

DECLARATION	3
ABSTRACT	4
DEDICATION	5
ACKNOWLEDGEMENTS	6
LIST OF TABLES AND FIGURES.....	7
SYMBOLS AND NOMENCLATURE	9
1 INTRODUCTION.....	10
1.1 PROBLEM DESCRIPTON.....	11
1.2 OBJECTIVES	11
1.3 RESEARCH METHODOLOGY.....	12
1.4 RESEARCH PROCEDURE.....	13
2 BACKGROUNDS ON SOUTH AFRICA	15
2.1 ECONOMY	15
2.1.1 MINERAL SECTOR'S ECONOMIC CONTRIBUTION	16
2.1.2 COUNTRY'S MINERAL WEALTH	16
2.2 ENERGY OVERVIEW.....	17
2.2.1 ENERGY SOURCES.....	18
2.2.2 ENERGY CONTENT IN FOSSIL FUELS	19
2.3 SOUTH AFRICA ENERGY SECTOR	20
2.3.1 AVAILABLE ENERGY SOURCES	21
2.3.2 ELECTRICITY.....	29
2.3.3 ENERGY BALANCE.....	35
2.3.4 FORECASTS AND TRENDS	36
2.3.5 ENERGY EFFICIENCY	45
2.3.6 DEMAND INTENSITY.....	47
2.3.7 ENERGY USED AND ENVIRONMENTAL EFFECTS.....	53
2.4 ENERGY USE STANDARDS.....	54
2.4.1 BENEFITS	55
2.4.2 FOCUS.....	56
2.5 CONCLUSION	56
3 ENERGY MANAGEMENT PRINCIPLES	58
3.1 CONCEPT	58
3.1.1 MANAGEMENT COMPONENTS	58
3.1.2 ENERGY MANAGEMENT STANDARDS	59
3.2 STANDARDS IN SA MINING INDUSTRY	60
3.2.1 REASONS	60
3.2.2 BENCHMARKING	61
3.3 CRITERIA AND ASSUMPTIONS	62
3.3.1 MINING DEPTH LEVEL	63
3.3.2 MECHANIZATION.....	64
3.3.3 PRODUCTIVITY AND PRODUCTION.....	65
4 BENCHMARKING OF DATA.....	67
4.1 COLLECTION AND ANALYSIS OF DATA.....	67
4.1.1 DATA SOURCES.....	67
4.1.2 DATA COLLECTION.....	69
4.1.3 DATA CIASSIFICATION	71

4.2 RESULTS BENCHMARKING	82
4.2.1 MINING OPERATION CONSUMPTION	82
4.2.2 ENERGY INTENSITY Vs DEPTH CATEGORY	86
4.2.3 ENERGY CONSUMPTION vs. MECHANIZATION	88
4.2.4 GREEN HOUSE GAS EMISSIONS INTENSITY 2006	89
4.2.5 ENERGY COSTS	90
4.3 TRENDS	92
4.3.1 RESERVES AND EXPANSION PROJECTS	94
4.3.2 PRODUCTIVITY FACTOR	95
4.4 SUMMARY OF FINDINGS	98
5 DISCUSSION AND CONCLUSION	101
5.1 DISCUSSION	101
5.2 SUGGESTIONS	105
5.3 CONCLUSION	106
6 REFERENCES	109
7 APPENDICES	113

DECLARATION

I declare that this dissertation is my own, unaided work. It is being submitted for the Degree of Master of Science to the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination to any other University.

(Name of Candidate)

____ day of _____ 2008

ABSTRACT

Benchmarking of selected energy use indicators and related best practices definition are helpful tools in establishing an effective energy reduction and energy efficiency strategy. The current energy scarcity exposed by electricity supply shortage in South Africa is an opportunity to assess and determine consumption limits for major consumers, including the mining sector for which gold and platinum producers are among the highest consumers. This dissertation develops, using a survey questionnaire, visits on mine sites and interviews for data collection and analysis, a range of energy consumption indicators and related costs. These indicators are related to mining depth, mechanization and production. These are the most energy intensive parameters for underground mines and influence the growth rate of energy consumption. A relationship between these parameters and the energy consumption data constitute the main findings of this work. The acceptable limits and averages of energy consumption can be used to compare different and specific energy intensive activities involved in the mining process, costs of mines operating in similar conditions, to develop energy efficiency improvement plans and saving targets and to forecast mine unit demand of power in short and mid-term for gold and platinum mines.

DEDICATION

To the Almighty GOD JEHOVAH JIREH, my provider for every need

ACKNOWLEDGEMENTS

I am so grateful to a number of following distinguished persons for their contribution to the fulfilment of this work:

Firstly to: Professor RCA Minnitt for his helpful supervision.

I will also like to acknowledge help from: Pr Eng Chris Van Heeswiegh and Kevin Moxham from Goldfields, Dr Keith and Gerhard Vandenberg from Anglo Platinum, Keith Arnold from AngloGold Ashanti, Lukunku from Northam and all friends from Eskom and Sasol.

Your assistance has contributed to make possible this work by allowing access to data and through helpful discussion.

| Especially grateful to my beloved Vianney and my family for their faithful expectations.

LIST OF TABLES AND FIGURES

TABLE 1: HISTORICAL ECONOMIC INDICATORS	15
TABLE 2: FOSSILS CONTENT & CARBON HEATING VALUE	19
FIGURE 1:- SHARE OF TOTAL PRIMARY SUPPLY IN 2004	21
TABLE 3:COAL EXPORTS BY COUNTRY	22
TABLE 4: HISTORICAL PRODUCTION, EXPORTS AND CONSUMPTION IN SOUTH AFRICA .	23
TABLE5:HISTORICAL OIL LOCAL SUPPLY AND EXPORTS	26
TABLE 6: HISTORICAL NATURAL GAS CONSUMPTION IN SA.....	28
TABLE 3:COAL EXPORTS BY COUNTRY	28
FIGURE 2: SHARE OF ELECTRICITY GENERATION PER SOURCE	29
FIGURE 3: POWER STATIONS LOCATION MAP IN SOUTH ARICA	30
TABLE 7: SA'S INSTALLED POWER STATIONS	30
TABLE8: SA HISTORICAL ELECTRICITY PROFILE 1993 – 2004	31
TABLE 9: EVOLUTION OF ESKOM EXPORTS.....	32
TABLE:10 SA ENERGY BALANCES.....	36
TABLE 11: SUMMARY OF WORLD FUEL ESTIMATE TRENDS	38
TABLE12: S A'S ADDITIONAL POWER CAPACITY PROFILE.....	40
FIGURE 5: SA SHARE OF FINAL ENERGY CONSUMPTION IN 2004.....	42
TABLE 13: ESKOM DEMAND GROWTH ASSUMPTION.....	43
FIGURE 6: NATIONAL POSITION IN ELECTRICITY PROGRESS	45
TABLE 14: TREND OF FOSSIL FUEL RELATED CO ₂ EMISSIONS IN SOUTH AFRICA, 1993 – 2003	46
FIGURE 7: US PROJECTED ENERGY INTENSITY RELATIVE TO 2004 BY INDUSTRY (TO 2030)	48
TABLE 15: HISTORICAL ENERGY INTENSITY RATIO, GDP AND PRIMARY ENERGY SUPPLY	50
FIGURE 8: ELECTRICITY CONSUMPTION BY INDUSTRY IN SOUTH AFRICA	51
FIGURE9: ELECTRICITY CONSUMPTION IN SA MINING INDUSTRY	52
TABLE 16: GOLD UNDERGROUND MINES DEPTH'S CLASSIFICATION	71
TABLE 17: PLATINUM UNDERGROUND MINES DEPTH'S CLASSIFICATION	73
TABLE 18: CLASSIFICATION OF GOLD MINES' MECHANIZATION	74
TABLE 19; CLASSIFICATION OF PLATINUM MINES' MECHANIZATION	74
TABLE 20: GOLD MINES PRODUCTION	75
TABLE 21: PGMs MINES PRODUCTION.....	75
FIGURE 10: PRODUCTION CHAIN PROCESS COMPONENTS.....	76
TABLE 22: GLOBAL CO ₂ EMISSIONS COAL EXCLUDED.....	79
TABLE 23: CO FROM COAL CONSUMPTION 1	80
TABLE 24: MINING CO ₂ INTENSITY IN 2006	81
FIGURE 11: GOLD CHAIN PROCESS TREE 2006	83
FIGURE 12: PLATINUM CHAIN PROCESS TREE 2006	84
FIGURE 13: PERCENTAGE PER ENERGY ACTIVITY.....	85
FIGURE 14: ENERGY INTENSITY PER GOLD MINE	86
FIGURE 15: ENERGY INTENSITY PER PLATINUM MINE	86

TABLE 25: BENCHMARK OF GOLD MINES ENERGY INTENSITY AND OPERATION COSTS ...	87
TABLE 26: BENCHMARK OF PLATINUM MINES ENERGY INTENSITY AND OPERATING COSTS	87
TABLE 27: AVERAGE INTENSITY AND COSTS	88
TABLE 28: GOLD MINES BENCHMARK OF ENERGY VS. MECHANIZATION	88
TABLE 29: PLATINUM MINES BENCHMARK OF ENERGY CONSUMPTION VS. MECHANIZATION	89
TABLE 30: GHG & CO ₂ EMISSIONS' INTENSITY FOR SELECTED MINES	89
FIGURE 16: COMPARISON OF GOLD MINES' AVERAGE OPERATING COSTS PROFILE	90
FIGURE 17: COMPARISON OF PLATINUM MINES' AVERAGE OPERATING COSTS PROFILE	91
FIGURE 18: GOLD MINES COST INDICES PROFILE	91
FIGURE 19: PLATINUM MINES COST INDICES PROFILE	92
FIGURE 20: HISTORICAL GOLD PRICE TREND FOR ONE YEAR	93
FIGURE 21: HISTORICAL PLATINUM PRICE TREND FOR ONE YEAR	94
FIGURE 22: FORECAST OF ELECTRICITY DEMAND IN SA GOLD AND PLATINUM MINES...	97
FIGURE 23: ANNUAL ENERGY CONSUMPTION PERFORMANCE CURVES (V R MINES) ¹ ...	99
FIGURE 24: COMPARATOR MODEL FOR MINING ACTIVITIES' ENERGY CONSUMPTION ¹	100

SYMBOLS AND NOMENCLATURE

- Bcf : Billion cubic feet
- Btu : British thermal unit
- GJ : Giga joule
- GWh : Giga Watt hour
- KWh : Kilo Watt hour
- MJ : Mega Joule
- Mt : Million tonne
- MWe : Mega watt equivalent
- PJ : Pico Joule
- Tcf : Trillion cubic feet
- TJ : Tera – Joule
- Toe : Tonne oil equivalent
- CPI : Consumer Price Index
- DME : Department of the Minerals and Energy
- DSM : Demand Side Management
- EDI : Electricity Distribution Industry
- GDP : Gross Domestic Product
- GHG : Green House Gas
- GNP : Gross National Product
- HVAC : High Voltage Alternative Current
- IEA : International Energy Agency
- IEP : Integrated national Electrification program
- NERSA: National Energy Regulator South Africa.
- PK & EM : Peak period and Emergency
- RSE : Relative Standard Error
- SARB : South African Reserve Bank
- UMECS: Underground Mine Energy consumption
- N/A: Not available

1 INTRODUCTION

Energy is an essential input for industrial activities and other sectors of economic development in the world. Energy is the driving force behind all industrial operations, including those of the mining industry. The mining industry is one of the largest consumers of energy, in its daily operations such as mineral extraction, plant processing, mill operations and others. South Africa is one of the world leaders in minerals extraction, but most mineral products are exported, with limited amounts being consumed locally. For example, mineral commodities accounted for 28.7% of total value of South African exports in 2004¹. The country's mineral industry is largely supported by gold, platinum, coal and diamond productions with an important contribution to the national economy (7.1% in 2004)¹. The high price trends of gold and platinum have motivated most companies operating in South Africa such as AngloGold Ashanti, Anglo Platinum, Gold Fields, DRD and others to commit to increasing production in line with growth in global demand.

A significant objective for these companies is controlling their input costs, particularly energy, in both their surface and underground mining operations. Energy used in mining activities such as drilling, handling, crushing, pumping, air conditioning, lightning; is generated from energy resources such as coal, hydropower, oil, natural gas, and nuclear.

In order to correctly account for energy consumption in mining operations, standards relating to energy supply and consumption are essential. Standards required are available and provide comprehensive criteria against which the efficient use of energy can be evaluated together with the associated financial implications.

1.1 PROBLEM DESCRIPTION

Significant studies in energy resources, their use, and the anticipated shortfall in the next 15 to 20 years have been undertaken in USA, France, and the United Kingdom¹. While global scarcity of energy, particularly a shortage of oil is expected, the impact on developing countries will be severe. South Africa, an economy that is reliant on production and export of primary products, is increasingly aware of the problems associated with energy shortages. South Africa's mining industry remains one of the largest contributing sectors to country's economy, but it consumes approximately 16.2% of the energy produced. The rate of consumption is not sustainable with the present electrical reticulation network and if nothing is done, South Africa will face energy supply reliability problems that are particularly acute for electrical power and oil.

The mining sector has to find ways of improving its performance and efficient use of energy as an input to the extractive industries. It is, therefore, essential to investigate energy usage standards and associated costs in the mining industry. Studies in the following areas of energy use in the minerals industry are essential:

- Energy supply and consumption;
- Energy intensive activities and the potential for energy saving improvements, and;
- Comparative energy input costs in the extraction of specific mineral commodities.

1.2 OBJECTIVES

The aim of this study is to quantify and cost energy consumption in the gold and platinum mining industry. Once these details become available, they should provide an indication of how energy use standards and patterns can improve energy efficiency and its associated costs in mining operations.

The study will compare the consumption of energy and associated costs at each stage of the mineral extraction process with a special attention to potential energy conservation measures for the different mineral commodities. The study will also consider the possibility of establishing long-term integrated energy use standards appropriate to the mining industry in line with those currently applied in the US and UK. This study has been motivated by:

- * The current world trend towards energy conservation;
- * The requirements to improve energy efficiency in regard of environmental impacts;
- * The drive by companies to increase returns by lowering production costs through energy drifting;
- * Provision control on the intensity of energy use as South African mines deepen, and;
- * The need to establish comparative energy standards, patterns for environmental assessment, industrial technology improvement and investment strategies, in the mining industry.

Energy consumption patterns vary greatly among developing countries. According to Energy Outlook 2005, the energy sector in the Southern African region depends heavily on coal (68%), while the rest of Africa is dominated by oil¹⁷. In particular, South Africa with an energy-intensive economy relies heavily on coal (74%), which is used essentially for power generation (DME)¹¹. Although electricity produced in South Africa is amongst the cheapest in the world, the country faces serious problems in regard to environmental requirements stressed in Kyoto protocols⁵. According to a recent report, developing countries including South Africa demonstrate a lack of commitment in regard to energy conservation. Such countries are still learning from the experiences of western nations. Furthermore, there is a scarcity of research and available data with regard to local energy use in mining and minerals industry.

1.3 RESEARCH METHODOLOGY

To achieve the objectives of this study, the following problems must be considered:

- The how and where of energy consumption in specific mining operations
- The standards and criteria to be considered in regard to energy use
- Identification of equivalent energy intensive activities and associated costs
- Measures to reduce cost
- The influence on mineral commodity markets

Information will be collected through:

- Literature review using library, internet and other sources such as interview;
- Visits to mining operations and the use of survey questionnaires;
- Data collection, analysis and interpretation, and;
- An analysis of Standards available, with potential suggestions for possible implementation on South African mines.

The investigation is limited to South African gold and platinum mining operations because of the easy accessibility of the well documented history of energy statistics, unlike in other SADC countries. The study covers only underground mines in South Africa since these are more energy intensive than surfaces mines. In addition, the energy sources considered are mainly coal, gas and oil.

1.4 RESEARCH PROCEDURE

The first section of the study provides a general overview of energy supply-demand balance and its consumption in the mining industry with an emphasis on energy conservation standards. The second section is concerned with energy resources, organisation of the energy sector and features, trends of power supply and power consumption in the mining sector in South Africa. The third section deals with data

collection and analysis through energy management including results interpretation. The fourth section provides a discussion of results, suggestions and a conclusion.

2 BACKGROUNDS ON SOUTH AFRICA

2.1 ECONOMY

South Africa is the biggest and the most advanced economy on the African continent, accounting for approximately 40% of Sub-Saharan Africa's GDP. It is an emerging market with a diversified economy. Particularly, the country's economy is growing rapidly with a total GDP estimate in 2005 at \$570.2 billion, four times that of its southern African neighbours and about 25% of the continent. It leads the continent in industrial output (40% of total output) and mineral production (45%) and generates most of Africa's electricity (~50%)¹. The figures below show the evolution of economic growth.

Table 1: Historical economic indicators

SA: SELECTED ECONOMIC INDICATORS					
	2001	2002	2003	2004	2005
Real GDP	2.7%	3.6%	2.8%	3.7%	4.3%
CPI	5.7%	9.2%	5.8%	1.4%	3.9%
CPIX	6.6%	9.3%	6.8%	4.3%	4.3%
Unemployment	29.5%	30.5%	28.2%	26.2%	25.3%
National debt (%GDP)	41.4%	37.1%	35.7%	35.8%	35.1%
External current account balance (% GDP)	0.1%	0.7%	-1.5%	-3.2%	-3.7%
External debt (% GDP)	26%	29.5%	22.4%	19.8%	19.1%
Gross reserves (in months of total imports)	2.9	2.8	2.2	3.1	3.7
Int. liquidity of SARB (in US\$-billion)	-4.8	-1.6	4.8	11.4	19.8
US\$ exchange rate (in rands)	12.13	8.64	6.64	5.64	...

Source: IMF country report 2005

Mining as one of major contributors to the economy is the largest industry sector, followed by manufacturing, oil and gas, chemicals, agriculture and tourism.¹

South Africa's economy has a marked duality, with a sophisticated financial and industrial economy having developed alongside an underdeveloped informal economy.

2.1.1 MINERAL SECTOR'S ECONOMIC CONTRIBUTION

The country's mineral industry is export-oriented as the domestic market for most of the mineral commodities produced is relatively small. In 2004, for example, sales of primary mineral products have accounted for 28.7% of South Africa's total export revenue. Also, mining contributed R 87.1 billion (US \$ 13.5 billion) or 7.1 % to gross value added. This contribution percentage is largely over the last decade, to the growth experienced in secondary and tertiary sectors of the economy and the contraction in the gold mining industry. During the same year, mining and quarrying contributed 9.9% to total fixed capital formation 38%.¹

2.1.2 COUNTRY'S MINERAL WEALTH

Since the late 19th century, South Africa's economy has been based on the production and export of minerals, which, in turn, have contributed significantly to the country's industrial development. As one powerful sector, the mineral industry is a well-established and resourceful sector of the economy, with high degree of technical expertise and the ability to mobilise capital for new development.⁶

As a world leader in mining, the country is renowned for an abundance of mineral resources, accounting for a significant proportion of both world production and reserves. South African mining companies dominate many sectors in the global industry.

South Africa mineral resources are found in diverse geological formations, some of which are unique and extensive by world standards. These include:

- The unique and extensive Witwatersrand basin, hosting a considerable portion of the world's gold resources, as well as uranium, silver, pyrite and osmiridium and yields some 98% of South Africa's gold output;
- The Bushveld Complex, contains more than half of the world's reserves of chrome ore and platinum group metals additionally, the complex hosts ores of vanadium, iron, titanium, copper, nickel and fluorspar;
- The coal and anthracite beds of the Karoo basins in Mpumalanga, Kwazulu Natal and Limpopo;
- The Kimberlitic, alluvial and marine deposits of diamond;

- The Phalaborwa Igneous complex, which hosts extensive deposits of copper, phosphate, titanium, iron, vermiculite and zirconium;
- Northern Cape's large deposits of lead/zinc ores associated to copper and silver;
- Heavy mineral sand occurrences containing titanium minerals, iron and zircon.

The country's mineral industry is largely supported by gold, diamond, coal, and platinum group metals production through which it is a leading world supplier of a range of minerals and mineral products of high quality.

In 2005, about 55 different minerals were produced from 1113 mines and quarries of which, 45 produced gold, 26 produced platinum-group minerals, 64 produced coal and 202 produced diamonds, all as primary commodities with an increase of 120 mines from 2004 essentially due to several new small-scale mining. The same year, mineral commodities were exported to 101 countries.⁶

2.2 ENERGY OVERVIEW

Energy is an ability to work, that can be obtained through energy systems in productive force. The definition of an energy system may include two steps according to energy conversion and utilisation. The first step deals with the location of primary energy that includes techniques used to supply energy and its ecological implications. These require the knowledge of how to collect or extract it, to ensure transport and obtained storage. Also important is the type of converters and the forms of final energy obtained. The second set of elements of the definition includes the ways in which energy is appropriated through converters and its consumer patterns.⁷

Access to energy is fundamental to our civilisation and economic and social development is fuelling a growing demand for reliable, affordable and clean energy which depends on availability of energy resources. Energy resources can be analysed from different point of view that arise different considerations.

From an economic point of view, difference is made between two kinds of energy sources: renewable energy sources such as solar radiation, wind, tidal and hydro energy and non-renewable sources including coal, oil and natural gas.

From an industrial development point of view, distinction must be made between traditional sources such as wood, vegetable and animals waste used long time ago and modern energy source namely coal, petroleum, products, natural gas and electricity, that play a significant role in the world.

From energy flow side¹, the process allows for a distinction between primary energy sources, secondary energy and final energy.

- Primary energy is that obtained directly from primary sources including energy available in the natural state such as wood, coal, crude oil, natural gas, uranium, hydro and solar energy. South African energy sector is dominated by coal, which is abundant and cheap according to international standards
- Secondary energy is energy defined at transmission and transport steps that involve converters, transport and distribution infrastructure to ensure energy supply. It is produced by conversion or transformation of primary energy or of another secondary form of energy, e g electricity, steam, refined petroleum products, and hydrogen. In South Africa, this step is covered mainly by the state owned utility, Eskom for electricity and Sasol for oil and gas.
- Final energy is defined as energy at end user step namely, energy consumption from which energy systems are differentiated by forms of appropriation of rent, the quantities of energy mobilized and their overall efficiency. The major energy use sectors in the country are: commerce, residential, transport, agriculture, industrial and mining.

2.2.1 ENERGY SOURCES

Amongst a large range of existing sources of primary energy, only those classified as non-renewable and modern, usually called commercial sources, are of concern in this study. These are essentially fossil fuels including coal, oil and natural gas. These

named fossil fuels can be transformed essentially into electricity or other forms of energy before reaching consumers. The conversion process for electricity generation can be conducted in coal-fired plants and turbines using gas or steam.

Measure and conversion factors given in appendix allow expressing energy content in fossil fuels on basis of carbon number as heating value: Lower Heating Value (LHV) and Higher Heating Value (HHV).

Coal is classified into four main types namely; lignite, sub-bituminous, bituminous and anthracite, depending on the amounts and types of carbon it contains and on the amount of energy it can produce.⁸

- Anthracite contains 86 % to 97 % carbon and its heating value is slightly lower than bituminous coal.
- Bituminous coal contains 45 % to 86 % carbon, and was formed under high heat and pressure. Its heating value is about two to three times that of lignite.
- Sub-bituminous coal contains 35 % to 45 % carbon and has higher heating value than lignite.
- Lignite with 25 % to 35 % carbon has the lowest energy content. It tends to be relatively young coal deposits that were not subjected to extreme heat or pressure. It is crumbly and has high moisture content. Mainly, it is burned at power plants for electricity generation.

2.2.2 ENERGY CONTENT IN FOSSIL FUELS

Energy content through heating value including condensation of combustion products is greater by between 5% in the case of coal and 10% for natural gas, depending mainly on the hydrogen content of the fuel. As all coal is not of the same composition, there is a strong correlation between energy content and carbon content⁹. The following table gives carbon content and corresponding heating value per unit of fuel considered.

Table 2: Fossils content & carbon heating value

	TYPE	UNIT	C Content	LHV	HHV
--	------	------	--------------	-----	-----

				Joules		Btu	
				Joules	Btu	Joules	Btu
Coal		1 metric tonne	746 kg				
	Anthracite			27 GJ	11500 Btu/lb	30GJ	13000Btu/lb
	Lignite/sb			15 GJ	6500 Btu / lb	19 GJ	8200 Btu/lb
Oil		1 US gal					
	Gasoline	3.79 l	2.42 kg	121 MJ	115,000 Btu	132 MJ	125,000 Btu
		1 metric tonne		43.5GJ/l		47.3 GJ/ l	
	Diesel oil	1 US gallon	2.77 Kg	36.4 MJ / l	130,500Btu/g		
N.Gas	Methane	1 cubic meter	0.49 kg	34.6MJ/m ³	930 Btu/ft ³	38.3MJ/m ³	1027Btu/ft ³

Source: Bio energy conversion factors .http://bioenergy.ornl.gov/papers/misc/energy_con.html

NB: The energy content of petroleum products per unit mass is fairly constant, but their density differs significantly, hence, the energy content of a litre, gallon varies between gasoline, diesel, and kerosene.

- The energy content per unit mass varies greatly between different ranks of coal. The non specified rank means bituminous coal, the most common fuel for power plants (19 – 27) GJ/t.

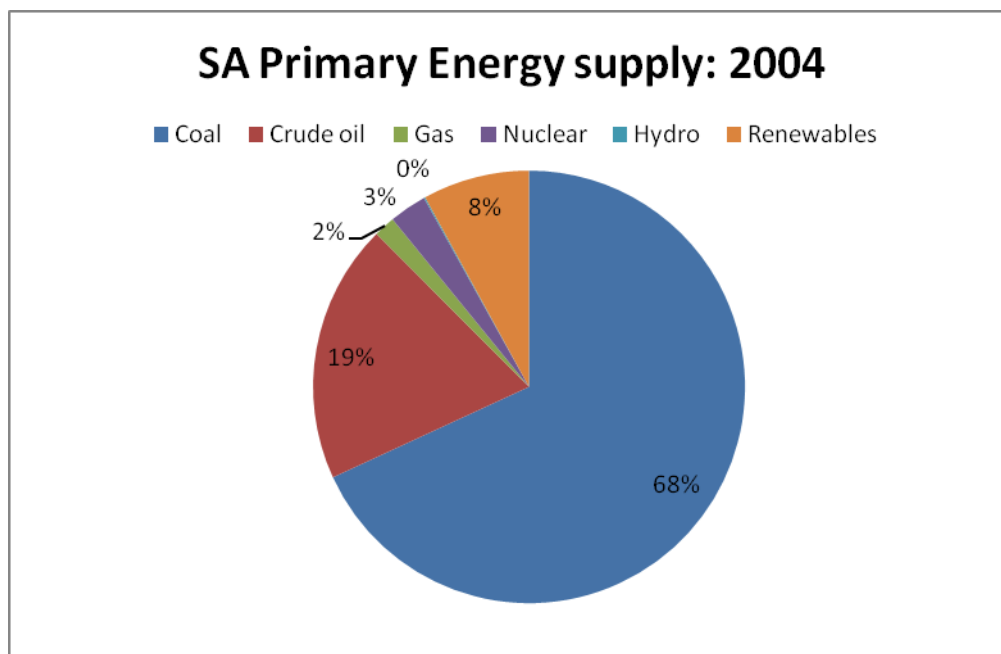
2.3 SOUTH AFRICA ENERGY SECTOR

The South African economy, from international standards, is high energy intensive, using a large amount of energy for every rand of value added, reflecting a high energy input per unit of gross national product (GDP). Energy comprises about 15% of South Africa's GDP .¹⁰

High energy intensity is largely a result of the economy's structure with its dominating large-scale, energy-intensive primary mineral beneficiation and mining industries. Energy relies heavily on coal for the generation of most the country's electricity and a significant proportion of its liquid fuels. Coal contributes 70 % of primary energy, making the economy to be carbon dioxide intensive. One benefit is in low energy costs, particularly for electricity, which is the cheapest in the world .¹³

According to Country Analysis Brief, South Africa is the largest energy consumer and second energy producer in Africa. The country is also a major coal producer and exporter. It has a highly developed synthetic fuel industry and small reserves of oil; most of her crude oil is imported. Some useful amounts of energy are obtained from biomass and nuclear power with small amounts from hydropower, natural gas, solar and wind.⁷

Energy supply deals with how many resources are available in various forms to sustain demand and consumption in different economic activity sectors and the infrastructure to allocate to production process.



Source: Digest of South African Energy Statistics – 2006

Figure 1:- Share of total primary supply in 2004

2.3.1 AVAILABLE ENERGY SOURCES

2.3.1.1 Coal

Amongst all fossil fuels resources, coal is the most abundantly distributed worldwide in terms of reserves. World coal reserves are huge; considering only reserves classified as proven. British Petroleum, in its annual report 2006, estimated at the end of 2005, the

total proven coal reserves at 909064 million tons, more than 155 years reserves to current production ratio. Well dispersed, the largest reserves are found in USA, Russia, China, Australia, India and South Africa.¹⁶ Indicatively, Over total production of 4595 Mt recorded in 2000 following figures are given by region: China (1033Mt), USA (997.1 Mt), India (314.4 Mt), Australia (304.0 Mt), Russia (249.4 Mt), South Africa (223.5 Mt), Germany (201.8 Mt), Poland (171.0 Mt), Canada (72.5 Mt) ¹⁴etc

Most of major countries with coal endowment are also major exporters. The following figures show exports of coal by country for 2003 and 2004 (million tons)

Table 3:Coal exports by country 1

Country	2003	2004
Australia	238.1	247.6
Indonesia	107.8	131.4
China	103.4	95.5
South Africa	78.7	74.9
South America	57.8	65.9
Russia	41.0	55.7
United States	43.0	48.0
Canada	27.7	28.8
Poland	16.4	16.3
Total	713.9	764.0

Source: <http://en.wikipedia.org/wiki/coal>

As the primary fuel produced and consumed in the country coal is a dominant South African indigenous energy resource, its resources are abundant; the country has the world's seventh largest amount of recoverable coal reserves estimated at 54.6 billion short tons, representing 5% of the world total. Proven coal reserves are expected to last more than 150 years. The country has 19 official coal fields of which 70% lie in the Highveld, Waterberg, and Witbank ¹⁶.

The country is the world's fifth largest coal producer with an average of 239 million tons (m mst) of coal annually as many of the deposits can be exploited at extremely favourable costs⁷. The Mpumalanga province accounts for 83 % of South African coal production, while Free State 9%, Limpopo 7%, and Kwazulu-Natal 1%.¹¹

The major companies involved in coal production are: Anglo Coal, BHP Billiton's Ingwe coal, Eyesizwe coal, Kumba, Sasol mining, and Xstrata coal.

Two-thirds of coal produced in the country is extensively used domestically, but some 30% is exported internationally through Richards Bay Coal Terminal to European Union and Asia, making South Africa the fourth largest exporter.¹⁸

From the coal use point of view, South Africa is the sixth greatest consumer, accounting for about 3.5% of the world annual total consumption. About 85% of coal consumed is used for electricity generation and the synthetic fuel industry. The key role played by coal in the South African economy is illustrated by the fact that Eskom, the national utility, is the seventh largest electricity generator in the world and Sasol the largest coal to chemicals producer. The table below shows a historical summary of coal production and consumption.¹⁹ Other coal consuming sectors include the non-synthetic fuels industrial sector, metallurgical industries, and the merchant and domestic sectors.

Table 4: Historical production, exports and consumption in South Africa

YEAR	PRODUCTION			EXPORTS	INLAND CONSUMPTION	
	Bituminous	Anthracite	Total		Available	Electricity gen
1992	171.10	3.32	174.42	49.54	129.8	76,836
1993	179.03	3.25	182.28	52.19	131.21	80,701
1994	193.52	2.22	195.35	54.84	134.17	82,564
1995	204.07	2.14	206.29	59.68	146.07	86,436
1996	203.90	2.47	206.36	60.22	146.56	90,893
1997	217.87	2.00	219.87	64.80	159.7	95,651
1998	222.79	2.04	224.83	66.13	157.37	99,631
1999	220.40	1.87	222.27	64.91	155.24	94,265
2000	222.52	1.62	224.14	69.91	154.69	98,143
2001	222.11	1.46	223.56	69.21	145.12	89,275
2002	218.91	1.30	220.29	69.23	150.87	92,726

2003	237.54	1.21	238.75	71.53	160.91	103,07
2004	241.57	1.25	242.82	67.95	172.71	109,974

Source: Digest of South African Energy Statistics 2006 and DOE/EIA

2.3.1.2 OIL

About 80 % of the world readily accessible oil reserves are located in the Middle East, with 62.5% coming from the Arab countries. Except USA and UK, most of these countries, including some others from Africa such as Algeria, Libya, Angola, and Gabon are exporters.

At world extent, it has been estimated that there was initially a total of 2,050 to 2,390 giga barrels (380kgm^3) of crude oil on the Earth of which, about 45% to 70% has been used so far. According to the 2006 BP Statistical Review of World Energy, from the years 1965-2005, approximately 917,558,609,280 barrels of oil were produced globally.¹⁵ The total world production/ consumption estimated in 2005 is approximately 84 million barrels per day.⁵ Most oil reserves are found in only a few countries, but estimates of their size vary widely. As the amount of oil left is an estimate, not a known amount, there are many differing estimates for the amount of oil remaining in different regions of the world.

South Africa has less proved oil and natural gas reserves, located along its western and southern coastline (on block 9 including the Oribi, Oryx and sable fields) are currently estimated (as of January 2005) at only about 16 million barrels, but this could increase by as much as an additional 40 barrels once preliminary development of adjacent discoveries is completed.

South Africa imports the majority of its crude oil (about 95%), from the Middle East, with Saudi Arabia and Iran as its chief's suppliers followed by Nigeria the third largest supplier. Other major oil sources include Kuwait, Russia, Angola and Equatorial Guinea.

But the import of refined products is restricted to special cases where local producers cannot meet the demand. It is subject to state control with a view to promote local refinery utilisation.

The remaining oil quantities are provided by the refining oil industry and the synthetic fuels. South Africa has the second largest capacity in Africa after Egypt (519,547bbl/day). The country has a highly developed synthetic fuels industry supported by abundant coal resources and offshore national condensate production in Mossel Bay. Sasol, with a capacity of 150,000bbl/d, and Petro SA 50,000bbl/d, are the major producers of synthetic fuel in the country. A historical summary of production, imports and consumption for main petroleum products such as petrol and diesel is given in figures below, from 1992 to 2004.²⁰

Table5:Historical oil local supply and exports

YEAR	PRODUCTION		IMPORTS		DOMESTIC SUPPLY	
	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel
1992	8742512	6182916	6888041	390711	9170436	4985184
1993	9708816	6943737	328878	168419	9202067	4976806
1994	10467381	6899224	191442	51319	9629565	5139875
1995	11736662	7928506	134752	75568	10344353	5482687
1996	1084193	7961507	630213	267283	10566755	5809638
1997	10712798	6334935	Na	Na	10712798	5912661
1998	10744141	8762426	786598	70217	10883203	5959204
1999	10651184	8493178	962332	72302	10848616	5984367
2000	11036056	8265373	179442	159847	10387164	6230110
2001	11740861	9116140	354669	781413	10334327	6486015
2002	11796957	8815388	283843	567643	10355404	6830544
2003	11577945	9066560	369634	311	10668350	7263272
2004	11554692	8526883	751389	554254	11291753	7682327

Source: Digest of South African Energy Statistics – 2006 and DOE/EIA

NB: With reference to 2004 figures, the share in consumption of petroleum products by sector is presented as follows: Transport (77%), Agriculture (6%) Residential (5%), Commerce (4%), Mining (3%), Industry (2%), Non- energy use (2%) and non specified (1%).²⁰

2.3.1.3 NATURAL GAS

Finally, the largest two natural gas fields are probably South Pars Gas field in Iran and Urengoy gas field in Russia, with reserves in the order of 10^{13} m^3 . Qatar also has 25 trillion m^3 (5% of the world's proven supply), enough to last 250 years at current production levels.¹⁴

The majority of Africa's proven gas reserves are located in major oil producing countries with Algeria leading 36% and Nigeria 34%. Southern Africa contains approximately 2% of Africa's natural gas reserves with Namibia (3Tcf), Mozambique (2Tcf), Angola (1.6Tcf) and South Africa (780Tcf).²⁴

Natural gas from Namibia's offshore Kudu and from Temane gas field in southern Mozambique is expected to be a source for power and industrial projects in these countries and South Africa.²⁴

Limited natural gas reserves exist around the South African coast. The existing gas discoveries are located on block 11A, which lies east of block 9. Offshore natural gas discoveries were made off South Africa's border with Namibia and are exploited by Petro SA at Mossel Bay where it is converted at the Moss gas plant into liquid fuels. Proved natural gas reserves are currently estimated at 350 billion cubic feet (bct as of January 2005) but the gas fields of South Africa's west coast and neighbouring Namibia may contain as much as 20 trillion cubic feet (tcf) of natural gas.

Natural gas produced accounts for about 1.5% of total primary energy supply.

Gas manufactured from coal accounted for 0.5% of net energy consumption, while liquid petroleum gas accounted for 0.6%.

In order to partially replace coal with natural gas as the synthetic-fuel feedstock, Sasol began importing gas from Mozambique's Temane gas field in 2004 through a 536 mile transport pipeline to Secunda, owned by a joint venture between Sasol, South African government and Mozambique's government. Temane and Panda fields are estimated to hold reserves of 3.2 Trillion cubic feet (tcf).¹⁰

Even though, the consumption of gas in the country has increased in recent years the mining industry remains the largest consumer. In following consumption figures, sectors named non-industrial are transport, residential, commerce and non-specified, but industry sector includes chemical, iron and steel, non-ferrous metals, non-metallic minerals, transport equipment, machinery, food, paper, wood, textiles etc

Table 6: Historical Natural Gas consumption in SA

YEAR	CONSUMPTION			
	INDUTRIAL		NON-INDUSTRIAL	TOTAL
	Mining	Others		
1992	461	21010	2526	23536
1993	466	21955	2513	24468
1994	430	23318	1566	24884
1995	478	25223	1307	26530
1996	325	28588	1324	29912
1997	549	28468	1427	29895
1998	498	31071	120	31191
1999	341	37466	291	37757
2000	378	39532	298	39830
2001	395	41241	311	41552
2002	412	43049	324	43372
2003	2334	48749	95	48244
2004	2312	50361	210	50571

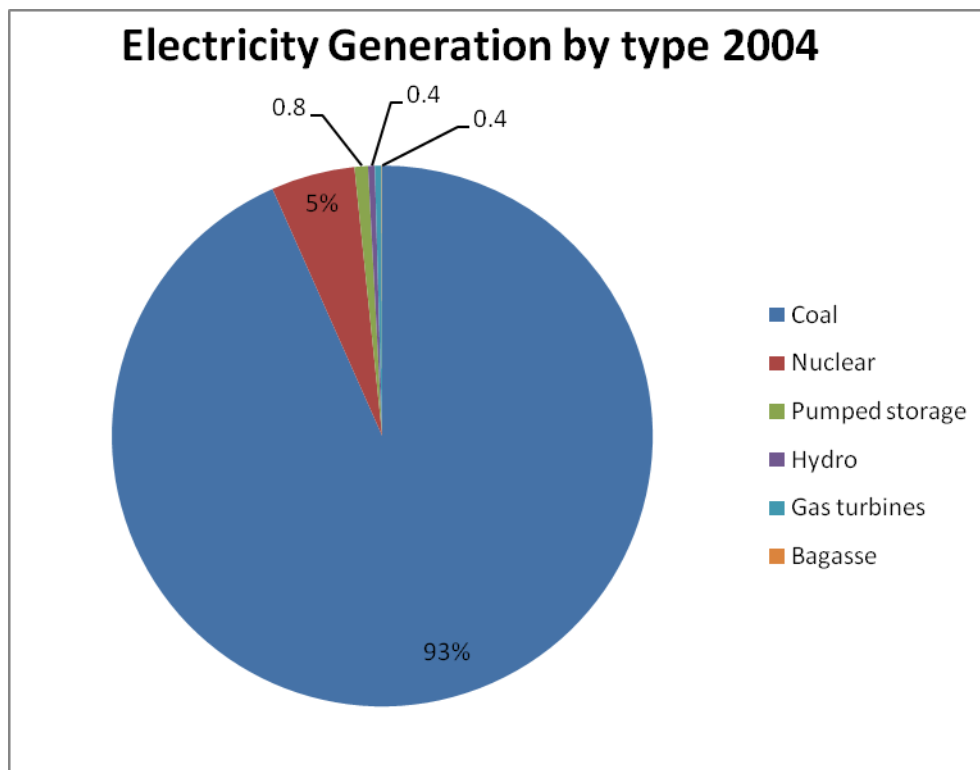
Table 3: Coal exports by country 2

Sources: National Energy Balance and digest of South African Energy statistics 2006, DOE/EIA 2005

Amongst several existing energy sources in South Africa, biomass mainly from natural woodlands is used by households in most rural areas for cooking and heating. Renewable energy sources such as solar and wind have not been fully exploited in the country and the existing hydro potential is small. Most of the above mentioned primary energy is transformed into liquid fuels or mostly converted in electricity as final step before end users.

2.3.2 ELECTRICITY

Electricity is the most used form of energy in South Africa's economy with 90 % of country electricity produced from coal. The rest comes mainly from oil, gas, nuclear, hydropower, and other biomass, solar in small quantities. The chart below illustrates the generation of electricity by source in South Africa in 2004.

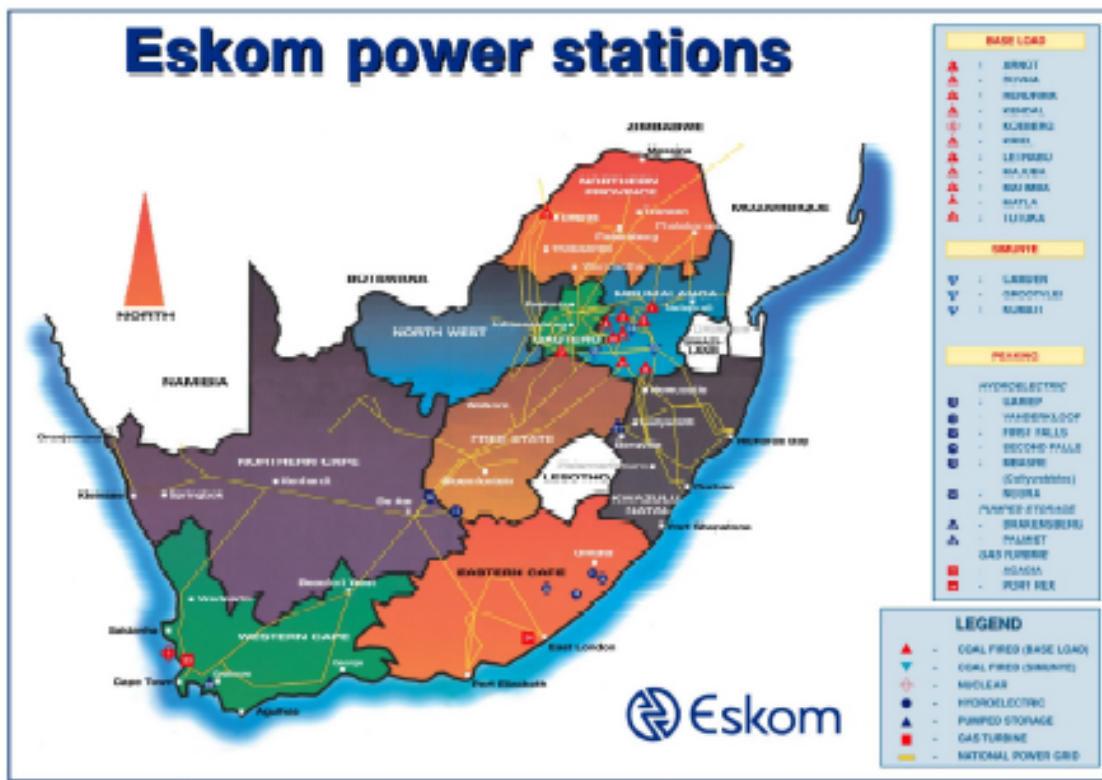


Sources: National energy Balances and Eskom Annual Report 2004

Figure 2: Share of electricity generation per source

Generation of electricity is dominated by the national state-owned company Eskom which also owns and operates the national electricity grid. Eskom is 11th largest utility in terms of generation capacity and 9th in terms of sales and generates 95% of country electricity (> 50 % of Africa). Other generating capacities are held by country municipalities (2436MW) and private (836MW).²³

With total installed capacity of 42000MW including 24 power stations from which 74 % are coal fired electricity consuming an average of 100000 Mt of coal annually, Eskom totalises 325010 km of power lines of all voltages²⁴. The location of the power generation units is presented in the figure 3.



Eskom Annual Report 2006

Figure 3: Power stations location map in South Arica

Indicatively, from Eskom nominal generating capacity in 2005 of 42011 MW, 37678 MW is primarily coal fired, 1930MW from one nuclear power station at Koeberg contributing for 5% of total electricity, 342 MW from two gas turbine facilities, six conventional hydroelectric plants producing 600MW, 1400 MW from two hydroelectric pumped storage stations and 3800 MW from three mothballed coal fired facilities.²⁵

The table below describes the profile of current South African power stations in commission from first quarter of 2005 .This profile includes for each unit the type related to primary source, nominal and net capacity in megawatts, the approximate age and current life level and technical services status. Additional observations are made for some of them about risks on outage frequency.

Table 7: SA's installed power stations

Power	Type	Capacity (MW)	Age	Status	Observation
-------	------	-----------------	-----	--------	-------------

station							
		Nominal	Net	years	current	Life	
Acacia	Gas Turbine	171	171			PK &E	
Arnot	Coal – fired	2100	1980	50	Over ML	B Load	Outage
Camden	Coal – fired	1600	190	45	Over ML	Mothb	RTS
Drakensberg	Pump storage	1000	1000	40	Over ML	Peak P	Outage
Duvha	Coal – fired	3600	3450	40	Over ML	B Load	Outage
Gariep	Hydroelectric	380	360	40		PK &E	
Grootvlei	Coal – fired	1200		45	Over ML	Mothb	RTS
Hendrina	Coal – fired	2000	1895	40		B Load	
Kendal	Coal – fired	4116	3840	45	ML	B Load	
Koeberg	Nuclear	1930	1800	45	Over ML	B Load	Outage
Komati	Coal – fired	1000		50	Over ML	Mothb	RTS
Kriel	Coal – fired	3000	2850	45	Over ML	B Load	Outage
Lethabo	Coal – fired	3708	3558	50	ML	B Load	
Majuba	Coal – fired	4110	3843	40		B Load	
Matimba	Coal – fired	3990	3690	45	ML	B Load	
Matla	Coal – fired	3600	3450	40	Over ML	B Load	Outage
Palmet	Pump storage	400	400	40		Peak p	
Port Rex	Gas Turbine	171	171			PK &E	
Tuluka	Coal – fired	3654	3510	45	ML	B Load	
vanderkloof	Hydroelectric	240	240	40		PK &E	

Source: - Eskom Annual Report 2006 and Engineering news. May 2007

NB: Peak and Emergency (P k & E), Base Load (B load), Mothballed (Moth b), Peak period (Peak P), Mid Life (ML), Return To Service (RTS)

South Africa presently ranks as the 15th largest electricity producer, accounting for about 1.4% of the world's total annual electricity production, and the 15th largest electricity consumer, accounting for about 1.3% of world total annual electricity consumption. The following figures show the increase in generation and consumption over past years with the related average peak level of electricity demand.²⁶ Also appears for the same periods are the total annual amounts of electricity exports and imports by the country.

Table8: SA historical electricity profile 1993 – 2004

YEAR	SUPPLY CAPACITY	DEMAND CAPACITY	EXPORTS	IMPORTS
------	-----------------	-----------------	---------	---------

	Net capacity	Net generation	Peak demand	Consumption		
	MW	GWh	MW	GWh	GWh	GWh
1993	37636	163.3	23169	149.4	2.6	0.1
1994	35926	170.7	24798	156.2	2.6	0.1
1995	35951	176.1	25133	160.9	3.0	0.1
1996	36563	187.0	27967	168.4	5.6	0.0
1997	37175	196.0	28329	175.7	6.6	0.0
1998	37848	191.9	27803	176.0	5.1	2.6
1999	38517	189.4	27813	178.3	4.5	6.7
2000	39186	196.5	29188	184.0	4.0	5.3
2001	39810	197.8	30599	184.2	7.0	7.2
2002	39810	205.7	31621	192.2	7.0	7.9
2003	39810	215.9	31621	197.4	7.0	6.7
2004	38436	220.2	34195		10.1	

Sources: Integrated National Electrification Planning manual, Eskom Annual Reports (2004), NER Electrification supply statistics 2003&2004, Digest of South African Energy Statistics 2006.

This electricity is used domestically and also exported to Botswana, Lesotho, Mozambique, Namibia, Swaziland and Zimbabwe.⁵⁷ The table below describes trends in South African electricity exports from 2002 to 2005.

Table 9: Evolution of Eskom exports

TWh	2002	2003	2004	2005
Botswana	1,124	1,390	1,699	2,111
Mozambique	3,907	5,875	8,076	10,108
Namibia	598	1,114	1,515	1,821
Zimbabwe	298	793	532	598
lesotho	16	38	12	13
Swaziland	799	796	697	872
Zambia	103	151	403	465

Source: Eskom annual report 2006

Electricity supply

Electricity supply industry is dominated by Eskom in generation and transmission level. In contrast, the electricity distribution industry (EDI) is highly fragmented. Eskom, as the largest single distributor, accounts for more than 56% of energy sales to final consumption and 39 % of the customers.

Eskom has a practical monopoly on bulk electricity and operates the integrated national high – voltage transmission system and supplies electricity directly to large consumers such as mines, mineral beneficiaries and other large industries. Eskom also provides electricity directly to commercial farmers and through the integrated national electrification programme (IEP) to a large number of residential consumers.

The general trend indicates that South Africa's excess electricity capacity will likely be exhausted by 2011; if the country's economy grows at higher rate than expected, capacity may be exhausted in 2007. Then, between 2003 and 2004 the country increased its electricity output by 6.9% power stations (Camdem in Ermelo, Grootvler in Balfour and Komati) generating 19270 GWh during March 2004 and consumption rose by 4.8 % to 17640 GWh.¹³

The other initiative is the Western Power Corridor Project (WESTCO), in which Eskom is involved in the upgrade of the 3500Mw Inga hydropower station in Democratic Republic of Congo and interconnected power lines to supply southern Africa's electricity growing needs including South Africa.²⁷



Source: Eskom Holdings limited Annual report 2006

Figure 4: Southern Africa grid map

2.3.3 ENERGY BALANCE

The concepts used in this study are derived from economics, physics and engineering. In this context, energy balance is an aggregate of industrial activities related to energy processes compiled on annual basis time. These energy processes are determined by flows and transformation in the system from which energy produced or used is quantified.

Basically, energy balance relies on the quantitative analysis of energy supply and demand¹⁸. As a core of country's energy accounts, it establishes equilibrium between supply and demand. It can rely on statistical data from energy suppliers such as Eskom in South Africa and others from demand data analysis. Some statistics are derived from energy balance sheets and historical series.

The energy balance is used to present an overview of the energy flows for a specific time period. It shows, in a consistent accounting framework, the production, transformation and consumption of all forms of energy for a given geographical area and economical sector. However, it does not provide at the final stage of consumption, the contribution in energy consumption of a specific mineral commodity production process. Balancing supply and demand can be achieved either on the supply side by facing all troubles of enhanced supply or by going to the demand side which means encountering all hardships of enhanced energy saving measures.

Energy balance presentation use the recognised international format developed by the International Energy Agency (IEA). The figures below show a summary of South African Energy balances limited to coal, oil (petrol and diesel), gas and electricity in this format for 2003 in RSA version 2 and 2004 version 2 using the Tera joule (TJ) as accounting unit.

Table:10 SA Energy Balances

	Year	COAL	OIL	GAS	ELECTRICITY
		TJ	TJ	TJ	TJ
Primary Supply					
	2003	3217600.42	-303147.87	50217.88	-7441.4
	2004	3573342.58	-195342.99	54152.32	-12367.6
Demand					
	2003	703675.19	850807.85	48844.39	686841.46
	2004	778229.9	882320.6	50670.64	816238.67
Balance					
	2003	2513925.23	-1153955.72	1373.49	-694282.86
	2004	2795112.68	-1077663.59	348168	-828606.27

Sources: Digest of South African Energy Statistics-2006

NB: From this data, only coal presents a large margin in progress

2.3.4 FORECASTS AND TRENDS

While geologists are sure that the world will eventually run out of oil, economists are sure that there will always be a price at which supply will meet demand, albeit possibly at a higher price than people would like to pay.

The continued deregulation of electricity markets and the removal of subsidies import barriers and other distortions will continue to drive a shift in coal production to the lowest-cost production regions. The international trade in coal is projected to grow at around 1.7% per annum, from around 406 M toe (637 Mt) in 2000 to 672 M toe in 2030, somewhat faster than demand at 1.4% per annum.³

Also, trends observed in the future of oil can be described through the peak theory, also known as peak oil. It assumes that oil reserves are not replenish able and predicts that future world oil production must inevitably reach a peak and then decline as these reserves are exhausted.

In regard of increasing consumer demand for petroleum products, world crude oil demand has been growing at an annualized compound rate, slightly in excess of 2 percent in recent years. Demand growth is highest in developing world, particularly in China and India and to a lesser extent, in Africa (0.8 billion) and South America (0.35 billion).¹⁴

Where high demand growth exists, it is primarily due to rapidly rising consumer demand for transportation via cars and trucks powered with internal combustion engines.

Considering the rate of demand growth, the rate at which technological advancement in petroleum product usage such as hybrid-powered automobiles, and the substitution of new energy source technologies; Energy Information Administration (EIA)'s long-term world oil supply analysis shows a scenario depicting the percent demand growth experience of recent years extended up to the production peak in 2026 and then a decline at constant Resource/ barrels per year.²⁸

Being a clean fuel is one of reason that the use of natural gas, especially for electricity generation, has grown so much and is expected to grow even more in the future. That power generation using natural gas is thus the cleanest source of power available using fossil fuels. This technology is widely used wherever gas can be obtained at a reasonable cost. Fuel cell technology may eventually provide cleaner options for converting natural gas into electricity, but as yet, it is not price-competitive. Also, the natural gas supply is said to peak around the year 2030, 20 years after the peak of oil. It is also projected that the world's supply of natural gas should be exhausted around the year 2085.²⁹

All the above information on fuels trend and associated forecast can be summarized in following figures showing current world's reserves, their lasting years, and the annual average of production and demand and the associated growth rate forecast.

Table 11: Summary of world fuel estimate trends

Fuel Type	Reserves	Estimate Life	Annual Production	Annual demand	Projected growth rate
Coal	909064 Mt(2005)	>= 155 years	2359Mt	5760Mt	3% / year
Oil	~1293 billion barrels (2006)	<= 20years	917,538,609,280 barrels	36500 million barrels	1.4% / year
N. gas	1,757,500 Tcf (2006)	> 70 years	34 Tcf	24 Tcf	2.4% / year

Source: - International Energy Outlook IEO 2006, -British petroleum report 2006, -Oil and gas journal

Therefore, fossil resources will continue to be indispensable to the world energy system until we have a sustainable system built around non- exhaustible sources. Thus, from then, there will be a slow but continuous change from the heavy reliance on relatively cheap and easy oil and natural gas to an extended period of using fossil fuels that cost more to extract and process and that have potentially larger and larger environmental impacts.

Amongst numerous issues related to energy delivering, cuts and shortage in oil, gas, and electrical power supply constitute some major ones. Nevertheless, to a large extent, inspired solutions come through conservation, substitution and stock reduction and power capacity increase. As such, the lack of electricity causes almost immediate output cutbacks, often proportional to the percentage of the deficit presented.

Therefore, critical shortage of fossil fuel supplies compels industrial organizations to create energy conservation programs that will reduce consumption and generate cost

savings. In the case of electricity generation, the rate of acceptable failure that set the installed power reserve in regard of peak power is one of the important factors determining sequence of production with security of transport and distribution network.

2.3.4.1 Electric capacity margin

Energy demand is closed to energy end-users or energy consumption concept. With advancing in growth in population and prosperity worldwide, economic sectors, including mining industry, are developing and the world is consuming energy faster than ever before. By 2020, some experts predict the world's energy consumption will be 40% higher than it is today.³⁰

Efficiency, improvements, and conservation are part of the solution, but will not, in themselves, meet the need for more energy. Increasing energy consumption will come from emerging economies, including South Africa.

Energy prices and economic expansion contributed to market increase in energy consumption. Security of energy supply in South Africa is assumed by Eskom that has the main responsibility for security of electricity supply (generation, transmission and somewhat distribution) at which the DME has to ensure that the annual margin (1000 MW) of peaking power generation is commissioned at the set date.

Actually, the capacity at breaking point, as warns by Eskom, shows a shortage of 6500 Mw due to 15 of its electricity generating units down. As a result, the normal operating margin of 1600 MW has been gradually eroded.³¹

But, the base line of security in supply level to be provided still has to be determined. This standard intends to define what level of reserve margin should be maintained and clarify meeting responsibility. For example, to attain a reserve margin of 5%, Eskom corporate plan based on extra high forecast (6% GDP growth, 4.4% electricity growth p.a) will require the need for a Combined Cycle Gas Turbine (CCGT) and two units of a new coal-fired power plant to be built by 2010, and an Open Cycle Gas Turbine (OCGT) peaking generation plant and the return to service (RTS) of the mothballed plant³⁴ as presented in middle term additional capacity profile in following table giving the project

to upgrade, or return in service, annual power capacity added and the expected date of final delivery

Table12: S A's additional power capacity profile

Power Stations	Need	Capacity additions per year in MW& date of delivery							
		2005	2006	2007	2008	2009	2010	2011	2012
Camden	RTS	380	380	570	190 *				
Grootvlei	RTS			188	376	564*			
Komati	RTS				101	215		Del*	
Coal CCGT	New								Del*
Pump Storage	New								Del*
OCGT	New			1050 *					
Annual Total		380	380	1808	667	1829			
Cum Total		380	760	2568	3235	5064			

Source: Eskom capacity expansion plan outlook 2003 - 2012

This also indicates the responsibility of Eskom to ensure that transmission system meets the required security standards (availability of sufficient transmission capacity at all locations in the country) and somewhat, as individual distribution network operators to comply with standards as required by National Electricity Regulator of South Africa (NERSA).

In the case of liquid fuels, about 37 % (41%) of South Africa's liquid fuels requirement is supplied by Sasol and Moss gas synthetic fuel plants. With its principal feed stocks obtained from coal, Sasol produces 23% of the country's required oil and the development of natural gas sector will help raise the use of natural gas as a primary energy supply source from 1.5% to 4.3% of total demand with pipeline capacity of 120giga-joules per year equivalent to 40000MW .²⁶

2.3.4.2 Industrial energy consumption

World energy consumption is projected to increase by 57% from 2002 to 2025. Much of this in worldwide energy use is dominated by industrialised countries regarding the

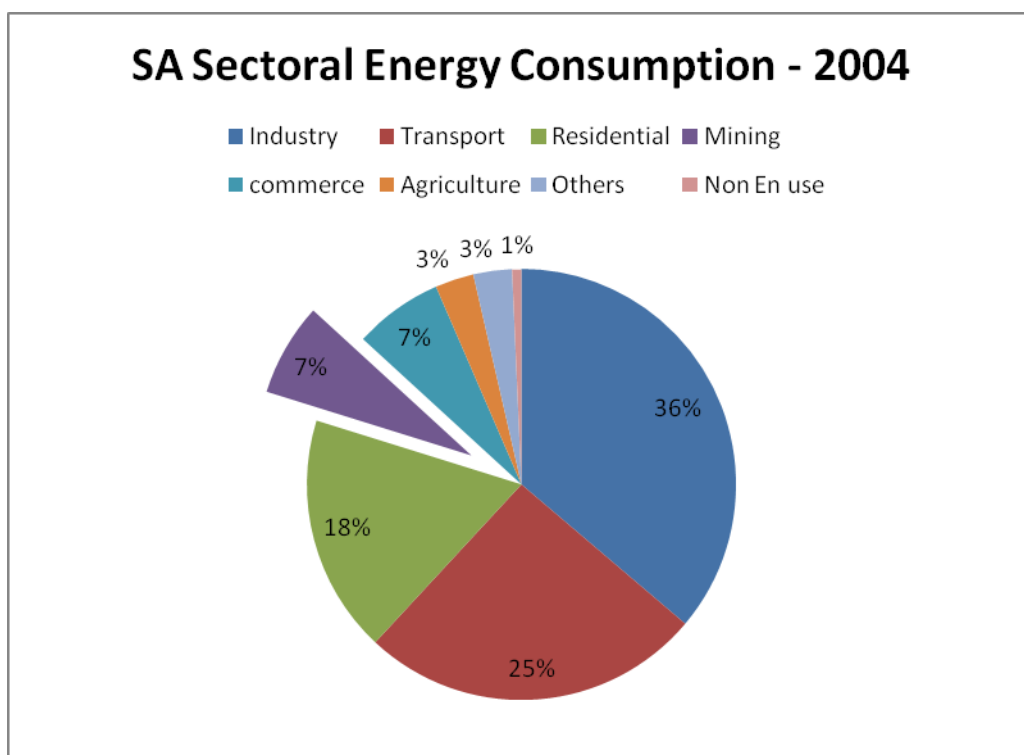
industrial sector, but growth in the IEO2005 reference case forecast is expected in the countries with emerging economies. The total energy use is projected to grow from 412 quadrillion Btu in 2002 to 553 quadrillion Btu in 2015 and 645 quadrillion Btu in 2025.³⁵

According to International Energy Administration, the transitional economies account for 23% while developing countries take 32%. Trends in end-user energy sector consumption can vary widely, according to the level and pace of economic development in a given region.

Following the historical demand, a comparison of energy consumption between 1992 and 2004 in South Africa shows that residential use has remained almost consistent at 18%, commerce and public service has fallen 7%, agriculture has fallen 3%, transport has risen 25%, mining and quarrying has fallen 7% and industry risen 36%.²⁰

Amongst productive sectors, Industry and mining are ones important sub sectors in terms of energy consumption. These sectors use mainly electricity and coal as energy sources followed by liquid fuels.

The mining industry depends heavily on electricity and less on liquid fuels used for fleet. Mineral and metal processing uses large amounts of electricity and coal, mostly in large-scale mineral beneficiation processes. The base metal is the largest single industrial energy consuming sub sector is also by far the most energy intensive one. Chemical and paper and pulps industries also consume large amounts of energy at high intensities.



Source: Digest of South African Energy Statistics - 2006

Figure 5: SA share of final energy consumption in 2004

Historical trends in energy demand for mining and quarrying industry are somewhat consistent with the gold mining output because gold mining uses more energy than all other mining. With mines deepening new technologies (HVAC system), efficiency alternatives must be developed to optimise ventilation and air conditioning, heating system and load management strategy used for deep mining.

2.3.4.3 Demand forecasts

Eskom demand forecast was developed over ten years as bottom-up process based on 100 individual sectors using 24 years of historical sector data. Amongst three scenarios (high, moderate, low), the moderate based on an average GDP growth of 4% per year was more credible according to the analysis. The relationship between the assumed level of annual GDP growth and the annual growth in electricity sale (GWh) and peak demand (MW) is illustrated by Table 13.

Table 13: Eskom Demand Growth Assumption

Forecast	GDP % average p.a growth	MW peak demand % average p.a growth
Extra High	6	4.4
High	5	3.2
Moderate	4	2.3
Low	3	1.4

Source: Eskom: may 2006

NB: It is not known exactly how the different assumptions of GDP growth drive the sector forecasts in Eskom's bottom-up approach, but it is clear that GDP is a highly significant driver to many sectors.

To meet the demand in the next 20 years, South Africa will need approximately between 1000 and 2000 MW every year for ensuring security of energy supply. In line with Eskom base-load plan revision of power generation, in regard of 6% GDP growth, the new infrastructure would not only have to keep pace with growth in demand but also fill the gap that will be left as aging power generation capacity is retired.⁷¹ But the manner in which GDP drivers demand would vary between sectors is not yet determined.

In mining and manufacturing sectors, the relationship between GDP growth and demand will be via the impact of GDP growth on each individual specific commodity industry. Thus, in mining industry, existing drivers influence over time change include production level, energy efficiency, commodity price etc.

South Africa has consumed 21262 ML of liquid-fuel products in 2002 and 25338 ML in 2003. Also, 36 % of the demand is met by synthetic fuels made largely from coal and a small amount from natural gas. The rest of the demand comes from locally refined oil and imported crude oil.²¹

It should be noted that the supply and demand for petroleum products is influenced by the domestic price generally aligned on price in US Dollars in the international markets combined with the Rand/Dollar exchange rate.³⁵

The South African's IEP through the Demand Side Management (DSM) shows that the overall electricity demand varies during the day. The maximum or peak demands are usually in the mornings and evenings for households but industry work is planned for 24 hours a day. The DSM is the process by which electricity utilities achieve predictable changes in customer demand, which can be considered as alternatives to the provision of an additional plant. Therefore, the main objective from the utility point of view is to improve efficiency by reducing the average costs of generating electricity and better utilisation of resources, but also in lower risk demand side alternatives as opposed to system expansion through the construction of new power stations.

Timeframe for new capacity graph shows the national position and includes approximately 5% of capacity and sales contributed by non-Eskom generations and imports from neighbouring countries. The ISEP plan considers it prudent to maintain a 15% reserve margin, as reflected in the graph. The peak demand for the review period was 33461MW (2005: 34195MW).²⁶

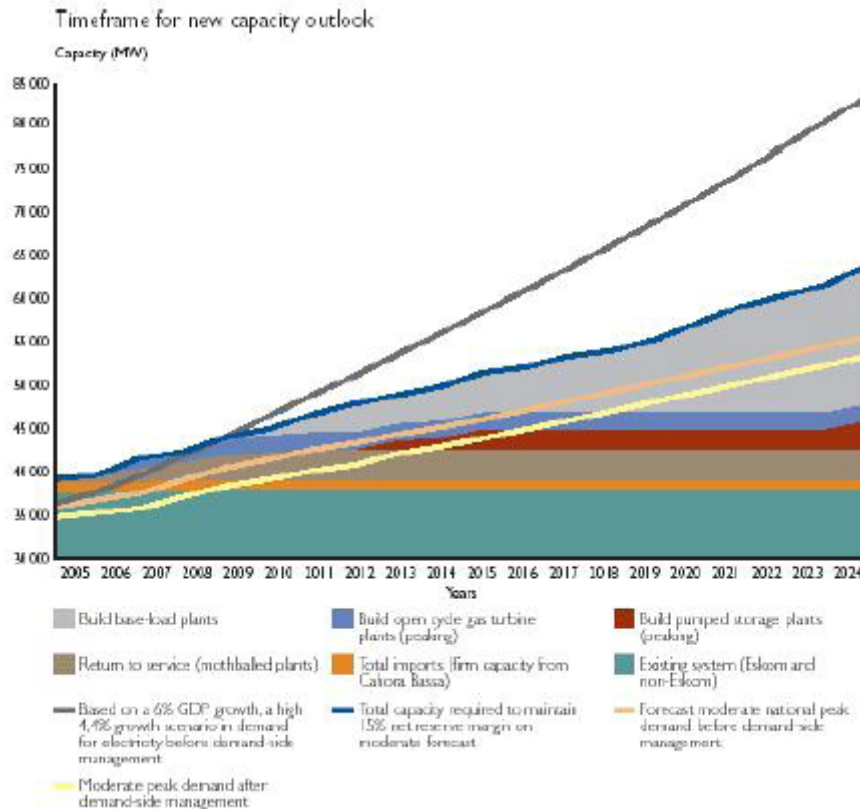


Figure 6: National position in electricity progress

Energy supply viewed from IEP include the supply side management that encompasses all those activities required to identify, evaluate, optimally select, implement, and monitor options for the generation, transmission, and distribution of electricity to meet forecast customer demand in the future. Taking into account issues such as economic growth rates, the electrification programme industrial investments and population growth, it may be assured that the electricity demand and supply infrastructure is going to increase on the supply side. Management process should address this issue, and make plans for future electricity supply. This must take into account the large resources in coal, oil, natural gas, uranium, and hydropower in central³⁷ and southern regions of Africa

2.3.5 ENERGY EFFICIENCY

Efficiency in energy sector of South Africa take in accounts the existing potential energy savings in all economic sectors and environmental improvement to sold out environmental issues relative to energy generation, transport and final use step.

The largest potential exists in industry, which uses 68% of all electricity.²¹ Savings in this sector can reach the level of 50% due to the fact that low cost of electricity is only a temporary phenomenon, and the energy efficient technologies are more easily available than in the past and the payback periods are short.

On other side, energy sector constitutes a major source of Green House Gas emissions (GHG) because of the heavy reliance on coal for electricity generation; the Sasol oil from coal process and a variety of other primary energy use. Thus, 57% of coal mining methane emissions can be attributed to these two uses of coal. The polluting effects of the energy sector are observed particularly in Mpumalanga, Highveld, the location of Eskom's coal powered stations and the largest Sasol plants.

Although the small contribution to GHG at global scale, the country produces more than 40% of Africa's fossil fuel-related carbon dioxide emissions, it is currently responsible for only about 1.6% of the world total. Below is the trend.³⁸

Table 14: Trend of fossil fuel related CO₂ Emissions in South Africa, 1993 – 2003

: ESKOM D G Ass	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
CO ₂ from coal	254	280.4	279.7	283.4	316.4	294.6	303.8	314.8	308.9	307.3	336.8
CO ₂ from N. Gas	3.5	3.8	3.8	3.6	3.5	3.1	3.0	3.5	4.4	4.8	4.9
CO ₂ from Oil	58.4	59.6	60.6	61.8	60.1	64.0	68.0	65.6	65.7	68.3	69.6
Total fossil fuels	316	343.8	344.1	348.8	380.0	361.8	374.8	383.9	379.0	380.4	411.3

Source: DOE / EIA

South Africa economy remains carbon intensive, producing only US \$ 259 per ton of carbon dioxide emitted as compared with US \$1131 for South Korea, US \$ 484 for

Mexico and US \$ 418 for Brazil.⁷⁰ As it is indicated, the consumption level and demand shape are significantly affected by changes in the efficiency of energy conversion at the point of use (for example in mine's operations) and the particular application of others demand-side measures designed to influence their patterns.

Generally, changes in mining energy efficiency are built into forecast in conjunction with other drivers such as new technologies and customer consumption patterns (gold, platinum mines). Otherwise, it is unclear as to how energy efficiency changes can impact on gold and platinum sector demand of energy.

Major barriers to implement energy efficiency in the past have been the low cost of electricity and the lack of knowledge among the public about the benefits of energy efficient technologies. However, the situation is set to change. But, maximum benefits to the national economy will only be realised if energy efficiency is practised across all sectors including mining, households, commercial, and transport. In regard to energy efficiency improvement, the national target set for 2014 is 12%.³⁹

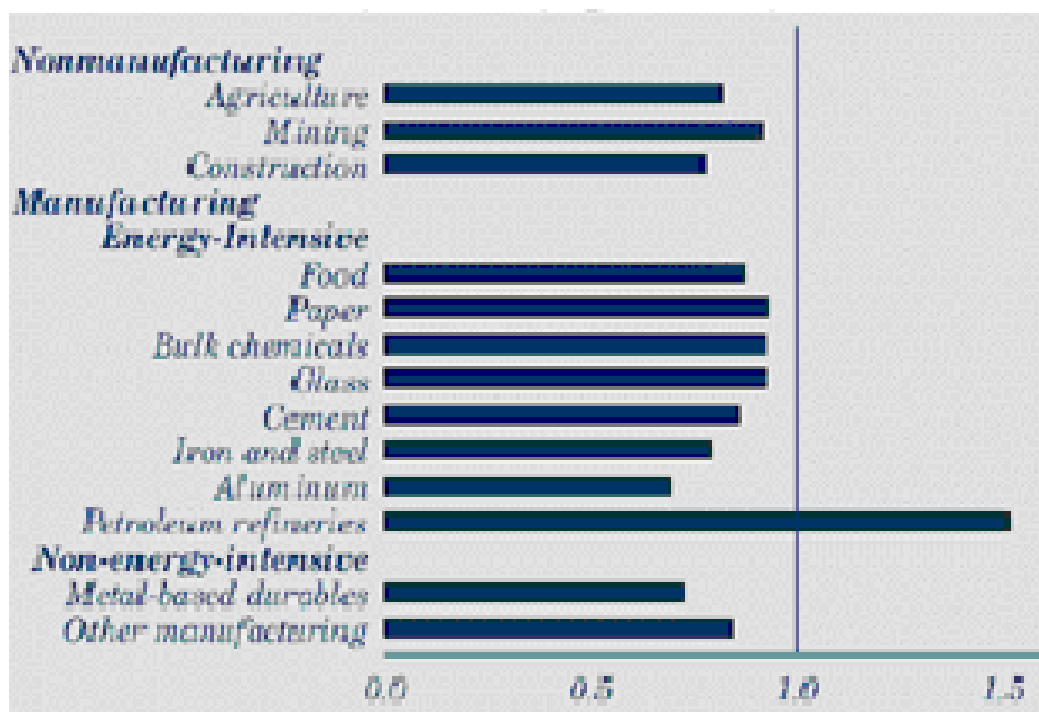
The achievement will include economic and legislative means, norms and standards and appliance labelling, energy audits and management, promotion of energy efficient technologies as well as the promotion of public awareness and information about energy efficiency measures.³⁹

2.3.6 DEMAND INTENSITY

Patterns guiding energy demand are economic growth and structural change that shaped industrial energy intensity⁶⁰. Industrial energy intensity can be measured as industrial delivered energy per dollar of GDP annually and energy consumption per carbon emission. In general, energy intensity tends to be highest in industrialised countries. In USA, for example, industrial energy use per dollar of GDP is projected to decline by 2.1 % per year on an average from 2004 through 2030. Per capita levels of energy consumption and energy related carbon emissions tend to be much lower in

Africa than in developed countries and are projected to remain roughly flat through 2020³³; except South Africa for which energy sector relies highly on coal.

In the industrial sector, energy requirements vary considerably from one sector to another. The non-manufacturing sub-sector such as agriculture, construction and mining are somewhat less intensive than manufacturing. Among the energy intensive sectors, the proportion of production cost for energy is substantial: cement (22%), inorganic chemicals (19%), Iron and Steel (17%), Textile finishing (13%), Building bricks (13%), Glass (12%) and paper and board (10%)⁷⁴. Considering industrial activities, the level of output is a major factor determining the energy consumption demand. This factor can be measured by Energy consumption per unit of production. Thus, energy consumption per unit of production in any given industrial sector is usually higher in the developing countries than in the industrialised nations. The following figure shows data projections in US Industry.



Source:

Energy Outlook 2006 with projection to 2030, U.S Department of commerce.

Figure 7: US projected energy intensity relative to 2004 by industry (to 2030)

Energy intensity in South Africa according to the total primary energy supply must grow following to the continual increasing demand along with the economic growth. This increase was 33, 6% (3933 PJ to 5241PJj) for a GDP growth of 39, 9% covering the period from 1993 to 2004 as given in Table 15.

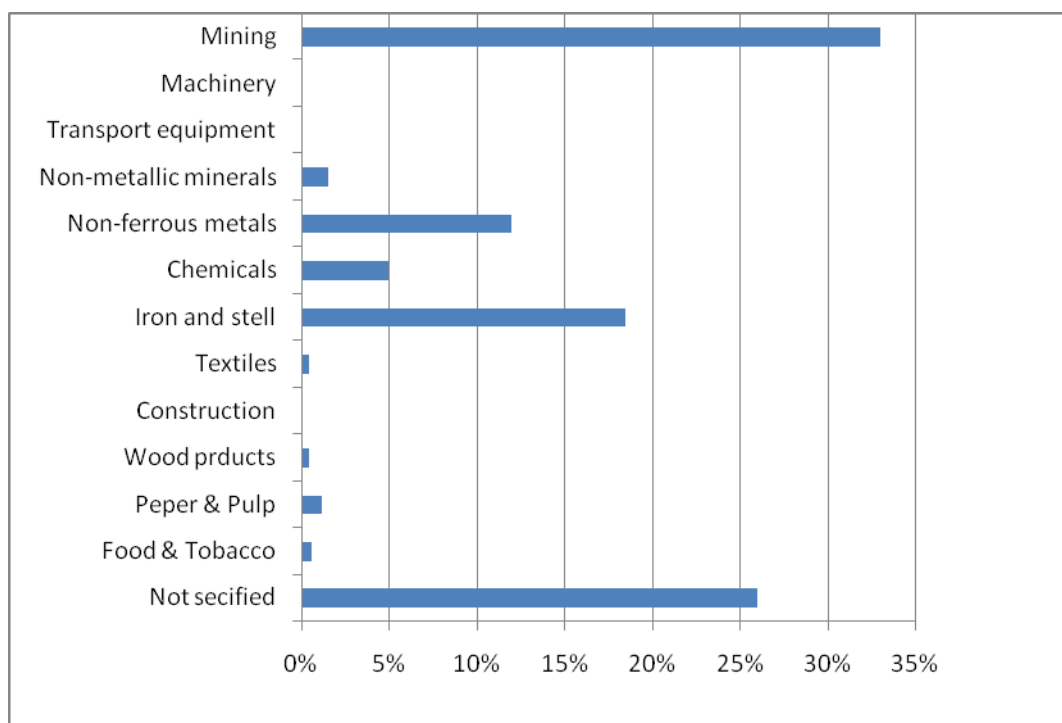
Table 15: Historical energy intensity ratio, GDP and Primary energy supply

Year	<u>GDP (market Prices)</u>	Primary energy supply (TJ)	Intensity MJ/R	Mining consumption
1993	755009	3924315	5.20	144908
1994	779494	4150999	5.33	145981
1995	803710	4299185	5.35	154043
1996	838326	4269622	5.09	159369
1997	860516	4423365	5.14	164078
1998	864968	4639614	5.36	166934
1999	885365	4636914	5.24	145386
2000	922151	4298220	4.66	130759
2001	947373	3972681	4.19	183744
2002	982327	4637437	4.72	183715
2003	1011556	4507518	4.46	180699
2004	1056771	5240908	4.96	190274

Sources: National energy Balances, Stats SA quarterly GDP by industry at 2000 prices

Also given is energy used in industry, an average consumption rate considered for the same period shows, as illustrated in graph below, that mining is the largest industrial consumer of electricity with 33 % over total industrial consumption

In fact, considering that the Eskom net electricity historical average output totalled 176520 GWh from 1993 to 2004 and the average final consumption of electricity of 153,607 GWh for the same period, about 55% are covered by industry consumption from which an average of 33% or 31,668GWh belong to mining activities. The figure below represents the electricity consumption profile for different major industrial sectors in South Africa in 2004.³⁰



Source:: DOE/EIA and

Digest of South African Energy Statistics 2006

Figure 8: Electricity consumption by industry in South Africa

- Energy consumption in Mining

In sub-sector such as mining, the quantity of material that must be extracted, transported, processed, and disposed is the key factor impacting energy consumption per unit of production for each commodity. Therefore, energy consumption in the industry including mining is dictated by the quantity of material that must be handled for every ton of saleable mineral product. Also necessary is the ratio showing the recovery of the selected commodities. Improvements in technology or techniques that reduce the quantity of waste material handled can improve energy efficiency in mining industry. Energy used in mining operations accounted for approximately 3.3 % of total industrial energy use in the US in 2000 or approximately 1125 quadrillion Btu.⁵⁷

Major energy sources used in mining include electricity as well as fuel oil, coal, and natural gas. About 35% of energy needs are met by electricity followed by fuel oil at 32 %. Coal, gas and gasoline supply the rest of energy. Major energy requirements include electricity for ventilation systems, water pumping and crushing and grinding operations.

Diesel fuel is used for hauling and other transportation needs. Although the mining industry is a significant energy user, it continues to make strides in improving productivity and energy efficiency.

Energy requirements vary considerably for each commodity and depend upon the type being mined, whether it is underground or surface, whether it must be beneficiated or processed, and the extent to which it must be beneficiated or processed. For example, energy requirements in underground gold mining are significantly higher on a per-ton basis than underground coal mining where the resource can be obtained in larger quantities. Underground mining operations require significantly greater amounts of energy than surface. While the majority of energy used in surface mining is diesel fuel for haulage, electricity is a major source of energy for underground mining where the ore must be hoisted to the surface and the mine ventilated.

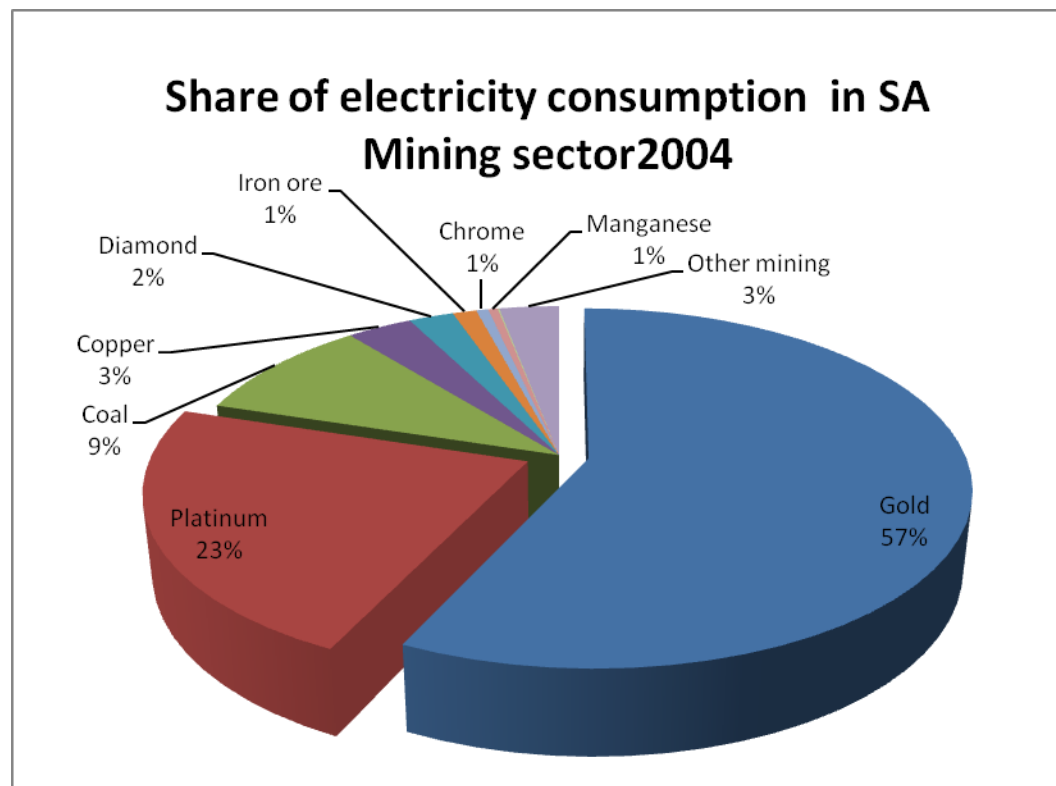


Figure9: Electricity consumption in SA mining industry

A substantial amount of energy, particularly electricity, is also used in beneficiation and processing operations. More efficient modes of transporting materials are needed along with mining innovative methods to mine small, deep, highly complex mineral ores. Also needed is, to adapt means to new beneficiation methods that are environmentally friendly or benign.

2.3.7 ENERGY USED AND ENVIRONMENTAL EFFECTS.

Electricity is the most widely used and rapidly growing form of secondary energy supply. Its generation accounts for about 40% of total primary energy supply. It offers great flexibility of distribution and use; it is relatively efficient, very safe for consumers, and environmentally benign in end-use. World electricity demand is forecast to double and the share of electricity in total energy consumed will rise from 16% in 2002 to 20% in 2030.³¹

The most important fuel for generating electricity is coal, which provides 39% of all electricity generated. Coal-fired power stations worldwide consume over 3200 million tonnes of coal each year to produce electricity.

There are environmental concerns with the use of any fuel. As with other fuels, burning natural gas produces carbon dioxide one of the highest greenhouse gas contributing to global climate change. Nevertheless, natural gas burns cleaner than other fossil fuels, such as oil and coal, and produces less greenhouse gas per unit energy released. For an equivalent amount of heat, burning natural gas produces about 30% less carbon dioxide than burning petroleum and about 45% less than burning coal.⁵⁰

Emissions of carbon dioxide from burning fossil fuels are about 25 billion tonnes a year worldwide, of which around 38 % comes from coal, 21% from gas and 41% from oil.

Each year, a 1000 MW coal-fired power station produces about 7 million tonnes of carbon dioxide, perhaps 200,000 tonnes of sulphur dioxide (depending on the particular coal) and typically about 200,000 tonnes of solids, mostly fly ash.⁴¹

Also, natural gas with other fuels affects the environment when it is produced, stored and transported mostly with methane and other greenhouse gas. Resultant products from the combustion reaction are:

- CO₂ (potential GHG and a major contributor to “global warming”, is produced at a rate of 2.73kg/l of fuel.
- SO_x the production is directly related to the amount of sulphur in the diesel fuel.
- NO_x is produced in the high temperature and high pressure diesel fuel combustion chamber.

Total world carbon emissions by region/country in 2005 in million tons are as follows: OCDE including North America, Europe and Pacific (3,542), No-OCDE including former Soviet Union (842), Eastern Europe (333), Asia (2,179), middle East (293), Central/South America (287) and Africa (254).¹⁷

2.4 ENERGY USE STANDARDS

According to the Oxford English Dictionary, standards are a set of rules, principles and values benchmarked or established as comprehensible criteria against which judgement about estimation, measures and deviation can be made.⁶⁶

Worldwide, standards and labels constitute an essential element in any institution portfolio of efficiency policies, conservation and change mitigation programs. For a specific economic sector, standards dictate basic references to help building supply and demand requirements for users' envelope, equipment aligned and good practices to be applied.

In the context of industrial energy use, standards can offer in a large portfolio of energy related standards that address conservation and efficiency requirements from start to finish from the production facility, through transmission, to the step point of use by consumers. Mining industry particularly includes seven general phases in process namely:

- Mine exploration
- Mine design
- Construction which includes mine site preparation
- Extraction operations in either underground or surface mines.
- Beneficiation operations consisting of crushing and grinding, separations, solvent extraction, electro wining
- Processing which consists of smelting or refining depending on the mineral and the final products
- Reclamation (closure and post-closing).

In each of these stages, there are a variety of equipment and materials used and practices applied. Equipment used in mining step activities depends on the type of mine and which mineral is being excavated. Standards follow the process step and equipment used varies significantly from commodity to commodity.

2.4.1 BENEFITS

Among several benefits offered by energy standards application, the following can be considered:

- With efficient applying, countries can enhance the overall efficiency of their national economy.
- Standards enhance consumer welfare by boosting energy efficiency (in some equipment models and features available to consumers that can increase with standards in place, and can have a lower than expected impact on prices).
- Efficiency standards and improved products can make local businesses including mining more profitable.
- Also, they can help a country meet climate change goals and avert regional pollution. Reducing energy consumption decreases both carbon and other emissions from fossil fuelled power plants.
- Finally, they can help to attract capital investments to afford projected energy demand over future period.

2.4.2 FOCUS

Focusing on underground gold and platinum activities, the five principal energy using units in mining process are drilling, blasting, loading, hauling and ancillary processes. The following shows the US mining energy consumption by stage.²⁹

- Extraction: 19 % with pumping accounting for 41% of total energy consumed.
- Materials handling at hauling: 41% with diesel accounting for 87 % of energy used and energy used by trucks consumes 54 % of the total energy required in mining.
- While beneficiation and processing: 39% where crushing and grinding and concentration represent 75% of energy used with grinding accounting for the majority ~ 45% of the energy consumed.

At present, the average world coal combustion efficiency in power station approximates 32%, while state of art is 42 to 45%.⁴² Studies on diesel fuel consumption on CAT Haul Truck show that operating cost savings, when moving to larger, with fuel efficiency and CO₂ emissions, reduced by 30% per horsepower basis: per tonne of truck capacity.⁴³

2.5 CONCLUSION

Energy use is determined by many factors including demographic, economic and technological aspects that consider population, labour force, GNP, labour productivity, energy price and consumer demand. Development of industrialization patterns must be consistent with the local patterns of energy availability.

Among primary energy consumption, including energy for electricity generation, coal and petroleum show the leading energy use increases. With some environmental improvements, increase in coal-fired base load capacity is expected in the future as the first choice for power plants as growth in natural gas consumption is restricted by its high price relative to coal. Increase in petroleum consumption is dominated by diesel fuel and gasoline used for transportation in vehicles and trucks in the mining sector as well.

It is, therefore, of utmost importance to clarify standards associated with energy management in mining industry. The efficient production and use of energy in plant levels will ensure maximum self-reliance. Controlling the standard indicators driving energy consumption such as per capita consumption, energy use per dollar of GDP, energy per carbon emission, and consumption per unit of production will help to eliminate waste due to current high energy consumption levels, to reduce the steeply rising demand associated with rapid growth, and to increase the benefit from lowering the overall importing energy required and reduction of carbon and sulphur emissions.

3 ENERGY MANAGEMENT PRINCIPLES

3.1 CONCEPT

Energy management is a logical planned method of reducing energy use through a variety of initiatives without causing hardship or inconvenience to staff ⁴⁴. According to its principles, the main purpose is to maximise the benefits derived from efficient energy including energy conservation through reduction of consumption.

As a plan, energy management takes in account energy usage in all its form, their impact on the environment and furthermore, the associated costs involved in this use.

Therefore, a comprehensive energy management plan should provide clear strategies through which the formulated plan actions can be organised in order to reduce energy consumption. In South Africa, the concept of energy management with implied conservation in industry is still at development stage.

3.1.1 MANAGEMENT COMPONENTS

From the above concept definition, it is clear that we cannot manage what we do not understand or do not measure. The method used to manage all energy utilities (electrical, fuel oil, and natural gas feed include two main steps: energy accounting and energy auditing).

3.1.1.1 Energy Accounting

Basically, it consists of book keeping for energy management systems including records, analysis and report for energy consumption and costs on a regular basis. It is a very critical step for effective management, providing a feedback on how much energy an organisation uses and how much it costs. It also provides a means to effectively communicate energy data usable by staff, managers, and other researchers to improve cost managements.

3.1.1.2 Energy Auditing

Energy auditing is a physical inspection of the conditions and operations of energy consuming industrial process plan. Energy audit orientation would provide positive results on reduction energy bill for which suitable preventive and cost-effective maintenance and quality control programmes are essential to enhance production and economic utility activities.

Two types of energy audit can be conducted: the preliminary one that highlights energy costs and identifies wastage in equipment processes and deep audit that gives details on process level consumption and input to production and costs involved.

The context of this study limits our investigations to the accounting step that allows gathering only the energy consumption data as recorded in the targeted gold and platinum underground mines. In fact, to establish a benchmark as a pre-step analysis to energy consumption standards in mining industry, energy use and costs figures records are required. Energy costs rely on the amount consumed and its associated price. Energy accounting will help to compare energy use and costs amongst facilities and to monitor the trend of energy use over time. It can also identify the energy intensive areas and the peak energy use period or sudden unexplained increase in consumption that requires investigation. It can help to evaluate potential energy savings limits to incorporate in future program success.

3.1.2 ENERGY MANAGEMENT STANDARDS

Energy management standards can be understood as a set of features, policies and mechanisms that help to establish best practices for the emerging area of energy efficiency. The purpose of an energy management standard is to provide guidance for industrial facilities including mining industry in integrating energy efficiency into their management practices.

The international energy management standard is consistent with the International Organization for Standardization (ISO) principles of measurement.³ Several energy management standards currently exist but only few are related to mining industry for

which some countries such as USA, Sweden, Canada, Australia and China record more advanced steps. The common international industrial standards include:

- Energy policies and procedures' training'
- Strategic plan that requires measurement; and
- Identified key performance indicators for each company and mining sector for specific country to measure progress and optimize industrial systems.

3.2 STANDARDS in SA MINING INDUSTRY

3.2.1 REASONS

Energy use in industries, including mining is much more related to operational practices. Various factors influencing energy consumption in mining industry should be considered as contributing to numerous uncertainties. A specific mineral commodity selected is viewed as a key mineral industry contributor for the South African economy in terms of both volume and ore tonnage.

Underground mines, including those of South Africa vary widely in size, depth and types of equipment used. These characteristics, along with the difference in mining and processing operations, have significant influence on energy consumption at all steps: materials handling, beneficiation and processing and extraction. For example, the ratio of material handled per unit of production varies greatly from commodity to commodity and from mine to mine according to technology applied and the associated equipment at each stage of the mining process. Both are aligned to the mine degree of mechanization and implies quantitatively and qualitatively the type of energy consumed in entire mining process through how it is used.

Therefore, it seems useful and helpful to establish standards in energy consumption that can allow energy consumption and costs comparison on operational units for similar facilities, locally and internationally and to monitor use trends. Benchmarking is one of method used to classify energy consumers using comprehensive indicators that are internationally defined.

3.2.2 BENCHMARKING

Energy benchmarking is the collection, analysis and reporting of data to provide industrial companies with a context of assessing comparative energy efficiencies. Using energy efficiently helps to improve productivity and making it more competitive while indirectly reducing Greenhouse Gases that contribute to climate change.

Energy benchmarking and monitoring allows companies to identify deficiencies and adopt better practices. Energy performance benchmarking focuses on a comparative analysis of energy use per unit of physical production, otherwise known as energy intensity.⁴⁵

3.2.2.1 Steps

Typical steps involved in energy performance benchmarking are⁴⁴:

- Determining the facility energy intensity by energy type
- Comparing the energy intensity with that of industrial sector to benchmarking reports.
- Accessing the tools and resources available that will help to improve the facility's energy performance.
- Selecting the task force to obtain additional information to the specification.

3.2.2.2 Best Practices

Best practices in benchmarking involve comparing operations and systems within the facility to the best in class operations. Generally, the steps involved in energy management and technological best practices benchmarking include⁵⁵:

- 1 – Identify the areas for improvement that will benefit most from the benchmarking study.
- 2 – Research and identify the key factors and usable variables to measure the above.
- 3 – Determine if the data are already available or how they will be obtained.
- 4 – Analyse the data and identify the best practice performance by selecting the best in class category with the highest energy efficiency
- 5 – Determine the conditions under which the best practices can be achieved and specify the actions that must be taken to achieve the desired results.

6 – Implementation through setting specific improvement target and deadlines and developing a continuous monitoring process.

3.2.2.3 Indicators

Energy benchmarking involves the development of quantitative and qualitative indicators through collection and analysis of related data and practices. Indicators enable industrial mining firms to compare their energy use level, similar operations, like showing how the facility stuck compared to others.⁵⁵ In South Africa, mining corporations, the energy consumption indicators selected for desired comparison and energy use trend monitoring refer to⁴⁹:

- Total energy cost
- Total energy consumption
- Per unit cost
- Per unit consumption
- Peak consumption and demands
- Load factor
- Overlapping bill periods reading

Remarks: The annual analysis is recommended to determine the most appropriate rate code for the mine as they change overtime. Tariff analysis codes for excessive demand charges ratchet demands, power factor penalties time of use pricing.

3.3 CRITERIA AND ASSUMPTIONS

The benchmarking of data in the present case is conducted according to the following selected criteria: the current mining depth level, the mine production, the degree of mechanization and productivity, environmental impact and costs associated to energy use.

The Witwatersrand is a gold placer deposit with gold being hosted by conglomerates and grits. The Wits sedimentary basin is massive and stretches through an arc of approximately 400 km across the Free State, North West and Gauteng Provinces. The gold bearing conglomerates or reefs are generally tabular with varying dips. On one

side, South African platinum group elements deposits are located in one of the largest layered intrusions the world, the Bushveld igneous Complex (BC). PGE's are recovered from the tabular Merensky Reef that is present along the entire strike length of eastern parts of the BIC. The UG2 and Plat reef also host economic quantities of PGE's. Platinum group metals include platinum, palladium, rhodium, iridium, and osmium, which occur together in ore seam and are mined in one operation.

Gold and PGMs mining challenges

Companies have been confronted by significant consolidation, escalating costs from mining at depths below 3000 m and decreasing grades and price fluctuation which has resulted in the decline in gold-mine production over the last thirty years.

South African gold-mining industry depends on the continued replacement of depleted ore reserves by discovery and conversion of new ore resources. As a consequence, gold mines are going deeper increasing temperature through geothermic gradient that force to improve ventilation and refrigeration necessary to healthy atmosphere in working places.(Survey : ventilation air circulate 6 m/s per 1000 ton of rock mined.)⁷²

The last issue in South African gold mines is closed to geologically proximity of the Transvaal dolomites. This geological unit is Karstic in many areas and is very extensive. Very large volumes of ground water can be found in the dolomites, and have given rise to major dewatering problems on the mines. Following this, large inflows into the mine have to be pumped out from underground at a suitably convenient level to maintain safety in workings (for some, 70 M litres/day to surface).⁷⁵

All above named challenges have impact on mining costs, particularly when considering energy consumption increase. Nevertheless, one remaining big issue is the need of mechanization to afford increasing demand subsequent to commodity price rising.

3.3.1 MINING DEPTH LEVEL

South Africa has thin and extensive precious metal reefs often lying several kilometres beneath the earth's surface and usually slopes dips at up to 20 degrees. The country's gold and somehow platinum corporations have to sink the deepest mine shafts in the

world sometimes close to 4000 m for Gold in depths to reach and extract the reefs. Gold ores mined at considerable depth, for example, presents problems in the form of the dual hazards of high rock pressures and the great heat bound up in deep rocks.

In fact, mining at deep levels such as 3900m in western deep level mines is usually highly problematic, because the temperature rises by one degree every 33m. These geothermic conditions require immense machinery and air conditioning to make the working underground conditions tolerable. At 4000m, cooling down air from 62 °C natural rock temperature to 28 °C – 32 °C degrees; use huge quantities of electricity needed to drive complex ventilation and cooling systems allowing people to work easily although with maximum humidity around.⁵¹

3.3.2 MECHANIZATION

Mining depends heavily on mechanical motor driven machinery for almost every aspect of the process, from initial rock extraction through transport to processing and refinery. Increasing the level of mechanisation plays an important role on operations efficiency and would greatly lower costs and increase productivity. Today, with the tremendous pressure on profit margins in the gold and platinum mining industry, and the declining gold grade at greater depth, there is more emphasis on mechanisation than before. Mechanisation should extend the mines longevity as it will enable them to mine lower grade ore, while employing a more productive workforce constituted of skilled people.

Actually, in some underground mine operations, mechanisation is taking place with new and improved technologies and required equipment including design sector, computerization, automation and control system and machinery involve in each step of production.

New technology used for trackless mining, backfilling, require hydropower equipment, vehicles on road way, conventional trappers on rails in underground haulages, drilling and blasting equipment, crushing, milling etc. Until recently, drilling operations always had to be carried out in such narrow stopes, utilising traditional labour intensive methods with crews of workers using hand-held drilling machines. Today, the rising

labour costs of traditional gold and platinum mining methods started to make the economics of mechanisation attractive. The example is given with expansion of electric rock drilling machine in underground mines.

Thus, mechanisation in mining activities is viewed through technology, equipment and the related energy consumption as for example:

- Drilling with hydraulic rigs and electric rock drills
- Blasting with non electric initiating systems
- Haulage with increase in size of loaders and hoisting speed in underground mines
- Communiton with energy reduction for crushing and milling etc

In underground mines, the major type of energy used remains directly and indirectly electricity for drills, crushers, mills, conveyors, pumps, skips, winches scrapers and lighting equipment. Fuel diesel oil is consumed currently by loco, underground and surface trucks from mine site to beneficiation plant and portable mining equipment.

In summary, mechanisation of underground mines activities can impact largely on mine's productivity relying basically on: the scale of production, the degree of automation and the process simplification.⁴⁸

3.3.3 PRODUCTIVITY AND PRODUCTION

Productivity is related to the quantity of materials handled, processed or recovered. In South African gold and platinum mines, the reefs mined are narrow and less than one meter. This necessarily impacts on production and productivity. Only improving mechanisation allows increasing productivity. Actually, experts agreed that the future of precious metals mostly gold mining industry in South Africa depends on increasing productivity although deeper gold and platinum less readily lend themselves to mechanization.

The mining industry needs improved overall mining systems such as the truly continuous mining methods, continuous haulage systems performing cyclically, more effective ventilation procedures and rapid intervention techniques to enhance

productivity and resource recovery. Performance indicators can be expressed in terms of estimation for materials handled or processed considering the resources allocated. In this case, the energy requirements per ton of materials for each equipment or operation activity associated will allow assessing consumption and costs per unit of output.

4 BENCHMARKING OF DATA

4.1 COLLECTION AND ANALYSIS OF DATA

The following section circumscribes data sources and the related collection methodology and analysis criteria to be followed.

4.1.1 DATA SOURCES

Data sources on energy use in mining can potentially be available in reports and publications from South African Department of Mineral and Energy (DME), Eskom, the Chambers of Mines and the Mining companies which are supposed to report energy consumption for each mineral commodity production process.

But no data is published that would disclose the data for an individual establishment or company in accordance with reports. Observation shows uncompleted or lack of data disclosing per type of fuel used (e.g. diesel fuel, natural gas, electricity) as related to different mining operations for a specific mineral commodity. In addition, there are no nationally published sources of data measuring energy consumption in mining per unit, neither of production nor by type of mining activity, or by type of equipment used in mining operations from drilling to minerals processing.

This type of data is very important to establish benchmark values necessary to energy efficiency definition and progress measurement in mine unit or in a company. The targeted potential sources of energy consumption data to be considered in South African mining are mostly from Eskom through payment records and from operating mining companies hosting underground gold or platinum mines.

The global criteria is basically related to the mining experience and expertise background of the targets for specific commodity and the interventional volume as a contributor to mining activities on South African economy.

Therefore, companies such as AngloGold Ashanti, Goldfields for Gold and Anglo Platinum, Northam Platinum for PGMs can play a representative role:.

AngloGold Ashanti is one of old and largest gold mining company in the world with 5.6 million ounces of gold production in 2006 from 21 operations located in 10 countries on four continents. It is the biggest gold producer in South Africa, contributing for 45% of company production and 40% reserves and represent more than 37 % of South African gold production.⁵² South African operations comprise seven underground mines located in two geographic areas on the Witwatersrand basin: The west Wits operations with Mponeng, Savuka and Tau Tona mines near Carlton Ville in North West Province; The Vaal River Operations with Great -Noligwa, Kopanang, Tau Lekoa and Moab Kathsong near Klerksdorp and Orkney Towns in North West and Free State provinces.

Goldfields is the fourth world largest and pure gold producer, operating internationally (Ghana, Venezuela, Australia) with annual production of 4.1 million from which 2.66 million ounces coming from South Africa in 2006 ().It has a great expertise in deep level mining. The underground operations in South Africa are Driefontein, Kloof, Beatrix and the recently acquired south deep mine all located near Carleton Ville.

Anglo Platinum is the world largest producer of PGMs including platinum and palladium with more than 50% of total production. South African production, with 6.3 million ounces in 2006 relies on huge ore reserves for more than 100 years. Currently, the company has six mining operations near Rustenburg: Rustenburg Platinum Mines (RPM), Rasimone, Union Section, and Amandelbult Situated on western limb of the BIC. Also Potgietersurt (open pit) and Lebowa Platinum mine on the Eastern Limb.⁴⁹

Northam Platinum is a old single mine company with the world deepest operating mine shaft. It is located North of Anglo platinum's Amandelbult section on the western limb of the Bushveld Complex.

4.1.2 DATA COLLECTION

A - Methodology

The data gathering is based on a set of survey questionnaire and interviews conducted on mine sites. The survey questionnaire was established and sent to mining companies in concern and it had to be completed essentially by respondents in charge of energy consumption services at mine site and gathering at the same occasion others energy use data figures.⁵⁵

Some required interviews and associated discussions were organised with managers of the mines and engineering services using physical contacts or telephones for additional information.

The basic unit considered in sample design for this survey is an operating underground gold or platinum mine. The sample includes multi-mine firms such as AngloGold Ashanti, Anglo platinum, and Goldfields and a single –mine firm such as Northam Platinum.

The frame considered in sampling includes essentially all energy consumers' activities in the mining production chain. Energy consumption data recorded figures from these operation activities.

The weight used in the estimates of final consumption measures were determined by the companies' measure of size represented locally by the contribution part in country's specific commodity production.⁵⁵

It is notable that there is a large amount of variation in energy usage among mining companies and operating mines in South Africa. The implications to this are:

- It is impossible to construct a single comprehensive size measure that will be equally effective for sampling to produce the several different energy measures derived from the survey because of the complexity of energy output.
- The global criteria of firms' size, experience and expertise above mentioned is a key judgement basic for sample selection.

B - Survey Questionnaire

The set questionnaire samples in appendix shows a total of 15 questions to be fulfilled by respondents. The questions series were grouped according to following needs:

- Source of information
Mine unit characteristics including depth, mining method, degree of mechanization, mine production chain process and the associated energy end uses equipments etc
- Mine production (daily or annual)
- Mine energy consumption figures.(Type, Amount, Peak period, Load charge, power factor applied and costs)
- Energy intensity areas and mining process limitations.

The question on source of information, for each mine is related to services consulted.

C - Survey Results

Results in following analysis subject to reserved conditions of:

- Mines characteristics were given at 75 % on the total required and the remaining 25% were recovered through interviews and visits on mine sites.
- Mine production figures for ore and waste were fulfilled referring to daily production estimates in comparison of those compiled annually in reports.
- Difficulty to describe clearly some end –uses energy consumers process has limited details on energy consumption spread sheets (1) figures to be compiled.
- Only few respondents were asked to define and categorized technologies used according to mining process inside corporation.

Although the compiled survey questionnaire answers are representative to the sampling, some aspects of the survey data should be controlled due to possible biases and low accuracy. For example, respondents giving answer roughly or in percentage that have to be treated. Also to be considered, some energy data available at establishment level such as: the type, function, and quantity that have not been a staff concern's interest.

The survey results are presented on compiled answer sheets in appendix as following:

- UMECS 1:APPENDIX B1: AngloGold Ashanti sample

- UMECS 2:APPENDIX B2: Goldfields sample
- UMECS 3:APPENDIX B3: Anglo Platinum sample
- UMECS 4: APPENDIX B4: Northam Platinum sample

4.1.3 DATA CLASSIFICATION

Data classification is categorised by commodity according to the above selected criteria including the average mining depth level, the degree of mechanization with subsequent productivity, the annual related mine production, environmental impacts for energy use and energy use cost figures.⁵³ The underground mines selected are numbered from one to ten for gold and from one to six for platinum

4.1.3.1 Criteria

1 – Mining Depth

Underground mine depth level is continuously dynamic and relies on production rate and changes every day accordingly until the end life of mine time. The values considered below represent an average between related current mining level and shaft bottom level of the mine.

The average mining depth level can be used to establish the four categories of underground gold mines and three types of platinum mines (cfr: survey answers).

A – Gold Underground Mines:

- Shallow: Depth level less than 2000 m
- Conventional medium: Depth between 2000 m and 3000m.
- Deep: Depth between 3000m and 4000 m
- Ultra – deep: Depth over 4000 m

B – Platinum Underground Mines:

- Shallow: Depth less 1000 m
- Medium level: between 1000m and 2000m
- Deep: more than 2000 m

Table 16: Gold underground mines depth's classification

No	Mine unit	Average depth (m)	Category	Expansion
----	-----------	-------------------	----------	-----------

project				
	Gold Mines			
1	Great Noligwa*	3400	Deep	Maintenance
2	Kopanang*	2600	Medium	Development
3	Tau Lekoa*	2700	Medium	Steady level
4	Moab Khotsong*	3000	Deep	Start up phase
5	Mponeng*	2800	Medium	Below 120 level
6	Savuka*	3800	Deep	Maintenance
7	Tau Tona*	4000	Ultra deep	Below 120 level
8	Driefontein**	2307	Medium	5 Sub vertical shaft
9	Beatrix**	1350	Shallow	3 shaft flexibility
10	Kloof**	2665	Medium	4 sub – vertical shaft
11	South Deep	2550	Medium	Re starting

* - AngloGold Ashanti Mines, ** - Goldfields Mine

Table 17: Platinum underground mines depth's classification

No	Mine unit	Average depth (m)	Category	Expansion project
1	Rustenburg***	1700	Medium	Boschfontein shaft
2	Amandelbult***			Shaft 3 deep
3	Union sec***			3 south UG decline
4	Leboa***			Maintenance
5	BRPM***			South & North shaft
6	Northam****	2060	Deep	Below 2120m

*** - Anglo Platinum Mines; **** - Single Northam platinum Mine

2 – Mechanization

The definition and description of mechanised mining varies between mines and mining companies. To clarify the understanding level of mechanization in mine operations, we have considered the following defined degrees of mechanization (cfr: survey answers):

- **Low:** level 1 or conventional mining level at which old technology such as handheld pneumatic drilling machines, scraper winches and rocker shovel face cleaning are continuously used.
- **Hybrid:** level 2 or semi-conventional combining traditional techniques to actual mechanisation such as hybrid mining with development and ore removal being done loaders and dozers.
- **High:** level 3 or full trackless with more than 75% of mechanized mining methods use low profile and extra low profile suite of drilling machines, roof bolters, load haul dumpers and cleaning dozers .

Table 18: Classification of gold mines' mechanization

No	Mine unit	Degree of mechanization	Comment
1	Great Noligwa	Hybrid	undergoing
2	Kopanang	Low	
3	Moab Kathsong	Hybrid	
4	Tau Lekoa	Low	
5	Mponeng	High	
6	Tau Tona	Hybrid	
7	Savuka	Low	
8	Driefontein	Low	
9	Beatrix	Low	
10	Kloof	Low	
11	South Deep	High	~70 % mechanised

Table 19; Classification of platinum mines' mechanization

No	Mine Unit	Degree of mechanization	Comment
1	Rustenburg	Hybrid	
2	Amendelbult	Hybrid	
3	Union sect	Hybrid	
4	Leboa	Low (conv)	
5	BRPM	Low (conv)	
6	Northam	Hybrid	Hydropower usage

3 – Production

Production refers to quantity of materials (waste and ore) handled, processed or recovered at different stage of mining production chain. Accordingly, the record figures are related to 2006 annual production of:

- Tonnes broken representing the ore tonnage moved to plant.
- Tonnes milled or materials processed at first step of beneficiation
- Ounces recovered at refinery stage.

- Contribution percentage for each mine unit to the total production of SA.

Table 20: Gold mines production

Mine unit No	Tons broken (000)	Tons milled	Ounces (000 oz)	% SA
1	n/a	2,400,000	615,000	7
2	n/a	2,000,000	446,000	5
3	n/a	200,000	44000	1.3
4	n/a	1,500,000	176000	
5	n/a	1,900,000	596,000	6.7
6	n/a	400,000	89,000	1
7	n/a	2,000,000	474,000	5.4
Sub total	n/a	10,400,000	2,440,000	
8	n/a	3,867,000	1,150,000	13
9	n/a	3,551,000	914,000	10.3
10	n/a	3,206,000	596,000	6.7
11	n/a	1,256,633	296,000	3.4
Sub total	n/a	11,880,633	3,035,000	
Total	n/a	22,280,633	5,475,000	62.5

NB: The above gold production represents 70 % of “CoM” Production, 66 % of underground mines gold production in South Africa and 63 % of total South African gold production for 2006.

Table 21: PGMs mines production

Mine unit No	Tons broken (000)	Tons milled	Ounces (000 oz)	% SA
1	13,793,000	12,386,000	833,200	12
2	8,136,000	6,974,000	595,200	8.5
3	4,263,000	5,926,000	316,700	4.5
4	2,282,000	1,653,000	112,000	1.6
5	1,546,000	1,443,000	217,000	3.2
Sub total	30,020,000	28,382,000	2,074,100	
6	2,681,011	2,355,441	362,925	5.2
Total	32,701,011	30,737,441	3,178,625	45

NB: This production represents 50 % of underground platinum mines and 45 % of total 2006 production of South Africa.

4.1.3.2 Energy Consumption Data

Energy data requirements include essentially two components; specific energy consumption figures and the costs associated.

A - Consumption figures

The consumption figures are related to the established value chain of production for precious metals that are somewhat different from gold to PGMs. The diagram below shows the main steps of production chain with associated mining activities regrouped starting from underground mine with succession of materials handling to plant recovery through beneficiation and process.

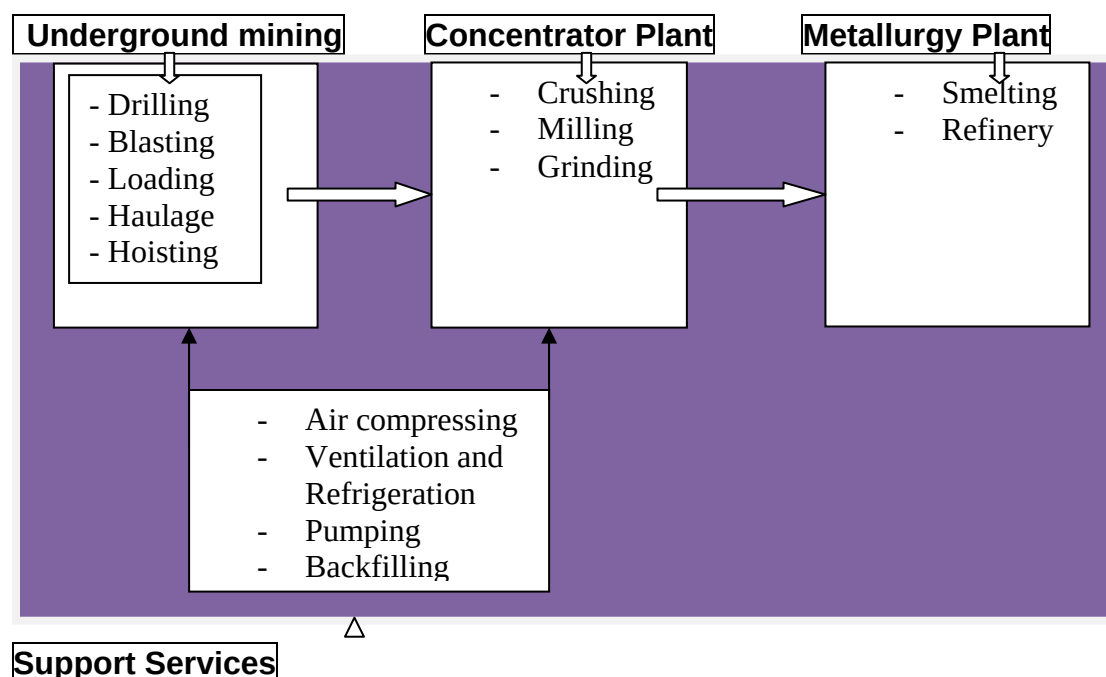


Figure 10: Production Chain Process components

This diagram is helpful to maintain the same understanding in mining activities group set. The reality is that energy consumption figures change from one mine to another according to the technology and associated equipment used at each step and house hold set of practices. The need of study standardization leads to assume limits to data recorded.

A1 Data validity

Energy consumption data received through survey sampling can be considered as descriptive at small scale. The harvest figures are obtained at close of annual season from records of engineering services related to mining operation activities. In some cases, the extra sample information available from reports, interviews etc, has been incorporated in procedure to establish marginal totals for adjustment consistency.

Internal consistency of data is checked by quick visual look on surveys that allow scanning and cleaning the data. Because of extra sample information introduced, some discrepancies occurred to attempt reconciliation. These allow errors of sampling due to natural variability among sampling units such as underground mining companies and companies selected. To avoid error impact, we assume that calculation of estimated sampling variance is usually fairly straightforward.⁴⁸

Systematic errors during data collection , treatment phase attributable to incorrect response, mistakes, in response or in tabulations and coverage are limited by determining the relative standard error of UMECS estimates $(RSE) = 0 > 0.98 > 1$.

A2 Assumptions on Data

- In these figures, electricity is most representative source of energy used and measured in underground mines; the fuel oil used to drive loco and other underground trucks relies on level of mining mechanization still at starting point for most of precious metals underground mines.
- Globally considered, support services are part of mining production energy consumption figures.
- In some figures, pre-concentration activities are operated on mine site. In this case, only the steps of underground mining are distinct from plant treatment.
- Metallurgy regroups in most of cases concentration, smelting and refining activities in both gold and platinum process.
- The cost of energy and the quantity used both describe energy consumption quantitatively.

- In this study, operating costs and production costs are considered relatively the same to make easier the inter-facilities comparison.
- Comparisons are restricted to facilities (underground mines) and countries for which similar data exist.

The energy consumption figures below include for each underground mine selected the values for total consumption, main chain operation steps and key stages activities in (KWh or GJ). Also given are the value of consumption per unit of output (KWh/tonne) and contribution on national production. The tables B_i ($i=1, 2, 3, 4$) in appendix, show:

- B_1 The table summarizes the total energy consumption data estimates per mining stage developed by aggregating values recorded from individual commodity in proportion of their 2006 annual production in Kilo Watt hour and Giga joules.
- B_2 Shows detailed energy consumption figures for main mining operations intervening at each stage of production chain process.
- B_3 give the percentage of energy consumed per elected source particularly electricity and liquid fuel such as diesel.
- B_4 outlines energy costs and operating costs per unit of output (tonnes mined, tonnes milled, and kg or ounces of precious metal produced).

B – Energy consumption and environment

Energy used in mining activities contributes directly or indirectly to impact environment and climate change mostly through CO₂ and Green House Gas (GHG) emissions. Directly, mining equipment powered by liquid fuels such as diesel, gasoline, heavy fuel oil and others natural gas, propane, explosives (ANFO) etc, produce CO₂ and others polluting GHG emissions. For example, diesel engines such as trucks and loco produce 200 cubic feet of exhaust gases (CO₂, GHG) per lb of fuel burned and consume approximately 0.45 lb of fuel per horsepower-hour.

In regard of this, underground trackless mine require 10 tons of fresh air to be circulated for each ton ore extracted and the hottest and deepest up to the double for each ton of ore mined, when considering strict limits of 350 micrograms of CO₂/ m³ on Diesel

particulate matter (DPM) exposure in underground mines set by The US Mine Safety and Health Administration (MSHA) in January 2007.⁴³

Indirectly, the environmental pollution impact relies particularly on coal consumption for electricity generation and metallurgical usage. Considering the actual physical effects of global warming due to climate change, the Kyoto Protocol, has globally committed nations' signatures, except US and Australia, to cut GHG emissions to 5% of 1990 levels by 2012.⁶⁹ Mining operations as ones of major contributors to pollution must deal with compulsory energy restrictions to set targets. Indicatively, the global mining and quarrying CO₂ and GHG emissions evolution show the values in tables 22 and 23:

Table 22: Global CO₂ emissions coal excluded

Year	1990	2000	2004
Global CO ₂ emissions Mt*	15,373.5	16.188.2	16,797
CO ₂ emissions excl coal**	54 %	63 %	79 %

* Source: UNFCCC

** Source: IEA 2006. CO₂ from fuel combustion

Table 23: CO from coal consumption 1

Year	1190	2000	2004
Global coal production			
CO ₂ Mt coal consumption	8,267	8,797	10,592
Coal consumption CO ₂ as % of total	52 %	54%	63%

Source: IEA 2006

The reporting emissions protocol quality depends on the requirements of the country in which a miner operates and how the country has implemented it. For developing countries like South Africa, this requirement is optional although the highest volume of pollution in Africa places South Africa amongst ten top in world.

Worldwide, there is an incentive to push more mining companies to commit themselves to the reporting of GHG emissions in signing protocol. Reporting standard organisation such as: Global Reporting Initiative (GRI), Sustainability Reporting Guidelines and Mining and Metals Sector Supplement, or Global Reporting Initiative and International Council on Mining and Metals (ICMM) allows members to report their economic, environmental performance.

South Africa mines rely largely on coal to fuel their enormous energy requirement. A study shows that most of mining companies within selected mines are currently aligned with international standards, "ISO" 14000/systems", with the requirements of the new ISO/2004 standards and have received certification to align the review of ISO 9000/Standards. From energy intensity in mining, comprehensive data shows generally good relationships between unit energy consumption and Green house gas emissions.

Table 24: Mining CO₂ Intensity in 2006

Company	CO ₂ emissions Mt	International guidelines
Alcoa	60	US climate Action partnership
BHP Billiton	51	BHP.B Intensity Index (GR)
Anglo American	36	GHP
Alcan	32	GRI
Rio Tinto	28	GHP
Xstrata	16	GRI
Anglo Gold Ashanti	4.7	GRI
Newmont	4.3	GHP
Tecklounmco	1.4	MAC/GHP

Source: Second International Conference⁴⁶

The figures above show indicatively the CO₂ intensity values disclosed in 2006 for major mining companies worldwide:

The resource consumption intensity and the sustainability of gold mining reveal an average of 3.7 tonne CO₂ / t ore for GHG emissions with a standard deviation of 2.8 for 2006, this average cover 3 mines.

C – Energy consumption Costs

Energy sources such as electricity, fuel oil, natural gas are provided as inputs to industrial chain production minerals commodities. Thus, energy costs in mining operations influence both price and availability of commodities on the market but also company's profitability.

With current price boosting for gold and PGMs, to sustain growing demand, the trend is on increasing production and productivity although steady deepening of South African precious metal underground mines. To maintain competitive and profitable profile, companies are focusing on mines operating costs reduction.

Each company defines costs according to its own accounting policies and practices. But the production cost standard exists on cost per ounce basis operating costs is one component of the mining total cash costs. The other component is indirect costs.

As direct costs, operating costs include direct mining expenses, depletion and development, consumables and energy costs etc. Several categories of energy cost and usage information can be examined. The objective of the analysis is to provide detailed inter-underground mines. Comparison of the cost per tonne mined, milled or recovered, split into costs per unit of energy and energy consumed per tonne. Therefore, indicators such as energy cost (\$/tonne of ore) and unit energy cost (\$/KWh) help to establish comparison.

4.2 RESULTS BENCHMARKING

The areas of concern on energy values benchmarking cover all underground mining and mineral processing activities, starting from drilling to concentration. Key factors that measure energy consumption are summarised by appropriate indicators selected, and the values estimated for each mine unit are given according to criteria.

All values benchmarked below are the result of estimates classified in tables B1 of appendix according to energy consumption per stage of operation and particular activity, energy intensity in regard of depth level, energy intensity in regard of mechanization, consumption operating costs, and GHG and CO₂ impacts.

4.2.1 MINING OPERATION CONSUMPTION

A – Energy Distribution

Tables B1.1 and B1.2 in appendix contain energy consumption values in KWh for electricity and sub – total or total in Giga joule within fuel for different stages of mining chain process. That includes underground and plant stages respectively for gold and platinum. The distribution of whole energy supplied to mining chain of production is illustrated by figure 11.

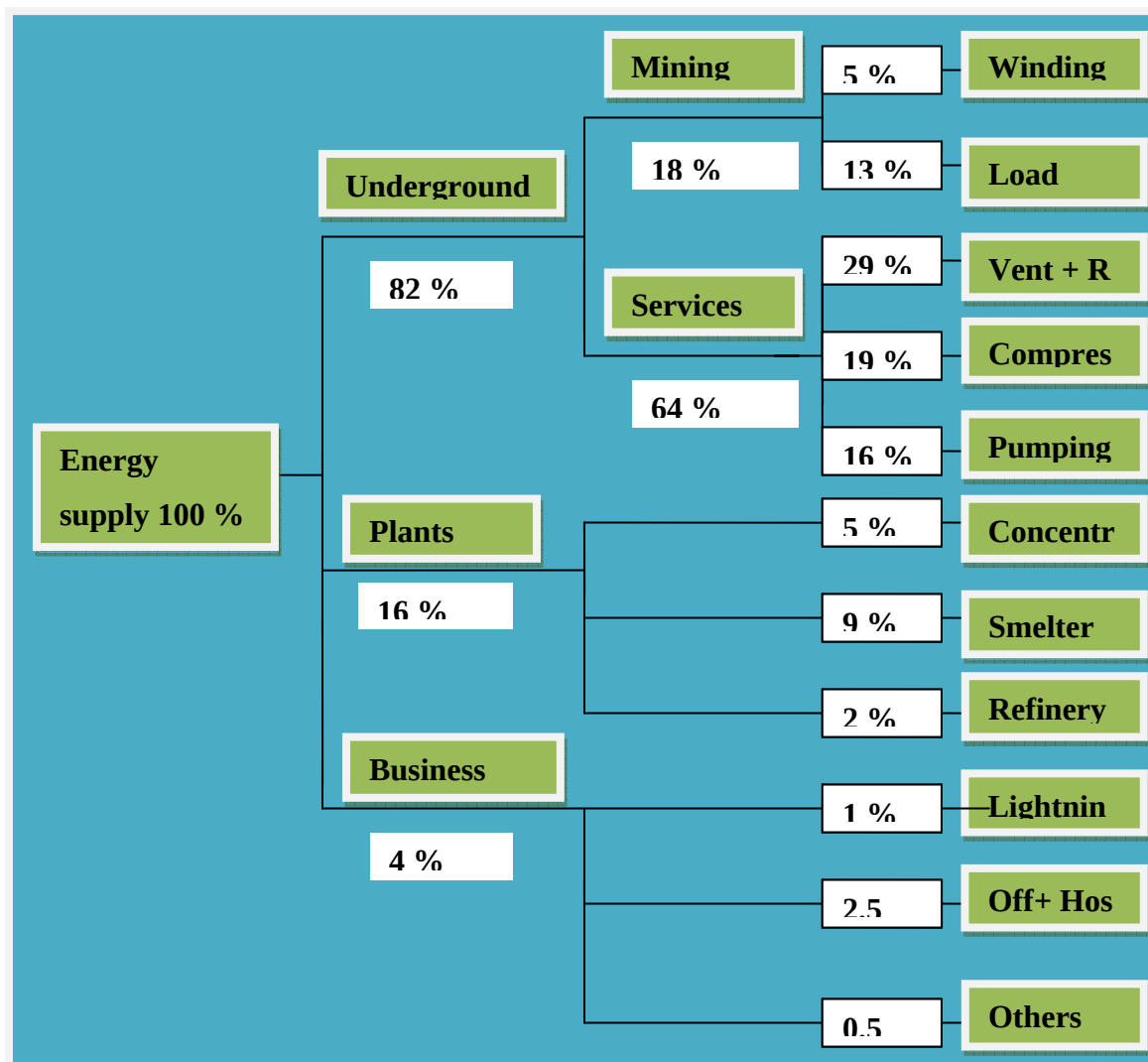


Figure 11: Gold chain process Tree 2006

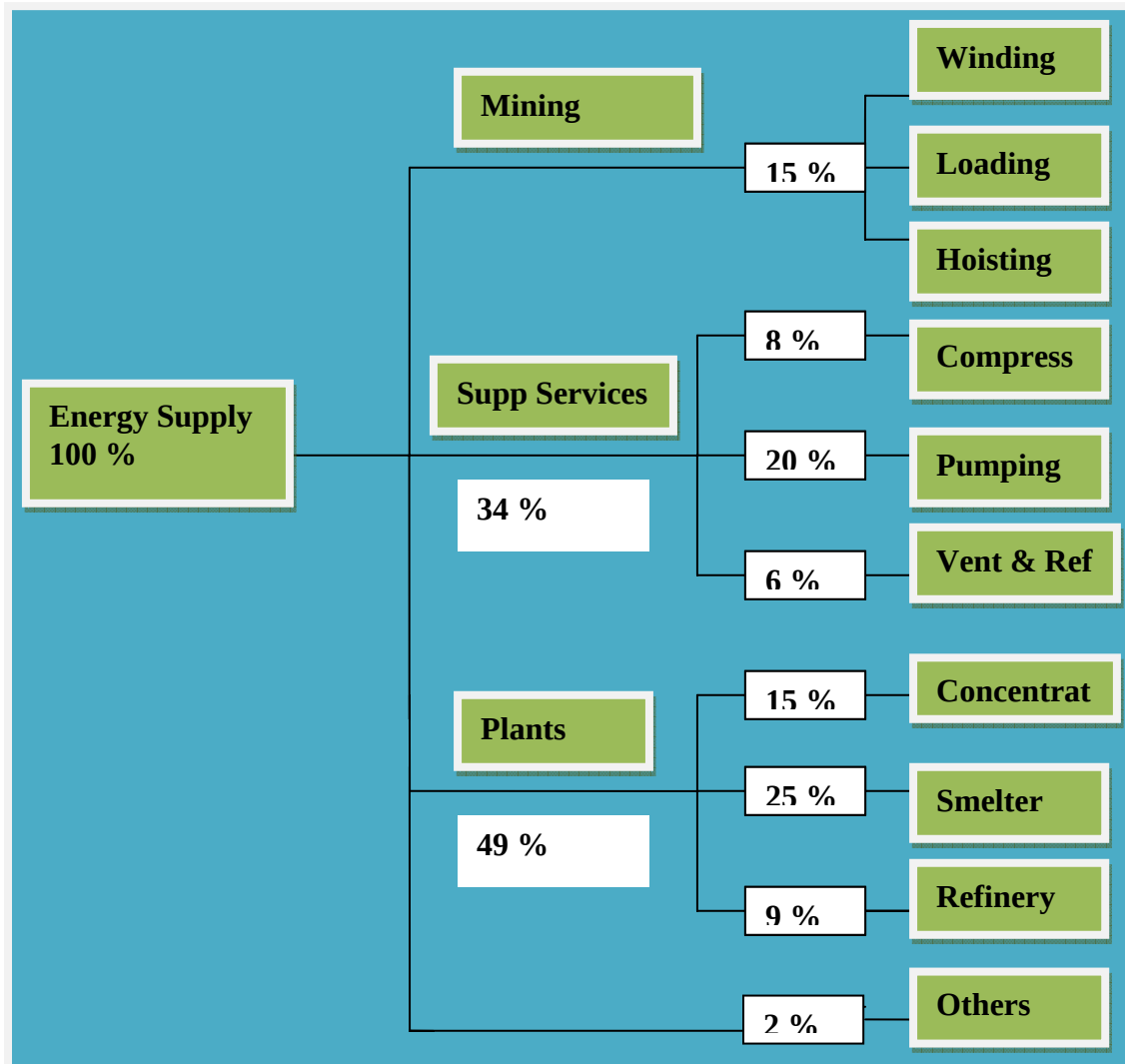


Figure 12: Platinum chain process Tree 2006

B - Energy consumption chart per activity

The figures below regroup the values in percentage of main mining activities including material handling, support services such as compression, pumping and air conditioning, and metallurgy with concentration, smelting and refinery. The others include business, lighting etc; as presented in appendix C2.1 and C2.2. The charts below allow comparing gold and platinum average percentage per key operations.

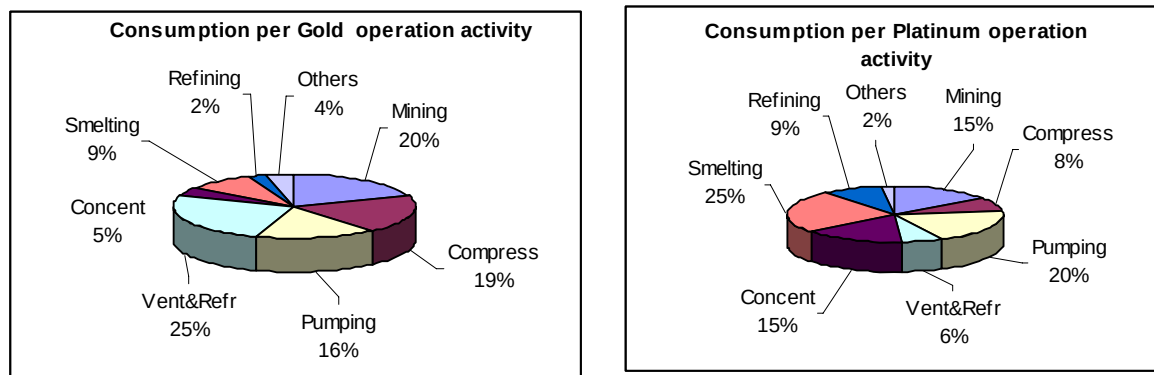


Figure 13: Percentage per energy activity

C – Energy Intensity per Unit of Output

The intensity of energy consumption for each underground mine selected is presented through an indicator of total energy consumed in KWh or Giga joules over the total tonnes extracted or milled for underground mines in 2006. Thus, the graphs below are built from data in tables 3.5 and 3.6 associated to those in Appendix C1.1 and C1.2 for gold and platinum

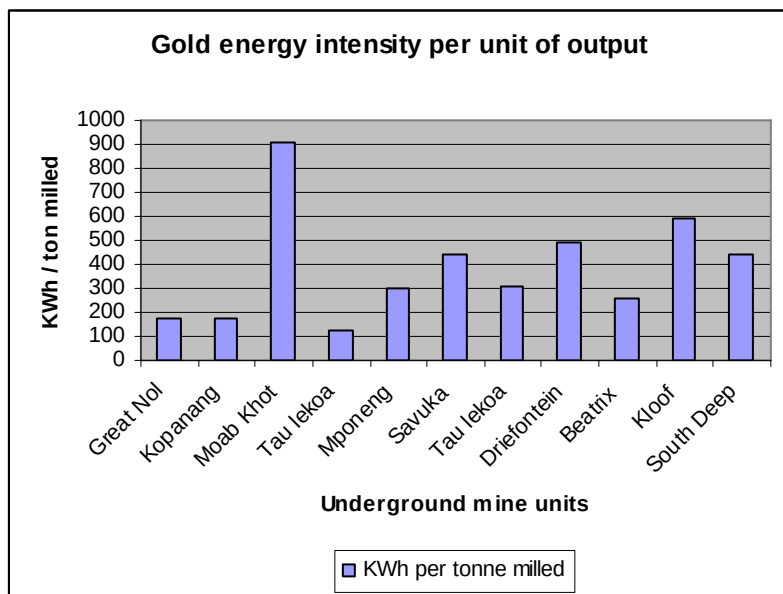


Figure 14: Energy intensity per gold mine

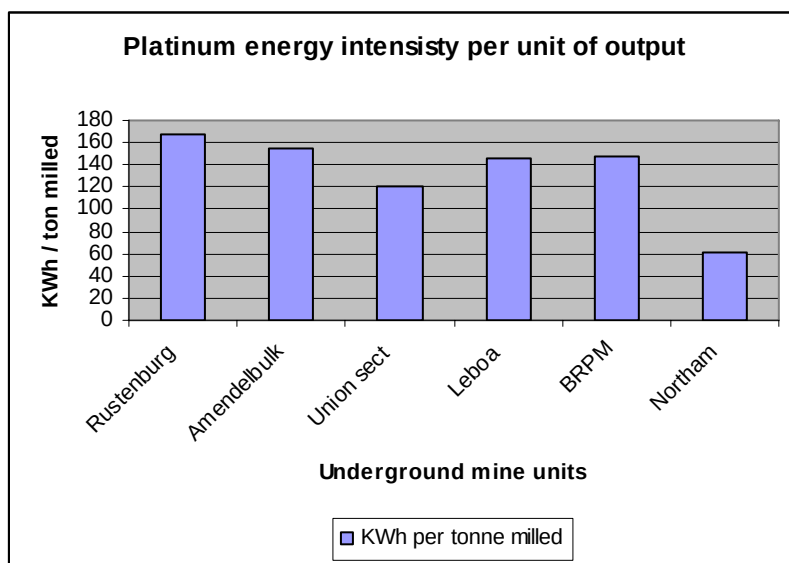


Figure 15: Energy intensity per platinum mine

4.2.2 ENERGY INTENSITY Vs DEPTH CATEGORY

The values recorded in the following tables come respectively from data classified in table 3.1 and 3.2 on depth category for the two first columns and tables C4 and C5 giving respectively the energy consumption intensity per unit of output (colon 3,4) and energy cost (column5,6) for gold table 3.10 and platinum table 3.11

Table25: Benchmark of gold mines energy intensity and operation costs

Depth category	Selected Mine	Energy Intensity range		Operating Costs range	
		KWh/ton mil	GJ/ton mil	R/Kg Au	US \$/ Kg Au
Shallow	9*	262	0.07	455	67
Medium	(2,3,5)*,(8,10,11)**	177 - 907	0.05 - 0.37	485 - 1584	71 - 233
Deep	1*,4*,6*	121 - 444	0.01 -0.12	490 - 882	72 - 130
Ultra Deep	7*	309	0.09	567	83

Table 26: Benchmark of platinum mines energy intensity and operating costs

Depth Category	Selected Mine	Energy Intensity range		Operating Costs range	
		KWh/ton milled	GJ/ Ton milled	R/ oz	US \$/oz
Shallow					
Medium	(21,22 ,23, 24, 24)***	228 - 338	0.08 - 0.17	4322 - 8012	638 -1022
Deep	26****	114	0.04	3892	572

The average values estimated for gold and platinum are recorded in the following table although there is difference in category depth definition.

Table 27: Average intensity and costs

Depth category	Average Gold		Average Platinum	
	KWh/t mill	R/Kg	KWh/t mill	R/oz
Shallow	262	455		
Medium	484	804	290	6050
Deep	245	629	114	3892
Ultra Deep	309	567		

4.2.3 ENERGY CONSUMPTION vs. MECHANIZATION

The estimates in the table below are results of combined values classified from tables 3.3 and 3.4 (column 1 and 2) and those from table in appendix D3 that report energy consumption per source for gold and platinum respectively.

Table 28; Gold mines benchmark of energy vs. Mechanization

Mechanization	Selected Mine	Energy Consumption (%)		Average (%)	
		Electricity	liquid fuels	Electricity	liquid fuels
Low	2*,3*,7*,8**,9** .10**	70 -98	2 – 30	93	7
Hybrid	1*, 4*, 6*	96.1 - 98.2	1.7 - 3.9	97	3
High	5*	78	24	78	24
Tot Average				90	10

Table 29: Platinum mines benchmark of energy consumption vs. Mechanization

Mechanization	Selected Mine	Energy Consumption (%)		Average (%)	
		Electricity	liquid fuels	Electricity	liquid fuels
Low	4***, 5***			77	23
Hybrid	1***,2***,3***,6***	77 - 98	2 - 23	82	18
Tot Average				80	20

4.2.4 GREEN HOUSE GAS EMISSIONS INTENSITY 2006

The environmental impact due to energy use in mining still constitutes one of critical reporting in the sector as most mining companies are not disclosing on gas emissions to avoid penalties and other consequences from public services in charge. The table below summarizes what is available for 2006 data.

Table 30: GHG & CO2 emissions' intensity for selected mines

Selected Mine	CO ₂ & GHG emissions	Comment
(1,2,3,4,5,6,7)*	Average* 4.7 Mt CO ₂	No detailed data quantified available for SA specific Mine.
8**,9**, 10**,11**	17,220 tonnes CO ₂ for 9**	Details on 8** , 10**, and 11** not reported
(21,22,23,24,25)***	Average 5.91 Mt CO ₂	Represent the total quantified from all sources: electricity, liquid fuel, coal, and Gas.
26****		Not available

26****: justify by intensive hydropower use

Mining sector in South Africa including gold and platinum relies largely on coal in power supply.

Therefore, energy efficiency as the ultimate objective for established energy consumption standards needs research efforts to be done on how to make the coal cleaner, find ways of safely and permanently capture and store the CO₂ emissions from burning coal.

4.2.5 ENERGY COSTS

Energy consumption costs analysis interest focuses on two indicators, including operating costs profile for mines units selected and the energy cost unit performance. Although, the detailed costs of energy for different stages are not recorded, the general operating costs profile for each mine unit in regard of the average calculated are presented below. Estimated values on the graphs are contained in appendix C5. The values in appendix C5 represent mine units operating costs (Rand) per unit of output (tonne ore milled)

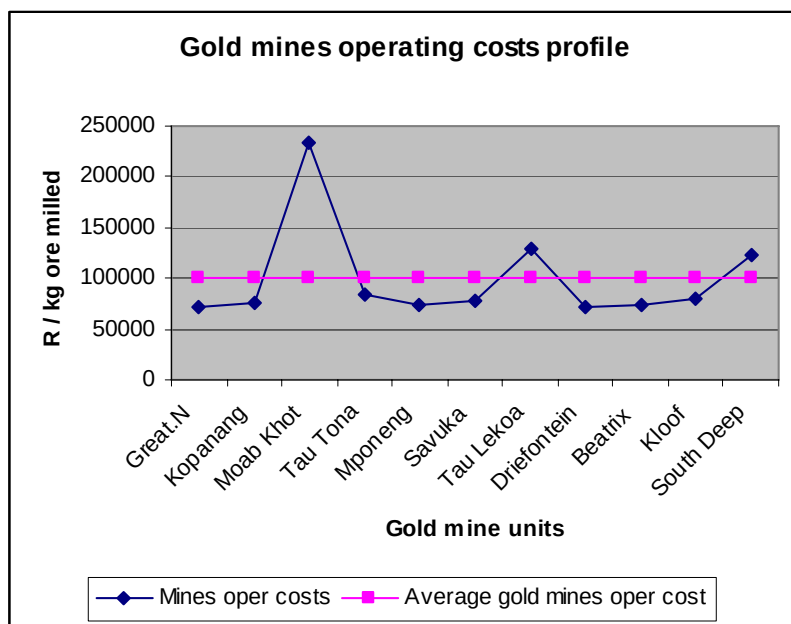


Figure 16: comparison of gold mines' average operating costs profile

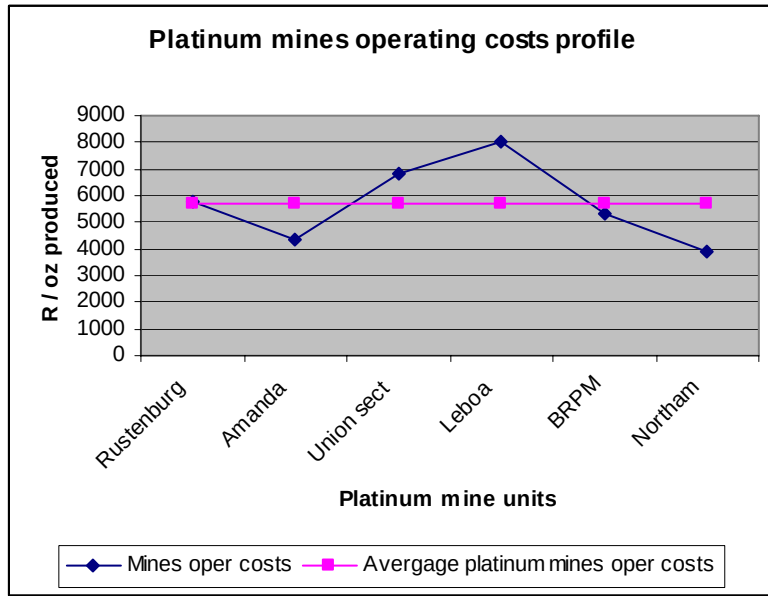


Figure 17: Comparison of platinum mines' average operating costs profile

Cost indices profile show mining energy cost performance that can be calculated as unit cost based on combined formula below and compared to average costs for energy used in selected underground mines operations:

$$\text{Cost Indices (R / MJ)} = (\text{R / ton milled}) \times (\text{Ton milled / MJ})$$

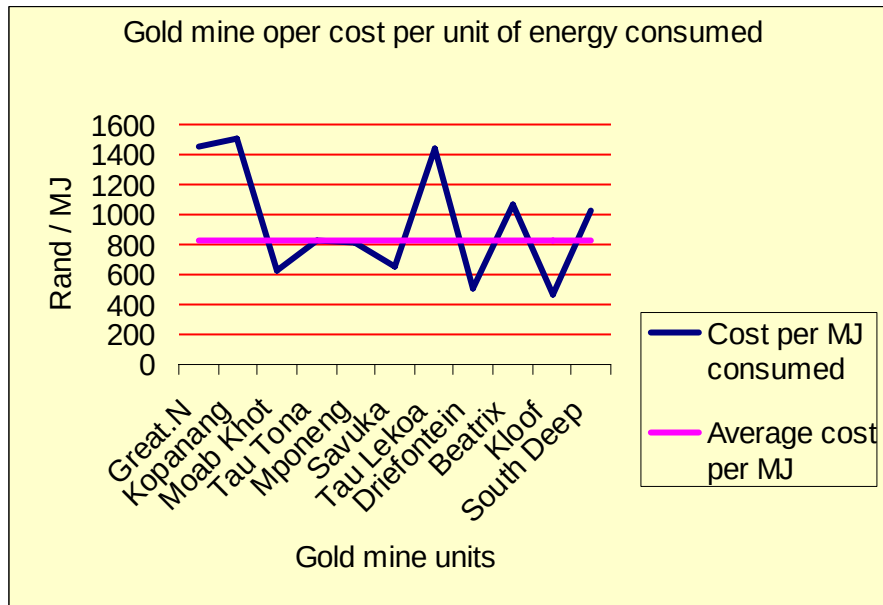


Figure 18: Gold mines cost indices profile

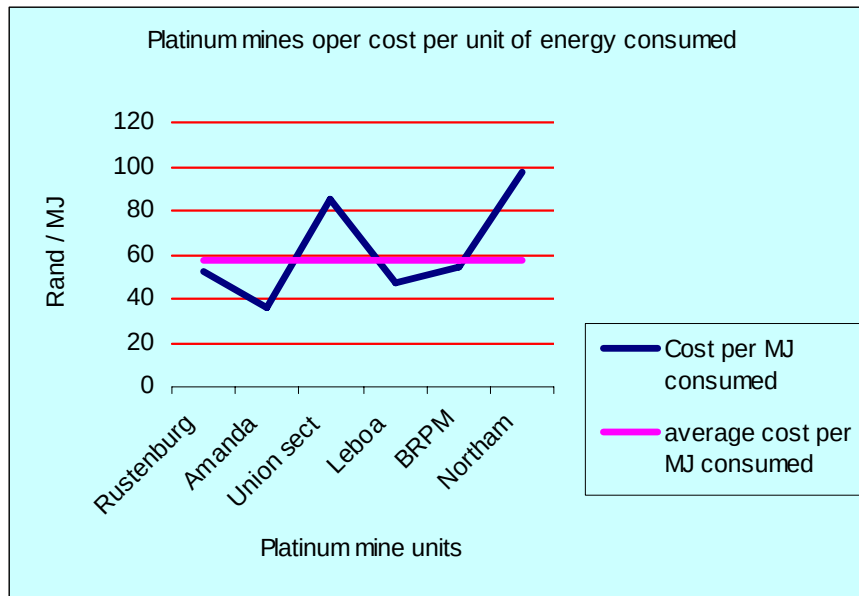


Figure 19: Platinum mines cost indices profile

4.3 TRENDS

Regarding the energy consumption in the South African mining industry within underground mines, the trend is driven by factors such as economic growth, the increasing market price and demand of precious metal commodities. Mineral reserves in gold and platinum and the associated expansion projects outlook is sufficient to justify the rising need of increasing productivity to satisfy market demand while reducing operating costs.

Economic growth and commodities market price add to the existing cheapest energy from coal is a key determinant to economic development of the sector. In 2006, an economic growth of 6% was recorded and the mining sector remains a major contributor accounting directly or indirectly for 15 % to 20 % of GDP and 16 % of electricity demand.²³

Gold and platinum are the main mineral commodities strengthening in the sector as market prices have inflated. Price escalation will continue as long as dollar currency

keeps weakening with the oil prices adding to some political uncertainties in the eastern Asian region.

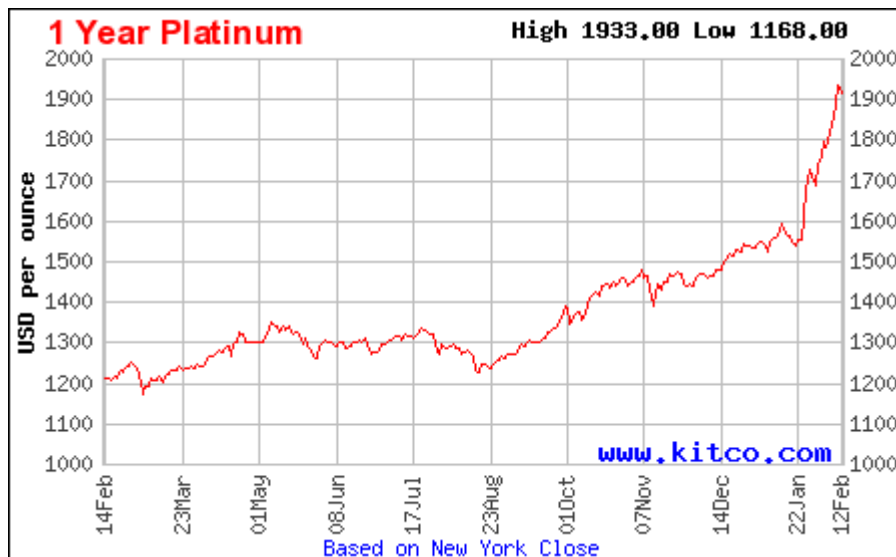
Gold demand is erratic from industrial, commercial and electronic product manufacturers. According to various analysts, the long-term support to gold prices upward trend will be provided by China that might even add more gold to its reserves. Gold demand forecast in 2007 rose in auto catalysts and jewellery to the extent that outweigh gains from higher mine production.²²

The consensus of analysts for these commodities price set an average for: Gold: US \$ 716 with US \$ 850 highest price and US \$ 580 lowest and Platinum: US \$ 1350 with US \$ 1495 highest and US \$ 1075 Lowest.⁶⁰ But the recent rise peaks of gold and platinum commodities prices due essentially to business market fear of American economy's recession and the series of power shortage negative effects call to revise some forecast analysis. The following diagrams show a need of updating analysis in giving an historical evolution chart on a year period⁶⁰:



Source: historical charts & data Kitco

Figure 20: Historical gold price trend for one Year



Source: historical data & charts Kit co anniversary

Figure 21: Historical platinum price trend for one Year

Precious metal boost for producers is a pressure to increase production and productivity and subsequent energy consumption.

4.3.1 RESERVES AND EXPANSION PROJECTS

Gold reserves evaluated to 364.1 million tonnes with an average grade of 5.41 per tonne of gold are lowering as they are going deeper underground. Thus, access required more, improved and efficient production means to be allocated. Only platinum reserves locations are somewhat still under 2000 m level.

Following expansion perspectives and the related projects development, the outlook shows:

- Gold production is expected to be increased to 5.8 million ounces. Except Tau Lekoa and Great Noligwa where production is expected slightly to decline, expansion projects at others mines are ongoing with deepening at Tau Tona, Mponeng, Moab Khotson and Kopanang: Production level is maintained at Kloof, Beatrix, Driefontein and South Deep is reopened.
- Platinum production at all selected mines was subject to increase or remains at the same level from 2006.

Although expecting increase in production, the productivity rate remains tributary to the current national risk of electrical power supply constraints.

4.3.2 PRODUCTIVITY FACTOR

Increasing production and productivity in the current context will require more energy consumption through additional equipment to be used. Because of lowering grade ores, for example, decline in average grade 9.3 % in 2006, there was an increase in tonnes milled of 1.5 %.(CoM).⁴⁸

About 95 % of gold mines in South Africa are underground operations. All selected underground mines in this study represent 65 % of national gold production; while the six platinum mines cover 45 % of South African output.

Considering the average energy consumption intensity values in appendix:

- Gold: 22,280,633 tonnes milled annually for 11 selected mines with 0.12 GJ/tonne milled and 0.69 GJ/ oz.
- Platinum: 30,737,441 tonnes milled annually for 6 selected mines with 0.103 GJ / tonne milled and 1.8 GJ / oz.

These values underline the increasing role of platinum mining due with subsequent energy consumption due essentially to the introduction of mechanization in underground mines.

The total estimated energy consumption can be set to 3,165,956 GJ for Gold underground mines and 7,035,459 GJ in case of Platinum underground mines. Global annual energy consumption estimates in Platinum underground mines appear to be relatively double of Gold underground mines because of the large amount tonnes milled, in the first case, add that to a number of electricity and oil consumer equipments used that allow more mechanization in platinum mines than gold mines. Also, in platinum cases, these values include the pre-concentration step that is not necessary treated separately.

Considering Eskom, the net capacity available is of 29,898 MW and the average demand of 31,000 MW, from which 16.2 % belongs to mining industry, including 18 %

for underground gold mines and 30 % for platinum mines.²⁷ According to the long-term energy planning by Eskom and the Department of Minerals and Energy through the new capacity generation, it appears that, the new country mothballed power stations (Komati, Grootvler and Camden) will not be enough to satisfy the projected medium to long-term growth in electricity demand.

Nevertheless, a new peak generation capacity will be required by 2009 and base load capacity by 2011⁶³. The rapid growth in demand of electricity in the country can be reached only through alternative Programs such as Demand Side Management initiated by Eskom with major targets Gold and PGMs firms. This recommends by applying Energy efficiency planning through new technologies and associated programs to save energy.

Others rely on alternative energy sources such as natural gas – based power generation for peak demand period. All these will be well done starting with basic benchmarking values in order to set goals, targeting issues, compare working standards and propose improvements.

All above treated factors help to establish an electricity demand forecast for South African gold and platinum mines for the next 12 years, as illustrated in the figure in which the trend take in account three period times:

- Up to 2007, the first period is related to power supply crisis appearance. The main issue consists in extreme limits reached by national power net capacity due essentially to gradual erosion of the reserve margin. The consequences are: sudden and unpredictable power cuts and shedding following power shortage that affect major consumers including gold and platinum mines with serious losses in production and money.
- The end of 2008 to 2013 is the second step related to power crisis accommodation. The main issues to face by the utility consist in risks of frequent forced outages due to ageing of power plants infrastructure. Major mining consumers have to deal with consumption reduction on a year to year rate of 1% to

2.5 % to reach the target of (10- 15) % set by the tandem Eskom-DME, by 2015.³⁶ Expected consequences are the redefinition and rescheduling of most of mine programmes and projects expansion that can slowdown some deepening gold mines projects and other platinum mechanization planning.

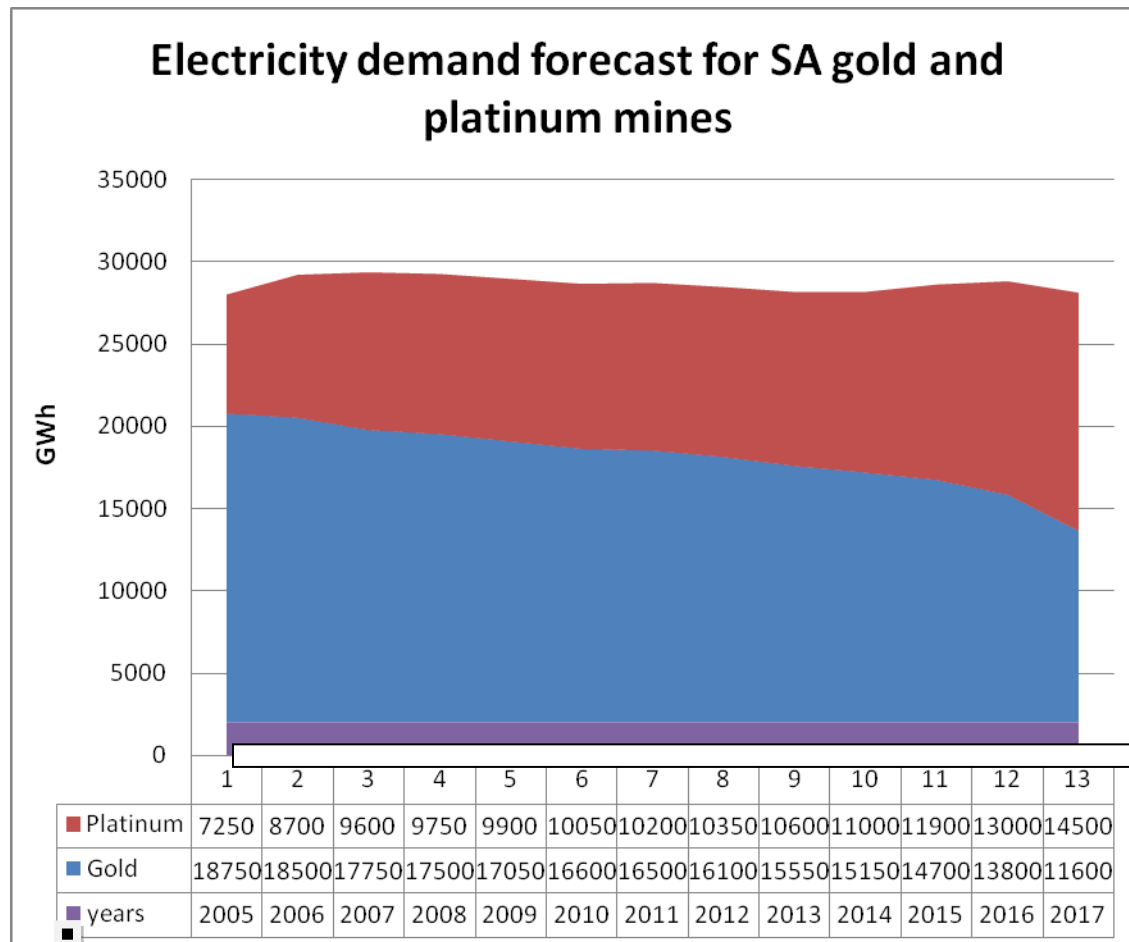


Figure 22: Forecast of Electricity demand in SA gold and platinum mines

- The last period starting by 2014 with capacity and Base-load re-establishment will boost some power consuming in platinum mines while decline affecting gold mines as they are deepening and lowering in ore grade will be replaced by assets economically more profitable in other countries than South Africa.

NB: This forecast considers a 10 % of contingencies (bottom space) to Allocate along all the study analysis period.

Number of uncertainties and deviations affecting energy consumption indicators and range of values considered as basic to the enhancement of best practices, can be eliminated in working and focus on standardization of values averages and limits over the whole mining sector.

4.4 SUMMARY OF FINDINGS

The main findings in this work are compiled as benchmarking of energy consumption data and as an integrated model usable professionally by miners to appreciate mining activity level of energy consumption.

Firstly: the benchmark of values includes:

- 1- The average values of energy consumption for different stages of the mining process (mining, services, plants for concentration, smelting and refining) for gold and platinum.
- 2- The average values of energy consumption for the main underground mining activities classified accordingly for gold (ventilation & refrigeration, compressing, pumping and loading – hoisting) and platinum (pumping, loading – hoisting).
- 3- The average energy intensity per unit of output (KWh/ Kg) of gold and platinum and the intensity level per mine demand.
- 4- Energy intensity (KWh/ ton milled) and associated costs range limits (R/Kg) in relation to mine depth level or the degree of mechanization.
- 5- Energy consumption per type of fuel consumed.
- 6- Operating costs per mine production (R/kg ore) and per energy consumed (R/MJ).
- 7- Forecast trend of electricity demand in gold and platinum mines for 12 years (2017).

Secondly, an integrated model in Excel easily usable by miner owner elaborated in two parts:

- The performance curve model (Sheet 4) allows comparison of energy consumption patterns (level of consumption and cost benefit) for different mines

using curves elaborated from information in Excel spreadsheet as recorded on monthly basis. These curves highlight performance in power consumption and costs over a year that can lead to appreciable failure, maintenance and savings. The following diagram illustrates the comparative performances record for four gold mines analysed.

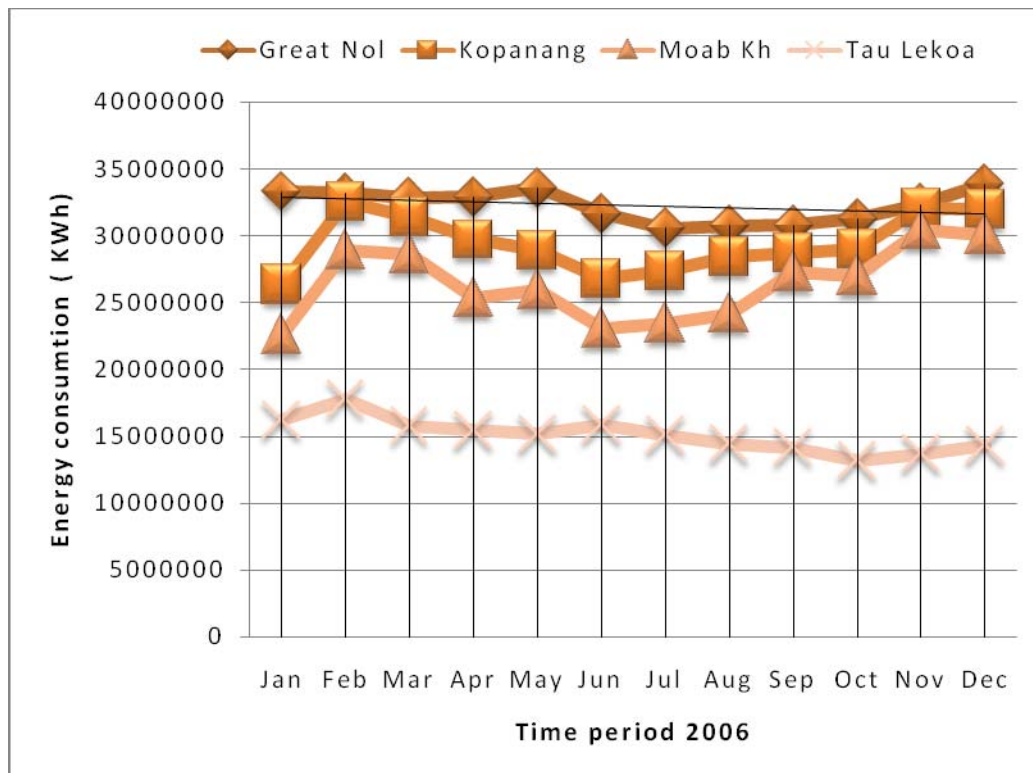


Figure 23: Annual energy consumption performance curves (Vaal River mines)¹

- The second component named “comparator model” enables miners to point out margin in energy intensity referring to an average and normal case defined for each underground mining activity.

This model use the Figure 11 on page 73 (Gold chain process tree) to integrate data from reference compiled information (Sheet 1) and display the difference between the average and the real level.

Thus, by entering average annual value of energy intensity per output for any recorded mine, the model displays automatically:

1 – The level of energy consumption (low. normal, high and very high)

2 - The difference in energy consumption for each particular mining activity with indication: red for excess energy usage, white for normal energy usage and grey for lower energy usage. The displaying diagram is showed below:

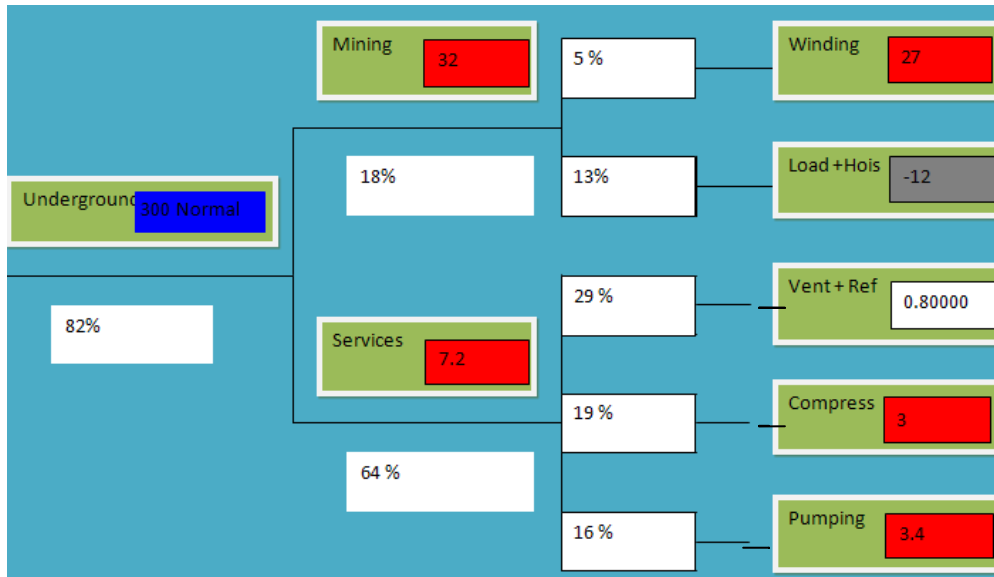


Figure 24: Comparator model for mining activities' energy consumption ¹

REMARKS:

- The model can run in Excel with macro activated as the displaying program is written in visual basic.
- A difference less than 0.5 is not displayed in a case of normal intensity.

5 DISCUSSION AND CONCLUSION

5.1 DISCUSSION

The following discussion is related essentially to the increasing demand and consumption of energy, particularly in the mining industry South Africa in line with the study's data results and interpretation.

Fact is that the growing demand and consumption of electricity in mining is driven by a call to increase production following mineral commodities price boost, particularly gold and platinum, which South Africa is the largest world producer. Gold demand continues to be driven by the jewellery sector, accounting for more than 70 % of the total fabrication in 2007.²

On the other side, the ongoing price boost, subsequent to demand increase, is related to factors such as Chinese stock building, fear of potential American economic recession and shortage of power supply in South African case. The resulting pressure on major gold company producers is illustrated by an increase in productivity in some mines such as Driefontein and Great Noligwa, the reopening and extension of exploitation in South Deep, Savuka mines and the implementation of new projects at Kloof, Beatrix, Moab Khotsong etc. The exploration expansion projects in Wit Basin, for example, have showed an overall 8% additional increase (582,000 ounces of gold to the total measured as indicated resources.⁷

In case of platinum, the global demand was expected to rise by 2% to 6, 7 million ounces in 2007. The improvement is essentially due to the automotive sector owing to growing demand of auto catalysts for diesel cars and trucks in Europe, Japan and USA; followed by manufacture of computer hard disks and LCD glass panels and jewellery.³² Expectation for a rapid growth in South African platinum supplies is to come in the next years.

Therefore, the largest major platinum producers such as Anglo Platinum, Impala and others are taking advantage of strong global demand for PGMs, coupled with an optimistic commodity price outlook to many projects expansion and other ones previously put on hold. These projects include Twickertram and Gapasha platinum mines on the eastern limb of the (BC), the Rustenburg, Amandabelt, Union and Bafokeng Rasimone Platinum mines on the western limb. To meet the demands, the target considered is an average production growth rate of 5% in medium term.

Power supply includes the availability of source and generation, the reserve margin and the risk presented by power supply. Particularly given that South African electricity is essentially from coal.

With increasing demand, locally, coal consumption is gradually growing, mostly through expansion and upgrading of coal-fired plants projects. Current national electric capacity generation from coal fire plants consumes about 71 % of coal (108.7 million tons) 2005. Up to now, the yearly increase is 4.5 %.

In regard to electricity generation, the nominal capacity of South Africa electricity is 42,011 MW, while the net capacity reaches actually 36,398 MW from which only 29,838 MW are available. The recorded shortage is about 6500 MW. But the average demands currently vary between 31,000 MW and 33,000 MW.

The previous normal operating margin of 1600MW was gradually reduced at the lowest reserve peak margin of 7.2 % while the required reserve margin aligned with international norms must be set at 15 % of reserves capacity over the long term to ensure the security of supply.³⁶

In addition, most of Eskom currently operating plants have reached the middle of design life. These impacts on the performance requiring outage line for maintenance and refurbishments. During 2006, for example, the energy availability factor of 87.4 % was achieved against a target of 89.2 % owing primarily to more forced outages (Eskom

Report, 2006). All the problems experienced on power plants availability and the ongoing power cuts have demonstrated very clearly the risk to which the security of electricity supply in

South Africa is currently exposed, taking in account low generation reserve margin available nationally and the requirement for high availability of power plants.

To meet the national growing electricity demand which has been aligned previously on 2%, then 3 % and now targeted to 6% yearly set, the state owned utility will need to augment existing national capacity by 2000 MW every year over the next 20 years as stated in recent Eskom report .³⁰

But this will not help easily providing quickly the security of power supply even in upgrading plants or in launching new projects because of the time taken to build a new electricity asset. In fact, building an electricity asset takes six to ten years and this asset has to last for forty to fifty years.

For this reason, the mid-term strategy based on anticipation over assets life time and incentives arrangements on efficiency and energy saving with major consumers including mining companies will help to work on return maximising and risk reduction.

All local mines and smelters are consuming more than 112,186 GWh or 46 % of the total amount of electricity sold by Eskom in 2005 and the need to upgrade by 2012 will essentially be consumed by major sectors such as mining for which gold and platinum mining are currently amongst top consumers with 80 % (897,488 GWh) as mentioned above in this study.

Though, the lack of security of power supply illustrated in recent shortages and power cuts forcing miners to halt operations losing about Rand 330 million in turnover a day ⁶⁴ remains a major concern for the future. Almost two-thirds of the mining industry particularly deep-level gold and some platinum mines have been severely affected.

Collection of energy consumption data through survey samples and associated discussions with provider services have shown some discrepancies in values estimated and practices on the ground. Disparities are related to mine units output being considered in establishing energy consumption indicators such as kilowatt hour or joule per unit of output (tonne ore hoisted, mined or milled and ounces produced) for energy intensity and related unit energy cost (SA Rand per KWh or US Dollar per GJ).

When considering the flow of activities in mining operational chain, it appears difficult to separate, in some cases, data from specific production stages such as pre-concentration and mine underground activities or refrigeration from ventilation operation.

All these confirm the need for standards in terms of common definition, operations classification and value ranges that allow inter-facilities comparison, efficiency targeting and technologies and/or equipment improvement strategies.

In this context, consideration of underground deep mines energy intensive activities in comparison to typical gold mine consumption show relative close values for most areas except ventilation and refrigeration which is three times more than a typical case (25 % / 7.9 %)³⁸, while smelting and processing remain the most consuming activity for platinum.

The indicators used: KWh or Gigajoules for energy intensity and US \$ and SA Rand for cash and operating costs are used in output ratio of tonne ore milled, Kg Au for gold and ounces (oz) for platinum.; Tonnes ore broken or hoisted are put aside by lack of uniformity in reporting values for different firms in concern.

The analysis and interpretation step was limited to select 2006 data and sample size in average results calculations. For consistent analysis, a three to five years based historical data will call to apply a weighted factor proportionally to sample unit size in order to apply sensitivity analysis to all selected parameters.

Following criteria applied to benchmark values the average energy consumption estimated is 229 GJ / Kg Au for 11 selected mines more than 187 GJ / Kg Au given for 3 gold mines selected by GFMS study⁶². And the average tonne milled is 331 KWh with a deviation of 51.06 units due essentially to Moab Khotsong mine which was in commissioning step with production capitalized against pre- production costs. The final process intensity estimated is by 0.51 GJ /oz more than 0.35 GJ /oz for 6 mines in GFMS case.

In platinum case, the average is 1.8 GJ /oz in end process end and 133 KWh / tonne milled. Deviation in energy consumption costs values are due to Northam mine using intensively hydropower as shown above. Operating costs are given in SA Rand per kg Au for gold and the average of following the same deviation due to M.K mine and average for platinum mine

5.2 SUGGESTIONS

Energy consumption standards are pre-required paths in energy efficiency programs. The related savings potential of industrial systems, including mining, remains largely unrealized because of deeply embedded operational activities and management practices. Identification and optimization of energy efficiency and saving projects need management focus and technology process analysis on the ground. The following suggestions can help to improve and support standards in this field:

- Values estimated in benchmarking can be considered basically indicative for further studies as data treated cover only one year (2006).
- To increase credibility for standards, historical data covering three to five years should be considered in further studies. In regard to this, increasing value estimates accuracy, a detailed accounting audit should be conducted for each energy consumer activities stage and associated equipments, involved in the production chain.

- To complete this study, an exhaustive data collection allowing a census sampling for more than 75 % of operational gold and platinum underground mines should be conducted for a consistent establishment of energy consumption standards. That can be a reference for further energy research.
- At the national level, energy consumption standards in the mining sector will need to extend the same studies to other major contributors of commodities such as coal, diamond etc

5.3 CONCLUSION

Energy consumption, particularly electricity in the South African mining industry, is one major target of the country's current energy efficiency programs and strategies set by DME and the state owner utility which includes in its Demand Side Management the consumption reduction target of 15 % by 2015.

Mining industry represents about 15.6 % of total national consumption of electricity and about 33% of total industrial consumption from which 80 % taken by together gold (57%) and platinum (23%).

Up to now, less was done by research and development in this field locally to raise up the need of establishing energy consumption standards in mining industry as the power produced locally, one of world cheapest was not a big issue for South Africa.

But the environmental and climate change constraints, the country electricity crisis exposing supply shortage through several and unpredictable power cuts and load shedding have painted the need of mining standards settings for energy consumption as an emergency. Settings can be obtained by analysing parameters such power supply load charge and peak demand from supply side to end users underground mines technologies, mining methods, equipments mine depth, mechanization and productivity in this case.

With current mineral commodities price increasing on international market, competitiveness of major South African companies producers, particularly for gold and platinum, relies on their ability to respond to production increase pressure while reducing operating costs and complying to national energy targets strategies in order to meet commodity's market demand.

Although there are large ore reserves remaining in South Africa, the gold ore grade will continue to decline and underground mines for gold and platinum to increase in depth. Technically, it is becoming very difficult to exploit such ore bodies and it is financially very expensive to operate when considering, for example, the energy input intensity, the GHG impacts and the implied costs.

This study has tried to compile and present broad ranges of data, using survey, discussions and interviews tools to collect gold and platinum underground mine data related to energy use for 2006. Analysis and interpretation of energy consumption data according to selected criteria of depth level, degree of mechanization productivity, and environmental impacts have permitted using physical and financial indicators to benchmark energy intensity and costs values for selected gold and platinum underground mines.

For most of the mines, ventilation and refrigeration constitute a major consuming activity from one and half to three time's energy according to the depth comparatively to a typical mine. Thus, estimated values and average of energy intensity per unit of output, cost per unit of energy operating costs per unit of output and relative state of GHG are presented.

From observation, it is not easy to develop an aggregate measure of energy intensity standards when considering the dynamic aspects of mining activities that make change and progress every day in production volume goals, the diversity of technologies and equipments to adapt and to improve following the constraints on ground, and practices applied by each mining company within each underground mine particularly.

Nevertheless, the finding values benchmarked constitute the indicative basic that can be updated and completed as suggested above, through further and wide studies extended to other major minerals in order to establish local national standards.

6 REFERENCES

- 1 An Mbendi Profile. An Mbendi country profile for for South Africa including economic. <http://www.mbendi.co.za/land/ef/sa/p0005.htm>. cited Dec 2005.
- 2 Abelson, Philip .H.(1994). Use, Conservation, and Supply energy. American Association for the advancement of Science, Washington D.C. USA.
- 3 Coal a fossil fuel. Energy Kid's page. <http://www.eia.doe.gov/kids/energyfacts/sources/non-renewable/coal.html> - 25k. November 2007.
- 4 Burger, D. About SA – Minerals & Energy: Electricity. <http://www.info.gov.za/aboutsa/mnerals.htm>. June 2007.
- 5 Energy Information Administration. (2005). International Energy outlook. <http://www.eia.doe.gov/emeu/cabs/archives/africa.htm>.
- 6 Mining journal on line. <http://www.miningjournal.com/journalarticle.asp?articles=17618>.
- 7 Klaus brendow. PR. (2004). World coal perspectives to 2030. Energy council Geneva/London.
- 8 Coal a fossil fuel. Energy kid's page. <http://www.eia.doe.gov/kids/energyfacts/sources/non-renewable/coal.html> - 25k. November 2007.
- 9 Bio energy Conservation Factors. http://www.bioenergy.oiml.gov/papers/misc/energy_conv.html.
- 10 Information about South Africa. Background about South Africa. <http://www.ngo.grida.no/soesa/nsoer/general/about.html> -16k. Cited April 2007.
- 11 An Energy summary of South Africa. Fag image courtesy of world flag database. <http://www.cslforum.org/safrica.htm>. February 24, 2007.
- 12 Anglo American plc. Annual Report 2005.
- 13 Swanepoel Esmarine. (2007). SA's electricity supply still at Risk. Engineering news. Vol 27 N^o 18. May 16.
- 14 Energy Information Administration (2005). International Energy outlook,2005. <http://www.eia.doe.gov/oiaf/electricity>.
- 15 Energy Information Administration. (2006). Annual Energy Outlook.
- 16 Mining and minerals in South Africa. South Africa Info. <http://www.safrika.info/doingbusiness/economy/key-sectors/mining.htm>.2007.
- 17 John .H, Gibbons and William Chandler. V. (1981). Energy, the conservation revolution. Plenum press. New York and London.
- 18 Matshamako T.C (2001). Preliminary Investigation of energy Conservation potential in the copper-nickel mining Industry in Botswana. MSC Thesis. University of Strathclyde. Glasgow p22-32.
- 19 Jerrold Krenz .H. (1980). Energy conversion and Utilization. Second edition. University of Colorado, Alyn and Bacon, Inc. USA.
- 20 Directorate (2006): Energy Planning and Development. Digest of South African energy statistics. DME RSA.

- 21 Sustainability. Sustainability reports site map.
<http://www.goldfields.co.za/site-map.asp-565>. Cited November 19, 2007.
- 22 Gold and Diamonds. Us library of congress. [http://www.countrystudies.US/South Africa? 66.htm](http://www.countrystudies.US/South%20Africa?66.htm) – 14K. Cited March 2007.
- 23 South Africa physical settings-Maps, climate, Natural resources.
<http://www.photinus.com/countries/South-Africa/geography>. Dec 2007
- 24 Exploring Africa.
[http://www.exploringafrica.matrix.msu. edu/students/curriculum/m20 – activity.2hp](http://www.exploringafrica.matrix.msu.edu/students/curriculum/m20-activity.2hp).
- 25 Creamer Terence. (2006). Formidable investment Plan. Engineering News Vol 26 N^o 10 March 24 – 30.
- 26 Eskom News. Energy consumption reduction challenges.
[Http://www.eskom.co.za/live/content.php?item_ID=880](http://www.eskom.co.za/live/content.php?item_ID=880).
- 27 Global info mine. [http://www.infomine.com/sarch link. Mining ules.asp?](http://www.infomine.com/sarchlink/Miningules.asp?)
- 28 An Mbendi profile. South Africa Mining: Platinum Group Element mining. <http://www.mbendi.co.za/indy/mining/plat/af/sa/p0005.htm>. 2006.
- 29 World energy Council. (2004). Survey of energy Resources. 20th edition. Elsevier. London. UK
- 30 Eskom holdings limited Annual Report 2005/2006.
- 31 Limuh, B. (2002). 'Delivered Energy consumption by industry'. Annual report.
<http://www.eia.doe.gov/oiaf/analysispaper/industry/consumption.html>
- 32 Madlala Olie. (2006). Platinum supply forecast to rise. Mining weekly Vol 27 N^o 4. P-10.
- 33 Mining Energy Analysis. Mining Industry of the future (2004). US Department of Energy. Energy Efficiency and Renewable energy.
- 34 Duncan .W and Ivan, Adams. Review of Security of Supply in South Africa. A report to the Department of Public enterprise. July 2008.
- 35 Energy Issues – Demand. Chevron – will you joinus.com. Discussion of energy issues. [http://www.willyoujoinus.com/issues/demand.July 2007](http://www.willyoujoinus.com/issues/demand.July%2007).
- 36 Vander Merwe Chrity. SA mines production skill halted. Mining weekly on line. [http://www.miningweekly.co .za/article.php/](http://www.miningweekly.co.za/article.php/) Cited December 2007.
- 37 World Bank .(2003). African development Indicators. Washington D.C p: 246- 247.
- 38 An Mbendi profile, South Africa Mining: gold mining – overview.
<http://www.mbendi.co.za/indy/mining/gold/af/sa/p0005>. August, 2007
- 39 Integrated energy Solutions Meeting Global.
[http://www.worldenergy.org/wec-geis/publications/default/tech- pap](http://www.worldenergy.org/wec-geis/publications/default/tech-pap). Cited August 14, 2007.
- 40 South Africa year book 2004/05.
- 41 ESKOM CER 1999 sustainability future planning.
[http://www.eskom.co.za/enviro report99/future.htm](http://www.eskom.co.za/enviro_report99/future.htm)
- 42 Long term world oilsupply. <http://www.eia.doe.gov/pub/oil->

- gas/petroleum/features.articles/2004/world.
- 43 Diesel Emissions evaluation for Mining Industry.
<http://www.smartimes.com/diesel Em.html>.
 - 44 Aimee Mc Kane, Lawrence Berkeley. (2007). Management Standards to stimulate persistent application of Energy Efficiency in Industry, Vienna, Austria.
 - 45 Mining Industry of the future . (2004). US Department of Energy. Mining energy analysis'. January 27, 2004, Southern Africa Using Energy Development community protocol on energy.
 - 46 History of oil use. (February 2004). Overview.
<http://www.by design.com/fossils fuels/links/html/oil-history.html> – 9k. March 2007.
 - 47 Howells MI (2006). The targeting of industrial energy audits for DSM Planning. Journal of energy in Southern Africa. Vol 17, N^o1. Energy Research Centre, University of Cape Town.
 - 48 Olivier Mariaan. (2006). Powerful 2012 promise. Engineering News vol 26 N^o 410. 16 Feb p.52.
 - 49 An Mbendi profile; south Africa mining platinum group element mining overview. <http://www.mbendi.co.za/indy/minng/plat/of/sa/p000.htm>. August, 2007
 - 50 Wendy Poulton Energy and Climate change. Eskom corporate sustainability 2002.
 - 51 Directorate: mineral economics. (2006). Operating gold mines and recovery plants in the Republic of South Africa. DME SA.
 - 52 Anglo Gold Ashanti Ltd. Company description. Performance review.
<http://www.anglogold.co.za/subwebs/information for investors/annual report05/report. august24>, 2006
 - 53 Herzog, Thomas, N. (2007). Data quality and record linkage techniques. Data and methodology for calculating energy consumption Estimates. USA
 - 54 Davenport Jade. (2006). World's biggest platinum mines. Anglo Platinum mine development. Mining weekly Dec 2005 – Jan 2006.
 - 56 Reis. A. Smith. I, Peube. JL, Stephan. K. (1985). Energy Economics and Management in Industry vol1,2. Pergamum press. UK.
 - 57 Anglo Gold Ashanti. News release. Market watch. [Http://www.anglogold Ashanti.com](http://www.anglogold Ashanti.com). July31, 2007.
 - 58 Brian .U. (2002). Delivered Energy Consumption projection by industry in the annual energy Outlook .
<http://www.eia.doc.gov/oiaf/analysispaper/industry/figure.html>. October 2007
 - 59 Chamber of mines of south Africa: Our organization.
<http://www.bullion.org.za/bulza/choorg/info1.htm>. November 2007
 - 60 Department of minerals and energy. Overview of the minerals ndustries.
<http://www. Dme.gov.za/pdfs/aboutdme/dme/520as.pdf>.september 2007.
 - 61 Diamonds, Gold and south Africa.

- <http://www.geology.ucdavis.edu/~cowen/~gel115/115chdiamonds.html> -22k.
March 2007.
- 62 Creamer medias minweekly on line, South Africa. Mining news.
<http://www.miningweekly.co.za/min/ms/today's/show=90612>.
 - 63 SEPCO Document: Bacground to the Energy sector.
<http://www.lses.org/Sepco> new/pages/country case study Sa/html.
 - 64 South Africa country Analysis Brief January 2005.
<http://www.eia.doe.gov/emeu/cabs/safrica.html>.
 - 65 Business Report. Power cuts shave ounces off simmer's load.
<http://www.busrep.co.za/indfex-php?farticle> ID=4227402, February 2008
 - 66 Oxford English Dictionnary. Second edition. Volume 16. Clarerdom
Press Oxford.
 - 67 Raymond, J. Jessen. (1978). Statistical Survey Techniques. Copyright
by john wiley.N.Y. United States of America.
 - 68 Rudenno, V. (2004). The mining valuation Handbook Second edition
Published, Australia, p110-166.
 - 69 SA Minerals Data. Historical charts. <http://www.kitco.com>. Cited January
2008.
 - 69 Second International Conference on Sustainability. Engineering &
science. Auckland. New Zealand. February20-23, 2007.
 - 70 South Africa. Bureau of African affairs Oct 2006. US Department of
State. <http://www.State.gov/r/pa/ei/bg/2898.htm>.
 - 71 South Africa economy overview. <http://www.south Africa.info/doing>
business/economy/economy/econoverview.htm. Cited December 2007.
 - 72 South African's mineral industry general review (2005)
<http://www.dme.gov.za/publications/annual reports/sai.2005>
 - 73 CIA, The world fact Book, <http://www.cia.gov/ce/publication 2006>
 - 74 South Africa, wikipedidia, the free encyclopedia.
<http://www.en.wikipedia.org/wiki/south africa 2006>
 - 75 US geological survey, Mineral commodity summaries, January 2006.

7 APPENDICES

Appendix: A

Energy Measures and Conversion factors

According to The World Energy Council (WEC) terms reconciliation⁶⁵, the following terms are used to convert energy and get energy equivalents.

1 – Basic Energy Units

1 joule (J) = 0.2388 calories (cal) and 1 cal = 4.1868 J

1 British thermal unit (Btu) = 1.055 kJ = 0.252 kcal

2 - WEC Standards Energy Units

1 tonne of oil equivalent (toe) = 42 GJ (net calorific value) = 10034 Mega cal

1 tonne of coal equivalent (toe) = 29.3 GJ (net calorific value = 7000 M cal

NB: the tonne of oil equivalent currently employed by the international Energy

Agency and the United Nations Statistics Division is defined as 10^7 K calories.

3 – Volumetric Equivalents

1 barrel = 42 US gallons = ~ 159 litres

1 cubic metre = 35.315 cubic feet = 6.2898 barrels

4 – Electricity

1 kWh of electricity output = 3.6 MJ = ` 860 kcal

5 – Representative average conversion factors

1 tonne of crude oil = ~ 7.3 barrels

1 tonne of natural gas liquids = 45 GJ (net calorific value standard cubic meters of
natural gas = 36 GJ (net calorific value

APPENDIX B: Survey sample answers

APPENDIX C: Compiled energy consumption and costs figures

