Improving DSM project implementation and sustainability through ISO standards

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ABSTRACT

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South African industries are challenged with above inflation electricity tariffs which may affect their competitiveness within their relative markets. In order to successfully manage these rising electricity costs and ensuing top market competition, a well organised demand side management (DSM) strategy must be implemented.

Energy service companies (ESCos) have been assisting Eskom, South Africa’s leading electricity utility, in managing energy projects around the country. These DSM projects have introduced remarkable electricity and cost savings. However, the need for a sustainable energy management system (EnMS) within these projects does exist.

This dissertation illustrates and discusses an EnMS designed to achieve maximum possible energy savings performances. The ISO 9 001 (quality management), ISO 14 001 (environmental management) and ISO 50 001 (energy management) standards were integrated for the development and implementation of this system. It provides a framework for project engineers and industrial clients to apply before, during and after project implementation.

The use of the Plan-Do-Check-Act (PDCA) cycle will be applied throughout the dissertation. The PDCA cycle follows basic steps recommended by the relevant ISO standards. This cycle emphasises the concept of continual improvement.
The developed EnMS was successfully implemented on various DSM projects. This selection includes previously maintained and new implemented projects. An analysis between the implementation and post-implementation performances supports the achieved results. The results of the case studies are presented in this dissertation.

This dissertation illustrates that the continual improvement of an ISO based EnMS will result in a sustainable increase in electricity savings. An overall increase in project quality can be defined and measured according to the electricity consumptions and electricity cost savings. These electricity cost savings from the selected projects resulted to nearly R18 million during project implementation. A total amount of R52 million was already saved during the maintenance phase of 2014. This cost savings only reflect the results of the eight selected projects for the first eight months in 2014.

The EnMS explained in this dissertation indicates that a continually controlled framework can improve the quality of DSM project implementation and sustainability. With the flexibility of changing the system according to impulsive constraints and client demands, the system can be used with various DSM projects.
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# NOMENCLATURE

<table>
<thead>
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<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GWh</td>
<td>Gigawatt hour</td>
</tr>
<tr>
<td>kW</td>
<td>Kilowatt</td>
</tr>
<tr>
<td>kWh</td>
<td>Kilowatt hour</td>
</tr>
<tr>
<td>MW</td>
<td>Megawatt</td>
</tr>
<tr>
<td>MWh</td>
<td>Megawatt hour</td>
</tr>
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</table>

# ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAC</td>
<td>Bulk Air Coolers</td>
</tr>
<tr>
<td>CA</td>
<td>Cooling Auxiliaries</td>
</tr>
<tr>
<td>CER</td>
<td>Certified Emission Reduction</td>
</tr>
<tr>
<td>CoC</td>
<td>Certificate of Completion</td>
</tr>
<tr>
<td>CPI</td>
<td>Consumer Price Index</td>
</tr>
<tr>
<td>DSM</td>
<td>Demand Side Management</td>
</tr>
<tr>
<td>EE</td>
<td>Energy Efficiency</td>
</tr>
<tr>
<td>EnMS</td>
<td>Energy Management System</td>
</tr>
<tr>
<td>EnPI</td>
<td>Energy Performance Indicator</td>
</tr>
<tr>
<td>ESCo</td>
<td>Energy Service Company</td>
</tr>
<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
</tr>
<tr>
<td>IEE</td>
<td>Industrial Energy Efficiency Improvement in South Africa</td>
</tr>
<tr>
<td>ISO</td>
<td>International Organisation of Standards</td>
</tr>
<tr>
<td>LS</td>
<td>Load Shift</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Full Form</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------</td>
</tr>
<tr>
<td>M&amp;V</td>
<td>Measurement and Verification</td>
</tr>
<tr>
<td>MAD</td>
<td>Measurement Acceptance Date</td>
</tr>
<tr>
<td>NWU</td>
<td>North-West University</td>
</tr>
<tr>
<td>OAN</td>
<td>Optimisation Air Network</td>
</tr>
<tr>
<td>PA</td>
<td>Performance Assessment</td>
</tr>
<tr>
<td>PC</td>
<td>Peak Clip</td>
</tr>
<tr>
<td>PDCA</td>
<td>Plan-Do-Check-Act</td>
</tr>
<tr>
<td>PLC</td>
<td>Programmable Logic Controller</td>
</tr>
<tr>
<td>SCADA</td>
<td>Supervisory Control And Data Acquisition</td>
</tr>
<tr>
<td>TOU</td>
<td>Time Of Use</td>
</tr>
</tbody>
</table>
1. CHAPTER 1: INTRODUCTION

1.1. PREAMBLE

South African industries get challenged with numerous economic constraints. Some of the main constraints include production costs, unpredictable labour actions and international competition [1]. Some of these constraints can be managed, while others are uncontrollable. Alternative solutions need to be obtained to deal with these uncontrollable problems.

Electricity costs in South Africa are also rising due to high and yet increasing demands. A comparison between the annual increased electricity tariff and the consumer price index (CPI) is illustrated in Figure 1-1. The higher inflation and rising electricity costs lead to an increase in production costs.

![Average electricity increase compared to average CPI](image)

**Figure 1-1:** Average electricity tariff increase compared to the average CPI [2].

Companies can reflect the electricity cost increases on their product selling prices. This can have an undesirable influence on their market shares when competing with their competitors’ lower prices. The more challenging but yet wiser decision will be to adapt to these increasing costs. Operational strategies can be adjusted without influencing production outputs.
A survey was done in 2013 among the energy intensive industry to investigate the effect of electricity cost increases in an organisation’s overall cost structure. The portion of electricity costs compared to their overall input costs increased with between 9% to 18% during 2007 - 2012 [3].

The management of effective energy usage involves many different aspects. Companies often oversee some of the most crucial elements in these management strategies due to limited resources.

Therefore various energy service companies (ESCos) have been established to assist Eskom in managing energy intensive projects in South Africa. ESCos will typically make use of an energy management system (EnMS). This can be presented on a spread sheet, by installing the relevant hardware (eg. energy saver lights), implementing suitable system strategies or in the form of a software program. The EnMS is usually implemented on a single service or technology.

It is recommended that the system is based on the ISO 9 001 (quality management) and ISO 50 001 (energy management) standards. General guidelines and requirements are stipulated within each of these standards. Companies who use a certified EnMS can also gain International Organisation of Standards (ISO) compliancy. This will assist them to improve their profitability and global competitiveness.

In 2010, the Western Cape’s largest electricity consumer initiated the Industrial Energy Efficiency Improvement in South Africa Project (IEE Project). They obtained an annual electricity cost savings of over R90 million since joining the project. The consumer also avoided greenhouse gas emissions of nearly 70 000 tons per year. The IEE Project motivates industries to develop and implement an EnMS based on the ISO 50 001 standard [4].

A British multinational brewing and beverage company (SAB Miller) has obtained a 17% reduction in their electricity consumption since 2008. They improved their energy usage through various strategies. Awareness programmes for employees, upgraded power metering, reduction in water temperature and energy efficient lighting were some of the main strategies [3].

An ISO compliant EnMS is not always efficient without the support of an Energy Information Management System. South African industries have already implemented these Energy Information Management Systems. One deficiency in the system is the absence of support to the management representatives who develop and implement efficiency reports [5].
Once the client has successfully implemented the projects on a specific site, the client can continue using the EnMS to maintain the performance results. As stipulated in the ISO standards, quality improvement is a continuous process. Therefore this study will focus on project implementation as well as the sustainability thereof.

1.2. DEMAND SIDE MANAGEMENT

1.2.1. BACKGROUND

Demand side management (DSM) serves as a solution to the short-term electricity supply constraint experienced by electricity providers. Actions should be taken to change the patterns in which large energy intensive industries manage their energy usages [6].

The DSM process entails the energy management of electrical components to best utilise their total energy profiles. Energy can either be shifted or clipped from peak periods [7]. Evidently, DSM projects are used to reduce energy consumptions during peak periods within a short implementation time.

With the strenuous lack of electricity supply in South Africa, the purpose of DSM project implementation differs slightly from those of comparing countries. China is one of the only countries that share the need for electricity supply over the required demand. The United States decided to manage the consumption of electricity due to increasing electricity costs. Germany initiated DSM to maintain a stable power system [7].

By implementing DSM projects, Eskom encourages industries to minimise their energy consumption. The programme supports the South African security and supply for energy. It improves the national economic crisis caused by high energy demands and thus power shortages [8].

Identifying accurate energy saving opportunities for DSM projects should be investigated by the relevant authorities. Energy intensive processes from large industries in South Africa emphasise the opportunities. These processes should be further investigated to recognise all possible sections.

Different role players have come together to explore feasible techniques to implement these strategies. These role players include Eskom, the Mining and Industrial Energy Optimisation
group, energy service companies (ESCos) and other relevant workforces within the mining sector [9].

Some of the major technologies identified to create opportunity for electricity savings include [9]:

- Electric motors (responsible for mechanical power in industrial plants),
- Pumping systems,
- Compressed air systems,
- Heating and refrigeration systems, etc.

DSM projects have been implemented since 2004. The annual savings have increased significantly ever since [7]. Figure 1-2 indicates the difference between Eskom’s annual target demand savings compared to the verified annual demand savings. Since 2008, the actual demand savings outranged the target demand savings [8].

![Cumulative demand savings relative to the target values](chart.png)

Figure 1-2: Eskom demand savings relative to the cumulated target per year [8].

Possible reasons for this good performance are the successful implementation of DSM projects and the awareness of efficient energy management. The installation of various equipment which assists in the savings of electricity was made possible by the increased awareness of the impact of electricity savings [10].

The motivation for industries to reduce the power demand during Eskom’s evening peak periods can be challenging. Eskom introduced different tariffs for the different time periods of the day.
The tariffs during peak hours are significantly higher than those of standard and off-peak hours [8]. This motivates end users to reduce the power load during peak hours. Figure 1-3 indicates the distributions of the tariffs relevant to the seasons and the hours of the day.

![Figure 1-3: TOU periods and seasonal distributions for WEPS, Megaflex, Miniflex and Ruraflex tariffs [11].](image)

To remain competitive, a company should ensure a well-balanced strategy between their input and output costs. The comparison between these costs should be analysed and improved when needed.

Eskom has divided the tariff costs into two groups according to the demands. Winter tariffs (high demand) are significantly higher than summer tariffs (low demand). A comparison of the Megaflex tariffs is being enlightened in Table 1-1. These compared tariffs are for mines operating between 300km - 600km from the power source, and with voltages ranging from 66kV to 132kV.

A more detailed tariff structure with additional costs is attached in Appendix A: Megaflex tariffs represented by Figure 5-1: Eskom Megaflex tariffs for 2014/2015.
Table 1-1: Megaflex tariff comparison for 2014/2015 [11].

<table>
<thead>
<tr>
<th>TOU period</th>
<th>High demand season (Jun - Aug)</th>
<th>Low demand season (Sep - May)</th>
<th>Seasonal comparison (% of winter exceeding summer)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak</td>
<td>212.63</td>
<td>69.36</td>
<td>307%</td>
</tr>
<tr>
<td>Standard</td>
<td>64.41</td>
<td>47.73</td>
<td>135%</td>
</tr>
<tr>
<td>Off peak</td>
<td>34.97</td>
<td>30.28</td>
<td>115%</td>
</tr>
</tbody>
</table>

The implementation of DSM projects can be used as an alternative but temporary solution for upcoming power plants in South Africa [12]. These DSM projects can be divided into three types of energy management strategies:

- Load shifting,
- Peak clipping, and
- Energy efficiency.

Each of these will be discussed in the following sections to illustrate the possible electricity saving strategies.

**LOAD SHIFTING**

Load shift (LS) projects entail the management of energy consumptions to maintain energy neutral profiles. The electricity load is shifted from peak and standard time periods into off-peak periods where the costs are cheaper.

The power profile for a LS project is illustrated in Figure 1-4. It is clear that the load should be kept to a minimum during evening peak periods. Noticeable electricity cost savings could be achieved if the actual power profile is kept under the original baseline, especially during the most expensive peak hours.

An example of LS projects includes process lines such as the production of cement. Storage silos are being used as buffers to allow the cement mills to run during cheaper time periods. DSM pumping projects from different industries are also an example of LS projects. Here, the dams are being used as storage buffers to allow the pumps to be scheduled and managed according to the cheapest tariff structure.
The first priority should be to reduce evening peak consumptions. The priority for avoiding morning peak periods will follow, where after standard times should be avoided. These loads should be shifted to the off-peak periods before considering the alternative periods.

**PEAK CLIPPING**

Peak clip (PC) projects are similar to LS projects. The energy consumption is also managed out of the peak periods, but the power profiles will not be energy neutral. Usually the actual power consumptions will be less than the original power consumption profile.

In extreme LS cases the consumptions during off-peak and standard periods can be significantly higher than the original profile. This can cause increased savings, but will still not be energy neutral to the original baseline. These power profiles are illustrated in Figure 1-5 below. In the example the power load was directly clipped during the expensive evening peak period.
Figure 1-5: Illustration of a DSM peak clipping power profile.

An example for a PC project includes the energy management of compressors. The compressors are switched off during no drilling periods.

ENERGY EFFICIENCY

Unlike the two project types mentioned above, energy efficiency (EE) projects entail the reduction of the total amount of energy demand throughout the day. The difference between the original and improved power profiles will never be energy neutral. The original power profile is reduced by a constant factor throughout the day. A typical power profile of an EE project is illustrated in Figure 1-6.

Figure 1-6: Illustration of an energy efficiency power profile
The management of an optimised air network and cooling auxiliaries are examples of EE projects.

1.2.2. ENERGY MANAGEMENT AWARENESS

Certain support functions can be implemented to keep DSM projects sustainable. One important requirement is for the client’s behaviour to change relevant to the management of energy. Industries are recommended to follow these steps to maintain a project [12]:

- Create awareness,
- Effective and lasting communication,
- Marketing of project strategies,
- Provide relevant training,
- Sustain educational level,
- Monitor project performance,
- Verify strategies continuously,
- Do consistent research to maintain project requirements, and
- Develop new strategies when needed.

Eskom is presently implementing various awareness campaigns for power demands during peak hours. The main focus is to reduce these loads during the evening peak [8]. One of these awareness campaigns is the “Power Alert” that is displayed on national television and radio. An example of a notification is displayed in Figure 1-7. This campaign has already achieved about 350 MW of electricity savings.

![Example of Eskom’s “Power Alert” awareness campaign being broadcasted on TV](image.jpg)
The national electricity demands can be defined as season dependent. The power profiles for the two defined seasons during the different hours of the day can be seen in Figure 1-8. It can be observed that the evening peak in the winter season is remarkably higher than in the summer. This is mainly caused by the residents living in residential areas. Electrical heating, air-conditioning and geysers are some of the main reasons for this increase during evening peak periods.

![Figure 1-8: Typical daily summer and winter demand profiles [8].](image)

1.2.3. DSM IMPLEMENTATION IN THE INDUSTRY

The different sectors in South Africa were investigated to determine their individual impacts on the economy. Non-ferrous metals and the gold mining industry are the largest electricity consumers in South Africa. A breakdown of the total electricity consumed among the different sectors in South Africa in 2010 is illustrated in Figure 1-9.

The contribution to the gross domestic product (GDP) was compared to the total electricity consumed within the sectors. With nearly a quarter of the total electricity consumed, the gold mining and the non-ferrous metals sectors contribute only 4% to the GDP [13]. The contribution to the GDP determines the influence on the national economy. Comparing the amount of energy consumed with the value added to the economy, these two sectors contribute minimum value to the GDP [13].
To stay competitive in the market, different companies within these sectors need to minimise their electricity consumption to improve their production output costs. These sectors consume a lot of energy to be able to meet the demands of their production. With effective energy management, these companies can obtain top market competition.

![Electricity consumption by sector (2010)](image)

Figure 1-9: Electricity consumption by various sectors in 2010 [13].

Gold mines are the most vulnerable of all mining companies in South Africa due to the electricity price increases [13]. The constraints include the need for deep mining operations that consume major units of electricity and the decreasing global demand for these metals.

The energy demand from Eskom is continually increasing. The supply and demand does not add up. The concern of supply lacking behind causes a negative impact on the South African economy. By implementing a successful EnMS, companies can obtain major economic benefits. Optimised production strategies can have a positive influence on input costs and return on investments [9].

The aim for these DSM projects is to optimise an ideal energy profile for all national industries. A strategy proposed by an ESCo to implement DSM projects is explained in the following section.
1.2.4. TYPICAL PROJECT STEPS FOR DSM

DSM projects implemented by the largest ESCo in South Africa can be divided into various technologies within the different industries. These different technologies are summarised in Table 1-2 below. The overall process steps and required documentation should however, remain consistent for all types of projects. The content within the reports and documents will be unique for each project.

<table>
<thead>
<tr>
<th>Technology</th>
<th>Full name</th>
<th>Project type</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAC</td>
<td>Bulk air coolers</td>
<td>LS</td>
</tr>
<tr>
<td>CA</td>
<td>Cooling auxiliaries</td>
<td>EE</td>
</tr>
<tr>
<td>CM</td>
<td>Compressor management</td>
<td>PC</td>
</tr>
<tr>
<td>FP</td>
<td>Fridge plant</td>
<td>LS</td>
</tr>
<tr>
<td>OAN</td>
<td>Optimised air network</td>
<td>EE</td>
</tr>
<tr>
<td>PL</td>
<td>Process line</td>
<td>LS</td>
</tr>
<tr>
<td>Pumping</td>
<td>Pumping system</td>
<td>LS</td>
</tr>
<tr>
<td>WSO</td>
<td>Water supply optimisation</td>
<td>EE</td>
</tr>
</tbody>
</table>

As indicated in Figure 1-10, the DSM project steps can be divided into four main sections. They include the following:

- Investigation phase,
- Project implementation,
- Monitoring and control, and
- Maintenance and sustainability.

The project process steps are further divided into five horizontal components. Each component represents a different stakeholder involved within the project. A swim lane diagram was used to graphically illustrate the responsibilities of the various stakeholders relevant to a DSM project.
An external stakeholder should be appointed to determine accurate results throughout the project lifetime. This is to verify that the claimed savings are correct and to eliminate possible treachery between the remaining stakeholders. This process is known as the measurement and verification (M&V) process. The team that is appointed should investigate and report on the project regularly. Each report should be signed and agreed on by the M&V team, the ESCo, the electricity provider and the client.
Each project phase includes certain steps that serve as prerequisite requirements or processes for the following phase. These individual processes will be discussed in more detail.

INVESTIGATION PHASE

During the investigation phase, potential projects will be identified and investigated. Project approval needs to be accepted by various stakeholders before implementation can commence. The order of events or actions is as follows:

1. The project identification by the ESCo quantifies the possibility of a project.
2. The necessary electricity bills and relevant site information should be obtained to start the investigation. This information should include the relevant component drawings, site layouts and the installed and running energy capacities of individual components. The electricity bills can be used to investigate the present energy profiles.
3. With the obtained information, the potential DSM project should be investigated to determine the possible energy and cost savings. Simulations and measurements will assist in obtaining some expected results. During this event, an electricity baseline should be compiled to best suit the operational situation on the site. The production demands and availability of the relevant components should also be investigated with great care.
4. After investigating the potential project, an executive summary should be compiled. The background of the project as well as the obtained results should be included in this investigation findings report. Possible upgrades or installations that will assist in obtaining the required results should be indicated in this report.
5. The investigation findings report will assist in compiling a proposal document to be sent to the energy provider. The energy provider will need to approve the project in order to offer the necessary funding for the project and installations.
6. The investigation findings report can be used in addition when compiling a complete project scope document. This document will be sent to the relevant client for approval. Top management on site will suggest requirements based on their internal processes.
7. The scope document will also be sent to the relevant contractor. The options for contractors should be thoroughly compared to determine the best engineering solution within budget prices and requirements for the specific project. Once the contractor is selected and the scope approved by the client, the order for installations can be placed.
M&V are required to attend an initial site visit accompanied by the ESCo. Two documents should be compiled by the M&V team after this site visit. The M&V scope report will include a general project overview. The purpose of the project and the potential savings should be included. The M&V plan report includes the detail of the relevant components involved in the project. The measurement details and expected baseline periods are stipulated in this report.

The M&V team will compile an additional report to confirm the submitted baseline. This baseline report will be generated as soon as the M&V scope report and the M&V plan report have been signed off by the relevant representatives. The M&V baseline report will include a detailed data analysis of the total energy profiles of the specific project. This submitted baseline will serve as the benchmarked baseline during project assessment.

PROJECT IMPLEMENTATION

After the scope document has been signed and the project proposal has been approved by the electricity provider, the project implementation phase can commence. During the implementation phase, the setup of the relevant systems which will assist in the assessment period will be installed. The relevant steps in the implementation phase include:

- The installations of the required infrastructure will be provided by the contractor. The contractor will need to provide an acceptance document after the installations have been done. This document will serve as confirmation of the accuracy and functioning of the installed items.

- The internal systems need to be set up and installed by the ESCo. These systems include the control strategies for the energy management of the components. Automated data collection and monitoring screens should be set up. The communication connections to the relevant energy systems on site should be activated.

- After the installations have been completed, the relevant training should be provided to the required personnel on site. This will ensure immediate response on the project when the ESCo is not available on site. The ESCo will provide continuous support and assistance during the project lifetime.

- As soon as all the steps mentioned above have been completed successfully, a certificate of completion (CoC) should be signed off by the client. This signed document will indicate that the implementation phase has been completed.
The M&V team should attend a post-implementation site visit after the CoC has been signed off. The site visit will confirm the accuracy of the installations specified in the M&V scope report.

**MONITORING AND CONTROL**

During this phase the actual project performance will be evaluated. The preparations and installations of the required systems have been completed to assist in the assessment period. The responsibility of the performance during this project phase is dependent on the ESCo.

- **Performance assessment (PA)** requires a three consecutive month evaluation period. During these three months the actual energy performance is compared to the contracted target. The ESCo needs to prove that the investigated potential can be achieved [2].
- The ESCo and M&V team should provide continuous feedback on the performances during this project phase. Reports can be generated daily, weekly and monthly. This will create awareness for the client regarding the performance. These reports should indicate the possible problems or opportunities to maintain the target performance.
- After the PA period has been completed, the client should approve the achieved performances. The measurement acceptance date (MAD) certificate will also transfer the responsibility of maintaining the performance to the client.

M&V performance tracking reports will be generated monthly. These reports will indicate the achieved performance compared to the set target. The under- and over performances will be indicated as a percentage of the target.

After the three PA months have been completed, the M&V team will compile a M&V performance certificate to indicate the average performance. If necessary, the project target will be adjusted for the remaining period of the project.

**MAINTENANCE AND SUSTAINABILITY**

DSM projects are signed for a five year contract [28]. The performance should however be maintained by the client for the remaining period. The contracts are signed during the investigation phase. Therefore the client has a contracted responsibility for about five years.

- The key requirement for the client is to maintain the energy performance target as agreed upon in the MAD certificate.
- The ESCo should provide continuous support during the duration of the project. The support includes the reporting of the performance and assistance, where necessary.
1.3. INTERNATIONAL ORGANISATION FOR STANDARDISATION (ISO)

1.3.1. GENERAL

ISO is an international federation that identifies fundamental requirements for certain standards around the globe. The federation consists of different national members around 160 countries. These countries are determined by their economy types and they adopt the standards accordingly. Technical committees prepare these international standards. ISO is a non-governmental and voluntary organisation [14].

ISO provides standards for most business sectors worldwide. The standards can be used to improve organisational and management strategies within companies. In complying with relevant ISO standards, a company’s global competitiveness and trades can be improved.

The purpose of the standards is to ensure safe, reliable and quality products or services. Companies that are ISO certified can experience various economical, technological and corporate benefits in the market [15].

Two beneficial values of international standards are the improvement of productivity and the introduction to new international markets. The standards set the principles within a competitive market which indicates fair trade. Other benefits for companies include [15]:

- Operational cost savings to increase profits,
- Higher operational and product qualities. Thus resulting in increased customer demands and sales due to higher client contentment,
- Improved competitiveness in international markets,
- Reduced environmental impacts.

The federation originated in London in 1946. With more than 19 500 standards published to date, they are known as the world’s largest federation for developing international standards [16]. In 2012, ISO covered most sectors within the business world as seen in Figure 1-11. Engineering and material technologies consist about half of these sectors.

Three ISO standards will be discussed in this dissertation. They include ISO 9 000 (Quality management), ISO 14 000 (Environmental management) and ISO 50 000 (Energy management).
Energy management will be the main focus for this study. The integration of the other two abovementioned standards will assist in utilising the ISO 50 001 standard most effectively.

1.3.2. ISO 9 000: QUALITY MANAGEMENT

The first standard for quality management was published in 1987. With the increasing success and awareness of the standard and its benefits, the ISO 9 000 has become one of the most popular standards [16].

It has been proved in a survey completed in Greece that the ISO 9 000 standards can introduce a strong foundation for an organisation’s internal structure. The improvement of internal structures and processes is one of the most valuable benefits for overall success [17].

The ISO 9 000 series addresses various aspects as indicated in Figure 1-12. Companies implement these standards to ensure continuous quality on their products and services as required by customers.
It has been proven over the past 60 years that a company’s competitiveness and economic status will increase with an effective quality management system [19].

**ISO 9001:2008 – QUALITY MANAGEMENT SYSTEM**

The ISO 9001 standard includes the requirement for certifying a quality management system in a company. The standard includes the process approach, customer requirements, top management and continuous improvements [20].

Internal audits of this standard are required for each organisation. It can also be audited by the client themselves. Each organisation can develop their unique quality management system according to their relevant management needs.

The process approach within an organisation refers to the identification, interaction, application and management of a system of processes to produce the preferred outcome.

The development of the ISO 9001 standard is influenced by [20]:

- The organisational environment;
- The requirements for the company for quality management;
- The organisation’s objectives;
- The products produced or services delivered;
• The various processes within the company; and
• The organisation’s size and structure.

A key focus for this international standard is to ensure that customers are satisfied with the required product or service. An effective quality management system can assist with satisfying the purpose. To implement an effective system, organisations have to identify and control relevant activities.

The successful management of inputs to obtain the required outputs can be defined as a process. These processes need to be investigated properly as outputs for one process could be inputs for the following processes.

If the standard’s requirements are implemented accurately, unnecessary processes may be eliminated. This will result in the innovative development of a system that delivers increased quality outputs for corporate achievements [21].

1.3.3. ISO 14 000: ENVIRONMENTAL MANAGEMENT

Similar to the ISO 9 000 family of standards, ISO 14 000 also defines various criteria specifically on environmental management. It assists in identifying an organisation’s impact on the environment. These impacts can be controlled with the assistance of provided guidelines to improve the organisation’s environmental performance [22].

1 Photo captured from The F.B. Andersen Group at http://fbandersengroup.com/
The ISO 14 001: 2004 and ISO 14 004: 2004 standards focus primarily on the development and implementation of an environmental management system. The remaining standards in the ISO 14 000 series define detailed process steps regarding environmental management [22].

ISO 14 001: 2004 – ENVIRONMENTAL MANAGEMENT SYSTEM

This international standard provides guidelines for organisations to implement an effective environmental management system. It does not define set requirements for companies’ environmental performances. It assures effective measurement and improvement of a company’s environmental impact [22].

ISO 14 001 certified companies have the following benefits [22]:

- Cost reduction on waste management,
- Energy savings,
- Distribution costs decrease,
- Enhanced competitiveness.

The environmental management system involves the improvement of a company’s environmental performance. The key solution to achieve this purpose is to create a management strategy which involves the individual awareness of environmental irregularities. Every employee should report all environmental risks as soon as it is discovered [23].

The complete and continuous awareness, education and the initiation of a positive environmental culture could result in an effective environmental management system. Small and large irregularities should be reported. These polluting factors should be prioritised and resolved [23].

1.3.4. ISO 50 001: ENERGY MANAGEMENT

ISO 50 001 is a published standard that describes an EnMS. The ISO 9 001 (quality management system) and ISO 14 001 (environmental management system) standards assisted in the development of this standard. Thereafter it was published and released by ISO in 2011 [24].

The standard provides specific requirements and guidelines to develop, implement, manage and improve an EnMS [25]. The main intention of the standard is to control and minimise the total energy consumption for companies. Employment behaviour and process changes within
feasible boundaries can outline the activities that will ensure the achievement of the purpose [26].

Unlike the ISO 9000 series, ISO 50001 does not have a series of standards. The ISO 50001: 2011 is the only standard that describes energy management and is used for certification. An integrated certification from some of the other ISO standards can be achieved and accepted by ISO 50001 [25].

These other standards include ISO 9001 (quality management), ISO 14001 (environmental management) and ISO 22000 (food safety management) [25]. An organisation can set its own requirements and goals to achieve within their EnMS. There is no predefined or set objectives in ISO 50001.

The main focus of the standard is for an organisation to follow a strategic model to successfully manage energy consumptions and performances. It is expected that the ISO 50001 standard will influence about 60% of the energy used internationally [27]. Similar to ISO 9001, it is meant to ensure continual improvement throughout its life cycle.

The Energy Intensive Users Group of Southern Africa investigated the effectiveness of implementing the ISO 50001 standard. According to a survey done in 2013, results indicated that 10% – 20% of electricity savings can be obtained within the first two years of implementation [3]. A 10% reduction on energy costs have been proven within the first year of implementing an EnMS according to ISO 50001 [28].

The ISO 50001 standard follows the continual Plan-Do-Check-Act (PDCA) cycle. Organisations need to implement this cycle into their daily energy management strategies [29]. Figure 1-13 illustrated the PDCA cycle according to the ISO 50001 standard. The energy policy and energy plan should be investigated and developed during the planning phase. The energy plan should then be implemented during the second phase.

During the act phase, an organisation’s energy performance and effectiveness of the management system should be analysed. Finally the necessary amendments should be modified on the system. The management’s decisions will be based on the performance results. The criteria and requirement for each step will be discussed in more detail in Chapter 2.
ISO 50 001 guides an organisation to achieve the following [24]:

- Develop a system to manage energy more efficiently,
- Establish unique requirements and goals to achieve within the system,
- Process data to explain and control energy usage more effective,
- Compare and provide intelligent feedback on the processed data,
- Monitor the system,
- Improve the EnMS continually.

An EnMS can be seen as a tool where relevant energy data is obtained by means of a structured process [26]. Hardware and software are used to obtain, manage and report on these processed data.

ISO 50 001 specifies general requirements to develop an EnMS. These requirements should however be met for an organisation to be ISO compliant based on their energy management. These general requirements include the establishment, documentation, implementation,
maintenance and improvement of an EnMs that complies with the published requirements of the international standard [29].

The published requirements entail the organisation’s unique scope and benchmarks to be properly defined and documented. The strategy on how the organisation will achieve their requirements should be determined. Continual improvement of both the organisation’s energy performance and the complete EnMS should serve as this strategy’s main purpose [29].

Management should commit their continuous support and involvement to the EnMS. They should ensure effective improvements overall. It is recommended for top management to appoint a representative to assist with the management of this process. This representative should possess the necessary skills and should be fully responsible to run with this process. The management team’s main responsibilities include the development of the energy policy, resource allocations and proper communication among all role players [29].

General recommendations and frameworks can be established within each uniquely developed EnMS. This will serve as the benchmark by which energy performances can be measured. By implementing a strategy with unique benchmarking targets, more realistic financial benefits can be seen.

1.3.5. INTEGRATING THE RELEVANT ISO STANDARDS

Three ISO standards were mentioned in this chapter. For the purpose of this study, the ISO 50 001 standard will be integrated to develop and implement a unique EnMS. The main purpose of DSM projects is to motivate efficient energy usage. The quality of these management strategies could be improved and therefore the integration of the ISO 9 001 and ISO 14 001 standards would be beneficial to the processes and in turn the end product.

A key purpose of ISO standards is to ensure quality processes. The effective transformation of inputs into outputs should be maintained to meet customer requirements. For the industrial sector, a balance should be maintained between production demands and energy management. The implementation of the required quality services within the ISO 9 001 standard could be integrated into the developed EnMS.

Companies can improve their environmental sustainability and their economic situation with efficient energy management. This can also help alleviate and control the climate changes [30].
Environmental management sets its own requirements and benefits within an EnMS. Environmental permits are required within various industries around the world. Without permits no operations can occur. Permits can be granted to companies with efficient management of energy resources [31].

For companies to maintain their environmental impacts, key performance indicators (KPI) should be defined. This integrates with the EnMS, as greenhouse gas emissions are being monitored and reported [31].

Demands of sustainable development for companies can be ensured with the efficient management of energy. Environmental and financial benefits are visible with the achievement of these EE targets [32].

Most organisations which have previously implemented the ISO 9 001 and ISO 14 001 standards, should already have certain elements of the ISO 50 001 standard in place. These elements include an energy policy (relative to a quality policy), performance goals and resource allocations and management [33].

A survey was conducted in 2008 among 27 companies to investigate the relevance of these ISO standards. The companies were distributed between various sectors such as the chemical, electronic and pharmaceutical industries.

The results of the comparison between energy policies and energy performance goals are indicated in Figure 1-14. Graph A indicates the amount of ISO 9 001 / ISO 14 001 certified companies with an existing energy policy. From the companies with an existing energy policy, a total of 93% also have energy performance goals. This result is illustrated in Graph B.

![Graph A: ISO 9 001 / ISO 14 001 certified companies with an existing energy policy.](image)

![Graph B: Energy performance goals for companies with an existing energy policy](image)

Figure 1-14: ISO 9 001 / ISO 14 001 certified companies' energy policies and energy performance goals.
Companies with a certified ISO 9001 or ISO 14001 system should be able to have an energy policy or relevant document. The quality policy developed during the ISO 9001 standard could be extended to an energy policy by adding the relevant energy performance objectives. No additional document is required when the quality policy exists [29].

1.4. THE NEED FOR AN ENERGY MANAGEMENT SYSTEM

As mentioned in Section 1.2, South Africa is in a stressed situation involving electricity usages. Due to the unreachable high electricity demand for Eskom, the electricity costs also rise significantly.

The annual electricity tariff increase is higher than the CPI. This results in an increase on production costs within local industries. With all these price increases, the need to obtain cost savings in various ways has become crucial.

The consumption of energy within big industries is manageable to a certain extent. Therefore, the need to develop and implement an EnMS arises. Companies with the focus on continuous improvements for their energy management processes and waste reduction, have increased their profitability and operative quality. This has resulted in improved productivity, global respect and significant profit increases [27].

The need for companies to manage their energy more efficiently has become so important, that two new tax policies were recently introduced. The 12L EE tax incentive took effect in November 2013 [2]. A 45 cents per kWh allowance will be awarded for annual electricity savings [32]. This is applicable to all energy sources.

South Africa is aiming to undergo a feasible transformation to a low-carbon economy. This will assist in maintaining a successful economy and growth strategy that is environmentally satisfied. The introduction of a carbon tax policy will also address the climate changing elements [32].

The carbon tax policy is planned to be operational by 2016 [2]. It serves as South Africa’s commitment to manage energy more efficiently. The reduction of greenhouse emission gasses is the main purpose behind this policy [3].

Penalties will be charged to those companies that do not strive for these behaviour changes. The proposed carbon tax will be billed at R120 per ton carbon equivalent [34]. On the contrary,
a reward system will also be initiated to help encourage this improvement in energy management. This tax policy has been effective in Europe, resulting in lasting behaviour changes [3].

The performance outcome of certain DSM projects decreases after PA. This is due to a lack of proper maintenance. With this inadequate management of energy consumption, money is wasted and electricity demands increase yet again. The possibility of penalties increase and funding for future DSM projects get limited when these projects underperform [2].

In order to increase the performance of EE projects, the awareness of the energy impact should be improved. Energy usage per component should be measured in more detail. Real-time measurements will also increase the awareness more frequently [35].

1.5. SCOPE OF THE STUDY

The mining industry in South Africa is one of the largest electricity consumers. They consume nearly 15% of the annual electricity provided by Eskom. Gold mines consume about 47% of the total electricity within the mining industry, making it the largest energy user in the industry [9].

Gold mines have to sustain their profit and production goals. With the conscious concern of increasing electricity costs and the weakened gold price in South Africa, proper energy management is essential for gold mines.

Various energy consuming areas in the mining industry can be managed in order to save electricity. Therefore different DMS projects will be used to compare when explaining the universal use of the EnMS. The total energy consumption cannot always be reduced, but can be managed according to the Eskom’s time of use (TOU) tariffs.

This dissertation will describe an effective EnMS developed and implemented according to ISO 9 001 and ISO 50 001 standards. South Africa’s third largest gold producer will be used to implement the EnMS for their DSM projects together with the ESCo model. It should result in an increase in the performance impact for the duration of project implementation as well as the maintenance period. The cost savings for these time periods should also increase after implementing the EnMS.
1.6. DISSERTATION OVERVIEW

As identified in the ISO standards above, the PDCA cycle approach will be followed throughout the thesis. ISO standards are based on continual improvements. An EnMS has to repeat the PDCA cycle in order to be successful and compliant. This will be illustrated in the thesis by defining each step of the PDCA cycle in the development of the EnMS. The basic steps of the PDCA cycle are illustrated in Figure 1-15.

![PDCA Cycle Diagram](image)

Figure 1-15: The PDCA cycle to implement the EnMS.

This chapter discussed the electricity crisis in South Africa together with an effective solution to the problem. DSM projects can be implemented to limit the crisis. A short overview of each of the ISO 9001, ISO 14001 and ISO 50001 standards was also provided.

**Chapter 2** discusses the benchmark methodology for developing the EnMS. The expected strategies and results were included. ISO 50001 requirements were integrated within the developed EnMS. The PDCA approach was followed to define the process steps.

**Chapter 3** provides the results of the implemented EnMS on a gold mining company. The PDCA approach was once again used to compare the benchmarked system and the actual results.

**Chapter 4** defines the conclusion of the results. Benefits of the EnMS and recommendations for further improvements were provided.
2. CHAPTER 2: DEVELOPMENT OF AN ENERGY MANAGEMENT SYSTEM FOR CONTINUAL PROJECT IMPROVEMENT

2.1. PREAMBLE

An EnMS serves as a centralised network for companies to manage their energy performance. The most efficient systems are created electronically and usually online. This ensures real-time data to be processed and therefore reported instantly. The management team can access the system from wherever internet access is available.

Figure 2-1 illustrates the research approach taken for this study which is based on the ISO 50 001 standard. The developed EnMS will be based on the requirements of the ISO 50 001 standard. The standard requirements and relative development activities will be discussed in this chapter. The results of the implemented EnMS on a gold mining company will be discussed in Chapter 3.

![Figure 2-1: Thesis methodology resulting in Chapter 3.](image-url)
Organisations need to be aware of the advantage and how to successfully manage the relevant ISO standards. The PDCA cycle represents a framework for these relevant processes to be improved continually, as seen in Figure 2-1. There is no final destination or conclusion for an ISO system.

Evidently the initial development process of an EnMS has to be done completely. The revisions will only be to improve on the work already done. With the regular monitoring of the system, results will become inputs to the next analysis or improvement. The PDCA cycle will help ensure the best possible implementation and sustainability for an EnMS.

This chapter will describe each step in the PDCA cycle for an EnMS according to two methodologies. The first will be the defined requirements set for each step published in the ISO 50 001 international standard. The second methodology will describe the unique strategy for the EnMS developed for this study.

The steps in the PDCA framework illustrated in Section 1.3.4 define the mandatory actions for an ISO compliant EnMS. These steps will be described in more detail under the relevant sections later in this chapter. All steps should be reviewed and updated when necessary.

### 2.2. PLAN: SYSTEM INVESTIGATION

**2.2.1. INTRODUCTION**

Due to the familiar awareness of the national energy crisis within South Africa, workforces in most industries are already aware of the need for electricity savings. Maximum electricity savings can be obtained with the implementation of an efficient EnMS. These electricity savings can result in increased profits, productivity and competitive advantages [15].

The first step when investigating the development of an EnMS is to decide on the correct type of information required to satisfy the uniquely defined purpose of the system. All relevant energy data should be collected in the most feasible and accurate way possible [26].

During the investigation phase, certain aspects should be analysed and determined [26]:

- Short- and long-term goals,
- Resources that should be accountable to manage the system,
- Identifying the areas for electricity savings, relevant costs and production processes,
• All the data obtained should be sorted,
• Develop legal requirements and guidelines,
• Set realistic goals for the operational plan,
• Drafting a predefined energy management plan.

2.2.2. REQUIREMENTS FOR ISO 50 001

Two mandatory requirements that have to be developed during the plan phase in the EnMS include a documented energy policy and an energy plan [29].

The energy policy’s main purpose defines the commitment of the company to achieve continual improvements on their energy performance. An accurate representation of the organisation’s energy usage and consumption history should be reflected in the policy. The benchmarking targets and energy related objectives should be established. The policy should define the availability of the required resources and information to obtain these targets and objectives [29].

An organisation’s energy planning framework should correspond to the energy policy mentioned above. This will indicate the action plan that will follow in order to achieve the objectives and targets defined in the policy. Legal requirements relative to an organisation’s energy situation should be revised. The energy planning framework should include a detailed energy review, baseline development, performance indicators and the established action plan for the objectives and targets [29].

2.2.3. PRACTICAL REQUIREMENTS FOR DEMAND SIDE MANAGEMENT AND ISO

The initial step in developing an ISO 50 001 based EnMS is to compile an energy policy. It should be easily understood and may consist of only a few sentences to a few paragraphs. It should correspond to the organisation’s operations and nature of the company [36].

The process of successfully implementing DSM projects can be challenging. The initial performance may indicate a good trend. Thereafter the personnel start losing interest and focus on different operational aspects. These aspects may be equally important or even more crucial than energy management.

All DSM projects should be maintained effectively after project implementation. The sustainability of these projects may have significant cost and environmental benefits. Electricity cost savings and environmental tax rebates can improve an organisation’s profit margins.
Companies end up paying more money in penalties and electricity costs than saving those energy performance costs. This emphasises the need for an energy management representative. This employee or management team should take full responsibility for effective energy usage for the duration of the project.

Various ESCos around South Africa can be contracted to assist in the energy management strategies. The project specific strategies applied to these industrial projects should consider each client’s demands. The strategies should be developed around an organisation’s production demands, forecasted sales, operational preferences and seasonal demands.

SOFTWARE

EnMS are usually developed online to increase the availability for accessing the system in real time. Developed software can ease the understanding of compared energy consumptions. Graphical illustrations of processed data, additional calculations and reporting can be set up according to the client specifications [26].

Automation of certain equipment can be developed. This automation can assist in the management of energy consumptions to avoid Eskom peak periods. Software can be developed to continually monitor the relevant buffer levels of the system.

The gold mining industry requires the capability of optimising their operations according to the production targets. The management of electricity intensive components such as winders and pulverising mills will result in major electricity cost savings. Mining events in the surrounding areas of the shafts usually cause production bottlenecks. Storage silos can be utilised as buffers in the optimisation structures [37].

With the relevant buffer levels, schedules can be optimised to prioritise energy consumptions within the different TOU periods. Off-peak hours will have the highest priority, and Eskom peak hours the lowest. Therefore the load will be shifted to off-peak, then standard, and finally peak hours. An example of automations is the dewatering pumps in deep level mines [2]. The buffer levels in this situation will be the water levels on the relevant dams.

Accurate optimisation and operational planning can indicate an immediate energy cost reduction. The modelling of such operations should be developed according to the specific industrial components. These components are divided into three different categories. They
include the: (a) components responsible for processing, (b) buffer constraints, and (c) distribution paths [37].

Two types of operational modelling techniques can be considered. These include discrete- and aggregate modelling. A comparison among the two techniques is summarised in Table 2-1 [37].

<table>
<thead>
<tr>
<th>Discrete modelling</th>
<th>Aggregate modelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time interval analysis (TOU).</td>
<td>Consider daily analysis</td>
</tr>
<tr>
<td>Variables represent time intervals.</td>
<td>Variables represent production volumes.</td>
</tr>
<tr>
<td>Manages buffer levels.</td>
<td>Manages production demands.</td>
</tr>
<tr>
<td>Results include real-time production volumes.</td>
<td>Production outputs are rearranged to compile daily operational schedules.</td>
</tr>
</tbody>
</table>

Discrete modelling can be used in LS and PC projects. The energy loads should be minimised during Eskom peak hours. The highest priority of energy consumption should be during off-peak hours, and alternatively standard hours.

The forecasted buffer levels such as silo and reservoir levels should be analysed in real time to compile these schedules. Associated industries can include cement production and water pumping networks. An illustration of the discrete modelling technique is indicated in Figure 2-2.
Unlike the discrete modelling technique, the aggregate modelling technique manages buffer levels at the end of an operational period. The related projects involve singular production extractions during this scheduling period.

The mining industry sets a good example of where aggregate modelling can be used. The single skips extracted from the mine can be managed accordingly. The aggregate modelling technique is graphically demonstrated in Figure 2-3.

![Figure 2-3: Example of the aggregate modelling approach.[37]](image)

The developed EnMS will include both these modelling techniques to accommodate various projects. The appropriate calculations for these techniques should be developed by skilled and experienced personnel.

**HARDWARE**

Relevant infrastructures could be crucial in managing energy usages effectively. In order to obtain the most accurate and relevant data, several measuring units should be available. The
appropriate measuring techniques have to be selected to send and communicate the data to the mining control system [26].

The required hardware installations will differ from each individual DSM project. The project requirements and available infrastructure should be investigated in detail before any decisions can be made. The client preferences could also provide a good indication. The mining personnel are aware of the existing systems and the lacking thereof.

Some of the proposed infrastructures that can be installed may include the following:

- Computer servers,
- Power meters,
- Flow meters,
- Level indicators,
- Programmable logic controllers (PLCs),
- Various pumping valves, etc.

MAINTENANCE REQUIREMENTS

DSM project funding from Eskom’s Integrated Demand Management programme includes the installation of certain equipment to assist in the implementation of the project. This equipment will also be necessary to work accurately during the maintenance periods. The different parameters should display accurate values in real time.

Specific skills may be required to maintain an EnMS effectively. With this responsibility comes certain doubts and slip ups. It is therefore strongly recommended to assign an ESCo to assist in the maintenance of the DSM project. Specialised training should be provided to the responsible client personnel.

ESCs specialise in the management of these implementation projects and provide a maintenance service. The benefits of contracting an ESCo for maintenance management include [2]:

- Reduce the client’s responsibilities and amount of work,
- Ensure that management and control strategies get updated continuously,
- The control system and relevant equipment are maintained when necessary,
- Project performances and operational philosophies are monitored. This assists in the achievement of maximum performances,
Reduce the possibility of penalties when underperforming,
Ensure that the relevant operational hardware is monitored and accurate. This may include certain pumps, valves etc.,
Available for day and night support,
Provide daily feedback reports regarding the previous day’s energy performance. The awareness can result in more electricity savings,
Arrange monthly meetings to provide feedback on the performances. Possible suggestions and problems will also be addressed,
Provide assistance through the management of the relevant installed infrastructures. The necessary upgrades and repairs will be arranged,
Share experience and provide assistance to client personnel about reporting, budgets, operational strategies etc.

Post implementation can be more valuable than the PA period. Effective project maintenance is responsible for sustainable electricity savings. Organisations are responsible for maintaining the target impact savings after the PA.

Eskom penalties will be charged for underperformances. The benefits of maintaining DSM projects effectively have positive effects on a company’s financial status. Instead of paying penalties, remarkable electricity cost savings can be achieved.

2.2.4. POSSIBLE CONSTRAINTS

Most industries find energy management optional within their operational strategies. Energy management is seen to be financially draining, but the complete opposite should occur when managing the system effectively [33].

Some of the most popular reasons why DSM projects underperform are [2]:

- The projects are being implemented and handed over without assigning a specific person to take full responsibility of the maintenance.
- Limited capacity and skills of the client personnel to ensure that the newly installed equipment for the project is maintained.
- Client personnel are cautious to claim project responsibility after PA. They are terrified that they will not be able to maintain the target amount of savings. It also increases their amount of work.
Supervision on the project performance does not occur daily. Breakdowns and other relevant problems may occur which may lead to long-term constraints. These problems should be prevented or otherwise investigated and solved as soon as possible.

Absence of continuous updates on the control strategy. When production and operational changes occur, so should the EnMS.

Electricity savings may be a lower priority to client personnel. Safety and production strategies are seen as higher priorities and therefore take all the time from an EnMS.

People are resistant to change. Companies do not see the actual money coming in. Electricity cost savings are therefore only an indication on actual money. They do not realise the impact of the savings. To motivate the idea of electricity savings, Eskom has announced incentives to reward companies who save energy. So instead of paying for electricity, they get paid for saving electricity.

Proper management training should be provided, whether ESCos are completely involved or not. With the confidence that employees are familiar with the strategies to save energy, the mind-set will automatically indicate positive performances.

Continuous communication between the operators and energy management team should be ensured. Operating schedules should be discussed and confirmed daily to guarantee the most efficient energy usage.

Data collection and the accuracy of data can be an uncontrollable constraint. Network communication between on site and external servers could get lost or have a slow connection. These connections usually take a lot of effort to repair. Crucial real-time data could get lost. The ideal setup would be to connect an alternative data source for data collection.

2.3. DO: IMPLEMENTING A MANAGEMENT SYSTEM

2.3.1. INTRODUCTION

As soon as the EnMS has been investigated sufficiently, action needs to be taken to implement the system. The steps in the action plan previously defined needs to be prioritised. These prioritised steps will then create the detailed working plan. A predetermined time needs to be allocated to each individual task. The necessary resources should be appointed accordingly [26].
Certain key events in implementing an EnMS should be emphasised. This includes the appropriate training for the selected personnel within various parts of the system. Continuous communication among all relevant stakeholders is crucial. The process steps of the system should be documented. These documents should be checked regularly [26].

2.3.2. REQUIREMENTS FOR ISO 50 001

This international standard defines general guidelines for the implementation of the action plan developed in the plan phase. Organisations should ensure that they employ skilled and educated teams. The necessary training and awareness programmes should be provided regularly. The team should be aware of their responsibilities as well as the consequences when not met [29].

External and internal communication is essential. The relative circumstance should be investigated to determine the appropriate communication method. The operational plan includes the processes relative to the general operations and the maintenance afterwards. New processes could be designed to improve energy performance [29].

2.3.3. ENMS INTERFACE

The online management system should include a company homepage where all the energy information is available for the relevant personnel. The web interface should always be online and accessible to the approved personnel.

Limited access should be granted to specific personnel. Managers should be able to analyse electricity accounts and financial information. Accurate business decisions could therefore be made as soon as possible.

Operators should be able to access component specific details. Actual running capacities and intensity figures should be monitored regularly. Daily operating schedules should be investigated and communicated to the relevant management team. The interface could also be displayed in the control room for effective control.

The web-based system should consist of two separate interfaces. The engineering interface where the development occurs and the client interface. The client interface could also be divided into various preferred screens as decided by the mining managers.
The development team should be able to access the administrative side of the system. The editing and setup buttons should be displayed to improve the system without any effort. Report generations should be compromised for editing as regular changes could occur.

Confidentiality contracts should always be signed to protect both the developer and the client. The client should also not be allowed to access the engineering interface as development strategies could also be seen as intellectual property.

The mining managers should meet and decide in advance which personnel should access specified parts of the system. The different interfaces could be accessible by personal login credentials set up by the developers.

Ideally the managers would have access to all the available information and data. Top management decisions should also be indicated on the EnMS for future references. These decisions could be shared to all users or only specified ones.

Operators and technical advisors would normally be able to access component and project details. The energy profiles and impact performances should be displayed on a daily, weekly and monthly basis. All the previous performances should also be accessible at any time. Project progress should be tracked when necessary.

Feedback reports should be available for investigation or to be downloaded. Various energy elements should be combined to investigate multiple levels of management simultaneously.

2.3.4. REPORTING

One of the key requirements throughout the ISO 50 001 standard is documenting and reporting on energy performances [29]. Top management should review these reports at planned time intervals. Regular feedback and suggestions will ensure effective energy management procedures. Reporting helps identifying new problems or constraints. These constraints should be addressed as soon as possible.

Energy data defined in the investigation phase should be obtained. For the most efficient reporting operation, the collection of real-time data is recommended. Various data collection methods are available from industries. These methods include the following:

- Supervisory control and data acquisition (SCADA) system or a similar mine controlling system (real time),
• Online databases (real time),
• Manual data collection. This includes power loggers, log sheets etc. (historical data),
• Electricity bills (historical data).

The reporting process also follows a PDCA cycle. Data is collected from the mine and sent to a centralised server through the available communication module. These methods and modules should be investigated to utilise the most effective path [28].

The received data is now processed at the centralised database. Various reports are generated from these processed data and sent to the required resources. Top management reviews the reports and verifies their accuracy [28].

Feedback and discussion meetings are held to communicate problems and improvements with the rest of the energy management team. After meetings, improvements or modified operational schedules can be sent to the system to be processed accordingly [28].

Feedback on various occasions is required due to the extent of investigations. It is therefore recommended to report on different sections of time. Daily, weekly and monthly reports will have corresponding information. The level of detail on each report will be the decisive indicator on what to provide feedback on. This section will provide the development and setup of the reports. The compiled reports and results will be discussed in Section 3.3.3.

**DAILY REPORTS**

Daily reports should contain excessive detail regarding the daily operations. Data can be analysed hourly or even half-hourly to improve the accuracy. The actual daily power profile will be compared to the benchmarked power profile (calculated baseline).

The energy performance and cost savings will be determined accordingly. Energy consumptions and production figures can also be compared to determine the efficient use of energy. The daily report will be based on an individual technology on the specific mine (project specific).

The daily reports will indicate the daily energy performance, daily cost savings and missed opportunities in monetary value. The cumulative values will also be included and summed up according to the month to date. The power profiles under comparison will be illustrated in a graph format. An indication will be provided to compare the different tariff usages over the entire day. This will be indicated as a percentage over the total hours per day.
WEEKLY REPORTS

Weekly reports include less intense data processing than the daily reports. This is due to the broader reporting period. These reports will focus on an entire mine with all its components involved. A breakdown of each component will be provided to indicate the performance and opportunities within the specific mine’s operations. This allows the mine to monitor all the DSM projects in one weekly report [28].

Actual power consumptions will be compared to the target amount of power consumed. The component specific targets should be provided by the mine. The data will include the total energy consumption for the reporting week, as well as the total for the month to date.

In the breakdown structure for each component, the abovementioned power consumptions will be illustrated cumulatively on a graph according to the daily performances. The average daily power profile for the week will be compared to the daily target. An illustration of the total power consumed during the different TOU time periods within the week will be included. The compared energy costs to the power consumed will also be included to illustrate the cost impacts.

MONTHLY REPORTS

Management uses monthly reports to obtain a wider view and average performance of the projects and mines. For more in-depth detail they can refer to the weekly and even daily reports. Monthly reports will consist of two different reports. The first will report on the monthly performances of a specific DSM project. The second will provide a monthly summary of the entire mining group.

Similar to the weekly report, the monthly report’s content will include average power profiles and performance impacts. The monthly reports will focus mainly on the energy performances and thus indicating the over- or underperformance for management to establish possible improvements. Total cost savings and missed opportunities will be included to assist with the management decisions.

The daily and weekly reports are used to analyse and manage each mine’s electricity usage. The monthly report contradicts these management strategies. It is used to review monthly targets, addressing risks associated with electricity costs and the effective allocation of resources [28].
CUSTOMISING REPORTS

Reports can be customisable in various aspects. The reporting time period could be selected as preferred. Personnel should be able to choose specific components or projects within a mine that should be included in these special reports.

Mining managers should be able to login onto the EnMS and generate reports according to their preferences. The distribution of the reports should either be emailed to selected personnel or downloaded to the present operating system.

Daily, weekly and monthly reports should also be customisable according to mining operations. The development and layout of these reports should be modified according to new technology areas. Additions and eliminations of certain elements should be made possible.

Continuous improvements on the system will be decided by top management. These improvements and suggestions should also be indicated accordingly on the reports.

2.3.5. CONTINUOUS AWARENESS AND TRAINING

After reports have been generated, they should be discussed on a daily, weekly and monthly basis. Even small suggestions and changes should be communicated to all relevant personnel. Small improvements could affect major impacts in the long term.

Individual problem identifications should be reported as soon as possible. The most effective problem solutions could then be developed. Top management should also keep operators informed about new operational changes. The awareness can be implemented instantaneously. Consequent improvement impacts should be visible sooner.

With the possible new improvements and strategies, come new responsibilities. Continuous training on these levels should be provided to obtain effective results. The required skills and education should be ensured before attempting new strategies.

The extent of the training should be determined wisely. External training could be provided where technology improvements occurred. Internal training would be better if operational changes were introduced. Speciality training should therefore be provided accordingly.
2.4. CHECK: MONITORING THE EFFECTIVENESS OF THE ENERGY MANAGEMENT SYSTEM

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2.4.1. INTRODUCTION

After the EnMS has been implemented, the quality of the system should be evaluated. The energy savings performance results should be interpreted. The over- or underperformance information should be discussed where after possible suggestions and improvements should be communicated.

The guidelines that require monitoring in an EnMS includes [26]:

- Performance measurement and supervision,
- Confirm legal compliancy,
- If certain goals have failed, creative solutions and preventative plans should be developed,
- Organise internal and external documents,
- Internal process inspections,
- Evaluation on resource management.

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2.4.2. REQUIREMENTS FOR ISO 50 001

Continuous monitoring, measurement and investigations of key requirements at planned intervals are essential when implementing an EnMS. Top management should provide input and output reviews at planned intervals [29].

The process of data collection is important in the overall EnMS. Accuracy of measuring equipment should be confirmed. Major deviations in the energy data should be investigated. Relative legal requirements should also be analysed [29].

Internal audits should be conducted to determine the efficiency of the energy plan. The present status and significance level should be determined and compared to previous results [29].

Where needed, actions should be taken to support possible and existing nonconformities. Preventative arrangements should be considered to reduce the additional time and resources to resolve future nonconformities. All actions should be relative to the extent and size of the problem [29].
2.4.3. QUALITY MANAGEMENT

The quality of the complete EnMS, project implementation and project sustainability should be determined continuously. A quality approved system is crucial in business operations. Major monetary expenditures are being spent to implement DSM projects.

Without regular quality checks, unnecessary expenses could influence the national economy. Money would be wasted on impossible systems. The investigation periods are not always completely accurate with the actual operations. Situations in certain industries may change annually. Some smaller companies could also experience changes on a daily basis which may have big influences if not managed properly.

If a project does not perform according to specifications, the necessary adjustments or eliminations should occur. One of the key measuring criteria of these energy management projects is to determine the actual energy performance relative to the contracted targets.

ENERGY MANAGEMENT

Various areas in the gold mining industry have been identified for opportunities to save energy. These areas are shown in Figure 2-4. Some specific areas that will be investigated in this study include compressed air, industrial cooling, fans and pumps. The DSM projects that can relate to these areas are bulk air coolers (BAC), optimisation air network (OAN), cooling auxiliaries (CA) and pumping projects.

These projects need to be evaluated based on their energy usages. LS and PC projects need to achieve their monthly energy impact targets. An average actual power profile will be developed to compare the energy usage to the target baseline.

EE projects also need to achieve their monthly energy impact targets. In addition, the total energy consumption on these projects will also be monitored and reported. With the development of the original target baseline, the total energy consumption of the baseline will be calculated. This comparison could also indicate project success.

Certain installed hardware could assist in achieving the energy objectives. It may not contribute directly to the energy consumptions, but may improve the functioning of the EnMS. Accurate measuring units and reporting tools could assist in instant feedback on nonconformities to the system. With instant feedback comes instant response and ideally immediate solutions.
The correct resource allocation on the correct area at the appropriate time could improve project performances. The management of these factors should be investigated and improved continuously. Specific skilled personnel could react impulsively on immediate situations. The experience from these personnel can benefit the company remarkably.

The energy performances should be investigated per project phase. The allocated responsibilities during the individual phases differ. The possible target adjustments should be investigated before commencing to the next project phase. This investigation will provide a good indication on the effectiveness of the EnMS.

2.4.4. NONCONFORMITIES MANAGEMENT

To find the best possible solution for existing or future constraints, the immediate identification of nonconformities is important. Problems should be reported as soon as the discovery is made. Doubts about possible problems should also be reported. A problem to one individual is not necessarily a problem to another.

 Individuals with specialised experiences may manage the same constraint differently. A detailed investigation should be done on these identified nonconformities. The EnMS should include an issue reporting element into the system. Early identification of problems could improve the resolving time and consequences.
2.4.5. MEASUREMENT AND VERIFICATION

Quality measurements are crucial in the verification process of any system. The system should be verified during the developmental phases as well as implementation periods. Continuous accuracy measurements should be taken for the EnMS to ensure an effective system.

Internal and external quality audits are required. The internal assessment should include the assurance of faultless operational devices. Installed hardware and software could influence the effectiveness of the EnMS.

Constant calculation checks should be done by the relevant project engineers. The experienced project engineers could compile manual calculations outside the EnMS and compare the results. Error investigations on the system should be resolved by the skilled developers.

The M&V of the project specific results should be analysed by an external source. This will illuminate possible cases of fraud into the performance results. As mentioned in Section 1.2.4, an M&V team should be appointed for each individual project.

The M&V team will attend at least two scheduled site visits. The project scope and confirmation of implementation objectives will be confirmed during these visits.

Several reports should be compiled. The details of these reports are discussed in Section 1.2.4. At least two documents are sent out during the investigation phase and at least one during the implementation phase. Three separate but similar monthly PA reports should indicate the actual energy performances compared to the contractual targets.

After PA, monthly performance tracking reports should be compiled to indicate the project sustainability. The reports will also indicate the opportunities to enhance project targets if necessary. The M&V teams use their calculations to obtain the results and compile their reports.

The results from the EnMS and the M&V teams should be compared on a continual basis. Differences should be discussed to identify faulty areas.
2.5. ACT: CONTINUAL IMPROVEMENT

2.5.1. INTRODUCTION

During the final stage of the EnMS development process, top management reviews should be done. The required criteria stipulated in the energy policy should be analysed. The effective functioning of the developed action plan should be determined.

As soon as the final confirmation of the performance results has been obtained, system enhancements can be implemented. The top management team is responsible to report decisive changes and improvements to the relevant stakeholders. Co-workers should be informed of internal changes, while the development team should implement system improvements and suggestions.

All these changes should be reported to ensure continual improvement on the EnMS and various DSM projects.

2.5.2. REQUIREMENTS FOR ISO 50 001

The final phase in the PDCA cycle of the ISO 50 001 standard defines the review from top management. The efficient development and energy performances should be investigated and reported on. These findings should also be documented for future references [29].

Top management can review the systems according to inputs and outputs. The input reviews should include the investigation results from the energy management applied. The entire system should be analysed as a complete unit as well as the individual elements. Energy policies, action plans, performance targets and auditing feedback should be reviewed [29].

The output feedback from top management will include the announcements of definite system changes. New targets, objectives, improvements and suggestions on the system and resources allocations should be stated. These changes should also be documented accordingly [29].

2.5.3. SYSTEM EVALUATION

Energy management involves various control systems. Every step of the management process is crucial in obtaining the preferred achievements. The accuracy for every sub-process should
be analysed continuously. The effective development of an EnMS should benefit a company in the long term with reducing efforts as it continues to develop.

Each sub-process involved in the developed EnMS should be evaluated separately to guarantee accurate functionality. The investigation should start at the data collection and the calculations thereof. The final reporting documents could end the investigation. If the reports contain accurate information and relevant suggestions, the EnMS should be effective.

The effectiveness of the EnMS is not necessarily influenced by the degree of the energy performances. A system could be one of the most effective systems and yet the projects do not perform. This could be due to extreme operational and production changes since the project investigation phase.

The performance targets and benchmarked baselines should be adjusted continuously to improve the EnMS in order to obtain the achieved results. The complete system should indicate energy savings. These savings could involve electricity cost savings or effective energy consumption, or preferably both.

2.5.4. POSSIBLE TARGET ENHANCEMENTS

Throughout the study, the importance of monitoring the accuracy of energy targets continuously has been emphasised. Contracted targets can be adjusted due to several reasons. Some of the most occurred reasons involve scope changes, operational changes and mass actions.

Scope changes could involve the addition or cancelation of components to the project scope. Unpredictable changes in parameters with a significant impact on energy usage are one of the reasons defined as operational changes. Another operational change involved permanent shift or working hour changes. The mass actions reason mainly includes strikes.

These enhancements should be reported to the relevant contractual stakeholders. The baselines for calculations could change to determine the new energy performances.

2.5.5. BUSINESS AND FINANCIAL IMPACT

A company’s main drive and objective is to increase profits. One of the most successful, but yet risky approaches to achieve this goal is to increase its competitiveness. Increasing market shares can get challenging in the modern era. Companies should invest in the latest
technologies. This could cost companies lots of money and set long unachievable payback periods.

An alternative way to increase profits is by efficient energy management. A survey was conducted in 1998 by 135 Dutch companies about the importance of investing in an efficient energy usage strategy. The results indicated that the majority of companies were aware of the financial effects of energy savings. About 45% of the companies thought it was moderately important to invest in EE, and at least 9% believed it to be very important [38]. The results of the survey are indicated in Figure 2-5.

With the remarkable increase in electricity costs since the survey was done, the trends should change significantly. More companies should realise the business benefits which energy savings has. Efficient energy management could result in significant energy savings. These cost savings could be utilised to invest in new technologies which in turn will increase global competitiveness.

2.6. CONCLUSION

Chapter 2 described the two development aspects for the EnMS. The requirements for an ISO 50 001 based system was defined for each step in the PDCA cycle. These requirements were compared and combined with the DSM process steps.
The ISO requirements were used to develop the most effective EnMS for energy intensive industries. Possible system and project constraints were identified. The necessity of specific software development and hardware requirements were discussed. These aspects were investigated according to project specifications.

As the EnMS is developed for various industries, most of the identified concepts should be adjusted to be project specific. These continuous changes improve energy performances as new investigations define new solutions.

The development of the online EnMS was described in this chapter. Information which is always available was the main focus during the development. Early identification of problem areas will result in early solution findings. Various reports were also set up to assist in the energy performance feedback requirement.

Finally, the required processes for energy performance measurements were discussed. External audits should be done at regular intervals to ensure quality results and performances. Where necessary and possible, objectives and targets should be enhanced to achieve maximum energy performances.
3. CHAPTER 3: IMPLEMENTATION OF THE ENERGY MANAGEMENT SYSTEM AND QUALITY IMPROVEMENT RESULTS

3.1. PREAMBLE

In this chapter, the ISO based EnMS described in Chapter 2 will be implemented in South Africa’s third largest gold producer. The company operates with several underground mines within the surrounding area of the Gauteng province, as indicated in Figure 3-1.

The ISO 50 001 based EnMS was implemented on five different mines. Eight different projects were selected within these five mines. Six projects represent EE projects, while the remaining two are LS projects. The distribution of projects is indicated in Table 3-1. All eight projects achieved remarkable energy savings throughout their project life cycles.
Table 3-1: List of the selected projects from the mining group under evaluation.

<table>
<thead>
<tr>
<th>Mine</th>
<th>DSM Project</th>
<th>DSM project type</th>
<th>Project technology</th>
<th>Contractual target (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mine A</td>
<td>Project A</td>
<td>LS</td>
<td>Pumping</td>
<td>2.29</td>
</tr>
<tr>
<td></td>
<td>Project B</td>
<td>EE</td>
<td>OAN</td>
<td>1.5</td>
</tr>
<tr>
<td>Mine B</td>
<td>Project C</td>
<td>EE</td>
<td>CA</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>Project D</td>
<td>EE</td>
<td>WSO</td>
<td>1.6</td>
</tr>
<tr>
<td>Mine C</td>
<td>Project E</td>
<td>EE</td>
<td>OAN</td>
<td>1.44</td>
</tr>
<tr>
<td></td>
<td>Project F</td>
<td>LS</td>
<td>Pumping</td>
<td>3.1</td>
</tr>
<tr>
<td>Mine D</td>
<td>Project G</td>
<td>EE</td>
<td>OAN</td>
<td>1.96</td>
</tr>
<tr>
<td>Mine E</td>
<td>Project H</td>
<td>EE</td>
<td>OAN</td>
<td>1.7</td>
</tr>
</tbody>
</table>

An ESCo was contracted to implement the EnMS. The system is accessible online, and thus the gold mining company can access the management system wherever internet connections are available.

According to the ISO 50 001 standard, an organisation requires an energy management representative. These responsibilities and skilled requirements were given to the ESCo during project implementation and PA.

Each individual mine appointed an internal representative for the remaining duration of the project. These internal representatives were continuously trained during the ESCos implementation time.

3.2. PLAN: ENERGY POLICY AND ENERGY PLAN

3.2.1. INTRODUCTION

During the investigation phase, the complete mining group as well as the separate mines’ energy policies and energy planning frameworks were developed. Objectives had been set and an effective action plan was developed to achieve these targets. The framework of the plan phase in the development of the EnMS is illustrated in Figure 3-2.

Assisting documentation templates were provided through the online EnMS. These documents were used to develop the EnMS effectively and thus ensure ISO 50 001 compliance.
3.2.2. ENERGY POLICY

The selected mining group has developed an energy policy to commit to certain requirements in order to achieve the performance targets. This policy was developed for the whole mining group. It is used for each individual mine after adjusting some of the deliverables to comply with the project specific components.

The unique policy can therefore be divided into two sections. The first describes the complete mining groups’ objectives and commitments. This statement was developed and agreed upon by the top management of the mining group.
The second section describes the objectives of the specific mine under investigation. Each individual mine or energy project has its unique energy intensive components to be managed. The identified components and their individual targets were described in the policy.

The mining group’s energy policy is explained according to the two sections described above.

ENERGY POLICY: FIXED ENERGY STATEMENT AND OBJECTIVES

As mentioned, the top management of the mining group agreed upon various objectives. The management teams of the individual groups were also consulted to develop these objectives more clearly and accurately. The fixed energy objectives for the entire mining group can be summarised as follows:

- Full commitment from top management for effective energy management. The energy management should be implemented to save energy costs and overall energy consumptions.
- Top management’s energy commitment will comply without influencing production targets.
- Energy management will comply without influencing health and safety agreements.
- The EnMS will be continually improved. With the addition or elimination of certain criteria, the EnMS will be adjusted accordingly.
- The complete mining group will achieve a total energy savings of 8 GWh per annum.
- These energy savings will deliver a minimum amount of R60 million per annum.
- The necessary educated personnel will be appointed to manage the performance targets.

Possible constraints identified to the functioning of an EnMS include:

- Mining employees uncertain about structure changes,
- Doubt from the client side regarding the accuracy of the EnMS,
- Offline systems or system crashes.

ENERGY POLICY: SPECIFIC MINING OBJECTIVES

Top management of each individual mine develops a unique statement to comply with the entire mining group’s energy management policy. This section of the energy policy will focus on the specific components involved in the energy project on the specific mine.
For this example, the policy for Mine A will be illustrated. The policy includes the following:

- Identification of all the relevant components, with the installed capacities and availability factors.
- Baseline development - the benchmarked baseline is used as an indication of normal operating situations. The submitted baseline will be used to determine the achieved energy performances throughout the project.
- The energy performance target was calculated and submitted on a 1.3 MW load reduction.
- The annual savings for this energy target has been estimated at R4 200 000.
- The total energy savings will result in a 14% reduction in energy usages for the identified components.
- The production manager will appoint two responsible operators to manage the energy schedules and performances. They will report to the production manager during the weekly feedback meetings.
- Continuous training is required for operators and managers. New production and operational strategies should be investigated. The EnMS should be improved accordingly. Training should be provided to educate the relevant personnel to work with the new system.
- Possible opportunities should be addressed and reported to the production manager for approval.
- Underperformance on the energy target should be investigated with great care. The underperformance should be reported to the relevant personnel to determine a better solution as soon as possible.
- Efficient energy management will be implemented as a high priority at Mine A.

3.2.3. ENERGY PLAN

The gold mining company implemented an energy plan for each individual mine developed by the ESCo. The plan corresponds to all the operations on the projects involved in this study. The ESCo developed the system to be as generic as possible which can be implemented among various projects. Certain detail within steps may differ when other project types are to be implemented. The energy plan framework is illustrated in Figure 3-2.
The key activities involved in the energy plan phase are the energy review, baseline development and the identification of unique performance indicators. These elements are displayed on the mine’s web interface of the EnMS. This ensures easy access for all relevant personnel whenever necessary.

**ENERGY REVIEW**

The initial setup for the EnMS of a mine usually consumes the most time. The first step was to collect the relevant energy and production data from the available sources. At Mine C these data tags were available in real time on the mine’s SCADA system.

The necessary authority was granted to the ESCo to obtain the relevant data. The ESCos data collection network was connected to the mine’s SCADA system. The relevant data tags were arranged into a compatible data file and sent to the network via email. These raw data files were sorted under the appropriate components involved at Mine C. The raw data was merged into the developed data processing software of the ESCo for further analysis.

The energy intensive components for Project B were discovered to be the compressors. A list of all the components with their installed capacities are summarised in Table 3-2. The compressors’ energy usage will be managed to obtain efficient energy savings.

<table>
<thead>
<tr>
<th>Component</th>
<th>Installed capacity (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressor 1</td>
<td>4 330 kW</td>
</tr>
<tr>
<td>Compressor 2</td>
<td>4 800 kW</td>
</tr>
<tr>
<td>Compressor 3</td>
<td>4 800 kW</td>
</tr>
<tr>
<td>Compressor 4</td>
<td>3 600 kW</td>
</tr>
<tr>
<td><strong>TOTAL:</strong></td>
<td><strong>17 530 kW</strong></td>
</tr>
</tbody>
</table>

**BASELINE DEVELOPMENT**

An energy baseline was developed to indicate the normal operational status of the compressors involved with Project B. This baseline was developed using the half-hourly power data (kW) from the compressors involved. The average hourly weekly, Saturdays and Sundays profiles
were compiled. These baselines are illustrated in Figure 3-3 below. The chosen data period was for June 2011 to August 2011.

The average weekday energy consumption of Project B was calculated to be 268,097 kWh.

PERFORMANCE INDICATORS

For Project B, a set of energy performance indicators were developed to measure the efficient management of energy usage. After the components were investigated and the power profiles were developed, an impact target was agreed upon. This target indicates a 1.5 MW energy saving over the 24 hour weekday period. The total weekday electricity savings are expected to be around 36 MWh.

The baseline developed in the previous section can also be used as a performance indicator. The actual power profiles will be compared to this baseline on a daily, weekly and monthly basis.

SOFTWARE

The software behind the online EnMS calculates the relevant energy management performances. The raw data from the compressors on Project B was processed into an actual
daily power profile. This actual power profile is then compared to the original baseline developed in the investigation phase. The baseline comparison is illustrated in Figure 3-4.

The performance impact can be determined from this data. For the baselines compared in Figure 3-4, the average daily impact was calculated as 2.27 MW savings. The average monthly profile for weekdays is also calculated in the software.

![Figure 3-4: Actual power profile for Project B compared to original baseline.](image)

The total energy consumptions are calculated daily and monthly. The total energy consumed from Project B for the day mentioned above was 213,720 kWh. Compared to the original baseline, this day consumed about 80% of the total weekday energy consumed during the investigation period.

The software of the EnMS has a function to calculate the daily and monthly electricity cost savings. This provides good motivation and an indication for the management team regarding the energy performance. Electricity cost savings of R312,18 for the day mentioned above were obtained by Project B.

**HARDWARE**

After the project investigation, certain hardware components were installed for Project B. These hardware components assisted in achieving the performance targets on the mine. The full list of
hardware installed is attached in Appendix G: Final bill of quantities for . Adding to the software development, the following hardware was installed for Project B:

- The relevant equipment and installations for the PLC connections to the compressors,
- Underground instrumentation that includes pipes and transmitters.

3.2.4. WEB INTERFACE

The EnMS provides an online web interface for the selected mining group. The complete mining group’s performances are displayed and accessible to all the relevant personnel. The individual mine’s profiles are also active to track individual performances. Limited access to the web interface can be granted to selected personnel.

HOME VIEW

The EnMS serves as a local destination where all energy-related information can be accessed in real time. A home page was developed for the selected mining group where the energy opportunities and risks are summarised for the present financial year. An example of the homepage is illustrated by Figure 3-5. The individual mines can also be selected to display their specific home pages.

Figure 3-5: Example of the mining group’s homepage on the online EnMS. Captured from the developed EnMS [39].
Historical data can be accessed by selecting the required financial year. Electricity bills, Eskom power reserves, electricity tariffs and energy saving risks and opportunities can be accessed on one central database.

**ENERGY CONTROL**

Templates for all the required ISO 50 001 documents have been uploaded onto the online system. The ISO process steps have been modelled into the system for guidance to the accreditation process.

Individual shafts can therefore access these ISO 50 001 templates and complete it according to their specific requirements and objectives. Table 3-3 indicates the list of uploaded templates available on the EnMS. These documents should be revised continually. The latest revision should always be uploaded onto the EnMS.

Table 3-3: List of the available ISO 50 001 templates on the online EnMS.

<table>
<thead>
<tr>
<th>Plan</th>
<th>Do</th>
<th>Check</th>
<th>Act</th>
</tr>
</thead>
</table>
| • Mine action plan  
• Mine energy baseline  
• Mine energy review  
• Mine legal compliance  
• Mine appointment letter for management team  
• Mine appointment letter for management representative  
• Mine energy policy  
• Mine top management representative appointment letter | • Mine competence training awareness  
• Mine communication  
• Mine documentation structure  
• Mine documentation control  
• Mine design  
• Mine procurement | • Mine monitoring measurements analysis  
• Mine record control  
• Mine evaluation with regards to legal requirements  
• Mine EnMS audit  
• Mine non conformance | • Mine top management review |

**ELECTRICITY MANAGEMENT**

Furthermore, a detailed information system can be accessed for the complete mining group or a specific mine within the group. The mining group’s total electricity usage and electricity costs for the present financial year are indicated on the home page of this section. The electricity
performance compared to the budget is indicated as a percentage. It is displayed as either under budget (green colour) or over budget (red colour).

This information has been divided into three main elements. The first involves all the energy costs, the second involves the energy usages and the final element summarises the account information.

The graphs and tables in the energy cost and energy usage elements represent similar information, with different units. Within the cost element, the electricity bills are divided into the various components and indicated in a pie chart.

The remaining information defines performance overviews. The total energy for the mining group is divided into the various mines involved to indicate the top ten energy consumers in the group. Monthly totals are plotted and compared to the budgets. A comparison of the total energy usage among all the shafts involved is indicated on one single graph.

The account info tab compares the components’ actual values with the corresponding budgets. These values can include energy costs, energy consumptions, production figures and intensity factors.

RISKS AND OPPORTUNITIES

Within the EnMS there are several energy risks and opportunities which are being reported and looked into. The risks involve the contribution to the Energy Conservation Scheme in response to the Power Conservation Programme penalties. The risks involved with carbon tax, electricity cost inflation and reactive powers are being recorded. All these risks are expressed as monetary values.

Various energy opportunities can be identified by the EnMS. These opportunities can result in possible energy and cost savings. They include Certified Emission Reduction (CER) savings, TOU savings, maximum demand savings, new DSM projects and EE tax reductions. The actual and potential savings are being recorded. The EnMS calculates the new 12L tax rebate as well.
3.3. DO: IMPLEMENTATION OF ENERGY PLAN

3.3.1. INTRODUCTION

As soon as the energy policy and energy plan have been compiled, the implementation of the energy plan can commence. Efficient implementation will ensure that the performance targets are achieved.

The calculations developed in the previous section are now transferred into useful information. The implementation framework is illustrated in Figure 3-6. Operating schedules are compiled to control the energy consumption of the compressors. Feedback reports are developed to review...
the energy performances. Continuous training will be provided to the relevant operators at the mine.

3.3.2. COMPRESSOR OPERATING SCHEDULES

There could be an automatic control system for the compressors. The compressors could be switched off when the drilling has stopped. It could also be manually operated according to a schedule. The schedule will be compiled on a daily basis and displayed in the control room for the relevant personnel to follow. The EnMS ensures that this scheduling and operations are being done correctly.

3.3.3. REPORT GENERATION

After the collection and necessary processing of data was completed, various reports have been generated. Three periodic report types were generated and provided to the relevant mining personnel. These report types can be associated at various time intervals.

The most efficient reporting tool throughout the development of the reports was the power profile comparisons. Figure 3-7 clearly illustrates the impact that was obtained during the specific day. The actual performance during the evening peak hours is illustrated in the graph.

![Project F: Daily energy performance](image)

Figure 3-7: Daily energy performance for Project F.
The reporting requirements stipulated in Section 2.3.4 were met in the development of the reports. The EnMS generates general reporting formats for gold mines, and thus the general reports will be discussed in this section. The reporting results include the following:

- Real-time and historical data was obtained from the selected mines’ SCADA systems and electricity bills.
- Certain data loss problems were indicated on the web interface as well as on the reports. These data losses were excluded in the energy calculations.
- The raw data was processed with the assistance of developed calculations in the EnMS.
- The generated reports were monitored for accurate measurements.
- After the accuracy has been confirmed, the reports were distributed to the relevant mining personnel. The reports can also be generated from the EnMS whenever required.
- Feedback and discussion meetings were held among the relevant mining operators and managers.

Reports were customised according to time period being reported on. The results for the daily, weekly and monthly reports will be discussed in the following sections.

**DAILY REPORTS**

The daily energy reports were compiled for each individual mine. The main purpose of the reports was to provide feedback on the daily energy performance and energy related costs for the specific mine. The electrical foreman on the mine will gain the most benefit from this report.

An indication on how the reports are presented is included in Appendix B. This report contains the most in-depth detail between the reports. This detail can always be examined at a later stage when an investigation on the performances is required. The daily report offers the following management criteria:

- The mining group, the specific mine and the relevant project name are mentioned on the front page. The reporting date is also visible on the front page.
- The additional project information included in the introduction includes the DSM project number, the relevant tariff structure being used by the mine and the project target.
- The actual performance impact is mentioned in the report. This includes the actual daily and the average month to date performances.
- The electricity cost savings for the reported day are indicated. The cumulative cost savings for the month are also calculated.
• The missed energy savings for the day and month are represented as a monetary value. This clearly indicates the opportunities the mine could have gained.
• The original and actual daily power profiles are being illustrated on the report.
• A graphical comparison of the daily energy usage is displayed on the report. This is being distributed among the three different TOU periods available for that specific day.

WEEKLY REPORTS

The weekly report has been compiled for each individual mine. This report provides an overview of the weekly performances delivered between the various projects involved on the specific mine. Weekly feedback meetings use this report to analyse and address the missed opportunities. The production managers and electrical foremen use this report for reference.

The representation of the report is included in Appendix C: Weekly report. The weekly report delivers the following results:

• The mining group, specific mine and reporting period is visible on the front page.
• The first page summarises the weekly performances in a table. A comparison between the different components on the mine can be seen clearly. The table compares each mining component’s actual power consumption to the provided budget. This data includes weekly and month to date values.
• Additional tables are included on the first page to compare the different projects involved at the mine. The tables are divided according to the different DSM project types. The monthly performance impact, target value, monthly cost savings and missed opportunities are displayed in the tables.
• The remaining pages of the report provide more detail for each component described in the initial summary table.
• Each component has the total daily power consumption for the present reporting month indicated on a graph. The daily budget amounts are also included to compare the performances. Cumulative power consumptions (actual and budget) are also provided on the same graph.
• The month to date power consumption for each component is divided among the different TOU periods. A comparing graph indicates the impact of the relevant energy costs of the total power consumed during the different TOU time periods.
Finally, an average weekly power profile for each individual component is provided. This profile is plotted on the same graph as the daily budget profile to evaluate the actual performance.

**MONTHLY REPORTS**

Two types of monthly reports were generated. The first report summarises the monthly energy performances of a specific project related to the mine. The second report contains feedback for the complete mining group’s energy performance for the reporting month. These reports are mainly used by the mine manager as well as the electricity managers.

**Project report**

The project specific report was generated to provide feedback on the monthly DSM performance. An example of the project monthly report is attached in Appendix D: Monthly report (Project). The information available in the reports includes the following:

- General project information - the project type, project number, allocated M&V team, project stage, contractual dates and targets are summarised on the first page.
- The performance summary indicates the average daily power impact, actual and missed cost savings, total energy consumption and the actual cost expenditure for the energy consumed. These parameters are reported on a monthly basis, as well as for the entire project lifetime to present.
- The average weekday power profiles (actual and original) are compared for the month. The distribution of the total energy consumption is also graphically compared relative to the TOU structure.
- The third section in the report provides daily performance feedback during the month. A table was developed to indicate the daily impact in MW, achieved cost savings, total energy usage and the actual energy cost. The daily performance indicator is being displayed according to a different colour scheme. The green indicates over performance, and the red indicates underperformance. Daily impact and cost saving graphs are included to graphically represent the performances as indicated in the previous table.
Group report

The monthly report for the selected mining group is attached in Appendix E: Monthly report (Group). This report provides a monthly summary as well as project specific performances. These two sections in the report include the following:

- The total energy consumed and energy cost expenditures for each project during the month is tabulated. The projects are then divided into the different project types (e.g. energy efficiency) and summarised accordingly. Related performance indicators for the specific project types are also summarised in three separate tables. The project target, average impact performance and total cost savings are reflected within each table for each project.

- Each project is then summarised on one page, sorted according to project types. This summary includes general project information and graphical performance indications. For the reporting month, the average weekday power profile is compared with the original power profile. The final graph for each project indicates the cumulative performance for the entire project lifetime. These monthly impact values are compared to the cumulative target value.

- Possible future projects for the mining group are listed on the last page. These potential projects are still under investigation by the ESCo.

CUSTOMISING REPORTS

Although these reports are developed to be simplified for the mining group, the preferences of the different personnel may vary. These reports can be improved and upgraded continually to deliver the most effective results. The preferences can be submitted to the EnMS and the reports will be customised accordingly.

Customised reports can also be managed by the user via the online EnMS. Certain criteria should be defined to compile a unique report. The requested financial year should be selected. Furthermore the electricity management criteria defined in Section 3.2.4 are listed on the setup page.

These main criteria include the electricity, risks and opportunities information. The detailed information under each section can be selected individually to be added to the unique report. After the report has been generated, it is sent to the selected personnel’s email addresses.
3.3.4. CONTINUOUS TRAINING

The ESCo provided the introductory training session for the EnMS. The functioning and management of the system were illustrated by a presentation to the control room operators. Each operator received a training certificate. An example of the training certificate is illustrated in Appendix F: Training certificate.

According to the ISO 50 001 standard, documentation of all processes should be compiled and updated continually. These training certificates should be provided whenever a new training level has been reached. The education and knowledge of the various operators should be recorded and documented.

Internal training at the mine should also be provided. Operators and managers need to be aware of any behaviour changes within the system. This may include production changes, operational strategy changes and energy management improvements.

Weekly feedback meetings are held at the various mines. The latest strategies are being discussed and explained to the relevant personnel.

3.4. CHECK: MONITORING THE QUALITY OF THE ENERGY MANAGEMENT SYSTEM

3.4.1. INTRODUCTION

The EnMS has been developed and the projects have been implemented. The next step is to analyse the results from the projects. The missed opportunities and possible risks need to be discussed to ensure continual improvement. General awareness from the daily, weekly and monthly activities will be under investigation.

Figure 3-8 illustrates the monitoring phase in the EnMS. The reports discussed in Section 3.3.3 were discussed by the relevant personnel. Weekly and monthly meetings were held to keep operators and management aware of the production and target enhancements. Internal audits were also performed when necessary.
 Define objectives and targets
Baseline development
Energy schedules
Performance Indicators
Mine SCADA database
Data collection
Data processing
Baseline development
Performance Indicators
Mining web interface
Energy plan
Energy policy
Internal audits
Monthly planning meetings
Weekly feedback meetings
Daily performance meetings
Improvements and suggestions
Audit results
Energy performance and EnPI
Targets achieved
Management review
Checking
Implementation
Reports generator
Energy schedules
Training on weekly energy behaviour
Energy plan
3.4.2. QUALITY MEASUREMENT

After implementing the EnMS, the selected mining group achieved remarkable energy savings. In this section, the energy performances between eight different projects will be compared. These projects and their contracted targets are indicated in Table 3-4. Five different mines were compared. Of these five, three mines had two different projects each under investigation.
Table 3-4: Target values for the eight selected projects of the selected mining company.

<table>
<thead>
<tr>
<th>Mine</th>
<th>DSM Project</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Project A</td>
<td>2.29</td>
</tr>
<tr>
<td></td>
<td>Project B</td>
<td>1.5</td>
</tr>
<tr>
<td>B</td>
<td>Project C</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>Project D</td>
<td>1.6</td>
</tr>
<tr>
<td>C</td>
<td>Project E</td>
<td>1.44</td>
</tr>
<tr>
<td></td>
<td>Project F</td>
<td>3.1</td>
</tr>
<tr>
<td>D</td>
<td>Project G</td>
<td>1.96</td>
</tr>
<tr>
<td></td>
<td>Project H</td>
<td>1.7</td>
</tr>
</tbody>
</table>

The energy performance results were analysed according to the specific project phases. As mentioned in Section 1.2.4, PA usually consists of three consecutive months. The performance responsibility is the ESCos for this period. If the target was not achieved during the three months, the target will be revised and reduced accordingly. The responsibility to achieve the new target will be the mine’s.

PERFORMANCE ASSESSMENT

Two projects that implemented the EnMS during their PA period are being compared. These projects represent Project C from Mine B and Project E from Mine C. Both are EE projects that reduced their total amount of energy consumed since the initial baseline was developed.

Project C introduced a total electricity cost savings of R2.3 million during the three PA months. The contracted target was submitted as 1.5 MW. The project achieved an average impact of 2.56 MW during this PA period. This resulted in a 170% over performance of the target. The average impact results of this project are illustrated in Figure 3-9.

This project’s PA period occurred during the summer season. As mentioned earlier in the dissertation, the summer tariffs are remarkably lower than the winter tariffs. Therefore the electricity cost savings could have been significantly higher if the same performance was maintained during the winter season.

These more expensive winter tariffs could result in higher cost savings, but could also indicate great economical risks. The ineffective management of energy or unexpected high production demands during the winter season may result in undesirable economic impacts for the company.
The comparing power profiles during Project C’s PA period are illustrated in Figure 3-10. The cumulative amount of energy consumed during this period was 10.54 GWh. Compared to the original baseline, an energy savings of 4.05 GWh was achieved.

The PA for Project E was also during the summer season. Despite this tariff constraint, the project still achieved an R1.8 million energy cost saving during this period. Project E obtained
an average impact of 1.65 MW compared to the target of 1.44 MW. They over performed by 115%. The PA results for Project E are illustrated in Figure 3-11.

![Figure 3-11: Performance assessment results for Project E.](image)

The selected mining group successfully completed the PA periods for all eight selected projects. The post-implementation periods commenced after PA until the maintenance contracts were signed. The results for the post-implementation and maintenance periods are being discussed in the following section.

**POST IMPLEMENTATION AND MAINTENANCE**

As soon as the PA period has been completed, the energy performance should be maintained. The post-implementation period starts directly after PA. From here on the performance responsibility is handed over to the mine to achieve the monthly target savings.

The selected mining group signed maintenance contracts for all their projects that completed their DSM project lifetimes. The maintenance contract serves as an extended contract for the ESCo to assist the mine in achieving the target savings.

The selected mining group signed their first maintenance contracts in August 2012. Four projects signed their maintenance contract during August 2012. The remaining two projects only completed their PA period after that. Therefore the two projects only signed their maintenance contracts after implementation. The results of the energy savings achieved by the six EE projects are displayed in Table 3-5.
Table 3-5: Summary of the maintenance performances for the six EE selected projects.

<table>
<thead>
<tr>
<th>Mine</th>
<th>DSM Project</th>
<th>Maintenance period (months)</th>
<th>Baseline energy (GWh)</th>
<th>Total energy consumption (GWh)</th>
<th>Energy saving (GWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mine A</td>
<td>Project B</td>
<td>26</td>
<td>144.24</td>
<td>139.2</td>
<td>49.54</td>
</tr>
<tr>
<td>Mine B</td>
<td>Project C</td>
<td>26</td>
<td>80.17</td>
<td>73.18</td>
<td>29.28</td>
</tr>
<tr>
<td></td>
<td>Project D</td>
<td>26</td>
<td>143.62</td>
<td>146.33</td>
<td>45.21</td>
</tr>
<tr>
<td>Mine C</td>
<td>Project E</td>
<td>9</td>
<td>68.82</td>
<td>177.18</td>
<td>9.68</td>
</tr>
<tr>
<td>Mine D</td>
<td>Project G</td>
<td>26</td>
<td>100.24</td>
<td>82.78</td>
<td>43.69</td>
</tr>
<tr>
<td>Mine E</td>
<td>Project H</td>
<td>16</td>
<td>46.94</td>
<td>83.39</td>
<td>14.52</td>
</tr>
</tbody>
</table>

The maintenance results obtained from Project G on Mine D are illustrated in Figure 3-12. The average performance for the entire maintenance period (over 25 months) was 3.4 MW. The target for Project G was submitted as 1.96 MW. The total amount of electricity cost savings for this period resulted in R32.6 million. The monthly cost savings relevant to the monthly impact performances are also indicated in Figure 3-12.

Figure 3-12: Maintenance performance for Project G.
From these results, one can positively confirm that the EnMS is effective. The continual improvement, training and feedback ensure sustainable performances for projects. The effect of the energy savings are also a major benefit for the mining company. The results and feedback from Project G and similar projects can help motivate other mines and projects to maintain their effective energy usages.

The maintenance performances for all eight selected projects have been investigated. The average impact of each project can be compared to the associated target value in Table 3-6. Each project’s cost savings for the entire maintenance period to date is also illustrated in the table. The most recent data available for this study was collected in September 2014.

Table 3-6: Summary of the maintenance performances and cost savings for the eight selected projects.

<table>
<thead>
<tr>
<th>Mine</th>
<th>DSM project</th>
<th>Maintenance period to date (months)</th>
<th>Target (MW)</th>
<th>Average impact (MW)</th>
<th>Cost saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mine A</td>
<td>Project A</td>
<td>26</td>
<td>2.29</td>
<td>2.58</td>
<td>R4 232 942.00</td>
</tr>
<tr>
<td></td>
<td>Project B</td>
<td>26</td>
<td>1.50</td>
<td>3.71</td>
<td>R35 669 912.00</td>
</tr>
<tr>
<td>Mine B</td>
<td>Project C</td>
<td>26</td>
<td>1.50</td>
<td>2.39</td>
<td>R23 259 253.00</td>
</tr>
<tr>
<td></td>
<td>Project D</td>
<td>26</td>
<td>1.60</td>
<td>3.69</td>
<td>R29 554 176.00</td>
</tr>
<tr>
<td>Mine C</td>
<td>Project E</td>
<td>9</td>
<td>1.44</td>
<td>1.58</td>
<td>R7 860 065.00</td>
</tr>
<tr>
<td></td>
<td>Project F</td>
<td>26</td>
<td>3.10</td>
<td>3.36</td>
<td>R5 000 353.00</td>
</tr>
<tr>
<td>Mine D</td>
<td>Project G</td>
<td>26</td>
<td>1.96</td>
<td>3.41</td>
<td>R33 648 267.00</td>
</tr>
<tr>
<td>Mine E</td>
<td>Project H</td>
<td>16</td>
<td>1.70</td>
<td>2.00</td>
<td>R12 904 606.00</td>
</tr>
</tbody>
</table>

Figure 3-13 illustrates the average performances of these projects during 2014. Each project’s average impact was calculated for the first eight months of 2014. The specific project targets and relative cost savings for the period are also illustrated on the same graph.

The EnMS provides a separate section on the web interface to track the maintenance performances of the projects. These performances can be accessed per day or month, similar to the reporting periods. The performances are being illustrated by different colour schemes according to the degree of the result. Whether days or months, the over performance periods are indicated by green blocks. The underperforming periods are indicated by red blocks.
The selected mining group saved a remarkable amount of energy costs from these eight projects to date. About R52 million was saved from these projects for this eight month period in 2014. A total amount of R152 million was saved from the initial maintenance contract signing date in 2012. The breakdown of these results is attached in Appendix H: Energy performance results.

3.4.3. ACCURACY CONFIRMATION

The first and continual process in the development of the EnMS is the collection of data. The accuracy of the power meters and servers should be investigated regularly. The selected mining group provides annual calibration certificates for all their power meters.

The incoming data is also measured for accuracy by comparing the energy consumption data with the relevant electricity bills. The developers of the EnMS compare these data points manually to eliminate duplication on the system.
Skilled and experienced personnel were involved in the development and improvement of the EnMS. They programmed the calculations according to production based formulas. The EnMS can be implemented in various other industries. These industries can include platinum mines, cement plants and water distribution networks. Additional calculations can be developed where necessary.

Each daily, weekly and monthly report is being checked by a representative of the ESCo. Possible unidentified data loss and system crashes need to be identified as soon as possible. When a problem is detected, the developers will be informed immediately. The EnMS also has an issue reporting option available to report minor issues. The developers will resolve the issues instantaneously.

3.4.4. MEASUREMENT AND VERIFICATION

All the energy data, calculations and reports are incorporated in the EnMS. An external measurement team is therefore required to confirm the accuracy. As described in Section 1.2.4, an external M&V team should be appointed to each individual team.

For Project E, an M&V team represented by the North-West University (NWU) was appointed. They attended an initial site visit to confirm the mine location, project related components and measuring meters on site. The project plan was described to the M&V team representative.

After the site visit two reports were compiled by the M&V team. The M&V scope report and M&V plan report was accepted and signed by the necessary personnel. These reports confirm the project objectives introduced by the ESCo.

With the specific data obtained by the M&V team, an M&V baseline report was compiled. This baseline was compared and confirmed with the ESCo calculated baseline. This specific report introduces the benchmarked baseline to be used in all the energy performance calculations.

The EnMS was developed and installed on site. As soon as the contractor was fully paid for the hardware installations, the ESCo again arranged an assisted site visit for the M&V team. This site visit was to confirm the accuracy of the action plan stated in the M&V scope report and M&V plan report.

Directly after the second site visit, a monthly M&V performance tracking report was compiled and delivered to the relevant personnel. The average impacts per weekday, Saturdays and
Sundays were recorded and reported on. The monthly over- or underperformance was indicated to track the project performance.

An M&V’s performance assessment certificate was compiled at the end of the three month PA period. The average impacts per month, as well as the overall PA average were included in the report. An over performance of 136.5% was recorded for Project E. The performance tracking reports continued on a monthly basis after PA.

The results from the internal EnMS and the M&V reports had a slight difference. The same measuring meters and calculations were used. A possible reason for the difference may be the intervals on which the calculations were compiled. The EnMS uses two minute intervals of data to calculate the energy performances. The M&V team’s spectrum might be broader which influences the accuracy slightly. The power profiles of the two systems followed the same trend, and were therefore corresponding.

### 3.5. ACT: MANAGEMENT REVIEW

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#### 3.5.1. INTRODUCTION

The final phase in the PDCA cycle of the EnMS represents the management review. During this phase the top management of the selected mining company reviewed the results obtained from the EnMS. The implemented projects performed according to targets, where some even over performed.

The top management requested upgrades to the EnMS. These improvements are discussed later in this chapter. The act phase of the EnMS is illustrated in the framework in Figure 3-14. The internal audit results were investigated to suggest possible changes to the EnMS.
The complete EnMS was reviewed by top management of the mining company. The ESCo initially presented a demonstration of the EnMS to promote the abilities of the online system. Various energy results of the mining company were displayed. The management team was satisfied with the system and decided to implement the system on the upcoming DSM projects.

Ever since, various projects (including the eight selected projects under investigation) have been implemented using the EnMS. The PA results from these projects were investigated by the management team. The monthly reports were mainly used to obtain a broad overview of the projects and their energy performances.
With the rising electricity prices in South Africa and the success of the project performances, the mining group agreed on a maintenance contract. The contracted ESCo will continue managing and controlling the EnMS to obtain maximum energy performances.

A possible constraint was identified by the management of the mining company. Eskom experienced DSM funding constraints during 2013. The mining managers should keep this in consideration. New potential projects could not be funded by Eskom. The mine should then cover the necessary installation costs and the ESCo service fees.

3.5.3. PERFORMANCE CONFIRMATION

To evaluate the effectiveness of the EnMS, energy performances should be analysed. The results from the selected projects were discussed in Section 3.4.2. The PA period serves as an accurate investigation phase to determine target accuracy.

Project targets can be adjusted for projects that underperform. Penalties could be given to projects that underperform by more than 10% of the original contracted target. Special preferences by the mine can also influence the target adjustment if the target was not achieved during PA.

When projects need to adjust their impact targets, the M&V team should also update their documents and calculations accordingly. The new target should be agreed on and signed by the relevant stakeholders.

From the eight selected projects, six achieved their PA targets. Project G achieved an average impact of 1.8 MW on a 1.96 MW target. The project under performed by 92%. This performance is still within 10% of the contracted target.

According to the M&V performance assessment certificate, Project B missed their target impact by only 3%. The project achieved an average impact of 1.46 MW on a 1.5 MW target. The M&V team and mine managers agreed to reduce the target impact to the actual achieved impact of 1.46 MW.

This target comparison is displayed on the MAD certificate. This is also where the mine takes full responsibility to achieve this new or valid old target. This target should be achieved for the remaining period of the project unless specified differently on the MAD certificate.
3.5.4. BUSINESS AND FINANCIAL BENEFITS

The efficient energy management awareness among the personnel improved the mining company’s production strategy. The operators have adapted the mind-set of operating outside peak hours. The sales demands were managed by advanced operational planning.

As indicated in Figure 3-15, Project E adjusted their average weekly power profile ever since the initial implementation period. The total energy savings for the project results in 9.06 GWh for a period of 12 months. The cost savings related to this energy savings was R7.4 million.

The project’s contractual target is 1.44 MW. Since the project implementation date (1 October 2013), the project has achieved an average impact of 1.56 MW. The original baseline as indicated in Figure 3-15 was developed by using data from 1 June 2012 until 31 August 2012.

The mining group’s financial status has improved drastically since they started implementing the EnMS for their DSM projects. The system has been developed to ensure sustainable energy performances. Therefore the company can look forward to a long-term solution in efficient energy management.

![Project E: Average weekday power profiles during PA and maintenance period](image)

Figure 3-15: Average weekday power profiles for Project E during PA and the maintenance period.

The financial and operational status of a company can include several benefits. The selected mining company can now control their business aspects more effectively. They can spend more money on additional improvements around the business to improve their market shares and
international competitiveness. They are presently the third largest gold mining company in the world.

3.6. CONCLUSION

The developed EnMS was implemented by the selected mining group. In this chapter, the energy performance results for this mining group were discussed. Various system phases were investigated to evaluate the efficiency of the EnMS.

All the steps involved in the PDCA cycle were discussed individually according to the relevant results. The plan and do phases focused mainly on the developed system and its functionalities. The defined energy objectives and targets were discussed in the energy policies of the mining group as well as for the individual mines.

From the energy policy, the energy action plan was developed. A descriptive diagram illustrates the action plan throughout this chapter. The diagram emphasises the different PDCA phases within the developed EnMS. The actual implementation of the activities for data collection, system setups and report generations were discussed.

The energy performance results were discussed during the check and act phases. The PA and maintenance periods were evaluated separately. The performance impacts were compared to the contracted targets. These targets were confirmed after PA and enhanced where necessary.

The mining group achieved significant savings on their electricity cost during the implementation and maintenance periods. All eight selected projects achieved their specified target values during the maintenance phase.
4. CHAPTER 4: CONCLUSION

4.1. OVERVIEW

Since the exponential and continuous rise in electricity costs, energy management has become one of the key operational strategies for organisations. Several operational and financial benefits were recorded since the implementation of an effective ISO based EnMS on DSM projects. This EnMS was developed based on the ISO 50 001 standard for energy management.

Some elements of the ISO 9 001 and ISO 14 001 standards corresponded to some of the ISO 50 001 requirements. Companies already accredited for either the quality management or environmental management standards can combine their accreditation to obtain ISO 50 001 certification.

Continuous quality improvements on the developed EnMS ensured an effective and useful tool for several industrial companies in South Africa. Various available ESCos can assist in the implementation of DSM projects. The developed EnMS will guide the ESCos and clients to achieve maximum possible energy savings.

With energy savings comes environmental benefits. The environmental impacts have been monitored by energy providers to either reward or penalise these industries. The companies’ clients also read about these environmental impacts in the news and make their informed decisions based on the achievements. Market shares can also be influenced accordingly.

Effective energy management improves a company’s profit margins. Electricity cost savings contribute to an extensive amount in these profits. Energy efficient companies have a positive contribution to the economy. Where energy costs used to be one of these companies’ biggest expenses, it has merely become a controllable expense.

4.2. REVISION OF THE NEED

The need for an EnMS has been emphasised and proved throughout this study. The EnMS itself has one main purpose. Within the EnMS, an energy policy has been created. Several company specific energy objectives have been set to achieve this main purpose. The main objective, as per any other EnMS, is to achieve the energy performance targets.
From the eight selected projects, only two did not reach their PA targets. Individually they missed their targets by only 3% respectively and the other by 8%. All eight projects maintained their target achievements after PA. The summary of the energy performances for Project C are illustrated in Figure 4-1.

Project C clearly over performed during its PA period. A slight performance decrease can be noted during the post-implementation phase, but still achieved the target. As soon as the maintenance contract was signed and additional assistance and guidance was provided, the performance impact rose noticeably.

Some exceptions can be seen during the maintenance period. These underperformances were due to strikes and operational changes. The months following these disturbances definitely made up for the underperforming months.
ISO CERTIFIED

The ISO develops standards, but does not provide certificates. External certification bodies are responsible for the certification process [40]. This means that a company can be ISO (standard requirements) compliant, but not certified by ISO (organisation).

ISO certification can be beneficial for companies to improve their trustworthiness for clients. The assurance that a company’s products and services meet customer requirements as specified by the relative standard can increase their global competitiveness.

It is strongly recommended that the companies certify their individual management strategies as implemented by the developed EnMS in this study.

For companies to be ISO 50 001 certified, they need to adapt to the standard requirements and prove their improved energy performance. The management strategy and results should then be certified by an external party [41].

4.3. BENEFITS OF THE ENERGY MANAGEMENT SYSTEM

Two definite benefits of the efficient EnMS include the remarkable electricity consumption savings and significant electricity cost savings. These benefits improve operational strategies as well as important business aspects. Companies can thus improve their financial strength in the economy.

Electricity cost savings achieved by the EnMS’s indicated market competitiveness. As mentioned in Chapter 1, one of South Africa’s largest electricity consumers saved about R90 million annually since joining the IEE project.

The selected mining group for this study has already achieved about R52 million of electricity cost savings for a part of 2014. This amount has been calculated from only eight selected projects for the duration of eight consecutive months.

The two industries may not provide similar products, but the implementation of an effective EnMS could improve national and global competitiveness within certain industries. Project sustainability should be maintained to achieve maximum savings.
4.4. RECOMMENDATIONS AND FUTURE WORK

Once an EnMS has been implemented and certified within an organisation, the next recommended step will be an energy audit. A new international standard has been developed to assist organisations to use energy more efficiently. This new standard is ISO 50 002:2014 [42].

According to Kit Oung, project leader in the development of the ISO 50 002 standard, the auditing guidelines will identify long-term solutions in the reduction of energy consumption [42]. The aim of the new standard is to create awareness of energy’s influence on the environment. With the audits, energy waste will decrease and environmental advantages will increase.

The ISO 50 000 series of standards are planning to expand in the future. As ISO 50 001 focuses mainly on the development of an EnMS, other focus areas will have their own standard to relate to. These standards include the following [42]:

- ISO 50 003 (defining auditing and certification requirements),
- ISO 50 004 (Implementation and sustainability guidance),
- ISO 50 006 (measurement of proposed performances),
- ISO 50 015 (specialise in the measurement and verification of performances).
### 5. APPENDICES

#### 5.1. APPENDIX A: MEGAFLEX TARIFFS

<table>
<thead>
<tr>
<th>Transmission zone</th>
<th>Voltage</th>
<th>Active energy charge [kWh]</th>
<th>Non-local authority charges [R/kVA/m]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Peak</td>
<td>Standard</td>
</tr>
<tr>
<td>≤ 300km</td>
<td>&lt; 600V</td>
<td>220.91</td>
<td>251.84</td>
</tr>
<tr>
<td></td>
<td>≥ 500V &amp; &lt; 66kV</td>
<td>217.44</td>
<td>247.88</td>
</tr>
<tr>
<td></td>
<td>≥ 66kV &amp; ≤ 132kV</td>
<td>210.56</td>
<td>240.04</td>
</tr>
<tr>
<td></td>
<td>&gt; 132kV*</td>
<td>198.45</td>
<td>226.23</td>
</tr>
<tr>
<td>&gt; 300km and ≤ 600km</td>
<td>&lt; 600V</td>
<td>222.71</td>
<td>253.89</td>
</tr>
<tr>
<td></td>
<td>≥ 500V &amp; &lt; 66kV</td>
<td>219.61</td>
<td>250.36</td>
</tr>
<tr>
<td></td>
<td>≥ 66kV &amp; ≤ 132kV</td>
<td>212.63</td>
<td>242.40</td>
</tr>
<tr>
<td></td>
<td>&gt; 132kV*</td>
<td>200.43</td>
<td>228.49</td>
</tr>
<tr>
<td>&gt; 600km and ≤ 900km</td>
<td>&lt; 600V</td>
<td>224.93</td>
<td>256.42</td>
</tr>
<tr>
<td></td>
<td>≥ 500V &amp; &lt; 66kV</td>
<td>221.81</td>
<td>252.86</td>
</tr>
<tr>
<td></td>
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<td>214.79</td>
<td>244.86</td>
</tr>
<tr>
<td></td>
<td>&gt; 132kV*</td>
<td>202.45</td>
<td>230.79</td>
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<tr>
<td>&gt; 900km</td>
<td>&lt; 600V</td>
<td>227.19</td>
<td>259.00</td>
</tr>
<tr>
<td></td>
<td>≥ 500V &amp; &lt; 66kV</td>
<td>224.02</td>
<td>255.38</td>
</tr>
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<td>216.95</td>
<td>247.32</td>
</tr>
<tr>
<td></td>
<td>&gt; 132kV*</td>
<td>204.43</td>
<td>239.05</td>
</tr>
</tbody>
</table>

* >132 kV or Transmission connected

Figure 5-1: Eskom Megaflex tariffs for 2014/2015 [11].
Daily report for
Mine C pumping system

15 May 2014

Generated on 11 November 2014
1 Project information

Project name: Mine C pumping system
Project number: xxxx
Tariff structure: MEGAFLEX
Target impact: 3.10 MW

2 Performance (Thursday 2014-05-15)

Performance of day:
Impact: 4.33 MW
Cost saving: R 8 005
Missed opportunities: -

Month-to-date performance:
Average impact: 3.56 MW
Cumulative cost savings: R 83 685
Cumulative missed opportunities: -

Figure 2-1: Power profile and baseline for 15 May 2014
Figure 2-2: Daily energy usage distribution - 15 May 2014
5.3. APPENDIX C: WEEKLY REPORT

Electricity consumption report

Mine C

18 Jul 2014 - 17 Aug 2014
## 1 Summary

<table>
<thead>
<tr>
<th>Component</th>
<th>Actual (kWh)</th>
<th>Budget (kWh)</th>
<th>Actual cost</th>
<th>Over/under(−) budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mine C</td>
<td>25 116 470</td>
<td>24 399 446</td>
<td>R 19 936 842</td>
<td>R −194 140</td>
</tr>
<tr>
<td>- Compressors</td>
<td>7 170 049</td>
<td>6 270 960</td>
<td>R 5 951 773</td>
<td>R −777 988</td>
</tr>
<tr>
<td>- Decline Pumping</td>
<td>540 775</td>
<td>290 808</td>
<td>R 438 729</td>
<td>R 198 801</td>
</tr>
<tr>
<td>- Fans</td>
<td>4 145 068</td>
<td>4 284 830</td>
<td>R 3 398 452</td>
<td>R −136 698</td>
</tr>
<tr>
<td>- General</td>
<td>608 995</td>
<td>581 025</td>
<td>R 522 056</td>
<td>R 41 453</td>
</tr>
<tr>
<td>- Hoisting</td>
<td>1 610 109</td>
<td>1 732 156</td>
<td>R 1 280 624</td>
<td>R −148 472</td>
</tr>
<tr>
<td>- Mining</td>
<td>4 587 108</td>
<td>4 672 395</td>
<td>R 3 730 184</td>
<td>R −124 723</td>
</tr>
<tr>
<td>- Pumping</td>
<td>3 264 187</td>
<td>2 484 229</td>
<td>R 2 071 547</td>
<td>R 21 962</td>
</tr>
<tr>
<td>- Refrigeration</td>
<td>3 499 915</td>
<td>4 083 043</td>
<td>R 2 861 865</td>
<td>R −506 052</td>
</tr>
</tbody>
</table>
2 Section summaries

2. Mine C total

Total power consumption

- Daily budget
- Daily actual
- Cumulative budget
- Cumulative actual

Consumption

- Off peak
- Standard
- Peak

Cost (R-thousand)

- Off peak
- Standard
- Peak

Average weekday profile

- Daily budget
- Daily actual

Confidential document generated on 31 November 2014
2.2 Compressors

**Total power consumption**

![Graph showing total and daily power consumption](image)

*Figure 2-4: Total and daily power consumption*

**Consumption**

- Off peak: 37%
- Standard: 14%
- Peak: 49%

**Cost (R-thousand)**

- Off peak: R 2 576
- Standard: R 1 218
- Peak: R 2 007

*Figure 2-5: TOU performance*

**Average weekday profile**

![Graph showing average weekday profile](image)

*Figure 2-6: Average weekday profile*
### 2.3 Decline Pumping

#### Total power consumption

![Graph showing total and daily power consumption](image)

*Figure 2-7: Total and daily power consumption*

#### Consumption

- 51% Off peak
- 35% Standard
- 14% Peak

#### Cost (R-thousand)

- R 312
- R 146

*Figure 2-8: TOU performance*

#### Average weekday profile

![Graph showing average weekday profile](image)

*Figure 2-9: Average weekday profile*
2.4 Fans

Total power consumption

Figure 2-10: Total and daily power consumption

Consumption

Cost (R-thousand)

Figure 2-11: TOU performance

Average weekday profile

Figure 2-12: Average weekday profile

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2.5 General

Total power consumption

Date
Daily consumption (MWh)
Cumulative consumption (MWh)

Figure 2-13: Total and daily power consumption

Consumption

Cost (R-thousand)

Off peak, Standard, Peak

Figure 2-14: TOU performance

Average weekday profile

Demand (MWh)
Hour

Daily budget, Daily actual

Figure 2-15: Average weekday profile
2.6 Hoisting

Total power consumption

![Graph showing total and daily power consumption](image)

Figure 2-16: Total and daily power consumption

**Consumption**

- Off peak: 2%
- Standard: 47%
- Peak: 41%

**Cost (R-thousand)**

- Off peak: R 177
- Standard: R 310
- Peak: R 494

Figure 2-17: TOU performance

**Average weekday profile**

![Graph showing average weekday profile](image)

Figure 2-18: Average weekday profile
2.7 Mining

Total power consumption

![Graph showing total and daily power consumption](image)

**Figure 2-19: Total and daily power consumption**

**Consumption**

- Off peak: 35%
- Standard: 51%
- Peak: 14%

**Cost (R-thousand)**

- Off peak: R 1,196
- Standard: R 1,572
- Peak: R 963

**Figure 2-20: TOU performance**

**Average weekday profile**

- Daily budget
- Daily actual

**Figure 2-21: Average weekday profile**
2.8 Pumping

**Total power consumption**

![Graph of total power consumption](image)

*Figure 2-22: Total and daily power consumption*

**Consumption**

![Pie chart for consumption](image)

*Figure 2-23: TOU performance*

**Cost (R-thousand)**

![Pie chart for cost](image)

**Average weekday profile**

![Graph of average weekday profile](image)

*Figure 2-24: Average weekday profile*
2.9 Refrigeration

Total power consumption

Figure 2-25: Total and daily power consumption

Consumption

Cost (R-thousand)

Figure 2-26: TOU performance

Average weekday profile

Figure 2-27: Average weekday profile
5.4. APPENDIX D: MONTHLY REPORT (PROJECT)

Mine C
report for

1 August 2014 - 31 August 2014

Generated on 11 November 2014
# Table of Contents

1 Project information ........................................................................................................... 1
2 Summary .......................................................................................................................... 1
3 Daily performance tracking ............................................................................................. 3
1 Project information

- Project type: Pumps
- Energy type: Load shifting
- Project number: xxxx
- M&V team: North West University
- Project stage: Maintenance agreement
- Contract completion date: 2006-05-31
- Actual completion date: 2005-09-13
- Contractual impact target: 3.10 MW
- Performance assessment (PA) impact: 4.19 MW
- Post-PA impact target: 3.10 MW

2 Summary

<table>
<thead>
<tr>
<th>Table 2-1: DSM summary for the period: 2014-08-01 to 2014-08-31</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td>Average daily impact</td>
</tr>
<tr>
<td>Cost savings</td>
</tr>
<tr>
<td>Missed opportunities</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Table 2-2: System summary (from 2014-08-01 to 2014-08-31)*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Energy usage</td>
</tr>
<tr>
<td>Cost</td>
</tr>
</tbody>
</table>

<table>
<thead>
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<th>Table 2-3: Project lifetime summary (from 2012-05-01 to 2014-08-31)</th>
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</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Average daily impact</td>
</tr>
<tr>
<td>Cumulative cost saving</td>
</tr>
</tbody>
</table>

* Faulty data replaced with extrapolated data.
Figure 2-1: Weekday average power profile and baseline for 1 August 2014 to 31 August 2014

Figure 2-2: Overall energy usage distribution - 1 August 2014 to 31 August 2014
### 3 Daily performance tracking

Table 3-1: DSM summary for the period: 2014-08-01 to 2014-08-31

<table>
<thead>
<tr>
<th>Date</th>
<th>Scaled impact (MW)</th>
<th>Scaled cost saving (R)</th>
<th>Energy usage (MWh)</th>
<th>Energy cost (R)</th>
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<tr>
<td>2014-08-01</td>
<td>4.88</td>
<td>34 413</td>
<td>59.40</td>
<td>65 554</td>
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<tr>
<td>2014-08-02</td>
<td>5.66</td>
<td>4 620</td>
<td>146.57</td>
<td>69 663</td>
</tr>
<tr>
<td>2014-08-03</td>
<td>2.44</td>
<td>0</td>
<td>74.58</td>
<td>39 415</td>
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<tr>
<td>2014-08-04</td>
<td>3.17</td>
<td>27 261</td>
<td>78.55</td>
<td>51 737</td>
</tr>
<tr>
<td>2014-08-05</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2014-08-06</td>
<td>3.57</td>
<td>32 847</td>
<td>83.98</td>
<td>51 616</td>
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<tr>
<td>2014-08-07</td>
<td>4.69</td>
<td>39 315</td>
<td>112.58</td>
<td>73 911</td>
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<tr>
<td>2014-08-08</td>
<td>4.78</td>
<td>49 419</td>
<td>117.13</td>
<td>72 383</td>
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<tr>
<td>2014-08-09</td>
<td>4.33</td>
<td>3 622</td>
<td>121.93</td>
<td>58 176</td>
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<tr>
<td>2014-08-10</td>
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<td>10.36</td>
<td>95.36</td>
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<td>100.48</td>
<td>69 183</td>
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<td>35 099</td>
<td>103.90</td>
<td>69 392</td>
</tr>
<tr>
<td>2014-08-14</td>
<td>3.89</td>
<td>29 852</td>
<td>96.02</td>
<td>68 613</td>
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<td>27 831</td>
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<td>2014-08-16</td>
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<td>112.32</td>
<td>51 498</td>
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<td>110.53</td>
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<td>15 547</td>
<td>117.69</td>
<td>103 068</td>
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<td>2014-08-29</td>
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<td>37 544</td>
<td>107.52</td>
<td>73 587</td>
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<td>2014-08-30</td>
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<td>4 035</td>
<td>76.78</td>
<td>34 880</td>
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<tr>
<td>2014-08-31</td>
<td>1.39</td>
<td>0</td>
<td>88.42</td>
<td>36 056</td>
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</tbody>
</table>

Total: 658 714 3 102.43 1 879 031
Figure 3-1: Daily impact - 1 August 2014 to 31 August 2014

Figure 3-2: Daily cost savings - 1 August 2014 to 31 August 2014
### Table 3-2: List of non-plantable days for the period: 2014-08-01 to 2014-09-31

<table>
<thead>
<tr>
<th>Date</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014-08-05</td>
<td>SCADA network down</td>
</tr>
<tr>
<td>2014-08-28</td>
<td>Production constraints</td>
</tr>
</tbody>
</table>
5.5. APPENDIX E: MONTHLY REPORT (GROUP)

Group report for Mining Group

1 August 2014 - 31 August 2014

Generated on 11 November 2014
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   2.3 Mine B water supply optimisation ................................................................................................. 5
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   2.5 Mine D optimisation of air networks ............................................................................................. 7
   2.6 Mine E optimisation of air networks ............................................................................................. 8
   2.7 Mine F optimisation of air networks ............................................................................................. 9
   2.8 Mine H OAN .................................................................................................................................. 10

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   3.1 Mine A pumping system .................................................................................................................. 11
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   3.3 Mine B pumping system .................................................................................................................. 13
   3.4 Mine C pumping system ................................................................................................................ 14
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   4.4 Mine H Heat Pumps ......................................................................................................................... 22

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1 Summary

<table>
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<tr>
<th>Table 1-1: Summary of energy efficiency projects</th>
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<td>Project</td>
</tr>
<tr>
<td>Mine A optimisation of air networks</td>
</tr>
<tr>
<td>Mine B cooling auxiliaries</td>
</tr>
<tr>
<td>Mine B water supply optimisation</td>
</tr>
<tr>
<td>Mine C optimisation of air networks</td>
</tr>
<tr>
<td>Mine D optimisation of air networks</td>
</tr>
<tr>
<td>Mine E optimisation of air networks</td>
</tr>
<tr>
<td>Mine F optimisation of air networks</td>
</tr>
<tr>
<td>Mine H QAN</td>
</tr>
<tr>
<td><strong>Totals:</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 1-2: Summary of load shifting projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project</td>
</tr>
<tr>
<td>Mine A pumping system</td>
</tr>
<tr>
<td>Mine B fridge plant system</td>
</tr>
<tr>
<td>Mine B pumping system</td>
</tr>
<tr>
<td>Mine C pumping system</td>
</tr>
<tr>
<td>Mine D fridge plant</td>
</tr>
<tr>
<td>Mine F pumping system</td>
</tr>
<tr>
<td>Mine G fridge plant system</td>
</tr>
<tr>
<td>Mine G pumping system</td>
</tr>
<tr>
<td><strong>Totals:</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 1-3: Summary of peak clipping projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project</td>
</tr>
<tr>
<td>Mine B compressor manager</td>
</tr>
</tbody>
</table>
### Table 1-3: Summary of peak clipping projects

<table>
<thead>
<tr>
<th>Project</th>
<th>Target</th>
<th>Impact</th>
<th>Baseline energy</th>
<th>Energy saving</th>
<th>Cost saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mine F compressor manager</td>
<td>2.40 MW</td>
<td>867.42 kW</td>
<td>2.02 GWh</td>
<td>500.02 MWh</td>
<td>R 84,927</td>
</tr>
<tr>
<td>Mine H compressed air</td>
<td>0.00 kW</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mine H Heat Pumps</td>
<td>0.00 kW</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Totals:</strong></td>
<td><strong>5.20 MW</strong></td>
<td><strong>3.03 MW</strong></td>
<td><strong>9.32 GWh</strong></td>
<td><strong>627.99 MWh</strong></td>
<td><strong>R 324,031</strong></td>
</tr>
</tbody>
</table>

### Table 1-4: System summary

<table>
<thead>
<tr>
<th>Project</th>
<th>Total energy consumption</th>
<th>Total energy cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mine A optimisation of air networks</td>
<td>5.19 GWh</td>
<td>R 4 274 373</td>
</tr>
<tr>
<td>Mine A pumping system</td>
<td>1.46 GWh</td>
<td>R 807 183</td>
</tr>
<tr>
<td>Mine B compressor manager</td>
<td>10.33 GWh</td>
<td>R 9 063 673</td>
</tr>
<tr>
<td>Mine B cooling auxiliaries</td>
<td>2.02 GWh</td>
<td>R 2 395 819</td>
</tr>
<tr>
<td>Mine B fridge plant system</td>
<td>5.40 GWh</td>
<td>R 4 675 085</td>
</tr>
<tr>
<td>Mine B pumping system</td>
<td>8.18 GWh</td>
<td>R 7 430 758</td>
</tr>
<tr>
<td>Mine B water supply optimisation</td>
<td>6.49 GWh</td>
<td>R 5 582 637</td>
</tr>
<tr>
<td>Mine C optimisation of air networks</td>
<td>6.71 GWh</td>
<td>R 5 596 545</td>
</tr>
<tr>
<td>Mine C pumping system</td>
<td>3.20 GWh</td>
<td>R 1 943 581</td>
</tr>
<tr>
<td>Mine D fridge plant</td>
<td>843.61 MWh</td>
<td>R 548 279</td>
</tr>
<tr>
<td>Mine D optimisation of air networks</td>
<td>2.83 GWh</td>
<td>R 2 406 551</td>
</tr>
<tr>
<td>Mine E optimisation of air networks</td>
<td>2.79 GWh</td>
<td>R 2 372 151</td>
</tr>
<tr>
<td>Mine F compressor manager</td>
<td>3.85 GWh</td>
<td>R 3 210 297</td>
</tr>
<tr>
<td>Mine F optimisation of air networks</td>
<td>3.85 GWh</td>
<td>R 3 210 613</td>
</tr>
<tr>
<td>Mine F pumping system</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mine G fridge plant system</td>
<td>510.11 MWh</td>
<td>R 342 604</td>
</tr>
<tr>
<td>Mine G pumping system</td>
<td>1.24 GWh</td>
<td>R 753 575</td>
</tr>
<tr>
<td>Mine H compressed air</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mine H Heat Pumps</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mine H DAN</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Totals:</strong></td>
<td><strong>65.48 GWh</strong></td>
<td><strong>R 54 013 636</strong></td>
</tr>
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</table>
2 Energy efficiency projects

2.1 Mine A optimisation of air networks

Project type: OAN (Energy efficiency)
Project number: xxxx
Actual completion date: 2012-05-31
Target impact: 1.50 MW
Actual impact: 4.19 MW
Cost saving: R 2 545 002

Figure 2-1: Weekday average power profile and baseline for 1 August 2014 to 31 August 2014

Figure 2-2: Cumulative performance graph
2.2 Mine B cooling auxiliaries

Project type: CA (Energy efficiency)
Project number: xxxx
Actual completion date: 2012-02-15
Target impact: 1.50 MW
Actual impact: 1.55 MW
Cost saving: R 692 970

Figure 2-3: Weekday average power profile and baseline for 1 August 2014 to 31 August 2014

Figure 2-4: Cumulative performance graph
2.3 Mine B water supply optimisation

Project type: WSO (Energy efficiency)
Project number: xxx
Actual completion date: 2011-02-28
Target impact: 1.60 MW
Actual impact: 2.27 MW
Cost saving: R 260 964

Figure 2-5: Weekday average power profile and baseline for 1 August 2014 to 31 August 2014

Figure 2-6: Cumulative performance graph
2.4 Mine C optimisation of air networks

<table>
<thead>
<tr>
<th>Project type:</th>
<th>OAN (Energy efficiency)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project number:</td>
<td>xxxx</td>
</tr>
<tr>
<td>Actual completion date:</td>
<td>2013-08-31</td>
</tr>
<tr>
<td>Target impact:</td>
<td>1.44 MW</td>
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<tr>
<td>Actual impact:</td>
<td>1.82 MW</td>
</tr>
<tr>
<td>Cost saving:</td>
<td>R 1 085 963</td>
</tr>
</tbody>
</table>
2.5 Mine D optimisation of air networks

Project type: OAN (Energy efficiency)
Project number: xxx
Actual completion date: 2011-02-28
Target impact: 1.96 MW
Actual impact: 4.00 MW
Cost saving: R 2 351 264

![Power Profiles Graph]

*Figure 2-9: Weekday average power profile and baseline for 1 August 2014 to 31 August 2014*

![Cumulative Performance Analysis Graph]

*Figure 2-10: Cumulative performance graph*
2.6 Mine E optimisation of air networks

Project type: OAN (Energy efficiency)
Project number: xxxx
Actual completion date: 2013-05-31
Target impact: 1.70 MW
Actual impact: 2.63 MW
Cost saving: R 1 513 433

Figure 2-11: Weekday average power profile and baseline for 1 August 2014 to 31 August 2014

Figure 2-12: Cumulative performance graph
2.7 Mine F optimisation of air networks

Project type: OAN (Energy efficiency)
Project number: xxx
Actual completion date: 2012-05-31
Target impact: 1.50 MW
Actual impact: 1.04 MW
Cost saving: R 442 443

Figure 2-13: Weekday average power profile and baseline for 1 August 2014 to 31 August 2014

Figure 2-14: Cumulative performance graph
## 2.8 Mine H OAN

<table>
<thead>
<tr>
<th>Project type</th>
<th>EE (Energy efficiency)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project number</td>
<td>xxxx</td>
</tr>
<tr>
<td>Actual completion date</td>
<td>2013-08-05</td>
</tr>
<tr>
<td>Target impact</td>
<td>0.00 MW</td>
</tr>
<tr>
<td>Actual impact</td>
<td>- MW</td>
</tr>
<tr>
<td>Cost saving</td>
<td>R 0</td>
</tr>
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</table>

No verified profile data available for this period

No verified cumulative data available for this period
3 Load shifting projects

3.1 Mine A pumping system

Project type: Pumps (Load shifting)
Project number: xxxx
Actual completion date: 2005-06-30
Target impact: 2.29 MW
Actual impact: 2.24 MW
Cost saving: R 347 394

Figure 3-1: Weekday average power profile and baseline for 1 August 2014 to 31 August 2014

Figure 3-2: Cumulative performance graph
3.2 Mine B fridge plant system

Project type: FP (Load shifting)
Project number: xxxx
Actual completion date: 2009-06-30
Target impact: 6.16 MW
Actual impact: -1.56 MW
Cost saving: R -54 443

![Power profiles](image)

*Figure 3-3: Weekday average power profile and baseline for 1 August 2014 to 31 August 2014*

![Cumulative performance analysis](image)

*Figure 3-4: Cumulative performance graph*
### 3.3 Mine B pumping system

<table>
<thead>
<tr>
<th>Project type:</th>
<th>Pumps (Load shifting)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project number:</td>
<td>xxxx</td>
</tr>
<tr>
<td>Actual completion date:</td>
<td>2004-05-31</td>
</tr>
<tr>
<td>Target impact:</td>
<td>3.00 MW</td>
</tr>
<tr>
<td>Actual impact:</td>
<td>0.04 MW</td>
</tr>
<tr>
<td>Cost saving:</td>
<td>R. 52 593</td>
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</tbody>
</table>

**Figure 3-5: Weekday average power profile and baseline for 1 August 2014 to 31 August 2014**

**Figure 3-6: Cumulative performance graph**
3.4 Mine C pumping system

Project type: Pumps (Load shifting)
Project number: xxxx
Actual completion date: 2005-09-13
Target impact: 3.10 MW
Actual impact: 3.87 MW
Cost saving: R 658 714

Figure 3-7: Weekday average power profile and baseline for 1 August 2014 to 31 August 2014

Figure 3-8: Cumulative performance graph
3.5 Mine D fridge plant

Project type: FP (Load shifting)
Project number: xxxx
Actual completion date: 2014-08-01
Target impact: 2.76 MW
Actual impact: 0.60 MW
Cost saving: R 50 415

![Power profiles]

*Figure 3-9: Weekday average power profile and baseline for 1 August 2014 to 31 August 2014*

![Cumulative performance analysis]

*Figure 3-10: Cumulative performance graph*
### 3.6 Mine F pumping system

<table>
<thead>
<tr>
<th>Project type:</th>
<th>Pumps (Load shifting)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project number:</td>
<td>xxxx</td>
</tr>
<tr>
<td>Actual completion date:</td>
<td>2014-10-07</td>
</tr>
<tr>
<td>Target impact:</td>
<td>2.52 MW</td>
</tr>
<tr>
<td>Actual impact:</td>
<td>- MW</td>
</tr>
<tr>
<td>Cost saving:</td>
<td>R 0</td>
</tr>
</tbody>
</table>

No verified profile data available for this period

No verified cumulative data available for this period
3.7 Mine G fridge plant system

Project type: FP (Load shifting)
Project number: xxxx
Actual completion date: 2014-04-25
Target impact: 2.72 MW
Actual impact: 0.47 MW
Cost saving: R 52 978

Figure 3-11: Weekday average power profile and baseline for 1 August 2014 to 31 August 2014

Cumulative performance analysis

Figure 3-12: Cumulative performance graph
3.8 Mine G pumping system

- Project type: Pumps (Load shifting)
- Project number: xxxx
- Actual completion date: 2005-09-13
- Target impact: 1.87 MW
- Actual impact: 1.83 MW
- Cost saving: R 271 311

![Power profiles graph](image)

*Figure 3-13: Weekday average power profile and baseline for 1 August 2014 to 31 August 2014*

![Cumulative performance analysis](image)

*Figure 3-14: Cumulative performance graph*
4 Peak clipping projects

4.1 Mine B compressor manager

Project type: CM (Peak clipping)
Project number: xxxx
Actual completion date: 2013-02-21
Target impact: 2.80 MW
Actual impact: 2.16 MW
Cost saving: R 239 103

Figure 4-1: Weekday average power profile and baseline for 1 August 2014 to 31 August 2014

Figure 4-2: Cumulative performance graph
4.2 Mine F compressor manager

- Project type: CM (Peak clipping)
- Project number: xxxx
- Actual completion date: 2012-05-31
- Target impact: 2.40 MW
- Actual impact: 0.87 MW
- Cost saving: R 84 927

![Power profiles](image)

*Figure 4-3: Weekday average power profile and baseline for 1 August 2014 to 31 August 2014*

No verified cumulative data available for this period
4.3 Mine H compressed air

<table>
<thead>
<tr>
<th>Project type</th>
<th>PC (Peak clipping)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project number</td>
<td>xxxx</td>
</tr>
<tr>
<td>Actual completion date</td>
<td>2013-08-05</td>
</tr>
<tr>
<td>Target impact</td>
<td>0.00 MW</td>
</tr>
<tr>
<td>Actual impact</td>
<td>- MW</td>
</tr>
<tr>
<td>Cost saving</td>
<td>R 0</td>
</tr>
</tbody>
</table>

No verified profile data available for this period

No verified cumulative data available for this period
4.4 Mine H Heat Pumps

Project type: PC (Peak clipping)
Project number: xxxx
Actual completion date: 2013-08-05
Target impact: 0.00 MW
Actual impact: - MW
Cost saving: R 0

No verified profile data available for this period

No verified cumulative data available for this period
5 Future projects

Table 5-1: Summary of new projects submitted to Eskom DSM

<table>
<thead>
<tr>
<th>Project</th>
<th>Type</th>
<th>Target (MW)</th>
<th>Eskom submission date</th>
<th>Client contribution (R)</th>
<th>Expected annual savings (R)</th>
<th>Next stage in Eskom process</th>
<th>Letter of intent signature</th>
<th>Proposal signature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>Totals:</td>
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<td></td>
<td></td>
<td></td>
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</tbody>
</table>

Table 5-2: Summary of projects being investigated

<table>
<thead>
<tr>
<th>Project</th>
<th>Type</th>
<th>Target (MW)</th>
<th>Letter of intent signature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mine I compressor manager</td>
<td>PC</td>
<td>2.50</td>
<td>-</td>
</tr>
<tr>
<td>Mine J Well Pumping system</td>
<td>LS</td>
<td>2.40</td>
<td>-</td>
</tr>
<tr>
<td>Mine A compressor manager</td>
<td>PC</td>
<td>3.11</td>
<td>-</td>
</tr>
<tr>
<td>Mine C Fridge Plant system</td>
<td>LS</td>
<td>3.60</td>
<td>-</td>
</tr>
<tr>
<td>Mine D Pumping system</td>
<td>LS</td>
<td>5.90</td>
<td>-</td>
</tr>
<tr>
<td>Mine H Pumping system</td>
<td>LS</td>
<td>3.80</td>
<td>-</td>
</tr>
<tr>
<td>Mine J Optimisation of air network</td>
<td>EE</td>
<td>1.52</td>
<td>-</td>
</tr>
<tr>
<td>Mine J Pumping system</td>
<td>LS</td>
<td>4.00</td>
<td>-</td>
</tr>
<tr>
<td>Totals:</td>
<td></td>
<td>26.73</td>
<td></td>
</tr>
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</table>
5.6. APPENDIX F: TRAINING CERTIFICATE

Certification

Training logo  Training logo  Training logo

Trainee name – ID number

has successfully completed the control room operator's course for:
Real-time Energy Management System (REMS - P),
and On-Site Information Management System (OSIMS - P).

March 2014

Senior Manager
5.7. APPENDIX G: FINAL BILL OF QUANTITIES FOR PROJECT B

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
<th>DESCRIPTION</th>
<th>UNIT</th>
<th>TOTAL</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>2</td>
<td>Masimong Compressor System Compressor PLC Equipment</td>
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<tr>
<td>A1</td>
<td>2</td>
<td>Quantum Power Supply 115/230 VAC Stand-Alone 11 Amp</td>
<td>8,722.19</td>
<td>17,444.38</td>
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<tr>
<td>A2</td>
<td>1</td>
<td>Quantum CPU, 2 M bytes Memory, 2 Modbus and 1 Modbus Plus port</td>
<td>63,511.10</td>
<td>63,511.10</td>
</tr>
<tr>
<td>A3</td>
<td>1</td>
<td>Quantum RIO head-end Adapter, Single</td>
<td>10,328.82</td>
<td>10,328.82</td>
</tr>
<tr>
<td>A4</td>
<td>1</td>
<td>Quantum RIO drop Adapter, Single</td>
<td>10,328.82</td>
<td>10,328.82</td>
</tr>
<tr>
<td>A5</td>
<td>1</td>
<td>FactoryCast Module for Quantum PLC Ethernet TCP/IP 10/100 BaseT</td>
<td>22,470.61</td>
<td>22,470.61</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Messaging, I/O Scanning Global Data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A6</td>
<td>4</td>
<td>Quantum Analog Input - Unipolar High Speed, 4-20 mA or 1-5 VDC, 12 bit, 16 ch.</td>
<td>17,465.46</td>
<td>69,861.84</td>
</tr>
<tr>
<td>A7</td>
<td>1</td>
<td>Quantum Analog Current Output, 4-20 mA, 12 Bit, 8 ch</td>
<td>16,406.95</td>
<td>16,406.95</td>
</tr>
<tr>
<td>A8</td>
<td>1</td>
<td>DC IN 24V/DC 6 x 16 + Cables</td>
<td>11,433.02</td>
<td>11,433.02</td>
</tr>
<tr>
<td>A9</td>
<td>1</td>
<td>DC OUT 24DC 6 x 16 Source + Cables</td>
<td>12,416.52</td>
<td>12,416.52</td>
</tr>
<tr>
<td>A10</td>
<td>3</td>
<td>Quantum Blanks</td>
<td>396.96</td>
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<td>A11</td>
<td>1</td>
<td>Quantum 10 slot backplane</td>
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<td>3,546.01</td>
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<tr>
<td>A12</td>
<td>1</td>
<td>Quantum 6 slot backplane</td>
<td>2,455.76</td>
<td>2,455.76</td>
</tr>
<tr>
<td>A13</td>
<td>1</td>
<td>Cables and Taps between RIO head-end Adapter and RIO drop Adapter</td>
<td>3,920.82</td>
<td>3,920.82</td>
</tr>
<tr>
<td>A14</td>
<td>1</td>
<td>Multi-function Graphic Touchscreen 12.1” 256 couleurs, TFT</td>
<td>33,745.59</td>
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</tr>
<tr>
<td>A15</td>
<td>1</td>
<td>Weidmuller Ethernet Switch 6 RJ45 - 2 Fibre Port Multimode</td>
<td>4,512.61</td>
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<tr>
<td>A16</td>
<td>1</td>
<td>Fibre Accessories 2x 3M Boxes with accessories (patchleads pigtail and mid-couplers)</td>
<td>872.00</td>
<td>872.00</td>
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<tr>
<td>A17</td>
<td>1</td>
<td>PAC353 (Design level B) Moore Controller with Ethernet Communications TGX:353A4F1CNB4</td>
<td>24,574.79</td>
<td>24,574.79</td>
</tr>
</tbody>
</table>

Sub Total: 617,879.04
## QUOTATION

**WELKOM INDUSTRIAL CONTROLS**

(Pty) Ltd 2000/001057/07

461 Welkom 9460 No.8 1st Street  
Phone: (057)367-5724 Fax(057)362-2155  
Email: norman@wic.co.za

<table>
<thead>
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<th>QTY</th>
<th>DESCRIPTION</th>
<th>UNIT</th>
<th>TOTAL</th>
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<td>B</td>
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<td><strong>Protection</strong></td>
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<tr>
<td>B1</td>
<td>1</td>
<td>Micon P241 Synchronous motor Protection unit</td>
<td>45 666.00</td>
<td>45 666.00</td>
</tr>
<tr>
<td>B2</td>
<td>1</td>
<td>Micon P225 Induction motor Protection unit</td>
<td>17 646.25</td>
<td>17 646.25</td>
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<tr>
<td></td>
<td></td>
<td><strong>Sub Total:</strong></td>
<td></td>
<td>63 312.25</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td><strong>Master PLC Equipment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C1</td>
<td>1</td>
<td>M1 Processor, 512K RAM, 1M Flash Ethernet &amp; I/O Bus Ports, IEC Exec</td>
<td>10 615.40</td>
<td>10 615.40</td>
</tr>
<tr>
<td>C2</td>
<td>1</td>
<td>Option Adapter, MB+, TOD Clock, Battery</td>
<td>3 236.70</td>
<td>3 236.70</td>
</tr>
<tr>
<td>C3</td>
<td>2</td>
<td>8 AI Base, Differential Input</td>
<td>12 562.40</td>
<td></td>
</tr>
<tr>
<td>C4</td>
<td>1</td>
<td>4 channel analog output base 4-20mA</td>
<td>6 281.20</td>
<td>6 281.20</td>
</tr>
<tr>
<td>C5</td>
<td>2</td>
<td>16 DI/16 DO Base, 24VDC</td>
<td>5 278.36</td>
<td></td>
</tr>
<tr>
<td>C6</td>
<td>4</td>
<td>Interbus S communications adapter</td>
<td>4 856.04</td>
<td></td>
</tr>
<tr>
<td>C7</td>
<td>4</td>
<td>Interbus S cable 100cm</td>
<td>2 026.84</td>
<td></td>
</tr>
<tr>
<td>C8</td>
<td>5</td>
<td>Terminal block</td>
<td>1 847.40</td>
<td></td>
</tr>
<tr>
<td>C9</td>
<td>1</td>
<td>Weidmuller Ethernet Switch</td>
<td>4 512.62</td>
<td>4 512.62</td>
</tr>
<tr>
<td>C10</td>
<td>1</td>
<td>Fibre Accessories</td>
<td>938.08</td>
<td>938.08</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2x 3M Boxes with accessories (patchleads pigtails and mid-couplers)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Sub Total:</strong></td>
<td></td>
<td>52 155.04</td>
</tr>
<tr>
<td>D</td>
<td>2</td>
<td><strong>MCC Panels</strong></td>
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<td></td>
</tr>
</tbody>
</table>
| D1    | 1   | Mild Steel Indoor c/w 400A 525v main Busbars, TeSysT motor starter/protection units  
The following parts are included into each starter:  
1) Ethernet Controller  
2) Voltage Monitor Unit  
3) E/F Toroid Transformer  
4) NS 3p circuit breaker with SD+OF and 24VDC shunt trip for E/F  
The following are the number of LT drives:  
1x 400A Incomer  
1x Aux Transformer to MCC  
1x Aux Feeder to PLC  
8 x Cubicals Equipped with Breaker, Tesys T & Contactor  
1x PSU & Network  
1x Field Termination | 279 240.50  | 279 240.50 |
| D3    | 8   | Pillar Stop/StartBoxes                                                       | 1 420.87   | 11 366.96 |
|       |     | **Sub Total:**                                                               |            | 581 214.92 |
### 5.8. APPENDIX H: ENERGY PERFORMANCE RESULTS

#### Mine Project Month 1  Month 2  Month 3  Month 4

<table>
<thead>
<tr>
<th>Mine</th>
<th>Project</th>
<th>Month 1</th>
<th>Month 2</th>
<th>Month 3</th>
<th>Month 4</th>
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</thead>
<tbody>
<tr>
<td>Mine A</td>
<td>Project A</td>
<td>2.32</td>
<td>2.64</td>
<td>2.79</td>
<td>2.47</td>
</tr>
<tr>
<td></td>
<td>Project B</td>
<td>2.12</td>
<td>1.98</td>
<td>1.85</td>
<td>1.99</td>
</tr>
<tr>
<td>Mine B</td>
<td>Project C</td>
<td>4.79</td>
<td>4.08</td>
<td>1.46</td>
<td>1.76</td>
</tr>
<tr>
<td></td>
<td>Project D</td>
<td>1.92</td>
<td>3.15</td>
<td>3.43</td>
<td>2.77</td>
</tr>
<tr>
<td>Mine C</td>
<td>Project E</td>
<td>1.45</td>
<td>1.28</td>
<td>1.58</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>Project F</td>
<td>4.08</td>
<td>3.72</td>
<td>3.67</td>
<td>3.84</td>
</tr>
<tr>
<td>Mine D</td>
<td>Project G</td>
<td>2.8</td>
<td>2.62</td>
<td>3.12</td>
<td>3.39</td>
</tr>
<tr>
<td>Mine E</td>
<td>Project H</td>
<td>1.42</td>
<td>1.24</td>
<td>1.73</td>
<td>1.98</td>
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#### Mine Project Month 5  Month 6  Month 7  Month 8

<table>
<thead>
<tr>
<th>Mine</th>
<th>Project</th>
<th>Month 5</th>
<th>Month 6</th>
<th>Month 7</th>
<th>Month 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mine A</td>
<td>Project A</td>
<td>2.22</td>
<td>2.05</td>
<td>2.32</td>
<td>2.24</td>
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<tr>
<td></td>
<td>Project B</td>
<td>2.64</td>
<td>4.29</td>
<td>3.97</td>
<td>4.19</td>
</tr>
<tr>
<td>Mine B</td>
<td>Project C</td>
<td>1.5</td>
<td>0.44</td>
<td>0.01</td>
<td>1.55</td>
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<tr>
<td></td>
<td>Project D</td>
<td>1.68</td>
<td>2.3</td>
<td>2.51</td>
<td>2.27</td>
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<td>Mine C</td>
<td>Project E</td>
<td>1.6</td>
<td>1.32</td>
<td>1.28</td>
<td>1.82</td>
</tr>
<tr>
<td></td>
<td>Project F</td>
<td>3.72</td>
<td>3.63</td>
<td>3.32</td>
<td>3.87</td>
</tr>
<tr>
<td>Mine D</td>
<td>Project G</td>
<td>4.27</td>
<td>4.62</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Mine E</td>
<td>Project H</td>
<td>2.82</td>
<td>3.17</td>
<td>2.57</td>
<td>2.62</td>
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</table>

#### Mine Project Month 1  Month 2  Month 3  Month 4

<table>
<thead>
<tr>
<th>Mine</th>
<th>Project</th>
<th>Month 1</th>
<th>Month 2</th>
<th>Month 3</th>
<th>Month 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mine A</td>
<td>Project A</td>
<td>R 83437.00</td>
<td>R 81574.00</td>
<td>R 93285.00</td>
<td>R 78167.00</td>
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<tr>
<td></td>
<td>Project B</td>
<td>R 699799.00</td>
<td>R 644263.00</td>
<td>R 675706.00</td>
<td>R 706629.00</td>
</tr>
<tr>
<td>Mine B</td>
<td>Project C</td>
<td>R 1584854.00</td>
<td>R 1253235.00</td>
<td>R 362781.00</td>
<td>R 551944.00</td>
</tr>
<tr>
<td></td>
<td>Project D</td>
<td>R 646297.00</td>
<td>R 1021970.00</td>
<td>R 1155689.00</td>
<td>R 961858.00</td>
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<tr>
<td>Mine C</td>
<td>Project E</td>
<td>R 551363.00</td>
<td>R 431703.00</td>
<td>R 608656.00</td>
<td>R 506078.00</td>
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<tr>
<td></td>
<td>Project F</td>
<td>R 150023.00</td>
<td>R 81715.00</td>
<td>R 126337.00</td>
<td>R 90014.00</td>
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<tr>
<td>Mine D</td>
<td>Project G</td>
<td>R 869154.00</td>
<td>R 827915.00</td>
<td>R 1070503.00</td>
<td>R 1043429.00</td>
</tr>
<tr>
<td>Mine E</td>
<td>Project H</td>
<td>R 451944.00</td>
<td>R 410916.00</td>
<td>R 583245.00</td>
<td>R 560435.00</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>R 5036871.00</td>
<td>R 4753291.00</td>
<td>R 4676202.00</td>
<td>R 4498554.00</td>
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### Table 1: Mine Project Costs

<table>
<thead>
<tr>
<th>Mine</th>
<th>Project</th>
<th>Month 5</th>
<th>Month 6</th>
<th>Month 7</th>
<th>Month 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mine A</td>
<td>Project A</td>
<td>R 81 318.00</td>
<td>R 331 564.00</td>
<td>R 416 743.00</td>
<td>R 347 394.00</td>
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<tr>
<td></td>
<td>Project B</td>
<td>R 942 562.00</td>
<td>R 2 553 861.00</td>
<td>R 2 529 239.00</td>
<td>R 2 545 002.00</td>
</tr>
<tr>
<td>Mine B</td>
<td>Project C</td>
<td>R 579 661.00</td>
<td>R 314 151.00</td>
<td>R -66 802.00</td>
<td>R 692 970.00</td>
</tr>
<tr>
<td></td>
<td>Project D</td>
<td>R 623 836.00</td>
<td>R 917 546.00</td>
<td>R 1 073 774.00</td>
<td>R 260 964.00</td>
</tr>
<tr>
<td>Mine C</td>
<td>Project E</td>
<td>R 641 670.00</td>
<td>R 625 624.00</td>
<td>R 719 658.00</td>
<td>R 1 085 963.00</td>
</tr>
<tr>
<td></td>
<td>Project F</td>
<td>R 142 374.00</td>
<td>R 601 009.00</td>
<td>R 594 253.00</td>
<td>R 658 714.00</td>
</tr>
<tr>
<td>Mine D</td>
<td>Project G</td>
<td>R 1 406 847.00</td>
<td>R 2 593 725.00</td>
<td>R 2 099 105.00</td>
<td>R 2 351 264.00</td>
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<td>Mine E</td>
<td>Project H</td>
<td>R 1 020 768.00</td>
<td>R 1 247 745.00</td>
<td>R 1 586 651.00</td>
<td>R 1 611 020.00</td>
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<td>R 5 439 036.00</td>
<td>R 9 185 225.00</td>
<td>R 8 952 621.00</td>
<td>R 9 553 291.00</td>
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### Table 2: Mine Project Cost Savings

<table>
<thead>
<tr>
<th>Mine</th>
<th>Project</th>
<th>Total cost savings</th>
<th>Average impact</th>
<th>Target</th>
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</thead>
<tbody>
<tr>
<td>Mine A</td>
<td>Project A</td>
<td>R 1 513 482.00</td>
<td>2.38</td>
<td>2.29</td>
</tr>
<tr>
<td></td>
<td>Project B</td>
<td>R 11 297 061.00</td>
<td>2.88</td>
<td>1.50</td>
</tr>
<tr>
<td>Mine B</td>
<td>Project C</td>
<td>R 5 272 794.00</td>
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<td>1.50</td>
</tr>
<tr>
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<td>Project D</td>
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<td>2.50</td>
<td>1.60</td>
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<tr>
<td>Mine C</td>
<td>Project E</td>
<td>R 5 170 715.00</td>
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<tr>
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<td>R 2 444 439.00</td>
<td>3.73</td>
<td>3.10</td>
</tr>
<tr>
<td>Mine D</td>
<td>Project G</td>
<td>R 12 261 942.00</td>
<td>3.60</td>
<td>1.96</td>
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<tr>
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<td>Project H</td>
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<tr>
<td>TOTAL</td>
<td></td>
<td>R 52 095 091.00</td>
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6. REFERENCES


[40] ISO. Certification... Available: http://www.iso.org/iso/home/standards/certification.htm