# PRELIMINARY INVESTIGATION OF ENERGY CONSERVATION POTENTIAL IN THE COPPER-NICKEL MINING INDUSTRY IN BOTSWANA

MATSHAMEKO T.C.

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Department of Mechanical Engineering

Energy Systems Division

University Of Strathclyde

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Author: Matshameko Thuso Cyril

Supervisor: Lori B. McElroy

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Finally, I dedicate this thesis to my family, more specially my wife for the marvellous support and encouragement they gave me during my stay in the City of Glasgow

## Abstract

In the twenty-seven years since the first oil in 1974,crisis there have been a number of studies of industrial energy use and the potential for energy conservation in industry. A good number of these studies were undertaken in developed countries such as the United Kingdom and have resulted in significant improvement in the efficient use of energy. The developing countries are still in the process of gaining momentum in this field and are learning from the experiences of the industrialised nations. Typically, such energy studies address a number of inter-related issues such as:

- how is energy used by industry?
- how much energy could be conserved?
- what factors influence the adoption of energy conservation measures?

However, significant efforts are required in order to improve the uptake of energy saving measures.

The profile of Botswana's energy supply is similar to most developing countries, particularly the Sub-Saharan countries. The energy supply is dominated by fuelwood, which contributes 58% to the total primary energy supplied. It is followed by coal at 23.1%, petroleum at 18.5 %, electricity at 0.5 % and solar energy, which contributes insignificantly compared to other sources. Fuelwood is mainly consumed in the residential sector, especially in rural areas, where the majority of the population resides and the degree of commercialisation is very low.

This report aims to investigate the potential of energy conservation opportunities in a copper–nickel mining industry in Botswana. The main objective of the investigation is to identify the most energy intensive areas of the mine and suggest measures which can be implemented to conserve energy or reduce energy consumption particularly electricity.

The first chapter gives a general overview on energy conservation strides in industrialised and developing countries with particular emphasis on benefits that are derived on embarking on energy conservation projects. It also states some barriers that need to be tackled before energy conservation can be fully accepted in many institutions.

The second chapter gives general background information on Botswana such as the physical features, population and the economy. It also highlights the current situation on Botswana's energy sector and the energy resources available within the country. The chapter also outlines the trend of electricity consumption by the mining sector.

The third chapter gives a general background of the area of study Bamangwato Concession Limited and its mining operations.

The fourth chapter is about energy management principles and also gives the current situation of energy management at Bamangwato Concession Limited. In this chapter a proposal on how the mine should set up an energy management structure is also presented.

The fifth chapter deals with the analyses of energy consumption data particularly coal and electricity through a set of logical steps viz:

Step I identifies the quantity and cost of various energy forms used in the plant.

Step II identifies energy consumption at the department and/or process level

Step III relates energy input to production (output) or cost thereby highlighting wastage in major equipment /process and how energy intensive is each process.

Through the analyses it emerged that electricity consumption seemed to be the main components of energy cost the mine.

In chapter six, discussions of the results are presented and conclusions are made in order to select the most energy intensive areas of the mine. As a result two potential areas for energy conservation were identified; the smelting process and non-process (offices and workshops).

Consequently, chapter seven presents some recommendations on measures that could be employed in order to reduce the consumption of electricity in the mine.

Finally, conclusions and the way forward on how best to implement energy conservation measures at the mine are suggested.

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## Abbreviations

1. BCL - Bamangwato Concession Limited

2. BPC - Botswana Power Corporation

3. BEMP – Botswana Energy Master Plan

4. E.A.D – Energy Affairs Division

5. IEA - International Energy Agency

6. NDP – National Development Plan

7.CSO - Central Statistics Office - Botswana

## Exchange rate used

Pound (£) to Pula (P)

$1 \approx 8$

1Pula = 100 thebe

## 1.0 Literature Review on Energy Conservation

The energy crisis of the 1970s, which came as a result of drastic cut in oil exports mainly from the Middle –East and the fact that all oil –exporting nations raised prices, led governments and industries to initiate policies emphasizing energy conservation with the aim of making significant contribution towards achieving national energy objectives.

Energy is the driving force behind all industrial operations because as industrialisation grows, energy consumption levels are growing exponentially, placing tremendous pressure on natural resources and the environment [/2/.] Conservation of energy is seen as a critical priority, both in terms of conserving the scarce resources, and also in terms of the consequent financial savings generated. The goal of energy conservation should be to reduce the polluting effects of fossil energy consumption and in addition to conserve these scarce energy resources.

Most countries have already done a lot of work regarding the management of energy conservation and the development of energy-saving technologies. However, with the global shift towards a market-driven economy, the existing energy conservation management system and policies need to be continual improved in order to accommodate changes associated with the global shift [/4/.] There is need for a new system for planning energy conservation and for managing energy demand under a market economy. Energy conservation should be carried out through out the entire process of production, processing and utilisation.

Industrial production processes often show a high specific energy demand. Industry is estimated to account for between 25% and 35 % of the global final energy consumption [/4/].

The industrialised countries dominate energy use in the industrial sector, which account for about 45 % of the world's industrial energy use whereas the developing countries account for 32 % and those of economies in transition account for 23 %. The most energy intensive industrial sub-sectors include iron & steel, chemicals, petroleum refining, pulp and paper and cement production. All these account for 45% of global industrial energy consumption [/11/].

Although great progress has been made in the rational use of energy in the industrial sector during the last two decades, improvements in cost-effective energy utilisation still have a long way to go [/1/]. This holds true for new plants as well as for existing industrial plants. Certainly, improvements in energy end-use efficiency offer the largest opportunity of all alternatives for meeting requirements of global world economy as the energy that would have been wasted could be used to meet other demands.

Ever since the industrial revolution global energy production and consumption has been on the rising. This puts some constraints on the depleting fossil fuel reserves and causes growing environmental concerns. Thus numerous calls from the Kyoto Protocol and the Rio declaration for stringent review of the present energy systems and energy sector development policies have been initiated. Energy production and use has environmental impacts at different levels, local, regional and global. Locally, in terms of air, water and land pollution and urban smog; regionally because of oil spills in national and international waters; globally due to greenhouse gases emissions and land and sea pollution effects [/12/].

In order to promote energy conservation or efficient us of energy in industries, three different steps must be taken into account:

- Efficient site management of energy efficiency through maintenance and house-keeping measures which involves no or only very minimal investment.
- Replacement or modification of selected equipment and /or systems, which may require medium size investment.
- Modification or replacement of entire manufacturing processes which may require large-scale investment.

Several recent studies conducted on the technical potential of energy efficiency improvements in some of the most energy intensive sub-sectors concluded that energy savings of up to 30, 40 or even 50% are technically possible in many areas [/2/].

Energy conservation is a low political priority as economic and political priorities take precedence. It is not central to the mission of the state agencies. Despite numerous efforts by organisations such as the Commonwealth, International Energy Agency (IEA) and the United Nations on energy conservation, there are still a lot of countries and industries, which are lagging behind.

Energy conservation could however, provide a cheap, quick and relatively painless way for most of developing countries to stretch energy supplies, slash energy costs, and save on foreign exchange. Also energy conservation could help to alleviate both the ever-increasing shortage of power supply in many countries and the associated problem of capital costs of building new generating capacity and other energy production and transformation units.

In situations where capital is not available experience has shown that technically proven, cost-effective energy conservation and efficiency measures can save developing countries an estimated 10 to 30% of their energy consumption [/3/]. However, it is important that energy conservation and new alternative energy forms can present opportunities and should not be regarded as a negative option.
Rather efforts should be aimed at increasing the efficiency of energy use e.g. through waste reduction. By producing more output with the same energy cost input, or reducing the energy costs of existing output it can be shown that energy conservation promotes economic efficiency and improves productivity and competitiveness of energy consuming enterprises.
In addition, by decreasing energy use, energy conservation and efficiency reduces energy production requirements, which mitigates the associated negative environmental impacts of energy resources exploration, development and production. This also reduces the atmospheric emissions from fossil fuel electric power plants and industrial facilities. The industrial sector accounts for some 41% of global primary energy demand and approximately the same share of $CO_2$ emissions [/10/] . Greenhouse gases emissions can be substantially cut in this sector through policies and initiatives that stimulate market transformation and new technologies. Thus it can be said that energy conservation promotes sustainable and environmentally sound economic growth and development.
In recent years, a number of developing countries have initiated policies and programmes to promote energy conservation and efficiency often with financial and technical assistance from international donors and lending institutions.

However, the general observation of the international donor community and many developing countries themselves has been that despite these recent efforts and tremendous benefits of energy conservation, only a fraction of the energy conservation potential in developing countries has been captured, especially for the projects that require significant investments [10]. This "inertia " is thought to be the result of numerous technical, economic, financial and institutional and policy barriers which affect the ability and willingness of energy users to make energy conservation investments.

Studies on incentives for energy conservation reveal that there have been no quantitative analyses of the barriers to energy conservation.

Energy conservation can be achieved through technological innovation, attitudinal and behavioural changes viz:

- **Technological innovation**: - focus on finding technical answers to the problem of reducing the energy requirements of energy consuming goods and processes. However, changes or savings do not occur overnight.
- **Attitudinal or behavioural changes** from a conservation ethic can produce more immediate energy savings. Developing a conservation consciousness and adjusting to energy saving attitudinal changes may initially impose some minor inconvenience, but this is a small price to pay for the substantial energy savings and economic benefits that would accrue from those efforts.

Energy conservation offers one of the best opportunities for industry to contribute to the mitigation of the overall energy dilemma and offers a positive approach for countering rising energy costs, as a means for reducing energy waste and the increased efficiency of energy utilisation.

Many of the ways in which energy is presently used to satisfy the needs of society are not particularly effective. Large quantities of energy are allowed to “leak” out of industrial sectors and available techniques for utilisation reject heat and waste heat in energy consuming process are seldom applied.

Faced with a shortage of non-polluting fuels and with the recognition that most fuels types are non-renewable resources, it is appropriate to give serious attention to improving the effectiveness with which energy is used, as well as to improving the national capacity to supply energy.

If energy utilisation is not improved, we would require the development of additional energy supply capacity with all of its economic and environmental implications. Thus, improving the effectiveness of energy utilisation is seen to be necessary both as a measure for conservation and as a measure for economic optimisation of investment in energy. The implementation of technological improvements in energy consuming process would require or would be greatly facilitated by appropriate price, tax, loan and regulatory policies, especially as these pertain to new industrial plant equipment [13].

## 1.1 The need for energy conservation

Few countries have all the energy resources they need within their own borders. Most countries have to rely on imports. Hence, energy conservation coupled with greater use of indigenous fuels can reduce dependence on imports. In some cases energy conservation can free up domestic energy supplies allowing greater availability of indigenous fuels for export. These are key issues for developing countries with high levels of international debts

Nevertheless, some countries especially in the developing world are successfully improving efficiency in order to raise productivity and ultimately improve upon their economic performances. Conservation of energy is needed to eliminate waste due to current high-energy consumption levels and in some cases to reduce the steeply rising demand for energy associated with rapid growth. For example in the United Kingdom, while fuel use in the industrial sector has dropped dramatically since 1970, industrial output has increased by 46% between 1970 and 1996, resulting in a considerable reduction in the energy intensity of the industry. In 1996 it required almost 60% less energy to produce each unit of output than in 1970. This has been brought about by changes in the structure of the industry, with a decline in the most energy intensive industries, and an increase in the efficiency of energy use. Fuel switching will also have had an impact. It is estimated that 15% of the fall is accounted for by structural change (i.e. the effect on energy consumption of changes in the relative importance of different industrial sectors), and the remainder (85%) by higher efficiency. [FS04 Key Trends in UK Industrial Sector Energy Use]

While the energy to be saved through increased energy conservation and fuel substitution is greatest in developed economies due to their high levels of energy consumption, the energy importing developing countries can also benefit significantly since increased efficiency of energy use would lower their overall energy requirements and thus reduce their energy bills.

Not only does energy conservation reduce energy bills but also it helps improve countries' economic performances and also provides environmental benefits such as the reduction of carbon dioxide and sulphur emissions, thus contributing to the global environmental concerns.

## 2.0 <u>Background Information on Botswana</u>

### 2.1 The Physical Features

Botswana is a southern African country, which is landlocked and straddles the Tropic of Capricorn in the centre of the Southern African Plateau. Its total land area is 582,000 $km^2$ and the country has a mean elevation of about 1,000-m above sea level. The mean annual rainfall ranges from 650 mm in the northern region to less than 250 mm in the southwestern region. The daily mean temperature varies between 22 °C in July and 33 °C in January, with minimum temperatures of 5 °C in July and 19 °C in January. The country is blessed with abundant sunshine hours ranging from 3000 to 3500 hours/year.

### 2.2 The Population

Botswana has a population of about 1.6 million (1999 estimated figure) and has a growth rate of 3.5%. The population *grew* from 574,000 in 1971 to 1,327,000 in 1991(CSO, 1993). The demographic setting of the country is such that 80% of the population is confined in the eastern region running along the railway line and about 20% in the countryside. This scenario creates a localised high population density of about 10 people per $km^2$ compared to the national average density of 2 people per $km^2$ (UNEP/RISO, 1995).

### 2.3 The Economy

The country exhibits an economy in transition in that at independence in 1966, the total GDP was US$6.13 million as opposed to US$ 988.15 million in 1997/8. The transformation is reflected by the change in the dominant sectors, in that at independence the economic drivers were the agricultural and services sectors whilst it is now powered by the mining sector.

Mining contributed 0% to the GDP at independence but now excels at 33% of the total GDP in 1995/6. Diamond is the single engine for economic growth and development and accounted for 39.3% of GDP and for 78% of the total export earnings in 1992 (CSO, 1993). Copper-nickel matte was the second export earner until 1994/5 when vehicles replaced it as second major export commodity.

## 2.4 Brief Description of Botswana's Energy Sector

The broad energy policy objectives and guiding principles as outlined in the National Development Plan 8 of the Republic of Botswana with regard to economic efficiency and environment are such that;

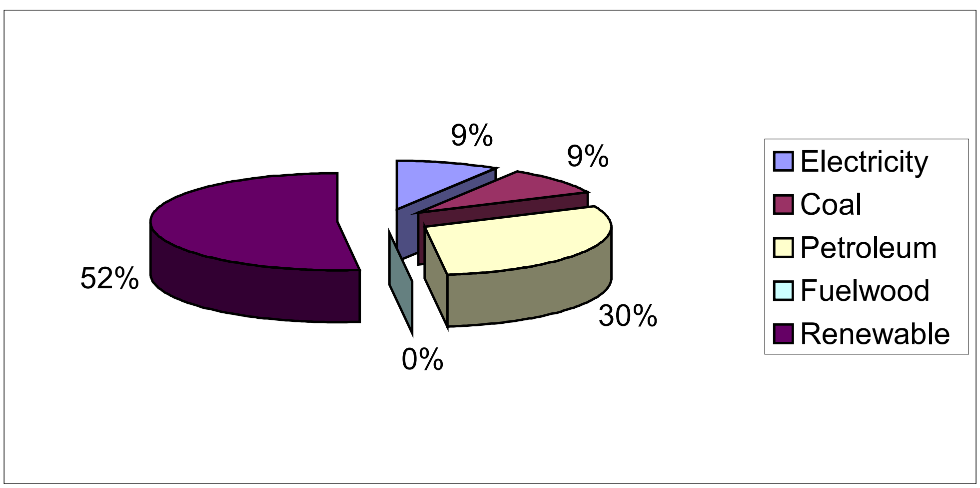
- energy services be supplied at least cost to the economy
- energy supply industry should be financially sustainable
- energy should be used efficiently
- energy extraction, production, transportation and use should not damage the environment or peoples health

These broad objectives have been re-emphasised by the Vision 2016, which attributes energy as a prerequisite to successful industrialisation. The Vision thereby encourages Botswana to develop cost-effective sources of energy and to co-operate with its neighbours to benefit from the economies of scale in electricity generation and supply.

The locally available energy resources are coal, biomass (fuel wood), wind and solar energy, with grid electricity being obtained from the coal resource. Other energy sources, primarily petroleum products and some electricity, are imported from the neighbouring countries. Solar irradiation within the country is on the average 24 $MJ/m^2$-day which is among the highest in the world and the government currently has National programmes in place to tap this rich resource. Wind energy and biogas resource assessment is currently in progress although both resources have been in use in Botswana for over two decades. Wind energy has been in use at small-scale level mainly for water pumping.

The coal-measured deposits stand at 7.2 billion metric tonnes and the only operational mine, the Morupule Colliery, is currently exploiting the resources at a low rate of 900,000 tonnes per annum. The coal is mainly used for power generation (70%) and industrial applications such as copper/nickel smelting, soda ash processing, and the meat processing and textile industries. The coal is classified as semi bituminous of a medium ranking quality (24.5 MJ/kg heating content). The urban poor and the rural populace mainly use fuel-wood. The fuel-wood accounted for 57.4% and 69.3% of primary and net energy respectively, supplied for the year 1995/6 (Energy Statistics, 1995/6). Together with the increasing population of the rural community, the use of this resource has resulted in a lot of pressure on the woodlands. Evidence of woodland depletion in some areas is significant and has raised a number of concerns from various quarters.

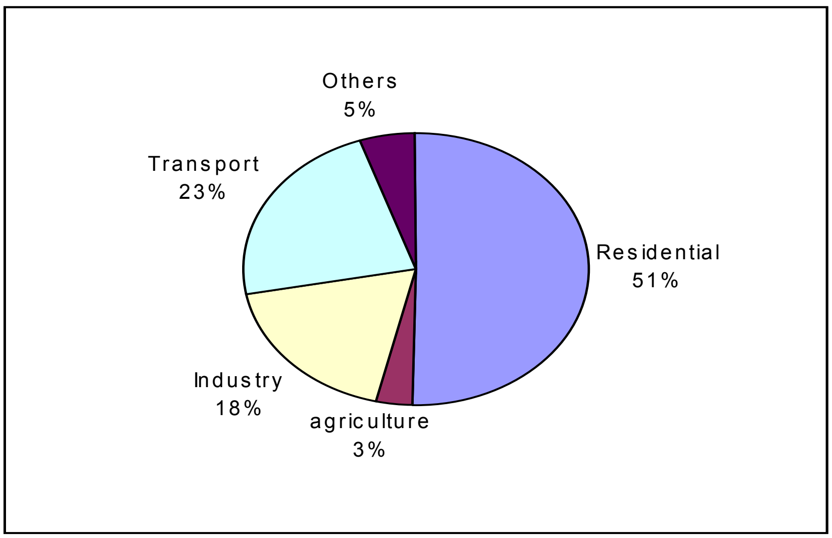
Figure 1 shows the percentage share of the various energy sources.




Source: Botswana National Development Plan 8

Typically, as shown in figure 2, in Botswana the residential or domestic sector has the largest share of energy consumption. Most residential areas use fuelwood as their main source of energy and in some cases liquid petroleum gas for cooking purposes. The industrial sector is the second largest energy users mainly in the form of coal and electricity. The residential sector accounts for 51 % of the national energy use whereas industry and transport accounts for 18 % and 23 % respectively.

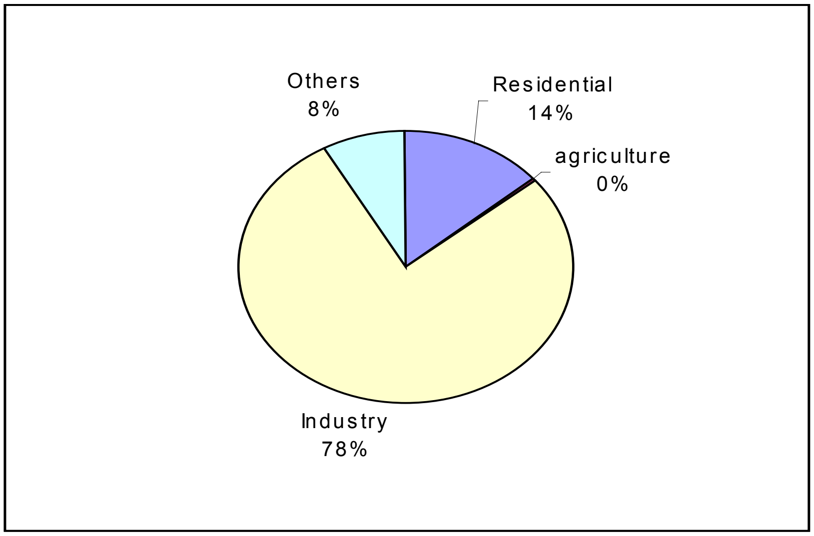
Figure 2. Shows energy consumption by sector in Botswana -1998




Source: CSO - Botswana

However, the when it comes to electricity consumption the industry accounts for almost 80 % of all the energy used as compared to only 14 % of domestic use as shown in figure3. Only less than 20 % of households in Botswana have got access to electricity.

Figure 3. Electricity use by sector in Botswana –1998




Source: CSO - Botswana

Unlike Botswana ‘s scenario, industrial energy consumption in 1998 accounted for 26 % of all primary energy in the UK. Gas made up 41% of all energy used in industry and is the most important fuel for the majority of industries, although coke is the main fuel used in the iron and steel sub-sector. Electricity made up 14% of energy used, solid fuel 32% and oil 12%. (FS04 Key Trends in UK Industrial)

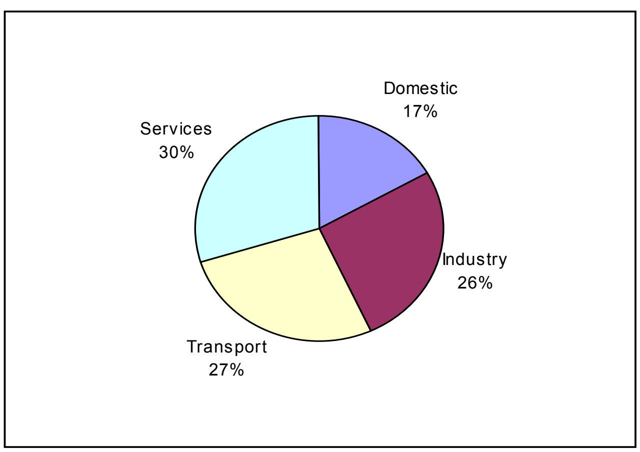
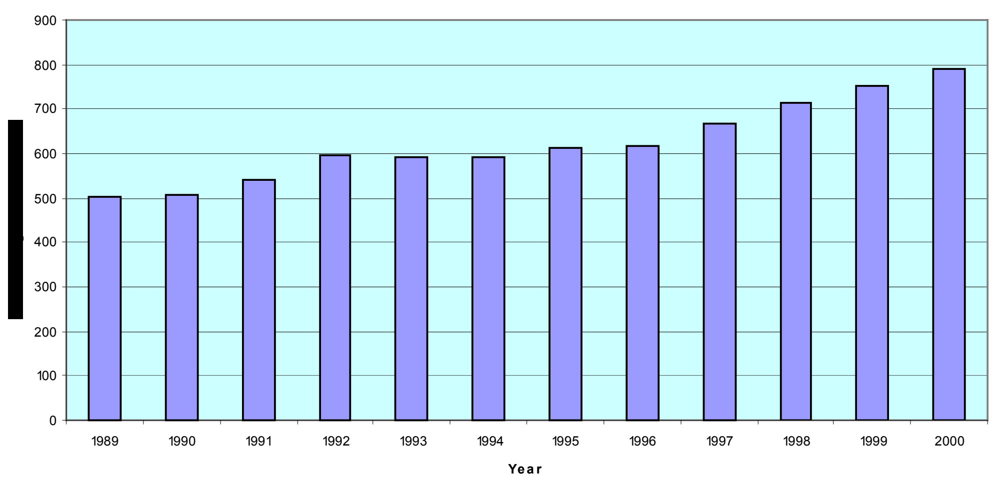



Figure 4. Energy consumption in UK- 1998 Statistics

The industry, commerce, transport and agriculture sub-sectors account for more than 85% of the non-fuelwood energy consumed in Botswana. Industry, mainly mining consumes 40% of non-fuelwood energy in proportion of 50% coal, 30% electricity and 20% diesel. The diamond mines and Bamangwato Concession Limited (BCL) – the Copper mine take up 85% of industrial energy use. Together they use nearly 50% of the national electricity, with BCL accounting for 30%. Electricity consumption in the industrial sector has been steadily growing with an estimated average annual increase of 4 % since 1989 up to the year 2000 as shown in figure2.

Figure 5. Shows the trend of electricity consumption by the industry

**Trend of electricity consumption in the industrial secor**




Source: Botswana Power Corporation – Annual Report 2000

Given the above scenario of the ever-increasing demand of energy, the government through its National Development Plan 8 has called for Integrated Energy Policy and Planning mechanisms, which will be formulated to address the usage, conservation and development of energy sources.

Improving energy efficiency and encouraging energy conservation could be cost effective and lead to deferment in investments in new generating plants. A summary of NDP 8 on energy issue is provided in App. 1.

The government will therefore encourage energy efficiency and conservation measures in all sectors of the economy through implementation of energy audits in energy intensive industries, thermal efficiency in buildings both at design and operational level, transport efficiency, provision of incentives and control in the use of energy.

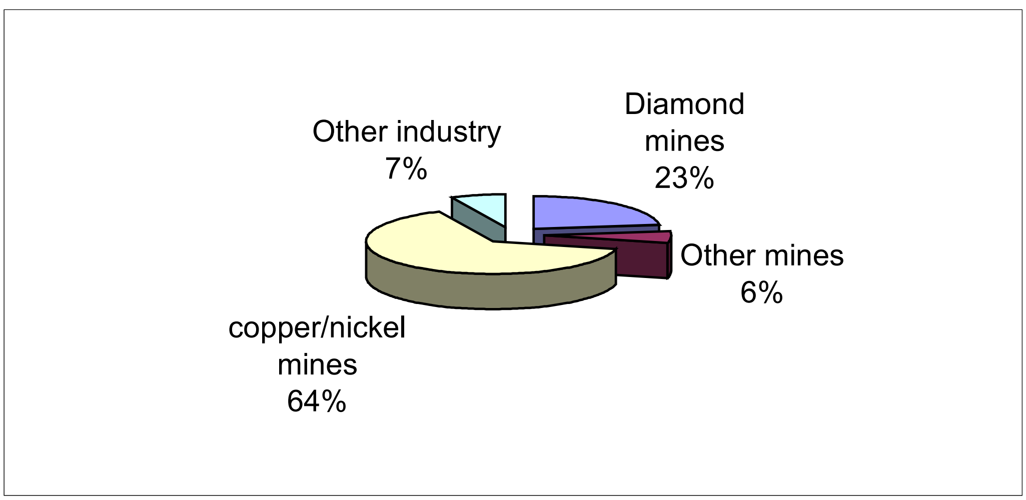
Thus, this report is a build up towards achieving the objective of improving energy conservation in industry in general.

## 2.5 The Country's Power Sector and Mining Industry

Currently, Botswana's electrical energy requirements are being met by local generation by the power utility - Botswana Power Corporation through a total installed capacity of 132MW at Morupule Power Station; isolated diesel generators; self-generation. About 40% *(1999/2000)* of electrical energy demand is met by imports, though by 2001 the electricity import percentage has now significantly increased to about 50% of the total consumption.

The principal end-user of electrical energy is the mining industry, which account for over 80% of the industrial sector's final energy demand. The copper-nickel smelting mine, the Bamangwato Concession Limited is the most energy intensive of the mining/industrial sector as indicated in Figure 3 and hence the decision to focus this study on assessing its energy consumption patterns in a bid to identify energy conservation potential.

Figure 6. Shows the share of mines in the final energy consumption pattern by industrial sector




Source: Botswana National Development Plan 8

## 3.0 Introduction to Bamangwato Concession Limited

The BCL limited is a jointly venture owned by the Botswana government and the Anglo American Corporation at a 51/49 percent market share. After prospecting activities, which commenced in the late 1950's, the ore deposits were discovered in 1962 and the mine started operation in 1973. The company had a staff of 4792 employees in 1999 of which locals constitute 97% [/8/].

The company operates three underground mines, and the extracted ore is fed to the on-site concentrator, then dried and smelted. The matte produced is of high-grade quality and it is exported for separation and refining. The mine, situated at the Selebi Phikwe town, is the main economic activity in the area and it is thus key in keeping the town alive and government's efforts in this regard has been enormous, especially during the unfavourable times when the worldwide copper/nickel prices are at the lowest. The company produced 271,373 tonnes of metal in matte for the year ending December 1999 [/9/]. This figure represented 5.75 % of the world copper –nickel production which is quite substantial for a small country like Botswana. BCL exports most of it copper-nickel matte output to Falconbridge' refinery in Norway and a small percentage to the Empress refinery in Botswana.

## 3.1 Copper- nickel mining process

The original Outokumpu nickel smelter process is applied in the mine. The Outokumpu flash smelting process combines the conventional operations of roasting, smelting and partial converting into one process. Preheated oxygen-enriched air is used to provide heat in such a manner that additional fuel is not required for the reactions to proceed. Copper concentrate is recovered from the slag and recycled through the smelter. The clean slag is sent for disposal. Heat and dust are recovered from the smelter gases producing dust for recycle to the smelter.

The smelter at BCL has a production capacity of 46,000 tonnes of high-grade matte per year. The concentrate is pumped to atomizer spray drying plants from which the dried concentrate is pneumatically conveyed to the Outokumpu Flash Smelting Furnace. It is fed into the furnace with silica flux, pulverized fuel and recycled boiler dust. Reaction air is steam heated to 250 °C and enriched to 24.5 % oxygen. Slag, tapped continuously from the furnace, is treated in electric arc slag cleaning furnaces. Low-grade matte, tapped intermittently from the furnace, is concentrated to a high-grade matte in Peirce-Smith converters. The waste heat boiler performs two functions. The first one is to cool the dust-laden flue gases before they enter two parallel electrostatic precipitators and the second one is to capture part of the dust load from the gases and return it to the furnace. The draft through the system is provided by induced draft fans down-stream of the electrostatic precipitators. The dust falling out in the precipitators is returned to the furnace and the cleaned gas vented through the stack. There is no acid plant.

## 3.2 Major operational sections of the mine

The process side of the operation is split into three main departments, namely: the mining, the concentrator and the smelter. However, fully-fledged service departments comprising engineering, finance and administration, personnel, loss control, laboratory and medical departments back these departments. Apart from the engineering and laboratory departments, little reference would be made to the service departments within the context of this report.

### 3.2.1 The Mining

The company has three mining areas at Phikwe, Selebi and Selebi North. The typical mining method used is the vertical hoisting shafts, using a certain number of man cage for transportation of personnel and heavy 6-to-12 tonne skips for ore and waste hoisting. The mining method varies from one mine to the next depending on the depth and thickness of the ore body and ground conditions. But generally the methods employed are the cut-and-fill, open stopping with rib pillars and hand jackhammers. Hole blasting is done using pneumatically loaded ammonium nitrate/fuel rich oil mixture inserted by a gelignite rich stick. Detonators ignited using slow burning igniters cord and electric starters are employed. The lump ore deposits are then transported by battery-operated locomotives or steam locomotives to the shafts for haulage to the surface. In an average month, 11000 ore skips are hoisted at Selebi and Phikwe shafts each, with an average of 3.4 and 4.2 tonnes/manshift at the mines respectively.

### 3.2.2 The Concentrator

From the mines, the ore is stored in a 230 mt capacity bin, and then transported to the primary crusher by means of a 500 mtph apron feeder and a belt conveyor. The primary crusher is in open circuit and consists of a double deck-vibrating screen. A nominal product size of 80-100 mm is allowed and stockpiled in a reclaimable course ore stockpile. Single-stage ball mills of 125 tonnes per hour rate, in close circuit with a 838 mm cyclone, are employed to crush the ore. The slurry is passed through a particulate monitor for measurement of its fineness and coarseness after removal of wood chips and tramp material. The product is then fed into the flotation plant where a total sulphide recovery is done.

### 3.2.3 The Smelter

Before the smelting process, the concentrate is dried by means of Niro Atomiser spray driers. The dried concentrate, blended with the dry silica sand, flue dust at 950$^{o}$C and pulverised coal is then fed into the flash smelting furnace. Pre-heated oxygen rich air at 0.36 ratio $O_2$ is fed on the concentrate mixture for ignition. An on-site oxygen plant of 220 tonnes per day plant has been built to improve upon oxygen enrichment of the furnace. The matte produced is packaged for export and refining. The sand combines with the iron oxides to produce slag for treatment in the electric furnace. Low-grade matte is produced with low percentages of 0.18 and 0.40 nickel and copper respectively.

## 4.0 Energy Management Principles

In order to maximise the benefits derived from implementing energy conservation, an effective energy management should be put in place. The essence of energy management is to enhance the quality of life while simultaneously conserving energy through a reduction in consumption. An energy management plan considers energy usage in all its forms, the impact it has on the environment and, importantly, the costs associated with this use.

Energy management is a logical, planned method of reducing energy use through a variety of initiatives, without causing hardship or inconvenience to staff.

A comprehensive energy management plan should provide clear strategies that will allow any organisation to reduce energy consumption through the formulation of an action plan and nomination of those responsible for agreed actions.

Energy management can be regarded as a combination of both **energy accounting** and **energy auditing**.

### 4.1 Energy Accounting

Energy accounting is a system to record, analyse and report energy consumption and cost on a regular basis. Just as financial accounting is used for the effective management of an organisation, energy accounting is critical to energy management. It can be one of the most cost-effective tools an organisation can use to cut energy costs.

Certainly, before one can manage energy costs, one has to know what they are. Energy accounting provides feedback on how much energy an organisation uses, and how much it costs. It also provides a means to effectively communicate energy data that facility staff, building occupants and managers can use to improve cost management.

Energy accounting will help an organisation to:

(a) Record and attribute energy consumption and costs.

Energy costs depend on the amount consumed and it's price. In an organisation with many facilities, energy accounting makes it possible to compare energy use and cost amongst facilities and to monitor how energy use changes over time. By communicating this information, those responsible for managing energy costs can get feedback on how they are doing.

(b) Troubleshoot energy problems and billing errors.

By consistently tracking energy use, you can identify problems. A sudden unexplained increase in consumption, for instance, means it's time to investigate the cause of the change.

(b) Evaluate energy program success and communicate results.

This helps to find out whether the expected savings were met or not. This gives the basis to reflect on the past performance and allows for further actions to achieve the target savings. The information from the evaluation exercise should be communicated to decision-makers and implementers who were responsible for the activities.

(c) Provide a basis for prioritising energy capital investments.

Facilities or processes which have the highest energy costs can be identified, and consider targeting them for energy retrofits or other energy management efforts.

Finally, energy accounting can help your organisation understand how energy is used and can help motivate people to take actions that can result in significant utility cost savings. However, many organisations do not realise the full benefit of tracking energy consumption and cost. The biggest pitfalls that keep organisations from effectively using energy accounting data are:

- Lack of staff time and commitment in maintaining the system.
- Failure to communicate the results to the right people.

To make the most of energy accounting, it is crucial to allocate sufficient staff time for setting up and maintaining the system, and to develop a system of communication with administrators, facilities staff, and others whose decisions affect energy use.

Energy accounting by itself will not save energy. But when used as a tool of energy management, it can help you make changes in operations or equipment that save energy dollars. Energy accounting can also help in budgeting, allocating resources for capital investment, and verifying the results of all of your energy management activities.

## 4.2 Energy Auditing

Unlike energy accounting, which is basically bookkeeping for energy management, energy auditing can be regarded as a physical inspection of the condition and operation of energy consuming process, industrial plant or a building.

The energy audit orientation would provide positive results in reduction in energy billing for which suitable preventive and cost effective maintenance and quality control programmes are essential, leading to enhanced production and economic utility activities. The type of energy audit to be performed depends on the function type of industry. There can be two stages Energy Audits; Preliminary audit and detailed audit.

### 4.2.1. Preliminary Energy Audit

The scope of this audit is to highlight energy costs and to identify, wastage in major equipment processes it sets priorities for optimising energy consumption. Usually it takes a very short time as compared to a detailed audit.

The methodology for the preliminary energy audit would be divided into three steps.

Step I identifies the quantity and cost of various energy forms used in the plant.

Step II identifies energy consumption at the department and/or process level

Step III relates energy input to production (output) or cost thereby highlighting wastage in major equipment /process and how energy intensive is each process.

These will lead to a set of recommendations and should identify of major areas that would require more in-depth analysis. A preliminary energy audit gives quantitative estimates of cost and savings

### 4.2.2 Detailed Energy Audit

A detailed energy audit goes beyond the quantitative estimates of cost and savings .It involves detailed mass and energy balance of major energy consuming equipment. This covers estimation of energy input for different processes, losses, and collection of past data on production levels and specific energy consumption. It is a comprehensive energy audit action plan to be followed effectively by the industry. The scope of this audit is to formulate a detailed plan on the basis of quantitative and control evaluation, to evolve detailed engineering for options to reduce total energy costs and consumption.

Usually a detailed audit study takes a period of three weeks or more to complete. The methodology mainly depends on the type of plant, size and processes involved.

### 4.2.3 Energy Management Situation at BCL

Generally, the concept of energy conservation and management in industries in Botswana is still at development stage or not existing at all. Henceforth the BCL mining company has not escaped the situation. However, the company does have organised energy data or information especially on electricity and coal as most of the energy data used later in this report was obtained directly from the mine. Interestingly this organised energy data is not put to good use for energy conservation purposes. Given the above scenario, further investigations and the use of the energy management matrix (appendix 3) to determine the mine's organisational approach to energy management has revealed that currently the mine lies at level 1 on the matrix. There is currently no dedication or proper co-ordination of energy management activities. Energy management activities have assigned to one professional as a part time responsibility and there are no clear guidelines on energy policy or action plan.

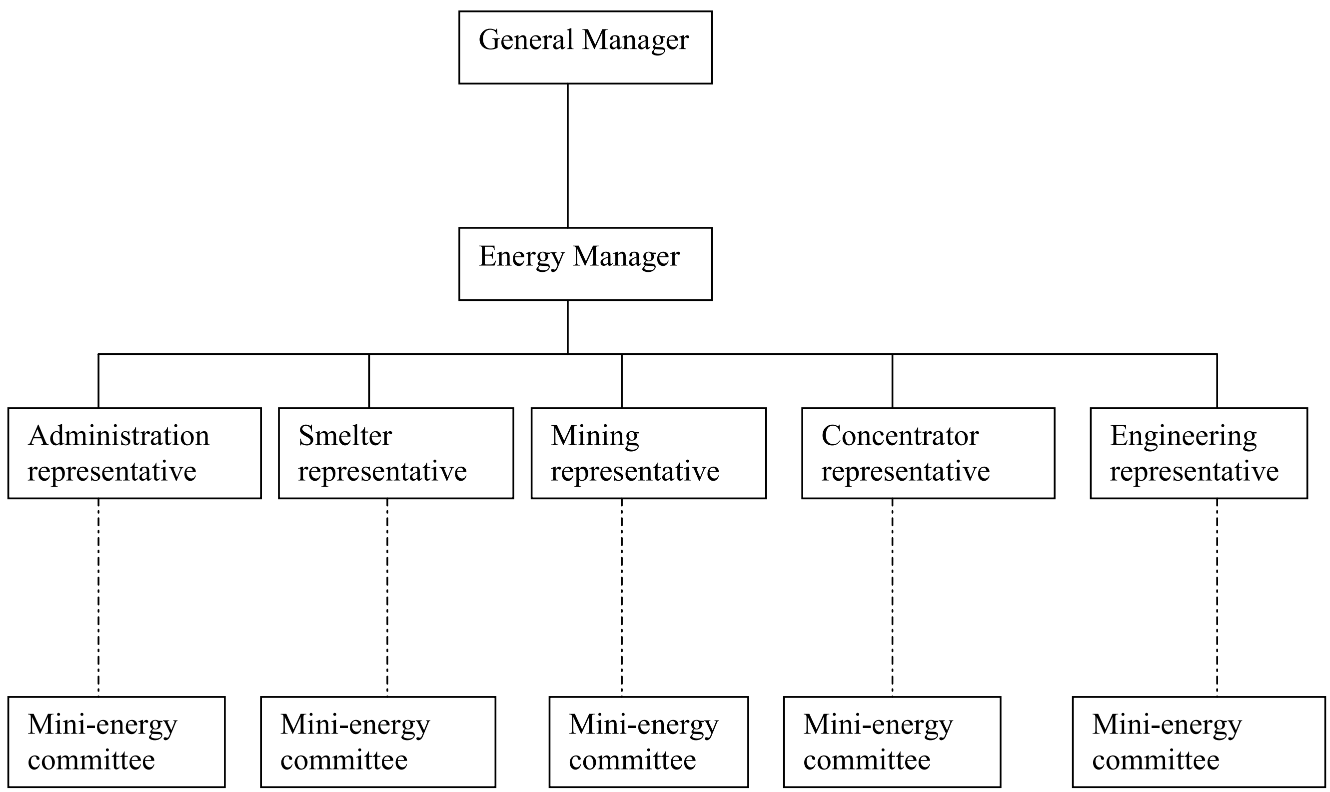
Thus given this situation the BCL mine management should energy management strategies in place before implementing any energy conservation measures. In order to achieve this, the mine must acquire the services of an experienced Energy Manager who would assist in developing a policy on energy management. A detailed summary set up of a proposed energy management structure is presented in the table below.

Table 1.A proposed energy management structure for the mine.

| **Responsible Person** | **Actions** |
|---|---|
| General Manager (Senior Management) | Show commitment through<br>• Appointing an Energy Manager<br>• Making funds available<br>• Energy Committee Member<br>• Providing leadership |
| Energy Manager | • Develops energy management plan<br>• Forms energy committee<br>• Drives the process through;<br>- co-ordinating the process<br>- promoting awareness<br>- compiling reports |
| Technical Staff | • Provide technical expertise in their particular fields<br>• Support the process |
| Energy Committee | • Determine priority plan<br>• Agree on action plan<br>• Provide benchmarking data, technical expertise and advise<br>• Support the Energy Manager<br>• Advise on policy development |

According to the proposed energy management structure presented above at least seven (7) people should sit in the energy committee at the mine. It should consist of the General Manager, the appointed Energy Manager (reporting directly to the General manager), and five others personnel from the following departments – Smelter, Mining, Concentrator, Engineering and Administration. Possibly the individual departments could form mini-energy committees. A proposed organisation hierarchy of the energy committee may be visualised as illustrated below:

Figure 7. Proposed organisation hierarchy for the energy committee



## 5.0 Energy Data Analysis

### 5.1 **Data Collection**

The energy data used in this report was mainly was obtained through gathering previous energy consumption statistics directly form the mine and some supplementary information relating to mine was obtained from other publications such as the Botswana's National Development Plan 8. For these reasons this analysis should be considered as a preliminary energy audit as technical or physical measurements were not carried. It is anticipated that a detailed energy audit would be suggest to the mine management in order to augment the findings on this study. However, the energy data used in this study is regarded reliable as the client supplied it and hence meaningful recommendations could be made.

### 5.2 Methodology

The methodology for the proposed preliminary energy audit is divided into three steps.

**Step I identifies the quantity and cost of various energy forms used in the plant.**

**Step II identifies energy consumption at the department and/or process level**

**Step III relates energy input to production (output) or cost thereby highlighting wastage in major equipment /process and how energy intensive is each process.**

These will lead to a set of recommendations and identification of a major process that require more in depth analysis for the detailed energy audit.

## 5.3 **Energy Use by Fuel Type**

The main types of fuel used by the industry are electricity and coal. Electricity is mainly used in the electric furnace, space heating, general lighting purposes and running electrical drives such as motors which constitutes about 70 % of plant machinery. Pulverised coal is used in the flash smelting furnace. Also oxygen is used during the smelting process for ignition. Diesel is also used mainly in transport but unfortunately its statistical usage is very scanty. However, at present about 800 000 litres of oil is used monthly. Electricity is wholly bought from the grid, that there is no co-generation or self – generation.

## 5.4 **Characteristics of various forms of energy used in the plant**

*Electricity Consumption and cost*

The trend analysis of electricity consumption from 1991 to 2000 shown by figure 4 below indicates that the average annual consumption of electricity has been increasing except for the years 1995 and 1997. The average annual electricity consumption overall increased from 28 841 MWh (1991) to 38 745 MWh in 2000. This represents a total percentage increase of 34%. It is also interesting to note that the electricity maximum demand for the mine has steadily increasing from 45MW to nearly 56MW as shown in table 1.

Following the increase in electricity consumption, the annual cost of electricity has increased from £0.42 million (1991) to £0.65million (2000) indicating an increase of £0.23million or (55% increase in cost of electricity). The discussions for the increase are outlined in section 5.9. The statistics for the annual cost of electricity is shown in figure 5. BCL falls under electricity tariff category 4 (App.2)

Figure 8 Average annual electricity consumption

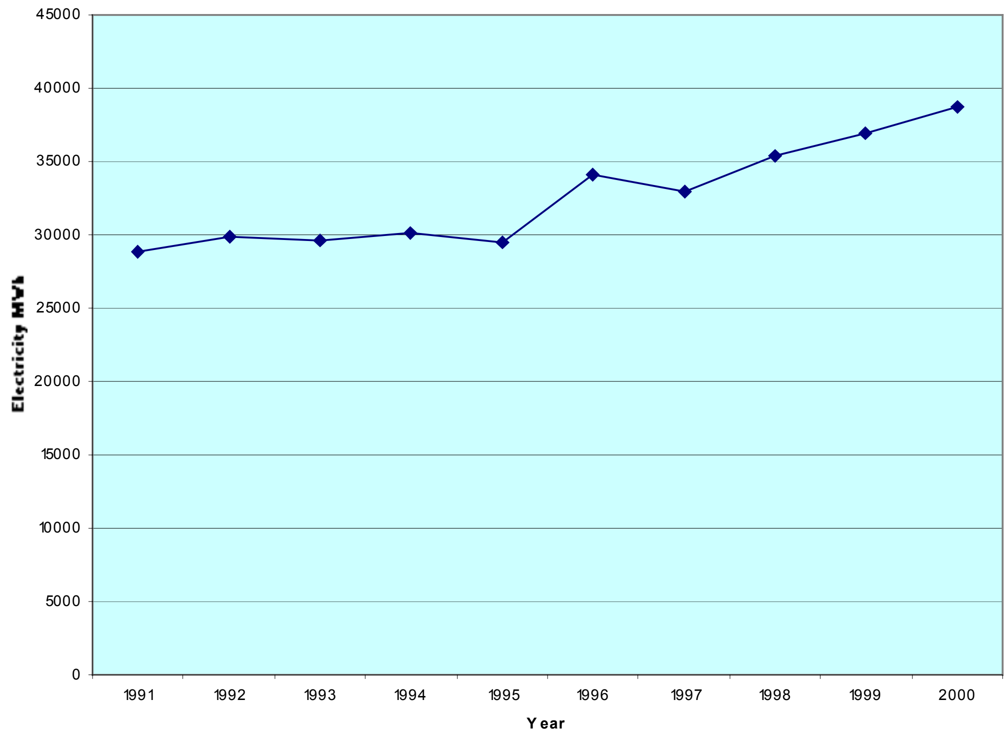



Table 2. Annual maximum demand in MW

| Year | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|
| Maximum Demand | 45 | 46.59 | 46.66 | 47.27 | 46.26 | 48.88 | 49.55 | 53.66 | 54.76 | 55.86 |
| % Variation | - | 3.5 | 0.2 | 1.3 | -2.1 | 5.7 | 1.4 | 8.3 | 2.0 | 2.0 |

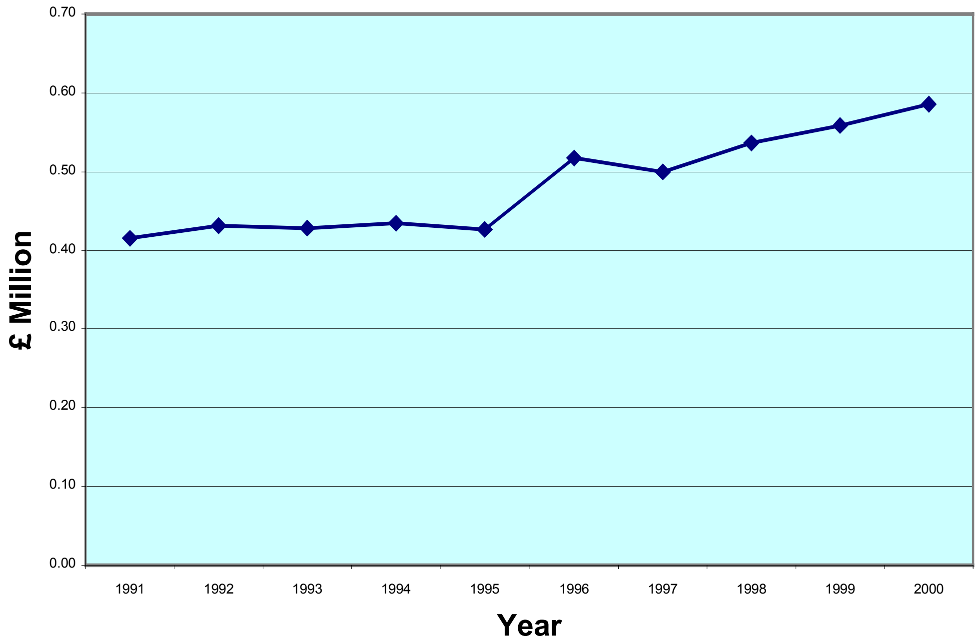



Figure 9: - Annual cost of electricity in Pounds

***Coal usage and cost***

The usage of coal over the period of analysis has been fluctuating at around 12,000 tonnes per year as indicated in figure 10.By comparison annual cost of this fuel was found to have steadily increased from £0.079 million to £ 0.096 million, an increase of 21.5 %.

Annual coal usage and cost

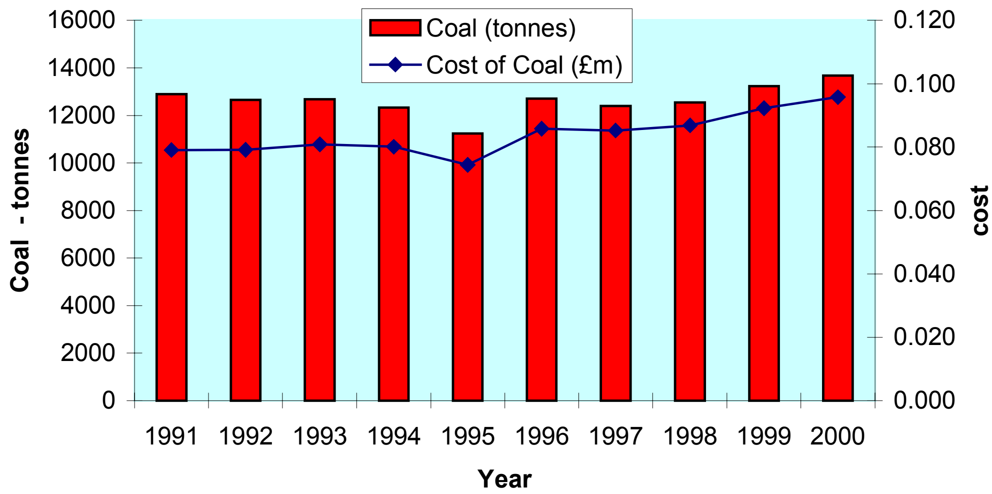



Figure 10: - Annual coal usage and cost

**<u>5.5 Identification of energy consumption at the department and /or process level</u>**

This part of analysis is based on the main departments namely: mining, concentrator, and the smelter, which together constitute the process section. The non-process part is composed of the engineering and administration department. Table 3 below shows the indicative monthly electricity consumption by each department.

| **Department** | **Indicative monthly consumption** | |
|---|---|---|
| **Process** | **MWh** | **%** |
| Smelter | 9602 | 25 |
| Concentrator | 6564 | 17 |
| Mining | 9050 | 23 |
| **Non-process** (Engineering& Administration) | 13450 | 35 |
| **Total** | 38 666 | 100 |

Table 3. Indicative monthly electricity consumption by department

From table 3, it can be seen that the smelter and the non-process use more electricity, at 25% and 35% respectively than any other department or process. Based on the following assumptions:

- Combined Floor area for the non-process is $8000m^2$
- Weather correction factor of 0.92
- Exposure factor of 0.9

A Normalised Performance Indicator (NPI) for annual energy use was estimated to be 1220 kWh / $m^2$ per year. This figure is rather high as compared to typical values of 325 kWh/$m^2$ of related industry such as Paper and Pulp industry. Probably, if the non-process energy component would be split into different uses such as lighting, space heating and a more accurate value of the NPI would be obtained.

**5.6 Relating energy input to production**

| **Year** | **Copper-nickel matte Production (x 000 tonne)** | **Energy Consumption MJ** | **Specific Energy consumption (MJ /tonne)** |
|---|---|---|---|
| 1991 | 39.9 | 103828 | 2.6 |
| 1992 | 39.3 | 107640 | 2.7 |
| 1993 | 41.7 | 106740 | 2.6 |
| 1994 | 41.8 | 108252 | 2.6 |
| 1995 | 38.6 | 106348 | 2.8 |
| 1996 | 48.2 | 122926 | 2.7 |
| 1997 | 42.1 | 118843 | 2.8 |
| 1998 | 37.0 | 127544 | 3.4 |
| 1999 | 44.2 | 132818 | 3 |
| 2000 | 44.1 | 132818 | 3.2 |

Table 4 Energy input related to matte production

The average specific energy consumption for the entire mine is approximately 2.8 MJ/ tonne. However, over the period of analysis, the yearly specific energy requirement increased from 2.6MJ/tonne to 3.4MJ/tonne. This represents a rise of about 50%.

## 5.7 Specific energy consumption by process

The specific energy consumption is the energy consumption per unit of output. It can be analysed in two ways:

- As a time series comparison of energy efficiency within a sub-sector
- As a cross-sectional comparison of energy intensity between sub-sections

In this study all the cases were taken into account as indicated in the table below.

| **Year** | **Specific energy consumption (MWh/tonne)** | | |
|---|---|---|---|
| | **Mining** | **Smelter** | **Concentrator** |
| 1991 | 1.16 | 11.78 | 0.27 |
| 1992 | 0.84 | 12.96 | 0.29 |
| 1993 | 0.93 | 12.17 | 0.28 |
| 1994 | 0.93 | 12.67 | 0.29 |
| 1995 | 0.88 | 16.11 | 0.29 |
| 1996 | 0.97 | 10.97 | 0.29 |
| 1997 | 1.08 | 10.95 | 0.32 |
| 1998 | 1.09 | 16.08 | 0.33 |
| 1999 | 1.17 | 10.59 | 0.34 |
| 2000 | 1.19 | 11.45 | 0.38 |

Table 5. Specific energy consumption by process

From the table 5 in the previous page, it is clearly revealed that amongst the three main processes, the smelter has the highest specific energy requirements. For example in 1992 the specific energy consumption for the smelter was 12.96 MJ/tonne as compared to 0.84MJ/tonne and 0.29MJ/tonne of mining and concentrator respectively. On average the energy input per ton to the smelter is about 13 times greater than that of the mining process and 45 times greater than of the concentrator.

## 5.8 Total energy cost in comparison to copper market prices

Clearly from figure 11 it can be seen that the metal prices, especially copper have been generally decreasing against ever increasing of the energy costs for production. The effects of issue are discussed in section 5.9.

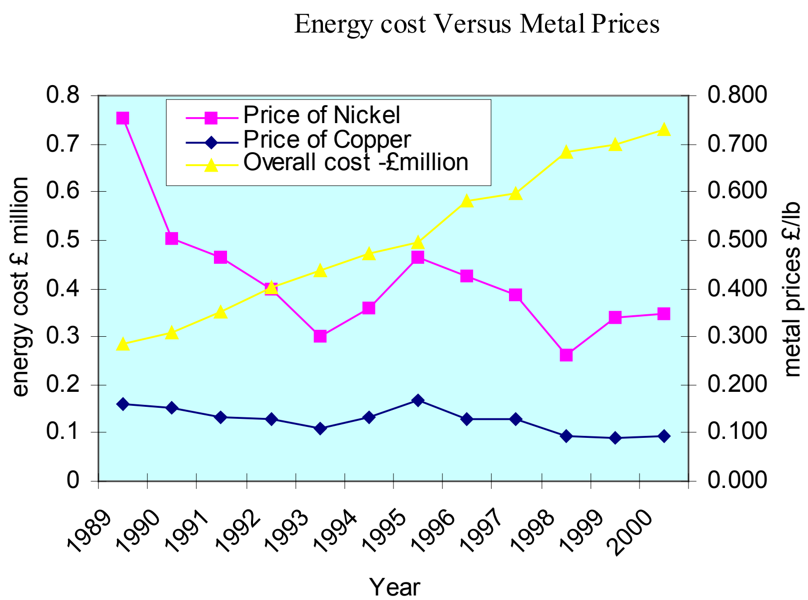



Figure 11. Energy cost against metal prices

World market copper prices have decreased by almost 31% from 1989 to the 2000 whereas the total energy cost of production in the Bamangwato Concession Limited mine was found to have increased by 40%.

## 6.0 Discussion

From the results analysis it is evident that as the electricity consumption has increased so has the associated energy cost. The production of matte increased by 11 % from 1991 to 2000 whereas the electricity consumption increased by 34% during the same period.

In order to identify potential for energy and cost savings, it will be necessary to identify key areas of high consumption.

This increase in the consumption and cost of electricity could be attributed some of the following factors;

- Old machinery, which could lead to a rise in general plant energy losses and inefficiencies.
- Increase in production of matte
- Energy Prices – yearly electricity tariff adjustments could have a significant on the final energy charges.
- Lack awareness of energy conservation.

It is also evident that there is high level of electricity consumption in the mine and that there will be potential make savings across the board. The specific energy consumption for the individual section can be regarded as having been constant as variations are very small. However, the comparison across sections singles out the smelting process as the most energy intensive in the mine. On the other hand the electricity consumption for the non-process is high than that of the smelter! This clearly needs further investigations.

Although there is no direct correlation between the metal prices and the cost of energy, it is probable to point out that due to low global market prices for copper/nickel the mine is experiencing financial constraints. As a result this has lead to government intervention to subsidize the mine by paying its energy bills. The government pays P3 million (£375 000) annually as part of the subsidy.

There is a general perception that such subsidies often discourage energy conservation, this is likely to be true in this particular case, as other problems take precedence.

## 6.1 Conclusions

As previously mentioned this study represents only a preliminary energy audit.

However, based on the analysis of the results the following conclusions can be drawn:

- Of all the processes, the smelter is the most energy intensive because of higher values of the specific energy consumption and therefore offers greatest opportunity for energy conservation.
- The non-process (engineering and administration blocks) uses a lot of electricity. It was found that this section consumes more energy than anticipated and as a result further investigation will be necessary. Despite this discrepancy, this area also offers great opportunity for energy conservation
- Coal and electricity are the main types of energy inputs used by the mine.

  In terms of energy costs it has been revealed that the electricity cost is almost six times higher than the cost of coal.

The next chapters will identify methods of reducing electricity consumption in the smelter and office buildings / workshops as an attempt to reduce the overall energy cost to the mine.

## 7.0 Selected Potential Opportunities for Electricity Conservation

After analysing the energy consumption data, it has been concluded that the main areas, which are most energy intensive within the industry, are the buildings (offices and workshops) referred to as non-process and the smelting process. The non-process uses approximately 13 450 MWh of electricity on monthly basis, representing 35% of electricity use. As mentioned earlier, the estimated NPI of 1200 $kWH/m^2$ which is consider to be very high. Unfortunately it was not possible to get breakdown of energy consumption for the non-process. On the other hand the smelting process uses 9 602 MWh electricity per month (25% of electricity use). Also it has been found that this process is characterised by high values of specific energy consumption as compared to other processes such as the concentrator. Because of its high figures of specific energy consumption, it is rendered the most energy intensive part of the overall mining process.

Thus, these two areas would be main options as potential energy (electricity) savings opportunities.

### 7.1 Opportunity1: Electricity conservation in buildings and offices

**Background**

There are several different uses of energy in buildings .The major uses are for lighting, heating &cooling, power delivery to office equipment and appliances. The amount that each contributes to the total energy use varies according to the climate, type of building and time of the year. In areas where very mild winters occur, cooling load will be greater than heating load in terms of the total energy use. In most buildings in certain climatic zones, the lighting load is often greater than either the heating or cooling loads, because there is a tendency to use electric light and glare control systems such as blinds in preference to daylight. And once switched on, lights are seldom switched off.

As a result in many organisations, lighting is the most obvious source of energy waste. This is often caused by ignorance of what is actually occurring in practice. Consequently electric lighting becomes a substantial energy consumer in buildings and it represents a significant energy cost. However, there are many opportunities for reducing lighting costs.  For example opportunities to maximise the use of natural daylight should be considered even in hotter countries. Furthermore different types of lighting systems and designs should be examined to identify where more efficient forms of lighting could be employed. When carrying out these identifications the safety and comfort of the building's occupant should be considered at all times. Moreover the occupants play an important role in controlling lighting use and can be encouraged to be responsible more in their use of lighting.

There have been several technological developments and research findings in the lighting industry, which can provide reduced energy consumption such as compact fluorescent lamps (CFLs) and automated lighting control devices. In addition, solar energy systems have become increasingly applicable for energy conservation (although this is less applicable). For instance active and passive solar system design in buildings can aid in heating and cooling of buildings. Most solar energy systems are used to supplement existing heating and cooling systems of building rather than to supply 100% of the building's needs.

Lighting systems or technologies in use today are incandescent, fluorescent tubes, mercury –vapour, metal halide and several others.

Incandescent lamps are characterised by low initial cost, simple to install and maintain, low efficiency and short life span. Whereas fluorescent lamps are also simple to install and maintain, but there are cheaper to operate and produce more light (lumens) per watt.

Conservation measures for energy used for lighting can be achieved through improved house –keeping or better lighting design. The lighting design of a building either new or old should consider initial cost, maintenance cost energy use and appropriateness for use. For existing lighting system design of a building it should be analysed to see if there are ways to reduce energy use without adversely affecting the lighting design.

### 7.1.1Energy Use and Potential Savings in BCL Building Offices and Plant Workshops (non-process)

When the buildings were constructed energy conservation was not seen as a national priority or a major financial constraint. Also, energy use in the buildings was not an important design factor.

Currently, electricity is the only conventional energy source available to the buildings. It is mainly used to provide lighting, heating and cooling, powering equipment and appliances.

It is estimated that these buildings account for 35% of the total monthly consumption of electricity by the mine which is equivalent to 427kWh/$m^2$ ,derived from the previous overall estimated NPI for the non-process . And it is also estimated that 60% (8070 MWh annually) of electricity consumption in these buildings is used for lighting purposes which is a huge potential for savings.

It has been established that most of the lighting installation system is in the form of incandescent lamps, which are characterised by high levels of energy wastage, this offers a major opportunity for energy conservation. For example, within the buildings energy savings could be achieved by substitution of existing lamps with low energy compact fluorescent alternatives.

#### 7.1.2 Recommended Energy Conservation Measure: Lamp Substitution

Recent developments have led to the introduction of lamps and luminaires (light fittings) that offer dramatic improvements in energy efficiency, so substantial running cost savings can often be achieved simply by replacing components. Compact fluorescent lamps are energy efficient alternatives to tungsten bulbs. They use about 40% of the power of a tungsten bulb of similar light output and last to eight times. The lighting system of the mines is dominated by installation of incandescent lamps. And as such replacement of incandescent lamps with energy saving fluorescent lamps should be considered.

Considering replacement 120 incandescent lamps rated at 100W, 2500 hrs of lifespan with compact fluorescent lamps rated at 25W, 10000 hrs (as per table below) with operating conditions of 9hrs per day on average. Energy cost at P0.1210 per kWh. (£0.015 per kWh)

Table 6 shows a comparison between the wattage of commonly available incandescent lamps and the wattage of compact fluorescent lamps that will provide similar light levels.

| Watt Incandescent | Watt Compact Fluorescent lamps |
|---|---|
| 25 | 5 |
| 50 | 9 |
| 60 | 15 |
| 75 | 20 |
| 100 | 25 |
| 120 | 28 |
| 150 | 39 |

(Ref. Energy Efficiency and Renewable Energy Network (EREN)- Consumer Energy Information)

**Annual Energy Savings:**

Annual operating hours = 3 285 hrs

Wattage Difference = 100 – 25 = 75 W

Savings = 75 x 3285 = 246 375 Whrs per lamp

Energy saving for 120 lamps: 29.57 MWh

**Cost Savings:**

Energy cost (Pula/kWh) x Energy savings = 0.1210 x 246.375 kWh

= P **29.81** per lamp

Cost savings for 120 lamps: 29.81 x 120 = P **3 577.37**

Thus the total annual cost saving for substituting 120 lamps would be **P 3 577.37 (£ 447.17)**

The cost of one fluorescent lamp is estimated be P70.00. Based on this cost substitution of lamps would have an estimated payback period of 2.3years.

**7.1,3 Other recommendations**

1. Improved house –keeping measures such as;
   - always turning lights off when they are not needed. This can be achieved by using stickers or reminders to make employees more aware.
   - regular maintenance checks of the lighting especially cleaning of lamps to remove dirt.
2. Where possible the use of daylight to maximise the advantage to reduce lighting should be encouraged
3. Establishment of a campaign programme to raise awareness of the benefits of energy conservation could happen change the attitudes or ignorance of the employees or any other stakeholder for a better prospect of responsibility.
4. Introducing automatic control systems, with light and or proximity sensors and time switches. These devices reduce energy consumption by limiting usage of lamps to those times when lighting is actually required, and available daylight is insufficient.

## 7. 2 Opportunity 2: Reducing electricity consumption in the smelting process (Smelter)

The smelting process is composed of inherently electrical energy consuming devices. These are the atomiser motor, electric furnace, electrostatic precipitators, power mills, compressors, slag cleaning, winders /motors and the oxygen plant. Table shows the historical averages of the specific energy consumption for the different sections of the smelter.

| Process | 1991 | 1992 | 1993 | 1994 | 1995 | Units |
|---|---|---|---|---|---|---|
| Drying plant | 12.3 | 12.6 | 12.4 | 13.2 | 10.8 | kWh/T dried |
| Coal plant | 57.8 | 54.2 | 59.8 | 54.9 | 43.8 | kWh/T coal milled |
| Flash.S.Furnace | 20.2 | 22.9 | 24.5 | 26.5 | 21.9 | kWh/T charged to flash |
| W.H.B/Superheater | 7.4 | 7.7 | 7.4 | 8.2 | 7.4 | kWh/T wet steam |
| **Matte handling** | **387.3** | **475.6** | **372.1** | **404** | **398.6** | **kWh/T metal** |
| Slag Cleaning | 48.0 | 53.7 | 80.8 | 51.3 | 44.1 | kWh/T discard slag |
| **Oxygen plant** | **462.6** | **410.7** | **425.3** | **476.7** | **330.5** | **kWh/T oxygen** |
| Compressor air | 37.4 | 42.4 | 32.2 | 21.4 | 22.8 | kWh/T concentrate |

Table 7. Historical average specific energy consumption for different smelter sections

Clearly, the matte handling and the oxygen plant use the greatest proportion of energy per unit output. However, all of the above processes have in common the fact that they rely on electrical drives, the majority (70%) being motors.

### 7.2.1 Recommended energy conservation strategy: Use of more efficient motors

The greatest scope for energy savings within the plant is therefore in industrial motors. More efficient ones can replace old motors, and the efficiency of any motor can be improved through better controls, use, and maintenance. Also the use of variable speed drives for driving pumps can save energy.

These motors reduce operating costs by lowering energy consumption, eliminating the need to expand the capacity of the building's electrical supply, and reducing downtime, replacement, and maintenance costs.

Electrical energy management by using more efficient motors should always be considered whenever a motor is installed. When considering energy efficient motors, two factors will affect the payback period: power cost and operating hours per year. Where electricity is inexpensive or operating time is low, it may take several years for the savings from installation of high efficiency motors to outweigh the difference in initial cost. On the other hand, where power costs and the operating hours per year are high, it may be possible to replace an existing standard efficiency motor with an energy efficient motor, and realise a shorter payback period. Furthermore, the economic advantages of energy efficient motors over rewound motors often provide the opportunity for an upgrade to energy efficient motors when old motors burn out. Motors perform best at full load. An under-loaded motor, energy efficient or not, is less efficient than a fully loaded motor. Energy efficient motors are most attractive economically when power costs and/or operating hours per year are high.

Energy efficient motors have other advantages over standard motors such as being quieter, operating at lower temperatures and lasting longer.

The mine could achieve substantial savings both in terms of energy and cost as illustrated below.

Considered here is replacing 50 of the 55kW motors, which drives a pump at full load in its mineral, processing plant. The motor is expected to run for 5950hours /year, for 350 days /year. A standard motor with an efficiency of 91.5 % costs P 15 900.00 (an equivalent of £ 1987.50) while a high efficiency motor with an efficiency of 94.2% costs P20 880.00 (an equivalent of £ 2610.00). The plant operates on large business electricity tariff structure (Appendix 1):

Yearly Saving (P) = L * C * RH $(100/_{stand} - 100/_{high})$

Where

- L = output load in kW
- C = unit cost of electricity in Pula per kWh
- RH = running time in hours per year and $_{stand}$ and $_{high}$ are the efficiencies of the standard and high efficiency motors at the given load respectively.

Demand Saving (P) = L *RD * DC * $(100/_{stand} - 100/_{high})$

Where

- RD = running time in days per year
- DC demand charge in P per day per kW maximum demand
- $_{stand}$ and $_{high}$ are as above

Thus:

**Yearly Savings (P)** = (55* 0.1210*5950)*(100/91.5-100/94.2)*50

= **P 62 019.00 ≈ £ 7 752.38**

**Demand Saving (P) =** {55 * 350* 30.24 **(100/91.5-100/94.2)**}*50

= **P 911 747.00 ≈ £ 113 968.34**

**Payback Period** = 50* (20 880 – 15 900) / (62 019.00 + 911 747)

= **0.26 years**

From the above calculations it was found that just replacing 50 standard motor with energy efficient one the mine could save a combined sum of **P** 973 766 .00 (an equivalent of £121 720.75) in 0.26 years. The potential savings from such installations with a payback period of 3 months are quite substantial. It is suggested that an inventory on standard motors in the smelter should be carried in order to identify the number of motors to be replaced. The replacement of motors could be done in phases depending on the availability of funds.

### 7.2.2 Other recommendations

These recommendations are mainly based on the fact that the plant is relatively old and no major renovations have taken place.

- Explore the possibilities of heat recovery for multiple uses including pre-heating combustion air and for hot water systems in ablutions. Energy recovery is the beneficial use of heat or cooling energy that would otherwise be lost or needs to be removed from a specific space. Technologies that recover heat and/or cooling energy reduce the cost and consumption of energy in commercial and institutional buildings.

The recaptured energy is potentially useful for heating and/or cooling/dehumidifying outdoor air brought into a building for ventilation, space heating, and water heating.

- Use of high efficiency burners and new catalysts.

  Increased efficiency would result in lower power costs and reductions in greenhouse gas emissions. Processes such the Selective Catalytic Reduction (SCR) remove the nitrogen pollutants from the flue gas and thus reducing NOx emissions to the environment.

- Use of adjustable speed drives

  By controlling motor speed so that it smoothly corresponds to varying load requirements, adjustable motor installation can increase energy efficiency. Huge energy savings can be realised.

- Investigation into power factor correction

  Improving power factor of an industrial plant reduces the electrical losses and increases electrical capacity.

- Consider re-scheduling production or other operations to spread out the electrical load and thus improve the load factor.

#### 7.2.3 Table 8 Summary of total cost of investments and savings

| Process/Department | Proposed energy conservation measure | Cost of Investment (£) | Cost Savings (£) | Payback (years) |
|---|---|---|---|---|
| **Non-process** | Replacement of incandescent lamps with Compact Fluorescent Lamps | 1050.00 | 447.00 | 2.3 |
| **Smelter** | Replacement of standard motors with energy efficient motors | 30 625.00 | 121 720.75 | 0.26 |

## 7.3 General comment

Further investigations and the use of the energy management matrix (appendix 3) to determine the mine's organisational approach to energy management has revealed that currently the mine lies at level 1 on the matrix. Energy management matrix gives a quick but effective way of establishing the energy management profile of an organisation.

There is currently no dedication or proper co-ordination of energy management activities. Energy management activities have assigned to one professional as part time responsibility and there are no clear guidelines on energy policy or action plan.

Although the energy consumption statistics especially on coal and electricity could be considered organised in that they are recorded, they are not used for the monitoring of energy consumption. Therefore, before the company could embark on energy conservation programmes it would be necessary for it to develop an energy management policy in order to ensure getting the most out of its investment on energy conservation initiatives. This would provide a mechanism to assist the mine to monitor energy consumption and to set targets for further improvements. By taking such action, the mine would gain control over its energy consumption and could thus easily maintain that control.

## 8.0 Conclusion

As mentioned earlier, this report should be considered as a preliminary study on investigating the potential for energy conservation opportunities at Bamangwato Concession Limited.

The study was mainly based on a theoretical analysis of energy consumption at the mine. Hence a detailed energy audit would have to be undertaken in order to establish more accurate energy consumption data. A detailed energy audit goes beyond the quantitative estimates of cost and savings .It would involves a detailed mass and energy balance of major energy consuming equipment. System efficiencies are evaluated and measures are identified for improving the end –use energy efficiency. However, despite these limitations, the study has establish that the mine is energy intensive especially its smelting process and a great amount of energy especially electricity is used in its office buildings and warehouses and puts forward a mechanism for the development of energy management and conservation strategy as outlined in chapter 3.

Two options on energy conservation measures were discussed on chapter five. Despite the fact that the measures are discussed at small-scale levels it is evident that the mine could actually make substantial savings energy savings. These savings could reduce the financial burden of the current energy bills and the dependence if the mine on government subsidies. There would also be environmental benefits derived from implementing energy conservation measures. There would be tremendous reduction of localised gaseous emissions to the environment.

Despite the great potential opportunities that exist for energy conservation in the BCL mine, the company needs to develop an effective energy management system before implementing any energy conservation measures.

It is advised that the mine should appoint an Energy Manager who will assist in implementing such an energy policy and also develop a comprehensive system for setting targets, monitoring consumption, quantifying saving and providing budget records. The energy manager would also assume the responsibility of educational awareness campaigns as way of changing the attitudinal behaviours of employees and even the management towards energy conservation.

It is also recommended that an energy conservation fund should be set up to assist with financing future energy conservation related investments.

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## Appendices

Appendix 1 Summary of Energy Policy from NDP 8

The National Development Plan 8 is based on the nation's four development planning objectives of rapid economic growth, social justice, economic independence and sustainable development. For this Plan, Government has adopted the theme of **Sustainable Economic Diversification.** Economic activities in Botswana must continue to be diversified across different sectors in order to foster strong economic growth in the future. But new programmes and projects must be sustainable on their own and not dependent on government subsidies for survival.

Energy Sector Policy and Strategy for NDP 8

Traditionally and world wide energy planning focused more on the supply side than on the demand side. The approach had deficiencies in that the focus was on the needs of the energy supply industry with resultant potential of over supply. These deficiencies will be overcome in NDP 8 through application of Integrated Planning (IP).

Energy policy objectives for NDP 8 are outlined as follows:

(a) **Economic Efficiency**

- Energy services will be supplied at least cost to the economy; this implies that the energy supply industry should operate efficiently and that energy prices should not include excessive profits.
- The energy supply should be financially sustainable.
- Within the context of efficiency, energy users (and potential users) should have access to appropriate energy services.
- Energy should be used efficiently.

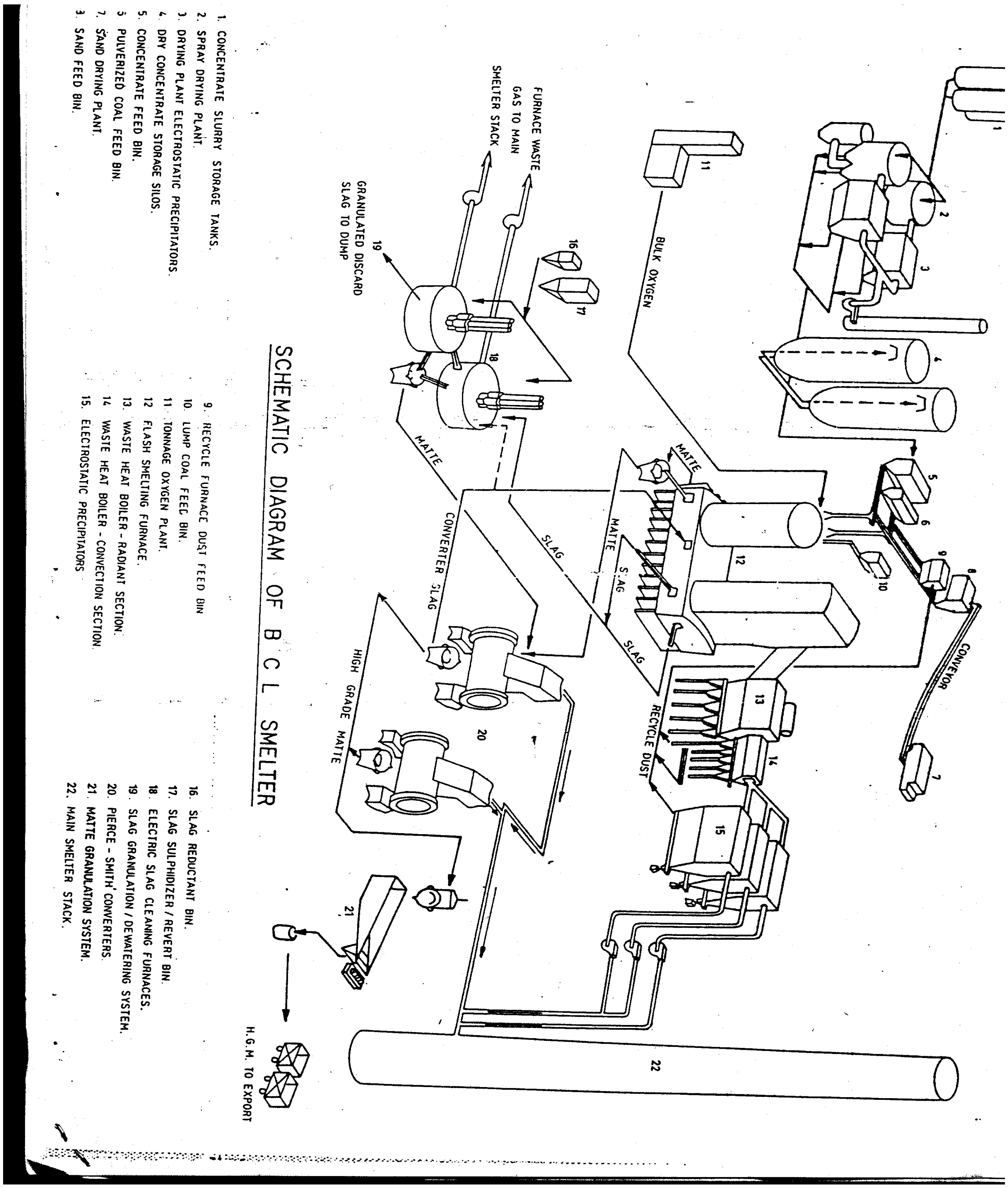
(c) **Social Services**

- Increasing access by households and community services to adequate and affordable energy service.

(d) **Environment, Quality, Sustainability and Security**

- Energy extraction, production, transportation and use should not damage the environment or people's health and safety.
- In the long term, sustainable energy usage must be implemented.
- Supplies must be reliable to ensure economic development and business confidence.

Appendix 2 Schematic diagram of BCL Smelter



Appendix 3. Botswana Power Corporation Electricity Tariffs Structure-February 2000

| | Domestic | Small Business | Medium Business | Large Business | Government | Water Pumping |
|---|---|---|---|---|---|---|
| **Fixed Charge per month** | P7.00 | P17.00 | P17.00 | P17.00 | P17.00 | P17.00 |
| **Energy Charge per kWh** | P.02523 | P0.2618 | P0.1342 | P0.1210 | P0.3392 | P0.2669 |
| **Demand Charge per kW** | Nil | Nil | P32.13 | P30.24 | Nil | Nil |

Courtesy: BPC Annual Report

*Notes: 1. Demand Charge – The charge payable calculated from the actual demand supplied or from 90% of the peak load recorded in the previous 12 months, whichever is greater.*

*2. BCL falls under category 4 (Large Business)*

Tariff Categories

1. **Domestic**: All consumers using electricity supplied at 230 Volts single phase, or 400 Volts three phase, for domestic purposes only.

2. **Small Business**: All business consumers supplied with electricity not exceeding 400 Volts, and in respect of loads not exceeding 35 Kilowatts.

3. **Medium Business**: All business consumers supplied with electricity not exceeding 400 Volts, and in respect of loads that exceeds 35 Kilowatts.

4. **Large Business**: All business consumers supplied with electricity at or above 11000 Volts.

5. **Government**: All Government, Municipal and Street lighting installations.

6. **Water Pumping**: A special tariff for consumers with water pumping applications

**Exchange rate used**

Pound (£) to Pula (P): 1: 8

1Pula = 100 thebe

Appendix 4.Energy Management Matrix –extract from BRESCU 1993

| Level | Energy Policy | Organising | Motivation | Information Systems | Marketing | Investment |
|---|---|---|---|---|---|---|
| 4 | Energy policy, action plan and regular review have commitment of top management as part of an environmental strategy | Energy management fully integrated into management structure. Clear delegation of responsibility for energy consumption | Formal and informal channels of communication regularly exploited by energy manager and energy staff at all levels | Comprehensive system sets targets monitors consumption,identifies faults, quantifies savings and provides budget tracking | Marketing the value of energy efficiency and the performance of energy management both within the organisation and outside it | Positive discrimination in favour of "green" schemes with detailed investment appraisal of all new build and refurbishment opportunities |
| 3 | Formal energy policy no active commitment from top management | Energy manager accountable to energy committee representing all users chaired by a member of board | Energy committee used as main channel together with direct contact with major users | M&T reports individual premises based on sub-metering not reported effectively to users | Programme of staff awareness and regular publicity campaigns | Same payback criteria employed as for all other investment |
| 2 | Unadopted energy policy set by energy manager or senior departmental manager | Energy manager in post, reporting to ad-hoc committee but line management and authority are unclear | Contact with major users through ad-hoc committee chaired by senior departmental manager | Monitoring and targeting reports based on supply meter data. Energy unit has ad-hoc involvement in budget setting | Some ad hoc staff awareness training | Investment using short term pay back period |
| **1** | **An unwritten set of guidelines** | **Energy management the part-time responsibility of someone with only limited authority or influence** | **Informal contacts between engineer and few users** | **Cost reporting based on invoice data. Engineer complies reports for use within technical department** | **Informal contacts used to promote energy efficiency** | **Only low cost measures taken** |
| **0** | **No explicit policy** | **No energy manager or any formal delegation of responsibility for energy consumption** | **No contact with users** | **No information system. No accounting for energy consumption** | **No promotion of energy efficiency** | **No investment in increasing energy efficiency in premises** |

Appendix 5. World Mine Production of Nickel (x 000tonnes) 1995 – 1999

| | **1995** | **1996** | **1997** | **1998** | **1999** |
|---|---|---|---|---|---|
| Russia | 235 | 232 | 235 | 235 | 245 |
| Canada | 181.8 | 192 | 190 | 208 | 188 |
| New Caledonia | 120.7 | 124.8 | 137.1 | 125.3 | 112 |
| Australia | 104 | 113 | 123.4 | 143.5 | 108 |
| Indonesia | 86.6 | 87.9 | 71.1 | 74.1 | 89 |
| Cuba | 42.7 | 53.6 | 61.5 | 67.8 | 67 |
| China | 41.8 | 43.8 | 46.7 | 47.7 | 50 |
| Brazil | 19.2 | 20.5 | 20.5 | 32.5 | 40 |
| Colombia | 24.2 | 27.7 | 31.2 | 29.4 | 39 |
| South Africa | 29.8 | 33.9 | 34.8 | 36.4 | 36 |
| **Botswana** | **21.1** | **24.2** | **22.9** | **24.8** | **26** |
| Dominica Republic | 30.9 | 30.4 | 66.8 | 25.2 | 25 |
| Other | 70.7 | 66.8 | 65.5 | 59.2 | 47 |
| Total | 1008.5 | 1015.2 | 1072.7 | 1109.1 | 1071 |

Source: World Nickel Statistics, International Nickel Study Group, March 2000

Notes. 1. This table only shows nickel statistics (copper statistics not included)

2. BCL produces copper and nickel in % proportion of 0.40 and 0.18 respectively