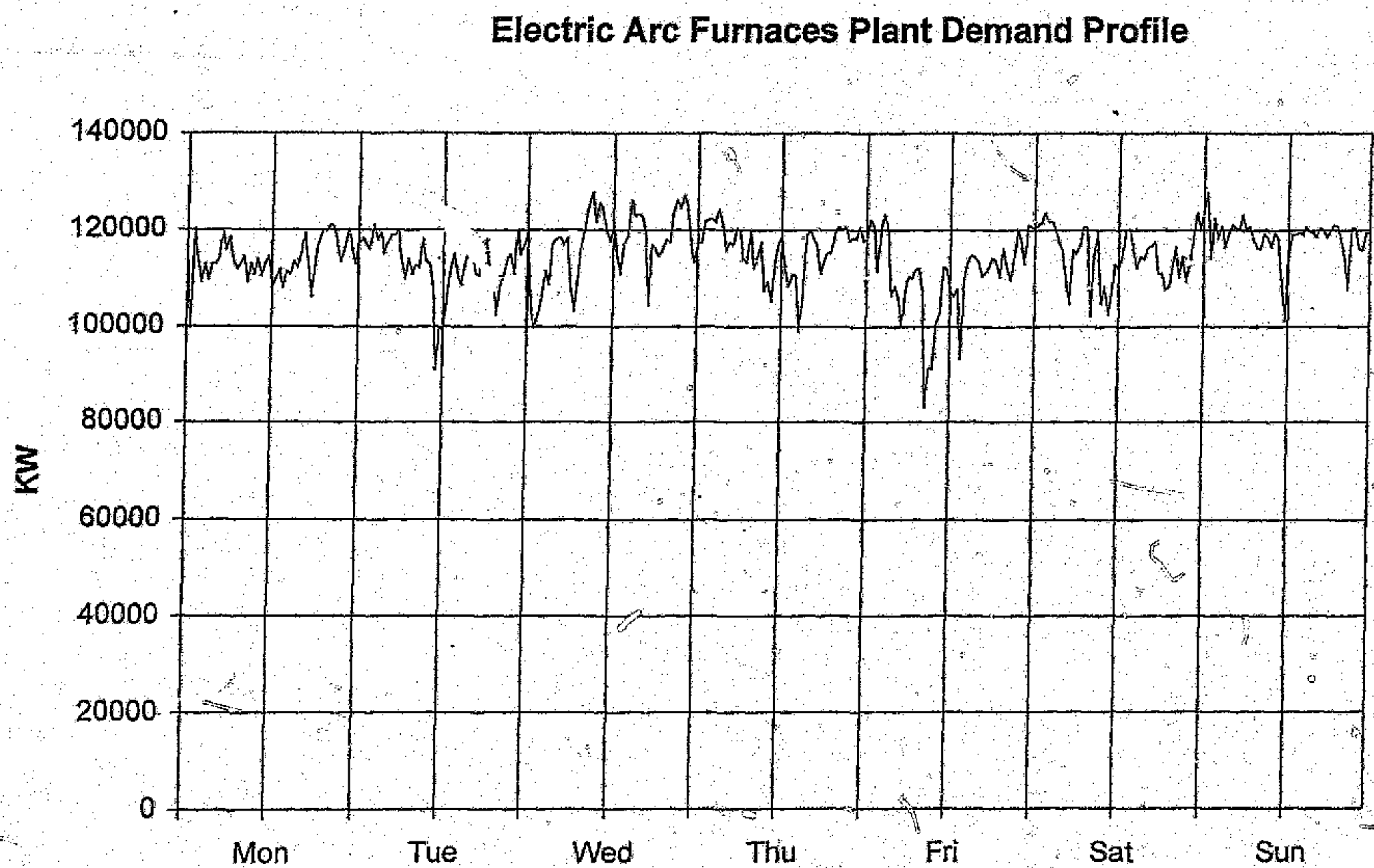


Figure 6.3 Electric Arc Furnace Plant Demand Profile
(Source - ESKOM)

Electricity Maximum Demand Profile

Figure 6.2 shows the daily and weekly demand profile for a large integrated plant with Blast Furnace/Basic Oxygen Furnace (BF/BOF) route for Steel making. Figure 6.3 gives the profile of a plant using a Electric Arc Furnace process.

Figure 6.2 illustrates demand for the BF/BOF route. Although the load factor is high for this plant, the thermal load supplied by electricity is relatively low, and most of the demand is for motor loads. Hence the load fluctuates throughout the day and during the week, depending on the mix of products being produced. The high base load is indicative of the attempt which has to be made to keep basic metal production and heating levels relatively continuous throughout the period for the large fossil - fired furnaces.

From Figure 6.3, for electricity demand by the EAF route , it can be noted that the although the thermal demands in this process are not as onerous as in the blast furnace/BOF route, the load can be managed for consistent demand. In the case of this example, the plant is operated throughout the weekend at the same level as during the week, and benefits from the off-peak Tariff E, which provides *"free megawatts"* during weekends and at night, subject to a minimum average energy charge.This is covered in Section 9, and demonstrated in Table 9.3.

6.1.5 Potential Future Electrical Technology Impacts

* The use of plasma for smelting and producing reduction gases has potential at approximately 2,5 - 2.6 MWh/ton of molten steel. Some work has been done in SA by Mintek and in Sweden by SKF on this, and was also reported by EPRI. (Granville, Stanko and Freeman, 1990; EPRI, 1987a)

* Additional use of EAFs in South Africa in mini-mill form in the 1990's would be new in RSA although it would not be rated as new technology internationally. With reasonable availability of DRI or scrap metals this has been identified as a distinct possibility. To be economic, mini-mills require access to sufficient scrap iron by the SA iron & and steel industry, which implies importation of scrap, or sponge iron production by DRI. Since initiating this report, the latter has been the purpose for a new plant as noted in Engineering News (1995b).

  A mill for production of 1,2 million tons of steel coil per annum has been proposed by the Industrial Development Corporation and Iskor for the Saldanha area, using Sishen-produced iron ore, i.e. approximately 600 GWhours per annum, or 90 MW. Sponge iron from the Iskor Corex process is planned for refining using a twin- shell EAF process, thin slab continuous casting, and hot strip rolling. No scrap will be required, but pelletised iron ore will be imported from Brazil. (Engineering News, 30 June 1995, Vol 15, No 25) This project has been controversial because of its location in an ecologically sensitive area. Although delayed through demands for additional environmental impact evaluation, the project has received approval to proceed.

* Preheating of scrap through induction heating has been reported as having potential, as does reheating of metal during the downstream processing and working of the metal. (EPRI,1987b)

* Additional use of EAFs in integrated steel mills to replace alternative routes like BOF, would represent a major change in energy and electricity consumption patterns.

6.2 FERRO CHROME PROCESSING

6.2.1 General

South Africa has ample reserves of chromite. There is also a largely unexplored reser··e in the UG2 deposit in the Transvaal bushveld complex, where chromite concentrates can be produced as a by-product of platinum.

6.2.2 Basic Processes

Reduction of the ore has been undertaken by a number of available routes. The submerged electric arc furnace has been extensively used. A DC transferred arc plasma furnace was already in use in SA from 1983, which was subsequently uprated from 16 MVA to 40 MVA in 1987. This was reputed to be the world's largest installation at the time. (Garz, 1992)

Th· finely ground chromite is pelletised and reduced to 70% metal c··tent in the kiln.

Pilot studies based on the Solid State Reduction of Chrome (SRC) developed by Showa Denko in which a rotary kiln reduction stage precedes smelting in a submerged arc furnace, uses run of mine fines and moved into commercial application. Mining Weekly (1996) reported use of two 33 MVA submerged arc furnaces at a Rustenburg plant for production of charge chrome. The CODIR or Chrome Direct Reduction (CDR) process which uses run of mine with high carbon content in a very high temperature rotary kiln to attain 90% pre-reduction has also been demonstrated.

Rotary kilns also represent a substantial motor load, as indicated in Table 2.1, 21% of electricity in the ferro-chrome sector is consumed in mechanical processes.

6.2.3 Specific Electricity Consumption for Ferro-chrome

There has been a substantial growth in South Africa of the ferro-chrome industry. Various methods of production have been applied. The range of specific electricity consumption levels for these processes were taken from a study undertaken by Granville, Stanko and Freeman, 1991. .

From Table 6.2 it can be noted the less electricity intensive method is the Japanese Solid State Reduction of Chrome or SRC by Showa Denko. The smelting stage is in a submerged arc furnace and is preceded by a rotary kiln reduction stage, at 2.7MWh per ton.

It has been reported that in Japan this process has been implemented such that it requires only 2 MWh/ton, of which 1.7 MWh is used in the furnace and 0.3 MWh in auxiliaries (Granville, Stanko and Freeman, 1991)

Table 6.2 Specific Electricity Consumption for Ferro-chrome (1990)

PRODUCTION PROCESS	MWh/TON	ESTIMATED kTONS PRODUCED
Submerged arc (open top) (closed top)	4,3 4,2	800
Solid State Reduction of Chrome + pre-reduction	2,7	200
Codir/Chrome Direct Reduction + pre-reduction (new)	1,5	-
DC Plasma arc (transferred arc)	4,5	100

6.2.4 Electricity Demand Characteristics

Electrical Energy

Figure 6.4 shows the historical growth in demand for electrical energy in GWh since 1980. This demonstrates the cyclic nature of the product demand in the world market, into which the majority of the SA production is exported.

The world depression in 1981/82 is reflected in the low level of demand for ferro-chrome and hence electricity for its production that period. New capacity was rapidly built up in SA since the mid-1980s as world demand and prices grew for ferro-chrome. Many other countries followed a similar path to achieve low cost production capacity. As can be seen from Figure 6.4, for much of 1992 and 1993, South African capacity was not in production because of world oversupply, low demand and hence a collapse of prices. The figure shows the renewed electricity growth in 1994, as the turn around of demand and prices in 1994 took effect.

Large additional capacity has been committed for 1995 and 1996. Chrome Resources increased chrome pellet production to feed four Chromecorp arc furnaces with a present capacity of 280 000 tons of ferro-chrome, and two additional EAFs planned for 1996, which will raise production to 440 000 tons per year. Samancor switched production from silico-manganese and ferro-manganese in existing furnaces in 1995, Tubatse slag recovery was being increased from 10 000 tons to 30 000 tons, and a new 50 000 tons a year plant would be commissioned at Ferrometals during 1995. A doubling of Chromecorp production within the next few years was being considered by their executive (Robinson, 1995a, b, c).

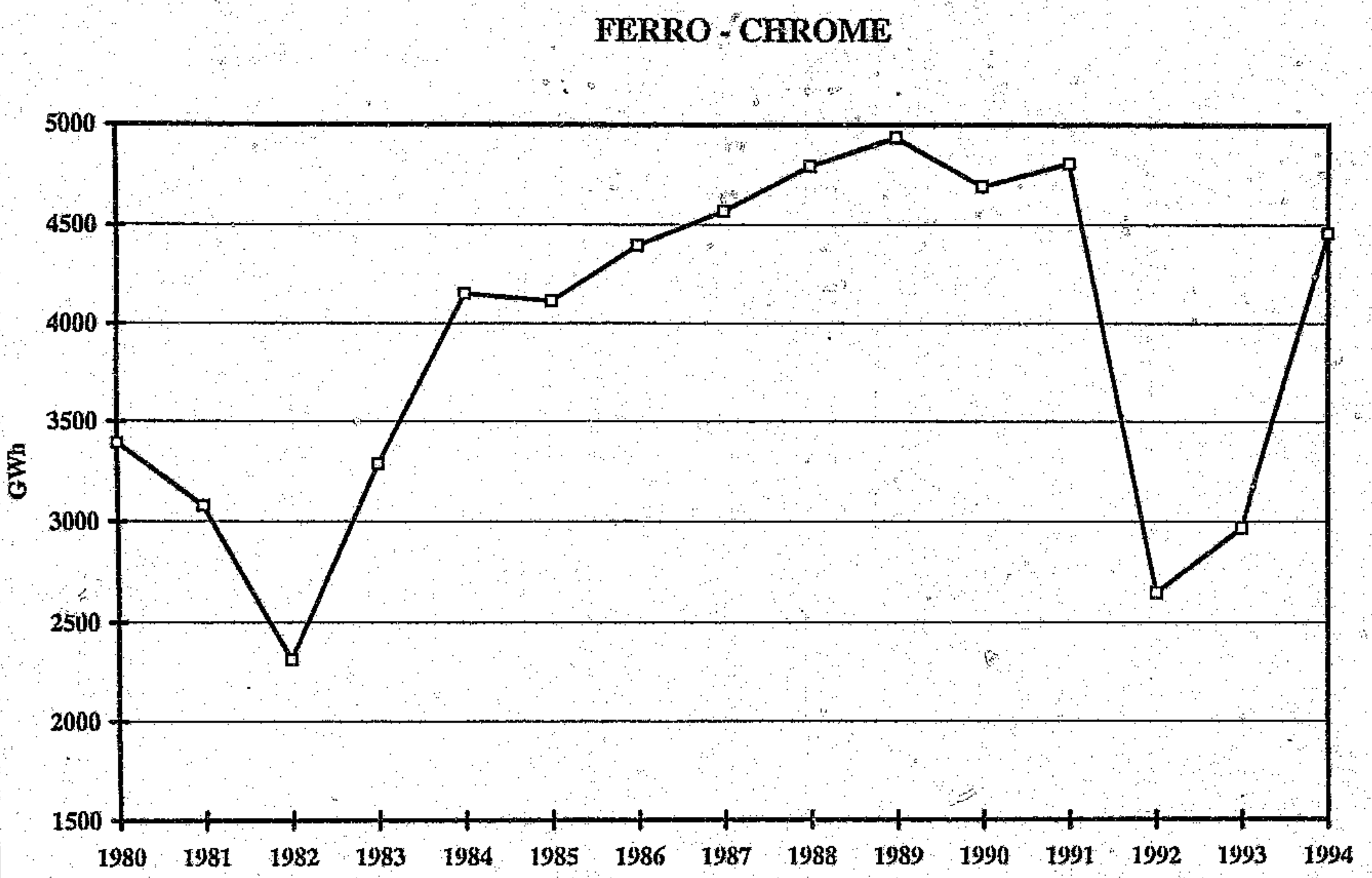
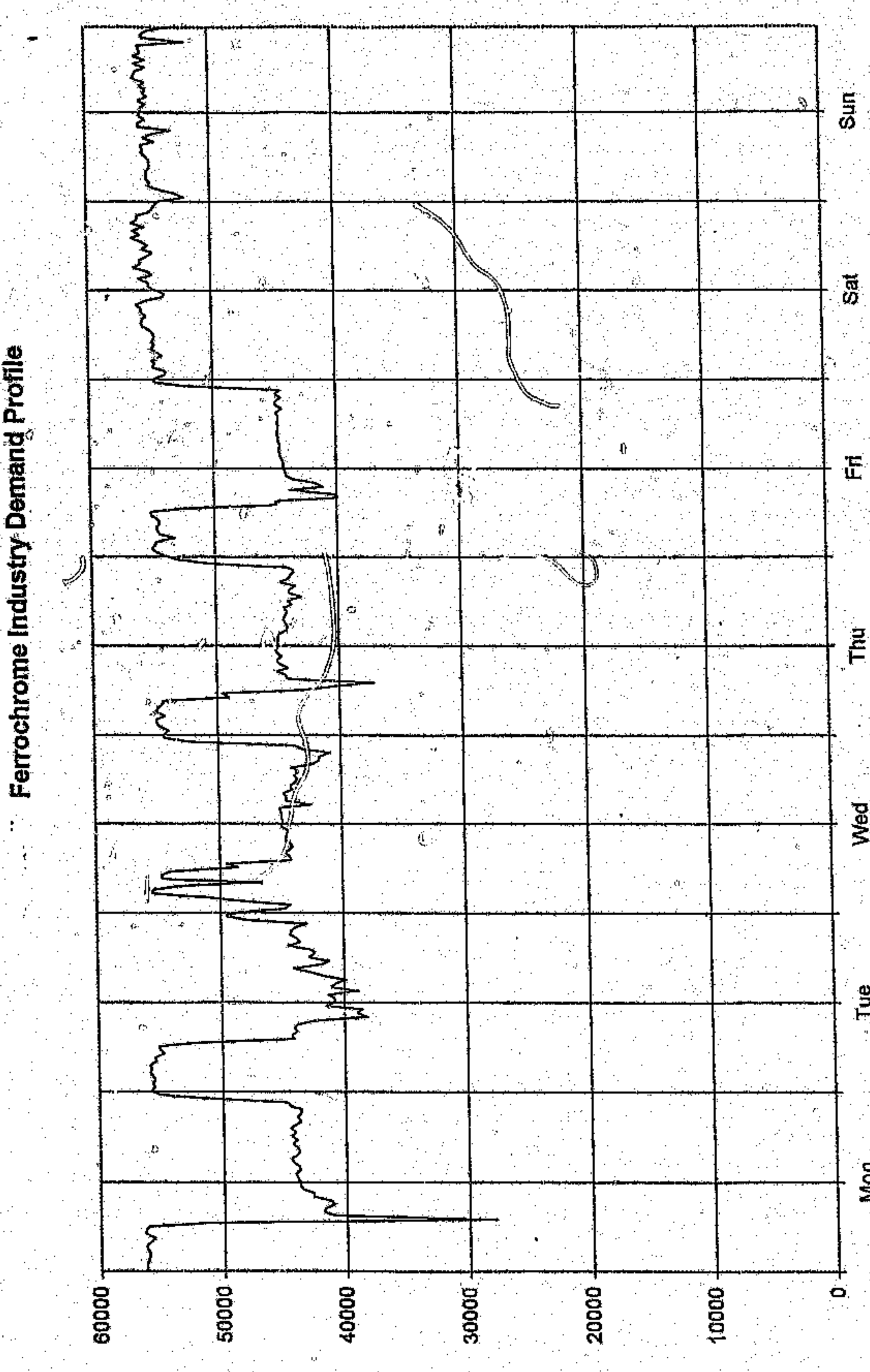


Figure 6.4 Electricity Consumption for Ferro-chrome
(Source - ESKOM)

Figure 6.5 Ferro-chrome Producer Demand Profile
(Source - ESKOM)



Electrical Maximum Demand

Figure 6.5 shows the daily and weekly maximum demand profile of a typical ferro-chrome producer. The consistently high load factor is indicative of the productivity required of such a plant in order to maintain operating temperatures.

The high night time and weekend load levels are directly influenced by the use of ESKOM's Tariff E, which allows demand charge free operation for specified periods at night and over weekends. The electricity pricing structure offered by ESKOM is described more fully in Section 9. The fluctuation in load in a day is substantial, of the order of 15 MW on a base of 40MW in the example shown. The electrical load is determined by the operating capacity of individual furnaces in a multi-furnace operation.

6.2.5 Potential for Future End-use Electrotechnology

Innovative technologies like plasma arc furnaces were reported as having the potential to find favour over the longer term (EPRI, 1987a; Granville and Freeman, 1991). The experience in South Africa of a major 40 MVA installation using DC transferred arc technology, and Mintek's registered patents in this technology, might well confirm this as a preferred future technology for replacement and new investment in the future.

Submerged arc furnaces of more efficient design have also been identified as being in the offing. Their application would be very dependent on new plant being built in a period of recovery of world demand for ferro-chrome especially for use in stainless steel. The capacity referred to by Robinson (1995c) was for commissioned plant comprising two 30 MVA, one 33 MVA and one 39 MVA submerged arc furnaces, which produced 280 000 tons per year of ferro-chrome. Additional capacity from two more arc furnaces would increase output to 440 000 tons per year.

Historical projections suggested scope for doubling the 1990 base of production of some 1,1 to 2.1 - 2.4 Megatons of ferro-chrome by 2000 (Granville and Freeman, 1991). Developments in South Africa, with announcements of new plans in 1995 and 1996, suggest that this projection is not unrealistic.

The risks remain of periodic worldwide overcapacity in this commodity. The aspiration of each producer is to be the low-cost producer which remains in profitable operation despite price declines. Electrical end-use technology is key to achieving this.

Because of fluctuations in world demand, the need for production flexibility has taken design of plant toward several smaller furnaces rather than a few large units. In this way, a complete unit can be shut down to reduce production throughput, instead of operating a large unit at lower capacity and efficiency according to Samancor (Engineering News, 26 July 1996). This could influence demand growth and load profiles by introducing smaller step changes in demand.

6.3 FERRO-MANGANESE PROCESSING

6.3.1 General

South Africa has very substantial reserves of manganese ore. There has been progressive decline in the use of ferro-manganese in steelmaking due to direct use of the manganese ore. The primary use for ferro-manganese has been for its favourable properties imparted to the metal in steelmaking. Very small quantities are involved, namely approximately 5kg per ton of raw steel.

6.3.2 Basic processes

Low grade ferro-manganese used to be mainly reduced from manganese ore in blast furnaces. The preferred technology of recent times has been submerged arc electric furnaces.

An advantage of the electrotechnology route has been that the high carbon ferro-manganese or the ferrosilico-manganese could be produced in the same furnace by changing the input feedstock.

6.3.3 Specific Electricity Consumption

The estimated production of ferro-manganese and ferrosilico - manganese for 1990 shown in Table 6.3 were extracted from the study by Granville, Stanko and Freeman (1991).

Table 6.3 Specific Electricity Consumption Ferro-manganese (1990)

PRODUCT	MWh/TON	TONS (10^6)
Ferro-manganese	3,0	0,3
Ferrosilico manganese	4,5	0,3
Average Total	3,4	0,6

By 1993 the local capacity for production had increased to 700 000 tons of Ferro-manganese, and 420 000 tons of ferrosilico-manganese. By 1994 the production capacities for these materials had reached approximately 1,1 million tons per annum. Rapid capacity expansion and periodic underutilisation of capacity has characterised this cyclic commodity industry.

6.3.4 Electricity Demand Characteristics

Electrical Energy

Figure 6.6 shows the growth since 1980 to 1994 of electrical energy for this industry sector. The cyclic nature of the industry is shown. This is dependent on international and local commodity demand has noticeable economic cycles.

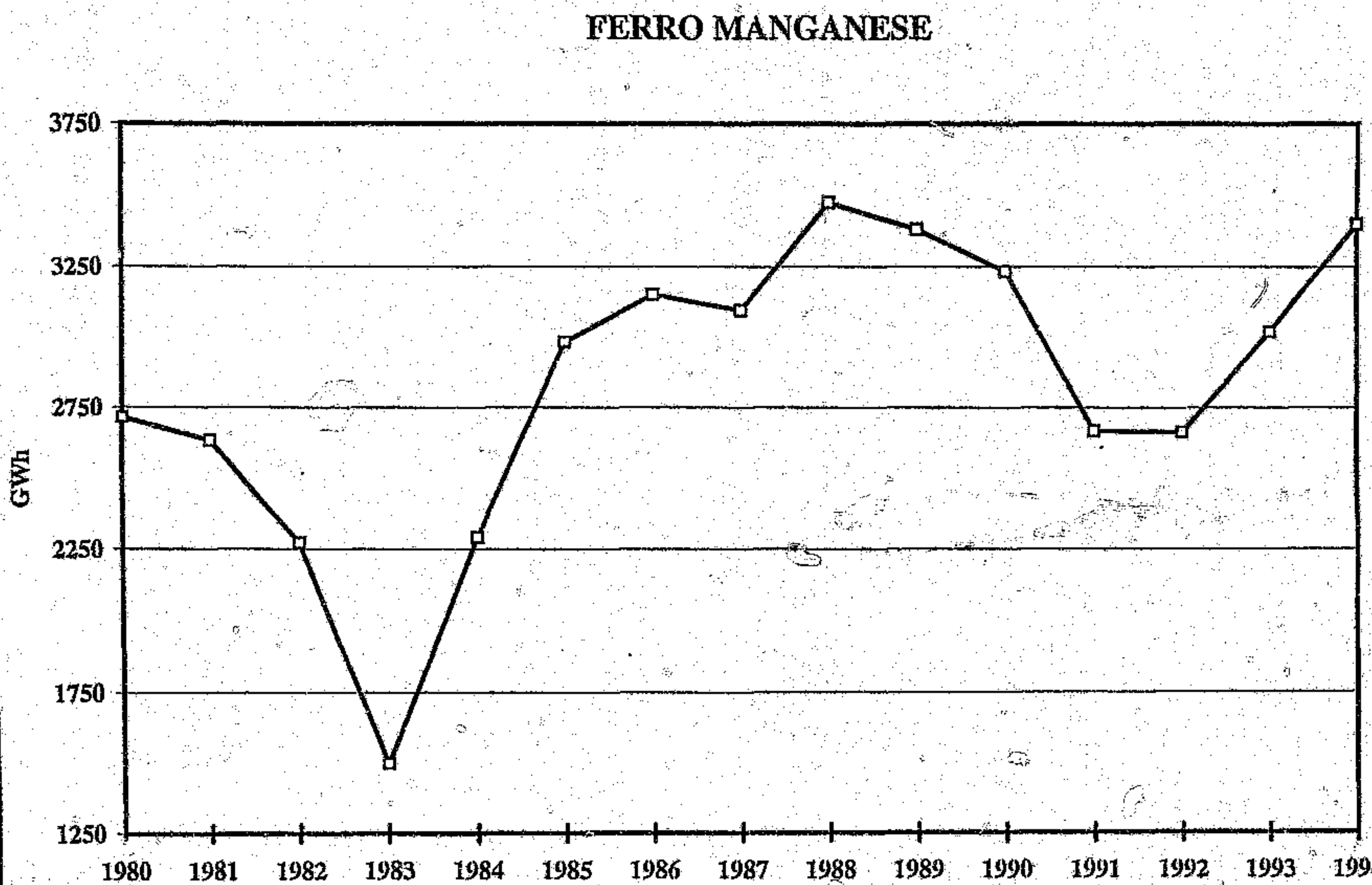


Figure 6.6 Electricity Consumption for Ferro-manganese
(Source - ESKOM)

There were sharp declines in electricity consumption in 1983 and 1991/1992 when world demand for ferro - manganese reduced. Growth over the period before 1991 was from new arc furnace capacity which was installed, as well as increased throughput of existing capacity.

The large size of individual installations contributes to the large steps on commissioning of new plant or turning down existing plant. For example a single DC transferred arc plant installed in the country is 10.8MVA capacity. An operational plasma arc furnace uses 3.8 to 4.5MWh/ton of metal.

6.3.6 Potential for Future Technology

Increased penetration of advanced technologies like plasma transferred arc, in a "boot furnace" which reduces vapour loss of manganese has been postulated (Garz, 1992; EPRI 1985.).

6.4 FERRO-SILICON PROCESSING

6.4.1 General

The main use of ferro-silicon has been as a deoxidiser in steelmaking and for slag treatment in extraction of valuable elements. There has been a substantial export market for this product as well as a market in South Africa for local consumption in steel making, such that 50% has been exported in the past. (Granville and Freeman, 1991).

6.4.2 Basic Processes

The material is normally reduced in submerged arc furnaces, as very high temperature is needed. A two stage process is used to reduce the dioxide to the required element.

6.4.3 Specific Electricity Consumption

The estimated specific electricity consumption for the production of ferro-silicon is shown in Table 6.4, derived from the report by Granville and Stanko (1990).

Table 6.4 Specific Electricity Consumption for Ferro-silicon (1990)

PRODUCT	MWh/ton	Quantity
Ferro-Silicon	* 9,6	90 000 t

* Average consumption varies across the range of Ferro-silicon:-
9 - 11 MWh for 75% Ferro-silicon
5 - 8 MWh for 45% "
3.5 MWh for 25% "
(Granville and Freeman, 1991)

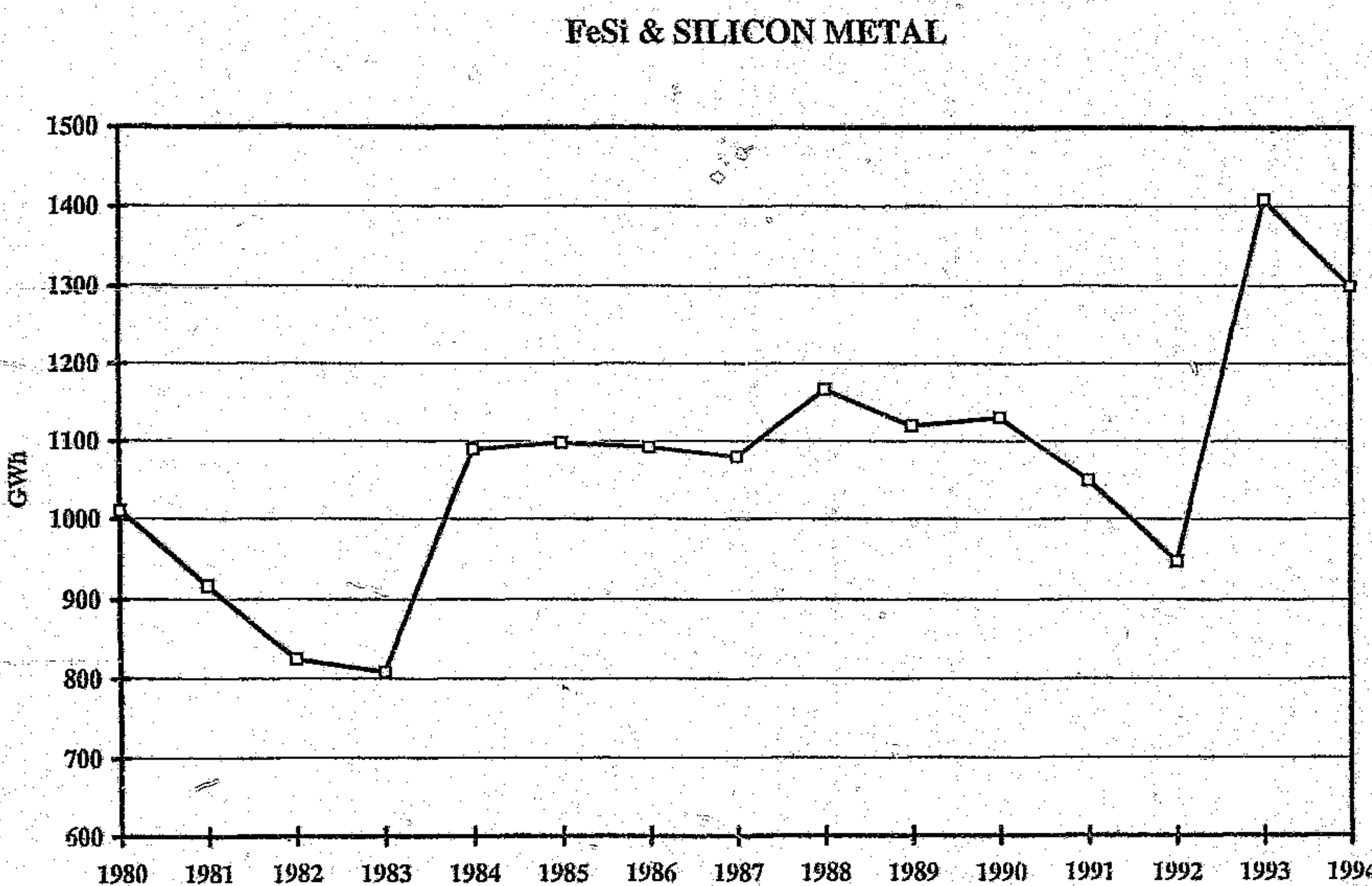


Figure 6.7 Electricity Consumption for Ferro-silicon and Silicon Metal (source - ESKOM)

6.4.4 Electricity Demand Characteristics

Electrical energy

Figure 6.7 depicts GWh consumption in electrical energy since 1980. The cyclic demand for energy reflects the world and local economic cycle in demand for steels and hence for ferro-silicon, as has been previously discussed for ferro-chrome and ferro-manganese.

Growth has been in physical plant, and in substantial levels of change of capacity use of that plant to serve export markets. The three Samancor furnaces total 98 MVA (Minerals Bureau,1989). The Samancor Ferro-silicon plant at Witbank has an electrical capacity of 48 MVA for 26 000 tons of product per year (Metal Bulletin Monthly, August 1990).

Electricity Maximum Demand

Data on daily and weekly demand profiles of a typical installation in this sector were not available, as plants produced mixed products, and measurements were not available made of individual plant performance.

6.4.5 Estimated Capacity of Major Plant

There are relatively few producers of Ferro-silicon in South Africa. These include Rand Carbide with 55 000 tons per annum capacity, Silicon Smelters which concentrated on silicon metal, and Ferrometals, a Samancor plant. In the relatively depressed demand of the 1990's, South African demand was only 40 000 tons, hence many of the furnaces were not operating.

In 1992/1993 a new entrant to the sector converted a Natal facility with two arc furnaces from the production of calcium carbide to production of ferro-silicon to enter this sector. Capacity was created of 65 000 tons for export. Installed capacity of electric arc furnaces in this sector in 1990 was 226 MVA (Granville and Freeman, 1991). New production capacity was announced in 1996.

6.4.6 Potential for Future Technology

Some potential exists for the use of plasma technology due to the high temperatures required. Such plant has been installed in Canada to make silicon and ferro-silicon. Refined versions of the electric arc furnace for new future plant will also be relevant (Garz, 1992; EPRI,1985).

6.5 STAINLESS STEEL PROCESSING

6.5.1 General

South Africa's stainless steel production in 1990 was of the order of 120 000 tons. World production was approximately 12 million tons, i.e SA production was only 1% of world total. All the raw materials and infrastructure especially electricity have been available locally for SA to be a successful world competitor.

Hence the commitment made by private sector investors to build a world-class plant such as Columbus is in line with this opportunity.

Planned annual capacity of Columbus has been reported as 350 000 in 1996, 600 000 tons by 1999. There are prospects of increasing this to over 1 million tons after the turn of the century. With Iskor developments in stainless steel, the RSA should be the sixth largest stainless steel producer in the world. (Doke, 1995)

6.5.2 Basic Process

The electric arc furnace has been the dominant thermal technology in use for stainless steel production, especially to avoid contaminating products. Special alloys of varying levels of carbon, chrome and other elements are used to achieve various grades of stainless steel.

Mechanical processes for material handling, rolling use conventional motor drives.

6.5.3 Specific Consumption

The estimated electricity consumption per ton of stainless steel at various stages of processing is given in Table 6.5. (Granville and Freeman, 1991)

Table 6.5 Specific Electricity Consumption for Stainless Steel

MWh/ton	Process
0,6	Smelting
0,17	Hot Strip Mill
0,23	Losses.
1.00	Total

6.5.4 Potential Future Technology

No major new technologies have been proposed. However potential exists to extend the industry with more production for export, e.g. the Columbus project. In a project of the magnitude of Columbus, the application of technologies to enhance productivity such as electric element pre-heating of parts of the process, e.g. tundishes, and induction heating of ladles which were proposed in studies like that of EPRI (1984b) have been realised. Electronic process and drive control have been extensively applied.

6.6 ALUMINIUM PROCESSING

6.6.1 General

Imported alumina is used in South Africa for production of aluminium at Alusaf in Richards Bay.

Until 1996, Bayside with 170 000 tons capacity was the only RSA primary production plant. In 1988 South African production was only 1% of the world total. Relatively little aluminium was exported, approximately 30 000 tons per year, as the product was focussed on local manufacturing needs. The upgrades planned for Bayside will increase capacity to 200 000 tons (Bridge,1995). Initial capacity in 1971 was 50 000 tons (Mechanical Technology, 1994).

The extensions to Alusaf at the new Hillside site at Richards Bay are expected to raise the electricity demand to 800 MW in order to produce an additional 466 kton per year of aluminium, primarily for export. The pot lines are claimed to be the largest in the world, with 579 cathodes located in four pot rooms, each nearly one kilometre in length (Engineering News, 28 July 1995 p59). This was commissioned in mid-1996.

6.6.2 Basic Process

Alumina is electrolysed in molten sodium aluminium fluoride. The operating temperature is about 1000º Celsius. The original process which was developed by Hall and Herault in 1886, is a direct current submerged arc process.

The dominant production cost element is electricity, which produces heat through direct current flow through the electrolyte. The aluminium is reduced from an ionic state to a metallic state, and it forms a molten pool at the bottom of the cell, which has to be drained periodically.

The submerged carbon anode is consumed in the process. Gas which is produced in the process is partially used for heating. Secondary processes such as casting, rolling and extrusion are predominantly motor driven.

Recycled scrap in small volumes is smelted in electric induction furnaces.

Casting at plants other than the integrated plant at Alusaf have used non-electricity intensive processes e.g. reverberatory furnaces to smelt scrap and primary aluminium.

6.6.3 Specific Consumption

Substantial research has been published internationally on the highly competitive aluminium industry. Electricity suppliers have had to compete on price to attract aluminium plants. Innovative electricity tariffs have been structured for the special nature of these high base load plants, e.g Bonneville Power Administration (USA), and more recently ESKOM.

These tariffs have been linked to internationally published market prices for aluminium in a risk sharing mode to reduce electricity prices when aluminium prices are low, and to increase the price of electricity when aluminium prices are high (EPRI,1988).

Specific electricity consumption is given in Table 6.6.

Over a ninety year period of technology maturity, the specific electricity required for the primary stage has dropped from 50 MWh/ton to less than 15 MWh/ton, as shown in a figure derived from Brenner by Granville, Stanko and Freeman (1993). The modifications at Alusaf Bayside will increase current throughput from 120kA to 165kA DC. The decline in specific consumption from 15kWh/kg to 13 kWh/kg is at the top of world standards.

Table 6.6 Specific Electricity Consumption for Aluminium Processing

ALUMINIUM PLANT PROCESS	MWh/TON
Electrolytic Production Ancillary Equipment	15,0 1,5
SUBTOTAL FOR PRIMARY	16,5
Rolling and Ext[illegible]on Metal Powder and De-oxidant Production	0,9 to 1,3 0,7 to 1,4
SUBTOTAL FOR SECONDARY	1,3
TOTAL	17,6

(From Granville, Stanko and Freeman, 1993)

It appears that local production is rapidly reaching and even exceeding international best practise.

6.6.4 Electricity Demand Characteristics

Electrical Energy

Figure 6.8 of GWh growth from 1980-1994 shows the energy demand pattern of a progressively upgraded plant operating at capacity. A further large "step function" growth for increased production capacity over the life of the plant will occur with the start of the modified Alusaf Bayside and new Hillside plants.

Electricity Maximum Demand

Unfortunately detailed data has not been presented which would exhibit the continuous operation of the plant, which is essential to maintain thermal characteristics of the metal.

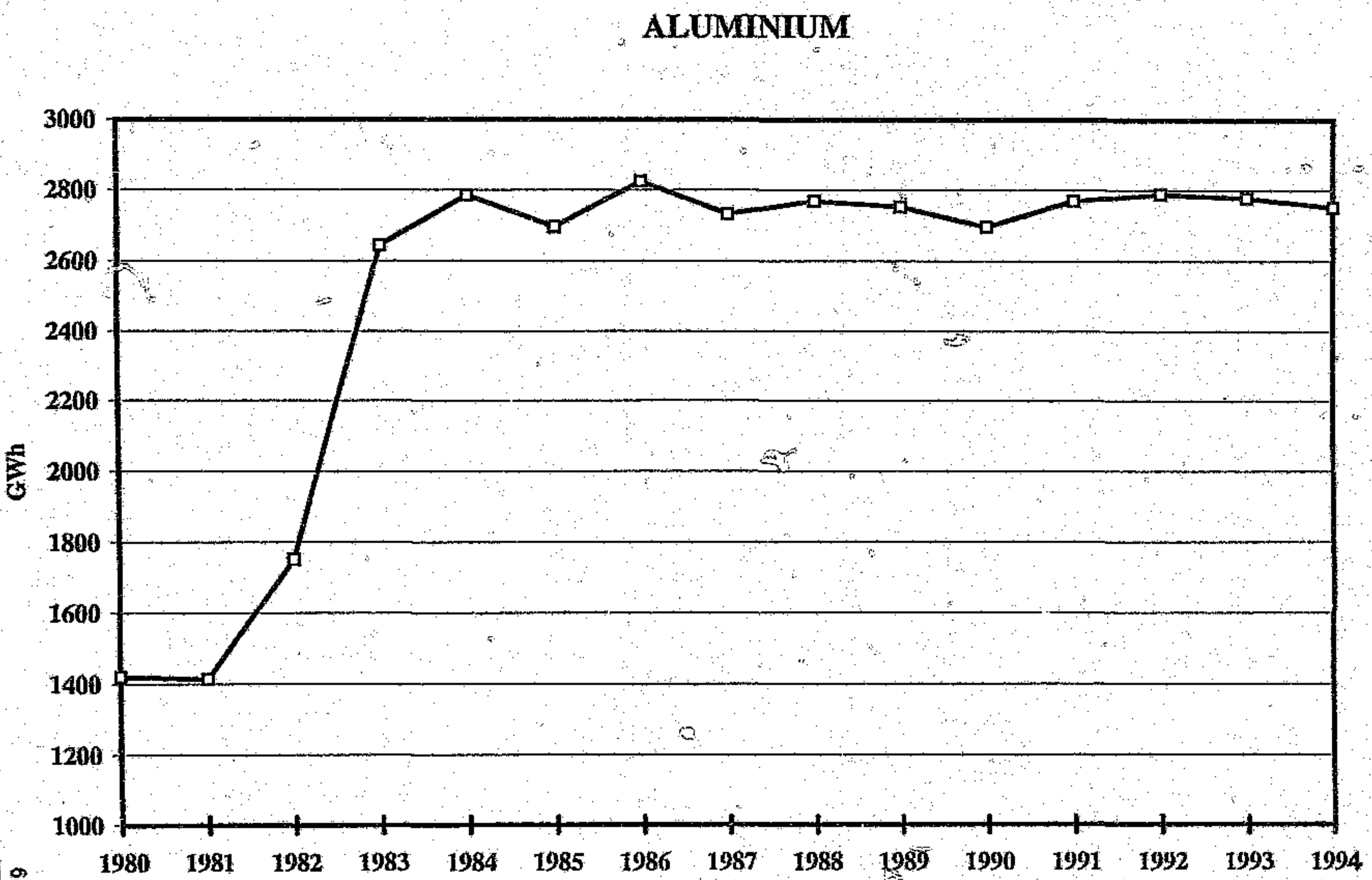


Figure 6.8 Electricity Consumption for Primary Aluminium
(Source – ESKOM)

6.6.5 Estimated Capacity of Major Plant

Alusaf is the dominant plant for primary production and currently comprises two pot lines at the Bayside Smelter, each of 100 MW capacity. The ancillary plant capacity is estimated at 50 MW.

New capacity at the Hillside plant will be 800MW (Engineering News, 23 June 1995, p7).

6.6.6 Potential Future Technology

Electrical efficiency has been a driving force in technology development. More efficient smelters have reached 14,5 kWh/kg and are working toward 13kWh/kg (Granville, Stanko and Freeman, 1993).

Internationally developers such as Pechiney and Alcoa have been working on refinements. It was widely reported in company press releases that SA has committed to the technology from the world leading French company, Aluminium Pechiney, for the production of 466 000 tons at the Hillside extension for Alusaf (Bridge, 1995).

Plasma technology has been tested on aluminium scrap recycling using nitrogen as the plasma gas, achieving throughput of some 200 - 250kg per hour (Garz,1992).

6.7 OTHER NON-FERROUS MINERALS PROCESSING

Under this heading, titanium extraction from beach sands, which is currently produced in titanium slag form, manganese metal and magnesium metal deserve special mention.

6.7.1 Titanium Slag

Current SA Situation

Richards Bay Minerals reached a production level of approximately 600 000 tons of titanium slag per annum primarily for export by 1992. The beach sands in the St Lucia coastal area of Natal have been mined in a stripping operation. The beach sands comprise up to 65% of heavy metals which contain titanium dioxide (TiO_2) but much is bonded with ferric oxide in ilmenite form. The rutile contains as much as 95% TiO_2.

Ilmenite is upgraded by electrothermal process, removing the iron as pig iron. A sulphate *or a chloride process* can be used on slag that contains 86-95% TiO_2. (The sulphuric acid effluent in the sulphate process has lead to the USA not building such plants since 1970.) The chloride process requires higher grade rutile ores such as found in SA. (EPRI,1985a)

The ilmenite concentrate is reduced in submerged arc electric furnaces to form titanium slag containing 86 to 95% TiO_2. Titanium dioxide pigment can be produced from the slag.

7 NON - ME;ALLIC MINERALS PROCESSING SECTOR

7.1 GLASS

7.1.1 General

The glass-making industry is fairly energy intensive, with specific energy consumption of 12,2 GJ/ton (Sater, 1990). By comparison, steel requires 21 GJ/t and ferro-chromium 73 GJ/t.

The main types of glass products made in SA are containers, flat glass and safety glass. Some speciality products are made.

The cost of energy in production is in the range 10 - 20 % of the input cost, hence there is reason for care in the choice of energy.

In 1995, PFG Building Glass indicated that a R500 million glass float manufacturing line was still under consideration to upgrade its competitive position. Provision was being made for installation of an electric melting process to increase output by 5 000 ton per year, as well as to reduce atmospheric pollution (Engineering News 15 June 1995, p6). In 1996, large new glass developments have been announced by Consol, a producer of container glass in South Africa, in which R150 million will be spent on new furnaces and increased automation (Engineering News, 8 September 1996, p6).

7.1.2 Basic Process

The following process for glass making has been summarised from the report by EPRI (1982).

Raw materials are batch mixed in dry or nearly dry form, comprising :
glass sand, for the SiO_2 which is previously crushed, washed and screened,
soda ash ($NaCO_2$),
limestone for CaO,
feldspar ($R_2OAl_2O_26SiO_2$)
and other elements for e.g. colouring, oxidising.

Melting takes place at temperatures of $\pm$ 2700° F ($\pm$ 1500°C). This temperature is a compromise among the need to remove seeds of entrained air and inclusions, to reach a sufficiently viscous state, and to cap the cost of energy.

Cullet, or recycled glass, can be added to this process as a means of reducing energy needs, as it aids in the chemical process of converting $CaCO_3$ to CaO. As high as 90 % cullet can be used, although 40 % is more usual - limited by the available recyclable supply of glass.

Melting is the most energy intensive stage, taking 70 to 80 % of total energy. Furnaces in SA typically use synthesis gas, producer gas, or liquid fuels.

There are also some all-electric furnaces in use.

6.7.3 Magnesium Metal

A view has been expressed that future prospects exist for production in SA of magnesium metal at a level of 10 ktons/year by the turn of the century. This would require 9 MWh/ton of metal, viz. 90 GWh, at an estimated 13 MW, using plasma arc technology (Granville and Stanko, 1992; Granville and Freeman, 1991).

7 NON - METALLIC MINERALS PROCESSING SECTOR

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limestone for CaO,
feldspar ($R_2OAl_2O_26SiO_2$)
and other elements for e.g. colouring, oxidising.

Melting takes place at temperatures of $\pm$ 2700° F ($\pm$ 1500°C). This temperature is a compromise among the need to remove seeds of entrained air and inclusions, to reach a sufficiently viscous state, and to cap the cost of energy.

Cullet, or recycled glass, can be added to this process as a means of reducing energy needs, as it aids in the chemical process of converting $CaCO_3$ to CaO. As high as 90 % cullet can be used, although 40 % is more usual - limited by the available recyclable supply of glass.

Melting is the most energy intensive stage, taking 70 to 80 % of total energy. Furnaces in SA typically use synthesis gas, producer gas, or liquid fuels.

There are also some all-electric furnaces in use.

Some use is also made of electrically-boosted furnaces. In the latter, electrodes in the bottom or the wall of the furnace produce strong convection currents, increasing output by up to 40 %. The homogeneity of the melt is also improved.

Non-electric furnaces in use in SA are end-port reverberative, cross-fired regenerative, and recuperative furnaces (Sater,1992).

The regenerative furnace , designed by Sir William Siemens in 1856, was a breakthrough in allowing continuous melting operations with a high thermal efficiency. Interestingly, the process requires the melt to be stirred from the bottom using inert gases, as the heat is applied from the top. The "upside down " nature of the process stimulated the search for a more effective method of glass melting to meet the higher quality needs of specialised container manufacture.

The *electric furnace* satisfies many of these needs. It was demonstrated as long ago as 1880, by direct discharge of electric current through glass, and melting it in the process. The electrically boosted furnace is a compromise between the conventional and the electric furnace. (EPRI, 1982)

Molten glass is cooled to 2350ºF. The fining step uses approximately 10 % of the energy, and homogenises the melt. It is then distributed to the forming stage of the process.

Forming of the viscous glass at temperature of 1500 to 2000ºF is done by moulding, pressing, rolling, blowing as needed. Fining and annealing stages follow, in which gas is often used.

Progressively the fining process has been converted to electricity, using electrodes in the forehearth of the furnace. Annealing in electric kilns/tunnels/lehrs is also more commonly used than previously for quality and controllability. Temperatures are ± 900ºF.

Product specific variations occur to cater for flat glass vs say, containers or fibre glass.

7.1.3 Specific Electricity Consumption for Saleable Product

The summary of specific electricity consumption in Table 7.1 was derived from Sater (1990), and partially updated by Granville (1995).

Because of the small number of producers of certain categories of glass products in South Africa, and their confidentiality requirements, further disaggregation of Table 7.1 is not possible.

Energy per unit of production has declined from 19.10 GJ/t in 1970 to 11.8 GJ/t in 1990. The relative contribution of electricity has increased over this period. Electricity represented 25% of net energy use in 1990, compared with just 16% in 1984 and 13.5% in 1970 (Granville, 1992a).

Table 7.1 Glass Production Specific Energy and Electricity Consumption (1990)

PRODUCT	%	ktons	GJ/t	GWh	GWh/t
Non-flat - various	75	574	11,0	507	0,88
Flat glass	16	120	14.1	43	0.36
Other glassware	(9	(69	12.0	7	(1.25
Safety & fibre glass	(-	(-	14.1	79	(-
TOTAL	100	763	11.8	636	0.83

The USA glass industry (EPRI, 1982) produced 15 million tons of container glass, which was 70% of the total; flat glass 15%; pressed and blown ware 12%; and fibres 3%. Melting takes 65 to 75% of total energy and furnaces of the order of 75 to 480 tons per day were in use. Trends have been to smaller plants of ± 160 tons per day for container glass, located near the user of the containers in order to reduce transport and other distribution costs.

The change in specific energy and electricity consumption is influenced by the technologies in use and their efficiency as well as the product mix being produced. From the available information presented above, it appears likely that there has been a shift toward the lower energy intensive production items, as well as efficiency of production in South Africa.

7.1.4 Electricity Demand Characteri 'cs

Figure 7.1 shows the electrical demand of a typical glass manufacturer with electrode furnaces. The loading and reloading cycles influence the pattern of consumption, which is kept high to maintain efficiency and throughput.

7.1.5 Potential for Future Electrotechnology Impacts

The key technologies of interest are the all-electric furnace, the electrically boosted furnace , and associated process control equipment. Their introduction has been linked to a commitment to higher quality product and productivity improvements. Some influence from environmental considerations may have an effect, as the electric furnace allows better energy efficiency, reduced waste material, and control of waste gases. (EPRI,1982)

The size of batch needed for manufacturing has affected the use of the electric furnace, as the size has been limited to + 100 tons/ day. As the market moves to smaller, more flexible production plants, and possibly the use of glass ribbon for later reprocessing and lamination into containers etc., size is not a limiting factor. The latter, coupled with the ability of electric melting to provide higher temperature melting would transform the industry into a far more electricity intensive industry. It would be limited mainly by the comparative costs of energy forms, especially natural gas vs electricity. (EPRI, 1982)

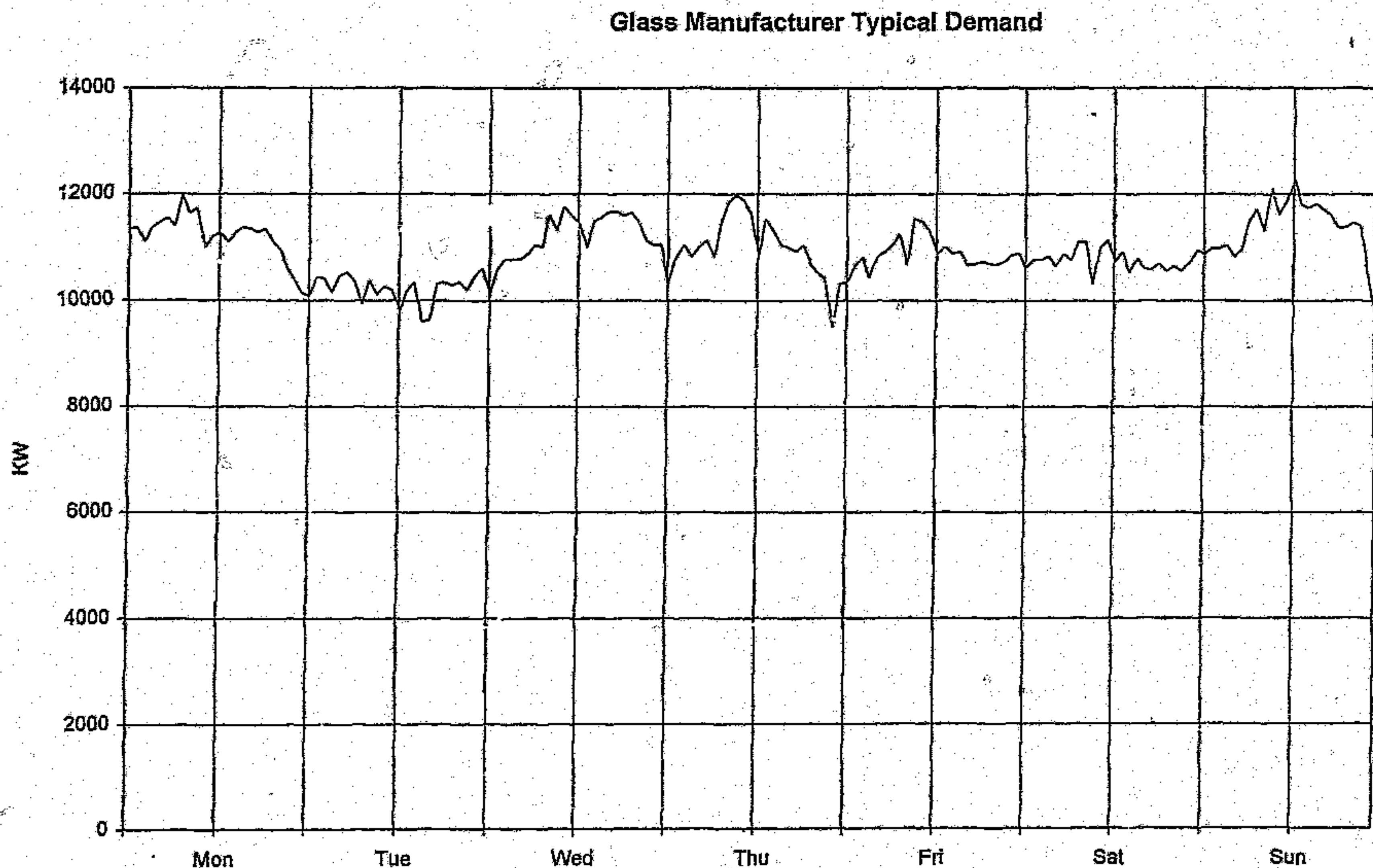


Figure 7.1 Glass Manufacturer Typical Demand
(Source - ESKOM)

The strength of laminated glass could lead to a reduction of the mass of glass used in a container.However such processes as *dielectric* heating of the product may then also be required, increasing the electricity intensity of production. *Laser* treatment for specialised containers during critical parts of the strengthening stage also offers benefits.

Speciality container glass, flat glass for automotive applications, where laminated and specially formed glass is increasingly used for aerodynamic enhancements, and fibre glass manufacturing are thus likely areas of increased electrotechnology applications.

Heat recovery for e.g. co-generation, to use the waste heat of the melting process may become attractive, if environmental impact considerations are seriously enforced.

7.2 CEMENT

7.2.1 General

SA has a substantial cement industry, built up over the early development years of the country and reaching a peak in the early 1980's. In 1990 only 63% of capacity was in use and major plant was in mothballs, as the infrastructure growth post-1985 did not materialise. With improved outlook in South African infrastructural growth, mothballed plant is being restored to service and additional capacity is being planned (Creamer T, 1995b).

Most of the electricity consumption is in materials handling, crushing, and milling.

7.2.2 Basic Processes

Subsequent to the mining process, limestone is crushed, finely ground and blended with additives. This blend is heated in a kiln to ± 1500ºC. The fusion reaction produces clinker cement.

Two types of process are used - the "wet" kiln is fed with a slurry of water and ground material, and the water is evaporated; the "dry" kiln has no water added to the process. This is an energy intensive process, requiring between 3 500 and 5 000 MJ per ton. In addition the electric power required to drive the kiln is 50 to 60 kWh per ton. This is primarily used for driers, dust control equipment and large suction fans.

Wet processes are no longer used in South Africa, as water supply limitations exist in many of the locations at which cement plants are located. The energy cost in evaporation in the "wet" process is also a large input cost, in a very cost-conscious industry.

The final stage is grinding the clinker and blending it with gypsum to produce Portland cement. This may also include blending in of fly ash or slagment, for specific applications.

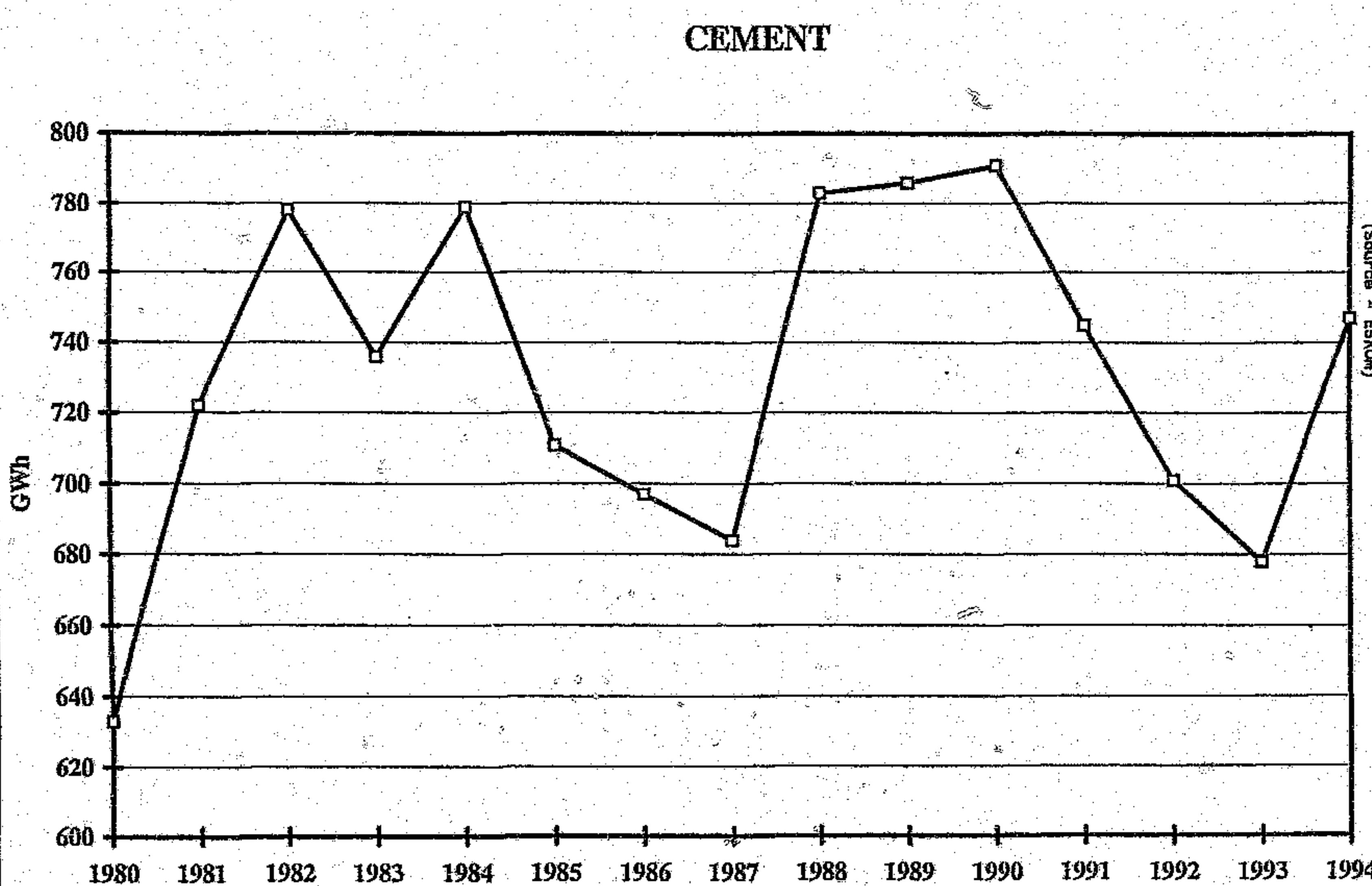


Figure 7.2 Electricity Consumption for Cement
(Source - ESKOM)

7.2.3 Specific Electricity Consumption

The range of specific electricity consumption per unit of production is shown in Table 7.2 (* : Average or norm excluding wet process).

Table 7.2 Specific Electricity Consumption in Cement Production

PROCESS	Energy MJ/t	Electricity %	kWh/t
Grinding	72 - 90	100 %	20 - 25
Fusion *	3500 - 5000	-	-
Evaporation	2370	-	-
Kiln operation	100 - 216	100 %	50 - 60
Clinker grinding	126 - 180	100 %	35 - 50
TOTAL	4000 - 5000		105- 135

7.2.4 Electricity Demand Characteristics

Electrical energy for major cement producers is shown in Figure 7.2. Due to the nature of fragmented data sources, the lack of a statutory reporting mechanism, and because most of the smaller cement producers are served by municipalities which do not collate this type of information complete data is not available (Cooper, 1993). The figure shown is that of direct ESKOM customers only. The figure shows the varying use of capacity in the country in a cyclic fashion typical of commodity markets.

7.2.5 Potential for Future Electrotechnology Improvements

Unless some *cost effective* electrical process for the fusion heating of the limestone mix is established, no profound change in the electricity intensity of the process is likely. Should this occur, the demand for electrical energy would change substantially.

Energy efficiency improvements through CHP (combined heat and power) has been reported as having potential. International best practice has shown electricity consumption as low as 70 kWh/ton, ranging up to a high of 104 kWh/ton, i.e. with no shift toward a more electricity intensive process in view (Sater, 1992). Thus the electricity consumption in this sector in likely to follow capacity of production and future new capacity for resumed growth for the economy in South Africa. Some potential exists for export growth.

7.3 CERAMICS

7.3.1 General

This section covers pottery, china, earthenware and special ceramics.

Products in this industry have been grouped into Ceramic tiles, Sanitaryware, Industrial ceramic products, Ornamental pottery, China and tableware and Other unspecified.

Energy represents some 15 to 23% of operating cost in the ceramics industry and is therefore an important input cost as well as being closely coupled to product process and quality concerns (Sater, 1992).

7.3.2 Basic Processes and Technologies

The common processes used are firing and glazing, in the temperature range of 1000 to 1500°C. The usual material handling requirements exist requiring motors, and air quality control hence needing extraction fans etc.

Kiln technology development has led to the use of coal, oil and gas-fired tunnel kilns in SA, and also some electric "top hat " kilns, especially in the manufacture of porcelains. These latter kilns use electric element heaters.

The cycle time for a typical gas fuelled kiln is 13 hours, and for an electric kiln, 24 hours. However newer fast-firing electrical top-hat kilns have reduced this time by as much as two thirds (Thermopower Furnaces S.A. Ltd, "TEMPO" technical brochure).

7.3.3 Specific Electricity Consumption

The table of sector specific consumption was developed from the report by Sater (1992), and is shown as Table 7.3.

Table 7.3 Specific Consumption of the Ceramics Sector

PRODUCT GROUP	KTONS PA	GWh PA	MWh/t
Ceramic tiles	149	60	0.4
Sanitary Ware	27	31	1.2
Industrial ceramics	40	42	1.1
Ornamental pottery	2	5	2.5
China and tableware	16	56	3.5
Other - unspecified	52	13	0.3
TOTAL	286	206	0.7

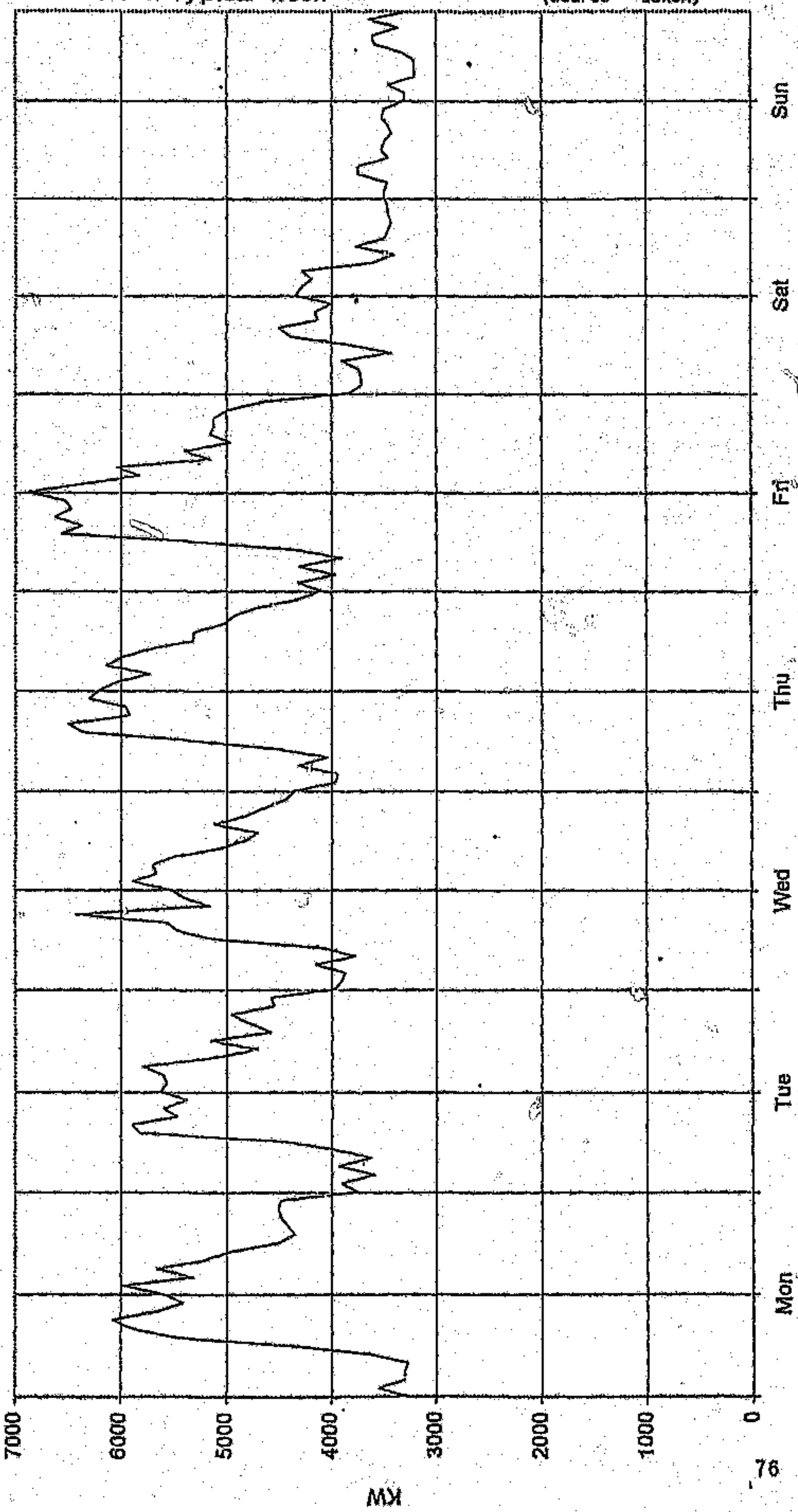
This is a very competitive industry. Importation of many of these products is eroding local manufacturers markets. Introduction of better quality , niche market products, may change the energy and electricity profile.

7.3.4 Electricity Consumption Characteristics

Figure 7.3 shows the load profile of a large integrated ceramics producer with significant numbers and sizes of top-hat kilns.

The heating and process cycles are relatively long, and occur relatively at random intervals, hence leading to no specific peaks during the time of normal national system peaks. By planning, consumption at off-peak periods at night and at weekends could be arranged for the best cost of electricity on ESKOM's Tariff E.

Figure 7.3 Load Profile of Large Integrated Ceramics Producer with Significant Numbers and Sizes of Top Hat Kilns for a Typical Week (Source - ESKOM)



7.3.5 Potential for Future Electrotechnology Impact

The electrical kiln has been the key technology. Increased use of electrical kilns for ceramics appears possible.

The performance characteristics of the kilns have been primarily aimed at reducing product cycling or turnaround time to speed up throughput and hence productivity of the investment. Two thirds reduction in such turnaround times have been achieved with a combination of convection and radiation firing. For a unit with an 800kg capacity, 100kW for 5 hours has been claimed by Thermopower Furnaces S. A. (Pty) Ltd, a South African manufacturer for their "TEMPO" range. This represents an 11% reduction on the sector average, and a 42 % reduction on the specific consumption for industrial ceramics (refer Table 7.3).

Some potential was suggested for use of electric arc furnaces, and microwave sintering for industrial ceramics (EPRI,1982). Industrial ceramics have not grown to a large sector in SA yet, advanced capabilities were established for the nuclear and armaments industries which could develop into leading edge manufacturing in the future. This area of materials has been widely reported as being a future growth area world wide. Even with development, this may not become a very large electricity consuming sector, due to low specific electricity consumption levels.

7.4 OTHER NON - METALLIC MINERALS

7.4.1 General

Within this grouping a range of non-metallic minerals and products are found, such as lime, cement, graphite products, gypsum plaster, asbestos cement, concrete products, and stone and slate products.

7.4.2 Basic Processes

Lime

Calcining at temperatures of ± 1300°C for lime, but only 1600°C for gypsum are needed.

Graphite

Carbonising at ± 1200°C in gas kilns is normal for graphite, in a 10 to 15 day cycle; followed by graphetising at ± 3000°C, using electric kilns on a 5 - 7 day cycle.

Gypsum and Cement

Lower temperature operations for drying and curing are in the range 140 to 180°C for gypsum and asbestos cement.

Concrete Products

Steam curing at ± 55°C is used for concrete products.

Stone and Slate Products

Sawing and polishing are the main processes for stone and slate products. Electric motors are used extensively.

7.4.3 Specific Electricity Consumption

To enable a comparison of the electricity intensity within the sector to be made, Table 7.4 was derived from the report by Sater (1992).

Table 7.4 Sector Specific Consumption of Other Non-Metallic Minerals Sector

MINERAL & PRODUCT	ELECTRICITY % OF ENERGY	ENERGY GJ/t	ENERGY % OF COST	MWh/t
Lime	4	10	50	0.11
Graphite	*	*	*	5.07
Gypsum	*	*	*	0.10
Asbestos	52	*	*	0.43
Concrete	17-43	0.5	2-7	0.04
Stone & Slate	100	0.5	5	0.14

Note : * not available for release for confidentiality reasons

7.4.4 Electricity Demand Characteristics

Specific per sector information is regrettably not available.

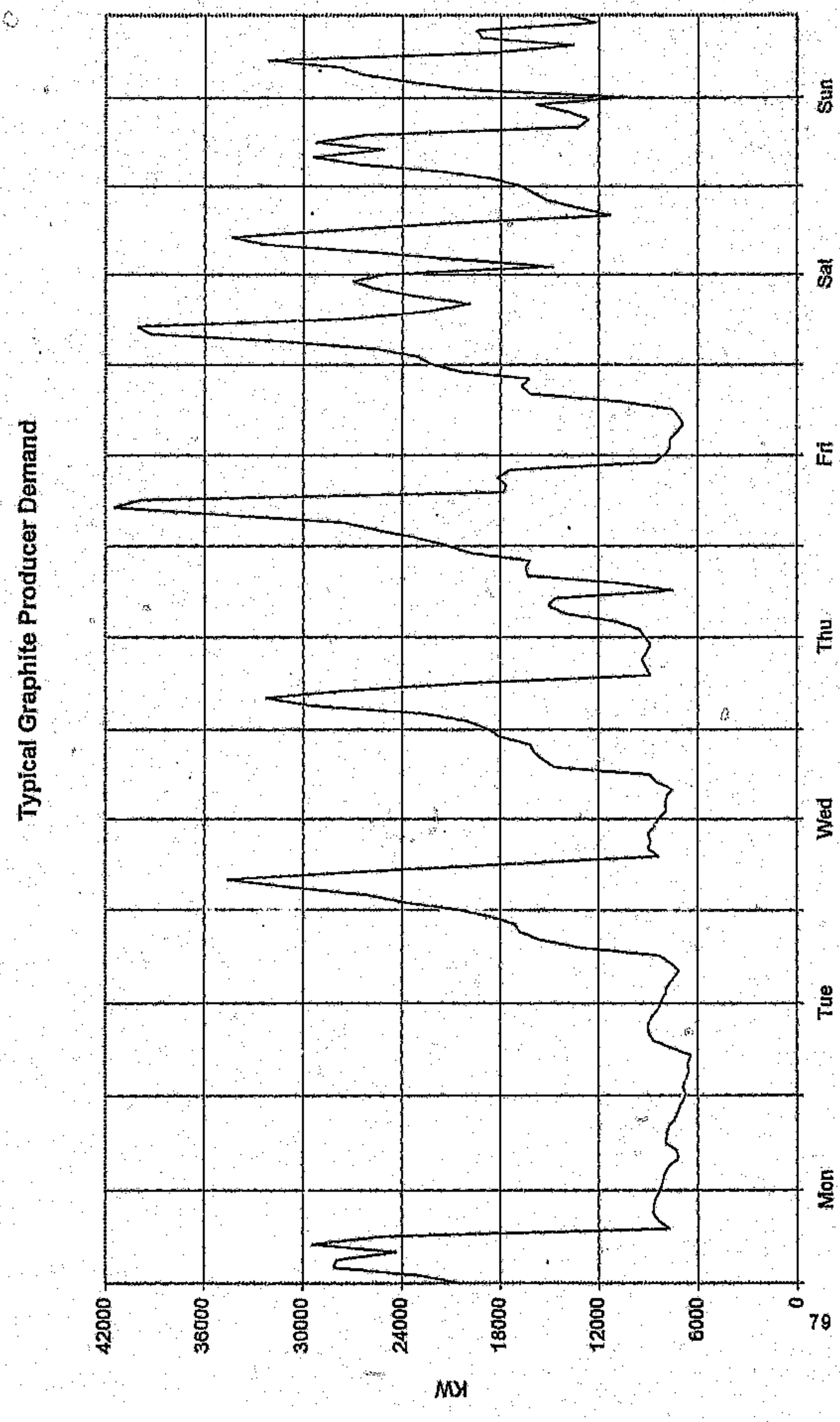
However a typical *graphite producer* has been included as Figure 7.4 because of the electricity intensity and size of the process, the high night time peaks, and the weekend high load level. The pattern demonstrates the cyclic nature of the process as kilns are loaded and unloaded over this period.

The use of Tariff E and the Time of Use Tariffs influenced this industry, as off-peak periods at night and over weekends represent substantial savings in electricity costs (Section 9). Although demonstrating a poor load factor, the timing of kiln operations would not impact the national peak demand period.

7.4.5 Potential for Future Electrotechnology Impacts

Other than for graphite production, electrical heating applications are not well represented in this sector, whereas gas and coal are used extensively. Partial drying/curing by heat pump at low temperatures is feasible, and some element heating could apply.
In some cases, microwave or RF drying might have some impact, especially for increased efficiency of heating processes. The capital involved in these low electricity intensive industries may not make investment in RF or microwave technology attractive in the short term, especially at relatively low alternative energy prices.

Figure 7.4 Typical Graphite Producer Demand Profile for a Typical Week (Source - ESKOM)



8 KEY CHARACTERISTICS OF APPLIED ELECTROTECHNOLOGIES.

8.1 INTRODUCTION

For convenience of the discussion to follow on the important applied end-use electrotechnologies, Table 8.1 has been constructed from selected extracts of Table 2.1 to highlight the proportion of each major end-use of electricity in the mining, metals and non-metallic minerals sectors.

Table 8.1 Electricity End- Use in the Selected Sectors of Mining and Minerals (GWh) (1990) (Cooper, 1992)

SECTORS	HEAT	MECHAN-ICAL	CHEM-ICAL	LIGHT-ING	TRANS-PORT	NON ENERGY	TOTAL
Coal Mining	120	2 042	0	63	1	0	2 226
Metal ore Mining	676	3 756	282	231	0	342	5 287
Gold Mining	3 297	19 923	0	667	149	0	24 036
Diamond Mining	46	831	0	40	0	0	917
Other Mining	139	1 183	0	70	0	0	1 392
Mining TOTAL	4 278	27 735	282	1 071	150	342	33 858
%	12,6	81,9	0,8	3,2	0,4	1,0	100,0
Ferrous basic Metals	10 081	3 251	1 827	365	0	15	15 539
Non-ferrous basic Metals	539	865	2 373	223	0	1	4 001
Metals TOTAL	10 620	4 116	4 200	588	0	16	19 540
%	54,4	21,1	21,5	3,0	0	0,1	100,0
Pottery	135	110	0	12	0	57	314
Glass	268	149	0	46	0	0	463
Other non-metallic minerals	239	2 703	1	97	1	1	3 042
Non-metallic TOTAL	642	2 962	1	155	1	58	3 819
%	16,8	77,6	-	4,1	-	1,5	100,0
Sectors TOTAL	15 541	34 813	4 483	1 814	151	416	57 217
%	27,2	60,8	7,8	3,2	0,3	0,7	100,0

Table 8.2 Electricity End-Use in the Selected Sectors of Mining and Minerals (GWh) (1991) (Cooper, 1993)

SECTORS	HEAT	MECHAN-ICAL	CHEM-ICAL	LIGHT-ING	TRANS-PORT	NON ENERGY	TOTAL
Coal Mining	199	2 058	-	83	41	-	2 381
Metal ore Mining	641	4 063	358	181	-	555	5 798
Gold Mining	2 556	18 828	-	606	783	-	22 773
Diamond Mining	49	845	3	67	-	5	969
Other Mining	146	1 241	-	73	-	-	1 460
Mining TOTAL	3 591	27 036	361	1 010	824	560	33 381
%	10.8	81.0	1.1	3.0	2.5	1.7	100.0
Ferrous basic Metals	7 394	5 886	2 560	757	-	12	16 609
Non-ferrous basic Metals	3 216	573	162	106	-	1	4 058
Metals TOTAL	10 610	6 460	2 722	863	-	13	20 668
%	51.3	31.3	13.2	4.2	-	-	100.0
Pottery	118	76	-	13	-	40	246
Glass	504	280	-	87			871
Other non-metallic minerals	175	2 493	1	172	-	28	2 869
Non-metallic TOTAL	797	2 849	1	272	-	68	3 986
%	20.0	71.5	-	6.8	-	1.7	100.0
Sectors TOTAL	14 998	36 344	3 084	2 144	824	641	58 035
%	25.8	62.6	5.3	3.7	1.4	1.1	100.

Table 8.3 Electricity End-Use in the Selected Sectors of Mining and Minerals (GWh) (1993) (Cooper, 1995)

SECTORS	HEAT	MECHAN -ICAL	CHEM -ICAL	LIGHT -ING	TRANS -PORT	NON ENERGY	TOTAL
Coal Mining	223	2 033	-	123	29	-	2 408
Metal ore Mining	395	4 997	71	189	858	-	6 510
Gold Mining	2 332	18 543	-	918	575	-	22 368
Diamond Mining] Other Mining]	74	1 288	3	104	9	-	1 478
Mining TOTAL	3 024	26 860	74	1 334	1 471	-	32 764
%	9.2	82.0	0.2	4.1	4.5	-	100.0
Ferrous basic Metals	11 007	4 243	1 403	617	3	-	17 273
Non-ferrous basic Metals	2 919	245	86	69	-	9	3 329
Metals TOTAL	13 926	4 488	1 489	686	3	10	20 602
%	67.6	21.8	7.2	3.3	-	-	100.0
Glass	456	313	-	74	-	-	843
Pottery &] Other non-metallic minerals]	305	2 474	43	183	1	7	3 012
Non-metallic TOTAL	761	2 787	43	257	1	7	3 855
%	19.7	72 3	1.1	6.7	-	-	100.0
Sectors TOTAL	17 711	34 135	1 606	2 277	1 475	18	57 221
%	31.0	60.0	2.5	4.0	2.6	-	100.0

A comparison of the key sector totals for 1990, 1991 and 1993 from Tables 8.1, 8.2 and 8.3 is shown in Table 8.4.

Table 8.4 Comparison of Electricity End-Use 1990, 1991 and 1992
(GWh)

SECTOR	HEAT	MECHAN -ICAL	CHEM -ICAL	LIGHT -ING	TRANS -PORT	NON ENERGY	TOTAL
Mining TOTAL 1990 %	4 278 12,6	27 735 81,9	282 0,8	1 071 3,2	150 0,4	342 1,0	33 858 100,0
Mining TOTAL 1991 %	3 591 10.8	27 036 81.0	361 1.1	1 010 3.0	824 2.5	560 1.7	33 381 100.0
Mining TOTAL 1993 %	3 024 9.2	26 860 82.0	74 0.2	1 334 4.1	1 471 4.5	– –	32 764 100.0
METALS							
Metals TOTAL 1990 %	10 620 54,4	4 116 21,1	4 200 21,5	588 3,0	0 0	16 0,1	19 540 100,0
Metals TOTAL 1991 %	10 610 51.3	6 460 31.3	2 722 13.2	863 4.2	– –	13 –	20 668 100.0
Metals TOTAL 1993 %	13 926 67.6	4 488 21.8	1 489 7.2	686 3.3	3 –	10 –	20 602 100.0
NON-METALLIC							
Non-metallic TOTAL 1990 %	642 16,8	2 962 77,6	1 –	155 4,1	1 –	58 1,5	3 819 100,0
Non-metallic 1991 TOTAL %	797 20.0	2 849 71.5	1 –	272 6.8	– –	68 1.7	3 986 100.0
Non-metallic TOTAL 1993 %	761 19.7	2 787 72.3	43 1.1	257 6.7	1 –	7 –	3 855 100.0
SECTORS TOTAL							
Sectors TOTAL 1990 %	15 541 27,2	34 813 60,8	4 483 7,8	1 814 3,2	151 0,3	416 0,7	57 217 100,0
Sectors TOTAL 1991 %	14 998 25.8	36 344 62.6	3 084 5.3	2 144 3.7	824 1.4	641 1.1	58 035 100.0
Sectors TOTAL 1993 %	17 711 31.0	34 135 60.0	1 606 2.5	2 277 4.0	1 475 2.6	18 –	57 221 100.0

Comparing the tables for the period 1990 to 1993, the relationships of end-use for electricity do not s[illegible] major differences relative to the accuracy of the data collection. The use of the 1990 data for comparison with EPRI data in this report should be reasonable.

8.2 MAJOR MOTOR SYSTEMS

It was shown in Table 2.1 that the predominant use of electricity across the majority of end-use sectors, namely 47%, has been in energy conversion into mechanical energy through the use of electric motors.

For the sectors covered in this report, the mechanical end-use was 60,8%, as shown in Table 8.1, and is as high as 81,9% for the mining sector. This compares closely with the American figures quoted in the EPRI report (1985a) of 70% in the industrial sector in 1985, which was an increase on the 67% achieved in 1980. In the EPRI report particular mention was made of the use of motors for three broad categories namely pumps, conveyors, fans and compressors, the broad spectrum of crushing, grinding, stamping, trimming, mixing, cutting, and milling operations, and the transport and handling of materials.

The mining sector in the USA has not been as large as the mining sector in South Africa, representing only 7% of industrial electricity consumption in 1985 (EPRI,1985a).

Partit[illegible]g of information to the level available in the EPRI (1985a) report [illegible]s not yet been achieved in South Africa. Their assessment was that in 1985, 41% of electricity for motor drives was used for pumps, fans and compressors for traditional air conditioning, and fluid processing purposes as well as the newer membrane separation technologies. Some 32% of electricity for motor drives was used for materials processing like crushing, grinding, and cutting of materials. The balance of 27% was used for materials handling by cranes, conveyors, elevators and robotics.

The largest growth in motor drive electricity consumption in the USA between 1980 and 1985 occurred in the categories for pumps, fans, compressors and in materials handling. The smallest growth occurred in materials processing, namely crushing, grinding and cutting of materials. Total electricity used for motors was 483 TWh in 1980 an[illegible] 508TWh in 1985.

Of particular note in the study by EPRI (1985a) was the rapid penetration of electronic a.c. adjustable speed drive technology which nearly tripled over the period from 4% to 11% of total electricity used in motor drives. The benefits of improved controllability and energy efficiency improvements were believed to be the driving forces for the rapid rate of growth, as the electricity efficiency figures quoted by EPRI were large, namely 5TWh in 1980 and 15TWh in 1985.

This implied an efficiency improvement of 1% and 2.9% in those years respectively through the use of electronic a.c. adjustable speed drive control. In a period of intense efforts to curb energy consumption in the USA this was very important, and would have been part of the national incentive to reduce electricity demand in an era when much of the power generation was oil fired. The benefits of these developments have spread throughout the world, and this trend should manifest itself in South Africa as well.

The technology underlying the d.c. and the a.c. motor are mature and well developed over more than a hundred years. Much refinement in design and construction has enhanced performance through materials technology for rotors, stators, insulation, and through cooling systems. South African applications technology and competence in this field has been recognised world wide.

The intense importance of very large motor drives for application in mining for ventilation, for materials hoisting and milling has had major influence in South African development of skills in this field.

Within the gold mining industry alone some 688 rotary mills are used to grind 110 million tons of ore per year. The platinum mining sector uses motors of a size such as those at the new Northam Mine where the mills use multiple 4 375kW variable speed drive a.c. machines, and the installed capacity of the 6 production winders at the two main shafts is 33 500kW. (Engineering News, 26 February 1993, p24).

With reasonable expectation of economic growth and exploitation of mineral resources and further beneficiation of those minerals in South Africa, it appears reasonable to expect that the share of electricity consumed by motors will continue to increase, and the type of efficiency and productivity improvements experienced in the USA through electronic drive control will increase.

8.3 ELECTRIC ARC FURNACES

An arc furnace is a cylindrical refractory lined vessel, with a typical diameter to height ratio of 4 to 6. The major components are the shell with a hearth lined with basic refractories to hold the charge, water cooled walls and roof panels, an electrode holding and automatic positioning mechanism to hold the correct arc length, a mechanism to remove the roof for charging, and a mechanism for tilting the furnace for tapping and deslagging.

The furnace electrical capacities range from 35MVA to 200MVA to serve capacities of 50 to 300tons. On-load tapchanging transformers are usual in the modern arc furnace, although off-load tap changing was typical in the older versions. Current carrying capacity of electrodes is 30 to 100kA and the three electrodes could range in size from 406 to 711mm in diameter.

Arc furnace regulators have been designed for computer control for best performance and productivity. Over the 20 year period 1965 to 1985 significant improvements were made to electric arc furnaces, namely tap-to-tap times were more than halved from 180 minutes to 70 minutes, electrode consumption was halved, electrical energy consumption was reduced by 25% from 630kWh/ton to 430kWh/ton (EPRI, 1987a). Many of these improvements were brought about by introducing further electrotechnologies to the electric arc furnace system, in the form of electrically preheating scrap or the metal charge in the charging bucket, and ladle furnaces. The latter examples could be element preheaters or induction heating.

The performance of the electric arc furnace and its effects on the electricity supply system has been studied extensively due to problems of "flicker" and harmonics generated when the arc makes and breaks especially during the early stage of charge melting. The Center for Materials Production (CMP) in the USA which specialises in such processes particularly for steel making established that modified operating practises in scrap handling and electrode drive into the charge could reduce the arc instability problems and hence the electrical interference (EPRI,1985b).

Design modifications have also been found to improve arc stability through reducing reactance by increasing cross section of copper connections, shortening connections from transformer to electrodes.

A Japanese design was developed with inward sloping electrodes giving a variable reactance as the electrodes were driven into the melting charge, but these were reported to be difficult to control for correct electrode geometry. (EPRI,1985)

An area of disadvantage in the use of arc furnaces for steelmaking has been the production of dust with sufficient levels of cadmium, chromium and leachable lead to be declared a hazardous material by the USA Environmental Protection Agency under the regulations of the Resource Conservation and Recovery Act. Extensive studies have been undertaken by the CMP to assist steelmakers and designers of electric arc furnaces to minimise dust production, and to manage dust disposal. (Granville, Stanko and Freeman, 1993)

The information on electricity for heat energy purposes in South Africa shown in Table 8.1 is unfortunately not available divided into the different types of heating processes. Nevertheless it does show that 27% of the electricity used in the sectors of interest is for heat energy, which is the second largest end-use application. The data highlights the substantial use of electricity for heating in gold mining, metal ore mining, ferrous basic metals and glass processing in the RSA.

Use of electric arc furnaces in South Africa was well established with the advent of the ferro-metals industry which has been a major user of the technology. Aided by extensive research by Mintech, South African producers became the worlds lowest cost producers and largest exporters especially of ferro-chrome. This prevailed until the demise of the USSR which lead to massive exports of ferrometals at very low prices in the early 1990's, and even resulted in many of the South African furnaces being shut down for extended periods.

The conventional three phase a.c. submerged arc type for smelting of ores has been used in the ferro-metals application in which an arc in the molten slag below a packed bed of ore, coke and fluxes heats the bed and it melts down into the slag. For stable operation at high currents, the three electrodes require large separation and hence large furnace diameter. The consequent low power density leads to longer residence time for the ores than the blast furnace methods that could be used in some cases.

Melting of metals has successfully used a.c. arc furnaces. In the case of metal melting the furnaces are typically charged with scrap metal to provide the conduction path between the electrodes. In the a.c. systems, three consumable graphite electrodes are used, and the arcing path can be from an electrode to the metal and from the metal to another electrode. Flux additions control the slag chemistry to ensure the correct metal composition. As was previously described, these furnaces are used with sponge iron from a DRI process or scrap steel for steel and stainless steel making, and are also used in foundries for casting (Garz, 1992c).

D.C. arc furnace systems have the advantage of eliminating flicker i.e. non-uniform current distribution, use smaller electrodes, have reduced electrode loss with the electrode used as the cathode, and allow better load balancing. They have unfortunately been more expensive than a.c. arc furnaces, and have limited power capacity compared with the a.c. systems (EPRI, 1985b).

The electric arc furnace has been in use in the USA since 1915, primarily in the steel industry for high alloy speciality steels, and since the mid-1970's also for carbon and low-alloy steels and in foundries. According to the EPRI study (1985b) 40% of electricity for heating was used in smelting, melting and holding operations for the manufacturing industry, and the balance for drying, curing and general heating. However 99.5% of electricity for heating was used in the primary metals production sector for melting.
The 1980 equivalent data were 47% and 99.5% respectively.

In this period there was a decline in total electricity used in primary metals production, which declined from 40% of process heat use of electricity in 1980 to only 33% in 1985. This was strongly influenced by the decline in USA steel making from 1977 to 1987.

Total electricity for process heat grew from 50,8TWh in 1980 to 59,2TWh in 1985, i.e. 16%. There was some growth in the stone, clay and glass products sector which compensated for the decline in metals production. Overall, electricity for heating represented 7% of total electricity in 1980, and in 1985 it was 8% (EPRI,1985b).

Comparing the South African data on electricity for heating from Table 8.1 with the USA data, admittedly for periods differing by 5 years, the RSA figure of 27% is very high relative to the 8% in the USA, confirming the large impact of primary metals and mining industry on RSA electricity consumption. (EPRI, 1985b; Cooper, 1991).

In the platinum industry, a 15MW electric arc furnace was installed to smelt flotation concentrate at 15 tons per hour, to produce a copper/nickel matt (Engineering News, February 26 1993).

In the copper industry it was recently reported (Engineering News, 17 September 1993) that a 4MVA, 60 ton electric arc furnace for production of blister copper quality product from molten copper flash furnace slag was being installed at Olympic Dam, Australia.

Unfortunately the IEA energy data (IEA Statistics, 1994; IEA Statistics, 1995) on Australia, Brazil, Canada, Poland and the former USSR, which are countries with a substantial mining and minerals base do not categorise energy by end-use, nor even by a separate mining category, for comparative purposes.

8.4 PLASMA ARC FURNACES

Plasmas are produced by exposing a variety of gases to a high intensity electric arc. Temperatures in excess of 5 500ºC can be achieved, which is well beyond the practical limits for fossil fuels. The very high temperature along with rapid heat transfer and controllability has resulted in plasma arc technology achieving a definite place as an efficient and economical means for effecting physical and chemical change in industrial materials. Predictions of the EPRI study (1988) in terms of the progression of plasma arc from the smaller scale applications in materials fabrication (welding, cutting and surface hardening) have already been fulfilled in the use of very large scale plant for titanium dioxide production.

Transferred arc and non-transferred arc systems have been developed. In a transferred arc system the one electrode is formed by the conductive material to be heated. In the non-transferred arc the arc forms between the two electrodes and heated gas is emitted. This latter form is often referred to as a plasma torch. A major advantage in the plasma arc is the production of a continuous arc which can be used for controlled heating of high intensity in a small area (Garz,1992b).

In an extensive study on the use of plasma arc for processes beyond the metals industry by EPRI (1985a) they focussed on the very high temperatures and gas used would be free of products of combustion without having to use expensive high temperature heat exchangers. Conversion efficiencies of up to 95% were quoted.

There is an important distinction to be made between the thermal or high pressure processes used in metals and minerals melting, and the low pressure or "cold plasma" systems used for example in etching of semiconductors. The latter are high frequency, low power devices in the kilowatt range.

Typically an industrial plasma processing system contains a d.c. or an a.c. power supply, a plasma gas delivery system, a reactant feed system, a product collection system, a coolant system and a control system. The field has been highly specialised and there were only 15 research and industrial organisations actively testing and 5 manufacturing plasma arc systems in 1985 (EPRI,1988). Amongst those quoted was Mintek of South Africa researching the field of ferro-alloy production. At the time the research was done, the leading torch producer was Westinghouse with a.c. and d.c. plasma torches up to 10MW.

Electrical design of importance in the plasma arc heater is to stabilise the arc and extend the life of the electrodes by rotating the arc.

By magnetically stabilising the arc with a field coil around the anode which is the outer part of the "nozzle" of the torch, the arc rotates at about 1000 Hz due to Lorenz forces on the ionised gas. Electrodes for plasma torches are usually water cooled and both copper alloy and graphite have been used. In the case of the transferred arc the single erodable electrode has typically been graphite for cases where graphite contamination is not a problem, or copper alloy where it is a problem.

South Africa has been a world leader in the application of and research into plasma arc systems. The EPRI study of 1988 into industrial electrotechnologies concluded that there were no plasma arc systems in use in the USA in 1980 nor yet in 1985, but that these would be significant consumers of electricity (4 360 TWh) by the year 2000 for steelmaking cupola retrofits, for electric arc furnace dust processing, for ferro alloy production and for direct ore reduction.

The wide range of applications in use or under test by 1992 (Garz, 1992b) indicated that plasma arc technology had found a place among electrotechnologies internationally. Uses for platinum recovery from autocatalysts (USA), melting aluminium scrap (USA), treatment of hazardous wastes (various), heating molten metal in tundishes and ladles (various), recovering zinc from zinc wastes (Italy), smelting ferro-chromium (RSA), chromite ore (Sweden), heating of blast furnaces to replace coke in iron blast furnaces (France), to quote only a few of the applications (Garz, 1992b).

In 1993 a joint venture company named Plasmatherm Services was established by Scaw Metals and the Council for Scientific and Industrial Research (CSIR) to provide plasma nitriding facilities. The plasma units available for advanced surface hardening were of 40kW and 160kW capacity (Sutton, 1993).

8.5 ELECTRICAL INDUCTION FURNACES

In induction melting an electric current is induced in a metallic conductor by coupling it suitably with a coil carrying an alternating current. The induced current heats the metal.

A key feature is that the process takes place in air at normal atmospheric pressure. Vacuum induction melting is also used. However the area of application is reserved for specialised materials such as high purity reactive and refractory metals used in aerospace applications, and production of super alloys which are nickel and cobalt-based.

A coreless induction furnace as used in steelmaking operates on the principle of a transformer with the charge acting as a single secondary turn which is heated when power is applied to the multiturn primary coil. Once the metal is molten, the electrical field causes stirring in the metal.

The frequency used can be mains frequency of 50 (or 60) Hz, medium frequency up to 1 kHz, and high frequency, above 1 kHz.

The stirring action is inversely proportional to the square root of the frequency, and directly proportional to the power. With careful selection of frequency and power, the mixing and melting rate can be designed for best technical/commercial compromise (EPRI, 1986). The introduction of increasingly reliable solid state frequency converters since the late 1960's has rapidly influenced the penetration of induction furnaces into the metals production sector. (EPRI, 1986).

Economics of melting by 1987 were such that induction furnaces operated at optimum level in the range 10 to 20 tons. Below 20 tons, induction melting was an economic alternative to electric arc furnaces, despite the electricity intensity per ton of metal which was some 10 to 20% higher in an induction furnace (EPRI, 1987a). Coreless induction furnaces have been operated at a size of 60 tons by Allegheny Ludium Steel of the USA (EPRI, 1987a).

Induction heating has also been used for channel induction furnaces where molten metals need to be held at temperature in foundries, or where scrap is to be melted. For a channel furnace a water cooled coil is constructed around a laminated magnetic steel core, with a surrounding channel formed by the refractory around the coil. The metal in the channel forms a continuous loop through the metal in the main body of the furnace.

Typically short channels of material are heated and then recirculated to a main furnace chamber. In a melter/mixer, several channel induction furnaces can be used to melt and mix different streams of metal in a large cylindrical container, such that cheaper scrap can be introduced into e.g. steel making.

At Iskor Newcastle six 2,5MW channel inductors of 1 650 tons capacity were reported to in use as a melter/mixer since 1983 with good results. Average electricity was 486 kWh per ton of scrap melted, with expectations of reducing this by 20%. (EPRI, 1988)

Principle applications of induction furnaces include the refining and holding of aluminium, copper, iron, and zinc alloys used in the casting industry, and in melting and superheating steel for subsequent processing in e.g. Basic oxygen furnaces.

The benefits of induction furnaces have been noted as follows:

* Fast start up from cold as full power is available in seconds, reducing the time to reach working temperature.
* Cold starting with limited scrap and no need for molten metal for medium frequency induction melting. Frequent alloy changes possible.
* Natural stirring action. Medium frequency units give strong stirring action resulting in homogenous melt.
* No by products of combustion, so a cleaner melt.
* Precise automated control possible.
* Long crucible life.
* Compact installation.
* Better working environment
* Energy conservation (progressive improvement over time, and 35 to 40 % more efficient than e.g. hot blast cupola).

This list of benefits supports the findings of the 1986 EPRI study into industry decision-making in converting to electrical processes.

It was found that conversion to electrotechnologies for metal melting has been driven more by the development of the technologies and the process benefits provided by these technologies rather than the relative cost of electrical energy (EPRI, 1986).

For coreless induction furnaces electrical design considerations include the provision of transformer taps to allow adjustment to input voltage as the refractory lining wears and the coupling between the crucible and the surrounding coil decreases. Profiled coil sections help to reduce eddy current losses. Compromises in coil electrical losses versus heat losses have to be made. Automatic power control to the furnace is needed to limit power consumption during operation.

Coreless induction furnace units as small as 6 tons per load under full computer control have been introduced successfully into foundries in South Africa. A 2.5ton furnace has been made available by the Atomic Energy Corporation for 140 to 150 ton/month of specialised castings. This was previously only available for in-house projects.(AEC,1996)

A few examples of substantial induction heating/melting plant installed in the RSA are:-

* Special 400 kg, dual induction furnaces with 250kW power control systems, have been installed at Richards Bay to produce molten cast iron at 1 480°C for cathode sealing at the new Alusaf Hillside aluminium smelter. (Engineering Mining News, 17 September 1993)

* Two 12.5 ton induction melting furnaces have been supplied to a highgrade stainless steel mini-mill in Durban with a 10MW inverter power supply, to ensure even pouring.(Doke, 1995)

The majority of the electricity used for heating in the mining and ferro-metals sectors in South Africa is assumed to be for electric arc furnaces, and at this stage although there is a proliferation of induction furnaces, the percentage that this represents of heating use of electricity is not certain. With the use of higher frequencies for induction furnaces which has been made possible by power electronics developments, and the ability to achieve better products and performance, the extended use of induction furnaces for the metals industry in South Africa appears likely.

8.6 ELECTRO CHEMICAL PROCESSES

Electrolytic reduction and separation are the main processes in use in the electrotechnologies of interest in this section. These intrinsically require direct current technologies of supply and end-use.

Design considerations include the stability of supply at high current levels, the rectifier configurations, filtering of the input supply and shielding of very high d.c. fields in the production plant, and electromagnetic compatibility of electronic control circuitry. These are all important for the success of this energy intensive electrotechnology.

The challenge of designing adjustable electrode systems and arc stability in the cells for effective performance, and automatic control systems to maintain operation optimally are similar in nature to the problems of the electric arc furnace discussed previously.

In electrolysis the electrical energy is changed into chemical energy. The application of electrical energy to an electrolytic cell brings about an oxidation - reduction process that would not take place of its own accord. The different conventions for voltaic cells and electrolytic cells must be kept in mind.

Although the anode is the electrode in both types of cell at which oxidation takes place and electrons enter the external circuit, in the voltaic cell it is the negative potential and in the electrolytic cell it is the positive potential. The cathode is the electrode at which reduction takes place in both cells, and is the point at which electrons enter the cell from the external circuit. In the voltaic cell the cathode is the positive potential, but in the electrolytic cell it is the negative potential.

Hence to connect the voltaic cell to the electrolytic cell for a desired reaction, the cathode of the voltaic cell is connected to the anode of the electrolytic cell, and the anode of the voltaic cell is connected to the cathode of the electrolytic cell. (In terms of potentials, the "positives" are connected together and the "negatives" are connected together.)

The predominant application internationally is in the production of aluminium in molten salt electrolysis. In the production of aluminium the electrolyte melting point is 940°C and the cell operates at 960 to 980°C by current flow from the anode of the cell through the electrolyte to the cathode. The aluminium is reduced from the ionic state to the metallic state by the electrons provided at the cathode. The molten pool of aluminium is periodically drained. Molten salt production of metals is also used for magnesium and sodium (EPRI, 1988; Garz, 1992).

The importance of this technology application in South Africa is confirmed in Table 8.1 where the predominant application in the non-ferrous metals industry is for aluminium. A total of 7.8% of electricity in the sectors of interest is used for chemical energy.

Electrolysis using aqueous electrolytes at temperatures around 100°c are also used for metals like zinc, copper,and manganese (EPRI, 1988). In the USA in 1985 40% of electricity consumption for electrolytic processes was concentrated in the metals production industries, as the technology had wide application in many other sectors such as waste stream treatment in the chemical, paper and pulp and textile industries.

Separation and concentration of elements dissolved in an electrolyte with a separating membrane are also used in the category of electrochemical technologies. In the USA 38% of electrical energy for electrochemical application was used for separation and/or concentration.

Less than 3% of electricity used for electrochemical applications were used for electrolytic deposition or removal. The application usually requires the deposition of a metal finish or removal of metal from a metallic workpiece.

Processes like electrogalvanising, electrofinishing and electrochemical machining fall into this category. The sector which would make most use of these processes would be metals fabrication, which is beyond the direct scope of this report. As South Africa moves down the path of more beneficiation of metals and minerals, towards more manufacturing, these processes will become more important and influence the electricity intensity of the relatively low electricity intensive sector of manufacturing.

8.7 ELECTRICAL HEATING - OTHER RESISTANCE HEATING

Direct resistance heating and melting

This has been used with direct current and alternating current. Electricity is applied directly to the workpiece which is of a relatively high resistance via electrodes in a furnace. The workpiece or material then heats directly as a consequence of its own resistive losses. This form of heating is commonly used in the glass industry, and for pre-drying of certain ceramics (EPRI, 1988).

Indirect resistance heating or melting

This is accomplished by passing an alternating current through a resistance heating element that transfers heat to the workpiece or material by convection and radiation. This method has been used for heat treatment of metals, metal melting, curing, glass tempering (EPRI, 1988).

RF Heating.

In the study by EPRI (1988) it was estimated that there was an installed capacity of 500 to 1000MW of RF heating and drying equipment in 1980 and the rate of growth was 2% per annum. They expected that the 2 TWh of electricity consumed in 1980 would increase to 2970 TWh by the year 2000.

Electromagnetic radiation in the radio frequency range, typically 13,56 MHz to 27,12 MHz, has been used to heat dielectric materials. The RF field induces vibration in the electrically-asymmetric polar molecules, dissipating energy and producing heat. A typical RF system is of 100 to 300 kW capacity.

9 OVERVIEW OF ELECTRICITY PRICING DEVELOPMENTS

9.1 INTRODUCTION

The subject of electricity pricing and the influence it has on customer decision making is a large, complex and even emotive one. It cannot be treated in depth in this project report as it justifies a detailed study in its own right.

In the context of major capital investments in production plant such as has characterised the industry sectors covered by this report, the estimated lifetime cost of electricity as an input cost is significant. In the aluminium sector the cost of electricity represents as much as 70 - 80% of input cost, in the ferrometals industry it is in the range 20 to 30 %, in the gold mining industry it ranges from 10 to 15%.

In an electricity utility, prices are normally structured to recover costs of generation, transmission, distribution, some capital expenditure on reticulation and administrative costs. In the case of ESKOM, standard tariffs cover the average costs of providing supply. Extension or capital charges are levied when the costs associated with a particular supply are significantly higher or if the service required includes unusual features. (Ferrando, Barnard, McDougall, 1991).

Since 1986, ESKOM prices have been "nationalised". The tariffs for the eight licensed electricity Undertakings, which differed substantially relative to their distance from the centres of generation, had already been brought closer together when the number of Undertakings were reduced to five in 1985.

The adjustment in 1986 subsequent to the De Villiers Commission Report on the electricity industry led to ESKOM consolidating its license to a single Undertaking and this meant that the tariffs and their parameters were made equal. A small transmission levy across defined zones of 0 to 3% allowed for the distance from Johannesburg to customers further away. The components of the tariff and the costs to be recovered by additional charges were also changed, making comparisons over the period 1973 to 1991 difficult.

Up to 1986 the Large Power User tariff was based on a 60:40 ratio for an historically estimated demand:energy relationship. This historically had the intention of signalling to the electricity user that the cost of satisfying high demand was very costly.

The customer's maximum demand could occur at any time of the day during a month and was charged at the same price, whether it co-incided with the system peak or not. The effective message to customers was that they were being charged for plant capacity regardless of the time when they used the supply.

The introduction of Tariff E was to influence customers to shift their peak demand away from the overall system peak. This was a signal that the cost of satisfying demand was no longer at the level of base load, but of peaking and load following generation.

Design of shielding systems to prevent interference with electronic equipment has been a vital component of effective RF heating designs.

A convenient application of RF heating has been the conversion of batch processes to continuous processes with workpieces moved through the field on a conveyor. In this case care is taken in the design to avoid radiation at the exit and input of the conveyor.

Information on RF heating in South Africa for applications in the sectors of interest has not come to hand to extend insight into the further potential of this electrotechnology locally. However assuming the example of the USA and the proliferation of installations, believed to have been between 50 000 and 100 000 with an average size of 10kW (EPRI, 1987c), there appears to be potential for increased use of RF in a variety of applications in industry in South Africa.

Microwave Heating

Microwave technology has been well proven but its high equipment costs for industrial applications has limited the areas of economic application.

Although extensively used in the agro-industries, limited non-metallic minerals industry application has been viable other than in the specialised ceramics field, and curing of foundry moulds. The frequency range of 300 MHz to 300 000MHz is used for industrial purposes for heating dielectrics. The most common dielectric heated has been water.

The estimated installed capacity of all industrial microwave equipment in the USA was 24MW in 1980, and this was expected to double by 2000 (EPRI, 1988). Since the efficiency of conversion of electrical energy to energy in the workpiece is some 50%, the energy cost of operation is relatively high, and the application has to economically justify the combined high cost of capital and running costs.

Candidate materials that justify special treatment are those which have thick cross sections that are prone to overheating the surface in order to heat the internal parts, heat sensitive material, and expensive material. Conversion of a batch to a continuous process, and a two shift operation that increases production from the same equipment could also be a candidate for microwave application.

It has been projected that the chemical industry could become a larger user of microwave heating for e.g. drying heat sensitive polymers (EPRI, 1984a). Combinations of hot air and microwave drying have been tested and found cost-effective for bulk drying of selected polymers. Destruction of organic waste has been demonstrated with the assistance of microwave plasmas at Rockwell, in the USA (EPRI, 1984a).

These systems have not been used intensively in the mining, metals and minerals sectors, but have been primarily used in plastics, wood, paper, textiles and the food preparation industries. They have progressively found use in drying of thin cross section ceramics, and small dimension post insulators prior to firing in kilns. The small sizes are chosen to ensure successful escape of heated water molecules without distorting the products.

Foundry cores, made of sand and a binder like resin, have been made more rapidly using radio frequency curing of the resin, hence reducing waiting time for cores from overnight baking process in ovens, to minutes in an RF heater (EPRI, 1987c).

RF heating installations are quite expensive. As a heating source electricity is also relatively expensive compared with fossil fuels both in South Africa and the USA. Use is usually dependent on specific product and process needs which cannot be provided by the alternative heating processes.

Much experience was gained over the time since RF heating was introduced in 1941 (EPRI,1987c).

Electrical design considerations are associated with the power transfer relationship $P = 2\pi f E^2 C \tan(d)$, where

- P = power in Watts
- f = frequency of energy in Hertz
- E = voltage across the dielectric in Volts
- C = Electrical capacitance in Farads, defined by the dimensions of the product and its dielectric constant.
- $\tan(d)$ = The loss tangent of the material

Hence the higher the voltage, the higher the power delivered to the workpiece. This is limited by the breakdown voltage between electrodes and the workpiece at which level arcing will occur. The design of the electrodes, their spacing from the workpiece and their maintenance has an important influence on the arcing voltage.

Selection of the frequency, typically in the range 2 MHz to 200 MHz, is also a function of the power delivery required as power in the workpiece is proportional to the frequency. The choice of frequency can offset the limitations imposed in some cases by voltage limits, and also of non-uniformity of distance between electrodes and workpieces.

The length of a conventional end fed electrode is normally chosen to be approximately 1/20th of the wavelength to ensure that the voltage remains within 95% of the input voltage across the electrode. Centre fed electrodes are also used with double the effective length of the end fed system.

For less critical applications the power can be allowed to drop to 80% at the end points of the electrode and hence the workpiece. For special applications the electrodes are tuned with inductive "stubbs" to change the voltage profile across an electrode to closer tolerance. Tuning might also be need to match the power source to the electrode system for maximum power transfer.

By 1989/1990 the level of overcapacity of electricity generating capacity in the South African electricity industry was substantial. Allowance was made for the varying cost of operating power plant over the varying daily load through the introduction of the Time-of-Day pricing option for large customers. Two options were introduced, (T1) for 1MVA or larger which included a demand charge element, and (T2) for 100 kVA up to 5 MVA without a demand charge element.

Hence in summary:-

* In 1973 the only industrial and mining tariff was the so-called Tariff (A) for Large Power Users, viz with a notified maximum demand exceeding 25 kW/KVA.
* By 1991 the large power user had a choice of:
    - Tariff (A),
    - Tariff (E) which allowed for periods of off-peak use without demand charge, subject to a minimum cost per kilowatthour consumed,
    - Tariff (F) for variable (mostly seasonal) use, which was directed to agricultural customers.
    - In addition two Time-of-use *options* were available, which had not yet been accepted by the Electricity Control Board as a scheduled tariff because of certain customer objections.

By 1996 the ESKOM Time-of-Use Tariffs were accepted as scheduled tariffs and some municipal electricity undertakings were considering introducing similar tariffs.

9.2 HISTORICAL GROWTH RATE OF PRICES

From 1973 to 1991 the cumulative real price increase was 11,27% below inflation. The cumulative revenue increase received by ESKOM was 35,61% above inflation. The difference was accounted for partly by tariff restructuring, partly by the change in customer mix (in particular a growth in industrial customers), and partly by customer consumption or load profiles (Ferrando et al 1991).

From 1985 to 1993 the real price of electricity reduced by 25% due to a concerted effort by ESKOM to reduce costs, which was partly achieved by substantial staffing level reductions, mothballing and decommissioning of some generating capacity and rationalising of administrative and field operations.

Figure 9.1 shows the ESKOM annual price increases in actual notified terms and equivalent real terms to a 1973 base for the CPI calculation. The very high growth in both notified and real terms in the early 1970's was caused by the need to catch up revenues for a high level of self-funding, in order to finance power station projects after a period of low price increases.

Table 9.1 shows the effective rates applicable to tariff (A) and the nominal prices paid over the period. Mining, metals and minerals industries predominate in the selected areas of the former Undertakings of the Rand and Orange Free State and the Eastern Transvaal (also named Regions for part of the period covered).

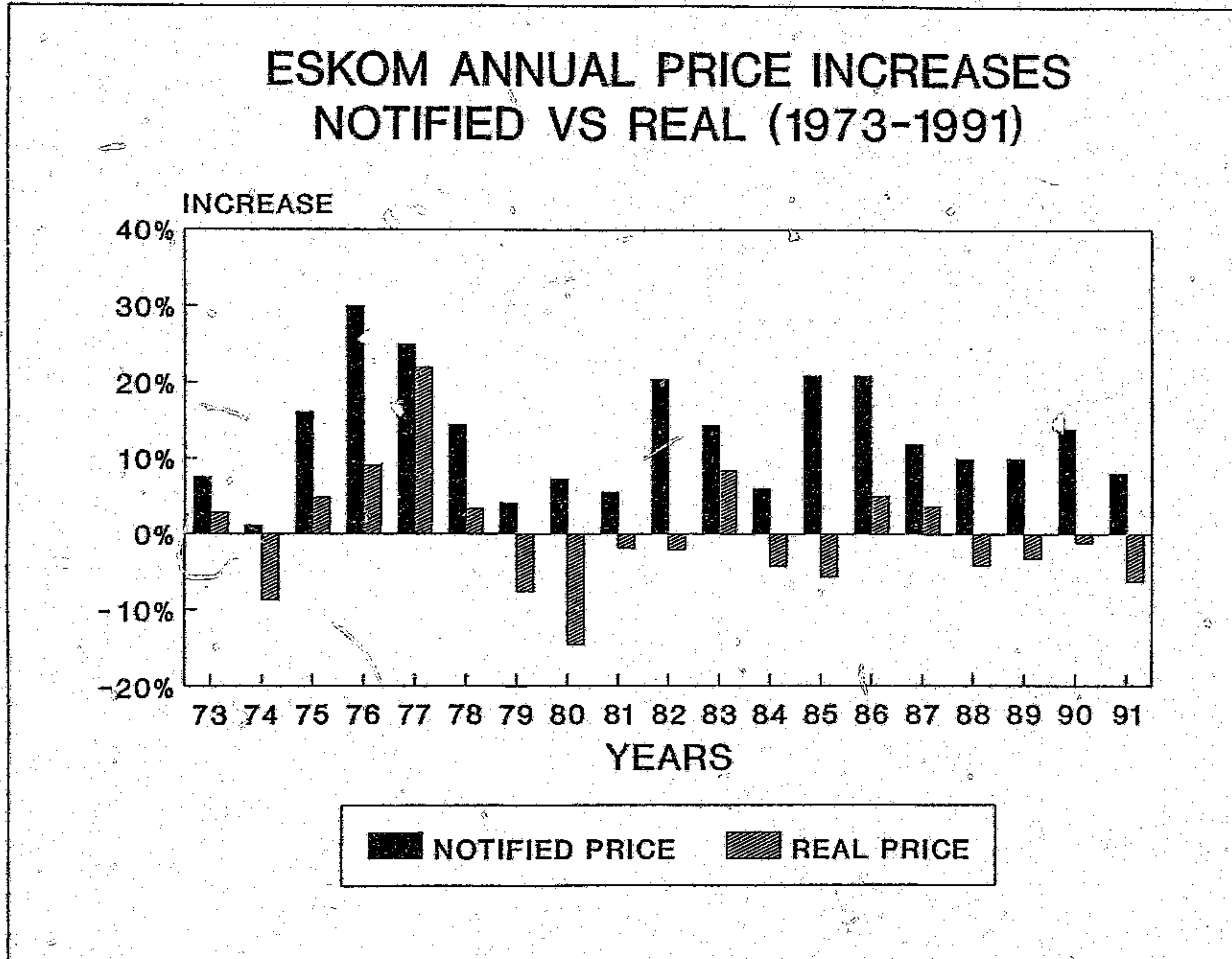


Figure 9.1 ESKOM Annual Price Increases 1973 to 1991 Notified and Real (Source - ESKOM)

Table 9.1 Tariff (A) Effective Rates 1973 to 1985 for Rand and OFS and Eastern Transvaal

Year	R & OFS		Eastern Transvaal	
	R/kW	c/kWh	R/kVA	c/kWh
1973	5.52	0.294	1.13	0.222
1977	4.13	0.903	3.25	0.561
1981	6.79	1.027	5.46	0.911
1985	9.28	1.823	9.18	1.823

Table 9.2 shows a doubling in *nominal* terms of the demand and energy component of the tariff as experienced by customers in the five year period from 1986 to 1991.

Table 9.2 Tariff (A) Effective rates for Various Voltages 1986 - 1991

Year	R/kVA				c/kWh
	380/220	380/66kV	66/132kV	>132kV	
1986	13.20	12.71	12.22	11.74	2.263
1990	22.44	21.59	20.77	19.94	3.845
1991	26.66	25.65	24.67	23.69	4.569

Table 9.3 shows the advantages offered to the customer able to shift load and hence take advantage of Tariff (E) which was introduced in 1986.

Table 9.3 Tariff (E) Effective Rates for Various Voltages 1986 - 1991

Year	R/kVA				c/kWh	c/kWh
	380/220	380/66kV	66/132kV	>132kV		(*Min)
1986	12.29	11.80	11.32	10.84	2.263	3.63
1990	20.87	20.04	19.22	18.40	3.845	6.17
1991	24.78	24.78	23.80	22.84	4.569	6.66

*Min is the minimum charge applied to the account, hence the sum of the demand and the energy charges, divided by the energy consumed should not be below this minimum rate.

The large electricity consumer, having made major capital investment decisions in the early 1970's including expectations of electricity prices over the following 20 years, could hardly have foreseen the rapid rise of inflation and the associated increase in the cost of electricity. In particular the periods of higher than inflation price increases had an important impact on the way in which maximum demand was managed by customers.

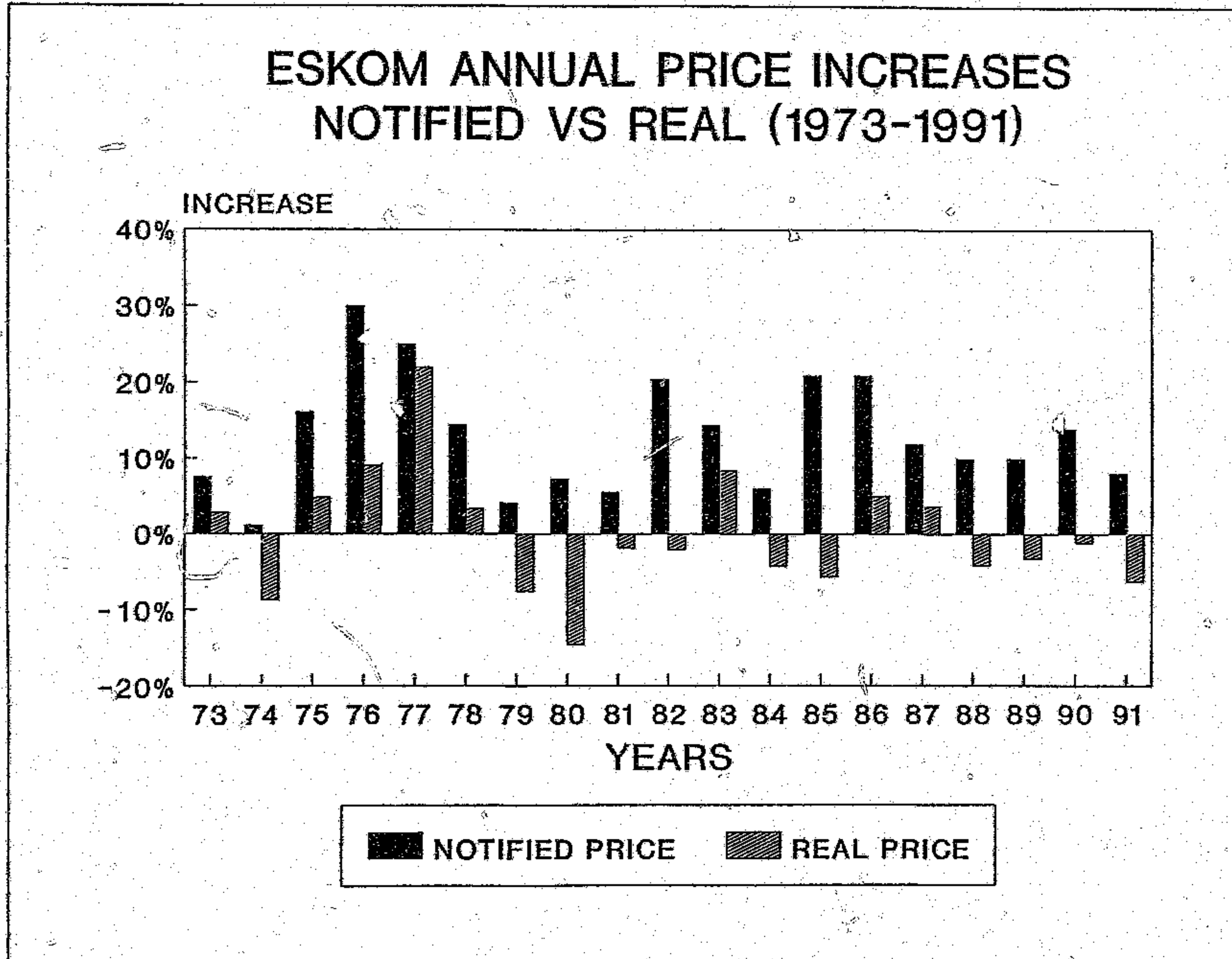


Figure 9.1 ESKOM Annual Price Increases 1973 to 1991 Notified and Real (Source - ESKOM)

Methods used included installation of computer controlled demand control systems, co-generation plant, and the choice of alternative processes using energy sources such as coal, oil and gas. Decision-making on electricity intensive process plant became extremely difficult as economic studies were difficult to conduct in the face of uncertainty about future price increases.

In 1990, in an attempt to assist with stability in customer planning for electricity intensive industries ESKOM entered into a voluntary compact with Government and customers to continue reducing the real price of electricity by limiting annual price increases to 2% points below the projected year's inflation rate over at least a five year period. This commitment was extended in 1995 for a further reduction until 2000.

9.3 NEW PRICING DEVELOPMENTS

Innovations in the area of electricity pricing in ESKOM have concentrated on load shaping in order to fill valley periods and reduce growth at the system peak, which has recently developed as a night-time peak due to the rapidly increasing low load factor domestic customer sector. Tariff (E), TOU options (T1) and (T2) were the initial innovations. TOU Tariffs were formally accepted as scheduled tariffs in 1996.

More recent development effort has been in the direction of Interruptible Tariffs. These range from pre-planned interruptions with a pre-arranged period of notice which are normally referred to as curtailable loads, to contractually agreed but unannounced interruptions at differing levels of price reduction.

Special pricing agreements have been reached with individual major customers such as Alusaf in which the electricity price has been linked to the internationally quoted metal price. This enables a risk sharing agreement to be reached between supplier and consumer in which electricity prices are high when the aluminium price is high, and reduced when world prices are low. This approach is in line with pricing structures in use in the USA by Bonneville Power Authority for their aluminium producers for some time.

9.4 IMPACT OF PRICING ON PEAK DEMAND

From internal ESKOM studies approximately 450 MW of load shaping had been achieved by 1993 due to Tariff (E) and this was expected to increase to at least 1 000MW by the turn of the century.

The contribution to demand reduction due to interruptibility agreements is expected to be approximately 1 500MW by the end of this century, primarily in the metallic minerals sector (Calitz,1995).

Additional future peak load reduction linked to pricing structures has been optimistically estimated, subject to further analysis (Calitz, (1995)) as Interruptable load of 1 400MW, Co-generation of 1 200MW, Electricity Conservation of 2 100MW giving a total of 4 700MW.

An update by Calitz (1996) gives the following estimates by 2015:-

Interruptable	3 200MW
Electricity Conservation	2 500MW
Load shift	1 600MW
Additional total	7 300MW

9.5 CONCLUSIONS

There have been substantial and progressive changes in industrial electricity prices due to increasingly innovative tariff restructuring in order to accommodate customer needs and to modify supply side investment commitments, and hence the need (or not) to fund new generation and transmission capacity. The level of national inflation has influenced both capital and operational expenses, which, because of the cost recovery basis of South African electricity pricing, have added to the price level in order to recover costs.

The way in which customer plant has been operated and demand control equipment has been installed to respond to the early negative, even punitive demand charges, and latterly to the more positive pricing signals, has been significant.

Future choices in end use electrotechnologies will continue to be influenced by the level and flexibility of pricing structures, the compatibility of production process equipment to maximise economic benefit from such electricity prices, and the willingness of process plant designers, purchasers and operators to modify their approach to these evolving options.

10 POTENTIAL FOR FURTHER RSA INDUSTRIAL ELECTRIFICATION

10.1 ENERGY CONSUMING SECTORS ACCESSIBLE TO ELECTRICITY END-USE TECHNOLOGIES

All sectors in which heating is not yet substantially provided by electrical means are potential candidates for increased use of electrotechnology solutions. The issue in the RSA has been related to access problems - i.e. a supply problem, as in the case of much of the domestic sector, or capital investment restraint as in the major sectors of food, pulp, industrial chemicals, non metallic minerals industries, ferrous metals, and non-ferrous metals.

In the case of many of the latter, the real restraints have been :-

a) lack of risk capital,
b) shortage of information on modern developments in processes and manufacturing techniques,
c) few SA based agents/suppliers of equipment,
d) long period of SA isolation during the sanctions era.

There are appropriate electrotechnologies for most of the heating processes currently served by coal, fuel oil and gas.
These are in the form of :

a) electrode boilers for steam-raising,
b) electric smelting and melting of metals (electric arc furnaces, plasma arc, induction furnaces),
c) infra-red and laser finishing of surfaces,
d) induction heat treatment of materials,
e) resistive heating of materials,
f) microwave and rf dielectric heating of materials.

The sectors of interest with the potential to demand higher levels of electrical energy are :

a) Iron and Steel - - - - - entire steelmaking sequence
b) Non-Metallic Minerals - - glass, chinaware, ceramics
c) Non-Ferrous Metals - - -titanium, magnesium, aluminium
d) Other Ferrous Metals - -ferro-alloys, stainless steel
e) Mining - - - - - - - - - - materials handling, and on-site drying and partial beneficiation.

10.2 PLASMA ARC HEATING

As was discussed in Section 8.3, South Africa has established competence in the use of plasma arc heating. Additional use of this electrotechnology can be considered likely in the ferrometals industry, in titanium production as an extension of existing processes.

New applications for plasma arc have been postulated for treatment of toxic waste like PCB's, but have further tests to undergo to satisfy environmental protective measures.

Direct ore reduction and also treatment of electric arc furnace dust with the advent of steel mini-mills can be expected to yield useful results, if the EPRI projections were applied in the RSA.

Autocatalyst platinum recovery by plasma arc can become a new industry when the motor vehicle industry in the RSA produces vehicles to suit the unleaded petrols due to be introduced in the near future. When a proposed zinc smelter investment with a proposed load of 100MW occurs in the RSA as has been evaluated by the IDC, the use of plasma arc furnaces to recover zinc from zinc wastes could become relevant.

10.3 ELECTRICAL INDUCTION HEATING

Growth in the use of electrical induction heating can be realistically expected across all the metal processing industries. It has a particular niche in the speciality metals and superalloys for e.g. aerospace applications for which some South African industries can find premium markets.

The rapid development in expertise in electronic controls for high frequency induction heating has opened up opportunities for specialised metals manufacturing for export markets.

Environmental pressures to reduce pollution from combustion processes will create new opportunities for the use of induction processes which provide a cleaner melt.

10.4 ELECTRIC ARC FURNACE

International commodity prices for products of the ferrometals industry, which is the largest user of arc furnaces in South Africa, can be expected to lead to the cyclic building of new and closure of existing furnaces. This will be a repetition of what has happened over the past 20 years already.

Since the start of this project report, the advent of the steel mini-mill using electric arc furnaces has already occurred in the RSA as has been the case in the USA. This has been an extremely successful development and has the potential for substantial increasing impact in the RSA. The control of dust was briefly covered in Section 8.2.

Growth in the stainless steel industry will depend on world prices and has lead to the establishment of more capacity using state of the art technology in the country.

10.5 MICROWAVE AND RF HEATING

Introduction
Within the sectors covered by this report only the non-metallic minerals show promise in the further application of microwave and RF heating technologies. Section 8.6 reviews of the technology.

Microwave Applications
Potential for microwave applications have been identified in the chemical industry, agricultural processing, paper and textiles processing and food processing. (EPRI,1984c)

In the USA 22.3MW of the 24MW of microwave applications assessed were in these sectors.

Applications of microwave technology would not be expected to be major electricity intensive loads in the way the South African large industry loads have traditionally grown. They are more likely to be dispersed loads as part of higher technology small to medium sized industrial and manufacturing developments. These technologies would add to the supply quality needs of those customers, and also potentially add generated electrical interference back into the supply system requiring some form of intervention.

Within the scope of microwave processing a number of unique uses of the high value process have been found and reported in the EPRI study (EPRI,1984c), which have not been applied to any substantial extent locally .

These are:-
* drying of polymers like polypropylene and polyethylene
* foamed rubber insulation for copper refrigeration pipes
* devulcanisation of rubber scrap
* foundry sand core drying
* dewaxing of precision casting moulds
* moist thread drying
* soil thawing for construction work in cold climates
* concrete fracturing for demolition
* fibreglass melting.

The load shape implications would vary depending on application, but it is likely that near-continuous or continuous processes for drying/curing would be used to maximise the benefits from expensive plant. Hence this would not necessarily add to peak power demand on the national system, but rather on local distribution supply networks.

RF Heating

It has been reported in the EPRI study on Radio - Frequency Dielectric Heating in Industry (EPRI,1987c) that applications exist in the following:-

* plastics preheating
* plastics welding
* drying of various material e.g. paper,paper coating, veneers, lumber, textiles
* wood applications for e.g.wood edge bonding, frames, joining, furniture assembly, particleboard and fibreboard.
* textiles such as wool bale warming, bonding interfacing, drying panthose, drying bulk yarn, drying tow/webs of woven material.
* ceramics bonding
* film drying
* grinding wheels curing
* foundry core drying
* book adhesive drying
* food baking, thawing.

A mix of applications from short duration processes e.g. welding through to continuous processes are involved in RF heating.

Consequently it is not realistic to estimate the overall effect of this technology on load shape. However it is likely that where such technology is introduced it is likely to be more energy efficient than the previous process in use, whether a non-electrical method or an electrical method was utilised.

11 CONCLUSIONS ON THE IMPACT OF ELECTROTECHNOLOGY DEVELOPMENT IN MINING AND MINERALS SECTORS OF THE RSA

11.1 INTRODUCTION

The impact of a substantial shift in end-use electrotechnologies in the various sectors which could impact the load profile, the quality of supply needed as well as influenced by the type of load, can significantly influence the planning, design and cost of electrical supply systems, and the nature of services and quality of supply needed by customers. In turn the education and training needed by members of the engineering team responsible for electricity supply to the point of use, in order to meet these needs, will be influenced.

The integration of the design and planning process to connect new electrotechnology loads successfully, may lead to a change in the method of interaction and contractual relationship of the formally separated design teams of the electricity supplier, the end user customer and the consulting engineering team often contracted to undertake design and project management.

At the point of application of electricity in industrial processes, the implications are that education and training in the electrical engineering disciplines will require attention. For such a transition into new/under-represented technologies to be sustainable and successful bridges between engineering disciplines will need to be strengthened.

The underlying driving forces that lead to changes in end use technologies and process practises are closely tied to increasing pressure for sustainable environmental practises, and global competition based on quality products and keenly structured prices.

A change in the electricity intensity of major industry has the potential to change the gross primary energy needs of the country in a positive sense, if new electrotechnology is more efficient than the older technology that was in use. This has constructive implications for the environment both from the point of view of pollution and extended life of non-renewable energy forms.

Policy decisions by the Government of the country are vital to facilitate a response to these global forces in the interests of increasing the opportunities for economic growth rate of the country, and the Southern African region. The policies emerging from this review, relate to industrial investment, research and development support, encouragement of centres of expertise at centres of higher education, energy and environmental policy.

11.2 ELECTRICITY DEMAND LEVEL AND LOAD PROFILE IMPACT

The sectors described are already relatively high load factor in nature. The electrotechnologies which have been successful within these sectors and those which could have further impact, mostly represent demand of a high load factor type. This is typical of continuous thermal processing. Such an increase in base load demand would be significant for the electricity supply industry. An improvement of the daily, weekly, and annual load factor is intrinsically advantageous from the point of view of the supply system as generation, transmission and distribution utilisation improvement can lead to savings over the longer term and potentially lower price increases to customers.

There is at this stage a demonstrated decline in the South African system load factor as an increasing number of residential customers with very low load factors are connected on to the system. As has been previously discussed, there has been a newly emerging evening winter peak that has shown progressive increase in size. This effect is expected to continue as the national imperative for electrification of homes, schools and clinics most of which have low load factors, is accelerated to reduce the historical backlog.

Opportunities therefore exist for the load profile to be managed in the customer environment at various levels in the supply chain with the benefit of increased capacity utilisation of reticulation, distribution, transmission and generation plant, to ensure that electricity service costs and customer prices are maintained or preferably improved over the long term.

Various characteristics of sector process loads and flexibility of operation of technologies can be harnessed to aid in the overall management of the supply-demand balance. For instance an increased size in the counter-cyclic load apparent in the weekly load pattern of the non-metallic minerals industry can be a particularly useful characteristic to enhance, as a partial means to counteract the decline in load factor due to residential demand patterns.

There is also a substantial risk in the growth of capacity of an even-larger-than-present customer base that has a process load dependent on cyclic world commodity markets, combined with a weak domestic demand. The cyclic fluctuation of international price cycles can lead to load capacity being idle as a result of economic decisions made by the management of the plant. From the graph of the ferro-metals industry, Figures 6.4, 6.6 and 6.8 one can see that from 1988/9 to 1991/2 this was as much as a total of 4 GWh drop in base load electricity consumed by the sector. This occurred with the collapse of the export market for ferro-chrome in particular. Such fluctuations can impose severe limits on the ingenuity of planners of electrical capacity as well as of developers of customer service interventions in the electricity supply industry. The effects on related industries that suffer a ripple effect of the commodity cycle through the national economy are also severe, as is also recognisable through electricity consumption figures, for instance in the mining industry.

However, in contrast to the risks, there is an advantage of a substantial thermally based customer pool as that offers the potential to structure large interruptible supply agreements in an innovative way to suit the thermal characteristics of the process plant.

With appropriate price incentives for the customer on the basis of either instantaneous or pre-arranged load reductions this approach has been used successfully in for example the USA and France. It has been estimated that interruptible loads on the current South African system could be as high as 3 000MW. (Etzinger,1995; Calitz, 1996)

Scope exists for a further development of the electricity supply industry in a way that could change the pricing structure through allowing innovative merchant or independent power producers to compete with a tax paying electricity supply industry. This could stimulate change in the nature of costing and pricing of electricity to the advantage of the economy.

The availability of natural gas imported into the South African energy economy could well be the catalyst to such developments. If prices of electricity from gas fired generation can be made attractive and competitive with existing electricity prices this could introduce a new competitive factor into the market. A barrier to this development is the lack of open access to the transmission system, because of the existing monopoly electricity purchase and selling position of the ESKOM transmission system.

It is too early in the development of the gas industry to attempt to prejudge the potential outcome. However since natural gas is a clean fuel to burn, it could well compete with electricity for direct heating purposes. As a consequence it may find its place as a premium heating fuel. Gas technologies would then compete for base load, bulk thermal applications with the various electrotechnologies which have been discussed in this report. In particular the metals melting industries could be the most influenced by such developments.

Erosion of the high load factor customer base for the conventional coal fired power generation system in South Africa by customers choosing to use gas in thermal process technology might stimulate the move to more flexible gas-fired power generation plant to cope with an even lower national electricity load factor. The competing generation for this type of load is hydro-generation imported from Southern Africa over the Southern African Power Pool. Depending on decisions on energy and electricity source diversity in a national energy policy, this may provide the opportunity needed by a new gas industry to start up in the RSA. (Discussion Document, Green Paper on National Energy Policy, 1995, Department of Mineral and Energy Affairs)

Operational control of power systems with the increased flexibility and economic trade-offs of power plant versus customer load modification has become more complex.

Where customer load modification options include customer-owned generation, the greater penetration of distributed embedded generation in a power system will impose more plant dispatching complexities than before. A need would arise for training and new computer support systems for power system operators and system designers.

11.3 NATIONAL POLICY IMPACT

11.3.1 Industrial Investment

The sectors and their electrotechnology options covered in this report are all capital intensive. Replacement of existing plant and investment in new "greenfields" production plant represents major financial commitment and associated risks in the face of global competition. The part that government policy plays in creating an "investor - friendly" climate in competing with other countries for limited investment funds has been postulated by many analysts, organised business (e.g. SACOB - the South African Chamber of Business), visiting foreign Heads of State (Kohl, 1995), and potential investors. The usual financial incentives are investment write-offs e.g. through accelerated depreciation allowances, tax 'holidays" of various types, subsidies and tariff protection.

It would seem to be important to ensure that new investment in process plant should meet criteria of acceptable international standards of energy efficiency and environmental emissions by providing suitable investment incentives. This might be an effective solution to create a "virtuous" cycle and break the costly cycle of allowing inefficient energy-intensive processes to be established, which leads to costly supply through new electricity infrastructure.

In particular coal-based industrial processes and power generation costs can be expected to increase substantially when higher standards of emission control are required. With inefficient production processes, subsidies or protection are often then required to compensate for high input costs and poor competitiveness, hence driving the overall cost spiral upward to the detriment of the economy as a whole. Removing such protection becomes very difficult and painful to remove, as is currently being experienced in South Africa in aligning with the requirements of the General Agreement on Tariffs and Trade and the new World Trade Organisation.

11.3.2 Pesearch and Development

It has been notable from the various EPRI references, and also the extensive use of their analysts by the Department of Mineral,and energy Affairs and also ESKOM, as shown by the References in this report, that MINTEK is a well recognised key player internationally in minerals processing. South Africa is rich in minerals and these are accepted as a part of the wealth of the country in the 1995 analyses by the World Bank. It would be appropriate to ensure that this expertise is nurtured for the Region. It is an exportable knowledge-based product.

Funding of research programmes and development of manpower through enhancing available mechanisms through industry partnerships could have powerful benefits. It was pleasing to note the establishment of a centre of excellence in Glass at the Pretoria Technikon, in association with Consol (Engineering News, 4 August 1995, p66).

Such associations with Mintek, perhaps creating satellite units specialising in electrotechnology innovations with joint venture partners as is done in the USA with the power utilities / Electric Power Research Institute (EPRI) / Centre for Materials Processing and the manufacturers of process plant may present a useful model of co-operation.

The Technology Research and Investigations unit of ESKOM may have potential for similar nurturing of expertise specifically for end-use electrotechnology development and demonstration for metals and minerals processing.

Associated centres of excellence in electrical engineering departments at higher education establishments could be linked into the network on a basis of specific electrotechnologies and also local minerals or metals developments. Existing centres of excellence of relevance in this context are potentially :-

* Rand Afrikaans University for power electronic drives
* University of the Witwatersrand for machines and high voltage
* University of Pretoria for modelling of electrotechnology, mining and process optimisation
* University of Stellenbosch for microwave technology.

This is not intended as an exhaustive list, but merely an indication of the possibilities of applying this context to research investment.

11.3.3 Energy Policy

The electricity intensity of South Africa has been commented on in various publications of the Department of Mineral and Energy Affairs. The origin of this intensity is associated with the mining and minerals sectors. This has lead to the establishment of a large electricity supply infrastructure. Given the minerals resources of the country as a source of wealth and the need to develop the economy and create jobs, investment in further minerals industries implies further energy and electricity intensive industrial development. In order to manage investment in electricity infrastructure on a national basis, incentives for electricity efficiency, load management including load shaping could be an important component of energy policy.

Stimulation of cost effective and efficient energy for direct thermal applications, other than electricity, to minimise electricity supply investment in the long term could also be an option e.g. natural gas imports from Mozambique and Namibia, through investment incentives and tax structure. Investment in new energy efficient power generation such as combined cycle gas fired generation and cogeneration systems could be targeted as investment incentives for foreign investors in the minerals industry and in the electricity generation sector. The latter would require specified energy policy.

The newly appointed National Electricity Regulator would require specific mandate to act in respect of new licenses for generation..

The use of power generation such as hydro - electricity imported from Sub Saharan African sources to support growth of new minerals industry investment may need a policy decision on the extent of dependence of the country on imported electricity and diversification of fuel sources for electricity generation.

Creation of a competitive electricity market may require policy decisions to introduce open access to the transmission grid, changing it from a trader in electricity to a transporter of electricity, hence encouraging entry of privately owned power plant.

11.3.4 Environmental Policy

The topic of environmental management and the related issues is very large, and cannot be dealt with in any depth in a report of this nature. However, the linkage of energy and electricity utilisation up the chain of delivery processes through to production has been recognised as an important means of reshaping *primary* energy use and also its conversion to electricity.

Non-renewable primary energy carriers used for electricity generation, such as coal and nuclear fuel, have been specifically targeted for reduced utilisation world wide. New technology like pebble-bed nuclear reactors may have a positive impact on this debate.

Where greater end-use efficiencies can be achieved through more effective and efficient electrotechnologies, the beneficial impact all along the supply/conversion chain has been recognised. This has been a major driving force within the USA regulatory forces which imposed specific demand side management programmes on electricity suppliers. The increase in environmental benefits has however been at the cost of increased investment in energy efficient customer equipment and some increase in per unit electricity costs. The latter have been partially offset by reduced energy consumption. The increased effectiveness in customer production quality and overall performance has been assumed to make up the difference in input costs.

There is evidence that during a period of great concern about the availability of oil and its price during the 1970's, major research funding was made available for the development of energy efficient end-use processes and conversion systems especially in the USA. Once the immediate concern subsided, the level of research funding diminished, as did the innovations in technologies. Regulations enacted in the USA requiring electricity utilities to promote energy conservation did however ensure development of efficient and innovative applications of technology. The development of similar initiatives and regulations in the RSA for demand side management to delay investment in new power plant through load shaping and energy efficiency measures has been a topic of debate for some time.

Various policy research and demonstration initiatives were launched by the National Energy Council from its inception in 1987. Since it was restructured as part of the Department of Mineral and Energy Affairs only policy research was permitted. This may need to be reconsidered.

From 1995 a National Electricity Regulator was established. This body has the right to issue licenses for generation and distribution of electricity and for regulating pricing systems and quality of customer services against specific criteria which still to be finalised.

Environmental criteria for electricity generation can be expected to feature more strongly in the future in licence approvals. The role of renewable electricity generation has not yet been clarified in the energy - environmental relationship.

Increased industrial emissions control requirements will create a partially stimulating opportunity for electrotechnologies that can assist in reducing or neutralising the effects of waste products and emissions, like the plasma arc, and may place some performance criteria on the use of electric arc furnaces.

11.4 EDUCATION AND TRAINING IMPLICATIONS

The emphasis in the curricula of electrical engineering departments at universities and technikons has for many years been on the supply of electricity and the use of electricity in electrical motors. Until recently this has been appropriate and has adequately covered the needs of industry as users of electricity and also the electricity supply industry in dealing with the challenges of supply performance. The complexity of designing integrated supply-demand systems with considerable uncertainties has also progressively changed the nature and complexity of power system planning.

With the stronger emergence of substantial electrotechnologies associated with thermal processes, dependent on a deep appreciation of materials science and thermodynamics, a new dimension has been added which has not been part of traditional curricula of electrical engineers. Synergy may be achieved through linkage of electrical engineering departments with multi - disciplinary engineering facilities which already exist. An example may be for the School of Process and Materials Handling at the University of the Witwatersrand to bridge the gap into end-use electrotechnologies for electrical engineering students from higher educational institutions within the region.

Most of the technologies described are dependent on sophisticated electronic control systems, and large loads are electronically switched.

Electronics designers require a substantial insight into the impact of their designs on power systems. The electrical engineers need an understanding of the impact of the electronic control systems on power systems and the means to introduce appropriate interventions to retain quality of supply within reasonable bounds.

Measurement of these phenomena has a vital role to play in successfully intervening and managing interactive systems.

Project management education and training to deal with the more interactive nature of design between electricity supplier and electricity user should be considered because of the nature of new electrotechnologies. Whether this is to deal with the work environment which might have a traditional organisational structure which separates design and production departments, or in the contractually separated electricity supply authority and the industrial or mining customer, it is important to learn how to deal with the change in method of working. This may be considered to fall in the category of "business re-engineering" already being implemented in many industries.

11.5 PROPOSED RESPONSE TO CONCLUSIONS REACHED

As has been described the review covered in this report has lead to some appreciation of the complex and interrelated nature of the national resource-rich economy, the process requirements and choices for the minerals mining and processing sectors,the energy and electricity needs and opportunities, environmental implications, research and development for the sector, and education and training opportunities. Overarching impacts of national policy for industrial development, energy and electricity, research and development and educational are fundamental to ensuring a virtuous cycle of sustainable economic growth.

The next part of the report, Section 12, will deal with specific recommendations following on the findings covered in Section 11.

12 RECOMMENDATIONS

From the review of electricity growth and end-use electrotechnologies in the key economic and electricity intensive sectors in the RSA, the conclusions reached have been covered in Section 11. The recommendations made in this section follow the sequence of Section 11.

12.1 Recommendation 1

Promotion of energy efficient end-use electrotechnology by means of an investment incentive formula for new plant investment in the RSA, as part of Government encouragement of foreign and local investment in new productive capacity.

12.2 Recommendation 2

Understanding of electricity load shape, load shaping opportunities should be extended through collection and publication of appropriately aggregated, formatted demand data for practitioners in a user-friendly format. Individual customer confidentiality must be guaranteed.

Establishment of non-partisan organisation/s to facilitate such collection and dissemination should be arranged for the benefit of enhanced research, development and implementation of end-use electrotechnologies.

12.3 Recommendation 3

Criteria for licensing of new distribution and generation participants should include energy efficiency commitments and a track record of, or commitment to, participating in effective integrated resource planning.

A means of openly debating proposed new major investment in power systems and power system demand by the various players in the RSA should be encouraged.

12.4 Recommendation 4

Policy decisions around the electricity industry structure need to be made in the very near term, to enable economic development of the sector in accordance with the real needs of the regional economy.

Allowing competition through independent power producers, facilitated by an open access transmission system, and establishing the reasonable level of dependency on imported primary energy and electrical energy is suggested as the means of taking a quantum step.

This would be in line with the developed economies, and current developments in Africa, as an encouragement to new industrial and power sector investment.

12.5 Recommendation 5

Excellence in research and development for the minerals sector and potential electrotechnologies should be stimulated by creative State incentives for "partnering" within South Africa, Southern Africa and with global centres of excellence.

University electrical, mechanical, and materials engineering faculties should be funded to encourage and enable them to undertake research projects of a multi-disciplinary nature.

12.6 Recommendation 6

Specific research should be conducted to establish a realistic basis for energy decision making in the RSA by clarifying the debate between the opposing views of "low cost energy (electricity) is needed for economic health" versus "high energy (electricity) costs are needed to ensure good energy efficient decisions for environmental health and hence sustainable economic health".

Internationally this is an issue and hence international specialists should also assist in the formulation of a proper understanding of this complex topic in the local context, particularly for electricity supply and demand relationships.

12.7 Recommendation 7

Attention should be given to the development of electricity utilisation and end-use electrotechnology courses as an option for undergraduate, postgraduate and continuing engineering education, at universities and technikons. These would require multi-disciplinary skills currently found in the separate departments of mechanical, electrical, and metallurgical engineering to be harnessed into new programmes.

With the funding difficulties at tertiary educational establishments this should become an opportunity for innovative industry liaison and support. The establishment of one or more "centres of excellence" with a particular industry focus might well be a useful model. This approach has been used successfully in the USA, facilitated by EPRI and its members.

12.8 Recommendation 8

The measurement of plant performance, management of volumes of data, interpretation and modelling of process and application options within a production system is complex and needs at least statistical, computer programming, electrical engineering, production management and product specific skills. The development of courses to educate practitioners in this area of engineering endeavour, which is new to South African industry and consulting, also requires putting together disciplines in a novel fashion.

The need for this type of course exists at all levels of the engineering educational process.

12.9 Recommendation 9

Engineering institutes such as the South African Institute of Electrical Engineers (SAIEE), South African Institute of Mechanical Engineers (SAIME), South African Institute of Energy (SAIE), South African Institute of Mining and Metallurgy (SAIMM) should play their part in stimulating debate and extending knowledge in this area of end-use electrotechnology in the mining and minerals sectors. Creation of jointly organised events such as conferences, workshops, visits, tutorials, for their members should be a relatively simple matter. These should be specifically designed to update the members on multi-disciplinary interests in end-use electrotechnology developments, opportunities and implications in the RSA.

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12.10 Comment in Conclusion

The recommendations made represent some key areas of decision making and opportunity revealed by the review conducted for this report.

The scope of the topic covered in the report has greater impact than the end-use electrotechnologies themselves because of the context and interconnectedness of electricity supplier and the key sectors which are the end-users, and the economy of the country.

The impact of the electricity supply - demand chain on the national economy and its associated energy economy, is significant as a result of the energy intensity, the capital investment and labour intensity involved.

Disclaimer

The views expressed in this report are entirely my own. They do not reflect the views of my former employers ESKOM, or the South African Institute of Electrical Engineers (SAIEE) of which I have been a Council Member for 15 years and an Office Bearer since 1991.

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ABBREVIATIONS

PREFIXES

k	kilo	(10^3)
M	Mega	(10^6)
G	Giga	(10^9)
T	Tera	(10^{12})

UNITS

A	Ampere
ac	alternating current
dc	direct current
Hz	Hertz
J	Joule
t	ton
W	Watt
Wh	Watthour
VA	VoltAmpere

ENERGY CONVENTION

1 Watthour = 3.6 kiloJoules

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